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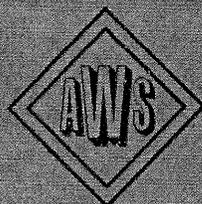
AWS B 3.0-77



TECHNICAL DEPT

American Welding Society
Standard

**Welding Procedure
and
Performance
Qualification**



AMERICAN WELDING SOCIETY

AWS B 3.0-77

**Welding
Procedure
and Performance
Qualification**

Superseding AWS B3.0-41

Prepared by
AWS Committee on Qualification

Under direction of
AWS Technical Activities Committee

Approved by
the AWS Board of Directors, March 22, 1977

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Foreword

In 1934, the American Welding Society appointed a committee to formulate a Standard Qualification Procedure which, it was hoped, would be adopted by all the major code writing bodies, thereby eliminating the wide discrepancies then existing between the qualification requirements of the various codes. This committee, known as the *Committee on Standard Qualification Procedure*, completed its first report in 1936 and issued two revisions, one in 1938 and one in 1941.

The provisions of the Standard Qualification Procedure were unique, originating "P-No." base metal groupings, etc., and were incorporated in the more important codes and specifications outside AWS, including those issued by American National Standards Institute (ANSI) and the American Society of Mechanical Engineers. This 1977 revision brings the B3.0 Standard up to date with regard to present materials and welding processes.

This is a general qualification standard for qualification of procedures and performance of welders and welding operators. It is intended for use in any welding situation where a specific product specification does not exist for the application. It is not intended to replace the qualification requirements of AWS or other recognized product codes and specifications.

Preface

The properties and quality of a welded joint will be determined by the specific joint welding procedure used and by the ability of the welder or welding operator to apply that procedure. Predictable results as to the properties and soundness of a joint can be secured only by adherence to a joint welding procedure that has been properly qualified. It cannot be expected that these predictable results will be obtained, even by careful and painstaking workmen, if poor material or inadequate or worn out equipment is used. Also, a properly qualified joint welding procedure will not result in the desired welded joint if the welders or welding operators have not been trained and are not properly supervised to be certain that all essential details of the specific welding procedure are followed. In addition, preparation of the coupons for testing must be done in a workmanlike manner to obtain proper and consistent test results.

In production welding there are two basic concerns which relate to successful application. These are (1) mechanical properties and composition, and (2) workmanship or quality. The mechanical properties of the weld metal, such as tensile strength, ductility, toughness, etc., and, in some cases, its composition will be determined by the joint welding procedure. The quality of the welded joint will be determined by the degree to which that weld metal is kept free of voids and inclusions and by its fusion to the base metal. Under a qualified joint welding procedure, these factors are the ones over which the welder or welding operator has control. It is therefore not necessary to test the welds in welder and welding operator qualification for mechanical properties. Having established that a given joint welding procedure is satisfactory, comparatively-simple tests are adequate to determine the ability of an individual to make a sound weld using that welding procedure.

The requirements for qualifying a welding procedure are given in Section 4 and the method of qualifying welders and welding operators is given in Section 5.

There are several variables involved in any joint welding procedure. If predictable results are to be obtained, certain limitations must be placed upon those variables. Having fixed upon these limitations, it is necessary that some tolerance or degree of departure from a given limitation, as stated in a joint welding procedure specification, be recognized as permissible without requiring that a qualification of a revised procedure be made. Departures from a qualified joint welding procedure that might affect the predictable results are referred to as changes in essential variables. The essential variables in this standard are those items, listed under limitations of variables, which will affect the mechanical properties or chemical properties, or both, of the weldment. Similarly, variables in a welding operation, such as change in process, etc., that reflect on the welder's or welding operator's ability are listed under limitations of variables. If these limitations of variables are exceeded, a new procedure qualification is required.

The International System of Units (SI) used to express measurements in this document are rounded units converted from the U.S. customary units following them in parentheses. The U.S. customary units are the principal ones to be used at this time. The SI units are given to acquaint the reader with them. At some future time, the SI units will become the principal units and the U.S. customary units may be deleted. For additional information, refer to the latest edition of AWS 2.3, Metric Practice Guide for the Welding Industry.

Operations involving welding, cutting, brazing, and allied processes should conform with the recommended practices of ANSI Z49.1, Safety in Welding and Cutting, for the protection of welders and nearby personnel from injury and illness and for the protection of property from damage.

Personnel should be protected against exposure to noise generated in welding and cutting processes in accordance with paragraph 1910.95, Occupational Noise Exposure, of the Occupational Safety and Health Standards, Occupational Safety and Health Administration, U.S. Department of Labor.

Procedures involving the use of arc and gas welding, cutting, brazing, and allied processes should conform with the recommendations of ANSI Z49.2/NFPA 51B, Fire Prevention in the Use of Cutting and Welding Processes, for the protection of property from fire and explosion.

Comments or inquiries pertaining to this standard are welcome. They should be addressed to: Secretary, Committee on Qualification, American Welding Society, 550 North LeJeune Rd., Miami, FL, 33135.

Welding Procedure and Performance Qualification

Scope

This standard sets forth the requirements for the qualification of welding procedures, welders, and welding operators for joining ferrous and nonferrous metals and applicable combinations of these materials using the shielded metal arc, gas metal arc, gas tungsten arc, flux cored arc, electroslag, electrogas, submerged arc, plasma arc, and oxyfuel gas welding processes for groove and fillet welds.

The standard is intended for use in any welding situation where a specific product specification does not exist for the application. It is not intended to replace the qualification requirements of AWS or other recognized product codes and specifications.

1. General Provisions

1.1 Definitions. The welding terms used in this standard shall be interpreted in accordance with the definitions given in the latest edition of AWS A3.0, Welding Terms and Definitions.

The term "plate," when used in this standard, is intended to cover sheet also and "pipe" is intended to cover cylindrical tubing also, except where differentiated.

1.2 Responsibility

1.2.1 Welding Procedure Specification Qualification.

Each manufacturer or contractor is responsible for the welding done by his organization. He shall prepare detailed written welding procedure specifications, have the necessary test plates or pipes welded and mechanical tests performed, as specified herein, to assure the criteria of this standard are met, and he shall record this information on a form for welding procedure qualification. Typical forms for a welding procedure specification and a welding procedure qualification are in Appendix A.

The interchange of welding procedure qualifications within a multifaceted organization is permissible provided the parent company exerts direct technical control of welding within its satellite groups.

1.2.2 Performance Qualification. Each manufacturer or contractor shall be responsible for conducting the performance tests necessary to qualify the welders and welding operators who will apply these procedures. Evaluation of the test assemblies may be made by the manufacturer, contractor, or an outside agency. See 5.1 for additional

requirements. A typical form for a welder or welding operator performance qualification is in Appendix A.

1.2.3 Records. Each manufacturer or contractor shall maintain the applicable welding procedure specification records, welding procedure qualification records, and performance qualification records at the job site. These records shall be available to those authorized to inspect them.

1.3 Welding Processes. This standard is applicable to the following welding processes and methods:

- (1) Shielded metal arc welding (SMAW)
- (2) Gas metal arc welding (GMAW)
- (3) Gas tungsten arc welding (GTAW)
- (4) Flux cored arc welding (FCAW)
- (5) Electroslag welding (ESW)
- (6) Electrogas welding (GMAW-EG & FCAW-EG)
- (7) Submerged arc welding (SAW)
- (8) Plasma arc welding (PAW)
- (9) Oxyfuel gas welding (OFW).

2. Base Metals

2.1 General. The grouping of base metals by P Number in Table 2.1 has been made on the basis of mechanical properties and chemical composition. Qualification of a joint welding procedure using one base metal qualifies the procedure for use with all other base metals within the same P number. P1A and P1B, for example, will require separate qualification. The groupings do not imply that base metals may be indiscriminately substituted for a base metal which was used in the qualification test without consideration of their metallurgical compatibility.

Coated materials, such as terneplate and galvanized or painted materials, shall require separate qualification if the coating is not removed.

2.2 Categories. Table 2.1 lists base metals by their ASTM, ABS, or API specification number. Included are:

- (1) Ferrous metals (P1A through P11C)
- (2) Aluminum and aluminum alloys (P21 through P25)
- (3) Copper and copper base alloys (P31 through P35)
- (4) Nickel and nickel base alloys (P41 through P45)
- (5) Unalloyed titanium (P51 and P52).

2.3 Base metals not listed herein shall require qualification of each individual welding procedure to be used with that base metal.

3. Filler Metals

3.1 General. The grouping of filler metals in Tables 3.1A, 3.1B, 3.1C, and 3.1D has been made on the basis of chemical composition, mechanical, metallurgical, and welding characteristics. The electrodes in each F number group are sufficiently similar to justify extension of a joint welding procedure qualification test or a welder, welding operator, or performance qualification test performed with any electrode within the group to cover every other electrode in that group. Additional extensions are noted in Sections 4 and 5. Grouping reduces the number of qualification tests required. The groupings do not imply that any other filler metal in a group may be indiscriminately substituted in an application for that used in the original qualification test. Selection of the filler metal should be based on a careful consideration of the requirements of the application and the characteristics of the base metal involved.

3.2 Filler Metal Specifications

3.2.1 General. The following AWS specifications provide the detailed requirements and general applicability of the electrodes which have been grouped for procedure and performance qualification in Tables 3.1A, 3.1B, 3.1C, and 3.1D.

3.2.2 Ferrous Filler Metals

- A5.1 Specification for Mild Steel Covered Arc-Welding Electrodes
- A5.2 Specification for Iron and Steel Gas-Welding Rods
- A5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
- A5.5 Specification for Low-Alloy Steel Covered Arc-Welding Electrodes
- A5.9 Specification for Corrosion Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
- A5.15 Specification for Welding Rods and Covered Electrodes for Welding Cast Iron
- A5.17 Specification for Bare Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
- A5.18 Specification for Mild Steel Electrodes for Gas Metal Arc Welding
- A5.20 Specification for Mild Steel Electrodes for Flux Cored Arc Welding
- A5.22 Specification for Flux Cored Corrosion Resisting Chromium and Chromium-Nickel Steel Electrodes
- A5.23 Specification for Bare Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding.

3.2.3 Nonferrous Filler Metals

- A5.3 Specification for Aluminum and Aluminum Alloy Arc Welding Electrodes
- A5.6 Specification for Copper and Copper-Alloy Covered Electrodes
- A5.7 Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes

- A5.10 Specification for Aluminum and Aluminum Alloy Welding Rods and Bare Electrodes
- A5.11 Specification for Nickel and Nickel Alloy Covered Welding Electrodes
- A5.13 Specification for Surfacing Welding Rods and Electrodes
- A5.14 Specification for Nickel and Nickel Alloy Bare Welding Rods and Electrodes
- A5.16 Specification for Titanium and Titanium-Alloy Bare Welding Rods and Electrodes.

3.2.4 Nonconsumable Electrodes

- A5.12 Specification for Tungsten Arc-Welding Electrodes.

4. Joint Welding Procedure Qualification

4.1 Test Positions

4.1.1 Test Positions for Groove Welds. Groove welds may be made in test material oriented in any of the positions shown in Fig. 4.1.1.1 or Fig. 4.1.1.2 and as described in the following paragraphs. An angular deviation of plus or minus 15 degrees from the specified horizontal and vertical planes and an angular deviation of plus or minus 5 degrees from the specified inclined plane are permitted during qualification test welding. Refer to Fig. 4.1.1 for definitions of welding positions which are thereby qualified. A groove weld does not qualify a fillet weld.

4.1.1.1 Plate Positions

4.1.1.1.1 Flat Position 1G. Plate in a horizontal plane with the weld metal deposited from above. Refer to Fig. 4.1.1.1(A).

4.1.1.1.2 Horizontal Position 2G. Plate in a vertical plane with the axis of the weld horizontal. Refer to Fig. 4.1.1.1(B).

4.1.1.1.3 Vertical Position 3G. Plate in a vertical plane with the axis of the weld vertical. Refer to Fig. 4.1.1.1(C).

4.1.1.1.4 Overhead Position 4G. Plate in a horizontal plane with the weld metal deposited from underneath. Refer to Fig. 4.1.1.1(D).

4.1.1.2 Pipe Positions

4.1.1.2.1 Flat Position 1G. Pipe with its axis horizontal and rolled during welding so that the weld metal is deposited from above. Refer to Fig. 4.1.1.2(A).

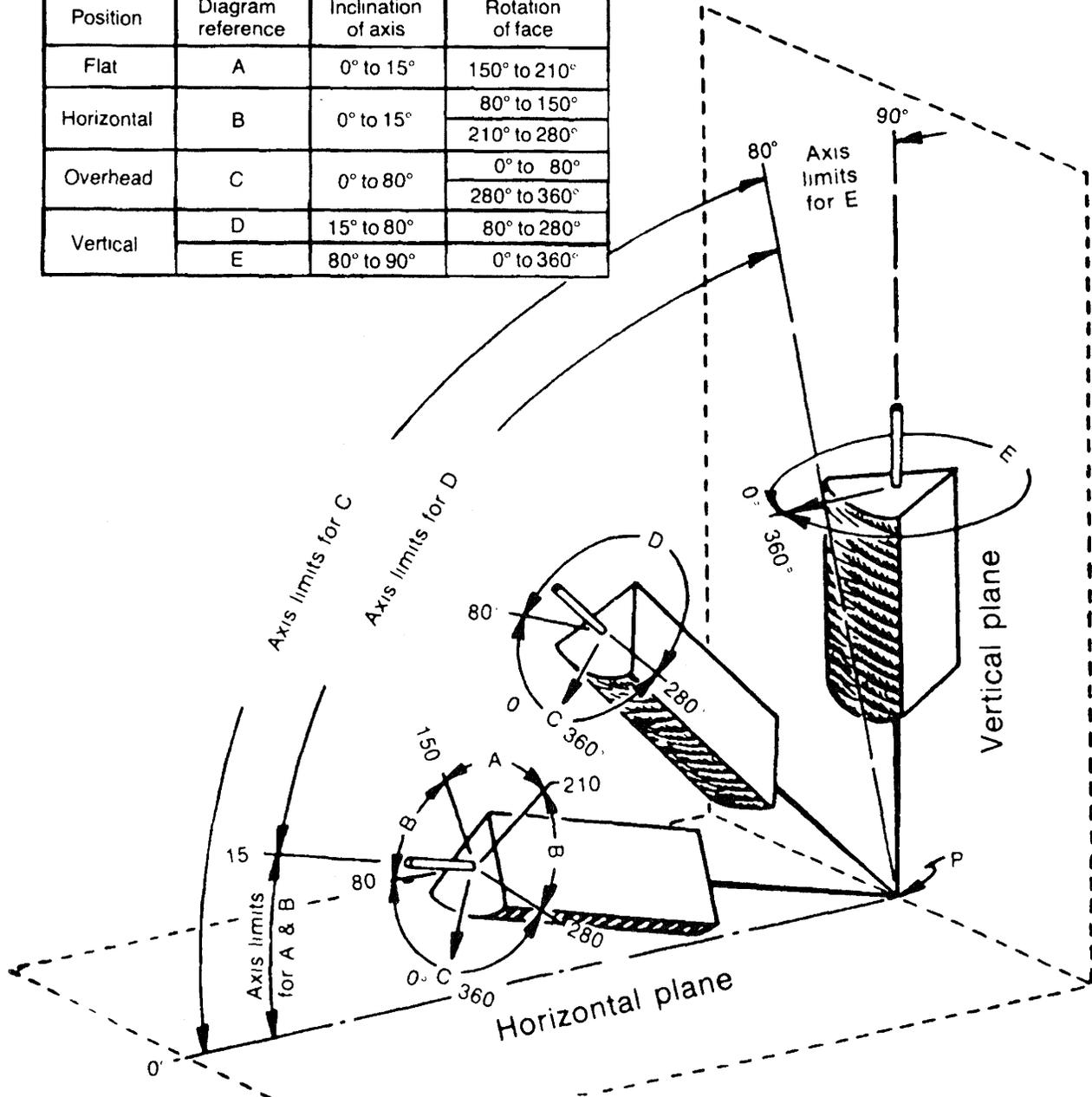
4.1.1.2.2 Horizontal Position 2G. Pipe with its axis vertical and the axis of the weld in a horizontal plane. Pipe shall not be rotated during welding. Refer to Fig. 4.1.1.2(B).

4.1.1.2.3 Multiple Positions 5G. Pipe with its axis horizontal and with the welding groove in a vertical plane. Welding shall be done without rotating the pipe. Refer to Fig. 4.1.1.2(C).

4.1.1.2.4 Multiple Positions 6G. Pipe with its axis inclined at 45 degrees to horizontal. Welding shall be done without rotating the pipe. Refer to Fig. 4.1.1.2(D).

4.1.1.2.5 Position 6GR. (Test for complete joint penetration groove welds of tubular T-, K-, and Y-connections). The test pipe shall be inclined at 45 degrees

Tabulation of positions of groove welds			
Position	Diagram reference	Inclination of axis	Rotation of face
Flat	A	0° to 15°	150° to 210°
Horizontal	B	0° to 15°	80° to 150°
			210° to 280°
Overhead	C	0° to 80°	0° to 80°
			280° to 360°
Vertical	D	15° to 80°	80° to 280°
	E	80° to 90°	0° to 360°



Notes:

1. The horizontal reference plane is taken to lie always below the weld under consideration.
2. Inclination of axis is measured from the horizontal reference plane toward the vertical.
3. Angle of rotation of face is determined by a line perpendicular to the theoretical face of the weld and which passes through the axis of the weld. The reference position (0°) of rotation of the face invariably points in the direction opposite to that in which the axis angle increases. The angle of rotation of the face of weld is measured in a clockwise direction from this reference position (0°) when looking at point P.

Fig. 4.1.1—Positions of groove welds

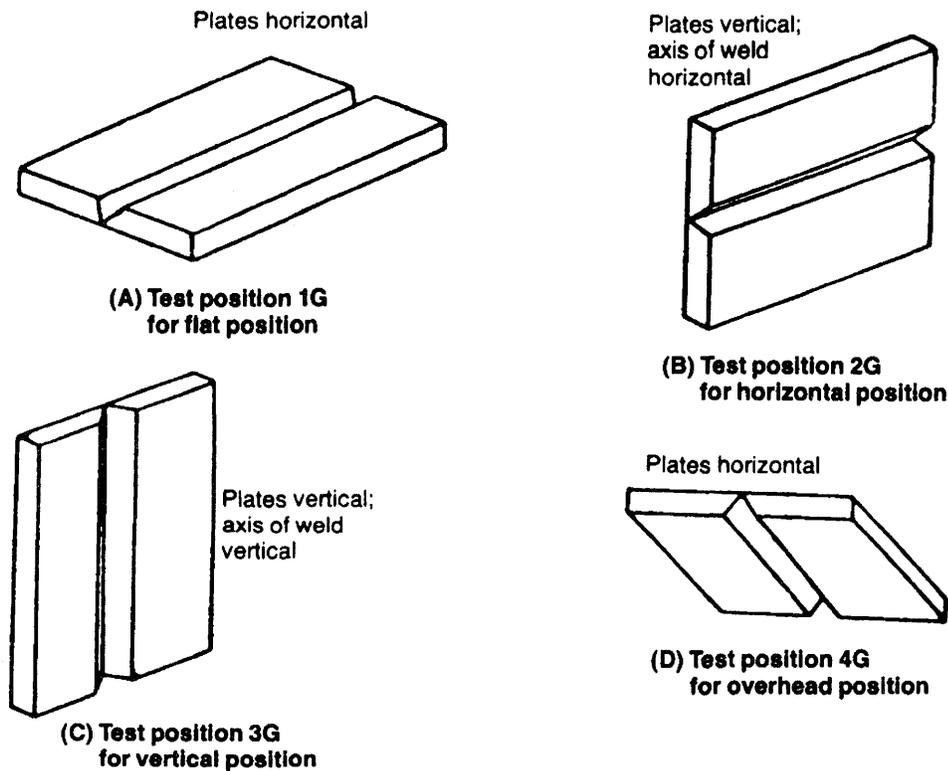


Fig. 4.1.1.1—Positions of test plates for groove welds

with the horizontal. The pipe or tube is not rotated during welding. Refer to Fig. 4.1.1.2 (E).

4.1.2 Test Positions for Fillet Welds. Fillet welds may be made in test material oriented in any of the positions shown in Fig. 4.1.2.1 and as described in the following paragraphs. An angular deviation of plus or minus 15 degrees from the specified horizontal and vertical planes is permitted during welding. Refer to Fig. 4.1.2 for definitions of welding positions.

4.1.2.1 Plate Positions

4.1.2.1.1 Flat Position 1F. Plates so placed that the weld is deposited with its axis horizontal and its throat vertical. Refer to Fig. 4.1.2.1(A).

4.1.2.1.2 Horizontal Position 2F. Plates so placed that the weld is deposited with its axis horizontal on the upper side of the horizontal surface and against the vertical surface. Refer to Fig. 4.1.2.1(B).

4.1.2.1.3 Vertical Position 3F. Plates so placed that the weld is deposited with its axis vertical. Refer to Fig. 4.1.2.1(C).

4.1.2.1.4 Overhead Position 4F. Plates so placed that the weld is deposited with its axis horizontal on the underside of the horizontal surface and against the vertical surface. Refer to Fig. 4.1.2.1(D).

4.1.2.2 Pipe Positions

4.1.2.2.1 Flat Position 1F. Pipe with its axis inclined at 45 degrees to horizontal and rotated during welding so that the weld metal is deposited from above and at the point of deposition; the axis of the weld is horizontal and the throat vertical. Refer to Fig. 4.1.2.2(A).

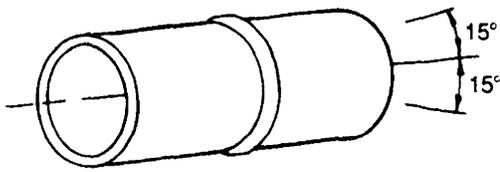
4.1.2.2.2 Horizontal Position 2F and 2FR

(1) Position 2F pipe with its axis vertical so that the weld is deposited on the upper side of the horizontal surface and against the vertical surface. The axis of the weld will be horizontal and the pipe is not to be rotated during welding. Refer to Fig. 4.1.2.2(B).

(2) Position 2FR pipe with its axis horizontal and the axis of the deposited weld in the vertical plane. The pipe is rotated during welding. Refer to Fig. 4.1.2.2(C).

4.1.2.2.3 Overhead Position 4F. Pipe with its axis vertical so that the weld is deposited on the underside of the horizontal surface and against the vertical surface. The axis of the weld will be horizontal and the pipe is not to be rotated during welding. Refer to Fig. 4.1.2.2(D).

4.1.2.2.4 Multiple Position 5F. Pipe with its axis horizontal and the axis of the deposited weld in the vertical plane. The pipe is not rotated during welding. Refer to Fig. 4.1.2.2(E).

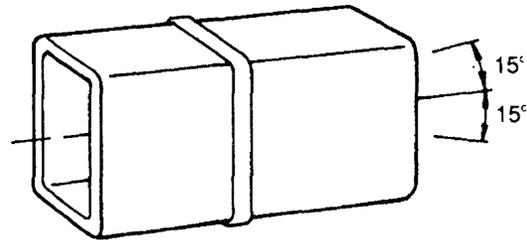
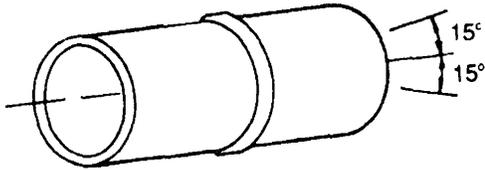
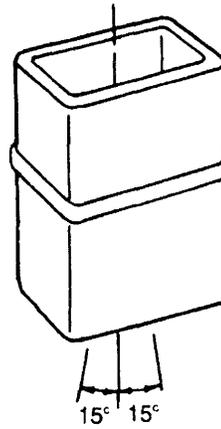
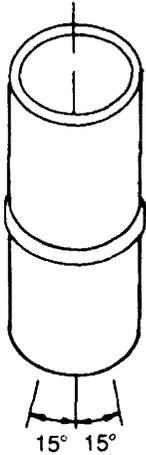


Pipe horizontal and rotated.
Weld flat ($\pm 15^\circ$) Deposit
filler metal at or near the top

**(A) Test position 1G
for flat position**

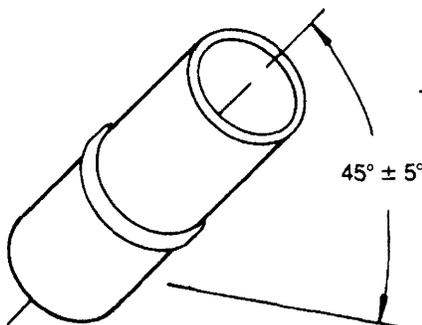
Pipe or tube vertical and
not rotated during welding.
Weld horizontal ($\pm 15^\circ$).

**(B) Test position 2G
for horizontal position**



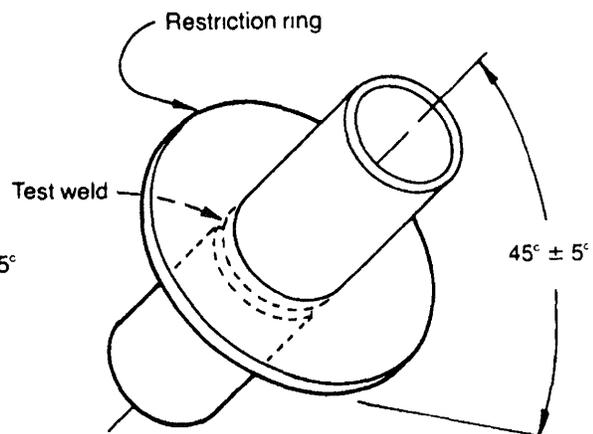
Pipe or tube horizontal fixed ($\pm 15^\circ$). Weld flat, vertical, overhead.

**(C) Test position 5G
for multiple position**



Pipe inclined fixed ($45^\circ \pm 5^\circ$) and not rotated during welding.

**(D) Test position 6G
for multiple position**



**(E) Test position 6GR
(T, K, or Y connections)
for multiple position**

Fig. 4.1.1.2— Positions of test pipes for groove welds

Tabulation of positions of fillet welds			
Position	Diagram reference	Inclination of axis	Rotation of face
Flat	A	0° to 15°	150° to 210°
Horizontal	B	0° to 15°	125° to 150°
			210° to 235°
Overhead	C	0° to 80°	0° to 125°
			235° to 360°
Vertical	D	15° to 80°	125° to 235°
	E	80° to 90°	0° to 360°

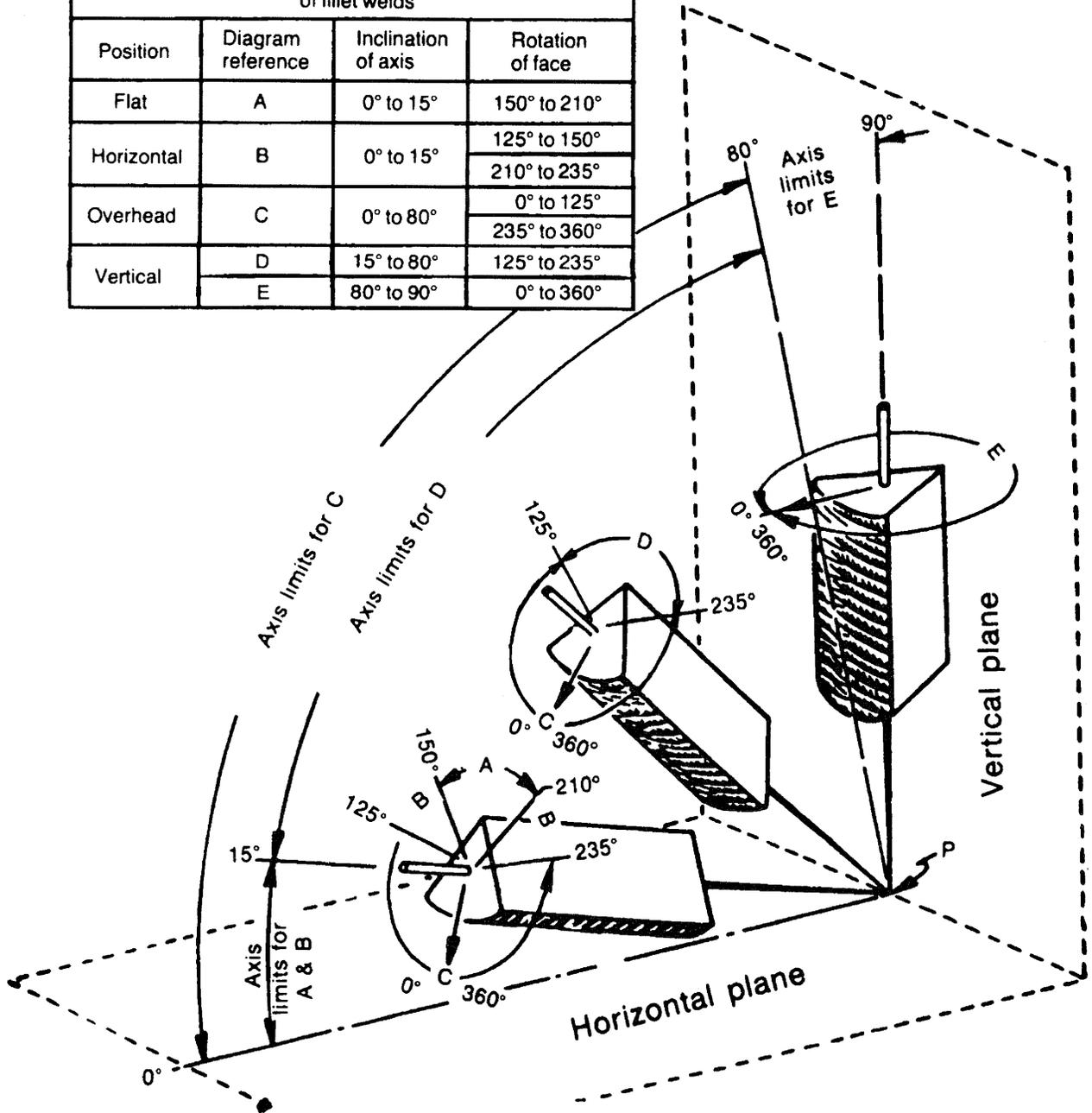


Fig. 4.1.2—Positions of fillet welds

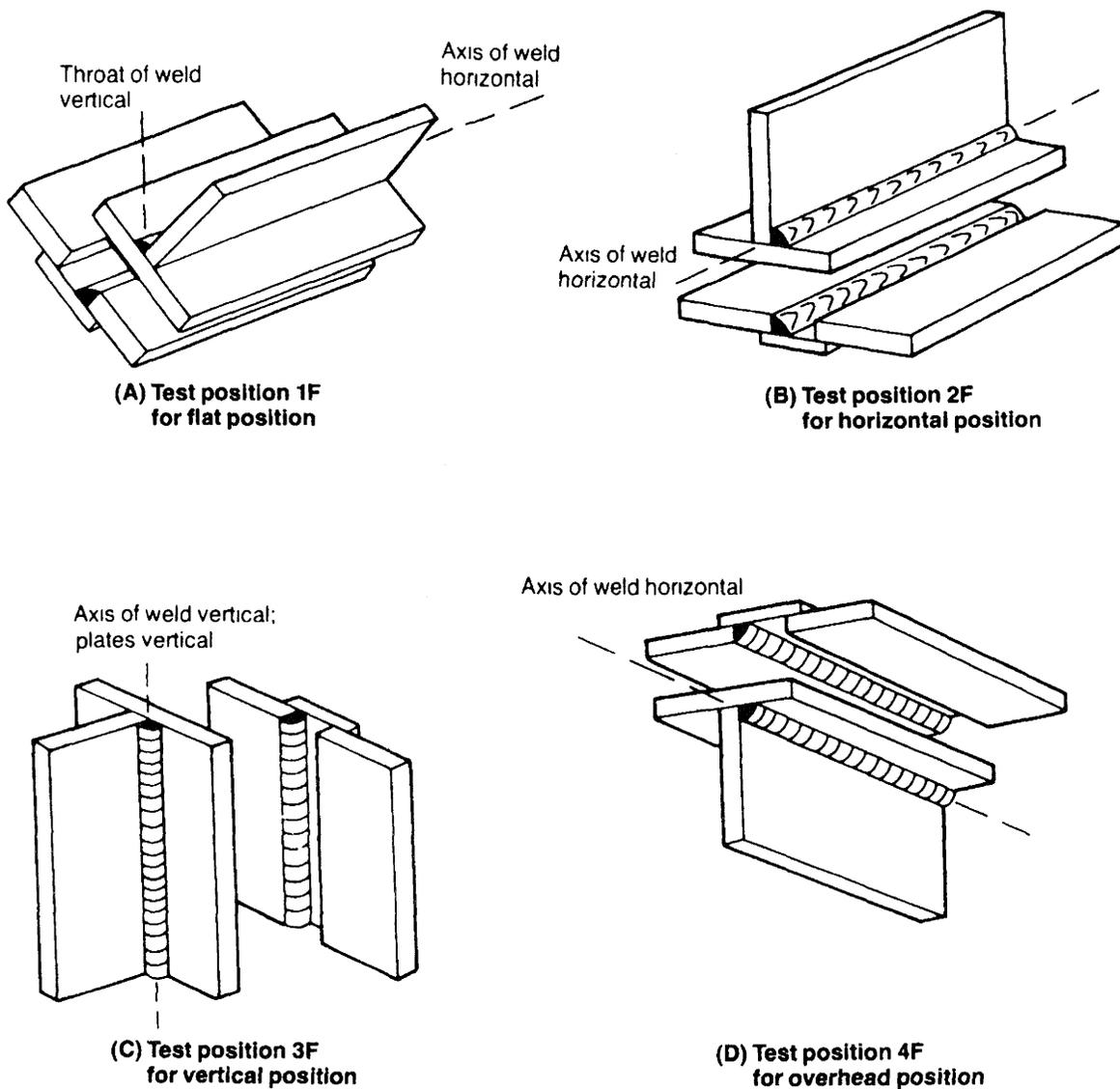


Fig. 4.1.2.1—Positions of test plates for fillet welds

4.2 Limitations of Variables

4.2.1 General Requirements

4.2.1.1 Those variables that will affect the mechanical properties or chemical properties or both are considered essential variables and must be controlled within the limits prescribed for the process. In preparing a welding procedure specification, the manufacturer, fabricator, contractor, or installer shall show specific values for the essential variables that are to be observed during qualification. When qualified, the essential variables are established and the procedure may be utilized within the limits hereinafter established. Changes in any essential variable, exceeding the prescribed limits, will require a new procedure incorporating the necessary change. The new procedure must then be qualified as required for the initial procedure.

