NOTICE OF INCORPORATION

United States Legal Document

☞ All citizens and residents are hereby advised that this is a legally binding document duly incorporated by reference and that failure to comply with such requirements as hereby detailed within may subject you to criminal or civil penalties under the law. Ignorance of the law shall not excuse noncompliance and it is the responsibility of the citizens to inform themselves as to the laws that are enacted in the United States of America and in the states and cities contained therein. ☜

⁂

ASME BPVC IX (2010), Boiler & Pressure Vessel Code, Section IX, Welding and Brazing Qualifications, as required by the States of Colorado, Connecticut, Delaware, Indiana, Minnesota, Nevada, North Carolina, Oklahoma, Rhode Island, Tennessee, et. alia.

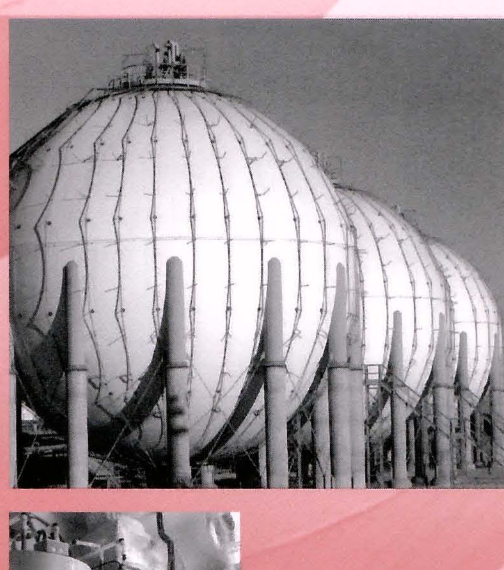
2010 ASME Boiler and Pressure Vessel Code

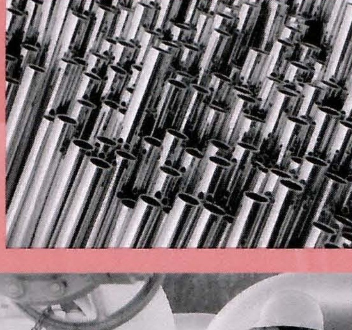
AN INTERNATIONAL CODE

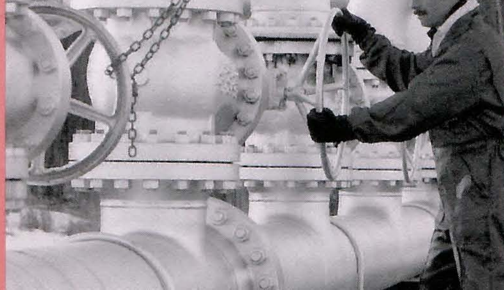
IX

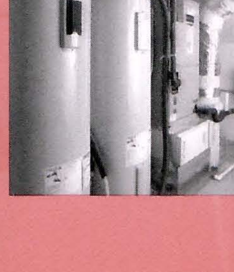
Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators

Welding and Brazing Qualifications









ASME

SETTING THE STANDARD

AN INTERNATIONAL CODE

2010 ASME Boiler & Pressure Vessel Code

2010 Edition

July 1, 2010

IX

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

ASME Boiler and Pressure Vessel Committee on Welding and Brazing

ASME

SETTING THE STANDARD

Three Park Avenue • New York, NY • 10016 USA

Date of Issuance: July 1, 2010
(Includes all Addenda dated July 2009 and earlier)

This international code or standard was developed under procedures accredited as meeting the criteria for American National Standards and it is an American National Standard. The Standards Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

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ASME accepts responsibility for only those interpretations of this document issued in accordance with the established ASME procedures and policies, which precludes the issuance of interpretations by individuals.

The footnotes in this document are part of this American National Standard.

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The above ASME symbols are registered in the U.S. Patent Office.

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Three Park Avenue, New York, NY 10016-5990

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BOILER AND PRESSURE VESSEL CODE

(10)

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ADDENDA

Addenda, which include additions and revisions to individual Sections of the Code, will be sent automatically to purchasers of the applicable Sections up to the publication of the 2013 Code. The 2010 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. Interpretations of Section III, Divisions 1 and 2, will be included with the update service to Subsection NCA.

Interpretations of the Code are posted in January and July at www.cstools.asme.org/interpretations.

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 that have been adopted will appear in the appropriate 2010 Code Cases book: "Boilers and Pressure Vessels" and "Nuclear Components." Supplements will be sent automatically to the purchasers of the Code Cases books up to the publication of the 2013 Code.

FOREWORD

(10)

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, relating only to pressure integrity, governing the construction[1] of boilers, pressure vessels, transport tanks and nuclear components, and inservice inspection for pressure integrity of nuclear components and transport tanks, and to interpret these rules when questions arise regarding their intent. This code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks and nuclear components, and the inservice inspection of nuclear components and transport tanks. The user of the Code should refer to other pertinent codes, standards, laws, regulations, or other relevant documents. With few exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. Recognizing this, the Committee has approved a wide variety of construction rules in this Section to allow the user or his designee to select those which will provide a pressure vessel having a margin for deterioration in service so as to give a reasonably long, safe period of usefulness. Accordingly, it is not intended that this Section be used as a design handbook; rather, engineering judgment must be employed in the selection of those sets of Code rules suitable to any specific service or need.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction 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.

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

Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute and published at *http://cstools.asme.org/csconnect/public/index.cfm?PublicReview=Revisions* to invite comments from all interested persons. After the allotted time for public review and final approval by ASME, revisions are published in updates 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. Revisions, except for revisions to material specifications in Section II, Parts A and B, become mandatory six months after such date of issuance, except for boilers or pressure vessels contracted for prior to the end of the six-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 Guidelines for Acceptable ASTM Editions and in the Guidelines for Acceptable Non-ASTM Editions, in Section II, Parts A and B. These Guidelines list, for each specification, the latest edition adopted by ASME, and earlier and later editions considered by ASME to be identical for ASME construction.

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.

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.

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 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 the Guidelines for Acceptable Editions in 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; Guidelines for Acceptable Editions in Section II, Part A and Guidelines for Acceptable Editions in 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 the Guidelines for Acceptable Editions in 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 the Guidelines for Acceptable Editions in 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.

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

(10)

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 that 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 that 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." An ASME corporate logo shall not be used by any organization other than ASME.

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.

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 that 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 that 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 2007 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 organization 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 2007 Edition of Section IX understand the basic criteria in reviewing the requirements which have been established.

Section IX does not contain rules to cover all welding and brazing factors affecting production weld or braze properties under all circumstances. Where such welding or brazing factors are determined by the Manufacturer to affect weld or braze properties, the Manufacturer shall address those welding or brazing factors to ensure that the required properties are achieved in the production weldment or brazement.

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 effect 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 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)

(e) standard welding procedures (Article V Welding)

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.

Beginning with the 2000 Addenda, the use of Standard Welding Procedure Specifications (SWPSs) was permitted. Article V provides the requirements and limitations that govern the use of these documents. The SWPSs approved for use are listed in Appendix E.

In the 2004 Edition, rules for temper bead welding were added.

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, welding operator, 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, or volumetric NDE of a test coupon, or the initial production weld. Brazers or brazing operators may not be qualified by volumetric NDE.

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, Nonmandatory Appendix D, has been included for users still wishing to locate groupings of metals by welding P-Number.

In the 2009 Addenda, S-Number base metals listed in the QW/QB-422 table were reassigned as P-Numbers and the S-Number listings and references were deleted.

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.

With the incorporation of the new Creep-Strength Enhanced Ferritic (CSEF) alloys into the Code, using the existing P-Number groupings to specify PWHT parameters can lead to variations in heat treatments that may significantly degrade the mechanical properties of these alloys.

CSEF alloys are a family of ferritic steels whose creep strength is enhanced by the creation of a precise condition of microstructure, specifically martensite or bainite, which is stabilized during tempering by controlled precipitation of temper-resistant carbides, carbo-nitrides, or other stable phases.

In the 2007 Edition of the Code, only P-No. 5B, Group 2 Base metals met this definition and was approved for Code construction. Looking forward, a number of CSEF alloys are already in use in Code Cases and drawing near to incorporation. To facilitate addressing their special requirements, P-Numbers 15A through P-Number 15F have been established for CSEF alloys.

SUMMARY OF CHANGES

The 2010 Edition of this Code contains revisions in addition to the 2007 Edition with 2008 and 2009 Addenda. The revisions are identified with the designation **(10)** in the margin and, as described in the Foreword, become mandatory 6 months after the publication date of the 2010 Edition. To invoke these revisions before their mandatory date, use the designation "2010 Edition" in documentation required by this Code. If you choose not to invoke these revisions before their mandatory date, use the designation "2007 Edition through the 2009 Addenda" in documentation required by this Code.

The Record Numbers listed below are explained in more detail in "List of Changes in Record Number Order" following this Summary of Changes.

Changes given below are identified on the pages by a margin note, **(10)**, placed next to the affected area.

Page	*Location*	*Change (Record Number)*
v, vi	List of Sections	(1) Paragraph below "Addenda" editorially revised (2) Second paragraph below "Interpretations" editorially revised (3) Paragraph below "Code Cases" editorially revised
vii, viii	Foreword	Ninth and eleventh paragraphs editorially revised
ix	Statement of Policy on the Use of Code Symbols	(1) In third paragraph, last sentence added (2) Last paragraph deleted
xxii, xxiii	Introduction	(1) Under "Procedure Qualifications," last paragraph, "2007" corrected to "2004" by errata *(09-2026)* (2) Under "In Performance Qualifications," first and last paragraphs revised *(08-1330)* (3) Under "Welding and Brazing Data," fifth paragraph, "2008" corrected to "2009" by errata *(09-2026)*
1	QW-100.3	In fifth paragraph, reference corrected to QW-420 by errata *(09-2026)*
3, 4	QW-142	Revised *(08-1330)*
	QW-143	Revised *(08-1330)*
7, 8	QW-191	Revised in its entirety *(08-1330)*
20	QW-252	For QW-403, last row deleted by errata *(09-2026)*
52	QW-300.1	Third paragraph revised *(08-1330)*
53–55	QW-302	(1) For QW-302.1, second sentence, second reference corrected to QW-463.2(g) by errata *(09-1364)* (2) QW-302.2 revised *(08-1330)*
	QW-304	Revised in its entirety *(08-1330)*
	QW-305	Revised in its entirety *(08-1330)*
56	QW-321.3	Revised *(08-1330)*
63	QW-403.6	In last sentence, "material" replaced with "or P-No. 10H material" *(09-588)*
	QW-403.18	Last reference corrected to QW-420 by errata *(09-2026)*
67	QW-406.3	In last sentence, "material" replaced with "or P-No. 10H material" *(09-588)*

Page	*Location*	*Change (Record Number)*
68	QW-407.4	Revised *(09-588)*
69	QW-409.1	Revised *(06-781, 09-588)*
	QW-409.8	Revised *(06-781)*
70	QW-409.26	Revised *(06-781)*
	QW-409.29	Subparagraph (b)(2) revised *(06-781)*
71	QW-410.9	In last sentence, "material" replaced with "or P-No. 10H material" *(09-588)*
	QW-410.10	In last sentence, "material" replaced with "or P-No. 10H material" *(09-588)*
74	QW-420	(1) Sixth paragraph added *(07-2001)* (2) In seventh paragraph, "2008" corrected to "2009" by errata *(09-2026)*
76–85	QW/QB-422	(1) For A 108, Min. Spec. Tensile entries deleted *(07-2001)* (2) A 148 deleted *(07-2001)* (3) SA-182, S34565 added *(09-320)* (4) For A 182, F60, Spec. No. changed to SA-182 *(09-767)* (5) A 182, S34565 deleted *(09-320)* (6) A 199 added *(09-1149)* (7) SA-213, TP310HCbN added *(09-322)* (8) SA-213, S34565 added *(09-320)* (9) For A 217, Welding P-No. and Welding Group No. changed to 15E and 1, respectively *(09-636)* (10) For SA-234, Product Form changed to "Piping fittings" *(09-1149)* (11) For SA-234, WP5 and WP9, Grades changed to WP5, Cl. 1 and WP9, Cl. 1, respectively *(09-1149)* (12) A 234 added *(09-1149)* (13) SA-240, 2205 added *(09-767)* (14) SA-240, S34565 added *(09-320)* (15) A 240, S32205 deleted *(09-767)* (16) A 240, S34565 deleted *(09-320)*
86–92	QW/QB-422	(1) For A 269, Min. Spec. Tensile entries deleted *(07-2001)* (2) For existing SA-299 line, Grade added *(09-650)* (3) SA-299, B added *(09-650)* (4) SA-312, S34565 added *(09-320)* (5) A 312 deleted *(09-320)* (6) For A 356, 12A, Welding P-No. and Welding Group No. changed to 15E and 1, respectively *(09-636)* (7) SA-376, S34565 added *(09-320)* (8) Eighth, ninth, and eleventh lines of A 381 deleted *(07-2001)*
93–101	QW/QB-422	(1) For A 403, S34565, Spec. No. changed to SA-403, Brazing P-No. added, and ISO 15608 Group changed to 8.3 *(09-320)* (2) SA-409, S34565 added *(09-320)* (3) SA-479, 2205 added *(09-767)* (4) SA-479, S34565 added *(09-320)* (5) For A 513, Min. Spec. Tensile entries deleted *(07-2001)*

Page	Location	Change (Record Number)
		(6) For A 519, Min. Spec. Tensile entries deleted *(07-2001)* (7) A 521 deleted *(07-2001)*
102–108	QW/QB-422	(1) For second through fifth lines of A 633, Grade corrected by errata *(09-2026)* (2) For SA-645, Grade added *(09-282)* (3) A 668 deleted *(07-2001)* (4) A 675, Welding P-No. and Welding Group No. deleted *(07-2001)* (5) A 691 revised *(09-1149)* (6) For A 707, Min. Spec. Tensile entries deleted *(07-2001)* (7) SA-789, S32205 added *(09-767)* (8) A 789 deleted *(09-767)* (9) SA-790, S32205 added *(09-767)* (10) A 790 deleted *(09-767)*
109, 110	QW/QB-422	(1) SA-815, S32205 added *(09-767)* (2) A 815 deleted *(09-767)* (3) SA-841 added *(09-1345)* (4) For A 890, Min. Spec. Tensile deleted *(07-2001)*
111, 114	QW/QB-422	(1) SA/AS 1548 deleted *(09-1010)* (2) For SA/AS 1548 lines, Grade revised *(09-1010)* (3) SA/EN 10025-2 added *(09-506)* (4) SA/EN 10028-2, P355GH added *(09-202)* (5) SA/EN 10028-2, 13CrMoSi5-5+QT added *(09-724)* (6) For SA/EN 10028-3, 51 (350) and 52 (360) added *(09-239)* (7) SA/EN 10028-4 added *(09-507)* (8) SA/EN 10088-2 added *(09-506)* (9) SA/EN 10216-2 added *(09-503)* (10) SA/EN 10217-1 added *(09-506)* (11) SA/EN 10222-2 added *(09-300)*
115–132	QW/QB-422	(1) For SB-169, C61400, Min. Spec. Tensiles 72 (495) and 70 (485) added *(09-673)* (2) For SB-169, C61400, 65 (450), Product Form revised *(09-673)* (3) SB-265, R56323 added *(09-1023)* (4) SB-338, R56323 added *(09-1023)* (5) SB-348, R56323 added *(09-1023)* (6) SB-363, R56323 added *(09-1023)* (7) SB-381, R56323 added *(09-1023)* (8) SB-861, R56323 added *(09-1023)* (9) SB-862, R56323 added *(09-1023)*
144	QW-451.1	(1) In last two rows, references to Note (3) deleted *(09-1497)* (2) Note (3) definition revised *(09-1497)*
149	QW-452.5	(1) First row revised *(08-210)* (2) Notes revised *(08-210)*
163	QW-462.4(a)	Revised *(08-1630)*
	QW-462.4(b)	Revised *(08-1630)*
169	QW-462.5(e)	Revised *(08-1630)*
184	QW-463.2(h)	In the bottom callout, "5f" corrected to "5F" by errata *(09-1364)*

Page	*Location*	*Change (Record Number)*
193, 196, 198, 200	QW/QB-492	(1) Definition of *instantaneous power or energy* added *(06-781)* (2) Definition of *waveform controlled welding* added *(06-781)* (3) Definition of *machine welding* revised *(09-210)* (4) Comma removed from "welding, operator" by errata *(09-1365)*
222	QB-451.3	Notes revised *(09-883)*
224	QB-452.1	Note (1) revised *(09-769)*
249	QW-482	Back revised *(06-781)*
250	QW-483	Revised *(06-781)*
252	QW-484A	Revised *(08-1330)*
253	QW-484B	Revised *(08-1330)*
258–275	Nonmandatory Appendix D	Table updated to reflect QW/QB-422 changes *(07-2001, 09-202, 09-239, 09-282, 09-300, 09-320, 09-322, 09-503, 09-506, 09-507, 09-636, 09-650, 09-673, 09-724, 09-767, 09-1010, 09-1023, 09-1149, 09-1345)*
276, 277	Nonmandatory Appendix E	Under Austenitic Stainless Steel Plate and Pipe, first designation corrected to B2.1-8-023-94 (R05) by errata *(09-1647)*
283, 284	Nonmandatory Appendix H	Added *(06-781)*

NOTE: Volume 60 of the Interpretations to Section IX of the ASME Boiler and Pressure Vessel Code follows the last page of this Edition.

LIST OF CHANGES IN RECORD NUMBER ORDER

Record Number	Change
06-781	Revised supplementary essential variable QW-409.1 to address heat input determination using instantaneous energy or power measurements. Revised nonessential variable QW-409.8 to address waveform controlled power source settings. Revised special process essential variable QW-409.26 to address heat input determination using instantaneous energy or power measurements. Revised temper bead welding essential variable QW-409.26 to address heat input determination using instantaneous energy or power measurements. Revised QW/QB-492 to add definitions for waveform controlled welding and instantaneous power. Revised QW-482 form to add provisions for specifying wire feed speed and energy or power and modify format of Electrical Characteristics columns. Revised QW-483 to provide a space for recording heat input. Added a nonmandatory appendix to discuss new and existing procedure qualifications using waveform controlled power sources.
07-2001	Deleted the following three material specifications from QW/QB-422: A148, A521, and A668 Revised QW-420.1 to require procedure qualification be done only with materials that have a minimum specified tensile strength value.
08-210	Revised QW-452.5 to clarify its intent and use.
08-1330	Revised Section IX text in Introduction, QW-142, QW-143, QW-191, QW-300.1, QW-302.2, QW-304, QW-305, and QW-321.3 to permit the qualification of welders and welding operators by UT examination in lieu of radiography or mechanical testing for test coupons and production welds. Revised QW-484A and QW-484B to change "radiographic" to "nondestructive," implementing these revisions on those forms.
08-1630	Revised figures QW-462.4(a), QW-462.4(b), and QW-462.5(e) to remove all dashed lines other than the lines where cuts are to be made to remove test specimens.
09-202	Revised QW/QB-422 and Appendix D to include SA/EN 10028-2, Grade P355GH as a P-No. 1 Group 2 material.
09-210	Revised the definition of "machine welding."
09-239	Revised QW/QB-422 to add SA/EN 10028-3 P275NH for plate thicknesses 4 in. to 6 in. (100 mm to 150 mm) and 6 in. to 10 in. (150 mm to 250 mm).
09-282	Added the Grade designation, Grade A, to the listings for SA-645 in table QW/QB-422 and Appendix D.
09-300	Revised QW/QB-422 and Appendix D to include SA/EN 10222-2, Grades P280GH, P305GH, 13CrMo4-5, 11CrMo9-10, and X10CrMoVNb9-1 and assign P-No. 1 Group 1, P-No. 1 Group 2, P-No. 4 Group 1, P-No. 5A Group 1, and P-No. 15E Group 1, respectively, to these materials.
09-320	Revised QW/QB-422 and Appendix D to add UNS S34565 materials.
09-322	Revised QW/QB-422 and Appendix D to add SA-213 310HCbN (UNS S31042) materials.
09-503	Revised QW/QB-422 and Appendix D to include SA/EN 10216 materials P235GH, P265GH, 16Mo3, 13CrMo4-5, 10CrMo9-10 and X10CrMoVNb9-1 and assign them as P-No. 1 Group 1, P-No. 1 Group 1, P-No. 3 Group 1, P-No. 4 Group 1, P-No. 5A Group 1, and P-No. 15E Group 1, respectively.
09-506	Revised QW/QB-422 and Appendix D to include SA/EN 10025-2 S236JR, SA/EN 10088-2 X6CrNiMoTi 17-12-2, and SA/EN 10217-1 P235TR2 material P-No. 1 Group 1, P-No, 8 Group 1 and P-No. 1 Group 1, respectively.
09-507	Revised QW/QB-422 and Appendix D to include SA/EN 10028-4, Grades X7Ni9 and X8Ni9 as P-No. 11A Group 1.
09-588	Revised QW-403.6, QW-406.3, QW-407.4, QW-409.1, and QW-410.9 to add "P-No. 10H materials."
09-636	Revised QW/QB-422 and Appendix D to delete P-No. 5B Group 2 assignments for A217 C12A, A356 12A, and A691 9Cr, Class 2 and add them as P-No. 15E Group 1 materials.
09-650	Revised QW/QB-422 and Appendix D to include SA-299 Grade B material as P-No. 1 Group 3 and show SA-299 Grade A as P-No. 1 Group 2 material.
09-673	Added two stress lines to QW/QB-422 for size breaks that were omitted (SB-169 C61400) and revised another.
09-724	Revised QW/QB-422 and Appendix D to add SA/EN 10028-2 material 13CrMoSi5-5+QT as P-No. 4 Group 1 material.

