2001 ASME BOILER & PRESSURE VESSEL CODE

AN INTERNATIONAL CODE



IX

WELDING AND BRAZING QUALIFICATION

The American Society of Mechanical Engineers

ASME BOILER AND PRESSURE VESSEL CODE
AN INTERNATIONAL CODE



QUALIFICATION STANDARD FOR WELDING AND BRAZING PROCEDURES, WELDERS, BRAZERS, AND WELDING AND BRAZING OPERATORS

2001 Edition
July 1, 2001

ASME BOILER AND PRESSURE VESSEL COMMITTEE SUBCOMMITTEE ON WELDING

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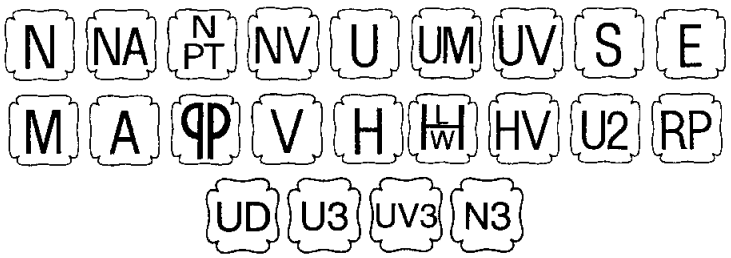
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2001 ASME
BOILER AND PRESSURE VESSEL CODE

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ADDENDA

Colored-sheet Addenda, which include additions and revisions to individual Sections of the Code, are published annually and will be sent automatically to purchasers of the applicable Sections up to the publication of the 2004 Code. The 2001 Code is available only in the loose-leaf format; accordingly, the Addenda will be issued in the loose-leaf, replacement-page format.

INTERPRETATIONS

ASME issues written replies to inquiries concerning interpretation of technical aspects of the Code. The Interpretations for each individual Section will be published separately and will be included as part of the update service to that Section. They will be issued semiannually (July and December) up to the publication of the 2004 Code. Interpretations of Section III, Divisions 1 and 2, will be included with the update service to Subsection NCA.

CODE CASES

The Boiler and Pressure Vessel Committee meets regularly to consider proposed additions and revisions to the Code and to formulate Cases to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing Code rules. Those Cases which have been adopted will appear in the appropriate 2001 Code Cases book: (1) Boilers and Pressure Vessels and (2) Nuclear Components. Supplements will be sent automatically to the purchasers of the Code Cases books up to the publication of the 2004 Code.

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FOREWORD

The American Society of Mechanical Engineers set up a committee in 1911 for the purpose of formulating standard rules for the construction of steam boilers and other pressure vessels. This committee is now called the Boiler and Pressure Vessel Committee.

The Committee's function is to establish rules of safety governing the design, fabrication, and inspection during construction of boilers and pressure vessels, and to interpret these rules when questions arise regarding their intent. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of pressure vessels. The objective of the rules is to afford reasonably certain protection of life and property and to provide a margin for deterioration in service so as to give a reasonably long, safe period of usefulness. Advancements in design and material and the evidence of experience have been recognized.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction[1] activities. The Code does not address all aspects of these activities and those aspects which are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable designers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code neither requires nor prohibits the use of computers for the design or analysis of components constructed to the requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and they are responsible for the application of these programs to their design.

The Code does not fully address tolerances. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters are considered nominal and allowable tolerances or local variances may be considered acceptable when based on engineering judgment and standard practices as determined by the designer.

The Boiler and Pressure Vessel Committee deals with the care and inspection of boilers and pressure vessels in service only to the extent of providing suggested rules of good practice as an aid to owners and their inspectors.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Boiler and Pressure Vessel Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code Cases, and requests for interpretations. Only the Boiler and Pressure Vessel Committee has the authority to provide official interpretations of this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Mandatory Appendix covering preparation of technical inquiries). Proposed revisions to the Code resulting from inquiries will be presented to the Main Committee for appropriate action. The action of the Main Committee becomes effective only after confirmation by letter ballot of the Committee and approval by ASME.

Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute and published in *Mechanical Engineering* to invite comments from all interested persons. After the allotted time for public review and final

[1] *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and pressure relief.

approval by ASME, revisions are published annually in Addenda to the Code.

Code Cases may be used in the construction of components to be stamped with the ASME Code symbol beginning with the date of their approval by ASME.

After Code revisions are approved by ASME, they may be used beginning with the date of issuance shown on the Addenda. Revisions, except for revisions to material specifications in Section II, Parts A and B, become mandatory 6 months after such date of issuance, except for boilers or pressure vessels contracted for prior to the end of the 6 month period. Revisions to material specifications are originated by the American Society for Testing and Materials (ASTM), and other recognized national or international organizations and are usually adopted by ASME. However, those revisions may or may not have any effect on the suitability of material, produced to earlier editions of specifications, for use in ASME construction. ASME material specifications approved for use in each construction Code are listed in the Appendices of Section II, Parts A and B. These Appendices list, for each specification, the latest edition adopted by ASME, and earlier and later editions considered by ASME to be identical for ASME construction.

Manufacturers and users of components are cautioned against making use of revisions and Cases that are less restrictive than former requirements without having assurance that they have been accepted by the proper authorities in the jurisdiction where the component is to be installed.

Each state and municipality in the United States and each province in Canada that adopts or accepts one or more Sections of the Boiler and Pressure Vessel Code is invited to appoint a representative to act on the Conference Committee to the Boiler and Pressure Vessel Committee. Since the members of the Conference Committee are in active contact with the administration and enforcement of the rules, the requirements for inspection in this Code correspond with those in effect in their respective jurisdictions. The required qualifications for an Authorized Inspector under these rules may be obtained from the administrative authority of any state, municipality, or province which has adopted these rules.

The Boiler and Pressure Vessel Committee in the formulation of its rules and in the establishment of maximum design and operating pressures considers materials, construction, methods of fabrication, inspection, and safety devices. Permission may be granted to regulatory bodies and organizations publishing safety standards to use a complete Section of the Code by reference. If usage of a Section, such as Section IX, involves exceptions, omissions, or changes in provisions, the intent of the Code might not be attained.

Where a state or other regulatory body, in the printing of any Section of the Boiler and Pressure Vessel Code, makes additions or omissions, it is recommended that such changes be clearly indicated.

The National Board of Boiler and Pressure Vessel Inspectors is composed of chief inspectors of states and municipalities in the United States and of provinces in Canada that have adopted the Boiler and Pressure Vessel Code. This Board, since its organization in 1919, has functioned to uniformly administer and enforce the rules of the Boiler and Pressure Vessel Code. The cooperation of that organization with the Boiler and Pressure Vessel Committee has been extremely helpful.

The Code Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The Scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules. Laws or regulations issued by municipality, state, provincial, federal, or other enforcement or regulatory bodies having jurisdiction at the location of an installation establish the mandatory applicability of the Code rules, in whole or in part, within their jurisdiction. Those laws or regulations may require the use of this Code for vessels or components not considered to be within its Scope or may establish additions or deletions in that Scope. Accordingly, inquiries regarding such laws or regulations are to be directed to the issuing enforcement or regulatory body.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the ASME Boiler and Pressure Vessel Committee. ASME is to be notified should questions arise concerning improper use of an ASME Code symbol.

The specifications for materials given in Section II are identical with or similar to those of the Specifications published by ASTM, AWS, and other recognized national or international organizations. When reference is made in an ASME material specification to a non-ASME specification for which a companion ASME specification exists, the reference shall be interpreted as applying to the ASME material specification. Not all materials included in the material specifications in Section II have been adopted for Code use. Usage is limited to those materials and grades adopted by at least one of the other Sections of the Code for application under rules of that Section. All materials allowed by these various Sections and used for construction

within the scope of their rules shall be furnished in accordance with material specifications contained in Section II or referenced in Appendices A of Section II, Parts A and B except where otherwise provided in Code Cases or in the applicable Section of the Code. Materials covered by these specifications are acceptable for use in items covered by the Code Sections only to the degree indicated in the applicable Section. Materials for Code use should preferably be ordered, produced, and documented on this basis; Appendix A to Section II, Part A and Appendix A to Section II, Part B list editions of ASME and year dates of specifications that meet ASME requirements and which may be used in Code construction. Material produced to an acceptable specification with requirements different from the requirements of the corresponding specifications listed in Appendix A of Part A or Part B may also be used in accordance with the above, provided the material manufacturer or vessel manufacturer certifies with evidence acceptable to the Authorized Inspector that the corresponding requirements of specifications listed in Appendix A of Part A or Part B have been met. Material produced to an acceptable material specification is not limited as to country of origin.

When required by context in this Section, the singular shall be interpreted as the plural, and vice-versa; and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

Publication of the SI (Metric) Edition of the ASME Boiler and Pressure Vessel Code was discontinued with the 1986 Edition. Effective October 1, 1986, the SI Edition was withdrawn as an ASME Boiler and Pressure Vessel Code document.

STATEMENT OF POLICY ON THE USE OF CODE SYMBOLS AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use Code Symbols for marking items or constructions which have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the Code Symbols for the benefit of the users, the enforcement jurisdictions, and the holders of the symbols who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the symbols, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications which might so indicate. An organization holding a Code Symbol and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code."

The ASME Symbol shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of a Code Symbol who may also use the facsimile in advertising to show that clearly specified items will carry the symbol. General usage is permitted only when all of a manufacturer's items are constructed under the rules.

The ASME logo, which is the cloverleaf with the letters ASME within, shall not be used by any organization other than ASME.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the official Code Symbol Stamp described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the various Code Symbols shall not be used on any item which is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME which tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

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INTRODUCTION

The following is a brief introduction to the 1998 Edition of Section IX and cannot be considered as a substitute for the actual review of appropriate sections of the document. However, this introduction is intended to give the reader a better understanding of the purpose and organizaton of Section IX.