4.2.1.2 Joint welding procedure specifications incorporating a combination of two or more welding processes in a single joint shall include the essential variables that apply to each process and which shall be observed during the use of each respective process. Changes exceeding the limitations for the essential variables of any one or more processes shall require establishment of a new procedure, incorporating the changes, and qualification of the new procedure.

4.2.1.3 Variables not listed are not considered essential for the specific process. However, their omission is not to be considered an indication that such variables should be ignored.

4.2.1.4 The ranges allowed in the limitations of variables are based on the individual values actually used in qualification of the welding procedure.

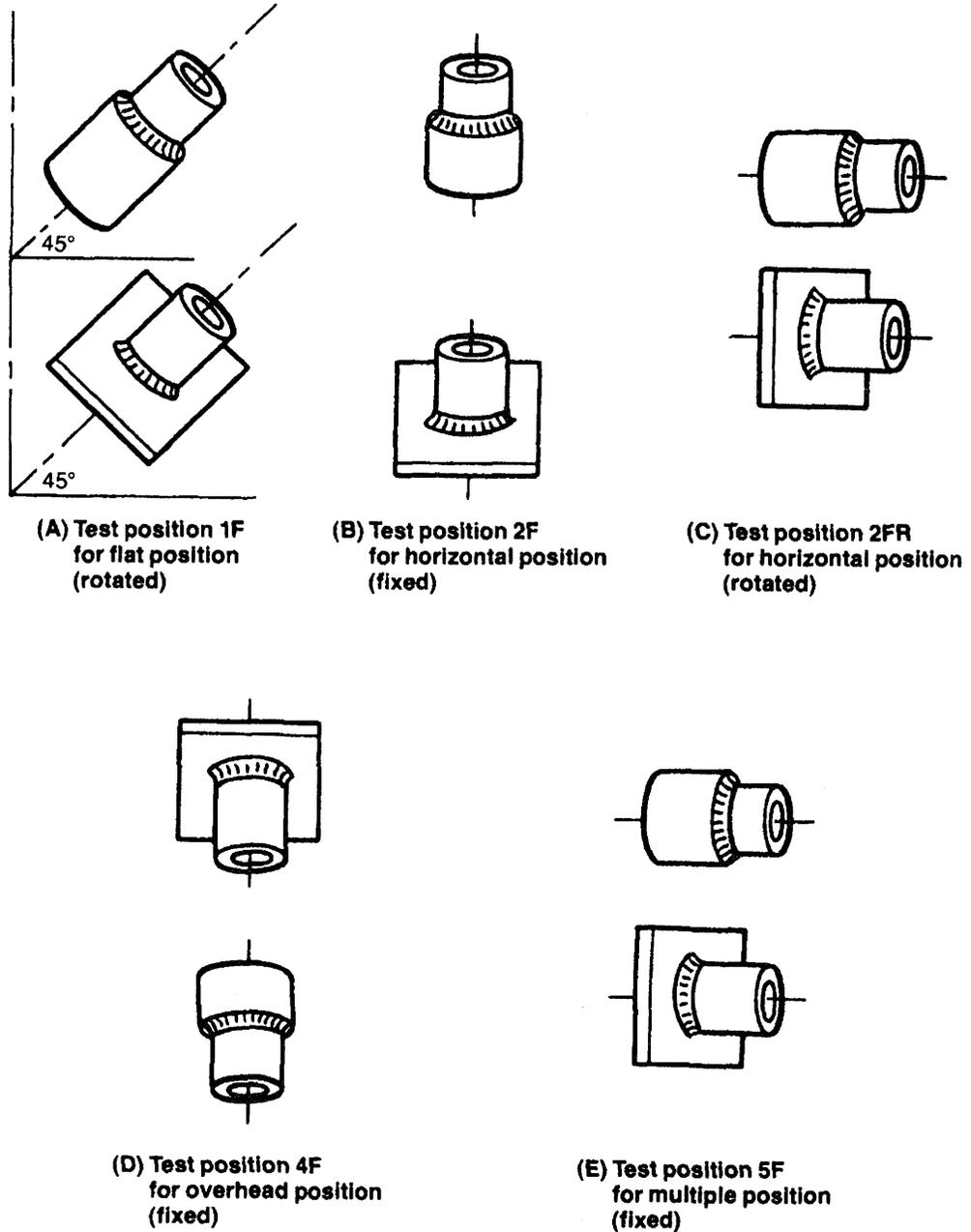


Fig. 4.1.2.2—Positions of test pipes for fillet welds

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4.2.1.5 Where a combination of two or more welding processes is used to complete a weld, the essential variables for each process shall apply to that portion of the weld in which the process is used. Where two or more welding processes are used in a single joint, the thickness of weld metal deposited by each process shall be as specified in the joint welding procedure specification. The thickness (of weld metal) qualified shall be as specified in the limitations of variables which shall apply severally to the weld deposited by each process.

4.2.2 Limitations of Variables by Process. The variables listed in 4.2.2 shall be considered essential variables of a joint welding procedure. Any change exceeding the limitations thereof shall require a new procedure incorporating those changes and qualification of that procedure.

4.2.2.1 Shielded Metal Arc Welding (SMAW)

*(1) A change in base metal from one P number grouping to another P number grouping.

(2) A change in the base metal thickness for single pass welding beyond the range of 0.75t to 1.5t for test plate of 1.60 mm¹ (0.063 in.) or less and 0.5t to 1.25t for thicker than 1.60 mm (0.063 in.). For multiple pass welding, 0.5t to 2t for test plate under 25.4 mm (1 in.) in thickness and 0.5t to unlimited for test plate 25.4 mm (1 in.) or over in thickness, where t is the thickness of the material used for procedure qualification.

*(3) A decrease of 14° C (25° F) or more in the minimum specified preheat or interpass temperature used in the procedure qualification.

*(4) A change increasing the maximum preheat or interpass temperature when specified for metallurgical considerations.

*(5) A change in the postweld heat treating temperature range and aggregate time at temperature beyond that specified.

(6) Filler metal:

(a) An increase in specified filler metal strength classification exceeding 69 MPa (10 000 psi) nominal.

(b) A decrease in filler metal strength classification.

(c) A change from one F number to any other F number.

*(d) A change in weld deposit from one A number to any other A number.

(7) A decrease of more than one standard size of filler metal diameter or an increase in standard filler metal diameter.

(8) A change in the welding position (refer to 4.1).

(9) A change in dimensions of the welding groove exceeding the following:

(a) Root opening: with backing + 6.4 mm (1/4 in.), - 1.6 mm (1/16 in.); without backing, ± 1.6 mm (1/16 in.).

*(b) Root face: ± 20 percent when back gouging is not used.

(c) Groove angle: + 20 degrees, - 5 degrees.

*(d) Groove radius: + 3.2 mm (1/8 in.), - 0.

(10) The omission of or change in the type of backing.

*(11) The omission of back gouging.

*(12) A change from single pass weld to multiple pass weld or vice versa.

(13) For a specified joint configuration and thickness, any change in the number of passes exceeding 25 percent unless the change is proportional to a change in groove area.

(14) A change in the second side root treatment of double welded joints (joints welded from two sides):

(a) A change from a mechanical method to a thermal method.

(b) A change in thermal method of preparation.

(c) Any increase in the remaining root face height.

(15) A change in welding current or electrode melting rate of more than 15 percent provided the change does not result in heat input outside the recommendation of the base metal producer or currents outside the range recommended by the electrode manufacturer.

(16) In vertical position welding, any change in the direction of progression of welding.

4.2.2.2 Gas Metal Arc Welding (GMAW)

(1) A change in feed rate of filler metal additions exceeding 20 percent.

(2) A change in the number of electrodes.

(3) A change in specified electrode extension exceeding 6.4 mm (1/4 in.).

(4) A change of more than 12.7 mm (1/2 in.) in the specified longitudinal spacing of electrodes.

(5) A change of more than 10 percent or 1.6 mm (1/16 in.), whichever is greater, in the specified lateral spacing of electrodes.

(6) In machine or automatic welding, any change in travel speed exceeding 10 percent.

(7) In machine or automatic welding, the addition or omission of oscillation or change in oscillation amplitude or frequency exceeding 10 percent.

(8) A change in shielding gas nominal composition.

(9) An increase of 25 percent or more or a decrease of 10 percent or more in the rate of flow of the shielding gas.

*(10) A change in base metal from one P number grouping to another P number grouping.

(11) A change in the base metal thickness for single pass welding beyond the range of 0.75t to 1.5t for test plates of 1.60 mm (0.063 in.) or less and 0.5t to 1.25t for thicker than 1.60 mm (0.063 in.). For multiple pass welding, 0.5t to 2t for test plates under 25.4 mm (1 in.) in thickness and 0.5t to unlimited for test plates 25.4 mm (1 in.)

1. Measurements are given in SI units and U.S. customary units in parentheses. The U.S. customary units are the principal units to be used. See the explanation in the preface.

*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2.

*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2.

or over in thickness, where t is the thickness of the material used for procedure qualification.

*(12) A decrease of 14° C (25° F) or more in the minimum specified preheat or interpass temperature used in the procedure qualification.

*(13) A change increasing the maximum preheat or interpass temperature when specified for metallurgical considerations.

*(14) A change in the postweld heat treating temperature and aggregate time at temperature beyond that specified.

(15) Filler metal:

(a) An increase in specified filler metal strength classification exceeding 69 MPa (10 000 psi).

(b) A decrease in filler metal strength classification.

(c) A change from one F number to any other F number.

*(d) A change in weld deposit from one A number to any other A number.

(16) A decrease of more than one standard size of filler metal diameter or an increase in standard filler metal diameter.

(17) Addition or omission of filler metal from a source other than the electrode.

(18) A change in the form or type of filler metal additions (e.g., wire to powder).

(19) A change in the welding position (refer to 4.1).

(20) A change in dimensions of the welding groove exceeding the following:

(a) Root opening: with backing, + 6.4 mm (1/4 in.), - 1.6 mm (1/16 in.); without backing, \pm 1.6 mm (1/16 in.).

*(b) Root face: \pm 20 percent when back gouging is not used.

(c) Groove angle: + 20 degrees, - 5 degrees.

*(d) Groove radius: + 3.2 mm (1/8 in.), - 0.

(21) The omission of or change in the type of weld backing or any change in backing gas nominal composition.

*(22) The omission of back gouging.

*(23) A change from single pass weld to multiple pass weld or vice versa.

(24) For a specified joint configuration and thickness, any change in the number of passes exceeding 25 percent unless the change is proportional to a change in groove area.

(25) A change in second side root treatment of double welded joints (joints welded from two sides):

(a) A change from a mechanical method to a thermal method.

(b) Any change in thermal method of preparation.

(c) Any increase in the remaining root face height.

(26) A change from alternating current to direct

current or vice versa, or a change in polarity for direct current.

(27) A change in welding current or electrode melting rate of more than 10 percent. A change of less than 10 percent must not result in heat input exceeding the recommendation of the base metal producer.

(28) A change of more than 2 V in arc voltage above or below the specified mean arc voltage. A change of less than 2 V must not result in heat input exceeding the recommendations of the base metal producer.

(29) The addition or omission of current pulsation or changes in pulse times or amplitudes exceeding 10 percent.

(30) A change from forehand to backhand welding or vice versa.

(31) In vertical welding, any change in the direction of progression of welding.

4.2.2.3 Gas Tungsten Arc Welding (GTAW)

(1) A change in tungsten electrode type, nominal size or end preparation.

(2) A change in the number of electrodes.

(3) A change of more than 12.7 mm (1/2 in.) in the specified longitudinal spacing of electrodes.

(4) A change of more than 10 percent or 1.6 mm (1/16 in.), whichever is greater, in the specified lateral spacing of electrodes.

(5) A change in travel speed exceeding 10 percent.

(6) A change in shielding gas nominal composition.

(7) An increase of 25 percent or more or a decrease of 10 percent or more in the rate of flow of the shielding gas.

(8) Additional limitations of variables for machine and automatic welding:

(a) Any change in arc voltage exceeding 1 V

(b) Any change in amperage exceeding 5 percent

(c) A change in upslope or downslope time program

(d) Addition or omission of magnetic fields for the control of the arc plasma

(e) A change in filler wire feed rate exceeding 10 percent

(f) A change in the filler wire size exceeding one nominal diameter

(g) A change from automatic voltage controlled head to manually positioned head

(h) The addition or omission of oscillation or change in oscillation amplitude exceeding 10 percent or 1.6 mm (1/16 in.), whichever is greater, or oscillation frequency exceeding 20 percent.

(9) A change from an autogenous weld to one made with filler wire and vice versa.

*(10) A change in base metal from one P number grouping to another P number grouping.

*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2

*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2.

(11) A change in the base metal thickness for single pass welding beyond the range of 0.75t to 1.5t for test plates of 1.60 mm (0.063 in.) or less and 0.5t to 1.25t for thicker than 1.60 mm (0.063 in.). For multiple pass welding, 0.5t to 2t for test plates under 25.4 mm (1 in.) in thickness and 0.5t to unlimited for test plates 25.4 mm (1 in.) or over in thickness, where t is the thickness of the material used for procedure qualification.

*(12) A decrease of 14° C (25° F) or more in the minimum specified preheat or interpass temperature used in the joint welding procedure qualification.

*(13) A change increasing the maximum preheat or interpass temperature when specified for metallurgical considerations.

*(14) A change in the postweld heat treating temperature range and aggregate time at temperature beyond that specified.

(15) Filler metal:

(a) An increase in specified filler metal strength classification exceeding 69 MPa (10 000 psi) nominal

(b) A decrease in filler metal strength classification

(c) A change from one F number to any other F number

*(d) A change in weld deposit from one A number to any other A number.

(16) A decrease of more than one standard size of filler metal diameter or an increase in standard filler metal diameter.

(17) Change in the welding position (refer to 4.1).

(18) A change in dimensions of the welding groove exceeding the following:

(a) Root opening: with backing, + 6.4 mm (1/4 in.), - 1.6 mm (1/16 in.); without backing, ± 1.6 mm (1/16 in.)

*(b) Root face: ± 20 percent when back gouging is not used

(c) Groove angle: + 20 degrees, - 5 degrees

*(d) Groove radius: + 3.2 mm (1/8 in.), - 0.

(19) The omission of or change in the type of backing. For single welded joints, addition or omission of consumable insert or change in shape or size of insert.

*(20) The omission of back gouging

*(21) A change from single pass weld to multiple pass weld or vice versa.

(22) For a specified joint configuration and thickness, any change in the number of passes exceeding 25 percent unless the change is proportional to a change in groove area.

(23) A change in second side root treatment of double welded joints (joints welded from two sides):

(a) A change from a mechanical method to a thermal method

(b) Any change in thermal method

(c) Any increase in the remaining root face height.

*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2

(24) A change from alternating current to direct current or vice versa, or a change in polarity for direct current.

(25) A change in welding current of more than 15 percent. A change of less than 15 percent must not result in heat input exceeding the recommendation of the base metal producer.

(26) A change of more than 2 V in arc voltage above or below the specified mean arc voltage. A change of less than 2 V must not result in heat input exceeding the recommendations of the base metal producer.

(27) The addition or omission of current pulsation or changes in pulse times or amplitudes exceeding 15 percent.

(28) A change from forehand to backhand welding or vice versa.

(29) In vertical position welding, any change in the direction of progression of welding.

4.2.2.4 Flux Cored Arc Welding (FCAW)

(1) A change in feed rate of metal additions exceeding 20 percent.

(2) A change in the number of electrodes.

(3) A change in specified electrode extension exceeding 9.5 mm (3/8 in.).

(4) A change of more than 12.7 mm (1/2 in.) in the specified longitudinal spacing of electrodes.

(5) A change of more than 10 percent or 1.6 mm (1/16 in.), whichever is greater, in the specified lateral spacing of electrodes.

(6) In machine or automatic welding, any change in travel speed exceeding 10 percent.

(7) In machine or automatic welding, the addition or omission of oscillation or change in oscillation amplitude or frequency exceeding 10 percent.

(8) A change in shielding gas nominal composition.

(9) An increase of 25 percent or more or a decrease of 10 percent or more in the rate of flow of the shielding gas.

*(10) A change in base metal from one P number grouping to another P number grouping.

(11) A change in the base metal thickness for single pass welding beyond the range of 0.75t to 1.5t for test plates of 1.60 mm (0.063 in.) or less and 0.5t to 1.25t for thicker than 1.60 mm (0.063 in.). For multiple pass welding, 0.5t to 2t for test plates under 25.4 mm (1 in.) in thickness and 0.5t to unlimited for test plates 25.4 mm (1 in.) or over in thickness, where t is the thickness of the material used for procedure qualification.

*(12) A decrease of 14° C (25° F) or more in the minimum specified preheat or interpass temperature used in the procedure qualification.

(13) A change increasing the maximum preheat or interpass temperature when specified for metallurgical considerations.

*(14) A change in the postweld heat treating tem-

*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2

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perature range and aggregate time at temperature beyond that specified.

- (15) Filler metal:
- (a) An increase in specified filler metal strength classification exceeding 69 MPa (10 000 psi) nominal
 - (b) A decrease in filler metal strength classification
 - (c) A change from one F number to any other F number
 - * (d) A change in weld deposit from one A number to any other A number.
- (16) A decrease of more than one standard size of filler metal diameter or an increase in standard filler metal diameter.
- (17) Addition or omission of filler metal from a source other than the electrode.
- (18) A change in the form or type of filler metal additions (e.g., wire to powder).
- (19) A change in the welding position (refer to 4.1).
- (20) A change in dimensions of the welding groove exceeding the following:
- (a) Root opening: with backing, 6.4 mm (1/4 in.), - 1.6 mm (1/16 in.); without backing, \pm 1.6 mm (1/16 in.)
 - * (b) Root face: \pm 20 percent when back gouging is not used
 - (c) Groove angle: + 20 degrees, - 5 degrees
 - * (d) Groove radius: + 3.2 mm (1/8 in.), - 0.
- (21) The omission of or change in the type of weld backing or any change in backing gas nominal composition.
- * (22) The omission of back gouging.
 - * (23) A change from single pass weld to multiple pass weld or vice versa.
- (24) For a specified joint configuration and thickness, any change in the number of passes exceeding 25 percent unless the change is proportional to a change in groove area.
- (25) A change in second side root treatment of double welded joints (joints welded from two sides):
- (a) A change from a mechanical method to a thermal method
 - (b) Any change in thermal method of preparation
 - (c) Any increase in the remaining root face height.
- (26) A change from alternating current to direct current or vice versa, or a change in polarity for direct current.
- (27) A change in welding current or electrode melting rate of more than 15 percent. A change of less than 15 percent must not result in heat input exceeding the recommendation of the base metal producer.
- (28) A change of more than 10 percent in arc voltage above or below the specified mean arc voltage. A change of less than 10 percent must not result in heat

input exceeding the recommendations of the base metal producer.

(29) A change from forehand to backhand welding or vice versa.

(30) In vertical welding, any change in the direction of progression of welding.

4.2.2.5 Electroslag Welding (ESW)

- (1) A change in the number of electrodes.
- (2) A change in vertical travel speed exceeding 20 percent.
- (3) A change in filler metal oscillation traverse speed exceeding 254 mm/min (10 ipm).
- (4) A change in filler metal oscillation traverse dwell exceeding two seconds.
- (5) A change in filler metal oscillation length affecting proximity of filler metal to the molding shoes by more than 6.4 mm (1/4 in.).
- * (6) A change in base metal from one P number grouping to another P number grouping.
- (7) A change in the base metal thickness beyond the range of 0.5t to 1.1t, where t is the thickness of the material used for procedure qualification.
- * (8) A decrease of 14° C (25° F) or more in the minimum specified preheat or interpass temperature used in the procedure qualification.
- * (9) A change increasing the maximum preheat temperature when specified for metallurgical considerations.
- * (10) A change in the postweld heat treating temperature range and aggregate time at temperature beyond that specified.
- * (11) A change in weld deposit from one A number to another A number.
- (12) A change of more than one standard size of filler metal diameter.
- (13) A change in consumable guide tube composition from (a) one having 0.30 percent carbon or less to one having over 0.30 percent carbon, or vice versa, or (b) a mild or low alloy steel to a high alloy steel or vice versa.
- (14) A change in the consumable guide cross-sectional area exceeding 30 percent.
- (15) A change in the flux system (cored electrode to magnetic electrode, to flux covered consumable guide, to externally added flux, etc.).
- (16) A change in the nominal chemical composition of the flux.
- (17) A change in the joint axis position from vertical by more than 10 degrees.
- (18) A change in dimensions of the welding groove exceeding the following:
 - (a) Root opening: + 6.4 mm (1/4 in.), - 1.6 mm (1/16 in.)
 - * (b) Root face: \pm 20 percent
 - (c) Groove angle: \pm 10 degrees
 - * (d) Groove radius: + 3.2 mm (1/8 in.), - 0.
- (19) The omission of or change in the type

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of weld backing, including a reduction in any cross-sectional dimension or area of solid nonfusing shoes, either fixed or movable, exceeding 25 percent.

*(20) The omission of back gouging.

*(21) A change from single pass weld to multiple pass weld or vice versa.

(22) A change in second side root treatment of double welded joints (joints welded from two sides):

(a) A change from a mechanical method to a thermal method

(b) A change in thermal method of preparation

(c) An increase in the remaining root face height.

(23) A change from alternating current to direct current or vice versa, or a change in polarity for direct current.

(24) A change in welding current exceeding 20 percent or electrode melting rate exceeding 10 percent. A change in welding current of less than 20 percent, or a change in electrode melting rate of less than 10 percent, must not result in heat input exceeding the recommendation of the base metal producer.

(25) A change of more than 10 percent in arc voltage above or below the specified mean arc voltage. A change of less than 10 percent must not result in heat input exceeding the recommendations of the base metal producer, except that any changes within the starting or finishing sumps are permissible provided the sumps are removed after welding.

4.2.2.6 Electrode Gas Welding (GMAW-EG & FCAW-EG)

(1) A change in the number of electrodes.

(2) A change in vertical travel speed exceeding 20 percent.

(3) A change in filler metal oscillation traverse speed exceeding 254 mm/min (10 ipm).

(4) A change in filler metal oscillation traverse dwell exceeding two seconds.

(5) A change in filler metal oscillation length affecting proximity of filler metal to the molding shoes by more than 3.2 mm (1/8 in.).

(6) A change in shielding gas nominal composition.

(7) An increase of 25 percent or more or a decrease of 10 percent or more in the rate of flow of the shielding gas.

*(8) A change in base metal from one P number grouping to another P number grouping.

(9) A change in the base metal thickness beyond the range of 0.5t to 1.1t, where t is the thickness of the material used for procedure qualification.

*(10) A decrease of 14° C (25° F) or more in the minimum specified preheat or interpass temperature used in the procedure qualification.

*(11) A change increasing the maximum preheat

temperature when specified for metallurgical considerations.

*(12) A change in the postweld heat treating temperature range and aggregate time at temperature beyond that specified.

*(13) A change in weld deposit from one A number to any other A number.

(14) A change of more than one standard size of filler metal diameter.

(15) A change in flux system (cored electrode to magnetic electrode, etc.).

(16) A change in the joint axis position from vertical by more than 10 degrees.

(17) A change in dimensions of the welding groove exceeding the following:

(a) Root opening: + 6.4 mm (1/4 in.), - 1.6 mm (1/16 in.)

*(b) Root face: ± 20 percent

(c) Groove angle: ± 10 degrees

*(d) Groove radius: + 3.2 mm (1/8 in.), - 0.

(18) The omission of or change in the type of weld backing, including a reduction in any cross-sectional dimension or area of solid nonfusing shoes, either fixed or movable, exceeding 25 percent. Any change in backing gas nominal composition.

*(19) The omission of back gouging.

*(20) A change from single pass weld to multiple pass weld or vice versa.

(21) A change in second side root treatment of double welded joints (joints welded from two sides):

(a) A change from a mechanical method to a thermal method

(b) Any change in thermal method of preparation

(c) An increase in the remaining root face height.

(22) A change from alternating current to direct current or vice versa, or a change in polarity for direct current.

(23) A change in welding current or electrode melting rate of more than 15 percent. A change of less than 15 percent must not result in heat input exceeding the recommendation of the base metal producer.

(24) A change of more than 10 percent in arc voltage above or below the specified mean arc voltage. A change of less than 10 percent must not result in heat input exceeding the recommendations of the base metal producer.

4.2.2.7 Submerged Arc Welding (SAW)

(1) A change in feed rate of welding electrodes, exceeding 20 percent.

(2) A change in the number of electrodes.

(3) A change in specified electrode extension exceeding 9.5 mm (3/8 in.).

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*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2.

(4) A change of more than 12.7 mm (1/2 in.) in the specified longitudinal spacing of electrodes.

(5) A change of more than 10 percent or 1.6 mm (1/16 in.), whichever is greater, in the specified lateral spacing of electrodes.

(6) A change of more than 15 percent above or below the specified mean travel speed.

*(7) A change in base metal from one P number grouping to another P number grouping.

(8) A change in the base metal thickness for single pass welding beyond the range of 0.75t to 1.5t for test plates of 1.60 mm (0.063 in.) or less and 0.5t to 1.25t for thicker than 1.60 mm (0.063 in.). For multiple pass welding, 0.5t to 2t for test plates under 25.4 mm (1 in.) in thickness and 0.5t to unlimited for test plates 25.4 mm (1 in.) or over in thickness, where t is the thickness of the material used for procedure qualification.

*(9) A decrease of 14° C (25° F) or more in the minimum specified preheat or interpass temperature used in the procedure qualification.

*(10) A change increasing the maximum preheat or interpass temperature when specified for metallurgical considerations.

*(11) A change in the postweld heat treating temperature range and aggregate time at temperature beyond that specified.

(12) A change increasing the minimum specified deposited weld metal strength level; e.g., 552 to 621 MPa (80 000 to 90 000 psi) but not vice versa.

(13) A decrease of more than one standard size of filler metal diameter or an increase in standard filler metal diameter. For welding with an alloy flux, any change in standard diameter of filler metal.²

(14) Addition or omission of filler metal from a source other than the electrode.

(15) A change in the form or type of filler material additions or amounts exceeding 20 percent.

*(16) A change in weld deposit from one A number to any other A number.

(17) A change in electrode and flux combination not covered by AWS Specification A5.17 or A5.23.

(18) A change in the welding position (refer to 4.1).

(19) A change in dimensions of the welding groove exceeding the following:

(a) Root opening: with backing, + 6.4 mm (1/4 in.), - 1.6 mm (1/16 in.); without backing, ± 1.6 mm (1/16 in.)

*(b) Root face: ± 20 percent when back gouging is not used

(c) Groove angle: + 20 degrees, - 5 degrees

*(d) Groove radius: + 3.2 mm (1/8 in.), - 0.

(20) The omission of or change in the type of backing.

(21) The omission of back gouging.

(22) A change from single pass weld to multiple pass weld or vice versa.

(23) For a specified joint configuration and thickness, any change in the number of passes exceeding 25 percent unless the change is proportional to a change in groove area.

(24) A change in second side root treatment of double welded joints (joints welded from two sides):

(a) A change from a mechanical method to a thermal method

(b) Any change in thermal method of preparation

(c) Any increase in the remaining root face height.

(25) A change in type of current (ac or dc) or a change in polarity.

(26) A change in welding current of more than 10 percent. A change of less than 10 percent must not result in heat input exceeding the recommendation of the base metal producer.

(27) A change of more than 15 percent in arc voltage above or below the specified mean arc voltage. A change of less than 15 percent must not result in heat input exceeding the recommendations of the base metal producer.

4.2.2.8 Plasma Arc Welding (PAW)

(1) A change in tungsten electrode type, size or end preparation.

(2) In machine or automatic welding, the addition or omission of oscillation or change in oscillation amplitude or frequency exceeding 10 percent.

(3) A change in shielding or plasma gas nominal composition.

(4) An increase or decrease in the rate of gas flow of:

(a) ± 10 percent in plasma gas

(b) + 25 percent, - 10 percent in shielding or backing gas.

(5) Additional limitations of variables for machine and automatic welding:

(a) The omission or addition of upslope or downslope control, or both, of either current or gas flow

(b) Addition or omission of magnetic fields for the control of arc plasma

(c) For circumferential welding, a change from fixed head to traveling head or vice versa

(d) Any change in travel speed exceeding 5 percent.

(6) A change in nominal torch orifice size.

(7) A change in nominal distance between electrode and torch orifice.

(8) A change from an autogenous weld to one made with filler wire and vice versa.

² An alloy flux is a flux upon which the alloy content of the weld is largely dependent

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*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2.

***(9)** A change in base metal from one P number grouping to another P number grouping.

(10) A change in the base metal thickness for single pass welding beyond the range of 0.75t to 1.5t for test plates of 1.60 mm (0.063 in.) or less and 0.5t to 1.25t for thicker than 1.60 mm (0.063 in.). For single pass welding employing the keyhole technique, the maximum thickness welded in production shall not exceed the thickness of the test piece. For multiple pass welding, 0.5t to 2t for test plates under 25.4 mm (1 in.) or over in thickness, where t is the thickness of the material used for procedure qualification.

(11) A decrease of 14° C (25° F) or more in the minimum specified preheat or interpass temperature used in the procedure qualification.

(12) A change increasing the maximum preheat or interpass temperature when specified for metallurgical considerations.

***(13)** Any change in the postweld heat treating temperature range and aggregate time at temperature beyond that specified.

(14) Filler metal:

(a) An increase in specified filler metal strength classification exceeding 69 MPa (10 000 psi) nominal

(b) A decrease in filler metal strength classification

(c) A change from one F number to any other F number

***(d)** A change in weld deposit from one A number to any other A number.

(15) A decrease of more than one standard size of filler metal diameter or an increase in standard filler metal diameter.

(16) A change in welding position (refer to 4.1).

(17) A change in dimensions of the welding groove exceeding the following:

(a) Root opening: with backing, + 6.4 mm (1/4 in.), - 1.6 mm (1/16 in.); without backing, ± 1.6 mm (1/16 in.)

***(b)** Root face: ± 20 percent when back gouging is not used

(c) Groove angle: + 20 degrees, - 5 degrees

***(d)** Groove radius: + 3.2 mm (1/8 in.), - 0.

(18) The omission of or change in the type of weld backing; for single welded joints, addition or omission of consumable insert or change in shape or size of insert; any change in backing gas nominal composition.

***(19)** The omission of back gouging.

***(20)** A change from single pass weld to multiple pass weld or vice versa.

(21) For a specified joint configuration and thickness, any change in the number of passes exceeding 25 percent unless the change is proportional to a change in groove area.

(22) For second side preparation of double welded joints (welds made from two sides):

(a) A change from a mechanical method to a thermal method

(b) A change in thermal method of preparation

(c) An increase in the remaining root face height.

(23) A change from alternating current to direct current or vice versa, or a change in polarity for direct current.

(24) A change in welding current or electrode melting rate of more than 10 percent. A change of less than 10 percent must not result in heat input exceeding the recommendation of the base metal producer.

(25) A change of more than 2 V in arc voltage above or below the specified mean arc voltage. A change of less than 2 V must not result in heat input exceeding the recommendations of the base metal producer.

(26) The addition or omission of current pulsation or changes in pulse frequency or amplitude.

(27) A change from forehand to backhand welding or vice versa.

(28) In vertical welding, any change in the direction of progression of welding.

4.2.2.9 Oxyfuel Gas Welding (OFW)

(1) A change from the fuel gas qualified to any other fuel gas.

(2) A change from oxyfuel gas to air fuel gas welding.

(3) A change in tip size.

(4) A change from autogenous weld to one made with filler wire and vice versa.

(5) A change in base metal from one P number grouping to another P number grouping.

(6) A change in the base metal thickness for single pass welding beyond the range of 0.75t to 1.5t for test plates of 1.60 mm (0.063 in.) or less and 0.5t to 1.25t for thicker than 1.60 mm (0.063 in.). For multiple pass welding, 0.5t to 2t where t is the thickness of the material used for procedure qualification.

***(7)** A decrease of 14° C (25° F) or more in the minimum specified preheat or interpass temperature used in the procedure qualification.

***(8)** A change increasing the maximum preheat or interpass temperature when specified for metallurgical considerations.

***(9)** A change in the postweld heat treating temperature range and aggregate time at temperature beyond that specified.

(10) A change in weld metal strength exceeding 69 MPa (10 000 psi) nominal.

(11) A decrease of more than one standard size of filler metal diameter or an increase in standard filler metal diameter.

*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2.

*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2.

*(12) A change in weld deposit from one A number to any other A number.

(13) The addition, omission, or change in the type or nominal composition of the flux.