Record Number	Change
09-767	Revised QW/QB-422 and Appendix D to include product forms of UNS S32205 material as P-No. 10H.
09-769	Revised QB-452.1 to explain when sectioning tests are to be used.
09-883	Added footnote 4 to QB-451.3 referring to QB-451.5
09-1010	Added new grade designations of SA/AS 1548 to QW/QB-422 and Appendix D.
09-1023	Added Grade 28 to Table QW/QB-422 and Appendix D as shown in the proposal.
09-1149	Added P-Number listings in QW/QB-422 and Appendix D for: A 199 T5; A 199 T9; A 199 T11; A 199 T21; A 199 T22; A 234 WP5 Cl.1; A 234 WP5 Cl.3; A 234 WP9 Cl.3; A 234 WP11 Cl.3; A 234 WP12 Cl.2; A 234 WP22 Cl.3; A 234 WP9 Cl.1; and A 691 91.
09-1345	Revised QW/QB-422 and Appendix D to add SA-841 Grade A, Class 1 and Grade B, Class 2.
09-1364	Errata correction. See Summary of Changes for details.
09-1365	Errata correction. See Summary of Changes for details.
09-1497	Revised QW-451.1 by removing Note (3) from thicknesses over 6 in. and added PAW to Note (3).
09-1647	Errata correction. See Summary of Changes for details.
09-2026	Errata correction. See Summary of Changes for details.

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) (10)
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 rules under which Section IX requirements are mandatory, in whole or in part, and give additional requirements. 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 except as specified in QW-420.

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 a signature or other means as described in the manufacturer's or contractor's Quality Control System 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 figure QW-461.1 or figure 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 figure QW-461.3 or figure 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 figure QW-461.3, illustration (a).

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

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

QW-121.4 Overhead Position 4G. Plate in a horizontal plane with the weld metal deposited from underneath. Refer to figure QW-461.3, illustration (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 figure QW-461.4, illustration (a).

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 figure QW-461.4, illustration (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 figure QW-461.4, illustration (c).

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

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 figure QW-461.4, illustration (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 figures 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 figure QW-461.5 or figure 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 figure QW-461.5, illustration (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 figure QW-461.5, illustration (b).

QW-131.3 Vertical Position 3F. Plates so placed that the weld is deposited with its axis vertical. Refer to figure QW-461.5, illustration (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 figure QW-461.5, illustration (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 figure QW-461.6, illustration (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 figure QW-461.6, illustration (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 figure QW-461.6, illustration (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 figure QW-461.6, illustration (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 figure QW-461.6, illustration (e).

QW-140 TYPES AND PURPOSES OF TESTS AND EXAMINATIONS

QW-141 Mechanical Tests

Mechanical tests used in procedure or performance qualification are specified in QW-141.1 through QW-141.5.

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 figures 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 (10)

Radiographic or ultrasonic examination per QW-191 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 (10)

Radiographic or ultrasonic examination per QW-191 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 standards.

QW-150 TENSION TESTS

QW-151 Specimens

Tension test specimens shall conform to one of the types illustrated in figures 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 figure 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 figure QW-462.1(b) may be used for tension tests on all thicknesses of pipe having an outside diameter greater than 3 in. (75 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. (75 mm) or less, reduced-section specimens conforming to the requirements given in figure QW-462.1(c) may be used for tension tests.

QW-151.3 Turned Specimens. Turned specimens conforming to the requirements given in figure 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 figure QW-462.1(d) possible for test coupon thickness [per Note (a) of figure 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 $\frac{5}{8}$ 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 figure QW-462.1(e) may be used for testing pipe with an outside diameter of 3 in. (75 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

QW-153.1 Tensile Strength. Minimum values for procedure qualification are provided under the column heading "Minimum Specified Tensile, ksi" of table 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) less than ½ in. (13 mm). For Aluminum Alclad materials ½ 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 figures 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 figure QW-462.2.

Specimens of base metal thickness equal to or greater than 1½ in. (38 mm) may be cut into approximately equal strips between ¾ in. (19 mm) and 1½ 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 figure 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 figure QW-462.3(a). For subsize transverse root bends, see QW-161.4.

QW-161.4 Subsize Transverse Face and Root Bends. Bend specimens taken from small diameter pipe coupons may be subsized in accordance with General Note (b) of figure QW-462.3(a).

QW-161.5 Longitudinal-Bend Tests. Longitudinal-bend tests may be used in lieu of the transverse side-bend, face-bend, 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 figure 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 figure 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 figure QW-466.1 or figure 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 ⅛ in. (3 mm) diameter wire cannot be inserted between the specimen and the die of figure QW-466.1, or the specimen is bottom ejected if the roller type of jig (figure QW-466.2) is used.

When using the wrap around jig (figure 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 figure 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 discontinuity in the weld or heat-affected zone exceeding $\frac{1}{8}$ in. (3 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. (1.5 mm), measured in any direction, shall be permitted in the cladding, and no open discontinuity exceeding $\frac{1}{8}$ in. (3 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 figure 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 figure 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 figure QW-462.4(a) or figure 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. (50 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. (50 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 figure QW-462.4(b) or figure QW-462.4(c). The test coupon for plate-to-plate shall be cut transversely to provide a center section approximately 4 in. (100 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 figure 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. (50 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. (100 mm) performance specimen center section in figure QW-462.4(b) or the stem of the quarter section in figure 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 $\frac{3}{8}$ in. (10 mm) in figure QW-462.4(b) or 10% of the quarter section in figure QW-462.4(c).

QW-183 Macro-Examination — Procedure Specimens

One face of each cross section of the five test specimens in figure QW-462.4(a) or four test specimens in figure 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

(a) visual examination of the cross sections of the weld metal and heat-affected zone shall show complete fusion and freedom from cracks

(b) there shall be not more than $\frac{1}{8}$ in. (3 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. (25 mm) long, in figure QW-462.4(b) or the cut end of one of the pipe quarter sections in figure 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

(a) 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 $\frac{1}{32}$ in. (0.8 mm) shall be acceptable

(b) the weld shall not have a concavity or convexity greater than $\frac{1}{16}$ in. (1.5 mm)

(c) there shall be not more than $\frac{1}{8}$ in. (3 mm) difference in the lengths of the legs of the fillet

QW-190 OTHER TESTS AND EXAMINATIONS

QW-191 Volumetric NDE (10)

QW-191.1 Radiographic Examination

QW-191.1.1 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 image quality requirements on production or technique radiographs shall be considered satisfactory evidence of compliance with Article 2 of Section V

(b) final acceptance of radiographs shall be based on the ability to see the prescribed image and the specified hole of a hole-type image quality indicator (IQI) or the designated wire of a wire-type IQI. The acceptance standards of QW-191.1.2 shall be met.

QW-191.1.2 Acceptance Criteria

QW-191.1.2.1 Terminology

(a) 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.

(b) 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-191.1.2.2 Qualification Test Welds. 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) $\frac{1}{8}$ in. (3 mm) for t up to $\frac{3}{8}$ in. (10 mm), inclusive

(b) $\frac{1}{3}t$ for t over $\frac{3}{8}$ in. (10 mm) to $2\frac{1}{4}$ in. (57 mm), inclusive

(c) $\frac{3}{4}$ in. (19 mm) for t over $2\frac{1}{4}$ 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 $\frac{1}{8}$ in. (3 mm), whichever is smaller.

(2) For welds in material less than $\frac{1}{8}$ in. (3 mm) in thickness, the maximum number of acceptable rounded indications shall not exceed 12 in a 6 in. (150 mm) length of weld. A proportionately fewer number of rounded indications shall be permitted in welds less than 6 in. (150 mm) in length.

(3) For welds in material $\frac{1}{8}$ in. (3 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 $\frac{1}{32}$ 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-191.1.2.3 Production Welds. The acceptance criteria for welders or welding operators who qualify on production welds by radiography as permitted in QW-304.1 or QW-305.1 shall be per QW-191.1.2.2.

QW-191.2 Ultrasonic Examination

QW-191.2.1 Method

(a) The ultrasonic examination in QW-142 for welders and in QW-143 for welding operators may be conducted on test welds in material $\frac{1}{2}$ in. (13 mm) thick or greater.

(b) Ultrasonic examinations shall be performed using a written procedure verified by the manufacturer to be in compliance with paragraph T-150, Article 1, Section V and the requirements of Article 4, Section V for methods, procedures, and qualifications.

(c) Ultrasonic examination personnel shall meet the requirements of QW-191.2.2.

QW-191.2.2 Personnel Qualifications and Certifications

(a) The Manufacturer shall verify all personnel performing ultrasonic examinations for welder and welding operator qualifications have been qualified and certified in accordance with their employer's written practice.

(b) The employer's written practice for qualification and certification of examination personnel shall meet all applicable requirements of SNT-TC-1A1 for the examination method and technique.

(c) Alternatively, the ASNT Central Certification Program (ACCP) or CP-1891 may be used to fulfill the examination and demonstration requirements of SNT-TC-1A and the employer's written practice.

(d) Provisions for the training, experience, qualification, and certification of NDE personnel shall be described in the Manufacturer's Quality Control System.

QW-191.2.3 Acceptance Criteria for Qualification Test Welds. Indications shall be sized using the applicable technique(s) provided in the written procedure for the examination method. Indications shall be evaluated for acceptance as follows:

(a) All indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

(b) Indications exceeding $\frac{1}{8}$ in. (3 mm) in length are considered relevant, and are unacceptable when their lengths exceed

(1) $\frac{1}{8}$ in. (3 mm) for t up to $\frac{3}{8}$ in. (10 mm).

(2) $\frac{1}{3}t$ for t from $\frac{3}{8}$ in. to $2\frac{1}{4}$ in. (10 mm to 57 mm).

(3) $\frac{3}{4}$ in. (19 mm) for t over $2\frac{1}{4}$ in. (57 mm), where t is the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t.

QW-191.2.4 Acceptance Criteria for Production Welds. The acceptance criteria for welders or welding operators who qualify on production welds by ultrasonic examination as permitted in QW-304.1 or QW-305.1 shall be per QW-191.2.3.

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

QW-192 Stud-Weld Tests

QW-192.1 Procedure Qualification Specimens

QW-192.1.1 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 figure 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 figure 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 figure QW-466.6, except that studs without heads may be gripped on the unwelded end in the jaws of the tensile testing machine.

QW-192.1.2 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-192.1.3 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. (mm)	Threads/in. and Series Designated	Testing Torque, ft-lb (J)
1/4 (6.4)	28 UNF	5.0 (6.8)
1/4 (6.4)	20 UNC	4.2 (5.7)
5/16 (7.9)	24 UNF	9.5 (12.9)
5/16 (7.9)	18 UNC	8.6 (11.7)
3/8 (9.5)	24 UNF	17 (23.0)
3/8 (9.5)	16 UNC	15 (20.3)
7/16 (11.1)	20 UNF	27 (36.6)
7/16 (11.1)	14 UNC	24 (32.5)
1/2 (12.7)	20 UNF	42 (57.0)
1/2 (12.7)	13 UNC	37 (50.2)
9/16 (14.3)	18 UNF	60 (81.4)
9/16 (14.3)	12 UNC	54 (73.2)
5/8 (15.9)	18 UNF	84 (114.0)
5/8 (15.9)	11 UNC	74 (100.0)
3/4 (19.0)	16 UNF	147 (200.0)
3/4 (19.0)	10 UNC	132 (180.0)
7/8 (22.2)	14 UNF	234 (320.0)
7/8 (22.2)	9 UNC	212 (285.0)
1 (25.4)	12 UNF	348 (470.0)
1 (25.4)	8 UNC	318 (430.0)

Required Torque for Testing Threaded Austenitic Stainless Steel Studs

Nominal Diameter of Studs, in. (mm)	Threads/in. and Series Designated	Testing Torque, ft-lb (J)
1/4 (6.4)	28 UNF	4.5 (6.1)
1/4 (6.4)	20 UNC	4.0 (5.4)
5/16 (7.9)	24 UNF	9.0 (12.2)
5/16 (7.9)	18 UNC	8.0 (10.8)
3/8 (9.5)	24 UNF	16.5 (22.4)
3/8 (9.5)	16 UNC	14.5 (19.7)
7/16 (11.1)	20 UNF	26.0 (35.3)
7/16 (11.1)	14 UNC	23.0 (31.2)
1/2 (12.7)	20 UNF	40.0 (54.2)
1/2 (12.7)	13 UNC	35.5 (48.1)
5/8 (15.9)	18 UNF	80.00 (108.5)
5/8 (15.9)	11 UNC	71.00 (96.3)
3/4 (19.0)	16 UNF	140.00 (189.8)
3/4 (19.0)	10 UNC	125.00 (169.5)
7/8 (22.2)	14 UNF	223.00 (302.3)
7/8 (22.2)	9 UNC	202.00 (273.9)
1 (25.4)	14 UNF	339.00 (459.6)
1 (25.4)	8 UNC	303.00 (410.8)

Alternatively, where torquing to destruction is not feasible, tensile testing may be used. For carbon and austenitic stainless steel studs, the failure strength shall be not less than 35,000 psi (240 MPa) and 30,000 psi (210 MPa), respectively. For other metals, the failure strength shall not be less than half 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-192.1.4 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 10X magnification, which is required by QW-202.5 when studs are welded to metals other than P-No. 1.

QW-192.2 Performance Qualification Specimens

QW-192.2.1 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 figure QW-466.4.

QW-192.2.2 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-193 Tube-to-Tubesheet Tests

When the applicable Code Section requires the use of this paragraph for tube-to-tubesheet demonstration mockup qualification, QW-193.1 through QW-193.1.3 shall apply.

QW-193.1 Procedure Qualification Specimens. Ten mockup welds are required to qualify each procedure. The mockup assembly shall essentially duplicate the tube hole configuration and the tube-to-tubesheet joint design within the limits of the essential variables of QW-288. The thickness of the mockup tubesheet is not required to be thicker than 2 in. (50 mm) and the cladding may be represented by base material of essentially equivalent chemical composition to the cladding composition. The mockup welds shall be submitted to the following tests sequentially and must meet the applicable acceptance criteria.

QW-193.1.1 Acceptance Criteria — Visual Examination. The accessible surfaces of the welds shall be examined visually with no magnification required. The welds shall show complete fusion and no evidence of burning through the tube wall, and shall be free from cracking or porosity.

QW-193.1.2 Acceptance Criteria — Liquid Penetrant. The liquid penetrant examination shall meet the requirements of Section V, Article 6. The weld surfaces shall meet the requirements of QW-195.2.

QW-193.1.3 Acceptance Criteria — Macro-Examination. The mockup welds shall be sectioned through the center of the tube for macro-examination. The four exposed surfaces shall be smoothed and etched with a suitable etchant (see QW-470) to give a clear definition of the weld and heat-affected zone. Using a magnification of 10X to 20X, the exposed cross sections of the weld shall confirm

(a) minimum leak path dimension required by the design

(b) no cracking

(c) complete fusion of the weld deposit into the tubesheet and tube wall face

(d) complete penetration of the weld deposit to within $\frac{1}{64}$ in. (0.4 mm) of the root of the joint

(e) porosity shall not reduce the weld throat below the required minimum leak path thickness

QW-193.2 Performance Qualification Specimens. Five mockup welds are required to qualify each welder or welding operator. The same rules as that for procedure qualification (QW-193.1) shall be followed. Only one mockup weld is required to renew a welder's or welding operator's qualification when that qualification has expired or been revoked per the requirements of QW-322.1.

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

relevant indications: indications with major dimensions greater than $\frac{1}{16}$ in. (1.5 mm).

linear indications: an indication having a length greater than three times the width.

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 in the following:

(a) relevant linear indications

(b) relevant rounded indications greater than $\frac{3}{16}$ in. (5 mm)

(c) four or more relevant rounded indications in a line separated by $\frac{1}{16}$ in. (1.5 mm) or less (edge-to-edge)

QW-196 Resistance Weld Testing

QW-196.1 Macro-Examination

QW-196.1.1 Welds shall be cross-sectioned, polished, and etched to reveal the weld metal. The section shall be examined at 10X magnification. Seam welding specimens shall be prepared as shown in figure QW-462.7.3. The sectioned weldment shall be free of cracks, incomplete penetration, expulsions, and inclusions. Porosity shall not exceed one void in the transverse cross section or three voids in the longitudinal cross section of a specimen. The maximum dimension of any void shall not exceed 10% of the thickness of the weld bead.

QW-196.1.2 For spot and seam welds, the minimum width of the weld nugget shall be as follows in relation to thickness, t, of the thinner member.

Material Thickness, in. (mm)	Weld Nugget Width
< 0.010 (0.25)	6*t*
≥ 0.010 (0.25) and < 0.020 (0.50)	5*t*
≥ 0.020 (0.50) and < 0.040 (1.00)	4*t*
≥ 0.040 (1.00) and < 0.069 (1.75)	3*t*
≥ 0.069 (1.75) and < 0.100 (2.54)	2.50*t*
≥ 0.100 (2.54) and < 0.118 (3.00)	2.25*t*
≥ 0.118 (3.00) and < 0.157 (4.00)	2*t*
≥ 0.157 (4.00)	1.80*t*

The weld depth (extent of fusion) shall be a minimum of 20% of the thickness of the thinner ply (in each member) and a maximum of 80% of the total thickness of all plies.

QW-196.1.3 For projection welds, the width of the nugget shall be not less than 80% of the width of the projection.

QW-196.2 Mechanical Testing

QW-196.2.1 Shear test specimens shall be prepared as shown on figure QW-462.9. For spot and projection welds, each test specimen shall equal or exceed the minimum strength, and the average strength specified in tables 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 figure QW-462.8.1 for spot and projection welding and per figure QW-462.8.2 for seam welding. 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

QW-197.1 Procedure Qualification Specimens

QW-197.1.1 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 figure QW-464.1. The tension shear specimens shall conform to the dimensions indicated in the table of figure QW-464.1. The longitudinal and transverse sections indicated in figure 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 transverse 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 transverse specimens shall be measured to the nearest hundredth of an inch and recorded.

QW-197.1.2 Acceptance Criteria — Tension Shear Tests. In order to pass the tension shear test(s), the requirements of QW-153 shall apply.

QW-197.1.3 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-197.2 Performance Qualification Specimens

QW-197.2.1 Required Tests. A peel test specimen at least 6 in. (150 mm) long shall be prepared as shown in figure QW-464.2 illustration (a) and macro specimens as shown in figure QW-464.2 illustration (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-197.2.2 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.

QW-199 Flash Welding

QW-199.1 Procedure Qualification Test Coupons and Testing

QW-199.1.1 Test Coupon Preparation. For coupons NPS 1 (DN 25) and smaller, four test welds shall be made, and for pipes over NPS 1 (DN 25), three test coupons shall be made using one set of welding parameters (i.e., the same equipment, base metals, joint preparation, and other essential variables to be utilized for production welding.) These variables shall be recorded on the qualification record.

QW-199.1.2 Tensile Tests. For pipes NPS 1 (DN 25) and smaller, and nontubular cross sections, two full-section tensile specimens shall be prepared in accordance with figure QW-462.1(e). For pipes greater than NPS 1 (DN 25), two reduced section tension specimens shall be prepared in accordance with figure QW-462.1(b) or figure

QW-462.1(c) from one coupon. For nontubular cross sections, two reduced section tension specimens shall be prepared in accordance with figure QW-462.1(a) or figure QW-462.1(d) from two of the coupons. The specimens shall be tested in accordance with QW-150.

QW-199.1.3 Section and Bend Testing. The entire circumference of each remaining pipe coupon shall be cut along the axis of the pipe into an even number of strips of a length sufficient to perform bend tests. The maximum width of each strip shall be $1\frac{1}{2}$ in. (38 mm) and the minimum width

$w = t + D/4$ for pipes NPS 2 (DN 50) and smaller
$w = t + D/8$ for pipes greater than NPS 2 (DN 50)

where

D = OD of the tube
t = nominal wall thickness
w = width of the specimen

One edge of one strip from each coupon shall be polished to a 600 grit finish with the final grinding parallel to the long axis of the strip. The polished surface shall be examined at 5X magnification. No incomplete fusion or other open flaws on the polished surface are acceptable. Defects occurring in the base metal not associated with the weld may be disregarded. For nontubular cross sections, four side-bend specimens shall be prepared from the two remaining coupons as specified in figure QW-462.2 and polished for examination.