Section IX of the ASME Boiler and Pressure Vessel Code relates to the qualification of welders, welding operators, brazers, and brazing operators, and the procedures employed in welding or brazing in accordance with the ASME Boiler and Pressure Vessel Code and the ASME B31 Code for Pressure Piping. As such, this is an active document subject to constant review, interpretation, and improvement to recognize new developments and research data. Section IX is a document referenced for qualification by various construction codes such as Section I, III, IV, VIII, etc. These particular construction codes apply to specific types of fabrication and may impose additional welding requirements or exemptions to Section IX qualifications. Qualification in accordance with Section IX is not a guarantee that procedures and performance qualifications will be acceptable to a particular construction code.

Section IX establishes the basic criteria for welding and brazing which are observed in the preparation of welding and brazing requirements that affect procedure and performance. It is important that the user of the 1998 Edition of Section IX understand the basic criteria in reviewing the requirements which have been established.

The purpose of the Welding Procedure Specification (WPS) and Procedure Qualification Record (PQR) is to determine that the weldment proposed for construction is capable of having the required properties for its intended application. It is presupposed that the welder or welding operator performing the welding procedure qualification test is a skilled workman. This also applies to the Brazing Procedure Specifications (BPS) and the brazer and brazing operator qualifications. The procedure qualification test is to establish the properties of the weldment or brazement and not the skill of the personnel performing the welding or brazing. In addition, special consideration is given when notch toughness is required by other Sections of the Code. The notch-toughness variables do not apply unless referenced by the construction codes.

In Welder or Brazer/Brazing Operator Performance Qualification, the basic criterion is to determine the ability to deposit sound weld metal, or to make a sound braze. In Welding Operator Performance Qualification, the basic criterion is to determine the mechanical ability of the welding operator to operate the equipment.

In developing the present Section IX, each welding process and brazing process that was included was reviewed with regard to those items (called variables) which have an affect upon the welding or brazing operations as applied to procedure or performance criteria.

The user of Section IX should be aware of how Section IX is organized. It is divided into two parts: welding and brazing. Each part is then divided into four articles. These articles deal with the following:

(a) general requirements (Article I Welding and Article XI Brazing)

(b) procedure qualifications (Article II Welding and Article XII Brazing)

(c) performance qualifications (Article III Welding and Article XIII Brazing)

(d) data (Article IV Welding and Article XIV Brazing)

These articles contain general references and guides that apply to procedure and performance qualifications such as positions, type and purpose of various mechanical tests, acceptance criteria, and the applicability of Section IX, which was in the Preamble of the 1980 Section IX (the Preamble has been deleted). The general requirement articles reference the data articles for specifics of the testing equipment and removal of the mechanical test specimens.

PROCEDURE QUALIFICATIONS

Each process that has been evaluated by Section IX is listed separately with the essential and nonessential variables as they apply to that particular process. In general, the Welding Procedure Specifications (WPS) and the Brazing Procedure Specifications (BPS) are to list all essential and nonessential variables for each process that is included under that particular procedure

specification. If a change is made in any essential variable, requalification of the procedure is required. If a change is made in a nonessential variable, the procedure need only be revised or amended to address the nonessential variable change. When notch toughness is required by the construction code, the supplementary essential variables become additional essential variables and a change requires requalification of the procedure.

In addition to covering various processes, there are also rules for procedure qualification of corrosion-resistant weld metal overlay and hard-facing weld metal overlay.

PERFORMANCE QUALIFICATIONS

These articles list separately the various welding and brazing processes with the essential variables that apply to the performance qualifications of each process. The welder, brazer, and brazing operator qualifications are limited by essential variables.

The performance qualification articles have numerous paragraphs describing general applicable variables for all processes. QW-350 and QB-350 list additional essential variables which are applicable for specific processes. The QW-350 variables do not apply to welding operators. QW-360 lists the additional essential variables for welding operators.

Generally, a welder or welding operator may be qualified by mechanical bending tests, radiography of a test plate, or radiography of the initial production weld. Brazers or brazing operators may not be qualified by radiography.

WELDING AND BRAZING DATA

The welding and brazing data articles include the variables grouped into categories such as joints, base materials and filler materials, positions, preheat/postweld heat treatment, gas, electrical characteristics, and technique. They are referenced from other articles as they apply to each process.

These articles are frequently misused by selecting variables that do not apply to a particular process. Variables (QW-402 to QW-410 and QB-402 to QB-410) only apply as referenced for the applicable process in Article II or Article III for welding and Article XII or Article XIII for brazing. The user of Section IX should not try to apply any variable which is not referenced for that process in QW-250, QW-350, QW-360, QB-250, or QB-350.

These articles also include assignments of P-Numbers and F-Numbers to particular base materials and filler materials. Article IV also includes A-Number tables for reference by the manufacturer.

Beginning with the 1994 Addenda, the welding P-Numbers, brazing P-Numbers, and nonmandatory S-Numbers were consolidated into one table identified as QW/QB-422. Both the QB-422 table (brazing P-Numbers) and Appendix C table (S-Numbers) were deleted. The new QW/QB-422 table was divided into ferrous and nonferrous sections. Metals were listed in numerical order by material specification number to aid users in locating the appropriate grouping number. An abbreviated listing of metals grouped by P-Numbers, Appendix D, has been included for users still wishing to locate groupings of metals by welding P-Number.

The QW-451 and QB-451 tables for procedure qualification thickness requirements and the QW-452 and QB-452 tables for performance thickness qualifications are given and may only be used as referenced by other paragraphs. Generally, the appropriate essential variables reference these tables.

Revisions to the 1980 Edition of Section IX introduced new definitions for position and added a fillet weld orientation sketch to complement the groove-weld orientation sketch. The new revision to position indicates that a welder qualifies in the 1G, 2G, 3G, etc., position and is then qualified to weld, in production, in the F, V, H, or O positions as appropriate. QW-461.9 is a revised table that summarizes these new qualifications.

The data articles also give sketches of coupon orientations, removal of test specimens, and test jig dimensions. These are referenced by Articles I and XI.

QW-470 describes etching processes and reagents.

At the end of Articles IV and XIV is a list of general definitions applicable to Section IX, welding and brazing, respectively. These may differ slightly from other welding documents.

Nonmandatory Forms for welding and brazing procedure and performance qualifications appear in Appendix B. These forms are provided for the aid of those who do not wish to design their own forms. Any form(s) that address all applicable requirements of Section IX may be used.

The 2001 Edition of the Code contains both U.S. Customary and SI units. In all cases, the U.S. Customary units are the standard and SI units are provided for the convenience of the user.

SUMMARY OF CHANGES

The 2001 Edition of this Code contains revisions in addition to the 1998 Edition with 1999 and 2000 Addenda. The revisions are identified with the designation **01** in the margin and, as described in the Foreword, become mandatory six months after the publication date of the 2001 Edition. To invoke these revisions before their mandatory date, use the designation "2001 Edition" in documentation required by this Code. If you choose not to invoke these revisions before their mandatory date, use the designation "1998 Edition through the 2000 Addenda" in documentation required by this Code.

Changes given below are identified on the pages by a margin note, **01**, placed next to the affected area.

Page	*Location*	*Change*
5	QW-153.1	(1) Subparagraph (d) revised (2) Subparagraph (e) added (3) QW-153.1.1 deleted
16	QW-202.2	(1) Subparagraph (c) revised (2) Subparagraph (d) deleted
	QW-202.4	Subparagraph (b)(1) revised
21	QW-253	QW-410.9 added
29	QW-256	QW-404.50 added
45	QW-283.4	Revised in its entirety
47, 48	QW-300.3	Fifth paragraph revised
	QW-301.4	Last sentence revised
54	QW-381	Subparagraphs (a) and (c) revised
	QW-382	Subparagraphs (a) and (c) revised
58	QW-403.16	Revised
61	QW-404.50	Added
63	QW-408.2	Last paragraph added
	QW-408.9	Revised
	QW-408.10	Revised
68	QW-420.2	First sentence added
69–130	QW/QB-422	Revised
188, 190, 192	QW/QB-492	Definitions of *brazing, torch; oscillation;* and *weave bead* revised
200	QB-153.1	(1) First sentence added (2) Subparagraph (d) added (3) QB-153.1.1 deleted
215	QB-402.1	Last paragraph revised
	QB-402.2	Revised
	QB-406.1	Revised
219	QB-451.3	Note (2) added
236	QB-463.2(c)	Revised
246, 247	Form QW-484	Revised in its entirety

Page	*Location*	*Change*
254	Appendix D	For P-No.1 Grp. No. 1, SA/EN 10028-2 added
261	Appendix D	For P-No. 8 Grp. No. 4, SA-403 added
262	Appendix D	For P-No. 10C Grp. No. 1, SA-841 deleted
265–268	Appendix D	(1) For P-No. 44, SB-333, SB-335, SB-366, SB-564, SB0-619, and SB-622 added (2) For P-No. 44, Grade or UNS No. N10629 added for SB-626 (3) For P-No. 45, Grade or UNS Nos. N08031 and R20033 added for SB-564, SB-581, SB-619, SB-622, SB-625, SB-626, and SB-649 (4) For P-No. 46, Grade or UNS No. N06045 added for SB-166, SB-167, SB-168, SB-366, SB-516, SB-517, and SB-564 (5) For P-Nos. 51, 52, and 53, SB-337 deleted (6) For P-Nos. 51, 52, and 53, SB-861 and SB-862 added

NOTE:
Volume 48 of the Interpretations to Section IX of the ASME Boiler and Pressure Vessel Code follows the last page of the Edition to Section IX.

PART QW WELDING

ARTICLE I
WELDING GENERAL REQUIREMENTS

QW-100 GENERAL

Section IX of the ASME Boiler and Pressure Vessel Code relates to the qualification of welders, welding operators, brazers, and brazing operators, and the procedures that they employ in welding and brazing according to the ASME Boiler and Pressure Vessel Code and the ASME B31 Code for Pressure Piping. It is divided into two parts: Part QW gives requirements for welding and Part QB contains requirements for brazing. Other Sections of the Code may specify different requirements than those specified by this Section. Such requirements take precedence over those of this Section, and the manufacturer or contractor shall comply with them.