(14) A change in the welding position (refer to 4.1).

(15) A change in dimensions of the welding groove exceeding the following:

(a) Root opening: ± 1.6 mm (1/16 in.)

*(b) Root face: ± 20 percent when back gouging is not used

(c) Groove angle: ± 5 degrees

*(d) Groove radius: + 3.2 mm (1/8 in.), - 0.

*(16) The omission of back gouging.

*(17) A change from single pass weld to multiple pass weld or vice versa.

(18) For a specified joint configuration and thickness, any change in the number of passes exceeding 25 percent unless the change is proportional to a change in groove area.

(19) A change from forehand to backhand welding or vice versa.

(20) In vertical welding, any change in the direction of progression of welding.

(21) A change in the type of flame: neutral, oxidizing, or reducing (or carburizing).

4.3 Tests

4.3.1 General

4.3.1.1 Each welding procedure shall be qualified by making weld tests. The types of tests outlined below are to determine the mechanical properties, soundness, and appearance of welded joints made under a given procedure specification. (More comprehensive information on test methods and specimen preparation may be found in AWS B4.0, Standard Methods for Mechanical Testing of Welds.)

4.3.1.2 The specific tests to be employed in qualification of joint welding procedures are described below. Use of additional nondestructive testing is optional. It is strongly recommended that joint welding procedure qualification tests be subjected to the same type and level of nondestructive test as will be required for the production welds on which the procedure is to be employed. The test methods and acceptance requirements described in the following paragraphs are minimum requirements. Other methods and additional acceptance criteria are a matter of agreement between the contractor and purchaser.

4.3.1.3 Test plate and pipe sizes shall be sufficiently large to enable removal of the test specimens required in 4.3.2.

4.3.2 Tests Required and Description of Specimens and Tests

4.3.2.1 Groove Welds. For all but cast iron, refer to Table 4.3.2.1 for the type and number of test specimens required to qualify a groove welding procedure. The test assemblies and order of removal of specimens are shown

in Figs. 4.3.2.1A, B, C, D, and E. Bend tests shall be made in a jig having the contour shown in Fig. 4.3.2.1 F1, F2, or F3. For cast iron only, the test assembly, number of tests, test specimens and test acceptance criteria are shown in Fig. 4.3.2.1G.

4.3.2.1.1 Reduced Section Tension Test for Tensile Strength. Tension test specimens for plate and pipe shall conform to Fig. 4.3.2.1.1A. Pipe 76.2 mm (3 in.) or less may be tension tested in full section in place of reduced section specimens. Two tension specimens are required conforming to Fig. 4.3.2.1.1B. The method of mounting the specimens for testing is also shown in this figure.

4.3.2.1.2 Side-Bend Test for Soundness. Side-bend specimens shall conform to Fig. 4.3.2.1.2.

4.3.2.1.3 Face-Bend Test for Soundness. Face-bend specimens shall conform to Fig. 4.3.2.1.3.

4.3.2.1.4 Root-Bend Test for Soundness. Root-bend specimens shall conform to Fig. 4.3.2.1.3.

4.3.2.1.5 Visual Test for Appearance and Soundness. Each sample weld shall be inspected as follows:

(1) Prior to assembly of the test pieces—to assure that the proper materials are being used, that the parts have been cleaned, and that the joint preparation is correct.

(2) After fit-up—to check the joint clearances.

(3) After welding has been completed (including any postheating)—to detect any surface defects.

4.3.2.2 Fillet Welds. One test weld shall be made to conform to Fig. 4.1.2.2 or 4.3.2.2A. Where a range of fillet weld sizes is to be used in construction, one test shall be made with the maximum size single pass fillet weld and one test shall be made with the minimum size multiple pass fillet weld.

4.3.2.2.1 Macroetch Test for Soundness

(1) For plate, macroetch tests shall be made on each test weld. Three macroetch specimens shall be cut as shown in Fig. 4.3.2.2A and one end of each specimen shall be macroetched.

(2) For pipe-to-pipe specimens and pipe-to-plate specimens, the test assemblies shall be quartered as shown in Fig. 4.3.2.2B. One face of each quarter shall be polished and macroetched.

4.3.2.2.2 Visual Test for Appearance and Soundness. The entire length of fillet welds shall be visually examined.

4.3.3 Acceptance Criteria

4.3.3.1 Reduced Section Tension Test and Full Section Pipe Test. The tensile strength shall not be less than the minimum specified tensile strength of the base metal to be used in construction. The tensile specimen may fail in the base metal, the heat-affected zone, or in the weld deposit. For welds between base metals of different specified minimum tensile strengths, the specimens shall have a tensile strength not less than the metal with the lowest strength.

4.3.3.2 Side-, Face-, and Root-Bend Tests. The guided-bend specimens shall have no open discontinuities exceeding 3.2 mm (1/8 in.) measured in any direction on

*An asterisk indicates those essential variables which are common to all the welding processes listed under 4.2.2.

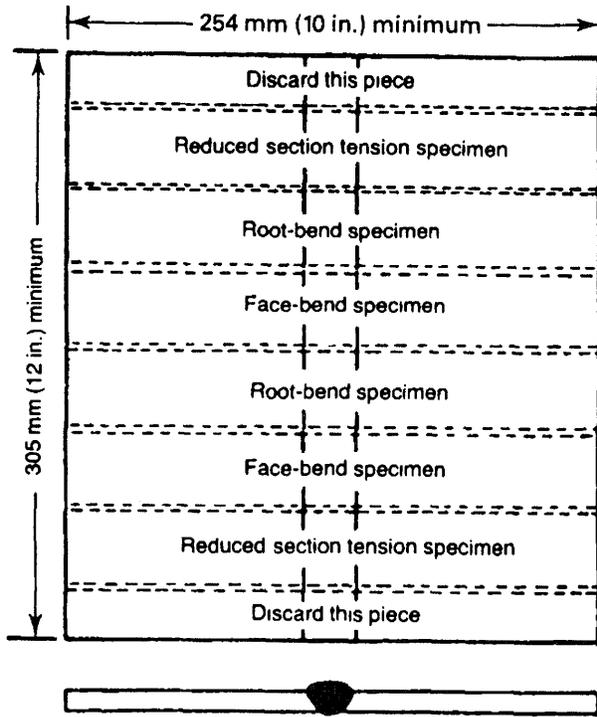


Fig. 4.3.2.1A—Plates 1.6 mm (1/16 in.) to 19 mm (3/4 in.)—procedure qualification

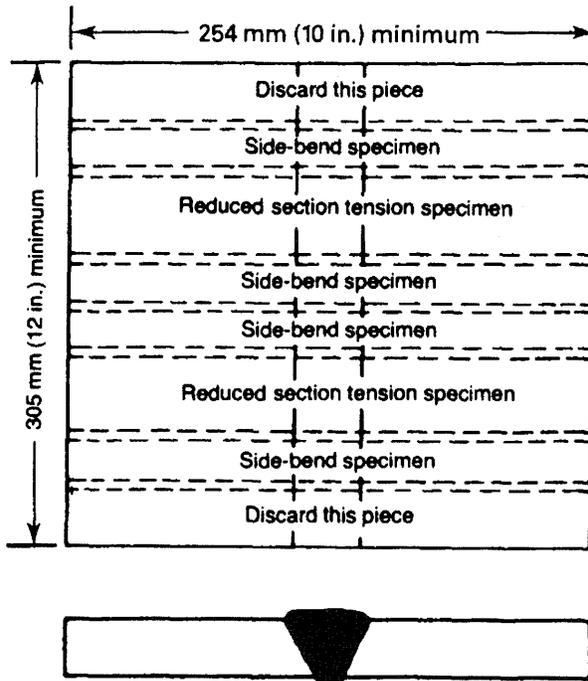


Fig. 4.3.2.1B—Plates over 19 mm (3/4 in.) and alternate 9.5 mm (3/8 in.) to 19 mm (3/4 in.)—procedure qualification

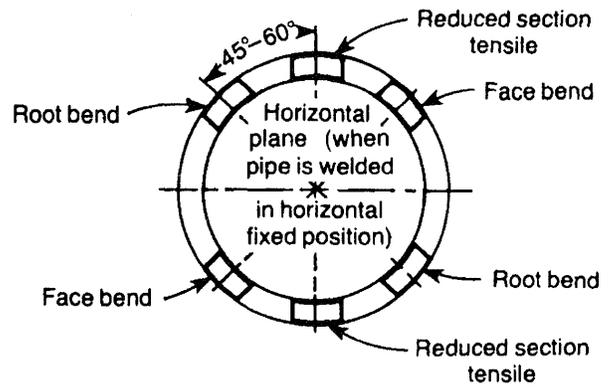


Fig. 4.3.2.1C—Pipes 1.6 mm (1/16 in.) to 19 mm (3/4 in.)—procedure qualification

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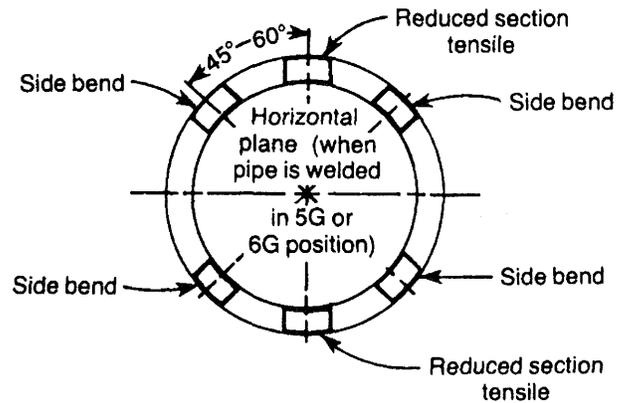


Fig. 4.3.2.1D—Pipes alternate over 9.5 mm (3/8 in.) to 19 mm (3/4 in.)—procedure qualification

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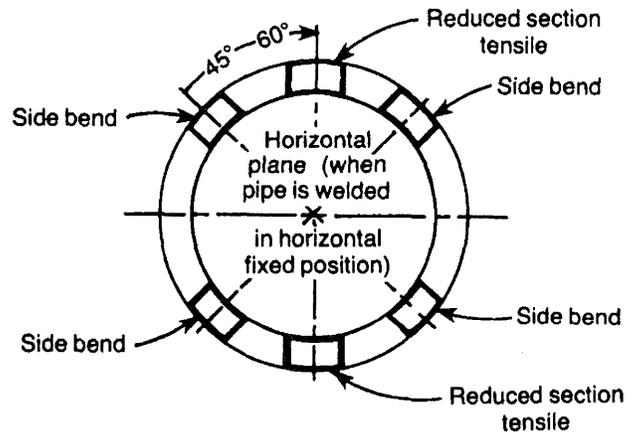
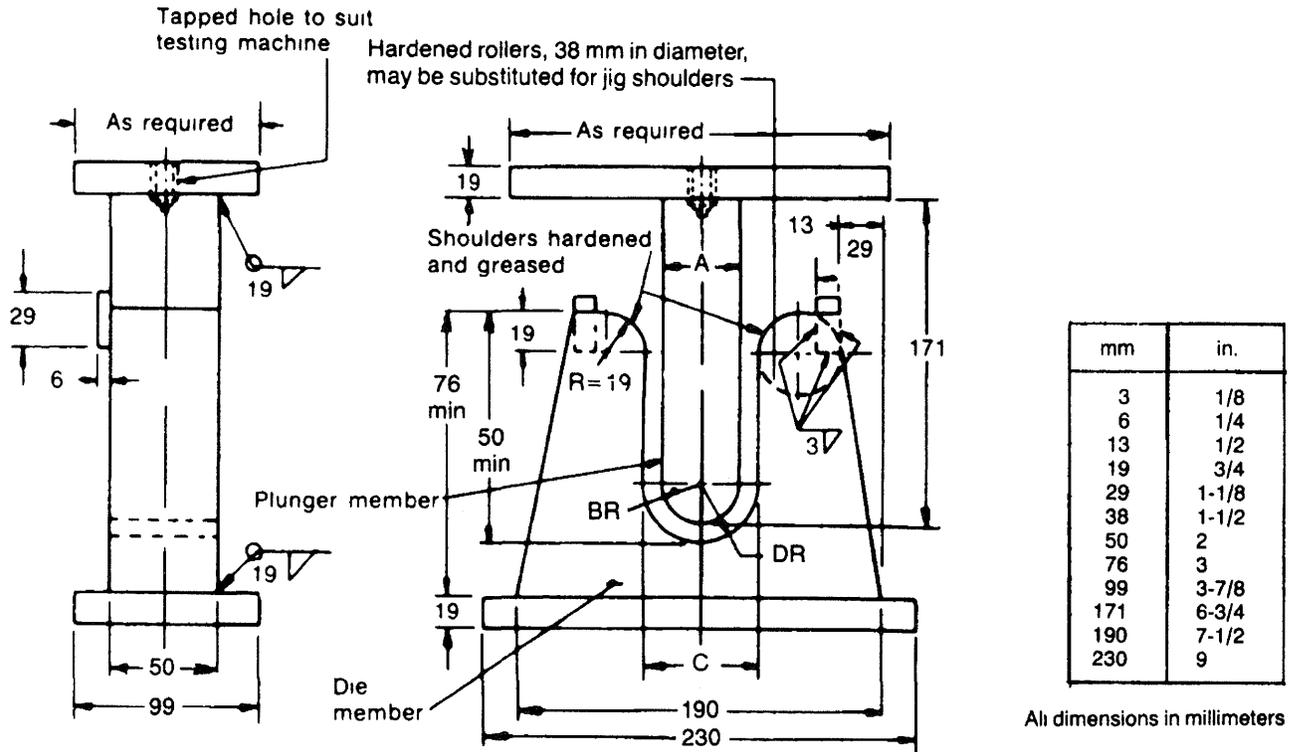


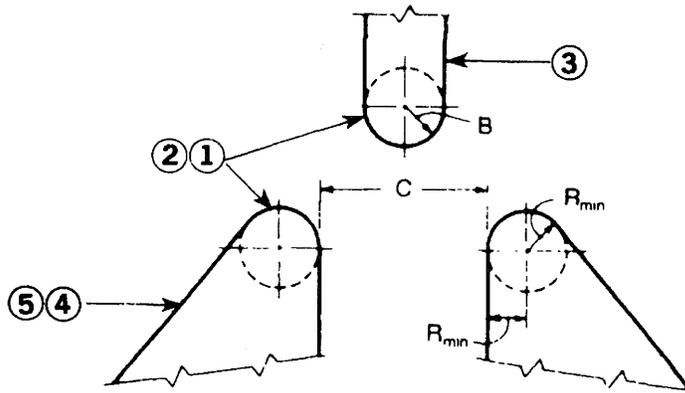
Fig. 4.3.2.1E—Pipes over 19 mm (3/4 in.)—procedure qualification

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Material	Thickness of specimens		B		C		D	
	mm	in.	mm	in.	mm	in.	mm	in.
P-52	2-10 incl.	1/16-3/8 incl.	5t	5t	12t+3	12t+1/8	6t+2	6t+1/16
P-51	2-10 incl.	1/16-3/8 incl.	4t	4t	10t+3	10t+1/8	5t+2	5t+1/16
P-11 & P-25	10 t	3/8 t	32 3-1/3t	1-1/4 3-1/3t	85 8-2/3t+3	3-3/8 8-2/3t+1/8	44 4-1/2t+2	1-11/16 4-1/2t+1/16
P-23 & B-171 Alloy 628	3	1/8	26	1-1/32	61	2-3/8	30	1-3/16
All others	0.7595-3.1453 10 t	0.0299-0.1345 3/8 t	6 19 2t	1/4 3/4 2t	22 61 6t+3	7/8 2-3/8 6t+1/8	11 30 3t+2	7/16 1-3/16 3t+1/16

Fig. 4.3.2.1F(1)— Guided-bend test jig

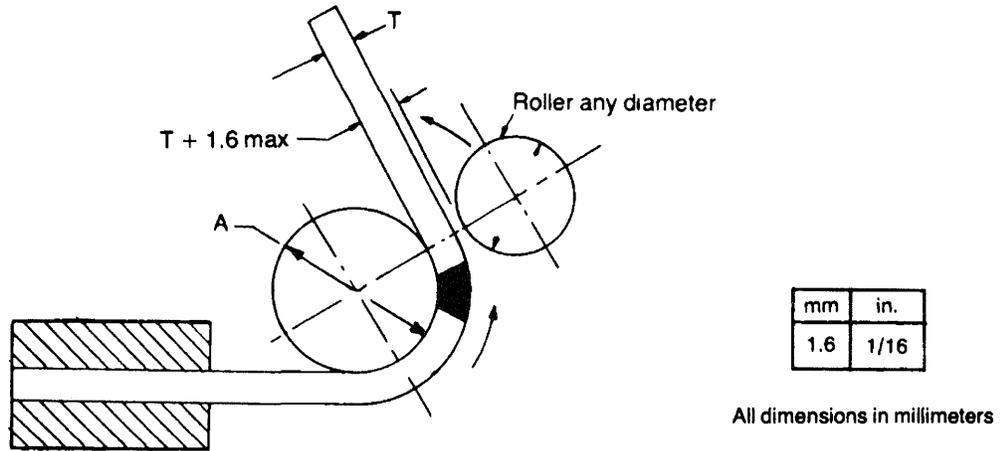


Material	Thickness of specimens		B		C	
	mm	in.	mm	in.	mm	in.
P-52	1.6-3 incl.	1/16-1/8 incl.	5t	5t	12t+3	12t+1/8
P-51	1.6-3 incl.	1/16-1/8 incl.	4t	4t	10t+3	10t+1/8
P-11 & P-25	10 t	3/8 t	32 3-1/3t	1-1/4 3-1/3t	85 8-2/3t+3	3-3/8 8-2/3t+1/8
P-23 & P-35 B-171, Alloy 628	3	1/8	26	1-1/32	61	2-3/8
All others	0.7595-3.4153 10 t	0.0299-0.1345 3/8 t	6 19 2t	1/4 3/4 2t	22 61 6t+3	7/8 2-3/8 6t+1/8

Notes:

1. Either hardened and greased shoulders or hardened rollers free to rotate shall be used.
2. The shoulders or rollers shall have a minimum bearing surface of 51 mm (2 in.) for placement of the specimen. The rollers shall be high enough above the bottom of the jig so that the specimens will clear the rollers when the ram is in the low position.
3. The ram shall be fitted with an appropriate base and shall be designed to minimize deflection and misalignment; provision shall be made for attachment to the testing machine. The ram to be used with the roller jig shall be of identical dimensions to the ram shown in Fig. 4.3.2.1F(1).
4. If desired, either the rollers or the roller supports may be made adjustable in the horizontal direction so that specimens of t thickness may be tested on the same jig.
5. The roller supports shall be fitted with an appropriate base designed to safeguard against deflection or misalignment and they shall be equipped with means for maintaining the rollers centered, midpoint and aligned with respect to the ram.
6. The weld and heat-affected zone in the case of a transverse weld-bend specimen shall be completely within the bend portion of the specimen after testing.

Fig. 4.3.2.1F(2)— Guided-bend roller test jig

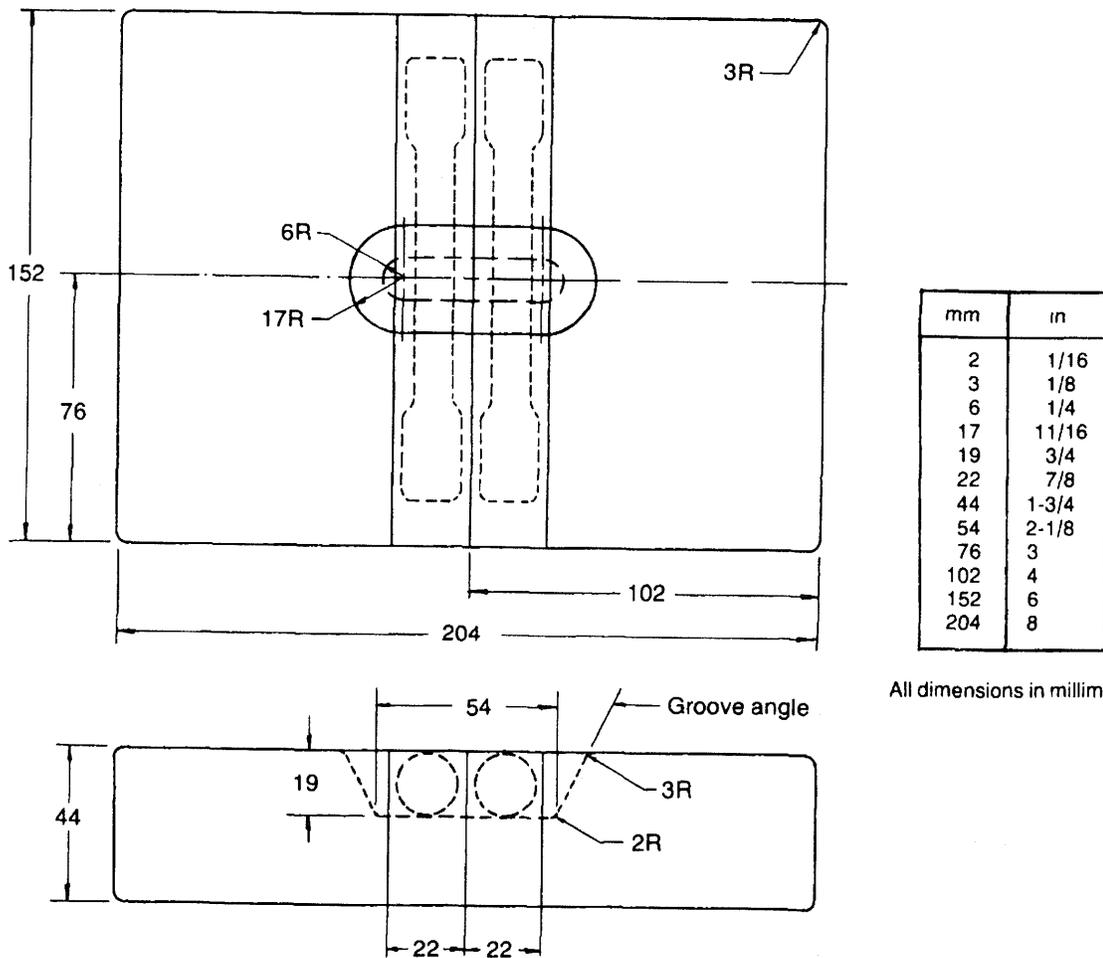


Material	Thickness of specimens (t)		A	
	mm	in.	mm	in.
P-52	1.6-10 incl.	1/16-3/8 incl.	10t	10t
P-51	1.6-10 incl.	1/16-3/8 incl.	8t	8t
P-11 & P-25	10 t	3/8 t	63 6-2/3t	2-1/2 6-2/3t
P-23 & P-35 B-171, Alloy 628	3	3/8	52	2-1/16
All others	0.7595-3.1453 10 t	0.0299-0.1345 3/8 t	13 38 4t	1/2 1-1/2 4t

Notes:

1. Dimensions not shown are the option of the designer. The essential consideration is to have adequate rigidity so that the jig parts will not spring.
2. The specimen shall be firmly clamped on one end so that there is no sliding of the specimen during the bending operation.
3. Test specimens shall be removed from the jig when the outer roll has been removed 180 degrees from the starting point.

Fig. 4.3.2.1F(3)—Guided-bend wraparound test jig

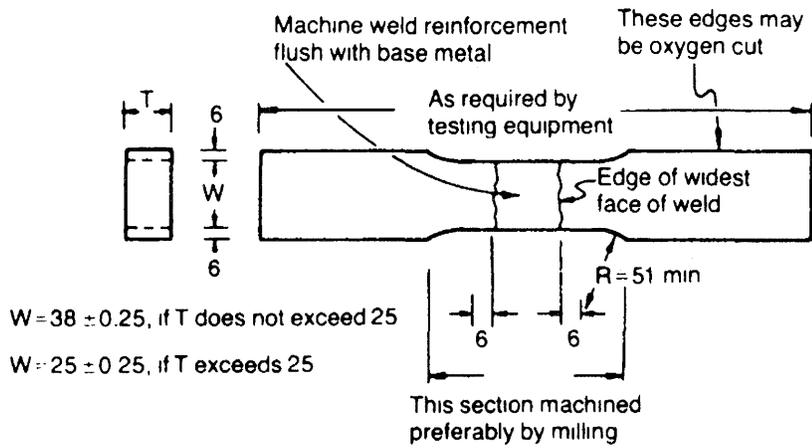


All dimensions in millimeters

Notes:

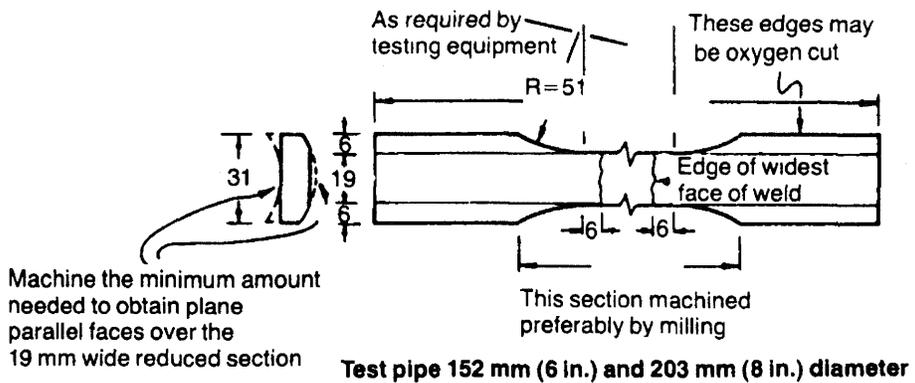
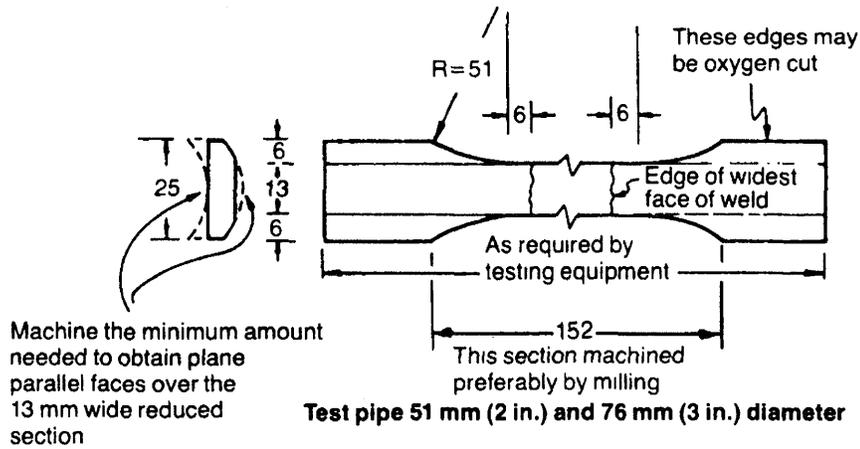
1. Groove angle—30° for electric arc welding, 45° for oxyfuel gas welding.
2. Tests required—two round 12.8 mm (0.505 in.) diameter tension test specimens transverse weld.
3. Transverse weld tensile strength must equal or exceed 80% of the minimum specified tensile strength for the base metal.
4. Performance or procedure qualification, or both, shall qualify for unlimited thickness only for the position in which the test assembly was welded.

Fig. 4.3.2.1G—Cast iron test assembly—procedure and performance qualification



For plates over 25 mm thick, specimens may be cut into the minimum number of approximately equal strips not exceeding 25 mm in thickness. Test each strip and average the results.

Test plate



mm	in.
0.25	0.001
6	1/4
13	1/2
19	3/4
25	1
31	1-1/4
38	1-1/2
51	2
76	3
152	6
203	8

All dimensions in millimeters

Fig. 4.3.2.1.1A — Reduced section tension specimens

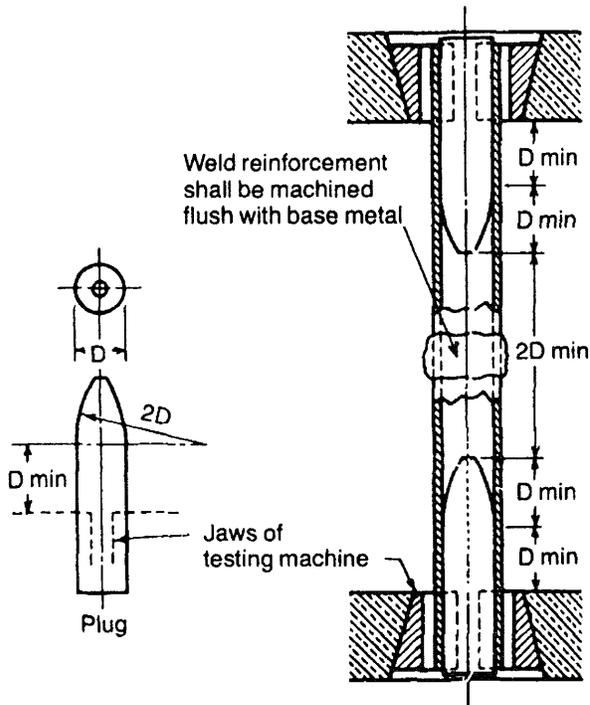


Fig. 4.3.2.1.1B—Tension—full section—small diameter pipe

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the convex surface of the specimen after bending, except that cracks occurring on the corners shall not be considered, unless there is definite evidence that they result from slag inclusions or other internal discontinuities.

4.3.3.3 Macroetch Test. Visual examination of the cross sections of the weld metal and the heat-affected zone shall show complete fusion and freedom from cracks. Fusion beyond the root is not necessary unless specified by the welding procedure specification. There shall not be more than 3.2 mm (1/8 in.) difference in the length of the legs of the fillet.

4.3.3.4 Visual Inspection. The following is required for a sample weld to pass visual inspection:

4.3.3.4.1 The weld shall be free of cracks and surface discontinuities (slag and porosity).

4.3.3.4.2 The weld shall be free of craters.

4.3.3.4.3 For butt joints, the face of the weld shall be at least flush with the surface (no underfill), and the weld shall merge smoothly with the base metal. Weld face reinforcement shall not exceed the following:

Test material thickness (t)		Maximum face reinforcement (R)	
mm	in.	mm	in.
9.5 and less	3/8 and less	1/4t	1/4t
Over 9.5 to 19.1	Over 3/8 to 3/4 incl.	3.2	1/8
Over 19.1	Over 3/4	4.8	3/16

4.3.3.4.4 Depth of undercut shall not be more than 0.8 mm (1/32 in.).

4.3.3.4.5 The root of the groove weld shall be examined, and there shall be no evidence of cracks, incomplete fusion or inadequate joint penetration. The root surface concavity or root reinforcement (in welds made from one side only) shall not exceed the values shown in the table below:

Test material thickness (t)		Maximum root surface concavity		Maximum root reinforcement	
mm	in.	mm	in.	mm	in.
9.5 and less	3/8 and less	1.6	1/16	1.6	1/16
Over 9.5	Over 3/8	1.6	1/16	3.2	1/8

4.3.3.4.6 Profiles of fillet and groove welds shall be in accordance with Fig. 4.3.3.4.6 and the following:

(1) The faces of fillet welds may be slightly convex, flat or slightly concave as shown in Fig. 4.3.3.4.6A, B, and C. Unacceptable profiles are shown in Fig. 4.3.3.4.6D.

(2) Groove weld profiles shall be free of the discontinuities shown in Fig. 4.3.3.4.6F.

(3) Welds shall be free from overlap.

4.3.4 Repair of Test Assembly

4.3.4.1 Test assemblies may be repair welded, using the written welding procedure being qualified, only under the following conditions:

(1) No cracks other than crater cracks may be repair welded. Other cracks shall not be repaired.

(2) Only one cycle of repair welding is permitted.

(3) All test results, including a description of the nondestructive test results which failed to meet the requirements and the repair work performed to correct the condition, shall be made a part of the joint welding procedure qualification test record.

(4) The defects repaired are representative of defects that would be rejected by nondestructive tests required for production work.

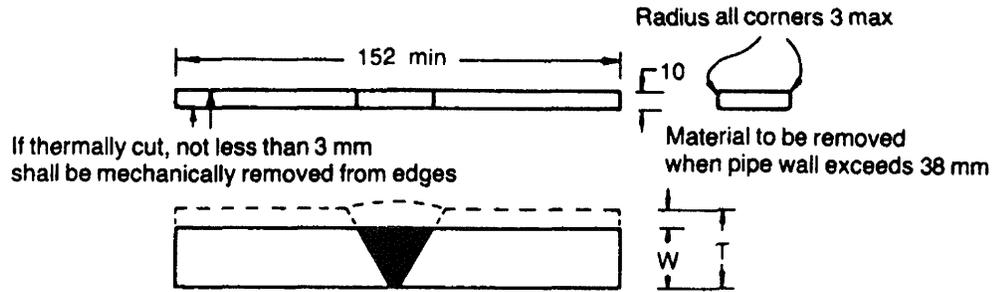
(5) The repair welding is representative of repair welding that would be permitted on production work.

5. Performance Qualification

5.1 General. When this document is specified by owner or architect/engineer as the governing document, the manufacturer/contractor shall be responsible for conducting the applicable performance tests of each welder/operator according to the rules of this section before the welder/operator engages in any production work.

Performance tests shall be conducted to conform to the manufacturer's approved welding procedure specifications (refer to Section 4) and shall be documented on appropriate performance qualification records (refer to Appendix A).