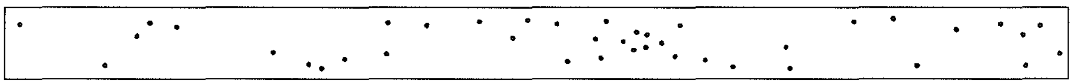
All flash shall be removed from the strips and the welds shall be visually examined per QW-194. Half of the strips from each pipe specimen shall then be prepared as root bend specimens and the remaining strips shall be prepared as face bend specimens in accordance with QW-160. The specimens shall be tested in accordance with QW-160, except for the following:

(a) For P-No. 1, Groups 2 through 4 materials, the minimum bend radius (dimension B in figure QW-466.1) shall be three times the thickness of the specimen.

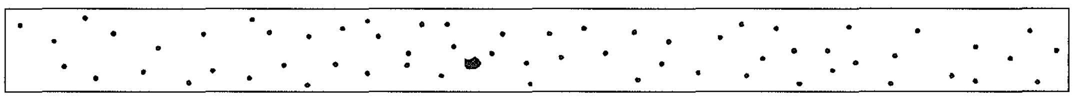
(b) In lieu of QW-163, the sum of lengths of individual open flaws on the convex surface of all the bend test specimens taken from each pipe individually shall not exceed 5% of the outside circumference of that test pipe.

QW-199.2 Flash Welding — Performance Qualification Test Coupons and Testing. One test coupon shall be welded, cut into strips, visually examined, and bend tested in accordance with QW-199.1.3. Polishing and examination of a cross-section is not required.

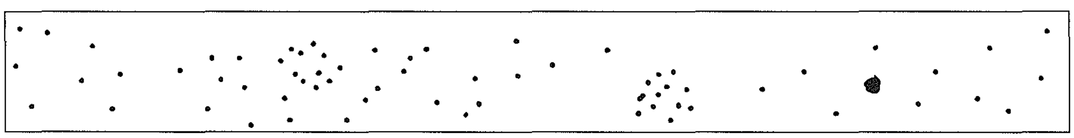
APPENDIX I
ROUNDED INDICATION CHARTS
(See QW-191.2)



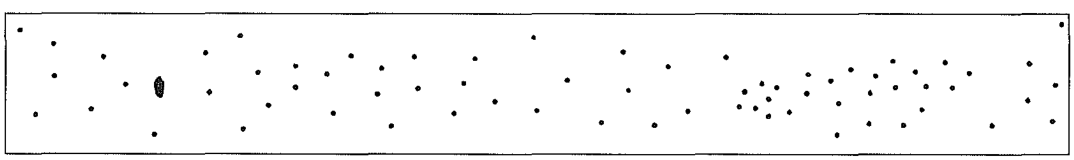
Typical Quantity and Size Permitted in 6 in. (150 mm) Length of Weld $^1/_8$ in. (3 mm) to $^1/_4$ in. (6 mm) Thickness



Typical Quantity and Size Permitted in 6 in. (150 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. (150 mm) Length of Weld Over $^1/_2$ in. (13 mm) to 1 in. (25 mm) Thickness



Typical Quantity and Size Permitted in 6 in. (150 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 that 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.

One or more combinations of welding processes, filler metal, and other variables may be used when welding a test coupon. The approximate thickness of weld metal deposited shall be recorded for each set of essential and, when required, supplementary essential variables. Weld metal deposited using each set of variables shall be included in the tension, bend, notch toughness, and other mechanical test specimens that are required.

(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. (1.5 mm) through $1\frac{1}{4}$ in. (32 mm) if PQRs exist for both the $\frac{1}{16}$ in. (1.5 mm) through $\frac{3}{16}$ in. (5 mm) and $\frac{3}{16}$ in. (5 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 (table 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.

QW-200.4 Combination of Welding Procedures

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

Where more than one WPS specifying different processes, filler metals, or other essential or supplementary essential variables is used in a joint, QW-451 shall be used to determine the range of base metal thickness and maximum weld metal thickness qualified for each process, filler metal, or set of variables, and those limits shall be observed. Alternatively, qualification of WPSs for root deposits only may be made in accordance with QW-200.4(b).

When following a WPS that has more than one welding process, filler metal, or set of variables, each process, filler metal, or set of variables may be used individually or in different combinations, provided

(1) the essential, nonessential, and required supplementary essential variables associated with the process, filler metal, or set of variables are applied

(2) the base metal and deposited weld metal thickness limits of QW-451 for each process, filler metal, or set of variables 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 $\frac{1}{2}$ 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 tables 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 that 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.

When it can be determined that the cause of failure is not related to welding parameters, another test coupon may be welded using identical welding parameters.

Alternatively, if adequate material of the original test coupon exists, additional test specimens may be removed as close as practicable to the original specimen location to replace the failed test specimens.

When it has been determined that the test failure was caused by an essential or supplementary essential variable, a new test coupon may be welded with appropriate changes to the variable(s) that was determined to cause the test failure. If the new test passes, the essential and supplementary variables shall be documented on the PQR.

When it is determined that the test failure was caused by one or more welding related factors other than essential or supplementary essential variables, a new test coupon may be welded with the appropriate changes to the welding related factors that were determined to cause the test failure. If the new test passes, the welding related factors that were determined to cause the previous test failure shall be addressed by the manufacturer to ensure that the required properties are achieved in the production weldment.

Where qualification is for fillet welds only, the requirements are given in QW-202.2(c); and where qualification is for stud welds only, the requirements are given in QW-202.5.

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 table 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 table 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. 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. 49, 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-202.6 Tube-to-Tubesheet Qualification. When the applicable Code Section requires the use of QW-193 for tube-to-tubesheet demonstration mockup qualification tests, QW-193.1 shall apply. If specific qualification test requirements are not specified by the applicable Code Section, tube-to-tubesheet welds shall be qualified with one of the following methods:

(a) groove welds per the requirements of QW-202.2 and QW-202.4

(b) a demonstration mockup per the requirements of QW-193.1

(c) fillet welds per the requirements of QW-202.2(c) (for nonpressure retaining tube-to-tubesheet welds only)

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 dimensions 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-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 table 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 tables 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 requirements specified in QW-216.1 through QW-216.4 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 table 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 table 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 table 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 table 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 table 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 table QW-453, Note 9 for those elements.

QW-219 Flash Welding

Flash welding shall be limited to automatic electrical resistance flash welding. Procedure qualification tests shall be conducted in accordance with QW-199.1.

QW-219.1 Tolerances on Variables. Flash welding variables that may require adjustment during production welding are synergistically related. Accordingly, even though the variables shown in table QW-265 provide tolerances on many welding variables, the WPS shall specify the same specific variables shown on the PQR with tolerance shown for no more than one variable (e.g., if it is desired to provide a tolerance on the upset current, all other variables shown on the WPS must be the same as they are shown on the PQR). If it is desired to provide tolerances in the WPS for two variables, the first variable with a tolerance shall be set at the midpoint of its tolerance and two test coupons shall be welded with each of the upper and lower extremes of the tolerance for the second variable (i.e., four coupons must be welded). These coupons shall be examined and tested in accordance with QW-199.1.3.

If it is desired to provide tolerance for a third variable, the first two variables shall be set at the midpoint of their tolerance, and two test coupons shall be welded with each of the upper and lower extremes of the new tolerances for the third variable (i.e., four coupons must be welded). These coupons shall be examined and tested in accordance with QW-199.1.3.

No more than three essential variables on a WPS may show tolerances.

Production tests conducted in accordance with the requirements of other Sections may be used to satisfy this requirement.

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 tables 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.

(10)

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		
QW-404 Filler Metals	.3	ϕ Size			X
	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.12	ϕ Classification	X		
QW-405 Positions	.1	+ Position			X
QW-406 Preheat	.1	Decrease > 100°F (55°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
	.64	Use of thermal processes	X		

Legend:

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

QW-252.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Oxyfuel Gas Welding (OFW)

Paragraph		Special Process Essential Variables: Hard-Facing Overlay (QW-216)	Special Process Essential Variables: Corrosion-Resistant Overlay (QW-214)	Hard-Facing Spray Fuse (QW-216)
QW-402 Joint	.16	< Finished t		
	.17			> Finished t
QW-403 Base Metals	.20	ϕ P-Number		ϕ P-Number
	.23	ϕ T Qualified	ϕ T Qualified	ϕ T Qualified
QW-404 Filler Metals	.12	ϕ Classification		ϕ Classification
	.42			> 5% Particle size range
	.46			ϕ Powder feed rate
QW-405 Positions	.4	+ Position		+ Position
QW-406 Preheat	.4	Dec. > 100°F (55°C) preheat > Interpass		Dec. > 100°F (55°C) preheat > Interpass
	.5			ϕ Preheat maint.
QW-407 PWHT	.6	ϕ PWHT		ϕ PWHT
	.7			ϕ PWHT after fusing
QW-408 Gas	.7	ϕ Type of fuel gas		
	.14	ϕ Oxyfuel gas pressure		
	.16			ϕ > 5% Gas feed rate
	.19			ϕ Plasma/feed gas comp.
QW-410 Technique	.38	ϕ Multiple to single layer		ϕ Multiple to single layer
	.39	ϕ Torch type, tip sizer		
	.44			ϕ > 15% Torch to workpiece
	.45			ϕ Surface prep.
	.46			ϕ Spray torch
	.47			ϕ > 10% Fusing temp. or method

Legend:

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

QW-253
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Shielded Metal-Arc Welding (SMAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	− Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	T Limits impact		X	
	.8	ϕ T Qualified	X		
	.9	t Pass > $\frac{1}{2}$ in. (13 mm)	X		
	.11	ϕ P-No. qualified	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.7	ϕ Diameter > $\frac{1}{4}$ in. (6 mm)		X	
	.12	ϕ Classification		X	
	.30	ϕ t	X		
	.33	ϕ Classification			X
QW-405 Positions	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	T Limits	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
QW-410 Technique	.1	ϕ String/weave			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.9	ϕ Multiple to single pass/side		X	X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

Legend:

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

QW-253.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Shielded Metal-Arc Welding (SMAW)

Special Process Variables						
		Essential Variables				
Paragraph		Hard-Facing Overlay (HFO) (QW-216)		Corrosion-Resistant Overlay (CRO) (QW-214)		Nonessential Variables for HFO and CRO
QW-402 Joints	.16	<	Finished t	<	Finished t	
QW-403 Base Metals	.20	ϕ	P-Number	ϕ	P-Number	
	.23	ϕ	T Qualified	ϕ	T Qualified	
QW-404 Filler Metals	.12	ϕ	Classification			
	.37			ϕ	A-Number	
	.38					ϕ Diameter (1st layer)
QW-405 Positions	.4	+	Position	+	Position	
QW-406 Preheat	.4		Dec. > 100°F (55°C) preheat > Interpass		Dec. > 100°F (55°C) preheat > Interpass	
QW-407 PWHT	.6	ϕ	PWHT			
	.9			ϕ	PWHT	
QW-409 Electrical Characteristics	.4	ϕ	Current or polarity	ϕ	Current or polarity	
	.22		Inc. > 10% 1st layer		Inc. > 10% 1st layer	
QW-410 Technique	.1					ϕ String/weave
	.5					ϕ Method of cleaning
	.26					± Peening
	.38	ϕ	Multiple to single layer	ϕ	Multiple to single layer	

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

QW-254
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Submerged-Arc Welding (SAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	− Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	T Limits		X	
	.8	ϕ T Qualified	X		
	.9	t Pass $\frac{1}{2}$ in. (13 mm)	X		
	.11	ϕ P-No. qualified	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.9	ϕ Flux/wire class.	X		
	.10	ϕ Alloy flux	X		
	.24	± ϕ Supplemental	X		
	.27	ϕ Alloy elements	X		
	.29	ϕ Flux designation			X
	.30	ϕ t	X		
	.33	ϕ Classification			X
	.34	ϕ Flux type	X		
	.35	ϕ Flux/wire class.		X	X
	.36	Recrushed slag	X		
QW-405 Positions	.1	+ Position			X
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	T Limits	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X

QW-254
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS) (CONT'D)
Submerged-Arc Welding (SAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-410 Technique	.1	ϕ String/weave			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.7	ϕ Oscillation			X
	.8	ϕ Tube-work distance			X
	.9	ϕ Multi to single pass/side		X	X
	.10	ϕ Single to multi electrodes		X	X
	.15	ϕ Electrode spacing			X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

Legend:

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

QW-254.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Submerged-Arc Welding (SAW)

Paragraph		Special Process Variables				
		Essential Variables				
		Hard-Facing Overlay (HFO) (QW-216)		Corrosion-Resistant Overlay (CRO) (QW-214)		Nonessential Variables for HFO and CRO
QW-402 Joints	.16	<	Finished t	<	Finished t	
QW-403 Base Metals	.20	ϕ	P-Number	ϕ	P-Number	
	.23	ϕ	T Qualified	ϕ	T Qualified	
QW-404 Filler Metals	.6					ϕ Nominal size of electrode
	.12	ϕ	Classification			
	.24	±	or ϕ > 10% in supplemental filler metal	±	or ϕ > 10% in supplemental filler metal	
	.27	ϕ	Alloy elements			
	.37			ϕ	A-Number	
	.39	ϕ	Nominal flux comp.	ϕ	Nominal flux comp.	
QW-405 Positions	.4	+	Position	+	Position	
QW-406 Preheat	.4		Dec. > 100°F (55°C) preheat > Interpass		Dec. > 100°F (55°C) preheat > Interpass	
QW-407 PWHT	.6	ϕ	PWHT			
	.9			ϕ	PWHT	
QW-409 Electrical Characteristics	.4	ϕ	Current or polarity	ϕ	Current or polarity	
	.26		1st layer — Heat input > 10%		1st layer — Heat input > 10%	
QW-410 Technique	.1					ϕ String/weave
	.5					ϕ Method of cleaning
	.7					ϕ Oscillation
	.8					ϕ Tube to work distance
	.15					ϕ Electrode spacing
	.25					ϕ Manual or automatic
	.26					± Peening
	.38	ϕ	Multiple to single layer	ϕ	Multiple to single layer	
	.40			−	Supplemental device	
	.50	ϕ	No. of electrodes	ϕ	No. of electrodes	

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

QW-255
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Metal-Arc Welding (GMAW and FCAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	− Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	T Limits		X	
	.8	ϕ T Qualified	X		
	.9	t Pass > $\frac{1}{2}$ in. (13 mm)	X		
	.10	T limits (S. cir. arc)	X		
	.11	ϕ P-No. qualified	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.12	ϕ Classification		X	
	.23	ϕ Filler metal product form	X		
	.24	± ϕ Supplemental	X		
	.27	ϕ Alloy elements	X		
	.30	ϕ t	X		
	.32	t Limits (S. cir. arc)	X		
	.33	ϕ Classification			X
QW-405 Positions	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	T Limits	X		

QW-255
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS) (CONT'D)
Gas Metal-Arc Welding (GMAW and FCAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-408 Gas	.1	± Trail or ϕ comp.			X
	.2	ϕ Single, mixture, or %	X		
	.3	ϕ Flow rate			X
	.5	± or ϕ Backing flow			X
	.9	− Backing or ϕ comp.	X		
	.10	ϕ Shielding or trailing	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.2	ϕ Transfer mode	X		
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
QW-410 Technique	.1	ϕ String/weave			X
	.3	ϕ Orifice, cup, or nozzle size			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.7	ϕ Oscillation			X
	.8	ϕ Tube-work distance			X
	.9	ϕ Multiple to single pass/side		X	X
	.10	ϕ Single to multiple electrodes		X	X
	.15	ϕ Electrode spacing			X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

Legend:

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

QW-255.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Metal-Arc Welding (GMAW and FCAW)

Special Process Variables

Paragraph		Essential Variables: Hard-Facing Overlay (HFO) (QW-216)		Essential Variables: Corrosion-Resistant Overlay (CRO) (QW-214)		Nonessential Variables for HFO and CRO
QW-402 Joints	.16	<	Finished t	<	Finished t	
QW-403 Base Metals	.20	ϕ	P-Number	ϕ	P-Number	
	.23	ϕ	T Qualified	ϕ	T Qualified	
QW-404 Filler Metals	.6					ϕ Nominal size of electrode
	.12	ϕ	Classification			
	.23	ϕ	Filler metal product form	ϕ	Filler metal product form	
	.24	±	or ϕ > 10% in supplemental filler metal	±	or ϕ > 10% in supplemental filler metal	
	.27	ϕ	Alloy elements			
	.37			ϕ	A-Number	
QW-405 Positions	.4	+	Position	+	Position	
QW-406 Preheat	.4		Dec. > 100°F (55°C) preheat > Interpass		Dec. > 100°F (55°C) preheat > Interpass	
QW-407 PWHT	.6	ϕ	PWHT			
	.9			ϕ	PWHT	
QW-408 Gas	.2	ϕ	Single, mixture, or %	ϕ	Single, mixture, or %	
	.3					ϕ Flow rate
QW-409 Electrical Characteristics	.4	ϕ	Current or polarity	ϕ	Current or polarity	
	.26		1st layer — Heat input > 10%		1st layer — Heat input > 10%	
QW-410 Technique	.1					ϕ String/weave
	.3					ϕ Orifice/cup or nozzle size
	.5					ϕ Method of cleaning
	.7					ϕ Oscillation
	.8					ϕ Tube to work distance
	.25					ϕ Manual or automatic
	.26					± Peening
	.38	ϕ	Multiple to single layer	ϕ	Multiple to single layer	
	.50	ϕ	No. of electrodes	ϕ	No. of electrodes	

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

QW-256
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Tungsten-Arc Welding (GTAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.5	+ Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	*T* Limits		X	
	.8	*T* Qualified	X		
	.11	ϕ P-No. qualified	X		
QW-404 Filler Metals	.3	ϕ Size			X
	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.12	ϕ Classification		X	
	.14	± Filler	X		
	.22	± Consum. insert			X
	.23	ϕ Filler metal product form	X		
	.30	ϕ t	X		
	.33	ϕ Classification			X
	.50	± Flux			X
QW-405 Positions	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.3	Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T &T range)		X	
	.4	*T* Limits	X		
QW-408 Gas	.1	± Trail or ϕ comp.			X
	.2	ϕ Single, mixture, or %	X		
	.3	ϕ Flow rate			X
	.5	± or ϕ Backing flow			X
	.9	− Backing or ϕ comp.	X		
	.10	ϕ Shielding or trailing	X		

QW-256
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS) (CONT'D)
Gas Tungsten-Arc Welding (GTAW)

Paragraph		Brief of Variables		Essential	Supplementary Essential	Nonessential
QW-409 Electrical Characteristics	.1	>	Heat input		X	
	.3	±	Pulsing I			X
	.4	ϕ	Current or polarity		X	X
	.8	ϕ	I & E range			X
	.12	ϕ	Tungsten electrode			X
QW-410 Technique	.1	ϕ	String/weave			X
	.3	ϕ	Orifice, cup, or nozzle size			X
	.5	ϕ	Method cleaning			X
	.6	ϕ	Method back gouge			X
	.7	ϕ	Oscillation			X
	.9	ϕ	Multi to single pass/side		X	X
	.10	ϕ	Single to multi electrodes		X	X
	.11	ϕ	Closed to out chamber	X		
	.15	ϕ	Electrode spacing			X
	.25	ϕ	Manual or automatic			X
	.26	±	Peening			X
	.64		Use of thermal processes	X		

Legend:

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

QW-256.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Tungsten-Arc Welding (GTAW)

Special Process Variables

Paragraph		Essential Variables: Hard-Facing Overlay (HFO) (QW-216)	Essential Variables: Corrosion-Resistant Overlay (CRO) (QW-214)	Nonessential Variables for HFO and CRO
QW-402 Joints	.16	< Finished t	< Finished t	
QW-403 Base Metals	.20	ϕ P-Number	ϕ P-Number	
	.23	ϕ T Qualified	ϕ T Qualified	
QW-404 Filler Metals	.3			ϕ Wire size
	.12	ϕ Classification		
	.14	± Filler metal	± Filler metal	
	.23	ϕ Filler metal product form	ϕ Filler metal product form	
	.37		ϕ A-Number	
QW-405 Positions	.4	+ Position	+ Position	
QW-406 Preheat	.4	> Dec. > 100°F (55°C) preheat Interpass	> Dec. > 100°F (55°C) preheat Interpass	
QW-407 PWHT	.6	ϕ PWHT		
	.9		ϕ PWHT	
QW-408 Gas	.2	ϕ Single, mixture, or %	ϕ Single, mixture, or %	
	.3			ϕ Flow rate
QW-409 Electrical Characteristics	.4	ϕ Current or polarity	ϕ Current or polarity	
	.12			ϕ Tungsten electrode
	.26	1st layer — Heat input > 10%	1st layer — Heat input > 10%	
QW-410 Technique	.1			ϕ String/weave
	.3			ϕ Orifice/cup or nozzle size
	.5			ϕ Method of cleaning
	.7			ϕ Oscillation
	.15			ϕ Electrode spacing
	.25			ϕ Manual or automatic
	.26			± Peening
	.38	ϕ Multiple to single layer	ϕ Multiple to single layer	
	.50	ϕ No. of electrodes	ϕ No. of electrodes	
	.52			ϕ Filler metal delivery

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

QW-257
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Plasma-Arc Welding (PAW)