QW-100.1 A Welding Procedure Specification (WPS) is a written document that provides direction to the welder or welding operator for making production welds in accordance with Code requirements. Any WPSs used by a manufacturer or contractor that will have responsible operational control of production welding shall be a WPS that has been qualified by that manufacturer or contractor in accordance with Article II, or it shall be an AWS Standard Welding Procedure Specification (SWPS) listed in Appendix E and adopted by that manufacturer or contractor in accordance with Article V.

Both WPSs and SWPSs specify the conditions (including ranges, if any) under which welding must be performed. These conditions include the base metals that are permitted, the filler metals that must be used (if any), preheat and postweld heat treatment requirements, etc. Such conditions are referred to in this Section as welding "variables."

When a WPS is to be prepared by the manufacturer or contractor, it must address, as a minimum, the specific variables, both essential and nonessential, as provided in Article II for each process to be used in production welding. In addition, when other Sections of the Code require notch toughness qualification of the WPS, the applicable supplementary essential variables must be addressed in the WPS.

The purpose for qualification of a WPS is to determine that the weldment proposed for construction is capable of providing the required properties for its intended application. Welding procedure qualification establishes the properties of the weldment, not the skill of the welder or welding operator.

The Procedure Qualification Record (PQR) documents what occurred during welding the test coupon and the results of testing of the coupon. As a minimum, the PQR shall document the essential variables and other specific information identified in Article II for each process used during welding the test coupon and the results of the required testing. In addition, when notch toughness testing is required for procedure qualification, the applicable supplementary essential variables for each process shall be recorded.

QW-100.2 In performance qualification, the basic criterion established for welder qualification is to determine the welder's ability to deposit sound weld metal. The purpose of the performance qualification test for the welding operator is to determine the welding operator's mechanical ability to operate the welding equipment.

QW-100.3 Welding Procedure Specifications (WPS) written and qualified in accordance with the rules of this Section, and welders and welding operators of automatic and machine welding equipment also qualified in accordance with these rules may be used in any construction built to the requirements of the ASME Boiler and Pressure Vessel Code or the ASME B31 Code for Pressure Piping.

However, other Sections of the Code state the conditions under which Section IX requirements are mandatory, in whole or in part, and give additional require-

ments. The reader is advised to take these provisions into consideration when using this Section.

Welding Procedure Specifications, Procedure Qualification Records, and Welder/Welding Operator Performance Qualification made in accordance with the requirements of the 1962 Edition or any later Edition of Section IX may be used in any construction built to the ASME Boiler and Pressure Vessel Code or the ASME B31 Code for Pressure Piping.

Welding Procedure Specifications, Procedure Qualification Records, and Welder/Welding Operator Performance Qualification made in accordance with the requirements of the Editions of Section IX prior to 1962, in which all of the requirements of the 1962 Edition or later Editions are met, may also be used.

Welding Procedure Specifications and Welder/Welding Operator Performance Qualification records meeting the above requirements do not need to be amended to include any variables required by later Editions and Addenda.

Qualification of new Welding Procedure Specifications or Welders/Welding Operators and requalification of existing Welding Procedure Specifications or Welders/Welding Operators shall be in accordance with the current Edition (see Foreword) and Addenda of Section IX.

QW-101 Scope

The rules in this Section apply to the preparation of Welding Procedure Specifications and the qualification of welding procedures, welders, and welding operators for all types of manual and machine welding processes permitted in this Section. These rules may also be applied, insofar as they are applicable, to other manual or machine welding processes permitted in other Sections.

QW-102 Terms and Definitions

Some of the more common terms relating to welding and brazing are defined in QW/QB-492.

Wherever the word pipe is designated, tube shall also be applicable.

QW-103 Responsibility

QW-103.1 Welding. Each manufacturer[1] or contractor[1] is responsible for the welding done by his organization and shall conduct the tests required in this Section to qualify the welding procedures he uses in the construction of the weldments built under this Code, and the performance of welders and welding operators who apply these procedures.

QW-103.2 Records. Each manufacturer or contractor shall maintain a record of the results obtained in welding procedure and welder and welding operator performance qualifications. These records shall be certified by the manufacturer or contractor and shall be accessible to the Authorized Inspector. Refer to recommended Forms in Nonmandatory Appendix B.

QW-110 WELD ORIENTATION

The orientations of welds are illustrated in QW-461.1 or QW-461.2.

QW-120 TEST POSITIONS FOR GROOVE WELDS

Groove welds may be made in test coupons oriented in any of the positions in QW-461.3 or QW-461.4 and as described in the following paragraphs, except that an angular deviation of ±15 deg from the specified horizontal and vertical planes, and an angular deviation of ±5 deg from the specified inclined plane are permitted during welding.

QW-121 Plate Positions

QW-121.1 Flat Position 1G. Plate in a horizontal plane with the weld metal deposited from above. Refer to QW-461.3 sketch (a).

QW-121.2 Horizontal Position 2G. Plate in a vertical plane with the axis of the weld horizontal. Refer to QW-461.3 sketch (b).

QW-121.3 Vertical Position 3G. Plate in a vertical plane with the axis of the weld vertical. Refer to QW-461.3 sketch (c).

QW-121.4 Overhead Position 4G. Plate in a horizontal plane with the weld metal deposited from underneath. Refer to QW-461.3 sketch (d).

QW-122 Pipe Positions

QW-122.1 Flat Position 1G. Pipe with its axis horizontal and rolled during welding so that the weld metal is deposited from above. Refer to QW-461.4 sketch (a).

[1] Wherever these words are used in Section IX, they shall include installer or assembler.

QW-122.2 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 QW-461.4 sketch (b).

QW-122.3 Multiple Position 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 QW-461.4 sketch (c).

QW-122.4 Multiple Position 6G. Pipe with its axis inclined at 45 deg to horizontal. Welding shall be done without rotating the pipe. Refer to QW-461.4 sketch (d).

QW-123 Test Positions for Stud Welds

QW-123.1 Stud Welding. Stud welds may be made in test coupons oriented in any of the positions as described in QW-121 for plate and QW-122 for pipe (excluding QW-122.1). In all cases, the stud shall be perpendicular to the surface of the plate or pipe. See QW-461.7 and QW-461.8.

QW-130 TEST POSITIONS FOR FILLET WELDS

Fillet welds may be made in test coupons oriented in any of the positions of QW-461.5 or QW-461.6, and as described in the following paragraphs, except that an angular deviation of ±15 deg from the specified horizontal and vertical planes is permitted during welding.

QW-131 Plate Positions

QW-131.1 Flat Position 1F. Plates so placed that the weld is deposited with its axis horizontal and its throat vertical. Refer to QW-461.5 sketch (a).

QW-131.2 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 QW-461.5 sketch (b).

QW-131.3 Vertical Position 3F. Plates so placed that the weld is deposited with its axis vertical. Refer to QW-461.5 sketch (c).

QW-131.4 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 QW-461.5 sketch (d).

QW-132 Pipe Positions

QW-132.1 Flat Position 1F. Pipe with its axis inclined at 45 deg 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 QW-461.6 sketch (a).

QW-132.2 Horizontal Positions 2F and 2FR

(a) 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 QW-461.6 sketch (b).

(b) 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 QW-461.6 sketch (c).

QW-132.3 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 QW-461.6 sketch (d).

QW-132.4 Multiple Position 5F. Pipe with its axis horizontal and the axis of the deposited weld in the vertical plane. The pipe is not to be rotated during welding. Refer to QW-461.6 sketch (e).

QW-140 TYPES AND PURPOSES OF TESTS AND EXAMINATIONS

QW-141 Mechanical Tests

Mechanical tests used in procedure or performance qualification are as follows.

QW-141.1 Tension Tests. Tension tests as described in QW-150 are used to determine the ultimate strength of groove-weld joints.

QW-141.2 Guided-Bend Tests. Guided-bend tests as described in QW-160 are used to determine the degree of soundness and ductility of groove-weld joints.

QW-141.3 Fillet-Weld Tests. Tests as described in QW-180 are used to determine the size, contour, and degree of soundness of fillet welds.

QW-141.4 Notch-Toughness Tests. Tests as described in QW-171 and QW-172 are used to determine the notch toughness of the weldment.

QW-141.5 Stud-Weld Test. Deflection bend, hammering, torque, or tension tests as shown in QW-466.4, QW-466.5, and QW-466.6, and a macro-examination performed in accordance with QW-202.5, respectively, are used to determine acceptability of stud welds.

QW-142 Special Examinations for Welders

Radiographic examination may be substituted for mechanical testing of QW-141 for groove-weld performance qualification as permitted in QW-304 to prove the ability of welders to make sound welds.

QW-143 Examination for Welding Operators

An examination of a weld by radiography may be substituted for mechanical testing of QW-141 for groove weld performance qualification as permitted in QW-305 to prove the ability of welding operators to make sound welds.

QW-144 Visual Examination

Visual examination as described in QW-194 is used to determine that the final weld surfaces meet specified quality conditions.

QW-150 TENSION TESTS

QW-151 Specimens

Tension test specimens shall conform to one of the types illustrated in QW-462.1(a) through QW-462.1(e) and shall meet the requirements of QW-153.

QW-151.1 Reduced Section — Plate. Reduced-section specimens conforming to the requirements given in QW-462.1(a) may be used for tension tests on all thicknesses of plate.

(a) For thicknesses up to and including 1 in. (25 mm), a full thickness specimen shall be used for each required tension test.

(b) For plate thickness greater than 1 in. (25 mm), full thickness specimens or multiple specimens may be used, provided QW-151.1(c) and QW-151.1(d) are complied with.

(c) When multiple specimens are used, in lieu of full thickness specimens, each set shall represent a single tension test of the full plate thickness. Collectively, all of the specimens required to represent the full thickness of the weld at one location shall comprise a set.

(d) 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. Each specimen of the set shall be tested and meet the requirements of QW-153.