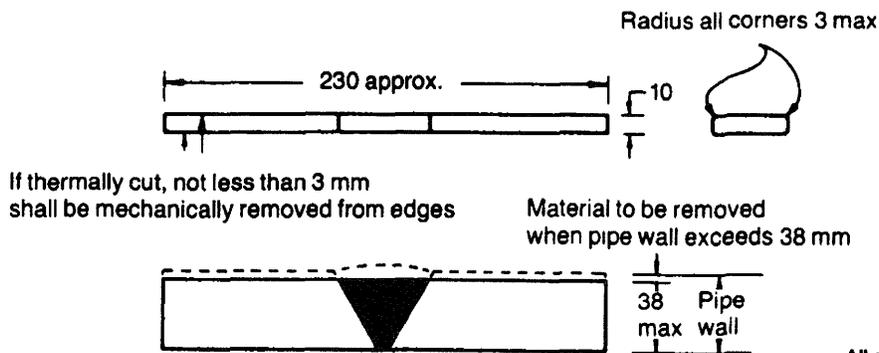
Performance qualification applicants shall be familiarized with parameters of the applicable joint welding procedure specification. It is recommended that the manufacturer's representative conducting these tests possess sufficient technical and supervisory ability to conduct such tests and



For plates 10 mm to 38 mm, width W equals plate thickness T. For plates over 38 mm thick, cut specimens into minimum number of approximately equal strips not exceeding 38 mm in width.

Plate

A longer specimen length may be necessary when using a wraparound type bending fixture or when testing steel with yield point of 620 MPa (90 ksi) or more.

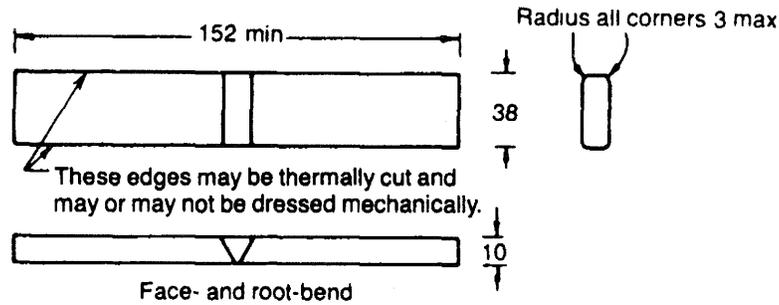


All dimensions in millimeters

Pipe

A longer specimen length may be necessary when using a wraparound type bending fixture or when testing steel with yield point of 620 MPa (90 ksi) or more.

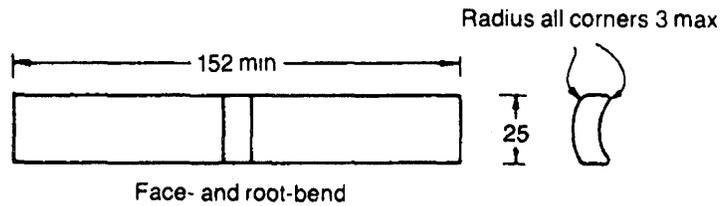
Fig. 4.3.2.1.2—Side-bend specimens



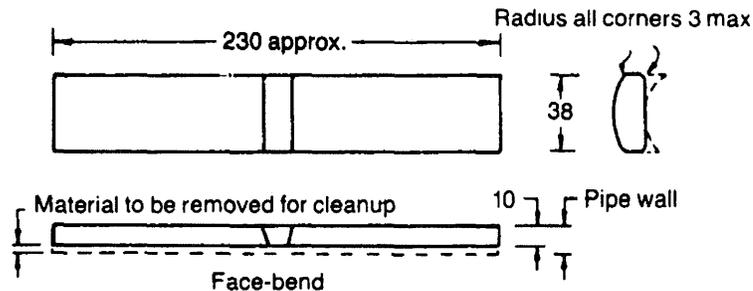
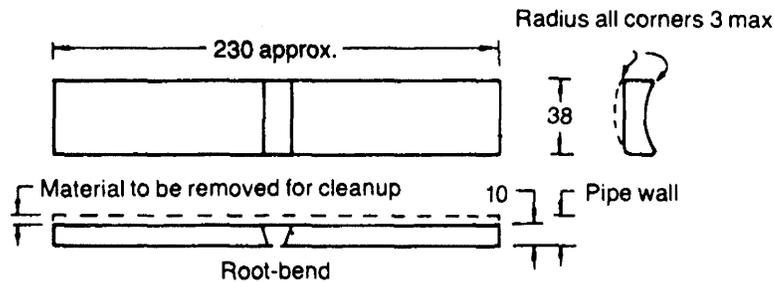
Weld reinforcement and backing, if any, shall be removed flush with the surface of the specimen (see 3.6.3). If a recessed backing is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the backing; in such cases the thickness of the finished specimen shall be that specified above.

Plate

A longer specimen length may be necessary when using a wraparound type bending fixture or when testing steel with yield point of 620 MPa (90 ksi) or more.



Test pipe 51 mm (2 in.) and 76 mm (3 in.) diameter



Test pipe 152 mm (6 in.) and 203 mm (8 in.) diameter

mm	in.
3	1/8
10	3/8
25	1
38	1-1/2
51	2
76	3
152	6
203	8
230	9

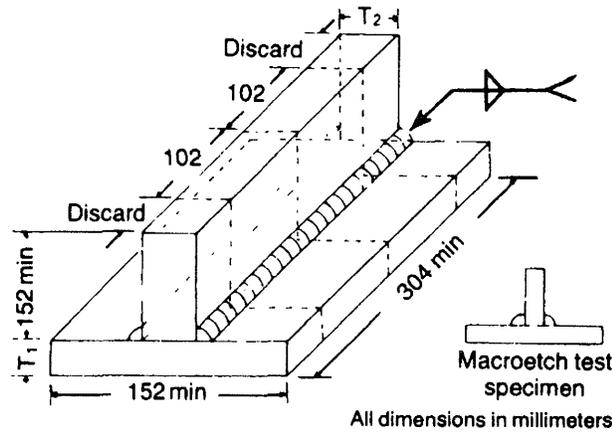
All dimensions in millimeters

Weld reinforcement and backing, if any, shall be removed flush with the surface of the specimen (see 3.6.3). Cut surfaces shall be smooth and parallel.

Pipe

A longer specimen length may be necessary when using a wraparound type bending fixture or when testing steel with yield point of 620 MPa (90 ksi) or more.

Fig. 4.3.2.1.3—Face- and root-bend specimens



All dimensions in millimeters

mm	in.	mm	in.	mm	in.
102	4	152	6	304	12

Weld size mm in.	Material thickness			
	T_1		T_2	
	mm	in.	mm	in.
	Plate			
5 3/16	13	1/2	5	3/16
6 1/4	19	3/4	6	1/4
8 5/16	38	1-1/2	8	5/16
10 3/8	57	2-1/4	10	3/8
13 1/2	76	3	13	1/2
16 5/8	76	3	16	5/8
19 3/4	76	3	19	3/4
19 3/4	76	3	25	1
	Sheet			
3 1/8	3.416	0.1345(10GA)	1.214	0.0478(18GA)
5 3/16	3.416	0.1345(10GA)	2.657	0.1046(12GA)
6 1/4	3.416	0.1345(10GA)	3.416	0.1345(10GA)

Fig. 4.3.2.2A— Fillet weld soundness test for procedure qualification—sheet metal and plate

ascertain beforehand that the applicants also possess a level of skill commensurate with this endeavor.

5.2 Testing Requirements. Tackers, welders, and welding operators shall make sample weldments within the limitations of variables as described in 5.3 and within the position ranges as described in Table 5.2A. Table 5.2B shall be used to govern the thickness or pipe size qualified and the testing required for qualification. Tackers may qualify using a single pass fillet or a groove weld procedure. Tacker tests on 9.5 mm (3/8 in.) thick material shall qualify for 4.8 mm (3/16 in.) and over.

5.3 Limitations of Variables for Welder and Welding Operator Performance Qualification

5.3.1 Welding Process. A change from one welding process to any other welding process or a combination of processes requires requalification. Where a combination of processes is used, each welder must be qualified for the particular process or processes he will be required to perform in production welding. Qualification for a combination may be either separate or combined in one test.

5.3.2 Base Metal

5.3.2.1 Ferrous Metals

(1) Qualification on any base metal listed in P-1A through P-5, except for P-2A through P-2D (cast iron), qualifies for all materials in this group or combination thereof.

(2) Qualification on P-6 or P-7 materials qualifies for either material.

(3) Qualification on P-9A or P-9B materials qualifies for either material.

(4) Qualification on P-10A, 10B or 10C materials qualifies for any of these materials.

(5) All other P groupings require separate qualification.

(6) Materials not listed each require separate qualification.

(7) Where materials of more than one P group are to be combined in one weld joint, qualification shall be

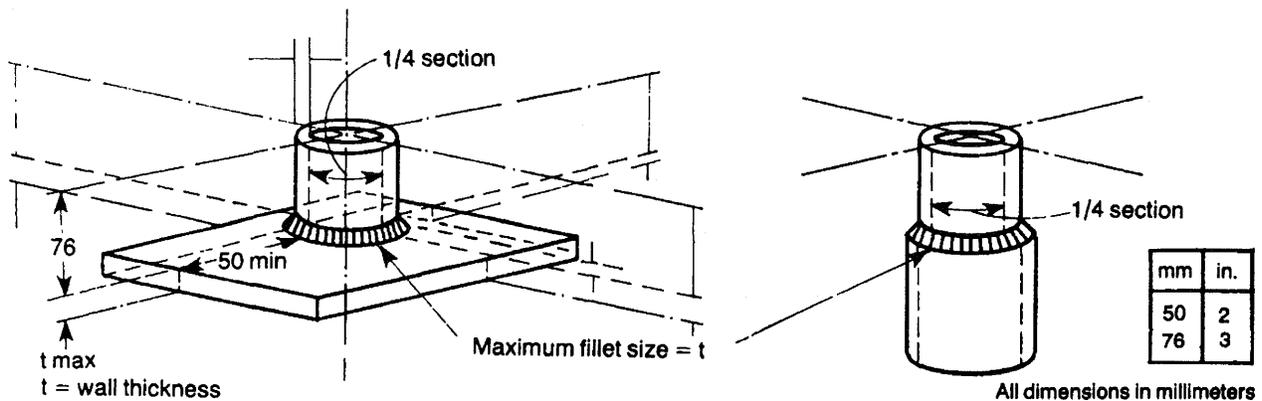
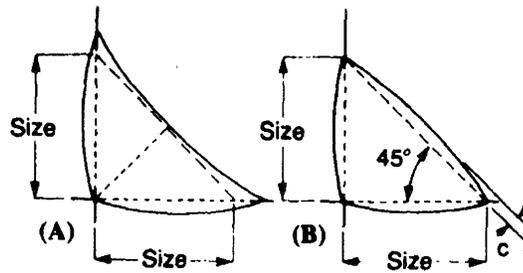
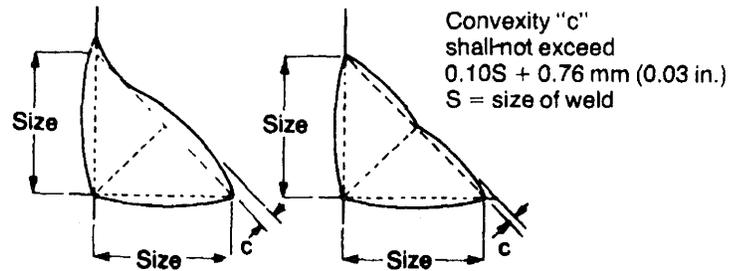


Fig. 4.3.2.2B— Sectioning of pipe-to-plate and pipe-to-pipe welds for macroetch testing

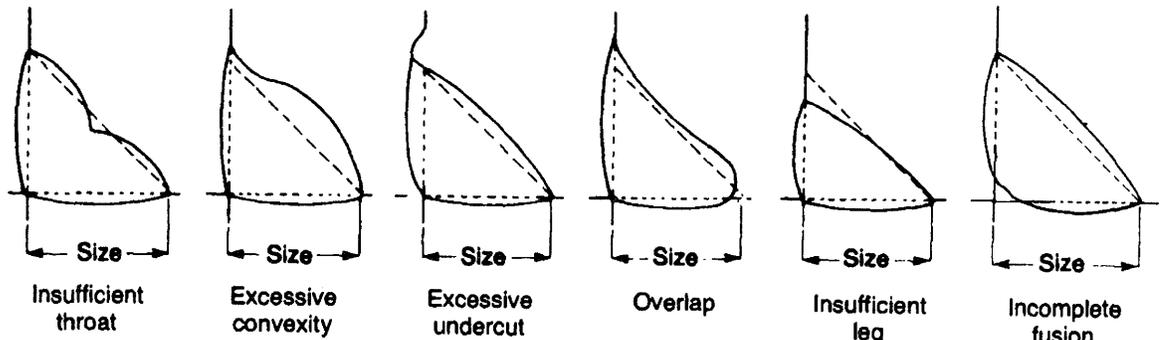
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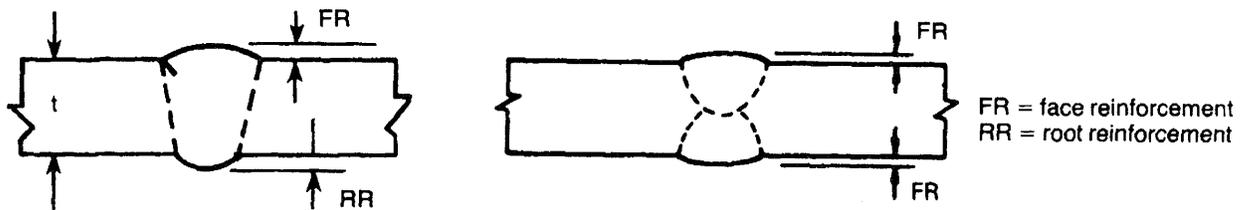
Desirable fillet weld profiles



(C) Acceptable fillet weld profiles

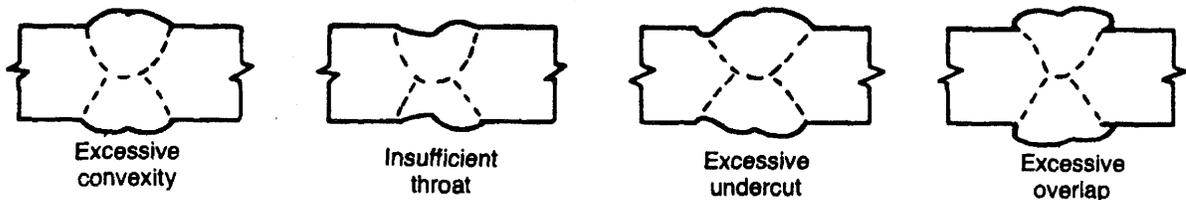


(D) Unacceptable fillet weld profiles



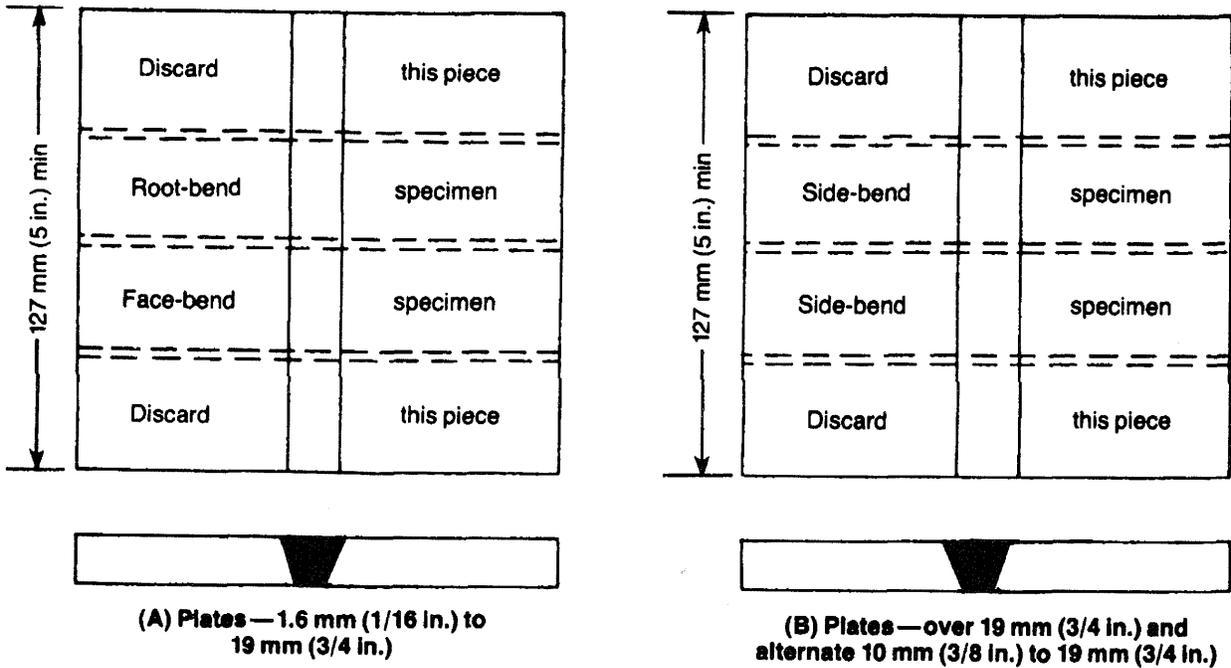
FR = face reinforcement
RR = root reinforcement

(E) Acceptable groove weld profiles



(F) Unacceptable groove weld profiles

Fig. 4.3.3.4.6—Acceptable and unacceptable weld profiles



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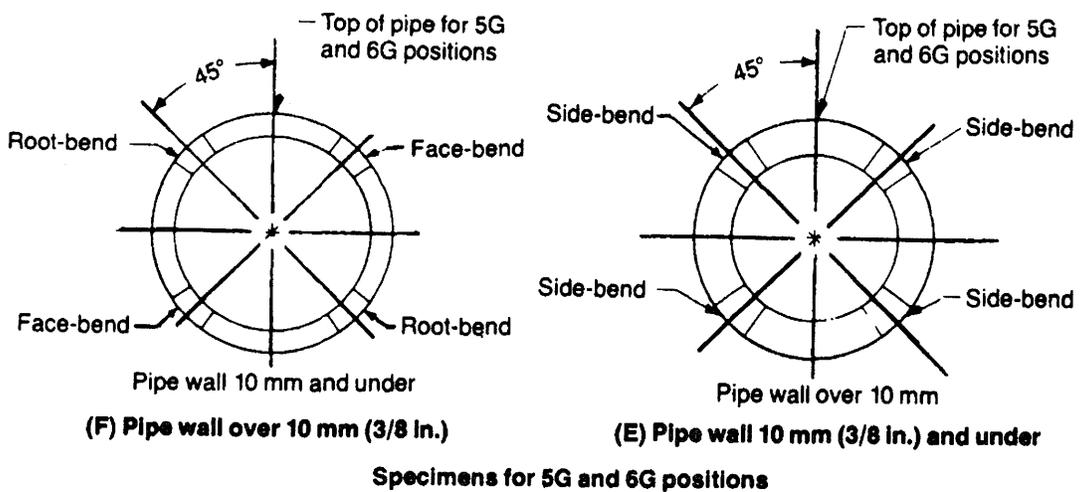
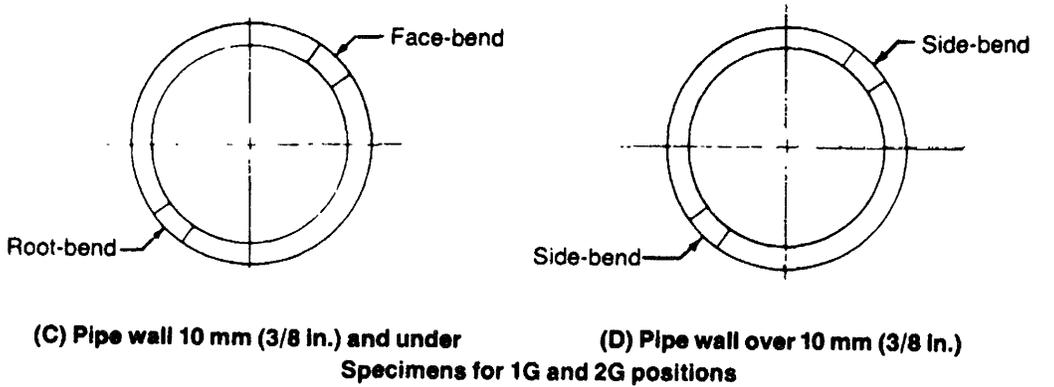


Fig. 5.4.1A—Location of test specimens on welded test pipe—welder qualification

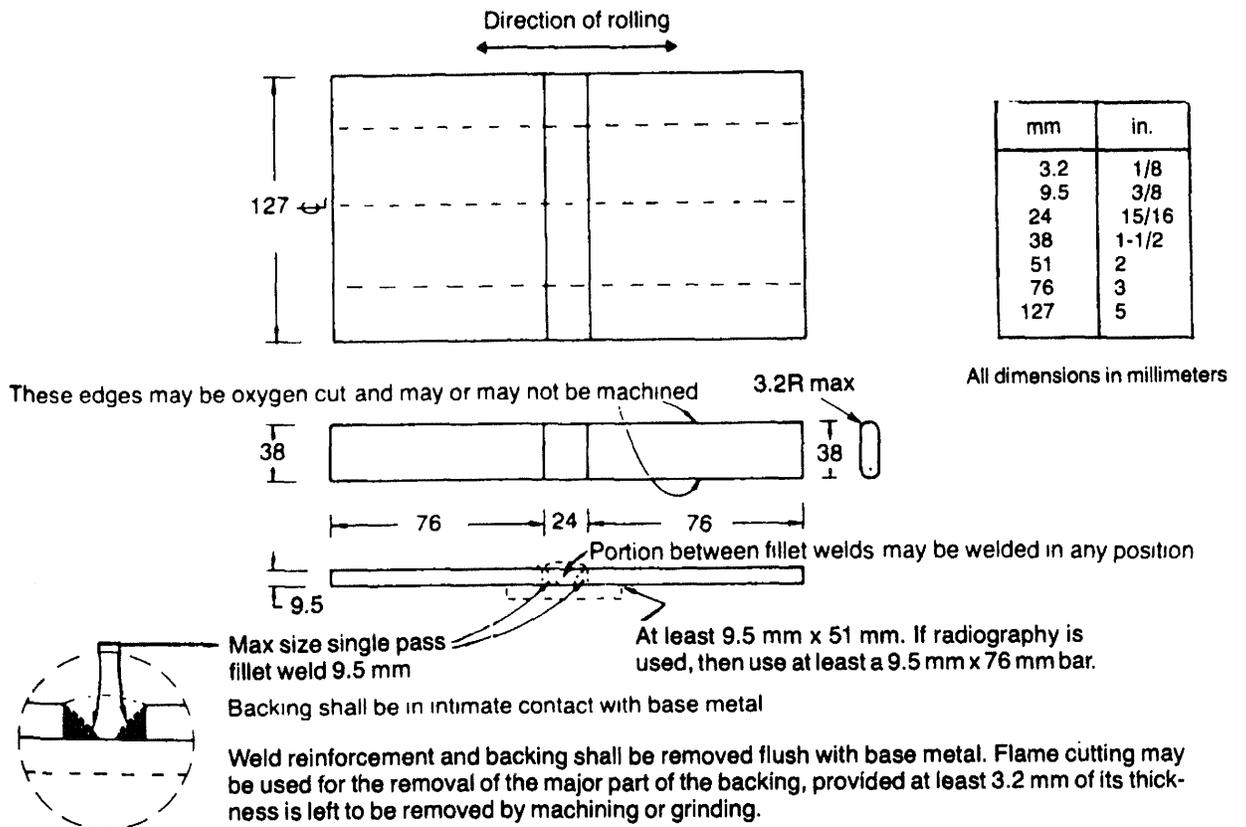


Fig. 5.4.1B—Fillet weld root-bend test plate—welder qualification

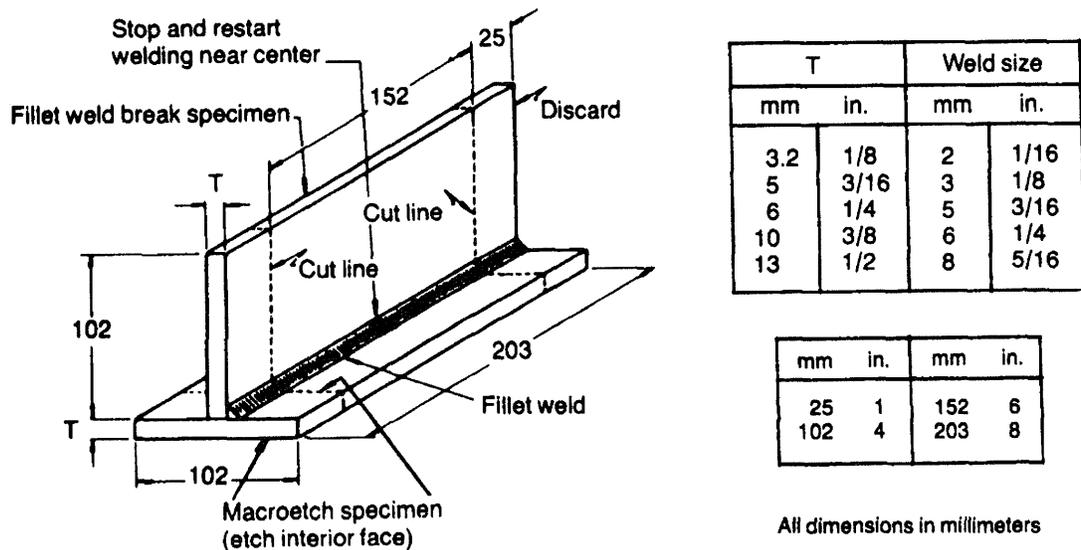


Fig. 5.4.1C—Fillet weld break and macroetch test plate—welder qualification

made for the higher P number group of the combination in the joint.

5.3.2.2 Aluminum and Aluminum Base Alloys.

Qualification on any base metal listed in P21, 22, 23, and 25 qualifies for any of these materials.

5.3.2.3 Copper and Copper Base Alloys. Separate qualification is required for each group of base metals in P31, 32, 33, 34, and 35.

5.3.2.4 Nickel and Nickel Base Alloys. Separate qualification is required for each group of base metals in P41, 42, 43A, 43B, 44, and 45.

5.3.2.5 Unalloyed Titanium. Qualification on P51 or P52 materials qualifies for either material.

5.3.3 Filler Metal. The Table 3.1B grouping of electrodes and welding rods is based essentially on their usability characteristics which fundamentally determine the ability of a welder to make satisfactory welds with a given electrode.

5.3.3.1 Ferrous Metals. Qualification with any F-1 through F-4 electrode with a total nominal alloy content not exceeding 6 percent shall also qualify for all lower F electrodes. F-Number 5, 6, 7, 8, and 9 electrodes require separate qualification.

5.3.3.2 Aluminum and Aluminum Base Alloys. Qualification with any F-21, 22, 23, or 24 qualifies for any F-21, 22, 23, or 24.

5.3.3.3 Copper and Copper Base Alloys. Qualification with any F-31, 32, 33, 34, 35, or 36 qualifies for any F-31, 32, 33, 34, 35, or 36.

5.3.3.4 Nickel and Nickel Base Alloys. Qualification with any F-41, 42, 43, or 44 qualifies for any F-41, 42, 43, or 44.

5.3.3.5 Unalloyed Titanium. F-51 requires separate qualification.

5.3.4 Welding Positions. Test positions and corresponding limits of qualifications for position are shown in Table 5.2A.

5.3.5 Joint Details. The omission of or change in type of backing requires requalification. In the GTAW or PAW processes, for single welded joints, the addition of or omission of consumable inserts requires requalification.

5.3.6 Thickness Qualified. For thickness of test plate and pipe and for thicknesses for which qualified, refer to Table 5.2B.

5.3.7 Electrical. In manual or semiautomatic processes, the addition of or omission of current pulsation requires requalification.

5.3.8 Technique. In vertical position welding, a change in direction of progression of welding requires requalification. Where a combination of up and down progression is to be used in production, a welder may be qualified by a single test using the same combination as specified for production welding.

5.4 Tests. Testing of weldments made for performance qualification shall be performed in accordance with the corresponding tests described in 4.4.

5.4.1 Bend test coupons as required in Table 5.2B shall be removed from the test specimen(s) as shown in Figs.

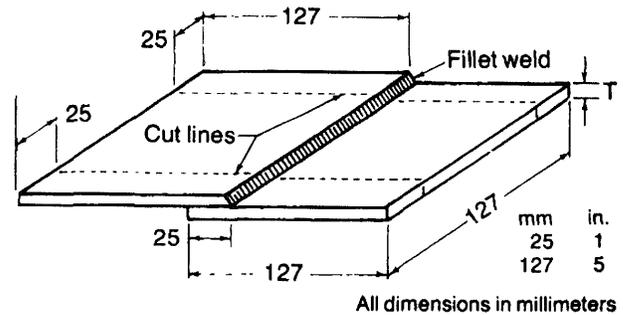
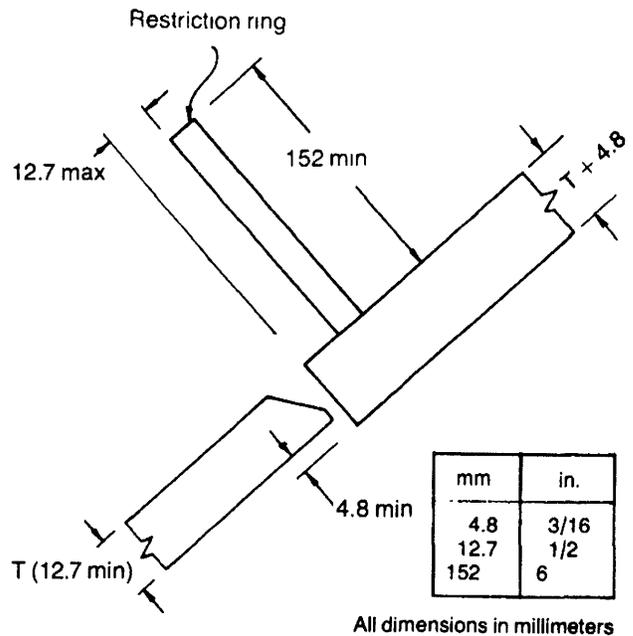


Fig. 5.4.1D—Macroetch test joint for welder qualification—lap joint in 16 gage or lighter material



Notes:

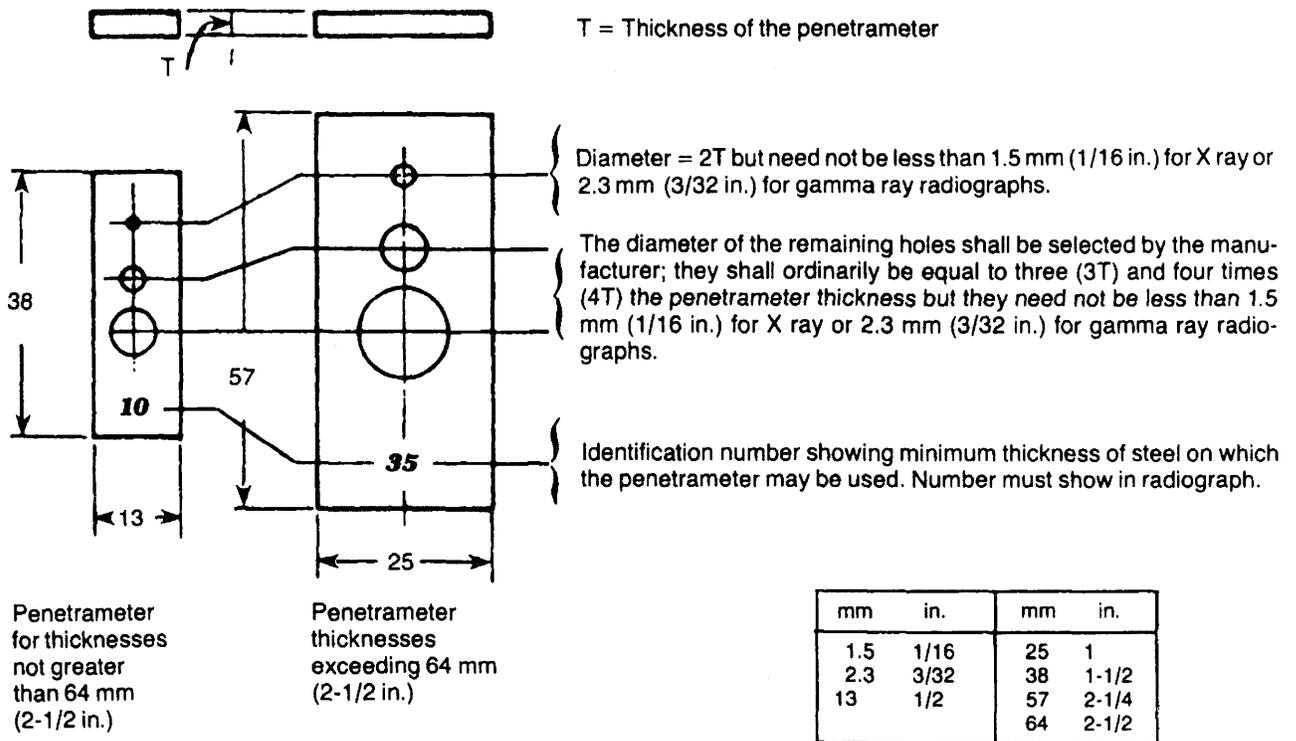
1. The restriction ring is removed after joint welding is completed.
2. Test specimens for side-bend tests shall be cut from the test joint as shown in Fig. 5.4.1 A (F) and prepared as shown in Fig. 4.3.2.1.2.