Paragraph			Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ	Groove design		X	
	.5	+	Backing			X
	.10	ϕ	Root spacing			X
	.11	±	Retainers			X
QW-403 Base Metals	.5	ϕ	Group Number		X	
	.6		*T* Limits		X	
	.8	ϕ	*T* Qualified	X		
	.12	ϕ	P-Number/melt-in	X		
QW-404 Filler Metals	.3	ϕ	Size			X
	.4	ϕ	F-Number	X		
	.5	ϕ	A-Number	X		
	.12	ϕ	Classification		X	
	.14	±	Filler metal	X		
	.22	±	Consum. insert			X
	.23	ϕ	Filler metal product form	X		
	.27	ϕ	Alloy elements	X		
	.30	ϕ	*t*	X		
	.33	ϕ	Classification			X
QW-405 Positions	.1	+	Position			X
	.2	ϕ	Position		X	
	.3	ϕ	↑ ↓ Vertical welding			X
QW-406 Preheat	.1		Decrease > 100°F (55°C)	X		
	.3		Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	ϕ	PWHT	X		
	.2	ϕ	PWHT (T & T range)		X	
	.4		*T* Limits	X		
QW-408 Gas	.1	±	Trail or ϕ comp.			X
	.4	ϕ	Composition	X		
	.5	±	Or ϕ backing flow			X
	.9	−	Backing or ϕ comp.	X		
	.10	ϕ	Shielding or trailing	X		
	.21	ϕ	Flow rate			X

QW-257
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS) (CONT'D)
Plasma-Arc Welding (PAW)

Paragraph		Brief of Variables		Essential	Supplementary Essential	Nonessential
QW-409 Electrical Characteristics	.1	>	Heat input		X	
	.4	ϕ	Current or polarity		X	X
	.8	ϕ	I & E range			X
	.12	ϕ	Tungsten electrode			X
QW-410 Technique	.1	ϕ	String/weave			X
	.3	ϕ	Orifice, cup, or nozzle size			X
	.5	ϕ	Method cleaning			X
	.6	ϕ	Method back gouge			X
	.7	ϕ	Oscillation			X
	.9	ϕ	Multiple to single pass/side		X	X
	.10	ϕ	Single to multiple electrodes		X	X
	.11	ϕ	Closed to out chamber	X		
	.12	ϕ	Melt-in to keyhole		X	
	.15	ϕ	Electrode spacing			X
	.26	±	Peening			X
	.64		Use of thermal processes	X		

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

QW-257.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Plasma-Arc Welding (PAW)

Special Process Variables					
		Essential Variables			
Paragraph		Hard-Facing Overlay (HFO) (QW-216)	Corrosion-Resistant Overlay (CRO) (QW-214)	Hard-Facing Spray Fuse (HFSF) (QW-216)	Nonessential Variables for HFO, CRO, and HFSF
QW-402 Joints	.16	< Finished t	< Finished t		
	.17			> Finished t	
QW-403 Base Metals	.20	ϕ P-Number	ϕ P-Number	ϕ P-Number	
	.23	ϕ T Qualified	ϕ T Qualified		
QW-404 Filler Metals	.12	ϕ Classification		ϕ Classification	
	.14	± Filler metal	± Filler metal		
	.37		ϕ A-Number		
	.41	ϕ > 10% Powder feed rate	ϕ > 10% Powder feed rate		
	.42			ϕ > 5% Particle size	
	.43	ϕ Particle size	ϕ Particle size		
	.44	ϕ Powder type	ϕ Powder type		
	.45	ϕ Filler metal form	ϕ Filler metal form		
	.46			ϕ Powder feed rate	
QW-405 Positions	.4	+ Position	+ Position	+ Position	
QW-406 Preheat	.4	Dec. > 100°F (55°C) preheat > Interpass	Dec. > 100°F (55°C) preheat > Interpass	Dec. > 100°F (55°C) preheat > Interpass	
	.5			ϕ Preheat maintenance	
QW-407 PWHT	.6	ϕ PWHT		ϕ PWHT	
	.7			ϕ PWHT after fusing	
	.9		ϕ PWHT		
QW-408 Gas	.1				± Trail or ϕ comp.
	.16	ϕ > 5% Arc or metal feed gas	ϕ > 5% Arc or metal feed gas	ϕ > 5% Arc or metal feed gas	
	.17	ϕ Type or mixture	ϕ Type or mixture		
	.18	ϕ > 10% Mix. comp.	ϕ > 10% Mix. comp.		
	.19			ϕ Plasma/feed gas comp.	
	.20			ϕ Plasma gas flow-rate range	
QW-409 Electrical Characteristics	.4	ϕ Current or polarity	ϕ Current or polarity		
	.12			ϕ Type or size of electrode	
	.23			ϕ > 10% I & E	
	.24	ϕ > 10% Filler wire watt.	ϕ > 10% Filler wire watt.		
	.25	ϕ > 10% I & E	ϕ > 10% I & E		

QW-257.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS) (CONT'D)
Plasma-Arc Welding (PAW)

Special Process Variables					
		Essential Variables			
Paragraph		Hard-Facing Overlay (HFO) (QW-216)	Corrosion-Resistant Overlay (CRO) (QW-214)	Hard-Facing Spray Fuse (HFSF) (QW-216)	Nonessential Variables for HFO, CRO, and HFSF
QW-410 Technique	.1				ϕ String/weave (HFO and CRO only)
	.3				ϕ Orifice/cup or nozzle size
	.5				ϕ Method of cleaning
	.7				ϕ Oscillation
	.25				ϕ Manual or automatic
	.26				± Peening
	.38	ϕ Multiple to single layer	ϕ Multiple to single layer	ϕ Multiple to single layer	
	.41	ϕ > 15% Travel speed	ϕ > 15% Travel speed		
	.43			ϕ > 10% Travel speed range	
	.44			ϕ > 15% Torch to workplace	
	.45			ϕ Surface preparation	
	.46			ϕ Spray torch	
	.47			ϕ > 10% Fusing temp. or method	
	.48	ϕ Transfer mode	ϕ Transfer mode	ϕ Transfer mode	
	.49	ϕ Torch orifice diameter	ϕ Torch orifice diameter		
	.52	ϕ Filler metal del.	ϕ Filler metal del.		

Legend:

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

QW-258
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Electroslag Welding (ESW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.10	ϕ Root spacing			X
	.11	± Retainers	X		
QW-403 Base Metals	.1	ϕ P-Number	X		
	.4	ϕ Group Number		X	
	.9	t Pass > $\frac{1}{2}$ in. (13 mm)	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.12	ϕ Classification		X	
	.17	ϕ Flux type or comp.	X		
	.18	ϕ Wire to plate	X		
	.19	ϕ Consum. guide	X		
	.33	ϕ Classification			X
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	T Limits	X		
QW-409 Electrical Characteristics	.5	ϕ ±15% I & E range	X		
QW-410 Technique	.5	ϕ Method cleaning			X
	.7	ϕ Oscillation	X		
	.10	ϕ Single to multiple electrodes	X		
	.15	ϕ Electrode spacing			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

Legend:

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

QW-258.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Electroslag Welding (ESW)

Special Process Variables				
		Essential Variables		
Paragraph		Hard-Facing Overlay (HFO) (QW-216)	Corrosion-Resistant Overlay (CRO) (QW-214)	Nonessential Variables for HFO and CRO
QW-402 Joints	.16	< Finished t	< Finished t	
QW-403 Base Metals	.20	ϕ P-Number	ϕ P-Number	
	.23	ϕ T Qualified	ϕ T Qualified	
QW-404 Filler Metals	.6			ϕ Nominal size of electrode
	.12	ϕ Classification		
	.24	± or ϕ > 10% in supplemental filler metal	± or ϕ > 10% in supplemental filler metal	
	.37		ϕ A-Number	
	.39	ϕ Nominal flux comp.	ϕ Nominal flux comp.	
QW-406 Preheat	.4	> Dec. > 100°F (55°C) preheat Interpass	> Dec. > 100°F (55°C) preheat Interpass	
QW-407 PWHT	.6	ϕ PWHT		
	.9		ϕ PWHT	
QW-409 Electrical Characteristics	.4	ϕ Current or polarity	ϕ Current or polarity	
	.26	1st layer — Heat input > 10%	1st layer — Heat input > 10%	
QW-410 Technique	.5			ϕ Method of cleaning
	.7			ϕ Oscillation (CRO only)
	.38	ϕ Multiple to single layer	ϕ Multiple to single layer	
	.40	− Supplemental device	− Supplemental device	
	.50	ϕ No. of electrodes	ϕ No. of electrodes	

Legend:

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

QW-259
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Electrogas Welding (EGW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.10	ϕ Root spacing			X
	.11	± Retainers	X		
QW-403 Base Metals	.1	ϕ P-Number	X		
	.5	ϕ Group Number		X	
	.6	*T* Limits		X	
	.8	ϕ *T* Qualified	X		
	.9	*t* Pass > ½ in. (13 mm)	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.12	ϕ Classification		X	
	.23	ϕ Filler metal product form	X		
	.33	ϕ Classification			X
QW-406 Preheat	.1	Decrease > 100°F (55°C)			X
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	*T* Limits	X		
QW-408 Gas	.2	ϕ Single, mixture, or %	X		
	.3	ϕ Flow rate			X
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
QW-410 Technique	.5	ϕ Method cleaning			X
	.7	ϕ Oscillation			X
	.8	ϕ Tube-work distance			X
	.9	ϕ Multiple to single pass/side		X	X
	.10	ϕ Single to multiple electrodes	X		
	.15	ϕ Electrode spacing			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

Legend:

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

GENERAL NOTE: Automated vertical gas metal-arc welding for vertical position only.

QW-260
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Electron Beam Welding (EBW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design	X		
	.2	− Backing	X		
	.6	> Fit-up gap	X		
QW-403 Base Metals	.1	ϕ P-Number	X		
	.3	ϕ Penetration	X		
	.15	ϕ P-Number	X		
QW-404 Filler Metals	.1	ϕ Cross section or speed	X		
	.2	< t or ϕ comp.	X		
	.8	± or ϕ Chem. comp.	X		
	.14	± Filler	X		
	.20	ϕ Method of addition	X		
	.21	ϕ Analysis	X		
	.33	ϕ Classification			X
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
QW-407 PWHT	.1	ϕ PWHT	X		
QW-408 Gas	.6	ϕ Environment	X		
QW-409 Electrical Characteristics	.6	ϕ I, E, speed, distance, osc.	X		
	.7	ϕ Pulsing frequency	X		
QW-410 Technique	.5	ϕ Method cleansing			X
	.7	ϕ Oscillation	X		
	.14	ϕ Angle of beam axis	X		
	.17	ϕ Type equip.	X		
	.18	> Pressure of vacuum	X		
	.19	ϕ Filament type, size, etc.	X		
	.20	+ Wash pass	X		
	.21	1 vs. 2 side welding	X		
	.64	Use of thermal processes	X		

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

QW-261
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Stud Welding

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.8	ϕ Stud shape size	X		
	.9	− Flux or ferrule	X		
QW-403 Base Metal	.17	ϕ Base metal or stud metal P-No.	X		
QW-405 Positions	.1	+ Position	X		
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
QW-407 PWHT	.1	ϕ PWHT	X		
QW-408 Gas	.2	ϕ Single, mixture, or %	X		
QW-409 Electrical Characteristics	.4	ϕ Current or polarity			X
	.8	ϕ I & E range			X
	.9	ϕ Arc timing	X		
	.10	ϕ Amperage	X		
	.11	ϕ Power source	X		
QW-410 Technique	.22	ϕ Gun model or lift	X		
	.64	Use of thermal processes	X		

Legend:

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

QW-262
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Inertia and Continuous Drive Friction Welding

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.12	ϕ ± 10 deg	X		
		ϕ Cross section > 10%	X		
		ϕ O.D. > ± 10%	X		
		ϕ Solid-to-tube	X		
QW-403 Base Metals	.19	ϕ Base metal	X		
QW-406 Preheat	.1	ϕ Decrease > 100°F (55°C)	X		
QW-407 PWHT	.1	ϕ PWHT	X		
QW-408 Gas	.6	ϕ Environment	X		
QW-410 Technique	.27	ϕ Spp. > ± 10%	X		
	.28	ϕ Load > ± 10%	X		
	.29	ϕ Energy > ± 10%	X		
	.30	ϕ Upset > ± 10%	X		
	.64	Use of thermal processes	X		

Legend:

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

QW-263
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Resistance Welding

Paragraph		Brief of Variables	Essential	Nonessential
QW-402 Joints	.13	ϕ Spot, projection, seam	X	
	.14	ϕ Overlap, spacing	X	
	.15	ϕ Projection, shape, size	X	
QW-403 Base Metals	.1	ϕ P-No.	X	
	.21	$\pm$ Coating, plating	X	
	.22	$\pm$ T	X	
QW-407 PWHT	.1	ϕ PWHT	X	
QW-408 Gas	.23	$-$ Gases	X	
QW-409 Electrical	.13	ϕ RWMA class	X	
	.14	$\pm$ ϕ Slope	X	
	.15	ϕ Pressure, current, time	X	
	.17	ϕ Power supply		X
	.18	Tip cleaning		X
QW-410 Technique	.31	ϕ Cleaning method	X	
	.32	ϕ Pressure, time	X	
	.33	ϕ Equipment	X	
	.34	ϕ Cooling medium		X
	.35	ϕ Throat		X
	.64	Use of thermal processes	X	

Legend:

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

QW-264
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Laser Beam Welding (LBW)

Paragraph			Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ	Groove design	X		
	.2	±	Backing	X		
	.6	>	Fit-up gap	X		
	.18	ϕ	Lap joint config.	X		
QW-403 Base Metals	.1	ϕ	P-Number	X		
	.3	ϕ	Penetration	X		
	.15	ϕ	P-Number	X		
QW-404 Filler Metals	.1	ϕ	Cross section or speed	X		
	.2	<	t or ϕ comp.	X		
	.8	±	or ϕ chem. comp.	X		
	.14	±	Filler metal	X		
	.20	ϕ	Method of addition	X		
	.21	ϕ	Analysis	X		
	.33	ϕ	Classification			X
QW-406 Preheat	.1		Decrease > 100°F (55°C)	X		
QW-407 PWHT	.1	ϕ	PWHT	X		
QW-408 Gas	.2	ϕ	Single, mixture, or %	X		
	.6	ϕ	Environment	X		
	.11	±	Gases	X		
	.12	ϕ	> 5% Gases	X		
	.13	ϕ	Plasma jet position	X		
QW-409 Electrical Characteristics	.19	ϕ	Pulse	X		
	.20	ϕ	Mode, energy	X		
	.21	ϕ	Power, speed, d/fl, distance	X		
QW-410 Technique	.5	ϕ	Method cleaning			X
	.7	ϕ	Oscillation	X		
	.14	ϕ	Angle of beam axis	X		
	.17	ϕ	Type/model of equipment	X		
	.20	+	Wash pass	X		
	.21		1 vs. 2 side welding	X		
	.37	ϕ	Single to multiple pass	X		
	.64		Use of thermal processes	X		

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

QW-264.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Laser Beam Welding (LBW)

Special Process Variables				
		Essential Variables		
Paragraph		Hard-Facing Overlay (HFO) (QW-216)	Corrosion-Resistant Overlay (CRO) (QW-214)	Nonessential Variables for HFO and CRO
QW-402 Joints	.16	< Finished t	< Finished t	
QW-403 Base Metals	.20	ϕ P-Number	ϕ P-Number	
QW-404 Filler Metals	.12	ϕ Classification	ϕ Classification	
	.27	ϕ Alloy elements	ϕ Alloy elements	
	.44	ϕ Particle type	ϕ Particle type	
	.47	ϕ Filler/powder metal size	ϕ Filler/powder metal size	
	.48	ϕ Powder metal density	ϕ Powder metal density	
	.49	ϕ Filler metal powder feed rate	ϕ Filler metal powder feed rate	
QW-405 Positions	.1	+ Position	+ Position	
QW-406 Preheat	.4	Dec. > 100°F (55°C) preheat > Interpass	Dec. > 100°F (55°C) preheat > Interpass	
QW-407 PWHT	.6	ϕ PWHT		
	.9		ϕ PWHT	
QW-408 Gas	.2	ϕ Single, mixture, or %	ϕ Single, mixture, or %	
	.6	ϕ Environment	ϕ Environment	
	.11	± Gases	± Gases	
	.12	ϕ % Flow rate	ϕ % Flow rate	
	.13	ϕ Plasma jet position	ϕ Plasma jet position	
QW-409 Electrical Characteristics	.19	ϕ Pulse	ϕ Pulse	
	.20	ϕ Mode, energy	ϕ Mode, energy	
	.21	ϕ Power, speed, d/fl, distance	ϕ Power, speed, d/fl, distance	
QW-410 Technique	.5			ϕ Method of cleaning
	.7	ϕ Oscillation	ϕ Oscillation	
	.14	ϕ Angle of beam axis	ϕ Angle of beam axis	
	.17	ϕ Type/model of equipment	ϕ Type/model of equipment	
	.38	ϕ Multiple to single layer	ϕ Multiple to single layer	
	.45	ϕ Method of surface prep.	ϕ Method of surface prep.	
	.52	ϕ Filler metal delivery	ϕ Filler metal delivery	
	.53	ϕ Overlap, spacing	ϕ Overlap, spacing	

Legend:

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

QW-265
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Flash Welding

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.19	ϕ Diameter or thickness	X		
	.20	ϕ Joint configuration	X		
	.21	ϕ Method or equip. used to minimize ID flash	X		
	.22	ϕ End preparation method	X		
QW-403 Base Metals	.24	ϕ Spec., type, or grade	X		
QW-406 Preheat	.7	ϕ > 10% Amperage or number of preheat cycles, or method, or > 25°F temperature	X		
QW-407 PWHT	.8	ϕ PWHT, PWHT cycles, or separate PWHT time or temperature	X		
QW-408 Gas	.22	ϕ Shielding gas composition, pressure, or purge time	X		
QW-409 Electrical Characteristics	.27	ϕ > 10% Flashing time	X		
	.28	ϕ > 10% Upset current time	X		
QW-410 Technique	.17	ϕ Type/model of equipment	X		
	.54	ϕ > 10% Upset length or force	X		
	.55	ϕ > 10% Distance between clamping dies or preparation of clamping area	X		
	.56	ϕ Clamping force	X		
	.57	ϕ 10% Forward or reverse speed	X		
	.64	Use of thermal processes	X		

Legend:

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

QW-283 Welds With Buttering

QW-283.1 Scope. This paragraph only applies when the essential variables for the buttering process are different than the essential variables for the process used for subsequent completion of the joint. Common examples are

(a) the buttered member is heat treated and the completed weld is not heat treated after welding

(b) the filler metal used for buttering has a different F-Number from that used for the subsequent completion of the weld

QW-283.2 Tests Required. The procedure shall be qualified by buttering the test coupon (including heat treating of the buttered member when this will be done in production welding) and then making the subsequent weld joining the members. The variables for the buttering and for the subsequent weld shall be in accordance with QW-250, except that QW-409.1 shall be an essential variable for the welding process(es) used to complete the weld when the minimum buttering thickness is less than $\frac{3}{16}$ in. (5 mm). Mechanical testing of the completed weldment shall be in accordance with QW-202.2(a).

If the buttering is done with filler metal of the same composition as the filler metal used to complete the weld, one weld test coupon may be used to qualify the dissimilar metal joint by welding the first member directly to the second member in accordance with Section IX.

QW-283.3 Buttering Thickness. The thickness of buttering which shall remain on the production buttered member after all machining and grinding is completed and before subsequent completion of the joint shall be required by the WPS. When this thickness is less than $\frac{3}{16}$ in. (5 mm), the thickness of buttering on the test coupon shall be measured before the buttered member is welded to the second member. This thickness shall become the minimum qualified thickness of buttering.

QW-283.4 Qualification Alternative. When an essential variable is changed in the portion of the weld to be made after buttering or when a different organization is performing the portion of the weld to be made after buttering, a new qualification shall be performed in accordance with one of the following methods:

(a) Qualify in accordance with QW-283.2 and QW-283.3. When the original qualification buttering thickness is less than $\frac{3}{16}$ in. (5 mm), the buttering thickness shall not be greater, nor the heat input higher than was used on the original qualification.

(b) When the original qualification buttering thickness is $\frac{3}{16}$ in. (5 mm) or greater, qualify the portion of the weld to be made after buttering using any P-Number material that nominally matches the chemical analysis of the buttering weld metal for the buttered base metal of the test coupon.