QW-151.2 Reduced Section — Pipe. Reduced-section specimens conforming to the requirements given in QW-462.1(b) may be used for tension tests on all thicknesses of pipe having an outside diameter greater than 3 in. (76 mm).

(a) For thicknesses up to and including 1 in. (25 mm), a full thickness specimen shall be used for each required tension test.

(b) For pipe thicknesses greater than 1 in. (25 mm), full thickness specimens or multiple specimens may be used, provided QW-151.2(c) and QW-151.2(d) are complied with.

(c) When multiple specimens are used, in lieu of full thickness specimens, each set shall represent a single tension test of the full pipe thickness. Collectively, all of the specimens required to represent the full thickness of the weld at one location shall comprise a set.

(d) 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. Each specimen of the set shall be tested and meet the requirements of QW-153.

For pipe having an outside diameter of 3 in. (76 mm) or less, reduced-section specimens conforming to the requirements given in QW-462.1(c) may be used for tension tests.

QW-151.3 Turned Specimens. Turned specimens conforming to the requirements given in QW-462.1(d) may be used for tension tests.

(a) For thicknesses up to and including 1 in. (25 mm), a single turned specimen may be used for each required tension test, which shall be a specimen of the largest diameter D of QW-462.1(d) possible for test coupon thickness [per Note (a) of QW-462.1(d)].

(b) For thicknesses over 1 in. (25 mm), multiple specimens shall be cut through the full thickness of the weld with their centers parallel to the metal surface and not over 1 in. (25 mm) apart. The centers of the specimens adjacent to the metal surfaces shall not exceed $^5/_8$ in. (16 mm) from the surface.

(c) When multiple specimens are used, each set shall represent a single required tension test. Collectively, all the specimens required to represent the full thickness of the weld at one location shall comprise a set.

(d) Each specimen of the set shall be tested and meet the requirements of QW-153.

QW-151.4 Full-Section Specimens for Pipe. Tension specimens conforming to the dimensions given in QW-462.1(e) may be used for testing pipe with an outside diameter of 3 in. (76 mm) or less.

QW-152 Tension Test Procedure

The tension test specimen shall be ruptured under tensile load. The tensile strength shall be computed by dividing the ultimate total load by the least cross-sectional area of the specimen as calculated from actual measurements made before the load is applied.

QW-153 Acceptance Criteria — Tension Tests

01 **QW-153.1 Tensile Strength.** Minimum values for procedure qualification are provided under the column heading "Minimum Specified Tensile, ksi" of QW/QB-422. In order to pass the tension test, the specimen shall have a tensile strength that is not less than:

(a) the minimum specified tensile strength of the base metal; or

(b) the minimum specified tensile strength of the weaker of the two, if base metals of different minimum tensile strengths are used; or

(c) the minimum specified tensile strength of the weld metal when the applicable Section provides for the use of weld metal having lower room temperature strength than the base metal;

(d) if the specimen breaks in the base metal outside of the weld or weld interface, the test shall be accepted as meeting the requirements, provided the strength is not more than 5% below the minimum specified tensile strength of the base metal.

(e) the specified minimum tensile strength is for full thickness specimens including cladding for Aluminum Alclad materials (P-No. 21 through P-No. 23) 0.499 in. (12.5 mm) and less. For Aluminum Alclad materials 0.5 in. (13 mm) and greater, the specified minimum tensile strength is for both full thickness specimens that include cladding and specimens taken from the core.

QW-160 GUIDED-BEND TESTS

QW-161 Specimens

Guided-bend test specimens shall be prepared by cutting the test plate or pipe to form specimens of approximately rectangular cross section. The cut surfaces shall be designated the sides of the specimen. The other two surfaces shall be called the face and root surfaces, the face surface having the greater width of weld. The specimen thickness and bend radius are shown in QW-466.1, QW-466.2, and QW-466.3. Guided-bend specimens are of five types, depending on whether the axis of the weld is transverse or parallel to the longitudinal axis of the specimen, and which surface (side, face, or root) is on the convex (outer) side of bent specimen. The five types are defined as follows.

QW-161.1 Transverse Side Bend. The weld is transverse to the longitudinal axis of the specimen, which is bent so that one of the side surfaces becomes the convex surface of the bent specimen. Transverse side-bend test specimens shall conform to the dimensions shown in QW-462.2.

Specimens of base metal thickness over $1\frac{1}{2}$ in. (38 mm) may be cut into approximately equal strips between $\frac{3}{4}$ in. (19 mm) and $1\frac{1}{2}$ in. (38 mm) wide for testing, or the specimens may be bent at full width (see requirements on jig width in QW-466). If multiple specimens are used, one complete set shall be made for each required test. Each specimen shall be tested and meet the requirements in QW-163.

QW-161.2 Transverse Face Bend. The weld is transverse to the longitudinal axis of the specimen, which is bent so that the face surface becomes the convex surface of the bent specimen. Transverse face-bend test specimens shall conform to the dimensions shown in QW-462.3(a). For subsize transverse face bends, see QW-161.4.

QW-161.3 Transverse Root Bend. The weld is transverse to the longitudinal axis of the specimen, which is bent so that the root surface becomes the convex surface of the bent specimen. Transverse root-bend test specimens shall conform to the dimensions shown in QW-462.3(a). For subsize transverse root bends, see QW-161.4.

QW-161.4 Subsize Transverse Face and Root Bends. See Note (2) of QW-462.3(a).

QW-161.5 Longitudinal-Bend Tests. Longitudinal-bend tests may be used in lieu of the transverse side-, face-, and root-bend tests for testing weld metal or base metal combinations which differ markedly in bending properties between

(a) the two base metals; or

(b) the weld metal and the base metal.

QW-161.6 Longitudinal Face Bend. The weld is parallel to the longitudinal axis of the specimen, which

is bent so that the face surface becomes the convex surface of the bent specimen. Longitudinal face-bend test specimens shall conform to the dimensions shown in QW-462.3(b).

QW-161.7 Longitudinal Root Bend. The weld is parallel to the longitudinal axis of the specimen, which is bent so that the root surface becomes the convex side of the bent specimen. Longitudinal root-bend test specimens shall conform to the dimensions shown in QW-462.3(b).

QW-162 Guided-Bend Test Procedure

QW-162.1 Jigs. Guided-bend specimens shall be bent in test jigs that are in substantial accordance with QW-466. When using the jigs illustrated in QW-466.1 or QW-466.2, the side of the specimen turned toward the gap of the jig shall be the face for face-bend specimens, the root for root-bend specimens, and the side with the greater discontinuities, if any, for side-bend specimens. The specimen shall be forced into the die by applying load on the plunger until the curvature of the specimen is such that a $\frac{1}{8}$ in. (3.2 mm) diameter wire cannot be inserted between the specimen and the die of QW-466.1, or the specimen is bottom ejected if the roller type of jig (QW-466.2) is used.

When using the wrap around jig (QW-466.3), the side of the specimen turned toward the roller shall be the face for face-bend specimens, the root for root-bend specimens, and the side with the greater discontinuities, if any, for side-bend specimens.

When specimens wider than $1\frac{1}{2}$ in. (38 mm) are to be bent as permitted in QW-462.2, the test jig mandrel must be at least $\frac{1}{4}$ in. (6 mm) wider than the specimen width.

QW-163 Acceptance Criteria — Bend Tests

The weld and heat-affected zone of a transverse weld-bend specimen shall be completely within the bent portion of the specimen after testing.

The guided-bend specimens shall have no open discontinuities in the weld or heat-affected zone exceeding $\frac{1}{8}$ in. (3.2 mm), measured in any direction on the convex surface of the specimen after bending. Open discontinuities occurring on the corners of the specimen during testing shall not be considered unless there is definite evidence that they result from lack of fusion, slag inclusions, or other internal discontinuities. For corrosion-resistant weld overlay cladding, no open discontinuity exceeding $\frac{1}{16}$ in. (1.6 mm), measured in any direction, shall be permitted in the cladding, and no open discontinuities exceeding $\frac{1}{8}$ in. (3.2 mm) shall be permitted along the approximate weld interface.

QW-170 NOTCH-TOUGHNESS TESTS

QW-171 Notch-Toughness Tests — Charpy V-Notch

QW-171.1 General. Charpy V-notch impact tests shall be made when required by other Sections.

Test procedures and apparatus shall conform to the requirements of SA-370.

QW-171.2 Acceptance. The acceptance criteria shall be in accordance with that Section specifying impact requirements.

QW-171.3 Location and Orientation of Test Specimen. The impact test specimen and notch location and orientation shall be as given in the Section requiring such tests.

When qualifying pipe in the 5G or 6G position, the notch-toughness specimens shall be removed from the shaded portion of QW-463.1(f).

QW-172 Notch-Toughness Tests — Drop Weight

QW-172.1 General. Drop weight tests shall be made when required by other Sections.

Test procedures and apparatus shall conform to the requirements of ASTM Specification E 208.

QW-172.2 Acceptance. The acceptance criteria shall be in accordance with that Section requiring drop weight tests.

QW-172.3 Location and Orientation of Test Specimen. The drop weight test specimen, the crack starter location, and the orientation shall be as given in the Section requiring such tests.

When qualifying pipe in the 5G or 6G position, the notch-toughness specimens shall be removed from the shaded portion of QW-463.1(f).

QW-180 FILLET-WELD TESTS

QW-181 Procedure and Performance Qualification Specimens

QW-181.1 Procedure. The dimensions and preparation of the fillet-weld test coupon for procedure qualification as required in QW-202 shall conform to the requirements in QW-462.4(a) or QW-462.4(d). The test coupon for plate-to-plate shall be cut transversely to

provide five test specimen sections, each approximately 2 in. (51 mm) long. For pipe-to-plate or pipe-to-pipe, the test coupon shall be cut transversely to provide four approximately equal test specimen sections. The test specimens shall be macro-examined to the requirements of QW-183.