Fig. 5.4.1E—Test joint for T, K and Y connections on pipe or square or rectangular tubing— welder qualification

5.4.1A, 5.4.1B, and 5.4.1E Fillet weld break and macroetch test specimens shall be prepared in accordance with Fig. 5.4.1C and Fig. 5.4.1D. Acceptance criteria shall be the same as required in 4.3.3, including visual inspection.

5.4.2 Fillet Weld Break Test

5.4.2.1 The entire length of the fillet weld shall be examined visually and then the 152 mm (6 in.) long speci-



Notes:

- All holes shall be true and normal to the surface and not chamfered.
- Penetrameters shall be made of radiographically similar materials.

All dimensions in millimeters

Fig. 5.4.3.1.1A—Details of penetrameters

men shall be loaded in such a way that the root of the weld is in tension. The load shall be steadily increased or repeated until the specimen fractures or bends flat upon itself.

5.4.2.2 The specimen shall pass the test if it bends flat upon itself. If the fillet weld fractures, the fractured surface shall show complete fusion to the root of the joint and shall exhibit no inclusion or porosity larger than 2.4 mm (3/32 in.) in greatest dimension. The sum of the greatest dimensions of all inclusions and porosity shall not exceed 9.5 mm (3/8 in.) in the 152 mm (6 in.) long specimen.

5.4.3 As an alternate in manual SMAW and GTAW, radiography may be used to determine the soundness of a test assembly containing a groove weld (butt joint). Acceptance criteria shall be as specified in 4.3.3.4 (visual) and 5.4.3.1.2 (radiographic). The minimum length of weld examined shall be the length of the test plate, not less than 127 mm (5 in.) less 25.4 mm (1 in.) from either end. For pipe and tube, the full circumference shall be examined. The first length of production welds may be examined in lieu of a performance test plate or pipe. When production welds are used, a minimum of 406 mm (16 in.) shall be examined.

5.4.3.1 Radiographic Test for Soundness

5.4.3.1.1 The procedures and standards set forth herein are to govern the radiographic testing of groove

welds in butt joints. Testing of fillet welds by radiographic methods is not recommended.

(1) Radiographs shall be made by either x-ray or isotope radiation method. All radiographs shall determine quantitatively the size of discontinuities having thickness equal to or greater than 2 percent of the thickness of the thinner of the parts joined by the weld under examination. They shall be clean, free of film processing defects, and have an H and D density of not less than 1.5 nor more than 4.0. Although radiographs (each single film) may have an H and D density of 1.5 minimum to 4.0 maximum, densities within the range of 2.5 to 3.5 are preferred. Radiographs, except as modified by 5.4.3.1.1(4), shall show:

(a) The 2T diameter hole in each penetrameter having a thickness T of 1/50 of the specimen thickness as specified by Fig. 5.4.3.1.1A. The details for fabricating penetrameters are also shown in this figure.

(b) The penetrameter identification number

(c) The radiographic identification and location marks indicated in Figs. 5.4.3.1.1B and C and required by 5.4.3.1.1(6).

(2) Radiography shall be performed in accordance with all applicable safety requirements.

(3) A weld that is to be radiographed need not be ground or otherwise smoothed for the purposes of radiographic testing unless its surface irregularities or juncture

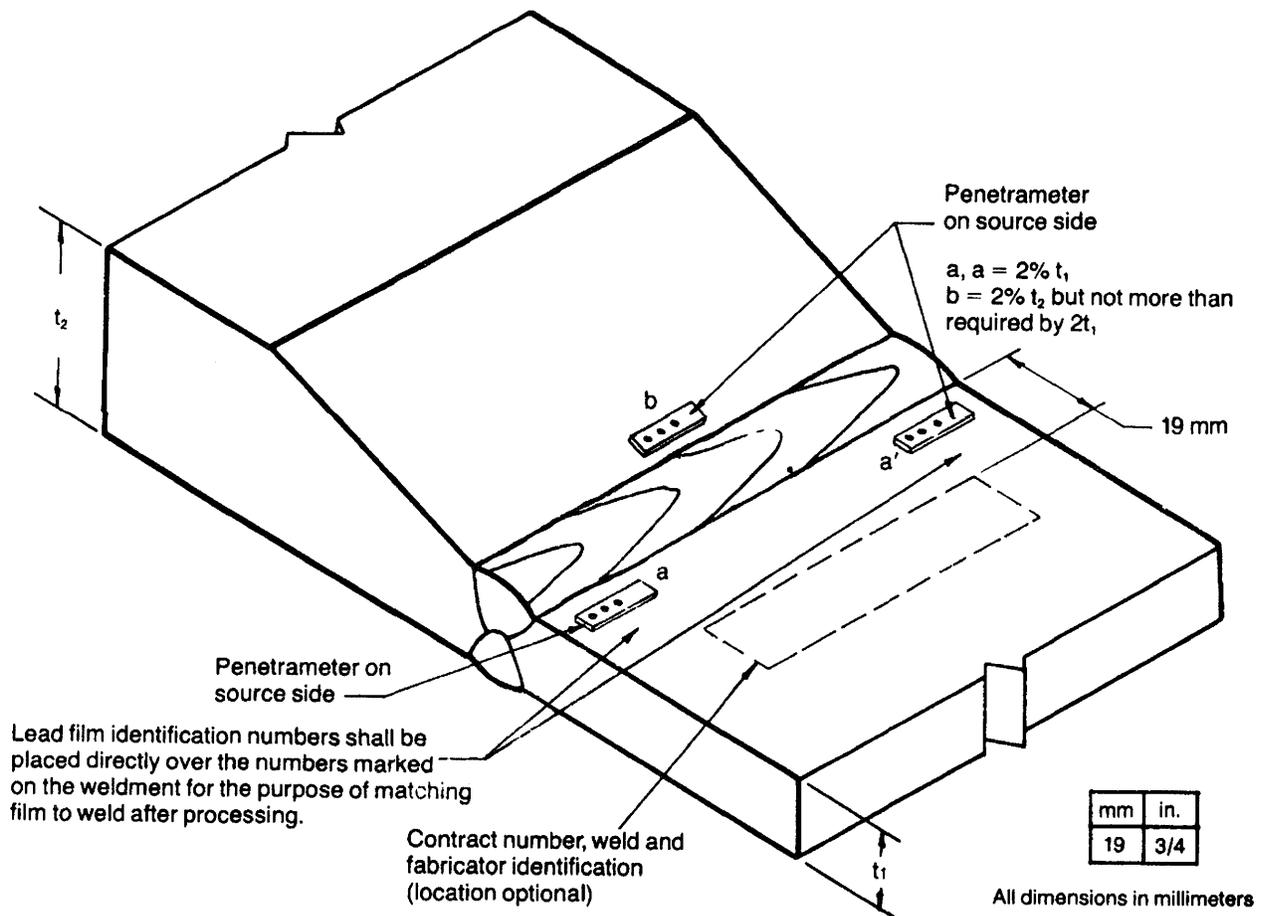


Fig. 5.4.3.1.1B—Radiograph identification and penetrameter location on transition joints

with the base metal could cause objectionable weld discontinuities to be obscured in the radiograph. When weld reinforcement or backing is not removed, shims of the same base metal shall be placed under the penetrameter so that the total thickness of metal between the penetrameter and the film is at least equal to the average thickness of the weld measured through its reinforcement and backing.

(4) When weld transitions in thickness are radiographed, where the ratio of the thicker weld section to the thinner weld section is 3 or greater, radiographs should be exposed to produce a density of 3.0 to 4.0 in the thinner section. When this is done, densities of less than 1.5 will be accepted in the thicker section. Except for this condition, densities outside the maximum and minimum limits specified in 5.4.3.1.1(1) shall be cause for rejection of the film. Penetrameters on transition joints shall be positioned as shown in Fig. 5.4.3.1.1B.

(5) Two or more penetrameters shall be used for each radiograph on a film 254 mm (10 in.) or more in length. Only one penetrameter need be used for radiographs

on films less than 254 mm (10 in.) in length. Penetrameters shall be placed on the side of the work nearer the radiation source, as shown in Figs. 5.4.3.1.1B and C. Penetrameters shall conform to the details shown in Fig. 5.4.3.1.1A except that other penetrameters, such as ASME, may be used provided they have identification numbers indicating penetrameter thickness in thousandths of an inch and comply with all other conditions of this paragraph and Fig. 5.4.3.1.1A. The thickness of each penetrameter shall be equal to or less than 2 percent of the thickness of the thinner of the parts joined by the weld under examination, but need not be less than 0.127 mm (0.005 in.).

(6) A radiograph identification mark and two location identification marks shall be placed on the weldment at each radiograph location. A corresponding radiograph identification mark, which shall show in the radiograph, and a location identification mark, which will show in the radiograph, shall be superimposed on each of the location identification marks made on the weldment to provide means for matching the developed radiograph to the

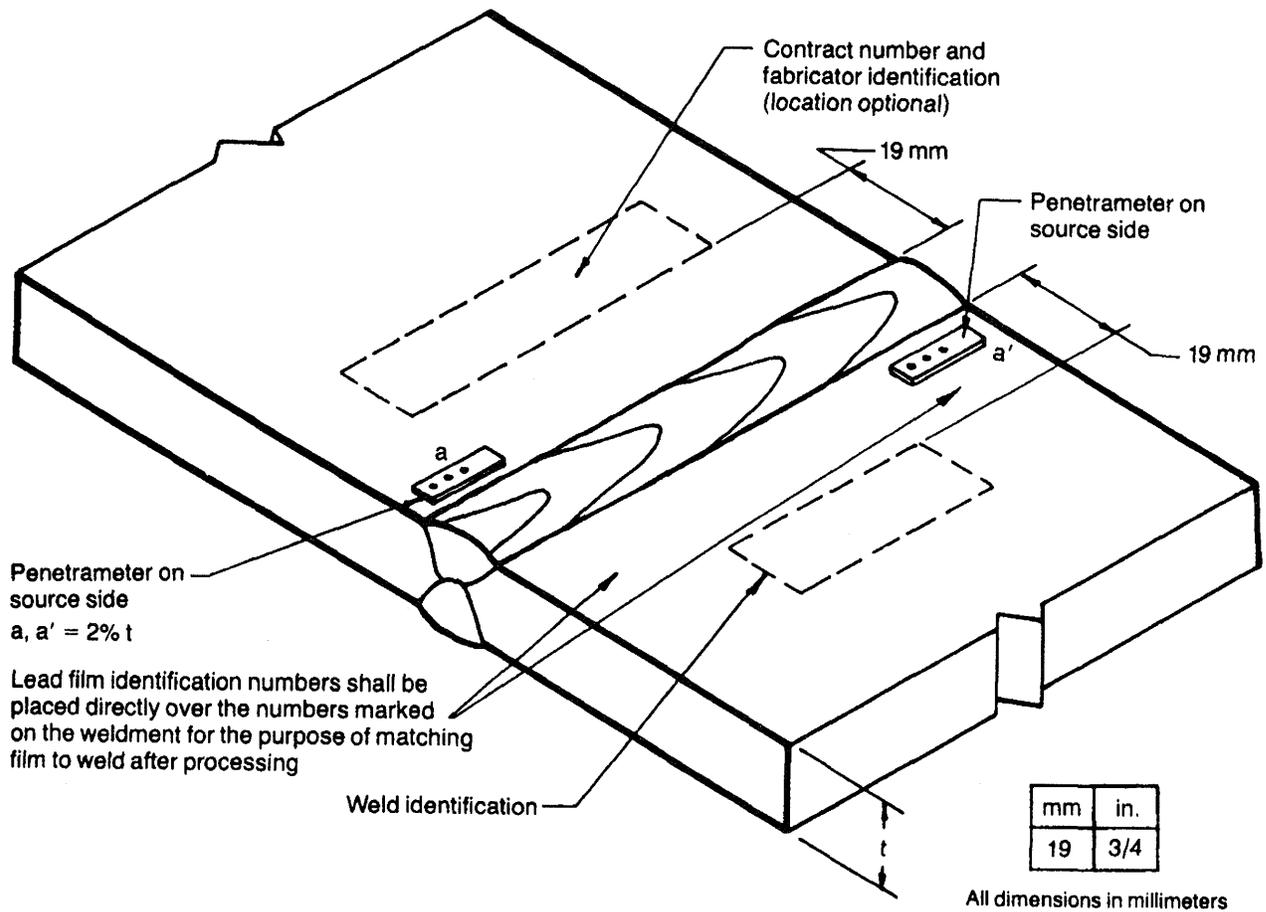


Fig. 5.4.3.1.1C — Radiograph identification and penetrameter location on approximately equal thickness joints

weld. Any additional information shall be indicated by lead figures on weldments or preprinted no less than 19.1 mm (3/4 in.) from the edge of the weld.

(7) Radiographs shall be made with a single source of radiation approximately centered with respect to the length of area being examined. The perpendicular distance from the radiation source to the film shall be not less than seven times the maximum thickness of the weld under examination, and the rays shall not penetrate the weld at an angle greater than 26.5 degrees from a line perpendicular to the weld surface. The film, during exposure, shall be as close to the surface of the weld opposite the source of radiation as possible.

5.4.3.1.2 Test welds having any of the following defects shall be unacceptable:

- (1) Any type of crack.
- (2) Incomplete fusion between the weld metal and base metal.
- (3) Incomplete fusion between any of the weld passes.
- (4) Inadequate joint penetration, except as provided by 4.3.3.4.5.

(5) Porosity and tungsten inclusions in excess of amounts shown in the porosity figures in Appendix B.

(6) Slag inclusions exceeding the following limits:

(a) An elongated slag inclusion which has a length greater than those listed below:

Weld thickness (t)		Maximum length of single slag inclusion in 152 mm (6 in.) of weld	
mm	in.	mm	in.
9.5	3/8 and less*	4.8	3/16
9.5	Over 3/8	6.4	1/4

*Below 1.6 mm (1/16 in.) thickness, separate qualification is required.

(b) A group of in-line slag inclusions in the weld will cause rejection when:

- (1) Any group of slag inclusions in line that have an aggregate length greater than t in a length of $12t$.
- (2) The distance between two such adjacent discontinuities is less than six times the length of the large discontinuity in the pair under consideration.

(7) Individual discontinuities, having a greatest dimension of 2.4 mm (3/32 in.) or greater, if the greatest dimension of a discontinuity is larger than 2/3 of the effective throat or 2/3 the weld size or 19.0 mm (3/4 in.).

5.4.4 Welding operators may be qualified by radiographic examination (in lieu of bend tests of test plates) of the first three feet of the production groove weld in accordance with 5.4.3.1.1. Acceptance criteria are given in 5.4.3.1.2.

5.5 Repair of Test Assembly. Completed test assemblies shall not be repaired.

5.6 Retests

5.6.1 In case a welder or welding operator fails to meet the requirements of one or more test welds, a retest may be allowed under the following conditions:

5.6.1.1 An immediate retest may be made consisting of two welds of each type on which he failed; all test specimens of which shall meet all the requirements specified for such welds.

5.6.1.2 A retest may be made consisting of only the originally required welds provided there is evidence that the welder or welding operator has had further training or practice.

5.7 Records. Records of test results shall be kept by the

manufacturer or contractor and shall be available to those authorized to examine them.

Appendix A contains sample forms that the Committee on Qualification has approved for the welding procedure specification and for recording the procedure qualification, welder qualification, and welding operator qualification data required by this standard. It is suggested that the qualification information required by this standard be recorded on these forms or similar forms which have been prepared by the user. Variations of these forms to suit the user's needs are permissible.

5.8 Period of Effectiveness. The tacker's, welder's, or welding operator's qualification shall remain in effect indefinitely unless (1) the welder is not engaged in the given process of welding for which he is qualified for a period exceeding six months or unless (2) there is some specific reason to question a welder's ability. The manufacturer or contractor shall maintain a process continuity record for each welder. Renewal of qualification under (1) need be made in only a single test joint (plate, sheet, pipe or tube) on any thickness, position or material to reestablish the welder's or welding operator's qualification for any thickness, position or base metal for which he was previously qualified.

Table 2.1 — Grouping of base metals for procedure qualification

P no.	Base metal specification		Minimum tensile strength		Type of base metal
			MPa	ksi	
			<u>Ferrous materials</u>		
1A	ASTM A31	Grade A	310	45	Carbon steel rivets
		Grade B	395	58	Carbon steel rivets
	ASTM A36		395	58	Carbon steel plate
	ASTM A53	Open hearth	310	45	Carbon steel pipe
		Grade A	330	48	Carbon steel pipe
	ASTM A106	Grade B	410	60	Carbon steel pipe
		Grade A	330	48	Carbon steel pipe
	ASTM A113	Grade B	410	60	Carbon steel pipe
		Grade C	330	48	Carbon steel plate
	ASTM A131	Grade A	395	58	Structural steel for ships
		Grade B	395	58	Structural steel for ships
		Grade C	395	58	Structural steel for ships
		Grade CS	395	58	Structural steel for ships
		Grade D	395	58	Structural steel for ships
	ASTM A135	Grade E	395	58	Structural steel for ships
		Grade A	330	48	Carbon steel pipe
	ASTM A139	Grade B	410	60	Carbon steel pipe
		Grade A	330	48	Welded steel pipe
	ASTM A161	Grade B	410	60	Welded steel pipe
		Grade C	410	60	Welded steel pipe
Grade D		410	60	Welded steel pipe	
Low carbon		320	47	Low C steel tubes	
ASTM A178	Grade T1	375	55	C-Mo steel tubes	
	Grade A	410	60	Carbon steel tubes	
ASTM A179	Grade C	410	60	Carbon steel tubes	
				Carbon steel tubes	

(Note 1)

1A	ASTM A181	Grade I	410	60	Carbon steel flanges
	ASTM A192		320	47	Carbon steel tubes
	ASTM A210	Grade A1	410	60	Carbon steel tubes
	ASTM A214			(Note 1)	Carbon steel tubes
	ASTM A216	Grade WCA	410	60	Carbon steel castings
	ASTM A226		320	47	Carbon steel tubes
	ASTM A236	Grade A		(Note 1)	Carbon steel forgings
		Grade B		(Note 1)	Carbon steel forgings
	ASTM A266	Class 1	410	60	Carbon steel forgings
	ASTM A283	Grade A	310	45	Carbon steel plates
		Grade B	340	50	Carbon steel plates
		Grade C	375	55	Carbon steel plates
		Grade D	410	60	Carbon steel plates
	ASTM A284	Grade A	340	50	C-Si steel plates
		Grade B	375	55	C-Si steel plates
		Grade C	410	60	C-Si steel plates
		Grade D	410	60	C-Si steel plates
	ASTM A285	Grade A	310	45	Carbon steel plates
		Grade B	340	50	Carbon steel plates
		Grade C	375	55	Carbon steel plates
	ASTM A306	Grade 45	310	45	Carbon steel bars
		Grade 50	340	50	Carbon steel bars
		Grade 55	375	55	Carbon steel bars
		Grade 60	410	60	Carbon steel bars
	ASTM A333	Grade 1	375	55	Carbon steel pipe, low temp.
		Grade 6	410	60	Carbon steel pipe, low temp.
	ASTM A334	Grade 1	375	55	Carbon steel tube, low temp.
		Grade 6	410	60	Carbon steel tube, low temp.
	ASTM A350	Grade LF 1	410	60	Carbon steel forgings
	ASTM A366			(Note 1)	Cold rolled steel sheet
	ASTM A381	Class Y35	410	60	Carbon steel pipe
		Class Y42	410	60	Carbon steel pipe
	ASTM A414	Grade A	310	45	Carbon steel sheet
		Grade B	340	50	Carbon steel sheet
		Grade C	375	55	Carbon steel sheet
		Grade D	410	60	Carbon steel sheet

Table 2.1 continued — Grouping of base metals for procedure qualification

P no.	Base metal specification	Minimum tensile strength		Type of base metal	
		MPa	ksi		
<u>Ferrous materials</u>					
1A	ASTM A442	Grade 55	375	55	Carbon steel plates
		Grade 60	410	60	Carbon steel plates
	ASTM A500	Grade A	310	45	Carbon steel tubing
		Grade B	395	58	Carbon steel tubing
	ASTM A501		395	58	Carbon steel tubing
	ASTM A512	Grade 1008		(Note 1)	Mechanical tubing
		Grade MT 1010		(Note 1)	Mechanical tubing
		Grade MT 1015		(Note 1)	Mechanical tubing
		Grade MTX 1015		(Note 1)	Mechanical tubing
		Grade 1016		(Note 1)	Mechanical tubing
		Grade 1017		(Note 1)	Mechanical tubing
		Grade 1018		(Note 1)	Mechanical tubing
		Grade 1019		(Note 1)	Mechanical tubing
		Grade 1020		(Note 1)	Mechanical tubing
		Grade MT 1020		(Note 1)	Mechanical tubing
		Grade MTX 1020		(Note 1)	Mechanical tubing
		Grade 1021		(Note 1)	Mechanical tubing
		Grade 1022		(Note 1)	Mechanical tubing
		Grade 1023		(Note 1)	Mechanical tubing
		Grade 1024		(Note 1)	Mechanical tubing
Grade 1025			(Note 1)	Mechanical tubing	
Grade 1026			(Note 1)	Mechanical tubing	
Grade 1027			(Note 1)	Mechanical tubing	
ASTM A513	Grade 1008		(Note 1)	Mechanical tubing	
	Grade MT 1010		(Note 1)	Mechanical tubing	

1A	ASTM A513	Grade MT 1015		(Note 1)	Mechanical tubing	
		Grade MTX 1015		(Note 1)	Mechanical tubing	
		Grade 1016		(Note 1)	Mechanical tubing	
		Grade 1017		(Note 1)	Mechanical tubing	
		Grade 1018		(Note 1)	Mechanical tubing	
		Grade 1019		(Note 1)	Mechanical tubing	
		Grade 1020		(Note 1)	Mechanical tubing	
		Grade MT 1020		(Note 1)	Mechanical tubing	
		Grade MTX 1020		(Note 1)	Mechanical tubing	
		Grade 1021		(Note 1)	Mechanical tubing	
		Grade 1022		(Note 1)	Mechanical tubing	
		Grade 1023		(Note 1)	Mechanical tubing	
		Grade 1024		(Note 1)	Mechanical tubing	
		Grade 1025		(Note 1)	Mechanical tubing	
		Grade 1026		(Note 1)	Mechanical tubing	
		Grade 1027		(Note 1)	Mechanical tubing	
		ASTM A515	Grade 55	375	55	C-Si steel plates
			Grade 60	410	60	C-Si steel plates
		ASTM A516	Grade 55	375	55	C-Si steel plates
			Grade 60	410	60	C-Si steel plates
		ASTM A519	Grade 1008		(Note 1)	Mechanical tubing
			Grade MT 1010		(Note 1)	Mechanical tubing
			Grade 1012		(Note 1)	Mechanical tubing
			Grade MT 1015		(Note 1)	Mechanical tubing
			Grade MTX 1015		(Note 1)	Mechanical tubing
			Grade 1016		(Note 1)	Mechanical tubing
			Grade 1017		(Note 1)	Mechanical tubing
	Grade 1018		(Note 1)	Mechanical tubing		
	Grade 1019		(Note 1)	Mechanical tubing		
	Grade 1020		(Note 1)	Mechanical tubing		
	Grade MT 1020		(Note 1)	Mechanical tubing		
	Grade MTX 1020		(Note 1)	Mechanical tubing		
	Grade 1021		(Note 1)	Mechanical tubing		
	Grade 1022		(Note 1)	Mechanical tubing		
	Grade 1025		(Note 1)	Mechanical tubing		
	Grade 1026		(Note 1)	Mechanical tubing		

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	<u>Minimum tensile strength</u>		<u>Type of base metal</u>
		<u>MPa</u>	<u>ksi</u>	
		<u>Ferrous materials</u>		
1A	ASTM A523 Grade A	330	48	Steel pipe
	Grade B	410	60	Steel pipe
	ASTM A524 Grade I	410	60	Carbon steel pipe
	Grade II	375	55	Carbon steel pipe
	ASTM A526		(Note 1)	Steel sheet, galvanized
	ASTM A527		(Note 1)	Steel sheet, galvanized
	ASTM A529	410	60	Structural steel
	ASTM A539	310	45	Coiled steel tubing
	ASTM A556 Grade A2	320	47	Carbon steel tubes
	Grade B2	410	60	Carbon steel tubes
	ASTM A562	375	55	Carbon, Mn, Ti steel plate
	ASTM A570 Grade A	310	45	Carbon steel sheet & strip
	Grade B	335	49	Carbon steel sheet & strip
	Grade C	355	52	Carbon steel sheet & strip
	Grade D	375	55	Carbon steel sheet & strip
	Grade E	395	58	Carbon steel sheet & strip
	ASTM A572 Grade 42	410	60	HSLA, Cb, V steel
	Grade 45	410	60	HSLA, Cb, V steel
	ASTM A575 Grade 1008		(Note 1)	Merchant quality bars
	Grade 1010		(Note 1)	Merchant quality bars
	Grade 1012		(Note 1)	Merchant quality bars
	Grade 1015		(Note 1)	Merchant quality bars
	Grade 1017		(Note 1)	Merchant quality bars
	Grade 1020		(Note 1)	Merchant quality bars
	Grade 1023		(Note 1)	Merchant quality bars
	Grade 1025		(Note 1)	Merchant quality bars

1A	ASTM A587		330	48	Carbon steel pipe
	ASTM A611	Grade A	285	42	Cold rolled steel sheet
		Grade B	310	45	Cold rolled steel sheet
		Grade C	330	48	Cold rolled steel sheet
		Grade D	355	52	Cold rolled steel sheet
	ASTM A709	Grade 36	395	58	Structural steel
	ABS	Grade A	395	58	Hull structural steel
		Grade B	395	58	Hull structural steel
		Grade D	395	58	Hull structural steel
		Grade E	395	58	Hull structural steel
		Grade DS	395	58	Hull structural steel
		Grade CS	395	58	Hull structural steel
	API 5L	Grade A25	310	45	Pipe
	API 5L	Grade A	330	48	Pipe
	API 5L	Grade B	410	60	Pipe
	API 5LS	Grade A	330	48	Pipe
	API 5LS	Grade B	410	60	Pipe
	API 5LS	Grade X42	410	60	Pipe
	API 5LX	Grade X42	410	60	Pipe
1B	ASTM A105		480	70	Carbon steel forgings
	ASTM A106	Grade C	480	70	Carbon steel pipe
	ASTM A131	AH32	470	68	Structural steel for ships
		DH32	470	68	Structural steel for ships
		EH32	470	68	Structural steel for ships
		AH36	485	71	Structural steel for ships
		DH36	485	71	Structural steel for ships
		ED36	485	71	Structural steel for ships
	ASTM A139	Grade E	455	66	Welded steel pipe
	ASTM A181	Grade II	480	70	Carbon steel flanges
	ASTM A210	Grade C	480	70	Carbon steel tubes
	ASTM A216	Grade WCB	480	70	Carbon steel castings
		Grade WCC	480	70	Carbon steel castings
	ASTM A242	Type 1	480	70 (Note 2)	HSLA, structural steel
		Type 2	480	70 (Note 2)	HSLA, structural steel
	ASTM A266	Class 2	480	70	Carbon steel forgings
		Class 3	515	75	Carbon steel forgings

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Minimum tensile strength		Type of base metal
		MPa	ksi	
		<u>Ferrous materials</u>		
1B	ASTM A299	515	75	C-Mn-Si steel plates
	ASTM A306 Grade 70	480	70	Carbon steel bars
	ASTM A350 Grade LF2	480	70	Carbon steel forgings
	ASTM A352 Grade LCB	445	65	Carbon steel castings
	ASTM A381 Class Y46	434	63	Carbon steel pipe
	Class Y48	460	67	Carbon steel pipe
	Class Y50	475	69	Carbon steel pipe
	Class Y52	495	72	Carbon steel pipe
	ASTM A414 Grade E	445	65	Carbon steel sheet
	Grade F	480	70	Carbon steel sheet
	Grade G	515	75	Carbon steel sheet
	ASTM A441	480	70 (Note 2)	HSLA structural steel
	ASTM A455 Type I	515	75	C-Mn steel plates
	Type II	500	73	C-Mn steel plates
	ASTM A508 Class 1	480	70	C-Si steel forgings
	ASTM A512 Grade 1030		(Note 1)	Mechanical tubing
	Grade 1033		(Note 1)	Mechanical tubing
	Grade 1035		(Note 1)	Mechanical tubing
	ASTM A513 Grade 1030		(Note 1)	Mechanical tubing
	Grade 1033		(Note 1)	Mechanical tubing
	Grade 1035		(Note 1)	Mechanical tubing
	ASTM A515 Grade 70	480	70	C-Si steel plates
	ASTM A516 Grade 70	480	70	C-Mn-Si steel plates
	ASTM A519 Grade 1030		(Note 1)	Mechanical tubing
	Grade 1033		(Note 1)	Mechanical tubing
	Grade 1035		(Note 1)	Mechanical tubing

1B	ASTM A537	Class 1	480	70	C-Mn-Si steel plates
	ASTM A541	Class 1	480	70	Forgings
	ASTM A556	Grade C2	480	70	Carbon steel tubes
	ASTM A557	Grade C	480	70	Carbon steel tubes
	ASTM A572	Grade 50	445	65	HSLA, Cb, V steel
		Grade 55	480	70	HSLA, Cb, V steel
		Grade 60	515	75	HSLA, Cb, V steel
	ASTM A573	Grade 65	445	65	Imp. Tough. steel plates
		Grade 70	480	70	Imp. Tough. steel plates
	ASTM A588	Grade A	480	70 (Note 3)	HSLA structural steel
		Grade B	480	70 (Note 3)	HSLA structural steel
		Grade C	480	70 (Note 3)	HSLA structural steel
		Grade D	480	70 (Note 3)	HSLA structural steel
		Grade E	480	70 (Note 3)	HSLA structural steel
		Grade F	480	70 (Note 3)	HSLA structural steel
		Grade G	480	70 (Note 3)	HSLA structural steel
		Grade H	480	70 (Note 3)	HSLA structural steel
		Grade J	480	70 (Note 3)	HSLA structural steel
	ASTM A595	Grade A	445	65	Tapered steel tubes
		Grade B	480	70	Tapered steel tubes
		Grade C	480	70	Tapered steel tubes
	ASTM A618	Grade I	480	70	HSLA structural tubing
		Grade II	480	70	HSLA structural tubing
		Grade III	445	65	HSLA structural tubing
	ASTM A633	Grade A	434	63	HSLA steel
		Grade B	434	63	HSLA steel
		Grade C	480	70 (Note 5)	HSLA steel
		Grade D	480	70 (Note 5)	HSLA steel
	ASTM A709	Grade 50	445	65	Structural steel
		Grade 50W	480	70	Structural steel
	ABS	Grade AH32	470	68	Hull structural steel
	ABS	Grade DH32	470	68	Hull structural steel
	ABS	Grade EH32	470	68	Hull structural steel
	ABS	Grade AH36	485	71	Hull structural steel
	ABS	Grade DH36	485	71	Hull structural steel
	ABS	Grade EH36	485	71	Hull structural steel

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification		Minimum tensile strength		Type of base metal
			MPa	ksi	
			<u>Ferrous materials</u>		
1B	API 5LS	Grade X46	434	63	Pipe
	API 5LS	Grade X52	455	66	Pipe
	API 5LS	Grade X56	485	71	Pipe
	API 5LS	Grade X60	515	75	Pipe
	API 5LX	Grade X46	434	63	Pipe
	API 5LX	Grade X52	455	66	Pipe
	API 5LX	Grade X56	485	71	Pipe
	API 5LX	Grade X60	515	75	Pipe
1C	ASTM A537	Class 2	550	80	C-Mn-Si steel plates
	ASTM A572	Grade 65	550	80	HSLA, Cb, V steel
	ASTM A612		570	83 (Note 4)	Plates, low temp. service
	ASTM A633	Grade E	550	80 (Note 6)	HSLA steel
	API 5LS	Grade X65	530	77	Pipe
	API 5LS	Grade X70	565	82	Pipe
	API 5LX	Grade X65	530	77	Pipe
	API 5LX	Grade X70	565	82	Pipe
2A	ASTM A48	Class 20	135	20	Gray iron castings
		Class 25	170	25	Gray iron castings
		Class 30	205	30	Gray iron castings
		Class 35	240	35	Gray iron castings
		Class 40	275	40	Gray iron castings
	ASTM A159	Grade G 1800	120	18	Gray iron castings
		Grade G 2500	170	25	Gray iron castings
		Grade G 3000	205	30	Gray iron castings

2A	ASTM A159	Grade G 3500	240	35	Gray iron castings
		Grade G 4000	275	40	Gray iron castings
2B	ASTM A48	Class 45	310	45	Gray iron castings
		Class 50	340	50	Gray iron castings
		Class 55	375	55	Gray iron castings
		Class 60	410	60	Gray iron castings
2C	ASTM A47	Grade 32510	340	50	Malleable iron castings
		Grade 35018	365	53	Malleable iron castings
	ASTM A197	275	40	Malleable iron castings	
2D	ASTM A220	Grade 40010	410	60	Malleable iron castings
		Grade 45006	445	65	Malleable iron castings
		Grade 45008	445	65	Malleable iron castings
	ASTM A602	Grade M3210	340	50	Malleable iron castings
		Grade M4504	445	65	Malleable iron castings
2E	ASTM A220	Grade 50005	480	70	Malleable iron castings
		Grade 60004	550	80	Malleable iron castings
	ASTM A602	Grade M5003	515	75	Malleable iron castings
		Grade M5503	515	75	Malleable iron castings
2F	ASTM A436	Type 1	170	25	Austenitic gray iron castings
		Type 1b	205	30	Austenitic gray iron castings
		Type 2	170	25	Austenitic gray iron castings
		Type 2b	205	30	Austenitic gray iron castings
		Type 3	170	25	Austenitic gray iron castings
		Type 4	170	25	Austenitic gray iron castings
		Type 5	135	20	Austenitic gray iron castings
Type 6	170	25	Austenitic gray iron castings		
2G	ASTM A439	Type D-2	395	58	Austenitic ductile iron cast.
		Type D-2B	395	58	Austenitic ductile iron cast.
		Type D-2C	395	58	Austenitic ductile iron cast.
		Type D-3	375	55	Austenitic ductile iron cast.
		Type D-3A	375	55	Austenitic ductile iron cast.
		Type D-4	410	60	Austenitic ductile iron cast.