QW-284 Resistance Welding Machine Qualification

Each resistance welding machine shall be tested to determine its ability to make welds consistently and reproducibly. A machine shall be requalified whenever it is rebuilt, moved to a new location requiring a change in power supply, when the power supply is changed, or any other significant change is made to the equipment. Spot and projection welding machine qualification testing shall consist of making a set of 100 consecutive welds. Every fifth of these welds shall be subjected to mechanical shear tests. Five welds, which shall include one of the first five and one of the last five of the set shall be metallographically examined. Seam welding machine qualification testing shall be the same as procedure qualification testing required per QW-286. Maintenance or adjustment of the welding machine shall not be permitted during welding of a set of test welds. Qualification testing on any P-No. 21 through P-No. 26 aluminum alloy shall qualify the machine for all materials. Qualification on P-No. 1 through P-No. 15F iron-base alloys and any P-No. 41 through P-No. 49 nickel-base alloys shall qualify the machine for all P-No. 1 through P-No. 15F and P-No. 41 through P-No. 49 metals. Qualification testing of the machine using base metals assigned to P-No. 51 through P-No. 53, P-No. 61, or P-No. 62 qualifies the welding machine to weld all base metals assigned to P-No. 51 through P-No. 53, P-No. 61, and P-No. 62. Testing and acceptance criteria shall be in accordance with QW-196.

QW-285 Resistance Spot and Projection Weld Procedure Qualification

Procedure qualification testing for spot or projection welds shall be done following a Welding Procedure Specification, and it shall consist of making a set of ten consecutive welds. Five of these welds shall be subjected to mechanical shear tests and five to metallographic examination. Examination, testing, and acceptance criteria shall be in accordance with QW-196.

QW-286 Resistance Seam Weld Procedure Qualification

QW-286.1 Test coupons described below shall consist of the same number of members, orientation, material grades/types, and thicknesses to be used in production welding.

QW-286.2 A test coupon as shown in figure QW-462.7.1 shall be prepared by drilling a hole in the center of one of the outer coupon members. In the case of a test coupon containing more than two members, a hole shall be drilled in each member except for one of the outer members. A pipe nipple shall be welded or brazed to the outer member at the hole. The test coupon shall then be welded around the edges, sealing the space between the members as shown in figure QW-462.7.1. The coupon shall be pressurized hydrostatically until failure occurs. The procedure qualification is acceptable if failure occurs in the base metal.

QW-286.3 A test coupon at least 10 in. (250 mm) long shall be made per figure QW-462.7.2. This test coupon shall be cut transverse to the length of the weld into ten pieces, each approximately 1 in. (25 mm) long. Four transverse weld specimens and four longitudinal weld cross section specimens shall be cut and prepared as detailed in figure QW-462.7.2. The specimens shall be metallographically examined for compliance with the requirements of QW-196.

QW-287 Variation of Settings for Electric Resistance Welding

Settings for preheating cycles, electrode pressure, welding current, welding time cycle, or postheating cycles may be varied by ±5% from the values recorded on the PQR, or by ±10% when only one of the above settings is changed.

QW-288 Tube-to-Tubesheet Qualification Essential Variables

The following shall be considered essential variables for tube-to-tubesheet welding qualifications in accordance with QW-193.

QW-288.1 All Processes

(a) A change in the welding process used.

(b) A change in the weld joint configuration (beyond the manufacturing tolerance) such as the addition or deletion of preplaced filler metal, an increase in the depth of the groove, a decrease in the groove angle, or a change in the groove type.

(c) For tubes of specified wall thickness of 0.100 in. (2.5 mm) or less, an increase or decrease of 10% of the specified wall thickness. For tubes of specified wall thickness greater than 0.100 in. (2.5 mm), only one qualification test is required.

(d) For tubes of specified diameter of 2 in. (50 mm) or less and a specified wall thickness of 0.100 in. (2.5 mm) or less, a decrease greater than 10% of the specified tube diameter. For tubes of specified diameter greater than 2 in. (50 mm), the minimum diameter qualified is 2 in. (50 mm). For tubes of specified wall thickness greater than 0.100 in. (2.5 mm), diameter is not an essential variable.

(e) A decrease of 10% or more in the specified width of the ligament between tube holes when the specified width of the ligament is less than the greater of $\frac{3}{8}$ in. (10 mm) or 3 times the specified tube wall thickness.

(f) A change from multiple passes to a single pass or vice versa.

(g) A change in the welding position of the tube-to-tubesheet joint from that qualified (see QW-461.1).

(h) A change in the progression of a vertical position weld from that qualified.

(i) A change in the P-No. of the tube or tubesheet material (if the tubesheet material is part of the weld), a change in the P-No. or A-No. of the tubesheet cladding material (if the cladding material is part of the weld), or a change in a material not assigned a P-No. or A-No.

(j) If filler metal is added, a change in the A-No. of the weld deposit or a change in the nominal composition of the weld deposit if there is no A-No.

(k) A decrease of more than 100°F (55°C) in the preheat temperature or an increase of more than 100°F (55°C) in the interpass temperature from that qualified.

(l) The addition or deletion of PWHT.

(m) A change of more than 10% in the current level from that qualified.

(n) A change in the polarity or current type (AC or DC) from that qualified.

(o) A change between manual, semiautomatic, machine, or automatic methods of application.

(p) The addition of tube expansion prior to welding.

(q) A change in the method of cleaning prior to welding.

QW-288.2 Shielded Metal Arc Welding

(a) An increase in the electrode diameter.

(b) A change in the F-No. of the electrode.

QW-288.3 Gas Tungsten Arc, Plasma Arc, and Gas Metal Arc Welding

(a) A change in the size or shape of preplaced metal inserts.

(b) A change from one shielding gas to another shielding gas or to a mixture of shielding gases.

(c) When using a mixed shielding gas, a change of ±25% or 5 ft^3/hr (2.5 L/min), whichever is the larger, in the rate of flow of the minor gas constituent.

(d) For GTAW or PAW, the addition or deletion of filler metal.

(e) For GTAW or PAW, a change in the nominal diameter of the filler metal or electrode.

(f) The elimination of an auxiliary gas shield system if used during qualification.

(g) A change in the F-No. of the electrode or filler metal.

QW-288.4 Explosion Welding

(a) A 10% change in the specified tube wall thickness or diameter for all diameters and wall thicknesses.

(b) A change in the method of pressure application.

(c) A change in the type of explosive or a change in the energy content of ±10%.

(d) A change of ±10% in the distance between the charge and the tubesheet face.

(e) A change of ±10% in the specified clearance between the tube and the tubesheet.

NOTE: QW-288.1(f), (h), (j), (k), (m), (n), and (o) do not apply for this process.

QW-290 TEMPER BEAD WELDING

When the applicable Code Section specifies the use of this paragraph for temper bead welding, QW-290.1 through QW-290.6 shall apply.

QW-290.1 Basic Qualification and Upgrading Existing WPSs. All WPSs for temper bead welding of groove and fillet weld shall be qualified for groove welding in accordance with the rules in QW-202 for qualification by groove welding or the rules in QW-283 for welds with buttering. WPSs for overlay shall be qualified in accordance with QW-214 or QW-216. Once these requirements and any additional qualification requirements of the applicable construction code have been satisfied, then it is necessary only to prepare an additional test coupon using the same procedure with the same essential and, if applicable, the supplementary essential variables with the coupon long enough to obtain the required temper bead test specimens. Qualification for groove welding, welding with buttering or cladding, and temper bead welding may also be done in a single test coupon.

When a procedure has been previously qualified to satisfy all requirements including temper bead welding, but one or more temper bead welding variables is changed, then it is necessary only to prepare an additional test coupon using the same procedure with the same essential and, if applicable, the supplementary essential variables and the new temper bead welding essential variable(s) with the coupon long enough to obtain the required test specimens.

QW-290.2 Welding Process Restrictions. Temper bead welding is limited to SMAW, GTAW, SAW, GMAW (including FCAW), and PAW. Manual and semiautomatic GTAW and PAW are prohibited, except for the root pass of groove welds made from one side and as described for making repairs to temper bead welds in QW-290.6. The essential variables listed in table QW-290.4 apply in addition to the variables applicable for the process(es) qualified as given in QW-250. When impact testing is the basis for acceptance, the supplementary essential variables of QW-250 applicable to the process being qualified shall apply. When these variables conflict with or provide more stringent limitations than those of QW-250, these variables shall govern.

QW-290.3 Variables for Temper Bead Welding Qualifications. Table QW-290.4 lists the essential and nonessential variables that apply when temper bead qualification is required. The column "Hardness Test Essential Variables" shall apply, except that when the applicable Construction Code or Design Specification specifies acceptance based on impact testing, the column "Impact Test Essential Variables" shall apply. The column "Nonessential Variables" applies in all cases.

QW-290.4
WELDING VARIABLES FOR TEMPER BEAD PROCEDURE QUALIFICATION

Paragraph		Brief of Variables	Hardness Test Essential Variables	Impact Test Essential Variables	Nonessential Variables
QW-402	.23	+ Fluid backing	X		
	.24	+ Fluid backing		X	
QW-403	.25	ϕ P-No. or Gr. No.		X	
	.26	> Carbon equivalent	X		
	.27	> T	X		
QW-404	.51	Storage			X
	.52	Diffusible hydrogen			X
QW-406	.8	> Interpass temperature		X	
	.9	< Preheat temperature	X		
	.10	Preheat soak time			X
	.11	Postweld bakeout			X
QW-408	.24	Gas moisture			X
QW-409	.29	ϕ Heat input ratio	X	X	
QW-410	.10	ϕ Single to multiple electrode	X	X	
	.58	− Surface temper beads	X	X	
	.59	ϕ Type of welding	X	X	
	.60	+ Thermal preparation	X	X	
	.61	Surface bead placement	X	X	
	.62	Surface bead removal method			X
	.63	Bead overlap	X	X	
	.65	± Grinding	X	X	

Legend:
+ Addition   > Increase/greater than   ϕ Change
− Deletion   < Decrease/less than

QW-290.5 Test Coupon Preparation and Testing

(a) The test coupon may be any geometry that is suitable for removal of the required specimens. It shall consist of a groove weld, a cavity in a plate, overlay, or other suitable geometry. The distance from each edge of the weld preparation to the edge of the test coupon shall be at least 3 in. measured transverse to the direction of welding. The depth of preparation shall be such that at least two layers of weld metal are deposited, one of which may be the surface temper bead layer and deep enough to remove the required test specimens.

(b) The test coupon shall be bend-tested in accordance with QW-451.

(c) When hardness testing is specified by a Construction Code or Design Specification or no specific testing is required, measurements shall be taken across the weld metal, heat-affected zone, and base metal using the Vickers method with a 10 kg load. Increments shall be not greater than 0.010 in. (0.25 mm) apart and shall include

(1) a minimum of two measurements in the weld metal fill layers

(2) measurements across all weld metal temper bead layers

(3) measurements across the heat-affected zone

(4) a minimum of two measurements in the unaffected base metal

The measurements shall be taken along a line at approximately mid-plane of the thickness of the test coupon weld metal, along a line 0.040 in. (1 mm) below the original base metal surface and, when the coupon was welded using a full-penetration groove weld made from one side, $\frac{1}{16}$ in. (1.5 mm) above the root side surface. The path of HAZ hardness measurements may angle across the HAZ as necessary to obtain the required spacing without interference of one impression with others.

Full-penetration groove weld test coupons qualify full and partial penetration groove welds, fillet welds, and weld build-up. Partial penetration groove weld test coupons only qualify partial penetration groove welds, fillet welds, and build-up. Overlay test coupons only qualify overlay welds.

Hardness readings shall not exceed the hardness limits specified by the Construction Code or Design Specification. Where hardness is not specified, the data shall be reported.

(d) When specified by the applicable Construction Code or Design Specification, the test coupon shall be Charpy V-notch impact tested. The extent of testing (i.e., weld metal, HAZ, unaffected base metal), the testing temperature, and the acceptance criteria shall be as provided in the applicable Construction Code or Design Specification. Impact test specimens shall be removed from the coupon in the weld metal and HAZ as near as practical to a depth of one-half the thickness of the weld metal for each process. For HAZ specimens, the specimen shall be oriented so as to include as much of the HAZ as possible at the notch. The impact specimens and testing shall be in accordance with SA-370 using the largest size specimen that can be removed from the test coupon with the notch cut approximately normal to the test coupon surface. More than one set of impact test specimens shall be removed and tested when weld metal and heat-affected zone material from each process or set of variables cannot be included in a single set of test specimens.

QW-290.6 In-Process Repair Welding

(a) In-process repairs to welds made using temper bead welding are permitted. In-process repairs are defined as repairs in which a flaw is mechanically removed and a repair weld is made before welding of a joint is presented for final visual inspection. Examples of such repairs are areas of removal of porosity, incomplete fusion, etc., where sufficient metal has been mechanically removed that localized addition of weld metal is necessary in order to make the surface geometry suitable for continuation of normal welding.

(b) Surfaces to be repaired shall be prepared by mechanical removal of flaws and preparation of the surface to a suitable geometry.

(c) For processes other than manual and semiautomatic GTAW and PAW, repairs shall be made using the parameters given in the WPS for production temper bead welding. The approximate location of beads to be deposited relative to the original base metal surface shall be identified, and the applicable parameters shall be used for the layers to be deposited as specified by the WPS.

(d) When it is necessary to make repairs using manual or semiautomatic GTAW or PAW, a WPS shall be prepared based on PQRs developed for temper bead welding using machine or automatic GTAW or PAW, respectively. This WPS shall describe the size of the beads to be deposited and the volts, amps, and travel speed to be used for the beads against the base metal, for each temper bead layer and for the fill and surface temper bead layers corresponding to the locations where repair welding is to be done. These shall be within the equivalent power ratio for machine or automatic welding for the respective layers given in QW-409.29.

(e) Welders who will use manual and semiautomatic GTAW or PAW shall be qualified to use these welding processes as required by QW-300. In addition, each welder shall complete a proficiency demonstration. For this demonstration, each welder shall deposit two or more weld beads using WPS parameters for each deposit layer. The test coupon size shall be sufficiently large to make the required weld bead passes. The minimum pass length shall be 4 in. (100 mm). The heat input used by the welder shall be measured for each pass, and the size of each weld bead shall be measured for each pass, and they shall be as required by the WPS. The following essential variables shall apply for this demonstration:

(1) a change from one welding procedure to another

(2) a change from manual to semiautomatic welding and vice versa

(3) a change in position based on a groove weld in either plate or pipe as shown in table QW-461.9

(4) continuity of qualification in accordance with QW-322 shall be based on following the WPS that was demonstrated in addition to using the process as required by QW-322

ARTICLE III
WELDING PERFORMANCE QUALIFICATIONS

QW-300 GENERAL

(10) **QW-300.1** This Article lists the welding processes separately, with the essential variables that apply to welder and welding operator performance qualifications.

The welder qualification is limited by the essential variables given for each welding process. These variables are listed in QW-350, and are defined in Article IV Welding Data. The welding operator qualification is limited by the essential variables given in QW-360 for each type of weld.

A welder or welding operator may be qualified by volumetric NDE of a test coupon or their initial production welding within the limitations of QW-304 and QW-305 or by bend tests taken from a test coupon.

QW-300.2

(a) The basic premises of responsibility in regard to welding are contained within QW-103 and QW-301.2. These paragraphs require that each manufacturer or contractor (an assembler or an installer is to be included within this premise) shall be responsible for conducting tests to qualify the performance of welders and welding operators in accordance with qualified Welding Procedure Specifications, which his organization employs in the construction of weldments built in accordance with the Code. The purpose of this requirement is to ensure that the manufacturer or contractor has determined that his welders and welding operators using his procedures are capable of developing the minimum requirements specified for an acceptable weldment. This responsibility cannot be delegated to another organization.

(b) The welders or welding operators used to produce such weldments shall be tested under the full supervision and control of the manufacturer, contractor, assembler, or installer during the production of these test weldments. It is not permissible for the manufacturer, contractor, assembler, or installer to have the welding performed by another organization. It is permissible, however, to subcontract any or all of the work of preparation of test materials for welding and subsequent work on the preparation of test specimens from the completed weldments, performance of nondestructive examination and mechanical tests, provided the manufacturer, contractor, assembler, or installer accepts full responsibility for any such work.

(c) The Code recognizes a manufacturer, contractor, assembler, or installer 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 the welder performance qualification for two or more companies of different names exists, the companies involved shall describe in the Quality Control system, the operational control of performance qualifications. In this case requalification of welders and welding operators within the companies of such an organization will not be required, provided all other requirements of Section IX are met.

(d) The Code recognizes that manufacturers or contractors may maintain effective operational control of Welder/Welding Operator Performance Qualification (WPQ) records under different ownership than existed during the original welder or welding operator qualification. When a manufacturer or contractor or part of a manufacturer or contractor is acquired by a new owner(s), the WPQs may be used by the new owner(s) without requalification, provided all of the following are met:

(1) the new owner(s) takes responsibility for the WPQs

(2) the WPQs reflect the name of the new owner(s)

(3) the Quality Control System/Quality Assurance Program reflects the source of the WPQs as being from the former manufacturer or contractor

QW-300.3 More than one manufacturer, contractor, assembler, or installer may simultaneously qualify one or more welders or welding operators. When simultaneous qualifications are conducted, each participating organization shall be represented during welding of test coupons by an employee who is responsible for welder performance qualification.

The welding procedure specifications (WPS) that are followed during simultaneous qualifications shall be compared by the participating organizations. The WPSs shall be identical for all the essential variables, except for the preheat temperature and PWHT requirements. The qualified thickness ranges for base metal and deposited weld metal need not be identical, but these thicknesses shall be adequate to permit welding of the test coupons. Alternatively, the participating organizations shall agree upon the use of a single WPS provided each participating organization has a PQR(s) to support the WPS covering the range of variables to be followed in the performance qualification. When a single WPS is to be followed, each participating organization shall review and accept that WPS.

Each participating organization's representative shall positively identify each welder or welding operator who is being tested. Each organizational representative shall also verify marking of the test coupon with the welder's or welding operator's identification, and marking of the top of the test coupon when the orientation must be known in order to remove test specimens.

Each organization's representative shall perform a visual examination of each completed test coupon and shall examine each test specimen to determine its acceptability. Alternatively, after visual examination, when the test coupon(s) are prepared and tested by an independent laboratory, that laboratory's report may be used as the basis for accepting the test results. When the test coupon(s) is radiographically examined (QW-302.2), the radiographic testing facility's report may be used as the basis for acceptance of the radiographic test.

Each organizational representative shall complete and certify a Welder/Welding Operator Performance Qualification (WPQ) Record for each welder or welding operator. Forms QW-484A/QW-484B (see Nonmandatory Appendix B) have been provided as a guide for the WPQ.

When a welder or welding operator changes employers between participating organizations, the employing organization shall verify that the welder's continuity of qualifications has been maintained as required by QW-322 by previous employers since his qualification date. If the welder or welding operator has had his qualification withdrawn for specific reasons, the employing organization shall notify all other participating organizations that the welder's or welding operator's qualification(s) has been revoked in accordance with QW-322.1(b). The remaining participating organizations shall determine that the welder or welding operator can perform satisfactory work in accordance with this Section.

When a welder's or welding operator's qualifications are renewed in accordance with the provisions of QW-322.2, each renewing organization shall be represented by an employee who is responsible for welder performance qualification. The testing procedures shall follow the rules of this paragraph.

QW-301 Tests

QW-301.1 Intent of Tests. The performance qualification tests are intended to determine the ability of welders and welding operators to make sound welds.

QW-301.2 Qualification Tests. Each manufacturer or contractor shall qualify each welder or welding operator for each welding process to be used in production welding. The performance qualification test shall be welded in accordance with qualified Welding Procedure Specifications (WPS), or Standard Welding Procedure Specifications (SWPS) listed in Appendix E, except that when performance qualification is done in accordance with a WPS or SWPS that requires a preheat or postweld heat treatment, these may be omitted. Changes beyond which requalification is required are given in QW-350 for welders and in QW-360 for welding operators. Allowable visual, mechanical, and radiographic examination requirements are described in QW-304 and QW-305. Retests and renewal of qualification are given in QW-320.

The welder or welding operator who prepares the WPS qualification test coupons meeting the requirements of QW-200 is also qualified within the limits of the performance qualifications, listed in QW-304 for welders and in QW-305 for welding operators. He is qualified only within the limits for positions specified in QW-303.

The performance test may be terminated at any stage of the testing procedure, whenever it becomes apparent to the supervisor conducting the tests that the welder or welding operator does not have the required skill to produce satisfactory results.

QW-301.3 Identification of Welders and Welding Operators. Each qualified welder and welding operator shall be assigned an identifying number, letter, or symbol by the manufacturer or contractor, which shall be used to identify the work of that welder or welding operator.

QW-301.4 Record of Tests. The record of Welder/Welding Operator Performance Qualification (WPQ) tests shall include the essential variables (QW-350 or QW-360), the type of test and test results, and the ranges qualified in accordance with QW-452 for each welder and welding operator. Suggested forms for these records are given in Forms QW-484A/QW-484B (see Nonmandatory Appendix B).

QW-302 Type of Test Required (10)

QW-302.1 Mechanical Tests. Except as may be specified for special processes (QW-380), the type and number of test specimens required for mechanical testing shall be in accordance with QW-452. Groove weld test specimens shall be removed in a manner similar to that shown in figures QW-463.2(a) through QW-463.2(g). Fillet weld test specimens shall be removed in a manner similar to that shown in figures QW-462.4(a) through QW-462.4(d) and figure QW-463.2(h).

All mechanical tests shall meet the requirements prescribed in QW-160 or QW-180, as applicable.