QW-181.1.1 Production Assembly Mockups. Production assembly mockups may be used in lieu of QW-181.1. The mockups for plate-to-shape shall be cut transversely to provide five approximately equal test specimens not to exceed approximately 2 in. (51 mm) in length. For pipe-to-shape mockups, the mockup shall be cut transversely to provide four approximately equal test specimens. For small mockups, multiple mockups may be required to obtain the required number of test specimens. The test specimens shall be macro-examined to the requirements of QW-183.

QW-181.2 Performance. The dimensions and the preparation of the fillet-weld test coupon for performance qualification shall conform to the requirements in QW-462.4(b) or QW-462.4(c). The test coupon for plate-to-plate shall be cut transversely to provide a center section approximately 4 in. (102 mm) long and two end sections, each approximately 1 in. (25 mm) long. For pipe-to-plate or pipe-to-pipe, the test coupon shall be cut to provide two quarter sections test specimens opposite to each other. One of the test specimens shall be fracture tested in accordance with QW-182 and the other macro-examined to the requirements of QW-184. When qualifying pipe-to-plate or pipe-to-pipe in the 5F position, the test specimens shall be removed as indicated in QW-463.2(h).

QW-181.2.1 Production Assembly Mockups. Production assembly mockups may be used in lieu of the fillet-weld test coupon requirements of QW-181.2.

(a) Plate-to-shape

(1) The mockup for plate-to-shape shall be cut transversely to provide three approximately equal test specimens not to exceed approximately 2 in. (51 mm) in length. The test specimen that contains the start and stop of the weld shall be fracture tested in accordance with QW-182. A cut end of one of the remaining test specimens shall be macro-examined in accordance with QW-184.

(b) Pipe-to-shape

(1) The mockup for pipe-to-shape shall be cut transversely to provide two quarter sections approximately opposite to each other. The test specimen that contains the start and stop of the weld shall be fracture tested in accordance with QW-182. A cut end of the other quarter section shall be macro-examined in accordance with QW-184. When qualifying pipe-to-shape in the 5F position, the fracture specimen shall be removed from the lower 90 deg section of the mockup.

QW-182 Fracture Tests

The stem of the 4 in. performance specimen center section in QW-462.4(b) or the stem of the quarter section in QW-462.4(c), as applicable, shall be loaded laterally in such a way that the root of the weld is in tension. The load shall be steadily increased until the specimen fractures or bends flat upon itself.

If the specimen fractures, the fractured surface shall show no evidence of cracks or incomplete root fusion, and the sum of the lengths of inclusions and porosity visible on the fractured surface shall not exceed $^3/_8$ in. (10 mm) in QW-462.4(b) or 10% of the quarter section in QW-462.4(c).

QW-183 Macro-Examination — Procedure Specimens

One face of each cross section of the five test specimens in QW-462.4(a) or four test specimens in QW-462.4(d), as applicable shall be smoothed and etched with a suitable etchant (see QW-470) to give a clear definition to the weld metal and heat affected zone. The examination of the cross sections shall include only one side of the test specimen at the area where the plate or pipe is divided into sections i.e., adjacent faces at the cut shall not be used. In order to pass the test:

Visual examination of the cross sections of the weld metal and heat affected zone shall show complete fusion and freedom from cracks; and

There shall not be more than $^1/_8$ in. (3.2 mm) difference in the length of the legs of the fillet.

QW-184 Macro-Examination — Performance Specimens

The cut end of one of the end plate sections, approximately 1 in. long, in QW-462.4(b) or the cut end of one of the pipe quarter sections in QW-462.4(c), as applicable, shall be smoothed and etched with a suitable etchant (see QW-470) to give a clear definition of the weld metal and heat affected zone. In order to pass the test:

Visual examination of the cross section of the weld metal and heat affected zone shall show complete fusion and freedom from cracks, except that linear indications

at the root not exceeding 1/32 in. (0.8 mm) shall be acceptable; and

The weld shall not have a concavity or convexity greater than 1/16 in. (1.6 mm); and

There shall be not more than 1/8 in. (3.2 mm) difference in the lengths of the legs of the fillet.

QW-190 OTHER TESTS AND EXAMINATIONS

QW-191 Radiographic Examination

QW-191.1 Method. The radiographic examination in QW-142 for welders and in QW-143 for welding operators shall meet the requirements of Article 2, Section V, except as follows.

(a) A written radiographic examination procedure is not required. Demonstration of density and penetrameter image requirements on production or technique radiographs shall be considered satisfactory evidence of compliance with Article 2 of Section V.

(b) The requirements of T-285 of Article 2 of Section V are to be used only as a guide. Final acceptance of radiographs shall be based on the ability to see the prescribed penetrameter image and the specified hole or the designated wire or a wire penetrameter. The acceptance standards of QW-191.2 shall be met.

QW-191.2 Radiographic Acceptance Criteria

QW-191.2.1 Terminology

Linear Indications. Cracks, incomplete fusion, inadequate penetration, and slag are represented on the radiograph as linear indications in which the length is more than three times the width.

Rounded Indications. Porosity and inclusions such as slag or tungsten are represented on the radiograph as rounded indications with a length three times the width or less. These indications may be circular, elliptical, or irregular in shape; may have tails; and may vary in density.

QW-191.2.2 Acceptance Standards. Welder and welding operator performance tests by radiography of welds in test assemblies shall be judged unacceptable when the radiograph exhibits any imperfections in excess of the limits specified below.

(a) Linear Indications

(1) any type of crack or zone of incomplete fusion or penetration;

(2) any elongated slag inclusion which has a length greater than:

(a) 1/8 in. (3.2 mm) for t up to 3/8 in. (10 mm), inclusive

(b) 1/3t for t over 3/8 in. (10 mm) to 2 1/4 in. (57 mm), inclusive

(c) 3/4 in. (19 mm) for t over 2 1/4 in. (57 mm)

(3) any group of slag inclusions in line that have an aggregate length greater than t in a length of 12t, except when the distance between the successive imperfections exceeds 6L where L is the length of the longest imperfection in the group.

(b) Rounded Indications

(1) The maximum permissible dimension for rounded indications shall be 20% of t or 1/8 in. (3.2 mm), whichever is smaller.

(2) For welds in material less than 1/8 in. (3.2 mm) in thickness, the maximum number of acceptable rounded indications shall not exceed 12 in a 6 in. (152 mm) length of weld. A proportionately fewer number of rounded indications shall be permitted in welds less than 6 in. (152 mm) in length.

(3) For welds in material 1/8 in. (3.2 mm) or greater in thickness, the charts in Appendix I represent the maximum acceptable types of rounded indications illustrated in typically clustered, assorted, and randomly dispersed configurations. Rounded indications less than 1/32 in. (0.8 mm) in maximum diameter shall not be considered in the radiographic acceptance tests of welders and welding operators in these ranges of material thicknesses.

QW-191.2.3 Production Welds. The acceptance standard for welding operators who qualify on production welds shall be that specified in the referencing Code Section. The acceptance standard for welders who qualify on production welds as permitted by QW-304.1 shall be per QW-191.2.2.

QW-191.3 Record of Tests. The results of welder and welding operator performance tests by radiography shall be recorded in accordance with QW-301.4.

QW-192 Stud-Weld Tests — Procedure Qualification Specimens

QW-192.1 Required Tests. Ten stud-weld tests are required to qualify each procedure. The equipment used for stud welding shall be completely automatic except for manual starting.

Every other welding stud (five joints) shall be tested either by hammering over until one-fourth of its length is flat on the test piece, or by bending the stud to an angle of at least 15 deg and returning it to its original position using a test jig and an adapter location dimension that are in accordance with QW-466.4.

The remaining five welded stud joints shall be tested in torque using a torque testing arrangement that is substantially in accordance with QW-466.5. Alternatively, where torquing is not feasible, tensile testing may be used, and the fixture for tensile testing shall be similar to that shown in QW-466.6 except that studs without heads may be gripped on the unwelded end in the jaws of the tensile testing machine.

QW-192.2 Acceptance Criteria — Bend and Hammer Tests. In order to pass the test(s), each of the five stud welds and heat affected zones shall be free of visible separation or fracture after bending and return bending or after hammering.

QW-192.3 Acceptance Criteria — Torque Tests. In order to pass the test(s), each of the five stud welds shall be subjected to the required torque shown in the following table before failure occurs.

Required Torque for Testing Threaded Carbon Steel Studs

Nominal Diameter of Studs, in.	Threads/in. and Series Designated	Testing Torque, ft-lb
1/4	28 UNF	5.0
1/4	20 UNC	4.2
5/16	24 UNF	9.5
5/16	18 UNC	8.6
3/8	24 UNF	17
3/8	16 UNC	15
7/16	20 UNF	27
7/16	14 UNC	24
1/2	20 UNF	42
1/2	13 UNC	37
9/16	18 UNF	60
9/16	12 UNC	54
5/8	18 UNF	84
5/8	11 UNC	74
3/4	16 UNF	147
3/4	10 UNC	132
7/8	14 UNF	234
7/8	9 UNC	212
1	12 UNF	348
1	8 UNC	318

Required Torque for Testing Threaded Austenitic Stainless Steel Studs

Nominal Diameter of Studs, in.	Threads/in. and Series Designated	Testing Torque, ft-lb
1/4	28 UNF	4.5
1/4	20 UNC	4.0
5/16	24 UNF	9.0
5/16	18 UNC	8.0
3/8	24 UNF	16.5
3/8	16 UNC	14.5
7/16	20 UNF	26.0
7/16	14 UNC	23.0
1/2	20 UNF	40.0
1/2	13 UNC	35.5
5/8	18 UNF	80.00
5/8	11 UNC	71.00
3/4	16 UNF	140.00
3/4	10 UNC	125.00
7/8	14 UNF	223.00
7/8	9 UNC	202.00
1	14 UNF	339.00
1	8 UNC	303.00

Alternatively, where torquing to destruction is not feasible, tensile testing may be used. For carbon and austenitic stainless steel studs, the failure strength shall not be less than 35,000 psi (241 MPa) and 30,000 psi (207 MPa), respectively. For other metals, the failure strength shall not be less than 1/2 of the minimum specified tensile strength of the stud material. The failure strength shall be based on the minor diameter of the threaded section of externally threaded studs except where the shank diameter is less than the minor diameter, or on the original cross-sectional area where failure occurs in a nonthreaded, internally threaded, or reduced-diameter stud.