Table 2.1 continued — Grouping of base metals for procedure qualification

P no.	Base metal specification	Minimum tensile strength		Type of base metal	
		MPa	ksi		
		<u>Ferrous materials</u>			
2G	ASTM A439	Type D-5	375	55	Austenitic ductile iron cast.
		Type D-5B	375	55	Austenitic ductile iron cast.
3A	ASTM A209	Grade T1	375	55	C-Mo tubes
		Grade T1a	410	60	C-Mo tubes
		Grade T1b	365	53	C-Mo tubes
	ASTM A213	Grade T2	410	60	C-Mo tubes
	ASTM A250	Grade T1	375	55	C-Mo tubes
		Grade T1a	410	60	C-Mo tubes
		Grade T1b	365	53	C-Mo tubes
	ASTM A355	Grade P1	375	55	Alloy steel pipe
		Grade P2	375	55	Alloy steel pipe
		Grade P15	410	60	Alloy steel pipe
	ASTM A369	Grade FP1	375	55	Alloy steel pipe
		Grade FP2	375	55	Alloy steel pipe
	ASTM A387	Gr 2, Class 1	375	55	Cr-Mo steel plates
	ASTM A426	Grade CP1	445	65	Alloy steel pipe
		Grade CP2		(Note 1)	Alloy steel pipe
3B	ASTM A182	Grade F1	480	70	C-Mo pipe flanges
		Grade F2	480	70	Cr-Mo pipe flanges
	ASTM A204	Grade A	445	65	C-Mo steel plates
		Grade B	480	70	C-Mo steel plates
		Grade C	515	75	C-Mo steel plates
	ASTM A217	Grade WC1	445	65	C-Mo steel castings
	ASTM A236	Grade C	515	75	Carbon steel forgings
	ASTM A299		515	75	Mn-Si plates

3B	ASTM A302	Grade A	515	75	Mn-Mo steel plates	
	ASTM A336	Class F1	480	70	C-Mo forgings	
	ASTM A352	Grade LC1	445	65	C-Mo castings	
	ASTM A381	Class Y48	495	72	Pipe	
		Class Y50	495	72	Pipe	
		Class Y52	515	75	Pipe	
ASTM A387	Gr 2, C1 2	480	70	Cr-Mo plates		
3C	ASTM A236	Grade D	550	80	Carbon steel forgings	
		Grade E	585	85	Carbon steel forgings	
		Grade F	605	88	Carbon steel forgings	
	ASTM A302	Grade B	550	80	Mn-Mo steel plates	
		Grade C	550	80	Mn-Mo-Ni steel plates	
		Grade D	550	80	Mn-Mo-Ni steel plates	
	ASTM A508	Class 2	550	80	Forgings	
		Class 3	550	80	Forgings	
	ASTM A533	Gr A, Class 1	550	80	Mn-Mo plate	
		Gr B, Class 1	550	80	Mn-Mo-Ni plate	
		Gr C, Class 1	550	80	Mn-Mo-Ni plate	
		Gr D, Class 1	550	80	Mn-Mo-Ni plate	
		Gr A, Class 2	620	90	Mn-Mo plate	
		Gr B, Class 2	620	90	Mn-Mo-Ni plate	
		Gr C, Class 2	620	90	Mn-Mo-Ni plate	
		Gr D, Class 2	620	90	Mn-Mo-Ni plate	
	ASTM A541	Class 2	550	80	Forgings	
		Class 3	550	80	Forgings	
	4A	ASTM A387	Gr 12, Class 1	375	55	Cr-Mo plates
		ASTM A543	Type A	310	45	Alloy steel plates
			Type B	395	58	Alloy steel plates
4B	ASTM A182	Grade F11	480	70	Cr-Mo pipe flanges	
		Grade F12	480	70	Cr-Mo pipe flanges	
	ASTM A199	Grade T3b	410	60	Cr-Mo tubes	
		Grade T11	410	60	Cr-Mo tubes	
	ASTM A200	Grade T4	410	60	Alloy steel tubes	
		Grade T21	410	60	Alloy steel tubes	
		Grade T22	410	60	Alloy steel tubes	

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Minimum tensile strength		Type of base metal	
		MPa	ksi		
		<u>Ferrous materials</u>			
4B	ASTM A202	Grade A	515	75	CMS plates
	ASTM A213	Grade T3b	410	60	Cr-Mo tubes
		Grade T11	410	60	Cr-Mo tubes
		Grade T12	410	60	Cr-Mo tubes
	ASTM A217	Grade WC4	480	70	Ni-Cr-Mo castings
		Grade WC5	480	70	Ni-Cr-Mo castings
		Grade WC6	480	70	Cr-Mo castings
	ASTM A335	Grade P11	410	60	Cr-Mo pipe
		Grade P12	410	60	Cr-Mo pipe
	ASTM A336	Class F12	480	70	Cr-Mo forgings
	ASTM A369	Grade FP3b	410	60	Cr-Mo pipe
		Grade FP11	410	60	Cr-Si-Mo pipe
		Grade FP12	410	60	Cr-Mo pipe
	ASTM A387	Gr 11, Class 1	410	60	Cr-Mo plate
		Gr 11, Class 2	515	75	Cr-Mo plate
		Gr 12, Class 2	445	65	Cr-Mo plate
	ASTM A389	Grade C23	480	70	Alloy steel castings
	ASTM A405	Grade P24	410	60	Alloy steel pipe
	ASTM A426	Grade CP11	480	70	Alloy steel pipe
		Grade CP12	410	60	Alloy steel pipe
4C	ASTM A202	Grade B	585	85	CMS plates
	ASTM A389	Grade C24	550	80	Alloy steel castings
	ASTM A404	Grade F24	550	80	Forged fittings
4D	ASTM A333	Grade 4	410	60	Alloy pipe
	ASTM A350	Grade LF4	410	60	Alloy forgings

4D	ASTM A410		410	60	Alloy plate
	ASTM A423	Grade 1	410	60	Alloy tubes
		Grade 2	410	60	Alloy tubes
5A	ASTM A182	Grade F21	515	75	Cr-Mo pipe flanges
		Grade F22	515	75	Cr-Mo pipe flanges
	ASTM A199	Grade T4	410	60	Cr-Mo tubes
		Grade T21	410	60	Cr-Mo tubes
		Grade T22	410	60	Cr-Mo tubes
	ASTM A200	Grade T4	410	60	Cr-Mo tubes
		Grade T21	410	60	Cr-Mo tubes
		Grade T22	410	60	Cr-Mo tubes
	ASTM A213	Grade T21	410	60	Cr-Mo tubes
		Grade T22	410	60	Cr-Mo tubes
	ASTM A217	Grade WC9	480	70	Cr-Mo castings
	ASTM A335	Grade P21	410	60	Cr-Mo pipe
		Grade P22	410	60	Cr-Mo pipe
	ASTM A336	Class F21	515	75	Cr-Mo forgings
		Class F21a	410	60	Cr-Mo forgings
		Class F22	515	75	Cr-Mo forgings
		Class F22a	410	60	Cr-Mo forgings
	ASTM A357		410	60	Cr-Mo pipe
	ASTM A369	Grade FP21	410	60	Cr-Mo pipe
		Grade FP 22	410	60	Cr-Mo pipe
	ASTM A387	Gr 21, Class 1	410	60	Cr-Mo plate
	Gr 21, Class 2	515	75	Cr-Mo plate	
	Gr 22, Class 1	410	60	Cr-Mo plate	
	Gr 22, Class 2	515	75	Cr-Mo plate	
ASTM A426	Grade CP21	410	60	Cast alloy pipe	
	Grade CP22	515	75	Cast alloy pipe	
5B	ASTM A182	Grade F5	410	60	Cr-Mo pipe flanges
		Grade F7	410	60	Cr-Mo pipe flanges
	ASTM A199	Grade T5	410	60	Cr-Mo tubes
		Grade T7	410	60	Cr-Mo tubes
		Grade T9	410	60	Cr-Mo tubes
	ASTM A200	Grade T5	410	60	Alloy steel tubes
		Grade T7	410	60	Alloy steel tubes
	Grade T9	410	60	Alloy steel tubes	

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Minimum tensile strength		Type of base metal	
		MPa	ksi		
		<u>Ferrous materials</u>			
5B	ASTM A213	Grade T5	410	60	Alloy steel tubes
		Grade T5b	410	60	Alloy steel tubes
		Grade T5c	410	60	Alloy steel tubes
		Grade T7	410	60	Cr-Mo tubes
		Grade T9	410	60	Cr-Mo tubes
	ASTM A335	Grade P5	410	60	Cr-Mo pipe
		Grade P5b	410	60	Cr-Mo pipe
		Grade P5c	410	60	Cr-Mo pipe
		Grade P7	410	60	Cr-Mo pipe
		Grade P9	410	60	Cr-Mo pipe
	ASTM A336	Class F5	410	60	Cr-Mo forgings
	ASTM A369	Grade FP5	410	60	Cr-Mo pipe
		Grade FP7	410	60	Cr-Mo pipe
		Grade FP9	410	60	Cr-Mo pipe
	ASTM A387	Grade 5, Class 1	410	60	Cr-Mo plate
		Grade 5, Class 2	515	75	Cr-Mo plate
	ASTM A426	Grade CP5	410	60	Cast alloy pipe
Grade CP7		410	60	Cast alloy pipe	
Grade CP9		410	60	Cast alloy pipe	
5C	ASTM A182	Grade F5a	550	80	Cr-Mo pipe flanges
		Grade F9	585	85	Cr-Mo pipe flanges
	ASTM A217	Grade C5	620	90	Cr-Mo castings
		Grade C12	620	90	Cr-Mo castings

5C	ASTM A336	Class F5a	550	80	Cr-Mo forgings
	ASTM A426	Grade CP5	620	90	Cast alloy pipe
		Grade CP9	620	90	Cast alloy pipe
	ASTM A487	Grade 8N	585	85	Alloy steel castings
	ASTM A542	Class 3	655	95	Alloy steel plates
		Class 4	585	85	Alloy steel
5D	ASTM A542	Class 1	720	105	Alloy steel plates
		Class 2	790	115	Alloy steel plates
6A	ASTM A240	Type 410	445	65	Stainless steel plate
	ASTM A268	Grade TP 410	410	60	Stainless steel tubes
		Grade TP 409	410	60	Stainless steel tubes
	ASTM A336	Grade F6	515	75	Stainless steel forgings
	ASTM A473	Type 410	480	70	Stainless steel forgings
	ASTM A473	Type 410	480	70	St. stl. bars & shapes
6B	ASTM A240	Type 429	445	65	Stainless steel plate
	ASTM A268	Grade TP 429	445	65	Stainless steel tubes
	ASTM A473	Type 429	445	65	Stainless steel forgings
		Type 430	480	70	Stainless steel forgings
	ASTM A479	Type 430	480	70	St. stl. bars & shapes
6C	ASTM A182	Grade F6	585	85	Alloy steel forgings
	ASTM A351	Grade CA15	620	90	Alloy castings
	ASTM A426	Grade CP CA15	620	90	Cast alloy pipe
7A	ASTM A240	Type 405	410	60	Stainless steel plate
		Type 410S	410	60	Stainless steel plate
	ASTM A268	Grade TP 405	410	60	Stainless steel tubes
	ASTM A473	Type 405	410	60	Stainless steel forgings
		Type 410S	445	65	Stainless steel forgings
7B	ASTM A240	Type XM-8	445	65	Stainless steel plate
8A	ASTM A167	Type 301	515	75	Stainless steel plate
		Type 302	515	75	Stainless steel plate
		Type 302L	515	75	Stainless steel plate

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Minimum tensile strength		Type of base metal	
		MPa	ksi		
		<u>Ferrous materials</u>			
8A	ASTM A167	Type 304	515	75	Stainless steel plate
		Type 304L	480	70	Stainless steel plate
		Type 305	480	70	Stainless steel plate
		Type 308	515	75	Stainless steel plate
		Type 309	515	75	Stainless steel plate
		Type 309S	515	75	Stainless steel plate
		Type 310	515	75	Stainless steel plate
		Type 316	515	75	Stainless steel plate
		Type 316L	480	70	Stainless steel plate
		Type 317	515	75	Stainless steel plate
		Type 317L	515	75	Stainless steel plate
		Type 321	515	75	Stainless steel plate
		Type 347	515	75	Stainless steel plate
		Type 348	515	75	Stainless steel plate
		Type XM-15	515	75	Stainless steel plate
	ASTM A182	Grade F304	515	75	Stainless pipe flanges
		Grade F304H	515	75	Stainless pipe flanges
		Grade F304L	445	65	Stainless pipe flanges
		Grade F316	515	75	Stainless pipe flanges
		Grade F316H	515	75	Stainless pipe flanges
		Grade F316L	445	65	Stainless pipe flanges
		Grade F321	515	75	Stainless pipe flanges
		Grade F321H	515	75	Stainless pipe flanges
		Grade F347	515	75	Stainless pipe flanges
		Grade F347H	515	75	Stainless pipe flanges
		Grade F348	515	75	Stainless pipe flanges
		Grade F348H	515	75	Stainless pipe flanges

8A	ASTM A213	Grade TP304	515	75	Stainless tubes
		Grade TP304H	515	75	Stainless tubes
		Grade TP304L	480	70	Stainless tubes
		Grade TP316	515	75	Stainless tubes
		Grade TP316H	515	75	Stainless tubes
		Grade TP316L	480	70	Stainless tubes
		Grade TP321	515	75	Stainless tubes
		Grade TP321H	515	75	Stainless tubes
		Grade TP347	515	75	Stainless tubes
		Grade TP347H	515	75	Stainless tubes
	ASTM A240	Grade TP348	515	75	Stainless tubes
		Grade TP348H	515	75	Stainless tubes
		Grade XP-15	515	75	Stainless tubes
		Type 302	515	75	Stainless plate
		Type 304	515	75	Stainless plate
		Type 304L	480	70	Stainless plate
		Type 316	515	75	Stainless plate
		Type 316L	480	70	Stainless plate
		Type 317	515	75	Stainless plate
		Type 317L	515	75	Stainless plate
ASTM A249	Type 321	515	75	Stainless plate	
	Type 347	515	75	Stainless plate	
	Type 348	515	75	Stainless plate	
	Type XM-15	515	75	Stainless plate	
	Grade TP304	515	75	Stainless tubes	
	Grade TP304H	515	75	Stainless tubes	
	Grade TP304L	480	70	Stainless tubes	
	Grade TP316	515	75	Stainless tubes	
	Grade TP316H	515	75	Stainless tubes	
	Grade TP316L	480	70	Stainless tubes	
Grade TP317	515	75	Stainless tubes		
Grade TP321	515	75	Stainless tubes		
Grade TP321H	515	75	Stainless tubes		
Grade TP347	515	75	Stainless tubes		
Grade TP347H	515	75	Stainless tubes		
Grade TP348	515	75	Stainless tubes		
Grade TP348H	515	75	Stainless tubes		
Grade XM-15	515	75	Stainless tubes		

Table 2.1 continued — Grouping of base metals for procedure qualification

P no.	Base metal specification	Minimum tensile strength		Type of base metal	
		MPa	ksi		
<u>Ferrous materials</u>					
8A	ASTM A269	Grade TP304	515	75	Stainless tubing
		Grade TP304L	480	70	Stainless tubing
		Grade TP316	515	75	Stainless tubing
		Grade TP316L	480	70	Stainless tubing
		Grade TP317	515	75	Stainless tubing
		Grade TP321	515	75	Stainless tubing
		Grade TP347	515	75	Stainless tubing
		Grade TP348	515	75	Stainless tubing
		Grade XM-15	515	75	Stainless tubing
	ASTM A270	Type 304		(Note 1)	Stainless tubing
	ASTM A271	Grade TP304	515	75	Stainless steel tubing
		Grade TP304H	515	75	Stainless steel tubing
		Grade TP321	515	75	Stainless steel tubing
		Grade TP321H	515	75	Stainless steel tubing
		Grade TP347	515	75	Stainless steel tubing
		Grade TP347H	515	75	Stainless steel tubing
		ASTM A312	Grade TP304	515	75	Stainless pipe
	Grade TP304H		515	75	Stainless pipe
	Grade TP304L		515	75	Stainless pipe
	Grade TP316		515	75	Stainless pipe
	Grade TP316H		515	75	Stainless pipe
	Grade TP316L		480	70	Stainless pipe
	Grade TP317		515	75	Stainless pipe
	Grade TP321		515	75	Stainless pipe
	Grade TP321H		515	75	Stainless pipe
	Grade TP347		515	75	Stainless pipe

8A		Grade TP347H	515	75	Stainless pipe	
		Grade TP348	515	75	Stainless pipe	
		Grade TP348H	515	75	Stainless pipe	
		Grade XM-15	515	75	Stainless pipe	
ASTM A336		Class F8	515	75	Alloy forgings	
		Class F8M	515	75	Alloy forgings	
		Class F8T	515	75	Alloy forgings	
		Class F8C	515	75	Alloy forgings	
ASTM A351		Grade CF3	480	70	Alloy castings	
		Grade CF3A	534	77.5	Alloy castings	
		Grade CF8	480	70	Alloy castings	
		Grade CF8A	480	70	Alloy castings	
		Grade CF3M	480	70	Alloy castings	
		Grade CF3A	480	70	Alloy castings	
		Grade CF8M	480	70	Alloy castings	
		Grade CF8C	480	70	Alloy castings	
ASTM A376		Grade TP304	515	75	Stainless tubes	
		Grade TP304H	515	75	Stainless tubes	
		Grade TP316	515	75	Stainless tubes	
		Grade TP316H	515	75	Stainless tubes	
		Grade TP321	515	75	Stainless tubes	
		Grade TP321H	515	75	Stainless tubes	
		Grade TP347	515	75	Stainless tubes	
		Grade TP347H	515	75	Stainless tubes	
		Grade TP348	515	75	Stainless tubes	
		Grade TP348H	515	75	Stainless tubes	
	ASTM A430		Grade FP304	480	70	Stainless tubes
			Grade FP304H	480	70	Stainless tubes
			Grade FP316	480	70	Stainless tubes
			Grade FP 316H	480	70	Stainless tubes
		Grade FP321	480	70	Stainless tubes	
		Grade FP321H	480	70	Stainless tubes	
		Grade FP347	480	70	Stainless tubes	
		Grade FP347H	480	70	Stainless tubes	
ASTM A451		Grade CPF8	480	70	Stainless castings	
		Grade CPF8M	480	70	Stainless castings	
		Grade CPF8C	480	70	Stainless castings	

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Minimum tensile strength		Type of base metal		
		MPa	ksi			
<u>Ferrous materials</u>						
8A	ASTM A452	Grade TP304H	515	75	Stainless pipe	
		Grade TP316H	515	75	Stainless pipe	
		Grade TP347H	515	75	Stainless pipe	
	ASTM A473	Type 202	620	90	Stainless forgings	
		Type 302	515	75	Stainless forgings	
		Type 302B	515	75	Stainless forgings	
		Type 303	515	75	Stainless forgings	
		Type 303Se	515	75	Stainless forgings	
		Type 304		(Note 8)	Stainless forgings	
		Type 304L	445	65	Stainless forgings	
		Type 316		(Note 8)	Stainless forgings	
		Type 316L	445	65	Stainless forgings	
		Type 321	515	75	Stainless forgings	
		Type 347	515	75	Stainless forgings	
		Type 348	515	75	Stainless forgings	
		ASTM A479	Type 302	515	75	St. stl. bars & shapes
			Type 304	515	75	St. stl. bars & shapes
	Type 304L		480	70	St. stl. bars & shapes	
	Type 316		515	75	St. stl. bars & shapes	
	Type 316L		480	70	St. stl. bars & shapes	
	Type 321		515	75	St. stl. bars & shapes	
	Type 347		515	75	St. stl. bars & shapes	
	Type 348	515	75	St. stl. bars & shapes		
8B	ASTM A182	Grade F10	550	80	Stainless pipe flanges	
	ASTM A213	Grade TP310	515	75	Stainless tubes	

8B	ASTM A240	Type 309S	515	75	Stainless plate
		Type 310S	515	75	Stainless plate
	ASTM A249	Grade TP309	515	75	Stainless tubes
		Grade TP310	515	75	Stainless tubes
	ASTM A312	Grade TP309	515	75	Stainless pipe
		Grade TP310	515	75	Stainless pipe
	ASTM A351	Grade CH8	445	65	Stainless castings
		Grade CH10	480	70	Stainless castings
		Grade CH20	480	70	Stainless castings
		Grade CK20	445	65	Stainless castings
		Grade CN7M	430	62.5	Stainless castings
		Grade CPH8	445	65	Stainless castings
	ASTM A451	Grade CPH8	445	65	Stainless castings
		Grade CPK20	445	65	Stainless castings
		Grade CPH20	480	70	Stainless castings
	ASTM A473	Type 309	515	75	Stainless forgings
		Type 309S	515	75	Stainless forgings
		Type 310	515	75	Stainless forgings
		Type 310S	515	75	Stainless forgings
	ASTM A479	Type 310S	515	75	St. stl. bars & shapes
8C	ASTM A182	Grade F310	655	95	Stainless pipe flanges
	ASTM A336	Class F25	655	95	Stainless forgings
9A	ASTM A203	Grade A	445	65	Ni-steel plates
		Grade B	480	70	Ni-steel plates
	ASTM A333	Grade 7	445	65	Ni-steel pipe
		Grade 9	434	63	Ni-steel pipe
	ASTM A334	Grade 7	445	65	Ni-steel tube
	ASTM A344	Grade 9	434	63	Ni-steel tube
	ASTM A352	Grade LC2	445	65	Ni-steel castings
9B	ASTM A203	Grade D	445	65	Ni-steel plate
		Grade E	480	70	Ni-steel plate
	ASTM A333	Grade 3	445	65	Ni-steel pipe
	ASTM A334	Grade 3	445	65	Ni-steel tube
	ASTM A350	Grade LF3	480	70	Ni-steel forgings
	ASTM A352	Grade LC3	445	65	Ni-steel castings

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	<u>Minimum tensile strength</u>		Type of base metal	
		<u>MPa</u>	<u>ksi</u>		
		<u>Ferrous materials</u>			
10A	ASTM A225	Grade A	480	70	Mn-V steel plates
		Grade B	515	75	Mn-V steel plates
	ASTM A487	Class 1N	585	85	Mn-V steel castings
		Class 1Q	620	90	Mn-V steel castings
10B	ASTM A213	Grade T17	410	60	Cr-V steel tubes
10C	ASTM A612	Grade A	570	83	Cr-Mn-Si steel plate
		Grade B	555	81	Cr-Mn-Si steel plate
10D	ASTM A268	Grade TP443	480	70	Stainless steel tubes
10E	ASTM A268	Grade TP446	480	70	Stainless steel tubes
		Grade TP329	515	75	Stainless steel tubes
10F	ASTM A487	Class 2N	585	85	Low alloy steel castings
		Class 2Q	620	90	Low alloy steel castings
		Class 4N	620	90	Low alloy steel castings
10G	ASTM A658		445	65	Alloy plates
10H	ASTM A669		630	92	Alloy tube
11A	ASTM A333	Grade 8	685	100	Ni-steel pipe
	ASTM A334	Grade 8	685	100	Ni-steel tube
	ASTM A353		685	100	Ni-steel plate
	ASTM A522		685	100	Ni-steel forgings

11A	ASTM A553	Type I	685	100	Ni-steel plate	
		Type II	685	100	Ni-steel plate	
	ASTM A645		655	95	Alloy steel plate	
	ASTM A487	Class 4Q	720	105	Alloy steel castings	
	ASTM A533	Class 3, Gr A	685	100	Mn-Mo plate	
		Class 3, Gr B	685	100	Mn-Mo plate	
		Class 3, Gr C	685	100	Mn-Mo plate	
		Class 3, Gr D	685	100	Mn-Mo plate	
11B	ASTM A514	Type A	790	115	Alloy steel plates	
		Type B	790	115	Alloy steel plates	
		Type C	790	115	Alloy steel plates	
		Type D	790	115	Alloy steel plates	
		Type E	790	115	Alloy steel plates	
		Type F	790	115	Alloy steel plates	
		Type G	790	115	Alloy steel plates	
		Type H	790	115	Alloy steel plates	
		Type J	790	115	Alloy steel plates	
		Type K	790	115	Alloy steel plates	
		Type L	790	115	Alloy steel plates	
		Type M	790	115	Alloy steel plates	
		Type N	790	115	Alloy steel plates	
		Type P	790	115	Alloy steel plates	
		ASTM A517	Grade A	790	115	Alloy steel plates
			Grade B	790	115	Alloy steel plates
	Grade C		790	115	Alloy steel plates	
	Grade D		790	115	Alloy steel plates	
	Grade E		790	115	Alloy steel plates	
	Grade F		790	115	Alloy steel plates	
	Grade G		790	115	Alloy steel plates	
	Grade H		790	115	Alloy steel plates	
	Grade J		790	115	Alloy steel plates	
	Grade K		790	115	Alloy steel plates	
	Grade L		790	115	Alloy steel plates	
	Grade M		790	115	Alloy steel plates	
	Grade N		790	115	Alloy steel plates	
	Grade P		790	115	Alloy steel plates	

Table 2.1 continued—Grouping of base metals for procedure qualification

<u>P no.</u>	<u>Base metal specification</u>	<u>Minimum tensile strength</u>		<u>Type of base metal</u>	
		<u>MPa</u>	<u>ksi</u>		
		<u>Ferrous materials</u>			
11B	ASTM A592	Grade A	790	115	Alloy steel forgings
		Grade E	790	115	Alloy steel forgings
		Grade F	790	115	Alloy steel forgings
	ASTM A709	Grade 100	755 (Note 7)	110	Structural steel
		Grade 100W	755 (Note 7)	110	Structural steel
11C	ASTM A513	Grade 4130	(Note 1)		Mechanical tubing
		Grade 8630	(Note 1)		Mechanical tubing

Notes:

1. Where material specifications do not include tensile strength, the fabricator and the purchaser shall agree on the tensile strength required at testing.
2. 480 MPa (70 ksi) min tensile strength for thicknesses 19 mm (3/4 in.) and under
460 MPa (67 ksi) min tensile strength for thicknesses over 19 mm to 38 mm (3/4 to 1 1/2 in.) incl.
435 MPa (63 ksi) min tensile strength for thicknesses over 38 mm to 102 mm (1 1/2 to 4 in.) incl.
410 MPa (60 ksi) min tensile strength for thicknesses over 102 mm to 203 mm (4 to 8 in.) incl.
3. 480 MPa (70 ksi) min tensile strength for thicknesses 102 mm (4 in.) and under
460 MPa (67 ksi) min tensile strength for thicknesses over 102 mm to 127 mm (4 to 5 in.) incl.
435 MPa (63 ksi) min tensile strength for thicknesses over 127 mm to 203 mm (5 to 8 in.) incl.
4. 570 MPa (83 ksi) min tensile strength for thicknesses 13 mm (0.5 in.) and under
555 MPa (81 ksi) min tensile strength for thicknesses over 13 mm to 25 mm (0.5 to 1 in.) incl.
5. 480 MPa (70 ksi) min tensile strength for thicknesses 64 mm (2.5 in.) and under
445 MPa (65 ksi) min tensile strength for thicknesses over 64 mm to 102 mm (2.5 to 4 in.) incl.
6. 550 MPa (80 ksi) min tensile strength for thicknesses 102 mm (4 in.) and under
515 MPa (75 ksi) min tensile strength for thicknesses over 102 mm (4 in.) to 152 mm (6 in.) incl.
7. 755 MPa (110 ksi) min tensile strength for thicknesses 64 mm (2.5 in.) and under
685 MPa (100 ksi) min tensile strength for thicknesses over 64 mm to 102 mm (2.5 to 4 in.) incl.
8. 515 MPa (75 ksi) min tensile strength for thicknesses 127 mm (5 in.) and under
485 MPa (70 ksi) min tensile strength for thicknesses over 127 mm (5 in.)

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Thickness		Minimum tensile strength		Type of base metal	Notes
		mm	in.	MPa	ksi		
<u>Aluminum and aluminum base alloys</u>							
21	ASTM B209	1.30 - 76.20	0.051 - 3.000	55	8	1060 (99.6 min. Al) Sheet, plate	
	ASTM B210	A11	A11	58	8.5	1060 Tube	(9)
	ASTM B221	A11	A11	58	8.5	1060 Bars, rods, shapes, tube	(9)
	ASTM B234	A11	A11	58	8.5	1060 Tube	(9)
	ASTM B241	A11	A11	58	8.5	1060 Tube	(9)
	ASTM B209	1.30 - 76.20	0.051 - 3.000	75	11	1100 (99.0 min. Al) Sheet, plate	
	ASTM B221	A11	A11	75	11	1100 Bars, rods, shapes, tube	
	ASTM B241	A11	A11	75	11	1100 Tube	
	ASTM B209	1.30 - 76.20	0.051 - 3.000	95	14	3003 (1.2 Mn) Sheet, plate	
	ASTM B210	A11	A11	95	14	3003 Tube	(9)
	ASTM B221	A11	A11	95	14	3003 Bars, rods, shapes, pipe, tube	(9)
	ASTM B234	A11	A11	95	14	3003 Tube	(9)
	ASTM B241	A11	A11	95	14	3003 Pipe, tube	(9)
	ASTM B247	Up thru 101.60	Up thru 4.000	95	14	3003 Die forgings	
	ASTM B209	1.30 - 12.67	0.051 - 0.499	85	13	Alclad 3003 (1.2 Mn) sheet, plate	(10)
		12.70 - 76.20	0.500 - 3.000	95	14	Alclad 3003 plate	(11)

21	ASTM B210	A11	A11	85	13	Alclad 3003 tube	(10)
	ASTM B234	A11	A11	85	13	Alclad 3003 tube	(10)
	ASTM B241	A11	A11	85	13	Alclad 3003 tube	(10)
	ASTM B209	1.30 - 76.20	0.051 - 3.000	120	18	5050 (1.2 Mg) Sheet, plate	
22	ASTM B209	1.30 - 76.20	0.051 - 3.000	150	22	3004 (1.2 Mn, 1.0 Mg) Sheet, plate	
	ASTM B209	1.30 - 12.67	0.051 - 0.499	140	21	Alclad 3004 (1.2 Mn, 1.0 Mg) sht., plt.	(10)
		12.70 - 76.20	0.500 - 3.000	150	22	Alclad 3004 plate	(11)
	ASTM B209	1.30 - 76.20	0.051 - 3.000	170	25	5052 & 5652 (2.5 Mg, 0.25 Cr) sht., plt.	
	ASTM B234	A11	A11	170	25	5052 Tube	(9)
	ASTM B241	A11	A11	170	25	5052 Tube	(9)
	ASTM B209	1.30 - 76.20	0.051 - 3.000	205	30	5154 & 5254 (3.5 Mg, 0.25 Cr) sht., plt.	
	ASTM B210	A11	A11	205	30	5154 Tube	(9)
	ASTM B221	A11	A11	205	30	5154 Bars, rods, shapes, tube	(9)
	ASTM B209	1.30 - 76.20	0.051 - 3.000	210	31	5454 (2.75 Mg, 0.8 Mn, 0.10 Cr) sht., plt.	
	ASTM B221	A11	A11	210	31	5454 Bars, rods, shapes, tube	(9)
	ASTM B234	A11	A11	210	31	5454 Tube	(9)
	ASTM B241	A11	A11	210	31	5454 Tube	(9)
	23	ASTM B209	1.30 - 152.40	0.051 - 6.000	165 ^a	24 ^a	6061 (1.0 Mg, 0.6 Si, 0.25 Cr) sht., plt.
ASTM B210		A11	A11	165 ^a	24 ^a	6061 Pipe, tube	(9)
ASTM B211		A11	A11	165 ^a	24 ^a	6061 Bars, rods	(9)
ASTM B221		A11	A11	165 ^a	24 ^a	6061 Bars, rods, shapes, pipe, tube	(9)
ASTM B234		A11	A11	165 ^a	24 ^a	6061 Tube	(9)
ASTM B241		A11	A11	165 ^a	24 ^a	6061 Pipe, tube	(9)
ASTM B308		A11	A11	165 ^a	24 ^a	6061 Shapes	(9)

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Thickness		Minimum tensile strength		Type of base metal	Notes
		mm	in.	MPa	ksi		
<u>Aluminum and aluminum base alloys</u>							
23	ASTM B247	Up thru 203.20	Up thru 8.000	165 ^a	24 ^a	6061 Forgings	
	ASTM B209	1.30 - 127.00	0.051 - 5.000	165 ^a	24 ^a	Alclad 6061 (1.0 Mg, 0.6 Si, 0.25 Cr) sheet, plate	
	ASTM B210	A11	A11	115 ^a	17 ^a	6063 (0.7 Mg, 0.4 Si) Tube	(9)
	ASTM B221	A11	A11	115 ^a	17 ^a	6063 (0.7 Mg, 0.4 Si) Bars, rods, shapes, pipe, tube	(9)
	ASTM B241	A11	A11	115 ^a	17 ^a	6063 (0.7 Mg, 0.4 Si) Pipe, tube	(9)
25	ASTM B209	1.30 - 38.10	0.051 - 1.500	275	40	5083 (4.5 Mg, 0.8 Mn, 0.15 Cr) sht., plt.	
		38.13 - 76.20	1.501 - 3.000	265	39	5083 Plate	
		76.23 - 127.00	3.001 - 5.000	260	38	5083 Plate	
		127.03 - 177.80	5.001 - 7.000	255	37	5083 Plate	
		177.83 - 203.20	7.001 - 8.000	245	36	5083 Plate	

25	ASTM B221	Up thru 127.00	Up thru 5.000	265	39	5083 Bars, rods, shapes, tube
	ASTM B241	Up thru 127.00	Up thru 5.000	265	39	5083 Tube
	ASTM B247	Up thru 101.60	Up thru 4.000	260	38	5083 Forgings
	ASTM B209	1.30 - 50.80	0.051 - 2.000	240	35	5086 (4.0 Mg, 0.5 Mn, 0.15 Cr) sht., plt.
		50.83 - 76.20	2.001 - 3.000	230	34	5086 Plate
	ASTM B241	Up thru 127.00	Up thru 5.000	240	35	5086 Tube
	ASTM B209	1.30 - 38.10	0.051 - 1.500	285	42	5456 (5.1 Mg, 0.8 Mn, 0.10 Cr) sht., plt.
		38.13 - 76.20	1.501 - 3.000	280	41	5456 Plate
		76.23 - 127.00	3.001 - 5.000	275	40	5456 Plate
		127.03 - 177.80	5.001 - 7.000	265	39	5456 Plate
		177.83 - 203.20	7.001 - 8.000	260	38	5456 Plate
	ASTM B221	Up thru 127.00	Up thru 5.000	280	41	5456 Bars, rods, shapes, tube
	ASTM B241	Up thru 127.00	Up thru 5.000	280	41	5456 Tube

Notes:

9. Some of the indicated product forms are not normally produced in all the sizes indicated.
10. Specified minimum tensile strength is for full-thickness specimens which include cladding.
11. Specified minimum tensile strength is for specimens taken from the core.
 - a. Value is not applicable to base metal in the annealed temper.