QW-302.2 Volumetric NDE. When the welder or welding operator is qualified by volumetric NDE, as permitted in QW-304 for welders and QW-305 for welding operators, the minimum length of coupon(s) to be examined shall be 6 in. (150 mm) and shall include the entire weld circumference for pipe(s), except that for small diameter pipe, multiple coupons may be required, but the number need not exceed four consecutively made test coupons. The examination technique and acceptance criteria shall be in accordance with QW-191.

QW-302.3 Test Coupons in Pipe. For test coupons made on pipe in position 1G or 2G of figure QW-461.4, two specimens shall be removed as shown for bend specimens in figure QW-463.2(d) or figure QW-463.2(e), omitting the specimens in the upper-right and lower-left quadrants, and replacing the root-bend specimen in the upper-left quadrant of figure QW-463.2(d) with a face-bend specimen. For test coupons made on pipe in position 5G or 6G of figure QW-461.4, specimens shall be removed in accordance with figure QW-463.2(d) or figure QW-463.2(e) and all four specimens shall pass the test. For test coupons made in both positions 2G and 5G on a single pipe test coupon, specimens shall be removed in accordance with figure QW-463.2(f) or figure QW-463.2(g).

QW-302.4 Visual Examination. For plate coupons all surfaces (except areas designated "discard") shall be examined visually per QW-194 before cutting of bend specimens. Pipe coupons shall be visually examined per QW-194 over the entire circumference, inside and outside.

QW-303 Limits of Qualified Positions and Diameters (See QW-461)

QW-303.1 Groove Welds — General. Welders and welding operators who pass the required tests for groove welds in the test positions of table QW-461.9 shall be qualified for the positions of groove welds and fillet welds shown in table QW-461.9. In addition, welders and welding operators who pass the required tests for groove welds shall also be qualified to make fillet welds in all thicknesses and pipe diameters of any size within the limits of the welding variables of QW-350 or QW-360, as applicable.

QW-303.2 Fillet Welds — General. Welders and welding operators who pass the required tests for fillet welds in the test positions of table QW-461.9 shall be qualified for the positions of fillet welds shown in table QW-461.9. Welders and welding operators who pass the tests for fillet welds shall be qualified to make fillet welds only in the thicknesses of material, sizes of fillet welds, and diameters of pipe and tube $2\frac{7}{8}$ in. (73 mm) O.D. and over, as shown in table QW-452.5, within the applicable essential variables. Welders and welding operators who make fillet welds on pipe or tube less than $2\frac{7}{8}$ in. (73 mm) O.D. must pass the pipe fillet weld test per table QW-452.4 or the required mechanical tests in QW-304 and QW-305 as applicable.

QW-303.3 Special Positions. A fabricator who does production welding in a special orientation may make the tests for performance qualification in this specific orientation. Such qualifications are valid only for the flat position and for the special positions actually tested, except that an angular deviation of ±15 deg is permitted in the inclination of the weld axis and the rotation of the weld face, as defined in figures QW-461.1 and QW-461.2.

QW-303.4 Stud-Weld Positions. Qualification in the 4S position also qualifies for the 1S position. Qualification in the 4S and 2S positions qualifies for all positions.

QW-303.5 Tube-to-Tubesheet Welder and Welding Operator Qualification. When the applicable Code Section requires the use of QW-193 for tube-to-tubesheet demonstration mockup qualification tests, QW-193.2 shall apply. If specific qualification test requirements are not specified by the applicable Code Section, welders and welding operators shall be qualified with one of the following methods:

(a) groove welds per the requirements of QW-303.1

(b) a demonstration mockup per the requirements of QW-193.2

QW-304 Welders (10)

Except for the special requirements of QW-380, each welder who welds under the rules of the Code shall have passed the mechanical and visual examinations prescribed in QW-302.1 and QW-302.4 respectively. Alternatively, welders may be qualified by volumetric NDE per QW-191 when making a groove weld using SMAW, SAW, GTAW, PAW, and GMAW (except short-circuiting mode for radiographic examination) or a combination of these processes, except for P-No. 21 through P-No. 26, P-No. 51 through P-No. 53, and P-No. 61 through P-No. 62 metals. Welders making groove welds in P-No. 21 through P-No. 26 and P-No. 51 through P-No. 53 metals with the GTAW process may also be qualified by volumetric NDE per QW-191. The volumetric NDE shall be in accordance with QW-302.2.

A welder qualified to weld in accordance with one qualified WPS is also qualified to weld in accordance with other qualified WPSs, using the same welding process, within the limits of the essential variables of QW-350.

QW-304.1 Examination. Welds made in test coupons for performance qualification may be examined by visual and mechanical examinations (QW-302.1, QW-302.4) or by volumetric NDE (QW-302.2) for the process(es) and mode of arc transfer specified in QW-304. Alternatively, a minimum 6 in. (150 mm) length of the first production weld(s) made by a welder using the process(es) and/or mode of arc transfer specified in QW-304 may be examined by volumetric NDE.

(a) For pipe(s) welded in the 5G, 6G, or special positions, the entire production weld circumference made by the welder shall be examined.

(b) For small diameter pipe where the required minimum length of weld cannot be obtained from a single production pipe circumference, additional consecutive circumferences made by the welder shall be examined, except that the total number of circumferences need not exceed four.

(c) The examination technique and acceptance criteria for production welds shall be in accordance with QW-191.

QW-304.2 Failure to Meet Examination Standards. If a production weld is selected for welder performance qualification and it does not meet the examination standards, the welder has failed the test. In this event, the entire production weld made by this welder shall be examined and repaired by a qualified welder or welding operator. Alternatively, retests may be made as permitted in QW-320.

(10) QW-305 Welding Operators

Except for the special requirements of QW-380, each welding operator who welds under the rules of this Code shall have passed the mechanical and visual examinations prescribed in QW-302.1 and QW-302.4, respectively. Alternatively, welding operators may be qualified by volumetric NDE per QW-191 when making a groove weld using SMAW, SAW, GTAW, PAW, EGW, and GMAW (except short-circuiting mode for radiographic examination) or a combination of these processes, except for P-No. 21 through P-No. 26, P-No. 51 through P-No. 53, and P-No. 61 through P-No. 62 metals. Welding operators making groove welds in P-No. 21 through P-No. 26 and P-No. 51 through P-No. 53 metals with the GTAW process may also be qualified by volumetric NDE. The volumetric NDE shall be in accordance with QW-302.2.

A welding operator qualified to weld in accordance with one qualified WPS is also qualified to weld in accordance with other qualified WPSs within the limits of the essential variables of QW-360.

QW-305.1 Examination. Welds made in test coupons may be examined by volumetric NDE (QW-302.2) or by visual and mechanical examinations (QW-302.1, QW-302.4). Alternatively, a minimum 3 ft (1 m) length of the first production weld(s) made entirely by the welding operator in accordance with a qualified WPS may be examined by volumetric NDE.

(a) For pipe(s) welded in the 5G, 6G, or special positions, the entire production weld circumference made by the welding operator shall be examined.

(b) For small diameter pipe where the required minimum length of weld cannot be obtained from a single production pipe circumference, additional consecutive circumferences made by the welding operator shall be examined except that the total number of circumferences need not exceed four.

(c) The examination technique and acceptance criteria for production welds shall be in accordance with QW-191.

QW-305.2 Failure to Meet Examination Standards. If a portion of a production weld is selected for welding operator performance qualification, and it does not meet the examination standards, the welding operator has failed the test. In this event, the entire production weld made by this welding operator shall be examined completely and repaired by a qualified welder or welding operator. Alternatively, retests may be made as permitted in QW-320.

QW-306 Combination of Welding Processes

Each welder or welding operator shall be qualified within the limits given in QW-301 for the specific welding process(es) he will be required to use in production welding. A welder or welding operator may be qualified by making tests with each individual welding process in separate test coupons, or with a combination of welding processes in a single test coupon. Two or more welders or welding operators, each using the same or a different welding process, may be qualified in combination in a single test coupon. For combination qualifications in a single test coupon, the limits for thicknesses of deposited weld metal, and bend and fillet testing are given in QW-452 and shall be considered individually for each welder or welding operator for each welding process or whenever there is a change in an essential variable. A welder or welding operator qualified in combination on a single test coupon is qualified to weld in production using any of his processes individually or in different combinations, provided he welds within his limits of qualification with each specific process.

Failure of any portion of a combination test in a single test coupon constitutes failure of the entire combination.

QW-310 QUALIFICATION TEST COUPONS

QW-310.1 Test Coupons. The test coupons may be plate, pipe, or other product forms. When all position qualifications for pipe are accomplished by welding one pipe assembly in both the 2G and 5G positions (figure QW-461.4), NPS 6 (DN 150), NPS 8 (DN 200), NPS 10 (DN 250), or larger diameter pipe shall be employed to make up the test coupon as shown in figure QW-463.2(f) for NPS 10 (DN 250) or larger pipe and in figure QW-463.2(g) for NPS 6 (DN 150) or NPS 8 (DN 200) diameter pipe.

QW-310.2 Welding Groove With Backing. The dimensions of the welding groove on the test coupon used in making qualification tests for double-welded groove welds or single-welded groove welds with backing shall be the same as those for any Welding Procedure Specification (WPS) qualified by the manufacturer, or shall be as shown in figure QW-469.1.

A single-welded groove-weld test coupon with backing or a double-welded groove-weld test coupon shall be considered welding with backing. Partial penetration groove welds and fillet welds are considered welding with backing.

QW-310.3 Welding Groove Without Backing. The dimensions of the welding groove of the test coupon used in making qualification tests for single-welded groove welds without backing shall be the same as those for any WPS qualified by the manufacturer, or as shown in figure QW-469.2.

QW-320 RETESTS AND RENEWAL OF QUALIFICATION

QW-321 Retests

A welder or welding operator who fails one or more of the tests prescribed in QW-304 or QW-305, as applicable, may be retested under the following provisions.

QW-321.1 Immediate Retest Using Visual Examination. When the qualification coupon has failed the visual examination of QW-302.4, retesting shall be by visual examination before conducting the mechanical testing.

When an immediate retest is made, the welder or welding operator shall make two consecutive test coupons for each position which he has failed, all of which shall pass the visual examination requirements.

The examiner may select one of the successful test coupons from each set of retest coupons which pass the visual examination for conducting the mechanical testing.

QW-321.2 Immediate Retest Using Mechanical Testing. When the qualification coupon has failed the mechanical testing of QW-302.1, retesting shall be by mechanical testing.

When an immediate retest is made, the welder or welding operator shall make two consecutive test coupons for each position which he has failed, all of which shall pass the test requirements.

(10) **QW-321.3 Immediate Retest Using Volumetric NDE.** When the qualification coupon has failed the volumetric NDE of QW-302.2, the immediate retest shall be by the same examination method.

(a) For welders and welding operators the retest shall be to examine two 6 in. (150 mm) plate coupons; for pipe, to examine two pipes for a total of 12 in. (300 mm) of weld, which shall include the entire weld circumference for pipe or pipes (for small diameter pipe the total number of consecutively made test coupons need not exceed eight).

(b) At the option of the manufacturer, the welder who has failed the production weld alternative test may be retested by examining additional weld areas equal to twice the required length or number of pipe circumferences of the same or consecutively made production weld(s) specified in QW-304.1. If this length of weld passes the test, the welder is qualified and the area of weld on which he had previously failed the test shall be repaired by him or another qualified welder. If this length does not meet the examination standards, the welder has failed the retest and all of the production welds made by this welder shall be examined completely and repaired by a qualified welder or welding operator.

(c) At the option of the manufacturer, the welding operator who has failed the production weld alternative test may be retested by examining additional weld areas equal to twice the required length or number of pipe circumferences of the same or consecutively made production weld(s) specified in QW-305.1. If this length of weld passes the test, the welding operator is qualified and the area of weld on which he had previously failed the test shall be repaired by him or another qualified welder or welding operator. If this length does not meet the examination standards, the welding operator has failed the retest and all of the production welds made by this welding operator shall be examined completely and repaired by a qualified welder or welding operator.

QW-321.4 Further Training. When the welder or the welding operator has had further training or practice, a new test shall be made for each position on which he failed to meet the requirements.

QW-322 Expiration and Renewal of Qualification

QW-322.1 Expiration of Qualification. The performance qualification of a welder or welding operator shall be affected when one of the following occurs:

(a) When he has not welded with a process during a period of 6 months or more, his qualifications for that process shall expire; unless, within the 6 month period, prior to his expiration of qualification

(1) the welder has welded with that process using manual or semiautomatic welding, under the supervision and control of the qualifying manufacturer or contractor or participating organization(s) as identified in QW-300.3; that will extend his qualification for an additional 6 months

(2) the welding operator has welded with that process using machine or automatic welding, under the supervision and control of the qualifying manufacturer or contractor or participating organization(s) as identified in QW-300.3; that will extend his qualification for an additional 6 months

(b) When there is a specific reason to question his ability to make welds that meet the specification, the qualifications

that support the welding he is doing shall be revoked. All other qualifications not questioned remain in effect.

QW-322.2 Renewal of Qualification

(a) Renewal of qualification expired under QW-322.1(a) may be made for any process by welding a single test coupon of either plate or pipe, of any material, thickness or diameter, in any position, and by testing of that coupon as required by QW-301 and QW-302. A successful test renews the welder or welding operator's previous qualifications for that process for those materials, thicknesses, diameters, positions, and other variables for which he was previously qualified.

Providing the requirements of QW-304 and QW-305 are satisfied, renewal of qualification under QW-322.1(a) may be done on production work.

(b) Welders and welding operators whose qualifications have been revoked under QW-322.1(b) above shall requalify. Qualification shall utilize a test coupon appropriate to the planned production work. The coupon shall be welded and tested as required by QW-301 and QW-302. Successful test restores the qualification.

QW-350 WELDING VARIABLES FOR WELDERS

QW-351 General

A welder shall be requalified whenever a change is made in one or more of the essential variables listed for each welding process.

Where a combination of welding processes is required to make a weldment, each welder shall be qualified for the particular welding process or processes he will be required to use in production welding. A welder may be qualified by making tests with each individual welding process, or with a combination of welding processes in a single test coupon.

The limits of weld metal thickness for which he will be qualified are dependent upon the approximate thickness of the weld metal he deposits with each welding process, exclusive of any weld reinforcement, this thickness shall be considered the test coupon thickness as given in QW-452.

In any given production weldment, welders may not deposit a thickness greater than that permitted by QW-452 for each welding process in which they are qualified.

QW-352
OXYFUEL GAS WELDING (OFW)
Essential Variables

Paragraph		Brief of Variables
QW-402 Joints	.7	+ Backing
QW-403 Base Metals	.2	Maximum qualified
	.18	ϕ P-Number
QW-404 Filler Metals	.14	± Filler
	.15	ϕ F-Number
	.31	ϕ t Weld deposit
QW-405 Positions	.1	+ Position
QW-408 Gas	.7	ϕ Type fuel gas

QW-353
SHIELDED METAL-ARC WELDING (SMAW)
Essential Variables

Paragraph		Brief of Variables
QW-402 Joints	.4	− Backing
QW-403 Base Metals	.16	ϕ Pipe diameter
	.18	ϕ P-Number
QW-404 Filler Metals	.15	ϕ F-Number
	.30	ϕ t Weld deposit
QW-405 Positions	.1	+ Position
	.3	ϕ ↑↓ Vertical welding

QW-354
SEMIAUTOMATIC SUBMERGED-ARC WELDING (SAW)
Essential Variables

Paragraph		Brief of Variables
QW-403 Base Metals	.16	ϕ Pipe diameter
	.18	ϕ P-Number
QW-404 Filler Metals	.15	ϕ F-Number
	.30	t Weld deposit
QW-405 Positions	.1	+ Position

QW-355
SEMIAUTOMATIC GAS METAL-ARC WELDING (GMAW)
[This Includes Flux-Cored Arc Welding (FCAW)]
Essential Variables

Paragraph		Brief of Variables
QW-402 Joints	.4	− Backing
QW-403 Base Metals	.16	ϕ Pipe diameter
	.18	ϕ P-Number
QW-404 Filler Metals	.15	ϕ F-Number
	.30	ϕ *t* Weld deposit
	.32	*t* Limit (S. Cir. Arc.)
QW-405 Positions	.1	+ Position
	.3	ϕ ↑↓ Vertical welding
QW-408 Gas	.8	− Inert backing
QW-409 Electrical	.2	ϕ Transfer mode

QW-356
MANUAL AND SEMIAUTOMATIC GAS TUNGSTEN-ARC WELDING (GTAW)
Essential Variables

Paragraph		Brief of Variables
QW-402 Joints	.4	− Backing
QW-403 Base Metals	.16	ϕ Pipe diameter
	.18	ϕ P-Number
QW-404 Filler Metals	.14	± Filler
	.15	ϕ F-Number
	.22	± Inserts
	.23	ϕ Solid or metal-cored to flux-cored
	.30	ϕ *t* Weld deposit
QW-405 Positions	.1	+ Position
	.3	ϕ ↑↓ Vertical welding
QW-408 Gas	.8	− Inert backing
QW-409 Electrical	.4	ϕ Current or polarity

QW-357
MANUAL AND SEMIAUTOMATIC PLASMA-ARC WELDING (PAW)
Essential Variables

Paragraph		Brief of Variables
QW-402 Joints	.4	− Backing
QW-403 Base Metals	.16	ϕ Pipe diameter
	.18	ϕ P-Number
QW-404 Filler Metals	.14	± Filler
	.15	ϕ F-Number
	.22	± Inserts
	.23	ϕ Solid or metal-cored to flux-cored
	.30	ϕ *t* Weld deposit
QW-405 Positions	.1	+ Position
	.3	ϕ ↑↓ Vertical welding
QW-408 Gas	.8	− Inert backing

Legend for QW-352 through QW-357:

ϕ Change ↑ Uphill
+ Addition ↓ Downhill
− Deletion

QW-360 WELDING VARIABLES FOR WELDING OPERATORS

QW-361 General

A welding operator shall be requalified whenever a change is made in one of the following essential variables (QW-361.1 and QW-361.2). There may be exceptions or additional requirements for the processes of QW-362, QW-363, and the special processes of QW-380.

QW-361.1 Essential Variables — Automatic Welding

(a) A change from automatic to machine welding.

(b) A change in the welding process.

(c) For electron beam and laser welding, the addition or deletion of filler metal.

(d) For laser welding, a change in laser type (e.g., a change from CO_2 to YAG).

(e) For friction welding, a change from continous drive to inertia welding or vice versa.

(f) For electron beam welding, a change from vacuum to out-of-vacuum equipment, and vice versa.

QW-361.2 Essential Variables — Machine Welding

(a) A change in the welding process.

(b) A change from direct visual control to remote visual control and vice-versa.

(c) The deletion of an automatic arc voltage control system for GTAW.

(d) The deletion of automatic joint tracking.

(e) The addition of welding positions other than those already qualified (see QW-120, QW-130, and QW-303).

(f) The deletion of consumable inserts, except that qualification with consumable inserts shall also qualify for fillet welds and welds with backing.

(g) The deletion of backing. Double-welded groove welds are considered welding with backing.

(h) A change from single pass per side to multiple passes per side but not the reverse.

QW-362 Electron Beam Welding (EBW), Laser Beam Welding (LBW), and Friction Welding (FRW)

The performance qualification test coupon shall be production parts or test coupons that have joint designs permitted by any qualified WPS. The coupon shall be mechanically tested in accordance with QW-452. Alternatively, when the part or coupon does not readily lend itself to the preparation of bend test specimens, the part may be cut so that at least two full-thickness weld cross sections are exposed. Those cross sections 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. The weld metal and heat affected zone shall exhibit complete fusion and freedom from cracks. The essential variables for welding operator qualification shall be in accordance with QW-361.

QW-363 Stud Welding

Stud welding operators shall be performance qualified in accordance with the test requirements of QW-192.2 and the position requirements of QW-303.4.

QW-380 SPECIAL PROCESSES

QW-381 Corrosion-Resistant Weld Metal Overlay

QW-381.1 Qualification Test

(a) The size of test coupons, limits of base metal thickness qualification, required examinations and tests, and test specimens shall be as specified in table QW-453.

(b) Welders or welding operators who pass the tests for corrosion-resistant weld metal overlay cladding shall only be qualified to apply corrosion-resistant weld metal overlay portion of a groove weld joining composite clad or lined materials.

(c) The essential variables of QW-350 and QW-360 shall apply for welders and welding operators, respectively, except there is no limit on the maximum thickness of corrosion-resistant overlay that may be applied in production. When specified as essential variables, the limitations of position and diameter qualified for groove welds shall apply to overlay welds, except the limitations on diameter qualified shall apply only to welds deposited in the circumferential direction.

QW-381.2 Qualification on Composite Welds. A welder or welding operator who has qualified on composite welds in clad or lined material, as provided in QW-383.1(b) is also qualified to deposit corrosion-resistant weld metal overlay.

QW-381.3 Alternative Qualification With Groove Weld Tests. When a chemical composition is not specified in the WPS, welders or welding operators who successfully complete a groove weld performance qualification test meeting the corrosion-resistant overlay bend test requirements of QW-163 may be considered qualified for corrosion-resistant overlay welding within the ranges defined in QW-350 or QW-360.