QW-192.4 Acceptance Criteria — Macro-Examination. In order to pass the macro-examination, each of five sectioned stud welds and the heat affected zone shall be free of cracks when examined at a magnification of ×10, which is required by QW-202.5 when studs are welded to metals other than P-No. 1.

QW-193 Stud-Weld Tests — Performance Qualification Specimens

QW-193.1 Required Tests. Five stud-weld tests are required to qualify each stud-welding operator. The equipment used for stud welding shall be completely automatic except for manual starting. The performance test shall be welded in accordance with a qualified WPS per QW-301.2.

Each stud (five joints) shall be tested either by hammering over until one-fourth of its length is flat on the test piece or by bending the stud to an angle of at least 15 deg and returning it to its original position using a test jig and an adapter location dimension that are in accordance with QW-466.4.

QW-193.2 Acceptance Criteria — Bend and Hammer Tests. In order to pass the test(s), each of the five stud welds and heat affected zones shall be free of visible separation or fracture after bending and return bending or after hammering.

QW-194 Visual Examination — Performance

Performance test coupons shall show complete joint penetration with complete fusion of weld metal and base metal.

QW-195 Liquid Penetrant Examination

QW-195.1 The liquid penetrant examination in QW-214 for corrosion-resistant weld metal overlay shall meet the requirements of Section V, Article 6. The acceptance standards of QW-195.2 shall be met.

QW-195.2 Liquid Penetrant Acceptance Criteria

QW-195.2.1 Terminology

(a) relevant indications — indications with major dimensions greater than $^1/_{16}$ in. (1.6 mm).

(b) linear indications — an indication having a length greater than three times the width

(c) rounded indications — an indication of circular or elliptical shape with the length equal to or less than three times the width

QW-195.2.2 Acceptance Standards. Procedure and performance tests examined by liquid penetrant techniques shall be judged unacceptable when the examination exhibits any indication in excess of the limits specified below:

(a) relevant linear indications;

(b) relevant rounded indications greater than $^3/_{16}$ in. (4.8 mm);

(c) four or more relevant rounded indications in a line separated by $^1/_{16}$ in. (1.6 mm) or less (edge-to-edge).

QW-196 Resistance Weld Testing

QW-196.1 Metallographic Examination

QW-196.1.1 Welds shall be cross-sectioned, polished, and etched to reveal the weld metal. The section shall be examined at a magnification of 10 times.

QW-196.1.2 The weld nugget shall be sound for 1.25 times the thickness of the thinner member.

QW-196.1.3 For spot welds, the nugget size shall be measured at the interface between the sheets being joined, and it shall equal or exceed $0.9\sqrt{t}$, where t is the thickness of the thinner sheet. For projection welds, the nugget size shall not be less than the initial size of the projection. For seam welds, the width of the fused weld cut transverse to the seam shall be not less than $0.9\sqrt{t}$, where t is the thickness of the thinnest sheet.

QW-196.2 Mechanical Testing

QW-196.2.1 Shear test specimens shall be prepared as shown on QW-462.9. For spot and projection welds, each test specimen shall equal or exceed the minimum strength, and the average strength specified in QW-462.10 and QW-462.11 for the appropriate material. Further, for each set, 90% shall have shear strength values between 0.9 and 1.1 times the set average value. The remaining 10% shall lie between 0.8 and 1.2 times the set average value.

QW-196.2.2 Peel test specimens shall be prepared as shown in QW-462.8. The specimens shall be peeled or separated mechanically, and fracture shall occur in the base metal by tearing out of the weld in order for the specimen to be acceptable.

QW-197 Laser Beam Welding (LBW) Lap Joint Tests — Procedure Qualification Specimens

QW-197.1 Required Tests. Six tension shear specimens and eight macro specimens are required to qualify each procedure. The qualification test coupon shall be prepared in accordance with QW-464.1. The tension shear specimens shall conform to the dimensions indicated in the table of QW-464.1. The longitudinal and traverse sections indicated in QW-464.1 shall be cross-sectioned as closely as possible through the centerline of the weld. A minimum of 1 in. (25 mm) shall be provided for examination of each longitudinal specimen. The traverse specimens shall be of sufficient length to include weld, the heat-affected zone, and portions of the unaffected base material. Cross-sections shall be smoothed and etched with a suitable etchant (see QW-470), and examined at a minimum magnification of 25X. The dimensions of the fusion zone and penetration of each weld of the traverse specimens shall be measured to the nearest hundredth of an inch and recorded.

QW-197.2 Acceptance Criteria — Tension Shear Tests. In order to pass the tension shear test(s), the requirements of QW-153 shall apply.

QW-197.3 Acceptance Criteria — Macro-Examination. In order to pass the macro-examination, each of the eight specimens shall meet the following criteria.

(a) The outline of the fusion zone shall be generally consistent in size and regular in shape and uniformity of penetration.

(b) The examination of the weld area shall reveal sound weld metal, complete fusion along the bond line, and complete freedom from cracks in the weld metal and heat-affected zone.

QW-198 Laser Beam Welding (LBW) Lap Joint Tests — Performance Qualification Specimens

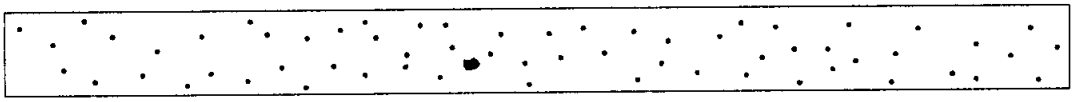
QW-198.1 Required Tests. A peel test specimen at least 6 in. (152 mm) long shall be prepared as shown in QW-464.2 sketch (a) and macro specimens as shown in QW-464.2 sketch (b). The peel test specimens shall be peeled apart to destruction and the fusion zone and penetration measured to the nearest hundredth of an inch. The end of each strip of the macro coupon shall be polished and etched to clearly reveal the weld metal. The width and depth of penetration of each weld shall be measured to the nearest hundredth of an inch. Each specimen shall be examined in accordance with QW-197.1.

QW-198.2 Acceptance Criteria — Peel Test and Macro-Examination. In order to pass the peel test and macro-examination, the dimensions of the fusion zone (averaged) and the penetration (averaged) shall be within the range of dimensions of those specified on the WPS that was used to make the test coupon.

APPENDIX I
ROUNDED INDICATION CHARTS
(See QW-191.2)



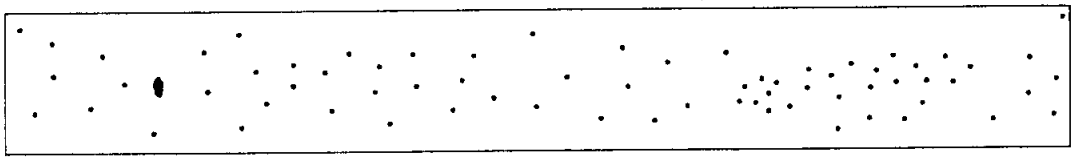
Typical Quantity and Size Permitted
in 6 in. (152 mm) Length of Weld
$^1/_8$ in. (3.2 mm) to $^1/_4$ in. (6 mm)
Thickness



Typical Quantity and Size Permitted
in 6 in. (152 mm) Length of Weld
Over $^1/_4$ in. (6 mm) to $^1/_2$ in. (13 mm)
Thickness



Typical Quantity and Size Permitted
in 6 in. (152 mm) Length of Weld
Over $^1/_2$ in. (13 mm) to 1 in. (25 mm)
Thickness



Typical Quantity and Size Permitted
in 6 in. (152 mm) Length of Weld
Over 1 in. (25 mm) Thickness

ARTICLE II
WELDING PROCEDURE QUALIFICATIONS

QW-200 GENERAL

QW-200.1 Each manufacturer and contractor shall prepare written Welding Procedure Specifications which are defined as follows.

(a) Welding Procedure Specification (WPS). A WPS is a written qualified welding procedure prepared to provide direction for making production welds to Code requirements. The WPS or other documents may be used to provide direction to the welder or welding operator to assure compliance with the Code requirements.

(b) Contents of the WPS. The completed WPS shall describe all of the essential, nonessential, and, when required, supplementary essential variables for each welding process used in the WPS. These variables are listed in QW-250 through QW-280 and are defined in Article IV, Welding Data.

The WPS shall reference the supporting Procedure Qualification Record(s) (PQR) described in QW-200.2. The manufacturer or contractor may include any other information in the WPS that may be helpful in making a Code weldment.

(c) Changes to the WPS. Changes may be made in the nonessential variables of a WPS to suit production requirements without requalification provided such changes are documented with respect to the essential, nonessential, and, when required, supplementary essential variables for each process. This may be by amendment to the WPS or by use of a new WPS.

Changes in essential or supplementary essential (when required) variables require requalification of the WPS (new or additional PQRs to support the change in essential or supplementary essential variables).

(d) Format of the WPS. The information required to be in the WPS may be in any format, written or tabular, to fit the needs of each manufacturer or contractor, as long as every essential, nonessential, and, when required, supplementary essential variables outlined in QW-250 through QW-280 is included or referenced.

Form QW-482 (see Nonmandatory Appendix B) has been provided as a guide for the WPS. This Form includes the required data for the SMAW, SAW, GMAW, and GTAW processes. It is only a guide and does not list all required data for other processes. It also lists some variables that do not apply to all processes (e.g., listing shielding gas which is not required for SAW). The guide does not easily lend itself to multiple process procedure specification (e.g., GTAW root with SMAW fill).

(e) Availability of the WPS. A WPS used for Code production welding shall be available for reference and review by the Authorized Inspector (AI) at the fabrication site.

QW-200.2 Each manufacturer or contractor shall be required to prepare a procedure qualification record which is defined as follows.