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Condition	Size(s) or thickness		Minimum tensile strength		Type of base metal
			mm	in.	MPa	ksi	
<u>Copper and copper base alloys</u>							
31	ASTM B11	Annealed	....	....	205	30	Cu nos. 122, 142 ^C plate Cu nos. 102, 103, 108, 120, 122 ^C pipe
		Drawn	3 - 51(s)	1/8 - 2(s)	310 ^b	45 ^b	
	ASTM B42	Drawn	63 - 305(s)	2 1/2 - 12(s)	245 ^b 205	36 ^b 30	Copper pipe alloys 102, 120 and 122
	ASTM B75	Annealed	....	....	205	30	Cu nos. 102, 103, 108, 109, 120, 122, 142 ^C seamless tube
	ASTM B111	Light drawn	....	....	245 ^b	36 ^b	Cu nos. 102, 103, 108, 120, 122, 142 ^C
	ASTM B152	Hard drawn	....	....	310 ^b	45 ^b	Seamless condenser
		Annealed	....	....	205	30	Cu nos. 102, 104, 105, 107, 122, 123 ^C sheet, plate, bar
	ASTM B88	Annealed	....	....	205	30	Seamless copper water tube
		Drawn	....	....	245 ^b	36 ^b	Cu nos. 102, 103, 108, 120, 122 ^C
	ASTM B447	Light drawn	....	....	245-320	36-47 ^b	Welded copper tube
		Drawn	....	....	245 ^b	36 ^b	Cu nos. 102, 103, 108, 120, 122, 142 ^C
	ASTM B586	Hard drawn	....	....	310 ^b	45 ^b	Welded copper alloy water tube Cu no. 194
		Annealed	....	....	310	45	
		Cold worked	....	....	410 ^b	60 ^b	

32	ASTM B171	Annealed	To 127	To 5	340	50	Alloy 464 (30 Zn, 75 Sn) naval brass, plate
	ASTM B171	Annealed	51 and under	2 and under	340	50	Alloy 365 (39 Zn, 0.6 Pb)
		Annealed	over 51 thru 89	over 2 thru 3.5	310	45	Leaded Muntz metal plate
		Annealed	over 89 thru 127	over 3.5 thru 5	275	40	
	ASTM B111	Annealed	....	....	310	45	Alloy 443 (28 Zn, 1 Sn, 0.06 As) admiralty, tube
	ASTM B111	Annealed	....	....	310	45	Alloy 444 (28 Zn, 1 Sn, 0.06 Sb) admiralty, tube
	ASTM B111	Annealed	....	....	310	45	Alloy 445 (23 Zn, 1 Sn, 0.06 P) admiralty, tube
	ASTM B111	Annealed	....	....	340	50	Alloy 280 (40 Zn) Muntz Metal, tube
	ASTM B111 B135, B43	Annealed	....	....	275	40	Alloy 230 (15 Zn), red brass tube, pipe
	ASTM B111	Annealed	....	....	340	50	Alloy 687 (30 Zn, 2Al, 0.06 As) aluminum brass
33	ASTM B96, B315	Annealed	....	....	340	50	Alloy 655 (3.3 Si) copper- silicon plate, sheet
	ASTM B98	Soft	....	....	355	52	Alloy 655 (3.3 Si) copper- silicon rod, bar, shapes
	ASTM B98	Soft	....	....	275	40	Alloy 651 (1.6 Si) copper- silicon rod, bar, shapes
	ASTM B315	Annealed	....	....	340	50	Alloy 655 (3.3 Si) copper- silicon pipe and tube
	ASTM B315	Annealed	....	....	275	40	Alloy 651 (1.4 Si) copper- silicon pipe and tube

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Condition	Size(s) or thickness		Minimum tensile strength		Type of base metal
			mm	in.	MPa	ksi	
<u>Copper and copper base alloys</u>							
34	ASTM B111	Annealed	....	....	355	52	Alloy 715 (30 Ni) copper-nickel tube
	ASTM B111	Annealed	....	....	310	45	Alloy 710 (20 Ni) copper-nickel tube
	ASTM B111	Annealed	....	....	275	40	Alloy 706 (10 Ni) copper-nickel tube
	ASTM B111	Annealed	....	....	260	38	Alloy 704 (5 Ni) copper-nickel tube
	ASTM B171, B402	Annealed	63 and under	2.5 and under	340	50	Alloy 715 (30 Ni) copper-nickel plate
	ASTM B171, B402	Annealed	over 63 to 127 incl.	over 2.5 to 5 incl.	310	45	Alloy 706 (10 Ni) copper-nickel plate
		Annealed	63 and under incl.	2.5 and under incl.	275	40	
	ASTM B466	Annealed	....	....	340	50	Alloy 715 (30 Ni) copper-nickel pipe and tube
		Annealed	....	....	310	45	Alloy 710 (20 Ni) copper-nickel pipe and tube
		Annealed	....	....	260	38	Alloy 706 (10 Ni) copper-nickel pipe and tube
		Annealed	....	....	255	37	Alloy 704 (5 Ni) copper-nickel pipe and tube
	ASTM B467	Annealed	....	....	340	50	Alloy 715 (30 Ni) welded copper-nickel pipe and tube

34	ASTM B467	Annealed	....	....	310	45	Alloy 710 (20 Ni) welded copper-nickel pipe and tube
		Annealed	....	....	275	40	Alloy 706 (10 Ni) welded copper-nickel pipe and tube
35	ASTM B169	Annealed	....	....	340	50	Alloy 612 (8 Al) all aluminum-bronze plate, sheet
		Annealed	13 and under	1/2 and under	495	72	Alloy 614 (7 Al, 2.5 Fe) aluminum bronze, plate, sheet
ASTM B171	ASTM B171	Annealed	over 13 to 51	over 1/2 to 2	480	70	Alloy 614 (7 Al, 2.5 Fe) Aluminum bronze, plate
		Annealed	over 51 to 127 incl.	over 2 to 5 incl.	445	65	
		Annealed	51 and under	2 and under	480	70	
ASTM B171	ASTM B171	Annealed	51 to 127 incl.	2 to 5 incl.	445	65	Alloy 614 (7 Al, 2.5 Fe)
		Annealed	51 and under	2 and under	620	90	Alloy 628 (0.5 Al, 2.5 Fe, 5.5 Ni, 1.25 Mn)
ASTM B111, B395	ASTM B111, B395	Annealed	over 51 to 89 incl.	over 2 to 3.5 incl.	585	85	Aluminum bronze plate
			over 89 to 127 incl.	over 3.5 to 5 incl.	550	80	Alloy 608 (5.8 Al) Al bronze tube
			....	....	340	50	

- b. If welded, the allowable stress values for the annealed condition shall be used.
- c. 102 oxygen free; 104, 105, 107 oxygen free, silver bearing; 120-deoxidized, low phosphorous; 122-deoxidized, high phosphorus; 123-deoxidized, phosphorized, silver bearing; 142-deoxidized, phosphorized, arsenical

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Alloy designation	Minimum tensile strength		Type of base metal	
			MPa	ksi		
<u>Nickel and nickel base alloys</u>						
41	ASTM B160	Annealed	200	375	55	Ni rod, bar (99.0 Ni)
		Hot rolled	200	410	60	Ni rod, bar (99.0 Ni)
	ASTM B161	Annealed	201	340	50	Low C Ni rod, bar (99.0 Ni)
		Hot rolled	201	340	50	Low C Ni rod, bar (99.0 Ni)
		Annealed	200	375	55	Ni pipe, tube (99.0 Ni)
		Str. rel.	200	445	65	Ni pipe, tube (99.0 Ni)
		Annealed	201	340	50	Low C Ni pipe, tube (99.0 Ni)
		Str. rel.	201	410	60	Low C Ni pipe, tube (99.0 Ni)
	ASTM B162	Annealed	200	375	55	Ni plate, sheet, strip (99.0 Ni)
		Hot rolled	200	375	55	Ni plate, sheet, strip (99.0 Ni)
		Annealed	201	340	50	Low C Ni plate, sheet, strip (99.0 Ni)
	ASTM B163	Hot rolled	201	340	50	Low C Ni plate, sheet, strip (99.0 Ni)
		Annealed	200	375	55	Ni condenser tube (99.0 Ni)
		Str. rel.	200	445	65	Ni condenser tube (99.0 Ni)
Annealed		201	340	50	Low C Ni condenser tube (99.0 Ni)	
Str. rel.		201	410	60	Low C Ni condenser tube (99.0 Ni)	
42	ASTM B127	Annealed	400	480	70	Ni-Cu plate, sheet, strip (67 Ni-30 Cu)
		Hot rolled	400	515	75	Ni-Cu plate, sheet, strip (67 Ni-30 Cu)
	ASTM B163	Annealed	400	480	70	Ni-Cu condenser tube (67 Ni-30 Cu)
		Str. rel.	400	585	85	Ni-Cu condenser tube (67 Ni-30 Cu)

42	ASTM B164	Annealed	400	480	70	Ni-Cu rod, bar (67 Ni-30 Cu)
		Hot fin. except hex. 54 mm (2 1/8") & under	400	550	80	Ni-Cu rod, bar (67 Ni-30 Cu)
		Hot fin. hex. over 54 mm (2 1/8")	400	515	75	Ni-Cu rod, bar (67 Ni-30 Cu)
		Str. rel. 102 to 305 mm (4" to 12") diam incl.	400	550	80	Ni-Cu rod, bar (67 Ni-30 Cu)
		Str. rel. 305 mm (12") diam and over	400	515	75	Ni-Cu rod, bar (67 Ni-30 Cu)
		ASTM B165	Annealed	400	480	70	Ni-Cu pipe, tube (67 Ni-30 Cu)
	Str. rel.	400	585	85	Ni-Cu pipe, tube (67 Ni-30 Cu)	
43A	ASTM B163	Annealed	600	550	80	Ni-Cr-Fe condenser tube (72 Ni-15 Cr-8 Fe)
		Annealed	600	550	80	Ni-Cr-Fe rod, bar (72 Ni-15 Cr-8 Fe)
	ASTM B166	Hot fin. 6 to 76 mm (1/4" to 3") incl.	600	620	90	Ni-Cr-Fe rod, bar (72 Ni-15 Cr-8 Fe)
		Hot fin. over 76 mm (3 in.) & hex.	600	585	85	Ni-Cr-Fe rod, bar (72 Ni-15 Cr-8 Fe)
	ASTM B167	Cold drawn annealed	600	550	80	Ni-Cr-Fe pipe, tube (72 Ni-15 Cr-8 Fe)
		Hot fin. 127 mm (5") o.d. & under	600	550	80	Ni-Cr-Fe pipe, tube (72 Ni-15 Cr-8 Fe)
		Hot fin. over 127 mm (5") o.d.	600	515	75	Ni-Cr-Fe pipe, tube (72 Ni-15 Cr-8 Fe)
		Hot fin. ann. 127 mm (5") o.d. & under	600	550	80	Ni-Cr-Fe pipe, tube (72 Ni-15 Cr-8 Fe)
		Hot fin. ann. over 127 mm (5") o.d.	600	515	75	Ni-Cr-Fe pipe, tube (72 Ni-15 Cr-8 Fe)
43B	ASTM B168	Annealed	600	550	80	Ni-Cr-Fe plate, sheet, strip (72 Ni-15 Cr-8 Fe)
		Hot rolled	600	585	85	Ni-Cr-Fe plate, sheet, strip (72 Ni-15 Cr-8 Fe)
		ASTM B443 Ann., Gr. 1	625	825	120	Ni-Cr-Mo-Cb plate, sheet, strip (60 Ni-22 Cr-9 Mo-3.5 Cb)
		Ann., Gr. 2	625	685	100	Ni-Cr-Mo-Cb plate, sheet, strip (60 Ni-22 Cr-9 Mo-3.5 Cb)

Table 2.1 continued—Grouping of base metals for procedure qualification

<u>P no.</u>	<u>Base metal specification</u>	<u>Alloy designation</u>	<u>Minimum tensile strength</u>		<u>Type of base metal</u>
			<u>MPa</u>	<u>ksi</u>	
<u>Nickel and nickel base alloys</u>					
43B	ASTM B444 Ann., Gr. 1	625	825	120	Ni-Cr-Cb pipe, tube (60 Ni-22 Cr-9 Mo-3.5 Cb)
	Ann., Gr. 2	625	685	100	Ni-Cr-Cb pipe, tube (60 Ni-22 Cr-9 Mo-3.5 Cb)
	ASTM B446 Ann., Gr. 1	625	825	120	Ni-Cr-Mo-Cb rod, bar (60 Ni-22 Cr-9 Mo-3.5 Cb)
	Ann., Gr. 2	625	685	100	Ni-Cr-Mo-Cb rod, bar (60 Ni-22 Cr-9 Mo-3.5 Cb)
44	ASTM B333 Annealed under 4.7 mm (3/16")	B	790	115	Ni-Mo plate, sheet (25 Mo-5 Fe)
	Annealed 4.7 to 19 mm (3/16"-3/4") incl.	B	685	100	Ni-Mo plate, sheet (25 Mo-5 Fe)
	Annealed over 19 to 63 mm (3/4"-2 1/2") incl.	B	620	90	Ni-Mo plate, sheet (25 Mo-5 Fe)
	ASTM B334 Annealed under 4.7 mm (3/16")	C	790	115	Ni-Mo-Cr plate, sheet (15.5 Cr-16 Mo-3.5 W)
	Annealed 4.7-19 mm (3/16"-3/4") incl.	C	685	100	Ni-Mo-Cr plate, sheet (15.1 Cr-16 Mo-3.5 W)
	Annealed over 19 to 63 mm (3/4"-2 1/2") incl.	C	620	90	Ni-Mo-Cr plate, sheet (15.5 Cr-16 Mo-3.5 W)

44	ASTM B335 Annealed 7.9-38 mm (5/16-1 1/2") incl.	B	790	115	Ni-Mo rod, bar (28 Mo-5 Fe)
	Annealed over 38-89 mm (1 1/2-3 1/2") incl.	B	685	100	Ni-Mo rod, bar (28 Mo-5 Fe)
	ASTM B336 Annealed 7.9-38 mm (5/16-1 1/2") incl.	C	755	110	Ni-Mo-Cr rod, bar (15.5 Cr-15 Mo-3.5 W)
	Annealed over 38-89 mm (1 1/2-3 1/2") incl.	C	685	100	Ni-Mo-Cr rod, bar (15.5 Cr-16 Mo-3.5 W)
45	ASTM B163 Ann., Gr. 1	800	515	75	Ni-Fe-Cr condenser tube (33 Ni-21 Cr)
	Ann., Gr. 2	800	445	65	Ni-Fe-Cr condenser tube (33 Ni-21 Cr)
	ASTM B407 Ann., Gr. 1	800	515	75	Ni-Fe-Cr pipe, tube (33 Ni-21 Cr)
	Ann., Gr. 2	800	445	65	Ni-Fe-Cr pipe, tube (33 Ni-21 Cr)
	ASTM B408 Ann., Gr. 1	800	515	75	Ni-Fe-Cr rod, bar (33 Ni-21 Cr)
	Ann., Gr. 2	800	445	65	Ni-Fe-Cr rod, bar (33 Ni-21 Cr)
	ASTM B409 Ann., Gr. 1	800	515	75	Ni-Fe-Cr plate, sheet, strip (33 Ni-21 Cr)
	Ann., Gr. 2	800	445	65	Ni-Fe-Cr plate, sheet, strip (33 Ni-21 Cr)
	ASTM B163 Annealed	825	585	85	Ni-Fe-Cr-Mo-Cu condenser tube (42 Ni-21.5 Cr-3 Mo-2.3 Cu)
	ASTM B423 Annealed	825	515	75	Ni-Fe-Cr-Mo-Cu pipe, tube (42 Ni-21.5 Cr-3 Mo-2.3 Cu)
	Annealed	825	585	85	Ni-Fe-Cr-Mo-Cu pipe, tube (42 Ni-21.5 Cr-5 Mo-2.3 Cu)
ASTM B424 Annealed	825	585	85	Ni-Fe-Cr-Mo-Cu plate, sheet, strip (42 Ni-21.5 Cr-4 Mo-2.3 Cu)	

Table 2.1 continued—Grouping of base metals for procedure qualification

P no.	Base metal specification	Minimum tensile strength		Type of base metal	
		MPa	ksi		
<u>Unalloyed titanium</u>					
51	ASTM B265	Grade 1	240	35	Ti strip, sheet, & plate-unalloyed Ti
		Grade 2	340	50	Ti strip, sheet, & plate-unalloyed Ti
	ASTM B337	Grade 1	240	35	Ti seamless & welded pipe-unalloyed Ti
		Grade 2	340	50	Ti seamless & welded pipe-unalloyed Ti
		Grade 7	340	50	Ti seamless & welded pipe-.18 Pd
	ASTM B338	Grade 1	240	35	Ti seamless & welded pipe-unalloyed Ti
		Grade 2	340	50	Ti seamless & welded pipe-unalloyed Ti
		Grade 7	340	50	Ti seamless & welded pipe-.18 Pd
	ASTM B348	Grade 1	240	35	Ti bars & billets-unalloyed Ti
		Grade 2	340	50	Ti bars & billets-unalloyed Ti
ASTM B381	Grade F-1	240	35	Ti forgings-unalloyed Ti	
	Grade F-2	340	50	Ti forgings-unalloyed Ti	
52	ASTM B265	Grade 3	445	65	Ti strip, sheet, & plate-unalloyed Ti
	ASTM B337	Grade 3	445	65	Ti seamless & welded pipe-unalloyed Ti
	ASTM B338	Grade 3	445	65	Ti seamless & welded tube-unalloyed Ti
	ASTM B348	Grade 3	445	65	Ti bars & billets-unalloyed Ti
	ASTM B381	Grade F-3	445	65	Ti forgings-unalloyed Ti

Table 3.1A — F number grouping of ferrous electrodes and welding rods for procedure and performance qualification

Type of weld deposit	Weld metal composition A no.	Electrode grouping F no.	Specification no.	AWS filler metal		
				Classification		
Mild steel	1	1	A5.1 & A5.5	EXX20, EXX24, EXX27, EXX28		
		2	A5.1 & A5.5	EXX12, EXX13, EXX14		
		3	A5.1 & A5.5	EXX10, EXX11		
		4	A5.1 & A5.5	EXX15, EXX16, EXX18		
		7	A5.17 & A5.23	FXX-EXXX		
		8	A5.18	E70S-X, E70U		
		9	A5.20	EXXT-X		
		Carbon-moly	2	1	A5.5	E7020-A1, E7027-A1
				3	A5.5	EXX10-A1, EXX11-A1
4	A5.5			E7015-A1, E7016-A1, E7018-A1		
6	A5.2			RGXX		
7	A5.23			FXX-EXXX-AX		
8	A5.18			E70S-1B		
Chrome (1/2 to 2%)-moly	3	4	A5.5	E80XX-B2, B2L		
		7	A5.23	FXX-EXXX-B1, B2, B4		
Chrome (2 to 6%)-moly	4	4	A5.4	E502		
		4	A5.5	E90XX-B3, B3L		
		7	A5.23	FXX-EXXX-B3, B6		
Chrome (6 to 10%)-moly	5	4	A5.4	E505, E7Cr		
Chrome-martensite	6	4	A5.4	E410		
		9	A5.22	E410T-X		
Chrome-ferritic	7	4	A5.4	E430		
		9	A5.22	E430T-X		
Chromium-nickel	8	5	A5.4	E308, E308L, E309, E309Cb E309Mo, E316, E316L, E317, E318 E347, E349		
		6	A5.9	ER308, ER308L, ER309, ER309Cb ER309Mo, ER316, ER316L, ER317 ER318, ER347, ER349		
		9	A5.22	E308T-X, E308LT-X, E308MoT-X E308MoLT-X, E309T-X, E309LT-X E316T-X, E316LT-X		
Chromium-nickel	9	5	A5.4	E310, E310Cb, E310Mo		
Nickel to 4%	10	4	A5.5	E80XX-CX		
		7	A5.23	FXX-EXXX-NiX		
Manganese-moly	11	4	A5.5	E90XX-D1, E100XX-D2		
		7	A5.23	FXX-EXXX-D1, D2		
Nickel-chrome-moly	12	4	A5.5	EXX18-M		
		7	A5.23	FXX-EXXX-F1, M1, M2, M5		

Table 3.1B—Grouping of ferrous electrodes and welding rods for qualification

<u>F no.</u>	<u>AWS specification no.</u>	<u>AWS classification no.</u>
	<u>Steel and steel alloys</u>	
1	A5.1 & A5.5	EXX20, EXX24, EXX27, EXX28
2	A5.1 & A5.5	EXX12, EXX13, EXX14
3	A5.1 & A5.5	EXX10, EXX11
4	A5.1 & A5.5	EXX15, EXX16, EXX18
4	A5.4 other than Cr-Ni electrode	E X XX-15, E X XX-16
5	A5.4 Cr-Ni electrode	E X XX-15, E X XX-16
6	A5.2	RGXX
6	A5.9	ER X XX
7	A5.17 & A5.23	F X X-E X XX
8	A5.18	E X XS-X, E X XU-X
9	A5.20	E X XT-X
9	A5.22 nom. total alloys 6% or less	E X XT-X
9	A5.22 nom. total alloys more than 6%	E X XT-X

Table 3.1C—Classification of weld metal analysis for procedure qualification

A no.	Types of weld deposit	C %	Cr %	Analysis (1) (2) (3)			Mn %	Si %
				Mo %	Ni %			
1	Mild steel	0.15					1.75	1.00
2	Carbon-moly	0.15		0.40-0.65			1.60	1.00
3	Chrome (1/2 to 2%)-moly	0.15	0.40- 2.00	0.40-0.65			1.50	1.00
4	Chrome (2 to 6%)-moly	0.15	2.00- 6.00	0.40-1.50			1.00	
5	Chrome (6 to 10%)-moly	0.15	6.00-10.50	0.40-1.50			1.50	1.00
6	Chrome-martensitic	0.15	11.00-15.00	0.70			2.00	1.00
7	Chrome-ferritic	0.15	11.00-30.00	1.00			1.00	3.00
8	Chromium-nickel	0.15	14.50-32.00	4.00		7.50-15.00	2.50	1.00
9	Chromium-nickel	0.30	25.00-28.00	4.00		20.00-25.00	2.50	1.00
10	Nickel to 4%	0.15				0.50- 4.00	1.50	1.00
11	Manganese-moly	0.15		0.25-0.75			2.25	1.00
12	Nickel-chrome-moly	0.15	1.50	0.80		2.50	2.50	1.00

Notes:

1. Where no values are shown, the maximum allowed analysis shall be 0.5% each element.
2. Single values shown are maximum.
3. Weld deposits having analysis outside the above range shall require separate qualification.

Table 3.1D—Grouping of nonferrous electrodes and welding rods for qualification

<u>F no.</u>	<u>AWS specification no.</u>	<u>AWS classification no.</u>		
		<u>E</u>	<u>R</u>	<u>ER</u>
<u>Aluminum and aluminum alloys</u>				
F -21	A5.3 & A5.10			ER1260 ER1100, A1-2
F -22				ER5183 ER5356 ER5556 ER5554 ER5654
F -23				ER4043 ER4047 ER4145
F -24			RSC51A RSG70A	
<u>Copper and copper base alloys</u>				
F -31	A5.6 & A5.7	ECu	RCu	
F -32		ECuSi	RCuSi-A	
F -33		ECuSn-A ECuSn	RCuSn-A	
F -34		ECuNi	RCuNi	

<u>F no.</u>	<u>AWS specification no.</u>	<u>AWS classification no.</u>		
		<u>E</u>	<u>R</u>	<u>ER</u>
F -35			RCuZn-A RCuZn-C	
F -36		ECuA1-A1 ECuA1-A2 ECuA1-B	RCuA1-A2 RCuA1-B	
<u>Nickel and nickel base alloys</u>				
F -41	A5.11 & A5.14	ENi-1	RNi-2	ERNi-3
F -42		ENiCu-4 ENiCu-1 ENiCu-2 ENiCuA1-1	RNiCu-5 RNiCu-6	ERNiCu-7
F -43		ENiCrFe-1 ENiCr-1 ENiCrFe-2 ENiCrFe-3	RNiCrFe-4	ERNiCrFe-5 ERNiCr-2 ERNiCr-3 ERNiCrFe-6 ERNiCrFe-7
F -44		ENiMo-1 ENiMo-3		ERNiMo-4 ERNiMo-5 ERNiMo-6
<u>Unalloyed titanium</u>				
F -51	A5.16			ERTi-1 ERTi-2 ERTi-3 ERTi-4

**Table 4.3.2.1 — Type and number of test specimens required for groove welds—
procedure qualification**

<u>Thickness, T, of test material, mm (in.)</u>	<u>Reduced- section tension</u>	<u>Side bend</u>	<u>Face bend</u>	<u>Root bend</u>	<u>Visual</u>
9.5 mm (3/8") and less	2	0	2	2	Yes
Over 9.5 mm (3/8"), but less than 19 mm (3/4")	2	(Note 1)	2	2	Yes
19 mm (3/4") and over	2(Note 2)	4	0	0	Yes

Notes:

1. Four side-bend tests may be substituted for the required face and root-bend tests.
 2. Specimens of full plate thickness shall be used for thickness up to and including 25 mm (1 in.).
 3. For plate thicknesses greater than 25 mm (1 in.), single or multiple specimens may be used, provided (4) and (5) are complied with.
 4. When multiple specimens are used, each set shall represent a single required tension test. Collectively, all of the specimens required to represent the full thickness of the weld at one location shall comprise a set.
 5. When multiple specimens are necessary, the entire thickness shall be mechanically cut into a minimum number of approximately equal strips of a size that can be tested in the available equipment.
- a. For cast iron, see Fig. 4.3.2.1F

Table 5.2A — Welder performance qualification — type and position limitations

Qualification test	Type of weld and position of welding qualified ^a				
	Test Positions ^b	Plate sheet		Pipe	
		Groove	Fillet	Groove	Fillet
Plate/sheet-groove	1G	F	F, H	F	F, H
	2G	F, H	F, H	F, H	F, H
	3G	F, H, V	F, H, V		
	4G	F, OH	F, H, OH		
	3G & 4G	All	All		
Plate/sheet-fillet	1F		F		F
	2F		F, H		F, H
	3F		F, H, V		
	4F		F, H, OH		
	3F & 4F		All		
Pipe-groove	1G	F	F, H	F	F, H
	2G	F, H	F, H	F, H	F, H
	5G	F, V, OH	F, V, OH	F, V, OH	F, V, OH
	6G	(Note 1)	(Note 1)	(Note 1)	(Note 1)
	2G & 5G	(Note 1)	(Note 1)	(Note 1)	(Note 1)
	6GR	All	All	All	All

Note:

1. Qualifies for all but groove welds for T-, Y-, and K-connections.

a. Positions of welding: F=flat, H=horizontal, V=vertical, OH=overhead.

b. Figs. 4.1.1.1, 4.1.1.2, and 4.1.2.1.

**Table 5.2B— Number and type of specimens and range of thickness qualification—
welder qualification**

<u>Type of weld</u>	<u>Thickness, t, of test plate or pipe as welded</u>		<u>Pipe or tube size qualified</u>	
	<u>mm</u>	<u>in.</u>	<u>mm</u>	<u>in.</u>
Groove	Under 1.59	Under 0.063		
Groove	1.59 - 4.57	0.063 - 0.180		
Fillet	2.66 and under See Fig. 5.4.1D	0.105 and under		
Groove	4.6 - 9.5	0.18 - 0.38		
Groove	25 and over	1 and over		
Fillet	See Fig. 5.4.1C ¹			
Fillet	See Fig. 5.4.1B ²			
Groove	51 mm Sch.80 or 76 mm Sch.40	2 in. Sch.80 or 3 in. Sch.40	Thru 102	Thru 4
Groove	152 mm Sch.80 or 203 mm Sch.120	6 in. Sch.80 or 8 in. Sch.120	102 and over	4 and over
Groove	See Fig. 5.4.1E		T, K, and Y connections	

Plate, pipe, or tube wall thickness qualified				Visual inspection	Bend tests Number of specimens						Fillet weld break	Macro- etch test
					All positions except 5G & 6G			5G & 6G positions Positions only				
min.		max.			Face	Root	Side	Face	Root	Side		
mm	in.	mm	in.									
Sheet metal tests												
0.75t	0.75t	2t	2t	Yes	1	1						
0.5t	0.5t	2t	2t	Yes	1	1						
t	t	2.66	0.105	Yes								2
Plate tests												
0.5t	0.5t	2t	2t	Yes	1	1						
		Unlimited ³		Yes			2					
0.5t	0.5t	2t	2t	Yes							1	1
0.5t	0.5t	2t	2t	Yes		2						
Pipe tests ⁴												
1.60	0.063	17.12	0.674	Yes	1	1		2	2			
4.75	0.187	Unlimited		Yes			2				4	
		Unlimited		Yes							4	

Notes:

1. Option No. 1
2. Option No. 2
3. Also qualifies for welding fillet welds on material of unlimited thickness.
4. Testing options for qualification with job size pipe:
 - a. In tubular products, both the diameter and wall thickness are variables in the welding. A concerted effort has been made to carefully select representative pipe sizes (for sample welds in the qualification tables) to take into account the effect of pipe or tube diameter and wall thickness. For sizes outside the ranges qualified by the sample welds, such as heavy wall, small diameter tube, individual tests should be performed as appropriate.
 - b. It is also recognized that cases will arise in fabrication where specific pipe sizes will be involved which do not include the sample weld sizes. In such instances, actual job size pipe may be substituted. For pipe wall less than 19 mm (3/4 in.), the qualification is limited to thicknesses between one-half and two times the wall thickness of the test pipe, but not more than 19 mm (3/4 in.). For job size pipe having a wall thickness over 19 mm (3/4 in.), the qualification limits shown in the tables may be used.

Appendix A

Sample Welding Forms

This appendix contains three sample forms that the AWS Committee on Qualification has suggested for the recording of procedure specifications, procedure qualification tests and welder qualification tests.

Typical welding procedure specification

Company name _____

Welding Procedure Specification no. _____

Rev no. _____

Date _____

Meets the requirements of AWS standard B3 and _____
(insert other codes)

Title:

Welding procedure for _____ Welding of
(manual, semiautomatic, automatic) (welding process or combination of processes)

_____ (base material name)

Scope:

This procedure is applicable for _____ within the base material thickness range of _____ mm (_____ in.)
(groove or fillet welds)
through _____ mm (_____ in). Welding may be performed in _____ positions. Procedure qualification was done in
_____ position(s).
(1G,2G,etc.)

Base material:

The base material shall conform to _____ (P no. _____ to P no. _____).
(ASTM – ASME specification no.)

Information on backing strips or bars (other than consumable insert type) shall be given here.

Filler metal:

The filler metal shall conform to _____
(AWS – ASME specification no.) (type)

The classification no. is [F– _____. The consumable inserts shall conform to _____
(AWS – ASME specification no.) (type)

Describe any special storage or drying requirements. If a nonconsumable electrode is used, give specification and classification numbers and end preparation (sketch).

Shielding gas:

The shielding gas shall be _____ flowing at the rate of _____ L/min (_____ CFH).
(gas or gases) (grade) (composition) (purity)

The torch nozzle or cup size is _____ mm (_____ in.).

Information on back purge or trailing shielding gas (type, flow rate, etc.) shall be given here.

Flux for submerged arc:

The flux-electrode combination shall conform to _____
(AWS – ASME specification no.) (classification no.)

_____ (manufacturer's trade name)

Flux storage, etc., shall be described here.