QW-382 Hard-Facing Weld Metal Overlay (Wear Resistant)

(a) The size of the test coupons, limits of base metal thickness qualification, required examinations and tests, and test specimens shall be as specified in table QW-453. Base material test coupons may be as permitted in QW-423.

(b) Welders and welding operators who pass the tests for hard-facing weld metal overlay are qualified for hard-facing overlay only.

(c) The essential variable, of QW-350 and QW-360, shall apply for welders and welding operators, respectively, except there is no limit on the maximum thickness of hard-facing overlay that may be applied in production. When specified as essential variables, the limitations of position and diameter qualified for groove welds shall apply to overlay welds except the limitations on diameter qualified shall apply only to welds deposited in the circumferential direction.

(d) Qualification with one AWS classification within an SFA specification qualifies for all other AWS classifications in that SFA specification.

(e) A change in welding process shall require welder and welding operator requalification.

QW-383 Joining of Clad Materials and Applied Linings

QW-383.1 Clad Materials

(a) Welders and welding operators who will join the base material portion of clad materials shall be qualified for groove welding in accordance with QW-301. Welders and welding operators who will apply the cladding portion of a weld between clad materials shall be qualified in accordance with QW-381. Welders and welding operators

need only be qualified for the portions of composite welds that they will make in production.

(b) As an alternative to QW-383.1(a), welders and welding operators may be qualified using composite test coupons. The test coupon shall be at least $\frac{3}{8}$ in. (10 mm) thick and of dimensions such that a groove weld can be made to join the base materials and the corrosion-resistant weld metal overlay can be applied to the completed groove weld. Four side bend test specimens shall be removed from the completed test coupon and tested. The groove weld portion and the corrosion-resistant weld metal overlay portion of the test coupon shall be evaluated using the respective criteria in QW-163. Welders and welding operators qualified using composite test coupons are qualified to join base materials as provided by QW-301, and they are qualified to apply corrosion-resistant weld metal overlay as provided by QW-381.

QW-383.2 Applied Linings

(a) Welders and welding operators shall be qualified following the rules for making groove or fillet welds in accordance with QW-301. Plug welds for attaching applied linings shall be considered equivalent to fillet welds for the purpose of performance qualification.

(b) An alternate test coupon shall consist of the geometry to be welded, except the base material need not exceed 1 in. (25 mm) in thickness. The welded test coupon shall be sectioned and etched to reveal the weld and heat-affected zone. The weld shall show penetration into the base metal.

QW-384 Resistance Welding Operator Qualification

Each welding operator shall be tested on each machine type which he will use. Qualification testing on any P-No. 21 through P-No. 26 metal shall qualify the operator for all metals. Qualification on any P-No. 1 through P-No. 15F or any P-No. 41 through P-No. 49 metals shall qualify the operator for all P-No. 1 through P-No. 15F and P-No. 41 through P-No. 49 metals. Qualification testing on any P-No. 51 through P-No. 53, P-No. 61, or P-No. 62 metal shall qualify the operator for all P-No. 51 through P-No. 53, P-No. 61, and P-No. 62 metals.

(a) Qualification for spot and projection welding shall consist of making a set of ten consecutive welds, five of which shall be subjected to mechanical shear tests or peel tests, and five to macro-examination. Examination, testing, and acceptance criteria shall be in accordance with QW-196.

(b) Qualification for seam welding shall consist of that testing specified in QW-286.3, except that only one transverse cross section and one longitudinal cross section are required.

QW-385 Flash Welding Operator Qualification

Each welding operator shall be tested by welding a test coupon following any WPS. The test coupon shall be welded and tested in accordance with QW-199. Qualification following any flash welding WPS qualifies the operator to follow all flash welding WPSs.

Production weld sampling tests required by other Sections may be used to qualify welding operators. The test method, extent of tests, and acceptance criteria of the other Sections and QW-199.2 shall be met when this is done.

ARTICLE IV
WELDING DATA

QW-400 VARIABLES

QW-401 General

Each welding variable described in this Article is applicable as an essential, supplementary essential, or nonessential variable for procedure qualification when referenced in QW-250 for each specific welding process. Essential variables for performance qualification are referenced in QW-350 for each specific welding process. A change from one welding process to another welding process is an essential variable and requires requalification.

QW-401.1 Essential Variable (Procedure). A change in a welding condition which will affect the mechanical properties (other than notch toughness) of the weldment (e.g., change in P-Number, welding process, filler metal, electrode, preheat or postweld heat treatment).

QW-401.2 Essential Variable (Performance). A change in a welding condition which will affect the ability of a welder to deposit sound weld metal (such as a change in welding process, deletion of backing, electrode, F-Number, technique, etc.).

QW-401.3 Supplementary Essential Variable (Procedure). A change in a welding condition which will affect the notch-toughness properties of a weldment (for example, change in welding process, uphill or down vertical welding, heat input, preheat or PWHT, etc.). Supplementary essential variables are in addition to the essential variables for each welding process.

When a procedure has been previously qualified to satisfy all requirements other than notch toughness, it is then necessary only to prepare an additional test coupon using the same procedure with the same essential variables, but additionally with all of the required supplementary essential variables, with the coupon long enough to provide the necessary notch-toughness specimens.

When a procedure has been previously qualified to satisfy all requirements including notch toughness, but one or more supplementary essential variable is changed, then it is only necessary to prepare an additional test coupon using the same welding procedure and the new supplementary essential variable(s), with the coupon long enough to provide the necessary notch-toughness specimens. If a previously qualified weld procedure has satisfactory notch-toughness values in the weld metal, then it is necessary only to test notch-toughness specimens from the heat affected zone when such are required.

When essential variables are qualified by one or more PQRs and supplementary essential variables are qualified by other PQRs, the ranges of essential variables established by the former PQRs are only affected by the latter to the extent specified in the applicable supplementary essential variable (e.g., essential variable QW-403.8 governs the minimum and maximum thickness of base metal qualified. When supplementary essential variable QW-403.6 applies, it modifies only the minimum thickness qualified, not the maximum).

QW-401.4 Nonessential Variable (Procedure). A change in a welding condition which will *not* affect the mechanical properties of a weldment (such as joint design, method of back gouging or cleaning, etc.)

QW-401.5 The welding data includes the welding variables grouped as joints, base metals, filler metals, position, preheat, postweld heat treatment, gas, electrical characteristics, and technique. For convenience, variables for each welding process are summarized in table QW-416 for performance qualification.

QW-402 Joints

QW-402.1 A change in the type of groove (Vee-groove, U-groove, single-bevel, double-bevel, etc.).

QW-402.2 The addition or deletion of a backing.

QW-402.3 A change in the nominal composition of the backing.

QW-402.4 The deletion of the backing in single-welded groove welds. Double-welded groove welds are considered welding with backing.

QW-402.5 The addition of a backing or a change in its nominal composition.

QW-402.6 An increase in the fit-up gap, beyond that initially qualified.

QW-402.7 The addition of backing.

QW-402.8 A change in nominal size or shape of the stud at the section to be welded.

QW-402.9 In stud welding, a change in shielding as a result of ferrule or flux type.

QW-402.10 A change in the specified root spacing.

QW-402.11 The addition or deletion of nonmetallic retainers or nonfusing metal retainers.

QW-402.12 The welding procedure qualification test shall duplicate the joint configuration to be used in production within the limits listed, except that pipe or tube to pipe or tube may be used for qualification of a pipe or tube to other shapes, and solid round to solid round may be used for qualification of a solid round to other shapes

(a) any change exceeding ±10 deg in the angle measured for the plane of either face to be joined, to the axis of rotation

(b) a change in cross-sectional area of the weld joint greater than 10%

(c) a change in the outside diameter of the cylindrical weld interface of the assembly greater than ±10%

(d) a change from solid to tubular cross section at the joint or vice versa regardless of QW-402.12(b)

QW-402.13 A change in the method of joining from spot to projection to seam or vice versa.

QW-402.14 An increase or decrease of more than 10% in the spacing of the welds when they are within two diameters of each other.

QW-402.15 A change in the size or shape of the projection in projection welding.

QW-402.16 A decrease in the distance between the approximate weld interface and the final surface of the production corrosion-resistant or hard-facing weld metal overlay below the minimum thickness qualified as shown in figures QW-462.5(a) through QW-462.5(e). There is no limit on the maximum thickness for corrosion-resistant or hard-facing weld metal overlay that may be used in production.

QW-402.17 An increase in the thickness of the production spray fuse hard-facing deposit above the thickness deposited on the procedure qualification test coupon.

QW-402.18 When the joint is a lap joint, the following additional variables shall apply:

(a) a change of more than 10% in the distance to the edge of the material

(b) a change of more than 10% in the joint overlap

(c) a change in the number of layers of material

(d) a change in the method of surface conditioning at the metal-to-metal interfaces

QW-402.19 A change in the nominal diameter or nominal thickness for tubular cross sections, or an increase in the total cross section area beyond that qualified for all nontubular cross sections.

QW-402.20 A change in the joint configuration.

QW-402.21 A change in the method or equipment used to minimize internal flash.

QW-402.22 A change in the end preparation method.

QW-402.23 For test coupons less than 1½ in. (38 mm) thick, the addition of a cooling medium (water, flowing gas, etc.) to the back side of the weld. Qualification on test coupons less than 1½ in. (38 mm) thick with a cooling medium on the back side of the weld qualifies base metal thickness equal to or greater than the test coupon thickness with and without coolant.

QW-402.24 Qualification with a cooling medium (water, flowing gas, etc.) on the root side of a test coupon weld that is welded from one side qualifies all thicknesses of base metal with cooling medium down to the thickness of the test coupon at the root or ½ in. (13 mm), whichever is less.

QW-403 Base Metals

QW-403.1 A change from a base metal listed under one P-Number in table QW/QB-422 to a metal listed under another P-Number or to any other base metal. When joints are made between two base metals that have different P-Numbers, a procedure qualification shall be made for the applicable combination of P-Numbers, even though qualification tests have been made for each of the two base metals welded to itself.

QW-403.2 The maximum thickness qualified is the thickness of the test coupon.

QW-403.3

(a) For full penetration single-sided welds without backing, where the measurement of penetration can be made by visual or mechanical means, requalification is required where the base metal thickness differs by 20% from that of the test coupon thickness when the test coupon thickness is 1 in. (25 mm) and under, and 10% when the test coupon thickness is over 1 in. (25 mm). Where the measurement of penetration cannot be made, requalification is required where the base metal thickness differs by 10% from that of the test coupon when the test coupon thickness is 1 in. (25 mm) and under, and 5% when the test coupon thickness is over 1 in. (25 mm).

(b) For full penetration single-sided welds with backing and partial penetration welds, the minimum base metal thickness qualified shall be equal to that used for the PQR test coupon. The depth of penetration qualified shall be equal to or greater than that measured on the PQR test coupon.

QW-403.4 Welding procedure qualifications shall be made using a base metal of the same type or grade or another base metal listed in the same group (see table QW/QB-422) as the base metal to be used in production welding. When joints are to be made between base metals from two different groups, a procedure qualification must be made for the applicable combination of base metals, even though procedure qualification tests have been made for each of the two base metals welded to itself.

QW-403.5 Welding procedure specifications shall be qualified using one of the following:

(a) the same base metal (including type or grade) to be used in production welding

(b) for ferrous materials, a base metal listed in the same P-Number Group Number in table QW/QB-422 as the base metal to be used in production welding

(c) for nonferrous materials, a base metal listed with the same P-Number UNS Number in table QW/QB-422 as the base metal to be used in production welding

For ferrous materials in table QW/QB-422, a procedure qualification shall be made for each P-Number Group Number combination of base metals, even though procedure qualification tests have been made for each of the two base metals welded to itself. If, however, two or more qualification records have the same essential and supplementary essential variables, except that the base metals are assigned to different Group Numbers within the same P-Number, then the combination of base metals is also qualified. In addition, when base metals of two different P-Number Group Number combinations are qualified using a single test coupon, that coupon qualifies the welding of those two P-Number Group Numbers to themselves as well as to each other using the variables qualified.

This variable does not apply when impact testing of the heat-affected zone is not required by other Sections.

(10) **QW-403.6** The minimum base metal thickness qualified is the thickness of the test coupon T or $\frac{5}{8}$ in. (16 mm), whichever is less. However, where T is less than $\frac{1}{4}$ in. (6 mm), the minimum thickness qualified is $\frac{1}{2}T$. This variable does not apply when a WPS is qualified with a PWHT above the upper transformation temperature or when an austenitic or P-No. 10H material is solution annealed after welding.

QW-403.8 A change in base metal thickness beyond the range qualified in QW-451, except as otherwise permitted by QW-202.4(b).

QW-403.9 For single-pass or multipass welding in which any pass is greater than $\frac{1}{2}$ in. (13 mm) thick, an increase in base metal thickness beyond 1.1 times that of the qualification test coupon.

QW-403.10 For the short-circuiting transfer mode of the gas metal-arc process, when the qualification test coupon thickness is less than $\frac{1}{2}$ in. (13 mm), an increase in thickness beyond 1.1 times that of the qualification test coupon. For thicknesses of $\frac{1}{2}$ in. (13 mm) and greater, use table QW-451.1 or table QW-451.2, as applicable.

QW-403.11 Base metals specified in the WPS shall be qualified by a procedure qualification test that was made using base metals in accordance with QW-424.

QW-403.12 A change from a base metal listed under one P-Number of table QW/QB-422 to a base metal listed under another P-Number. When joints are made between two base metals that have different P-Numbers, requalification is required even though the two base metals have been independently qualified using the same procedure. When the melt-in technique is used for joining P-No. 1, P-No. 3, P-No. 4, and P-No. 5A, a procedure qualification test with one P-Number metal shall also qualify for that P-Number metal welded to each of the lower P-Number metals, but not vice versa.

QW-403.15 Welding procedure qualifications for laser beam welding and electron beam welding shall be made using a base metal of the same type or grade or another base metal listed in the same P-Number (and the same group where given — see table QW/QB-422) as the base metal to be used in production welding. When joints are to be made between base metals from two different P-Numbers (or two different groups), a procedure qualification must be made for the applicable combination of base metals even though procedure qualification tests have been made for each of the two base metals welded to itself.

QW-403.16 A change in the pipe diameter beyond the range qualified in QW-452, except as otherwise permitted in QW-303.1, QW-303.2, QW-381.1(c), or QW-382(c).

QW-403.17 In stud welding, a change in combination of base metal listed under one P-Number in table QW/QB-422 and stud metal P-Number (as defined in the following Note), or to any other base metal/stud metal combination.

NOTE: Stud metal shall be classified by nominal chemical composition and can be assigned a P-Number when it meets the nominal composition of any one of the P-Number metals.

QW-403.18 A change from one P-Number to any other P-Number or to a base metal not listed in table QW/QB-422, except as permitted in QW-423, and in QW-420. (10)

QW-403.19 A change to another base material type or grade (type or grade are materials of the same nominal chemical analysis and mechanical property range, even though of different product form), or to any other base material type or grade. When joints are made between two different types or grades of base material, a procedure qualification must be made for the applicable combinations of materials, even though procedure qualification tests have been made for each of the two base materials welded to itself.

QW-403.20 A change from a base metal, listed under one P-Number in table QW/QB-422, to a metal listed under another P-Number or to any other base metal; from a base metal of one subgroup to any other grouping in P-No. 10 or 11.

QW-403.21 The addition or deletion of a coating, plating or cladding, or a change in the nominal chemical analysis or thickness range of the plating or cladding, or a change in type of coating as specified in the WPS.

QW-403.22 A change in the base metal thickness exceeding 10% of the thickness of the total joint from that qualified.

QW-403.23 A change in base metal thickness beyond the range qualified in table QW-453.

QW-403.24 A change in the specification, type, or grade of the base metal. When joints are to be made between two different base metals, a procedure qualification must be made for the applicable combination even though procedure qualifications have been made for each of the two base metals welded to themselves.

QW-403.25 Welding procedure qualifications shall be made using a base metal of the same P-Number and Group Number as the base metal to be temper bead welded. When joints are to be made between base metals from two different P-Number/Group Number combinations, a temper bead procedure qualification must be made for each base metal P-Number/Group Number to be used in production; this may be done in separate test coupons or in combination on a single test coupon. When base metals of different P-Number/Group Numbers are tested in the same coupon, the welding variables utilized and test results on each side of the coupon shall be documented independently but may be reported on the same qualification record. Where temper bead welding is to be applied to only one side of a joint (e.g., on the P-No. 1 side of a joint between P-No. 1 and P-No. 8 metals) or where cladding is being applied or repaired using temper bead techniques, qualification in accordance with QW-290 is required only for the portion of the WPS that applies to welding on the material to be temper bead welded.

QW-403.26 An increase in the base metal carbon equivalent using the following formula:

$$CE = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$$

QW-403.27 The maximum thickness qualified is the thickness of the test coupon, T, or it is unlimited if the test coupon is $1\frac{1}{2}$ in. (38 mm) thick or thicker. However, where T is $\frac{1}{4}$ in. (6 mm) or less, the maximum thickness qualified is $2T$. This limitation applies to fillet welds as well as to groove welds.

QW-404 Filler Metals

QW-404.1 A change in the cross-sectional area of the filler metal added (excluding buttering) or in the wire-feed speed greater than ±10% beyond that qualified.

QW-404.2 A decrease in the thickness or change in nominal specified chemical analysis of weld metal buttering beyond that qualified. (Buttering or surfacing is the deposition of weld metal on one or both faces of the joint prior to preparation of the joint for final electron beam welding.)

QW-404.3 A change in the size of the filler metal.

QW-404.4 A change from one F-Number in table QW-432 to any other F-Number or to any other filler metal not listed in table QW-432.

QW-404.5 (Applicable only to ferrous metals.) A change in the chemical composition of the weld deposit from one A-Number to any other A-Number in table QW-442. Qualification with A-No. 1 shall qualify for A-No. 2 and vice versa.

The weld metal chemical composition may be determined by any of the following:

(a) For all welding processes — from the chemical analysis of the weld deposit taken from the procedure qualification test coupon.

(b) For SMAW, GTAW, and PAW — from the chemical analysis of the weld deposit prepared according to the filler metal specification, or from the chemical composition as reported either in the filler metal specification or the manufacturer's or supplier's certificate of compliance.

(c) For GMAW and EGW — from the chemical analysis of the weld deposit prepared according to the filler metal specification or the manufacturer's or supplier's certificate of compliance when the shielding gas used was the same as that used to weld the procedure qualification test coupon.

(d) For SAW — from the chemical analysis of the weld deposit prepared according to the filler metal specification or the manufacturer's or supplier's certificate of compliance when the flux used was the same as that used to weld the procedure qualification test coupon.

In lieu of an A-Number designation, the nominal chemical composition of the weld deposit shall be indicated on the WPS and on the PQR. Designation of nominal chemical composition may also be by reference to the AWS classification except for the "G" suffix classification, the manufacturer's trade designation, or other established procurement documents.

QW-404.6 A change in the nominal size of the electrode or electrodes specified in the WPS.

QW-404.7 A change in the nominal diameter of the electrode to over $\frac{1}{4}$ in. (6 mm). This variable does not apply when a WPS is qualified with a PWHT above the upper transformation temperature or when an austenitic material is solution annealed after welding.

QW-404.8 Addition or deletion, or a change in nominal amount or composition of supplementary deoxidation material (in addition to filler metal) beyond that qualified. (Such supplementary metal may be required for weld metal deoxidation for some metals being welded.)

QW-404.9

(a) A change in the indicator for minimum tensile strength (e.g., the 7 in F7A2-EM12K) when the flux wire combination is classified in Section II, Part C.

(b) A change in either the flux trade name or wire trade name when neither the flux nor the wire is classified in Section II, Part C.

(c) A change in the flux trade name when the wire is classified in Section II, Part C but the flux is not classified. A change in the wire classification within the requirements of QW-404.5 does not require requalification.

(d) A change in the flux trade name for A-No. 8 deposits.

QW-404.10 Where the alloy content of the weld metal is largely dependent upon the composition of the flux used, any change in any part of the welding procedure which would result in the important alloying elements in the weld metal being outside of the specification range of chemistry given in the Welding Procedure Specification. If there is evidence that the production welds are not being made in accordance with the procedure specification, the authorized inspector may require that a check be made on the chemical composition of the weld metal. Such a check shall preferably be made on a production weld.

QW-404.12 A change in the filler metal classification within an SFA specification, or for a filler metal not covered by an SFA specification or a filler metal with a "G" suffix within an SFA specification, a change in the trade designation of the filler metal.