(a) Procedure Qualification Record (PQR). A PQR is a record of the welding data used to weld a test coupon. The PQR is a record of variables recorded during the welding of the test coupons. It also contains the test results of the tested specimens. Recorded variables normally fall within a small range of the actual variables that will be used in production welding.

(b) Contents of the PQR. The completed PQR shall document all essential and, when required, supplementary essential variables of QW-250 through QW-280 for each welding process used during the welding of the test coupon. Nonessential or other variables used during the welding of the test coupon may be recorded at the manufacturer's or contractor's option. All variables, if recorded, shall be the actual variables (including ranges) used during the welding of the test coupon. If variables are not monitored during welding, they shall not be recorded. It is not intended that the full range or the extreme of a given range of variables to be used in production be used during qualification unless required due to a specific essential or, when required, supplementary essential variable.

The PQR shall be certified accurate by the manufacturer or contractor. The manufacturer or contractor may not subcontract the certification function. This certification is intended to be the manufacturer's or

contractor's verification that the information in the PQR is a true record of the variables that were used during the welding of the test coupon and that the resulting tensile, bend, or macro (as required) test results are in compliance with Section IX.

When more than one welding process or filler metal is used to weld a test coupon, the approximate deposit weld metal thickness of each welding process and filler metal shall be recorded.

(c) Changes to the PQR. Changes to the PQR are not permitted except as described below. It is a record of what happened during a particular welding test. Editorial corrections or addenda to the PQR are permitted. An example of an editorial correction is an incorrect P-Number, F-Number, or A-Number that was assigned to a particular base metal or filler metal. An example of an addendum would be a change resulting from a Code change. For example, Section IX may assign a new F-Number to a filler metal or adopt a new filler metal under an established F-Number. This may permit, depending on the particular construction Code requirements, a manufacturer or contractor to use other filler metals that fall within that particular F-Number where, prior to the Code revision, the manufacturer or contractor was limited to the particular electrode classification that was used during qualification. Additional information can be incorporated into a PQR at a later date provided the information is substantiated as having been part of the original qualification condition by lab record or similar data.

All changes to a PQR require recertification (including date) by the manufacturer or contractor.

(d) Format of the PQR. Form QW-483 (see Nonmandatory Appendix B) has been provided as a guide for the PQR. The information required to be in the PQR may be in any format to fit the needs of each manufacturer or contractor, as long as every essential and, when required, supplementary essential variable, required by QW-250 through QW-280, is included. Also the type of tests, number of tests, and test results shall be listed in the PQR.

Form QW-483 does not easily lend itself to cover combinations of welding processes or more than one F-Number filler metal in one test coupon. Additional sketches or information may be attached or referenced to record the required variables.

(e) Availability of the PQR. PQRs used to support WPSs shall be available, upon request, for review by the Authorized Inspector (AI). The PQR need not be available to the welder or welding operator.

(f) Multiple WPSs With One PQR/Multiple PQRs With One WPS. Several WPSs may be prepared from the data on a single PQR (e.g., a 1G plate PQR may support WPSs for the F, V, H, and O positions on plate or pipe within all other essential variables). A single WPS may cover several essential variable changes as long as a supporting PQR exists for each essential and, when required, supplementary essential variable (e.g., a single WPS may cover a thickness range from $\frac{1}{16}$ in. (1.6 mm) through $1\frac{1}{4}$ in. (32 mm) if PQRs exist for both the $\frac{1}{16}$ in. (1.6 mm) through $\frac{3}{16}$ in. (4.8 mm) and $\frac{3}{16}$ in. (4.8 mm) through $1\frac{1}{4}$ in. (32 mm) thickness ranges).

QW-200.3 To reduce the number of welding procedure qualifications required, P-Numbers are assigned to base metals dependent on characteristics such as composition, weldability, and mechanical properties, where this can logically be done; and for steel and steel alloys (QW/QB-422) Group Numbers are assigned additionally to P-Numbers. These Group Numbers classify the metals within P-Numbers for the purpose of procedure qualification where notch-toughness requirements are specified. The assignments do not imply that base metals may be indiscriminately substituted for a base metal which was used in the qualification test without consideration of the compatibility from the standpoint of metallurgical properties, postweld heat treatment, design, mechanical properties, and service requirements. Where notch toughness is a consideration, it is presupposed that the base metals meet the specific requirements.

In general, notch-toughness requirements are mandatory for all P-No. 11 quenched and tempered metals, for low temperature applications of other metals as applied to Section VIII, and for various classes of construction required by Section III. Acceptance criteria for the notch-toughness tests are as established in the other Sections of the Code.

For certain materials permitted by the ASME/ANSI B31 Code for Pressure Piping or by selected Code Cases of the ASME Boiler and Pressure Vessel Code but which are not included within the ASME Boiler and Pressure Vessel Code Material Specifications (Section II), S-Number groupings are assigned in QW/QB-422. These groupings are similar to the P-Number groupings of QW/QB-422. Qualification limits are given in QW-420.2.

QW-200.4 Combination of Welding Procedures

(a) More than one procedure having different essential or nonessential variables may be used in a single production joint. Each procedure may include one or a combination of processes, filler metals, or other variables.

Where two or more procedures involving different processes or other essential variables are used in one joint, QW-451 shall be used to determine the range of base metal thickness qualified and the maximum thickness of deposited weld metal qualified for each process or procedure. Alternatively, qualification for root deposits only may be made in accordance with QW-200.4(b). The deposited weld metal of each process or procedure shall be included in the tension and bend specimens, and in the notch-toughness specimen (when required). One or more processes or procedures may be deleted from a qualified combination procedure. Each such process or procedure may be used separately provided:

(1) the remaining essential, nonessential, and supplementary essential variables are applied;

(2) the base metal and deposited weld metal thickness limits of QW-451 are applied.

(b) For GTAW, SMAW, GMAW, PAW, and SAW, or combinations of these processes, a PQR for a process recording a test coupon that was at least ½ in. (13 mm) thick may be combined with one or more other PQRs recording another welding process and any greater base metal thickness. In this case, the process recorded on the first PQR may be used to deposit the root layers using the process(es) recorded on that PQR up to 2t (for short-circuiting type of GMAW, see QW-404.32) in thickness on base metal of the maximum thickness qualified by the other PQR(s) used to support the WPS. The requirements of Note (1) of QW-451.1 and QW-451.2 shall apply.

QW-201 Manufacturer's or Contractor's Responsibility

Each manufacturer or contractor shall list the parameters applicable to welding that he performs in construction of weldments built in accordance with this Code. These parameters shall be listed in a document known as a Welding Procedure Specification (WPS).

Each manufacturer or contractor shall qualify the WPS by the welding of test coupons and the testing of specimens (as required in this Code), and the recording of the welding data and test results in a document known as a Procedure Qualification Record (PQR). The welders or welding operators used to produce weldments to be tested for qualification of procedures shall be under the full supervision and control of the manufacturer or contractor during the production of these test weldments. The weldments to be tested for qualification of procedures shall be welded either by direct employees or by individuals engaged by contract for their services as welders or welding operators under the full supervision and control of the manufacturer or contractor. It is not permissible for the manufacturer or contractor to have the supervision and control of welding of the test weldments performed by another organization. It is permissible, however, to subcontract any or all of the work of preparation of test metal for welding and subsequent work on preparation of test specimens from the completed weldment, performance of nondestructive examination, and mechanical tests, provided the manufacturer or contractor accepts the responsibility for any such work.

The Code recognizes a manufacturer or contractor as the organization which has responsible operational control of the production of the weldments to be made in accordance with this Code. If in an organization effective operational control of welding procedure qualification for two or more companies of different names exists, the companies involved shall describe in their Quality Control system/Quality Assurance Program, the operational control of procedure qualifications. In this case separate welding procedure qualifications are not required, provided all other requirements of Section IX are met.

A WPS may require the support of more than one PQR, while alternatively, one PQR may support a number of WPSs.

The manufacturer or contractor shall certify that he has qualified each Welding Procedure Specification, performed the procedure qualification test, and documented it with the necessary Procedure Qualification Record (PQR).

QW-201.1 The Code recognizes that manufacturers or contractors may maintain effective operational control of PQRs and WPSs under different ownership than existed during the original procedure qualification. When a manufacturer or contractor or part of a manufacturer or contractor is acquired by a new owner(s), the PQRs and WPSs may be used by the new owner(s) without requalification, provided all of the following are met:

(a) the new owner(s) takes responsibility for the WPSs and PQRs;

(b) the WPSs reflect the name of the new owner(s);

(c) the Quality Control System/Quality Assurance Program reflects the source of the PQRs as being from the former manufacturer or contractor.

QW-202 Type of Tests Required

QW-202.1 Mechanical Tests. The type and number of test specimens which shall be tested to qualify a groove weld procedure are given in QW-451, and shall

be removed in a manner similar to that shown in QW-463. If any test specimen required by QW-451 fails to meet the applicable acceptance criteria, the test coupon shall be considered as failed, and a new test coupon shall be welded. Where qualification is for fillet welds only, the requirements are given in QW-202.2(c) and (d); and where qualification is for stud welds only, the requirements are given in QW-202.5.

01 **QW-202.2 Groove and Fillet Welds**

(a) Qualification for Groove Full Penetration Welds. Groove-weld test coupons shall qualify the thickness ranges of both base metal and deposited weld metal to be used in production. Limits of qualification shall be in accordance with QW-451. WPS qualification for groove welds shall be made on groove welds using tension and guided-bend specimens. Notch-toughness tests shall be made when required by other Section(s) of the Code. The WPS shall be qualified for use with groove welds within the range of essential variables listed.

(b) Qualification for Partial Penetration Groove Welds. Partial penetration groove welds shall be qualified in accordance with the requirements of QW-451 for both base metal and deposited weld metal thickness, except there need be no upper limit on the base metal thickness provided qualification was made on base metal having a thickness of $1\frac{1}{2}$ in. (38 mm) or more.