Weld metal analysis:

The weld metal analysis number is A-_____.

If no A No. is found in Table 3.1C, list the principal alloying elements and the values.

Joint design and tolerances:

Sketch No. _____ substantially shows weld end preparation and fit-up.

(Show details such as the groove angle, the root opening, the root and face dimensions, the type of backing, the maximum mismatch permitted, the tolerance of each dimension, and any changes in the joint design based on changes in base metal thickness.)

Preparation of base metal:

The edges of parts to be joined shall be prepared by _____.

(State whether machined, ground, oxygen cut, etc.) State cleaning methods to remove foreign materials from the mating and adjoining surfaces prior to welding (such as solvent, cleaning, degreasing, etc.)

Joint alignment shall be maintained by _____.

(State which means are used such as jigs, fixtures, tack welds, etc.) If tack welds are used, describe the welding process and filler metal used (performed in accordance with a qualified welding procedure specification). State whether the tack welds are to be ground smooth with feathered edges or to be ground out entirely as welding progresses; state the number and the location of tack welds.

Power source and electrical characteristics:

A _____ type _____ power source furnishing
(constant current, constant voltage) (transformer, transformer-rectifier, motor-generator)

_____ current shall be used.

(alternating or direct)

The base metal shall be on the _____ side of the circuit, corresponding to _____ polarity.
(positive or negative) (reverse or straight)

Preheat:

When preheating is required, state methods of heating, minimum preheat temperature, and the equipment required to measure the temperature. If no preheating is used, state none.

Welding technique:

Fully describe the welding technique to be used including all the essential variables from Section 4 and such nonessential variables deemed relevant.

Interpass temperature:

Describe any interpass requirements and, if applicable, the requirements for interruption of welding and preheating prior to rewelding.

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Cleaning and repair of rejectable defects:

State the type and extent of cleaning (grinding, chipping, arc gouging, etc.) required between passes and at the completion of welding to control the weld contour and to remove surface defects. If double-groove welds are used, the method of preparing the underside of the weld shall be described. Describe any peening operations if applicable. Specify the appearance and maximum reinforcement of the cover pass. Provide information on repair as follows: List the method of removing any defects (mechanical, thermal means, or both), the procedure to be followed for rewelding (in accordance with a qualified welding procedure specification) and inspection methods.

In-process and final inspection:

Describe the in-process and final NDE procedures and the standards (for acceptance criteria) used to detect and evaluate the original weld and repairs.

Postheating:

This paragraph shall cover any heat treatment after welding. Include the type of heating, minimum width of heating requirements, temperature, time at temperature, method of measuring the temperature, range of differential heating allowed and the cooling rate.

Weld identification, marking or stamping:

Tell how joints are to be marked or recorded to establish the identity of each welder.

Sketches:

Include sketches furnishing information on joint fit-up and welding technique.

Joint Design	Welding technique	Nonconsumable electrode end preparation
--------------	-------------------	---

Sketch no. _____

Sketch no. _____

Sketch no. _____

Signed _____

(company name)

Date: _____

By _____

Typical welding procedure qualification

Company name _____

Manufacturer's record of procedure qualification test

Welding procedure specification no. _____ Rev. no. _____ Test date _____

Welding process(es): Manual/semiautomatic/automatic _____ welding

Base material thickness: _____ to _____ (P no. _____ to P no. _____)

Test material thickness: _____ Test pipe diameter _____ Wall thickness _____

Test position: _____ Backing strip material specification: _____ (P no. _____)

Type of power source: _____

Filler metal specification no. _____ Classification no. _____ (F no. _____)

Consumable insert specification no. _____ Classification no. _____ (F no. _____)

Nonconsumable electrode specification no. _____ Classification no. _____

(See sketch no. _____ for end preparation) Weld metal analysis No. A- _____

Type of weld: _____ Type of joint _____

Base metal preparation: _____

Precleaning: _____

Tack welds, jigs, fixtures: _____

Preheat temperature: _____ Interpass temperature: _____

Method of arc initiation: _____

Cleaning during welding: _____

Method of preparing the underside of weld: _____

Inspection prior to welding: _____

Inspection during welding: _____

Inspection after welding: _____

Postheating: _____

Sketches:

Joint design	Welding Technique	Nonconsumable electrode end preparation
--------------	-------------------	---

Submerged arc

Pass no.	Filler metal		Flux*	A		V	ac or dc	Travel speed	Holder angle to work
	Size	Type							

*Flux specification no., classification no., manufacturer's trade name:

Other processes or combinations

Pass no.

Inspection: _____

Visual inspection results _____

Liquid penetrant or magnetic particle results _____

Radiographic results

Radiograph no.	Results	Radiograph no.	Results
----------------	---------	----------------	---------

Tensile test:

Specimen no.	Dimensions		Area	Ultimate load, N (lb.)	Tensile strength, MPa (psi)	Fracture location
	Width	Thickness				

Guided-bend tests:

Type	Results	Type	Results
------	---------	------	---------

Special tests _____

Welder's name _____ Clock no. _____ Stamp: _____

Test conducted by _____ Test approved _____

Test witnessed by _____ Lab. test no. _____ Date _____

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of AWS Standard B3.0-_____

Signed _____
(company name)

Date _____

By _____

Typical welder qualification test record

Company name _____

Manufacturer's record of welder or welding operator
qualification tests

This form or its equivalent shall be used in conjunction with the:

Welding procedure specification no. _____ Rev. no. _____
 Welder's name: _____ Clock no. _____ Stamp _____
 Welding process(es): Manual/semiautomatic/automatic _____ welding
 Base metal specification _____ to _____ (P no. _____ to P no. _____)
 Backing strip material specification _____ P no. _____
 Test material thickness _____ Test pipe diam. _____ Wall thickness _____
 Thickness range qualified _____ Diam. range qualified _____
 Filler metal specification no. _____ Classification no. _____ F no. _____ Size _____
 Consumable insert specification no. _____ Classification no. _____ F no. _____
 Electrical characteristics: Current _____ Polarity _____ Volts _____
 Test position _____ Direction of welding _____
 Shielding gas or gases _____ Flow rate _____ L/min (ft³/h)
 Trailing/Backing Shielding Gas or Gases _____ Flow rate _____ L/min (ft³/h)
 Visual inspection results _____
 Radiographic test results _____
 Other tests _____

Guided-bend tests

Type	Results	Type	Results

Special tests _____

Test conducted by _____ Test approved _____
 Test witnessed by _____ Lab. test no. _____ Date _____

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of AWS Standard B3.0-_____

Signed _____
 (company name)

Date _____

By _____

Appendix B

Porosity Charts for Welder Qualification Tests

A1 Acceptance Standards for Radiographically Determined Porosity and Tungsten Inclusions in Welds

A1.1 These figures are applicable to ferritic, austenitic, and nonferrous welds, and any applicable combinations.

A1.2 Dark images of a generally circular or oval shape shall be interpreted as porosity. Light images of a generally circular nature shall be interpreted as tungsten inclusions in gas tungsten arc welds. For simplicity, porosity and tungsten inclusions are called "pores" in the figures and the combined indications shall not exceed the number and size shown in the figures.

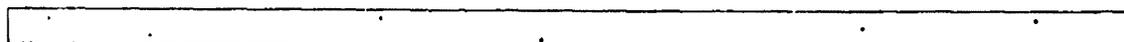
A1.3 The porosity figures in this appendix illustrate various types of assorted and uniform, randomly dispersed porosity indications. These figures for each thickness represent the maximum acceptable porosity. The figures represent full scale six inch radiographs, and shall not be enlarged or reduced. The porosity distributions shown are not necessarily the patterns that may appear on the radiographs, but are typical of the number and size of indications permitted. When porosity indications differ significantly from the porosity figures, the actual numbers and sizes of the pores may be measured and the total area of porosity calculated.

A1.4 Permissible porosity indications for weld thickness intermediate to those illustrated may be evaluated by comparison with the next thinner material.

A1.5 The total area of porosity as determined from the radiographic film shall not exceed $1.52 T \text{ mm}^2$ ($0.060 T \text{ in.}^2$) in any 152 mm (6 in.) length of weld, where T is the thickness of the weld. If the weld is less than 152 mm (6 in.) long, the total area of porosity will be reduced in proportion. The maximum pore dimension shall be 20 percent of T , or 3 mm ($1/8 \text{ in.}$), whichever is smaller, except that an isolated pore separated from an adjacent pore by 25 mm (1 in.) or more may be 30 percent of T , or 6 mm ($1/4 \text{ in.}$), whichever is less.

A1.6 In any 25 mm length of weld or $2 T$ (1 in. length of weld or $2 T$), whichever is smaller, porosity may be clustered to a concentration four times that permitted by $1.52 T \text{ mm}^2$ ($0.06 T \text{ in.}^2$). Such clustered porosity shall be included in the porosity in any 152 mm (6 in.) length of weld which includes the cluster.

A1.7 Aligned porosity shall be acceptable providing the summation of the diameters of the pores is no more than T in a length $12 T$, or 152 mm (6 in.), whichever is less, providing each pore is separated by a distance at least six times the diameter of the largest adjacent pore. Aligned porosity indications shall be counted in the total area of permissible indications in any 152 mm (6 in.) length of weld.



Pores shown are approximately 0.4 mm ($1/64 \text{ in.}$) in diameter.

Number of pores shown = 6

Notes:

The diameter of any pore shall not exceed 20% of the thickness.

No two pores shall be closer than 3 mm ($1/8 \text{ in.}$).

Fig. A1—Number and size of pores in welds less than 3 mm ($1/8 \text{ in.}$) thick



Pores shown are approximately 0.8 mm ($1/32 \text{ in.}$) in diameter.

Number of pores shown = 10

Fig. A2—Number and size of pores in welds from 3 mm ($1/8 \text{ in.}$) through 6 mm ($1/4 \text{ in.}$) thick

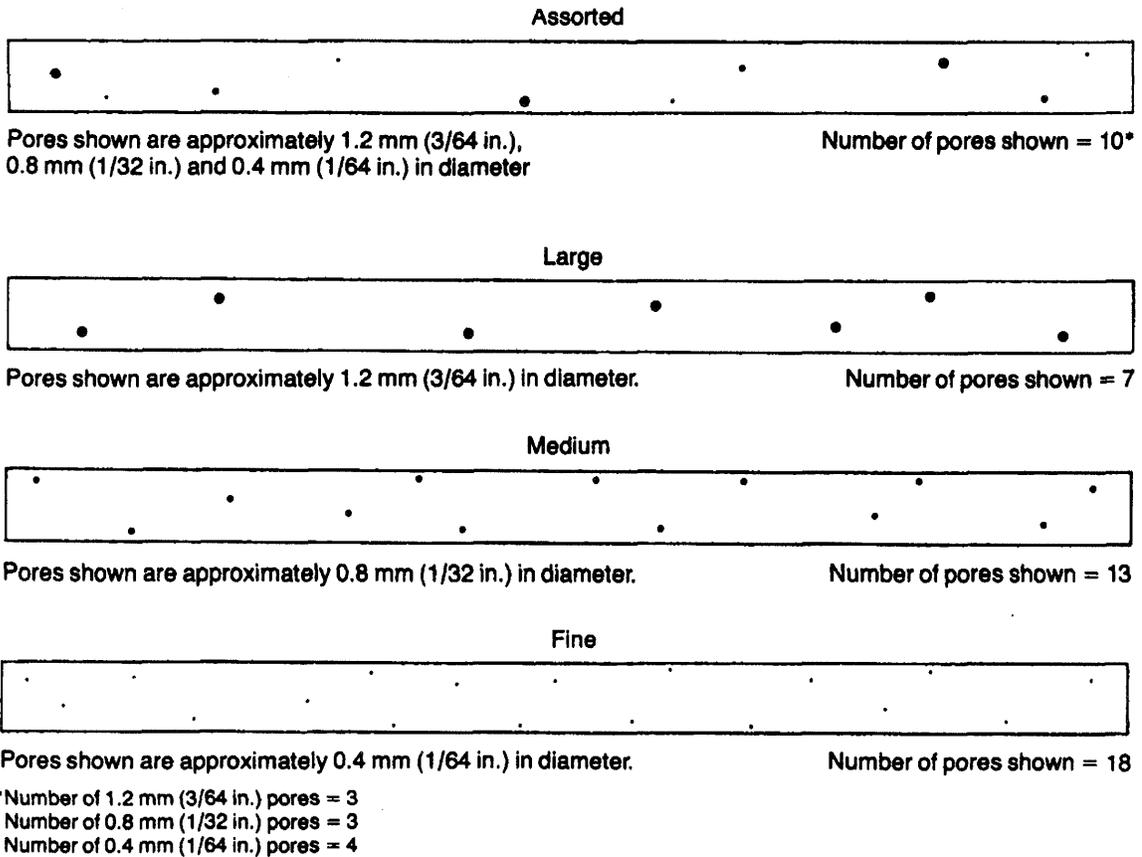
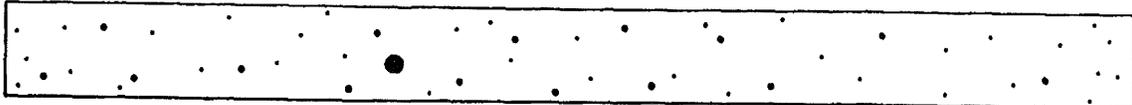


Fig. A3—Number and size of pores in welds over 6 mm (1/4 in.) to 13 mm (1/2 in.) thick

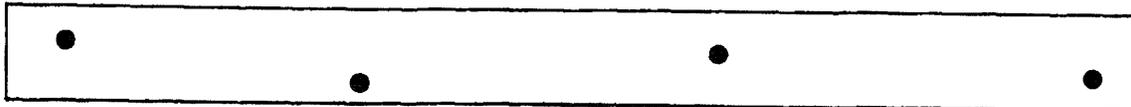
Assorted



Pores shown are approximately 2.4 mm (3/32 in.),
0.8 mm (1/32 in.) and 0.6 mm (3/128 in.) in diameter.
Total area of permitted porosity = 19 mm² (0.030 sq. in.)

Number of pores shown = 51*

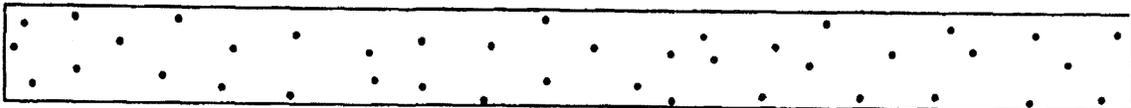
Large



Pores shown are approximately 2.4 mm (3/32 in.) in diameter.
Total area of permitted porosity = 19 mm² (0.030 sq. in.)

Number of pores shown = 4

Medium



Pores shown are approximately 0.8 mm (1/32 in.) in diameter.
Total area of permitted porosity = 19 mm² (0.030 sq. in.)

Number of pores shown = 40

Fine



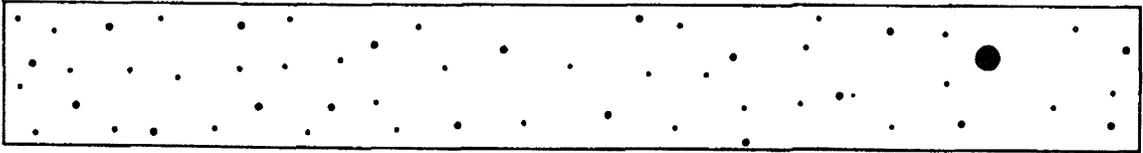
Pores shown are approximately 0.6 mm (3/128 in.) in diameter.
Total area of permitted porosity = 19 mm² (0.030 sq. in.)

Number of pores shown = 101

*Number of 2.4 mm (3/32 in.) pores = 1
Number of 0.8 mm (1/32 in.) pores = 15
Number of 0.6 mm (3/128 in.) pores = 35

Fig. A4—Number and size of pores in welds 12.7 mm (1/2 in.) thick

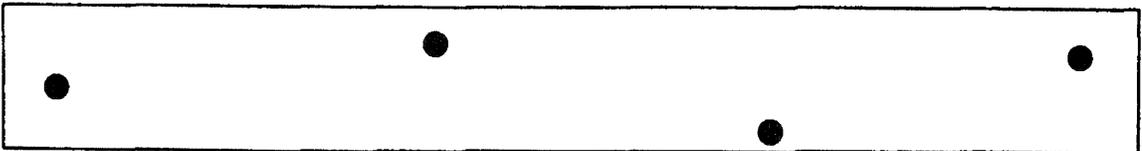
Assorted



Pores shown are approximately 3.2 mm (1/8 in.),
1.6 mm (1/16 in.) and 1.2 mm (3/64 in.) in diameter.
Total area of permitted porosity = 29 mm² (0.045 sq. in.)

Number of pores shown = 55*

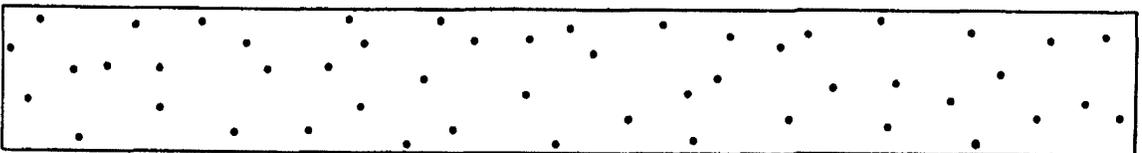
Large



Pores shown are approximately 3.2 mm (1/8 in.) in diameter.
Total area of permitted porosity = 29 mm² (0.045 sq. in.)

Number of pores shown = 4

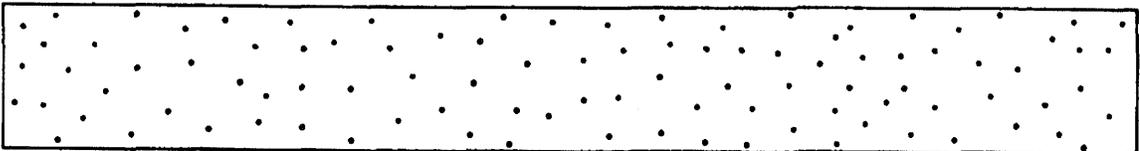
Medium



Pores shown are approximately 1.6 mm (1/16 in.) in diameter.
Total area of permitted porosity = 29 mm² (0.045 sq. in.)

Number of pores shown = 50

Fine



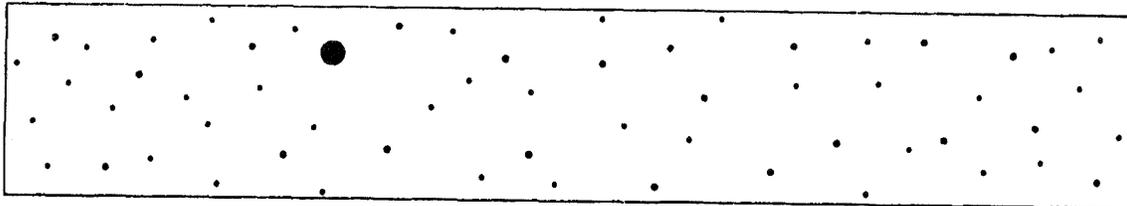
Pores shown are approximately 1.2 mm (3/64 in.) in diameter.
Total area of permitted porosity = 29 mm² (0.045 sq. in.)

Number of pores shown = 99

*Number of 3.2 mm (1/8 in.) pores = 1
Number of 1.6 mm (1/16 in.) pores = 19
Number of 1.2 mm (3/64 in.) pores = 35

Fig. A5—Number and size of pores in welds 19 mm (3/4 in.) thick

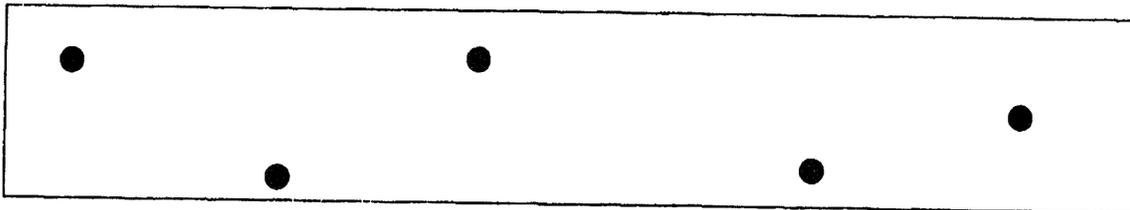
Assorted



Pores shown are approximately 3 mm (1/8 in.),
1 mm (5/128 in.) and 0.8 mm (1/32 in.) in diameter.
Total area of permitted porosity = 39 mm² (0.060 sq. in.)

Number of pores shown = 60*

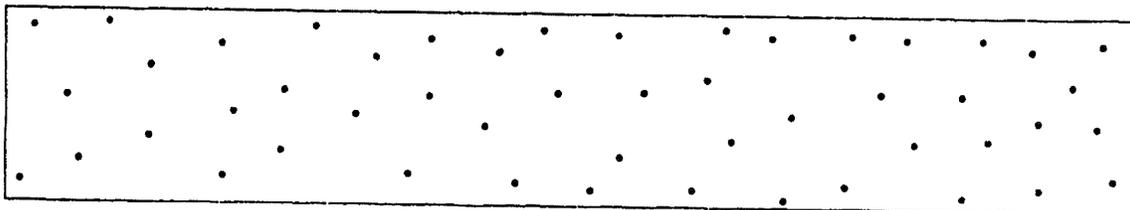
Large



Pores shown are approximately 3 mm (1/8 in.) in diameter.
Total area of permitted porosity = 39 mm² (0.060 sq. in.)

Number of pores shown = 5

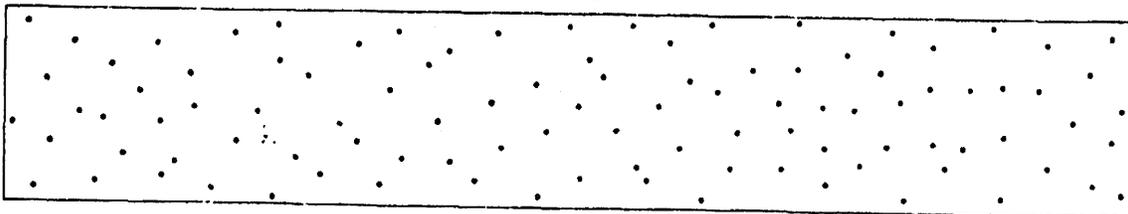
Medium



Pores shown are approximately 1 mm (5/128 in.) in diameter.
Total area of permitted porosity = 39 mm² (0.060 sq. in.)

Number of pores shown = 50

Fine

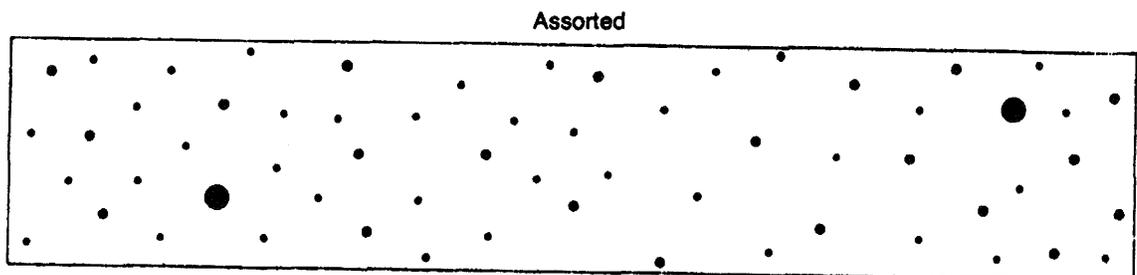


Pores shown are approximately 0.8 mm (1/32 in.) in diameter.
Total area of permitted porosity = 39 mm² (0.060 sq. in.)

Number of pores shown = 101

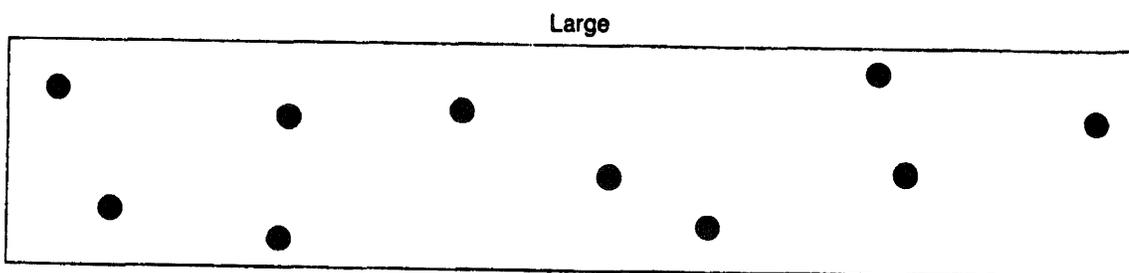
*Number of 3 mm (1/8 in.) pores shown = 1
Number of 1 mm (5/128 in.) pores shown = 21
Number of 0.8 mm (1/32 in.) pores shown = 38

Fig. A6—Number and size of pores in welds 25.4 mm (1 in.) thick



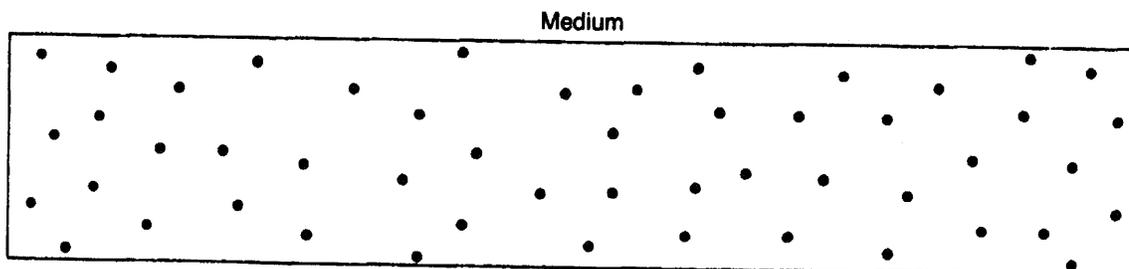
Pores shown are approximately 3 mm (1/8 in.),
1.4 mm (7/128 in.) and 1 mm (5/128 in.) in diameter.
Total area of permitted porosity = 77 mm² (0.120 sq. in.)

Number of pores shown = 61*



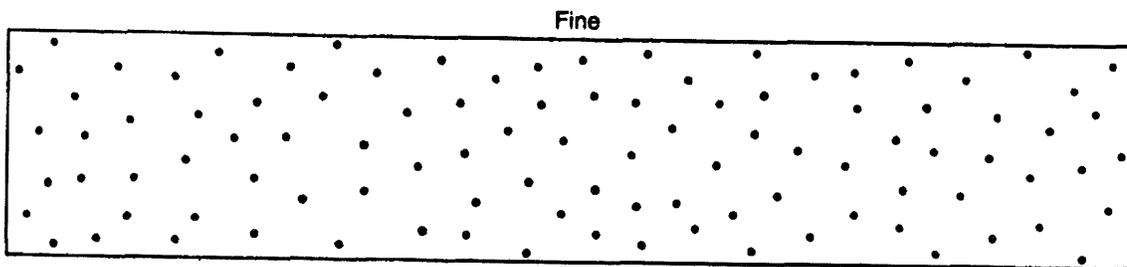
Pores shown are approximately 3 mm (1/8 in.) in diameter.
Total area of permitted porosity = 77 mm² (0.120 sq. in.)

Number of pores shown = 10



Pores shown are approximately 1.4 mm (7/128 in.) in diameter.
Total area of permitted porosity = 77 mm² (0.120 sq. in.)

Number of pores shown = 51

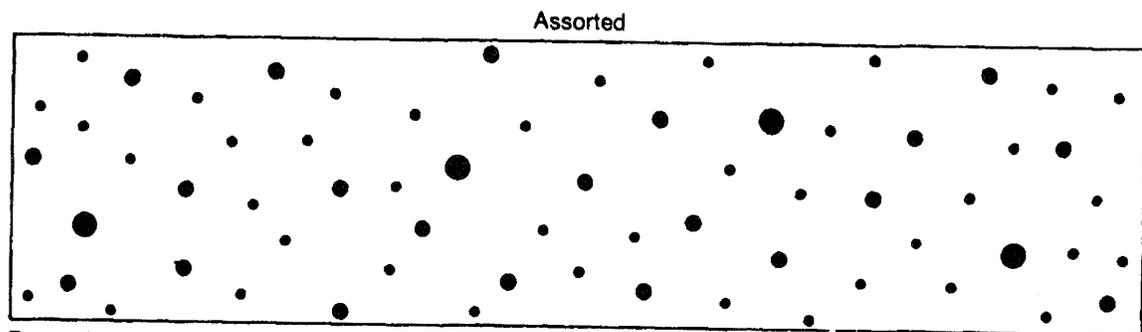


Pores shown are approximately 1 mm (5/128 in.) in diameter.
Total area of permitted porosity = 77 mm² (0.120 sq. in.)

Number of pores shown = 100

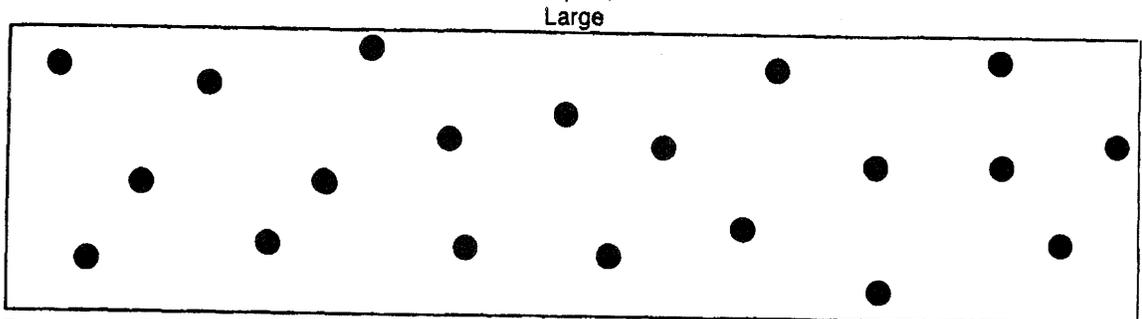
*Number of 3 mm (1/8 in.) pores = 2
Number of 1.4 mm (7/128 in.) pores = 21
Number of 1 mm (5/128 in.) pores = 38

Fig. A7—Number and size of pores in welds 51 mm (2 in.) thick



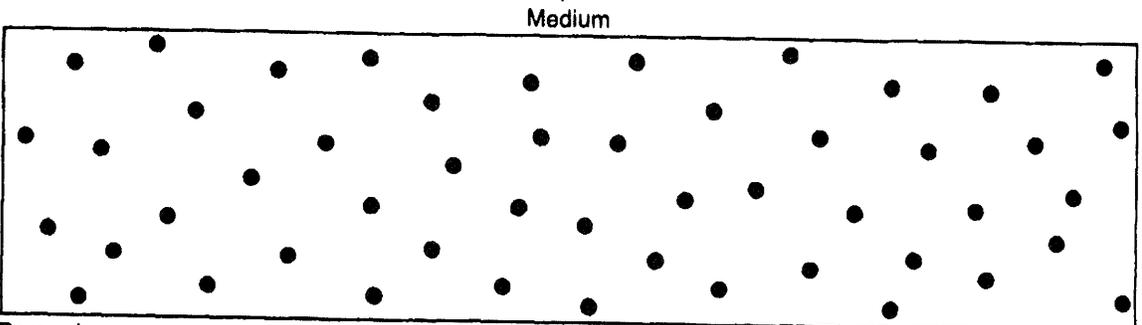
Pores shown are approximately 3 mm (1/8 in.),
2 mm (5/64 in.) and 1.4 mm (7/128 in.) in diameter.
Total area of permitted porosity = 155 mm² (0.240 sq. in.)

Number of pores shown = 65*



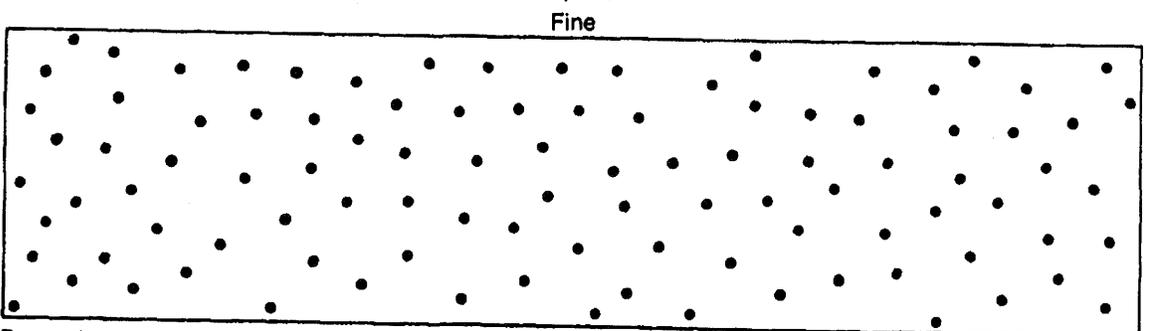
Pores shown are approximately 3 mm (1/8 in.) in diameter.
Total area of permitted porosity = 155 mm² (0.240 sq. in.)

Number of pores shown = 20



Pores shown are approximately 2 mm (5/64 in.) in diameter.
Total area of permitted porosity = 155 mm² (0.240 sq. in.)

Number of pores shown = 50



Pores shown are approximately 1.4 mm (7/128 in.) in diameter.
Total area of permitted porosity = 155 mm² (0.240 sq. in.)

Number of pores shown = 101

*Number of 3 mm (1/8 in.) pores shown = 4
Number of 2 mm (5/64 in.) pores shown = 21
Number of 1.4 mm (7/128 in.) pores shown = 40

Fig. A8—Number and size of pores in welds 3 mm thick