(c) Qualification for Fillet Welds. WPS qualification for fillet welds may be made on groove-weld test coupons using test specimens specified in QW-202.2(a) or (b). Fillet-weld procedures so qualified may be used for welding all thicknesses of base metal for all sizes of fillet welds, and all diameters of pipe or tube in accordance with QW-451.4. Nonpressure-retaining fillet welds, as defined in other Sections of the Code, may as an alternate be qualified with fillet welds only. Tests shall be made in accordance with QW-180. Limits of qualification shall be in accordance with QW-451.3.

QW-202.3 Weld Repair and Buildup. WPS qualified on groove welds shall be applicable for weld repairs to groove and fillet welds and for weld buildup under the following provisions.

(a) There is no limitation on the thickness of base metal or deposited weld metal for fillet welds.

(b) For other than fillet welds, the thickness range for base metal and deposited weld metal for each welding process shall be in accordance with QW-451, except there need be no upper limit on the base metal thickness provided qualification was made on base metal having a thickness of $1\frac{1}{2}$ in. (38 mm) or more.

QW-202.4 Dissimilar Base Metal Thicknesses. 01 WPS qualified on groove welds shall be applicable for production welds between dissimilar base metal thicknesses provided:

(a) the thickness of the thinner member shall be within the range permitted by QW-451;

(b) the thickness of the thicker member shall be as follows.

(1) For P-No. 8, P-No. 41, P-No. 42, P-No. 43, P-No. 44, P-No. 45, P-No. 46, P-No. 51, P-No. 52, P-No. 53, P-No. 61, and P-No. 62 metal, there shall be no limitation on the maximum thickness of the thicker production member in joints of similar P-Number materials provided qualification was made on base metal having a thickness of $\frac{1}{4}$ in. (6 mm) or greater.

(2) For all other metal, the thickness of the thicker member shall be within the range permitted by QW-451, except there need be no limitation on the maximum thickness of the thicker production member provided qualification was made on base metal having a thickness of $1\frac{1}{2}$ in. (38 mm) or more.

More than one procedure qualification may be required to qualify for some dissimilar thickness combinations.

QW-202.5 Stud Welding. Procedure qualification tests for stud welds shall be made in accordance with QW-192. The procedure qualification tests shall qualify the welding procedures for use within the range of the essential variables of QW-261. For studs welded to other than P-No. 1 metals, five additional welds shall be made and subjected to a macro-test, except that this is not required for studs used for extended heating surfaces.

QW-203 Limits of Qualified Positions for Procedures

Unless specifically required otherwise by the welding variables (QW-250), a qualification in any position qualifies the procedure for all positions. The welding process and electrodes must be suitable for use in the positions permitted by the WPS. A welder or welding operator making and passing the WPS qualification test is qualified for the position tested. See QW-301.2.

QW-210 PREPARATION OF TEST COUPON

QW-211 Base Metal

The base metals may consist of either plate, pipe, or other product forms. Qualification in plate also qualifies for pipe welding and vice versa. The dimen-

sions of the test coupon shall be sufficient to provide the required test specimens.

QW-212 Type and Dimensions of Groove Welds

Except as otherwise provided in QW-250, the type and dimensions of the welding groove are not essential variables.

QW-213 P-No. 11 Base Metals

For vessels or parts of vessels constructed with P-No. 11 base metals, weld grooves for thickness less than $\frac{5}{8}$ in. (16 mm) shall be prepared by thermal processes, when such processes are to be employed during fabrication. This groove preparation shall also include back gouging, back grooving, or removal of unsound weld metal by thermal processes, when these processes are to be employed during fabrication.

QW-214 Corrosion-Resistant Weld Metal Overlay

QW-214.1 The size of test coupons, limits of qualification, required examinations and tests, and test specimens shall be as specified in QW-453.

QW-214.2 Essential variables shall be as specified in QW-250 for the applicable welding process.

QW-215 Electron Beam Welding and Laser Beam Welding

QW-215.1 The WPS qualification test coupon shall be prepared with the joint geometry duplicating that to be used in production. If the production weld is to include a lap-over (completing the weld by rewelding over the starting area of the weld, as for a girth weld), such lap-over shall be included in the WPS qualification test coupon.

QW-215.2 The mechanical testing requirements of QW-451 shall apply.

QW-215.3 Essential variables shall be as specified in QW-260 and QW-264 for the applicable welding process.

QW-216 Hard-Facing Weld Metal Overlay

Hard-Facing Weld Metal Overlay refers to weld deposits made, using a variety of processes, to deter the effects of wear and/or abrasion. The following requirements apply regardless of which hard-facing process is used.

QW-216.1 The size of test coupons, limits of qualification, required examinations and tests, and test specimens shall be as specified in QW-453.

QW-216.2 Welding variables shall be as specified in QW-250 for the applicable process.

QW-216.3 Where Spray Fuse methods of hard-facing (e.g., Oxyfuel and Plasma Arc) are to be used, the coupons for these methods shall be prepared and welding variables applied in accordance with QW-216.1 and QW-216.2, respectively.

QW-216.4 If a weld deposit is to be used under a hard-facing weld metal overlay, a base metal with an assigned P-Number and a chemical analysis nominally matching the weld deposit chemical analysis may be substituted to qualify the PQR.

QW-217 Joining of Composite (Clad Metals)

The WPS for groove welds in clad metal shall be qualified as provided in QW-217(a) when any part of the cladding thickness, as permitted by the referencing Code Section, is included in the design calculations. Either QW-217(a) or (b) may be used when the cladding thickness is not included in the design calculations.

(a) The essential and nonessential variables of QW-250 shall apply for each welding process used in production. The procedure qualification test coupon shall be made using the same P-Number base metal, cladding, and welding process, and filler metal combination to be used in production welding. For metal not included in QW/QB-422, the metal used in the composite test plate shall be within the range of chemical composition of that to be used in production. The qualified thickness range for the base metal and filler metal(s) shall be based on the actual test coupon thickness for each as applied to QW-451, except that the minimum thickness of filler metal joining the cladding portion of the weldment shall be based on a chemical analysis performed in accordance with QW-453. Tensile and bend tests required in QW-451 for groove welds shall be made, and they shall contain the full thickness of cladding through the reduced section of the specimen. The bond line between the original cladding and the base metal may be disregarded when evaluating side-bend tests if the cladding was applied by a process other than fusion welding.

(b) The essential and nonessential variables of QW-250 shall apply for each welding process used in

production for joining the base metal portion of the weldment. The PQRs that support this portion of the WPS need not be based on test coupons made with clad metal. For the corrosion-resistant overlay portion of the weld, the essential variables of QW-251.4 shall apply and the test coupon and testing shall be in accordance with QW-453. The WPS shall limit the depth of the groove, which will receive the corrosion-resistant overlay in order to ensure development of the full strength of the underlying weld in the base metal.

QW-218 Applied Linings

QW-218.1 WPSs for attaching applied linings shall be qualified in accordance with QW-202.2(a), (b), or (c).

QW-218.2 As an alternative to the above, each process to be used in attaching applied linings to base metal shall be qualified on a test coupon welded into the form and arrangement to be used in construction using materials that are within the range of chemical composition of the metal to be used for the base plate, the lining, and the weld metal. The welding variables of QW-250 shall apply except for those regarding base metal or weld metal thickness. Qualification tests shall be made for each position to be used in production welding in accordance with QW-461.9, except that qualification in the vertical position, uphill progression shall qualify for all positions. One cross section for each position tested shall be sectioned, polished, and etched to clearly show the demarcation between the base metal and the weld metal. In order to be acceptable, each specimen shall exhibit complete fusion of the weld metal with the base metal and freedom from cracks.

QW-218.3 When chemical analysis of the weld deposit for any elements is required, a chemical analysis shall be performed per QW-453, Note 9 for those elements.

QW-250 WELDING VARIABLES

QW-251 General

QW-251.1 Types of Variables for Welding Procedure Specifications (WPS). These variables (listed for each welding process in QW-252 through QW-265) are subdivided into essential variables, supplementary essential variables, and nonessential variables (QW-401). The "Brief of Variables" listed in the Tables are for reference *only*. See the complete variable in Welding Data of Article IV.

QW-251.2 Essential Variables. Essential variables are those in which a change, as described in the specific variables, is considered to affect the mechanical properties of the weldment, and shall require requalification of the WPS.

Supplementary essential variables are required for metals for which other Sections specify notch-toughness tests and are in addition to the essential variables for each welding process.

QW-251.3 Nonessential Variables. Nonessential variables are those in which a change, as described in the specific variables, may be made in the WPS without requalification.

QW-251.4 Special Processes

(a) The special process essential variables for corrosion-resistant and hard-surfacing weld metal overlays are as indicated in the following tables for the specified process. Only the variables specified for special processes shall apply. A change in the corrosion-resistant or hard-surfacing welding process shall require requalification.

(b) WPS qualified for corrosion-resistant and hard-surfacing overlay welding, in accordance with other Sections when such qualification rules were included in those Sections, may be used with the same provisions as provided in QW-100.3.

QW-252
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Oxyfuel Gas Welding (OFW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.2	± Backing			X
	.3	ϕ Backing comp.			X
	.10	ϕ Root spacing			X
QW-403 Base Metals	.1	ϕ P-Number	X		
	.2	Max. *T* qualified	X		
	.13	ϕ P-No. 5/9/10	X		
QW-404 Filler Metals	.3	ϕ Size			X
	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.12	ϕ AWS class.	X		
QW-405 Positions	.1	+ Position			X
QW-406 Preheat	.1	Decrease > 100°F (56°C)			X
QW-407 PWHT	.1	ϕ PWHT	X		
QW-408 Gas	.7	ϕ Type fuel gas	X		
QW-410 Technique	.1	ϕ String/weave			X
	.2	ϕ Flame characteristics			X
	.4	ϕ ←→ Technique			X
	.5	ϕ Method cleaning			X
	.26	± Peening			X

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
− Deletion < Decrease/less than ↓ Downhill → Backhand

Location	Interpretation	File No.	Page No.
Part QW (Cont'd)			
QW-500	IX-01-14	BC01-332	433
QW-510	IX-01-11	BC01-089	429
QW-540	IX-01-11	BC01-089	429