When a filler metal conforms to a filler metal classification, within an SFA specification, except for the "G" suffix classification, requalification is not required if a change is made in any of the following:

(a) from a filler metal that is designated as moisture-resistant to one that is not designated as moisture-resistant and vice versa (i.e., from E7018R to E7018)

(b) from one diffusible hydrogen level to another (i.e., from E7018-H8 to E7018-H16)

(c) for carbon, low alloy, and stainless steel filler metals having the same minimum tensile strength and the same nominal chemical composition, a change from one low hydrogen coating type to another low hydrogen coating type (i.e., a change among EXX15, 16, or 18 or EXXX15, 16, or 17 classifications)

(d) from one position-usability designation to another for flux-cored electrodes (i.e., a change from E70T-1 to E71T-1 or vice versa)

(e) from a classification that requires impact testing to the same classification which has a suffix which indicates that impact testing was performed at a lower temperature or exhibited greater toughness at the required temperature or both, as compared to the classification which was used during procedure qualification (i.e., a change from E7018 to E7018-1)

(f) from the classification qualified to another filler metal within the same SFA specification when the weld metal is exempt from Impact Testing by other Sections

This exemption does not apply to hard-facing and corrosion-resistant overlays

QW-404.14 The deletion or addition of filler metal.

QW-404.15 A change from one F-Number in table QW-432 to any other F-Number or to any other filler metal, except as permitted in QW-433.

QW-404.17 A change in the type of flux or composition of the flux.

QW-404.18 A change from wire to plate electrodes, and vice versa.

QW-404.19 A change from consumable guide to non-consumable guide, and vice versa.

QW-404.20 Any change in the method by which filler metal is added, such as preplaced shim, top strip, wire, wire feed, or prior weld metal buttering of one or both joint faces.

QW-404.21 For filler metal additions, any change from the nominal specified analysis of the filler metal qualified.

QW-404.22 The omission or addition of consumable inserts. Qualification in a single-welded butt joint, with or without consumable inserts, qualifies for fillet welds and single-welded butt joints with backing or double-welded butt joints. Consumable inserts that conform to SFA-5.30, except that the chemical analysis of the insert conforms to an analysis for any bare wire given in any SFA specification or AWS Classification, shall be considered as having the same F-Number as that bare wire as given in table QW-432.

QW-404.23 A change from one of the following filler metal product forms to another:

(a) bare (solid) or metal cored

(b) flux cored

(c) flux coated solid or metal cored

(d) powder

QW-404.24 The addition, deletion, or change of more than 10% in the volume of supplemental filler metal.

QW-404.27 Where the alloy content of the weld metal is largely dependent upon the composition of the supplemental filler metal (including powder filler metal for PAW), any change in any part of the welding procedure that would result in the important alloying elements in the weld metal being outside of the specification range of chemistry given in the Welding Procedure Specification.

QW-404.29 A change in the flux trade name and designation.

QW-404.30 A change in deposited weld metal thickness beyond the range qualified in QW-451 for procedure qualification or QW-452 for performance qualification, except as otherwise permitted in QW-303.1 and QW-303.2. When a welder is qualified using radiography, the thickness ranges of table QW-452.1(b) apply.

QW-404.31 The maximum thickness qualified is the thickness of the test coupon.

QW-404.32 For the low voltage short-circuiting type of gas metal-arc process when the deposited weld metal thickness is less than $\frac{1}{2}$ in. (13 mm), an increase in deposited weld metal thickness beyond 1.1 times that of the qualification test deposited weld metal thickness. For weld metal thicknesses of $\frac{1}{2}$ in. (13 mm) and greater, use table QW-451.1, table QW-451.2, or table QW-452.1, as applicable.

QW-404.33 A change in the filler metal classification within an SFA specification, or, if not conforming to a filler metal classification within an SFA specification, a change in the manufacturer's trade name for the filler metal. When optional supplemental designators, such as those which indicate moisture resistance (i.e., XXXXR), diffusible hydrogen (i.e., XXXX H16, H8, etc.), and supplemental impact testing (i.e., XXXX-1 or EXXXXM), are specified on the WPS, only filler metals which conform to the classification with the optional supplemental designator(s) specified on the WPS shall be used.

QW-404.34 A change in flux type (i.e., neutral to active or vice versa) for multilayer deposits in P-No. 1 materials.

QW-404.35 A change in the flux/wire classification or a change in either the electrode or flux trade name when not classified in an SFA specification. Requalification is not required when a wire/flux combination conforms to an SFA specification and a change is made from one diffusible hydrogen level to another (i.e., a change from F7A2-EA1-A1H4 to F7A2-EA1-A1H16). This variable does not apply when the weld metal is exempt from impact testing by other Sections. This exemption does not apply to hard facing and corrosion-resistant overlays.

QW-404.36 When flux from recrushed slag is used, each batch or blend, as defined in SFA-5.01, shall be tested in accordance with Section II, Part C by either the manufacturer or user, or qualified as an unclassified flux in accordance with QW-404.9.

QW-404.37 A change in the composition of the deposited weld metal from one A-Number in table QW-442 to any other A-Number, or to an analysis not listed in the table. A change in the UNS number for each AWS classification of A-No. 8 or A-No. 9 analysis of table QW-442, or each nonferrous alloy in table QW-432, shall require separate WPS qualification. A-Numbers may be determined in accordance with QW-404.5.

QW-404.38 A change in the nominal electrode diameter used for the first layer of deposit.

QW-404.39 For submerged-arc welding and electroslag welding, a change in the nominal composition or type of flux used. Requalification is not required for a change in flux particle size.

QW-404.41 A change of more than 10% in the powdered metal feed rate recorded on the PQR.

QW-404.42 A change of more than 5% in the particle size range of the powder.

QW-404.43 A change in the powdered metal particle size range recorded on the PQR.

QW-404.44 A change from a homogeneous powdered metal to a mechanical mixed powdered metal or vice versa.

QW-404.45 A change in the form of filler metal from solid to fabricated wire, flux-cored wire, powdered metal, or vice versa.

QW-404.46 A change in the powder feed rate range qualified.

QW-404.47 A change of more than 10% in the filler metal size and/or powder metal particle size.

QW-404.48 A change of more than 10% in the powder metal density.

QW-404.49 A change of more than 10% in the filler metal or powder metal feed rate.

QW-404.50 The addition or deletion of flux to the face of a weld joint for the purpose of affecting weld penetration.

QW-404.51 The method of control of moisture pickup during storage and distribution for SMAW and GMAW-FC electrodes and flux for SAW (e.g., purchasing in hermetically sealed containers and storage in heated ovens, controlled distribution time, high-temperature baking prior to use).

QW-404.52 A change in the diffusible hydrogen level (e.g., from E7018-H8 to E7018-H16 or to no controlled diffusible hydrogen).

QW-405 Positions

QW-405.1 The addition of other welding positions than those already qualified. See QW-120, QW-130, QW-203, and QW-303.

QW-405.2 A change from any position to the vertical position uphill progression. Vertical-uphill progression (e.g., 3G, 5G, or 6G position) qualifies for all positions. In uphill progression, a change from stringer bead to weave bead. This variable does not apply when a WPS is qualified with a PWHT above the upper transformation temperature or when an austenitic material is solution annealed after welding.

QW-405.3 A change from upward to downward, or from downward to upward, in the progression specified for any pass of a vertical weld, except that the cover or wash pass may be up or down. The root pass may also be run either up or down when the root pass is removed to sound weld metal in the preparation for welding the second side.

QW-405.4 Except as specified below, the addition of other welding positions than already qualified.

(a) Qualification in the horizontal, vertical, or overhead position shall also qualify for the flat position. Qualification in the horizontal fixed position, 5G, shall qualify for the flat, vertical, and overhead positions. Qualification in the horizontal, vertical, and overhead positions shall qualify for all positions. Qualification in the inclined fixed position, 6G, shall qualify for all positions.

(b) A fabricator who does production welding in a particular orientation may make the tests for procedure qualification in this particular orientation. Such qualifications are valid only for the positions actually tested, except that an angular deviation of ±15 deg is permitted in the inclination of the weld axis and the rotation of the weld face as defined in figure QW-461.1. A test specimen shall be taken from the test coupon in each special orientation.

(c) For hard-facing and corrosion-resistant weld metal overlay, qualification in the 3G, 5G, or 6G positions, where 5G or 6G pipe coupons include at least one vertical segment completed utilizing the up-hill progression or a 3G plate coupon is completed utilizing the up-hill progression, shall qualify for all positions. Chemical analysis, hardness, macro-etch, and at least two of the bend tests, as required in table QW-453, shall be removed from the vertical up-hill overlaid segment as shown in figure QW-462.5(b).

(d) A change from the vertical down to vertical up-hill progression shall require requalification.

QW-406 Preheat

QW-406.1 A decrease of more than 100°F (55°C) in the preheat temperature qualified. The minimum temperature for welding shall be specified in the WPS.

QW-406.2 A change in the maintenance or reduction of preheat upon completion of welding prior to any required postweld heat treatment.

QW-406.3 An increase of more than 100°F (55°C) in the maximum interpass temperature recorded on the PQR. This variable does not apply when a WPS is qualified with a PWHT above the upper transformation temperature or when an austenitic or P-No. 10H material is solution annealed after welding. (10)

QW-406.4 A decrease of more than 100°F (55°C) in the preheat temperature qualified or an increase in the maximum interpass temperature recorded on the PQR. The minimum temperature for welding shall be specifed in the WPS.

QW-406.5 A change in the maintenance or reduction of preheat upon completion of spraying and prior to fusing.

QW-406.7 A change of more than 10% in the amplitude or number of preheating cycles from that qualified, or if other preheating methods are employed, a change in the preheating temperature of more than 25°F (15°C).

QW-406.8 An increase in the maximum interpass temperature of more than 100°F (56°C) from that achieved on the test coupon and recorded on the PQR. The interpass temperature shall be measured and recorded separately for each tempering weld bead layer and, if any, for the surface weld bead layer(s). The WPS shall specify the maximum interpass temperature limits for each tempering bead layer separately and for the surfacing weld bead layer(s), if any.

QW-406.9 A decrease in the preheat temperature from that achieved on the test coupon and recorded on the PQR. The preheat temperature shall be measured and recorded separately for each tempering weld bead layer and, if any, for the surface weld bead layer(s). The WPS shall specify the minimum preheat temperature limits for each tempering bead layer separately and for the surfacing weld bead layer(s), if any.

QW-406.10 The minimum preheating soaking time prior to the start of welding.

QW-406.11 The addition or deletion of a postweld hydrogen bakeout. When specified, the minimum soaking temperature and time shall be specified.

QW-407 Postweld Heat Treatment

QW-407.1 A separate procedure qualification is required for each of the following:

(a) For P-Numbers 1 through 6 and 9 through 15F materials, the following postweld heat treatment conditions apply:

(1) no PWHT

(2) PWHT below the lower transformation temperature

(3) PWHT above the upper transformation temperature (e.g., normalizing)

(4) PWHT above the upper transformation temperature followed by heat treatment below the lower transformation temperature (e.g., normalizing or quenching followed by tempering)

(5) PWHT between the upper and lower transformation temperatures

(b) For all other materials, the following postweld heat treatment conditions apply:

(1) no PWHT

(2) PWHT within a specified temperature range

QW-407.2 A change in the postweld heat treatment (see QW-407.1) temperature and time range

The procedure qualification test shall be subjected to PWHT essentially equivalent to that encountered in the fabrication of production welds, including at least 80% of the aggregate times at temperature(s). The PWHT total time(s) at temperature(s) may be applied in one heating cycle.

(10) **QW-407.4** For ferrous base metals other than P-No. 7, P-No. 8, and P-No. 45, when a procedure qualification test coupon receives a postweld heat treatment exceeding the upper transformation temperature or a solution heat treatment for P-No. 10H materials, the maximum qualified base metal thickness, *T*, shall not exceed 1.1 times the thickness of the test coupon.

QW-407.6 A change in postweld heat treatment condition in QW-407.1 or an increase of 25% or more in total time at postweld heat treating temperature.

QW-407.7 A change in the heat treatment temperature range qualified if heat treatment is applied after fusing.

QW-407.8 A separate PQR is required for each of the following:

(a) no PWHT

(b) a change of more than 10% in the number of PWHT heating current cycles following the welding cycle

(c) PWHT within a specified temperature and time range if heat treatment is performed separately from the welding operation

QW-407.9 A separate procedure qualification is required for each of the following:

(a) For weld corrosion-resistant overlay of A-No. 8 on all base materials, a change in postweld heat treatment condition in QW-407.1, or when the total time at postweld heat treatment encountered in fabrication exceeds 20 hr, an increase of 25% or more in total time at postweld heat treating temperature.

(b) For weld corrosion-resistant overlay of A-No. 9 on all base materials, a change in postweld heat treatment condition in QW-407.1, or an increase of 25% or more in total time at postweld heat treating temperature.

(c) For all other weld corrosion-resistant overlays on all base materials, a change in postweld heat treatment condition in QW-407.1.

QW-408 Gas

QW-408.1 The addition or deletion of trailing shielding gas and/or a change in its composition.

QW-408.2 A separate procedure qualification is required for each of the following:

(a) a change from a single shielding gas to any other single shielding gas

(b) a change from a single shielding gas to a mixture of shielding gasses, and vice versa

(c) a change in the specified percentage composition of a shielding gas mixture

(d) the addition or omission of shielding gas

The AWS classification of SFA-5.32 may be used to specify the shielding gas composition.

QW-408.3 A change in the specified flow rate range of the shielding gas or mixture of gases.

QW-408.4 A change in the composition of the orifice or shielding gas.

QW-408.5 The addition or deletion of gas backing, a change in backing gas composition, or a change in the specified flow rate range of the backing gas.

QW-408.6 Any change of environment shielding such as from vacuum to an inert gas, or vice versa.

QW-408.7 A change in the type of fuel gas.

QW-408.8 The omission of inert gas backing except that requalification is not required when welding a single-welded butt joint with a backing strip or a double-welded butt joint or a fillet weld. This exception does not apply to P-No. 51 through P-No. 53, P-No. 61 through P-No. 62, and P-No. 10I metals.

QW-408.9 For groove welds in P-No. 41 through P-No. 49 and all welds of P-No. 10I, P-No. 10J, P-No. 10K, P-No. 51 through P-No. 53, and P-No. 61 through P-No. 62 metals, the deletion of backing gas or a change in the nominal composition of the backing gas from an inert gas to a mixture including non-inert gas(es).

QW-408.10 For P-No. 10I, P-No. 10J, P-No. 10K, P-No. 51 through P-No. 53, and P-No. 61 through P-No. 62 metals, the deletion of trailing shielding gas, or a change in the nominal composition of the trailing gas from an inert gas to a mixture including non-inert gas(es), or a decrease of 10% or more in the trailing gas flow rate.

QW-408.11 The addition or deletion of one or more of the following:

(a) shielding gas

(b) trailing shielding gas

(c) backing gas

(d) plasma-removing gas

QW-408.12 A change of more than 5% in the flow rate of one or more of the following: shielding gas, trailer shielding gas, backing gas, and plasma-removing gas.

QW-408.13 A change in the position or orientation of plasma-removing gas jet relative to the workpiece (e.g., coaxial transverse to beam).

QW-408.14 A change in the oxygen or fuel gas pressure beyond the range qualified.

QW-408.16 A change of more than 5% in the flow rate of the plasma-arc gas or powdered metal feed gas recorded on the PQR.

QW-408.17 A change in the plasma-arc gas, shielding gas, or powdered metal feed gas from a single gas to any other single gas, or to a mixture of gases, or vice versa.

QW-408.18 A change of more than 10% in the gas mixture composition of the plasma-arc gas, shielding gas, or powdered metal feed gas recorded on the PQR.

QW-408.19 A change in the nominal composition of the powder feed gas or (plasma-arc spray) plasma gas qualified.

QW-408.20 A change of more than 5% in the plasma gas flow rate range qualified.

QW-408.21 A change in the flow rate of the orifice or shielding gas.

QW-408.22 A change in the shielding gas type, gas pressure, or purging time.

QW-408.23 For titanium, zirconium, and their alloys, the deletion of one or more of the following:

(a) shielding gas
(b) trailing shielding gas
(c) backing gas

QW-408.24 For gas-shielded processes, the maximum moisture content (dew point) of the shielding gas. Moisture control may be by specification of shielding gas classifications in SFA-5.32.

QW-409 Electrical Characteristics

(10) **QW-409.1** An increase in heat input, or an increase in volume of weld metal deposited per unit length of weld, over that qualified. The increase shall be determined by (a), (b), or (c) for nonwaveform controlled welding, or by (b) or (c) for waveform controlled welding. See Nonmandatory Appendix H.

(a) Heat input [J/in. (J/mm)]

$$= \frac{\text{Voltage} \times \text{Amperage} \times 60}{\text{Travel Speed [in./min (mm/min)]}}$$

(b) Volume of weld metal measured by

(1) an increase in bead size (width × thickness), or

(2) a decrease in length of weld bead per unit length of electrode

(c) Heat input determined using instantaneous energy or power by

(1) for instantaneous energy measurements in joules (J)

Heat input [J/in. (J/mm)]

$$= \frac{\text{Energy (J)}}{\text{Weld Bead Length [in./min]}}$$

(2) for instantaneous power measurements in joules per second (J/s) or Watts (W)

Heat input [J/in. (J/mm)]

$$= \frac{\text{Power (J/s or W)} \times \text{arc time (s)}}{\text{Weld Bead Length [in. (min)]}}$$

The requirement for measuring the heat input or volume of deposited weld metal does not apply when the WPS is qualified with a PWHT above the upper transformation temperature or when an austenitic or P-No. 10H material is solution annealed after welding.

QW-409.2 A change from spray arc, globular arc, or pulsating arc to short circuiting arc, or vice versa.

QW-409.3 The addition or deletion of pulsing current to dc power source.

QW-409.4 A change from AC to DC, or vice versa; and in DC welding, a change from electrode negative (straight polarity) to electrode positive (reverse polarity), or vice versa.

QW-409.5 A change of ±15% from the amperage or voltage ranges in the qualified WPS.

QW-409.6 A change in the beam current of more than ±5%, voltage of more than ±2%, welding speed of more than ±2%, beam focus current of more than ±5%, gun-to-work distance of more than ±5%, or a change in oscillation length or width of more than ±20% from those previously qualified.

QW-409.7 Any change in the beam pulsing frequency duration from that qualified.

QW-409.8 A change in the range of amperage, or except for SMAW GTAW or waveform controlled welding, a change in the range of voltage. A change in the range of electrode wire feed speed may be used as an alternative to amperage. See Nonmandatory Appendix H. (10)

QW-409.9 A change in the arc timing of more than $\pm \frac{1}{10}$ sec.

QW-409.10 A change in amperage of more than ±10%.

QW-409.11 A change in the power source from one model to another.

QW-409.12 A change in type or size of tungsten electrode.

QW-409.13 A change from one Resistance Welding Manufacturer's Association (RWMA) electrode class to another. In addition, a change in the following:

(a) for spot and projection welding, a change in the nominal shape or more than 10% of the contact area of the welding electrode

(b) for seam welding, a change of thickness, profile, orientation, or diameter of electrodes exceeding 10%

QW-409.14 Addition or deletion of upslope or downslope current control, or a change of more than 10% in the slope current time or amplitude.

QW-409.15

(a) A change of more than 5% in any of the following from that qualified:

(1) preheating current

(2) preheating current amplitude

(3) preheating current time duration

(4) electrode pressure

(5) welding current

(6) welding current time duration

(b) A change from AC to DC or vice versa.

(c) The addition or deletion of pulsing current to a DC power source.

(d) When using pulsing DC current, a change of more than 5% in the pulse amplitude, frequency, or number of pulses per cycle from that qualified.

(e) A change of more than 5% in the post-heating current time duration from that qualified.

QW-409.17 A change in the power supply primary voltage or frequency, or in the transformer turns ratio, tap setting, choke position, secondary open circuit voltage or phase control setting.

QW-409.18 A change in the procedure or frequency of tip cleaning.

QW-409.19 Any change in the beam pulsing frequency and pulse duration from that qualified.

QW-409.20 Any change in the following variables: mode of operation (from pulsed to continuous and vice versa), energy distribution across the beam (i.e., multimode or gaussian).

QW-409.21 Any change in the following variables: a change of more than 5% in the power delivered to the work surface as measured by calorimeter or other equivalent methods; a change of more than 2% in the travel speed; a change of more than 2% of the ratio of the beam diameter to focal length; a change of more than 2% of the lens to work distance.

QW-409.22 An increase of more than 10% in the amperage used in application for the first layer.

QW-409.23 A change of more than 10% in the ranges of amperage or voltage qualified.

QW-409.24 A change of more than 10% in the filler wire wattage recorded on the PQR. Wattage is a function of current voltage, and stickout dimension.

QW-409.25 A change of more than 10% in the plasma-arc current or voltage recorded on the PQR.

QW-409.26 For the first layer only, an increase in heat input of more than 10% or an increase in volume of weld metal deposited per unit length of weld of more than 10% over that qualified. The increase may be measured by the methods of QW-409.1. **(10)**

QW-409.27 A change in the flashing time of more than 10%.

QW-409.28 A change in the upset current time by more than 10%.

QW-409.29 **(10)**

(a) A change in the ratios of heat input or in the volume of weld metal deposited per unit length beyond the following (see figure QW-462.12):

(1) An increase or decrease in the ratio of heat input between the first tempering bead layer and the weld beads deposited against the base metal of more than 20% for P-No. 1 and P-No. 3 metals and 10% for all other P-Number metals.

(2) An increase or decrease in the ratio of heat input between the second tempering bead layer and the first tempering bead layer of more than 20% for P-No. 1 and P-No. 3 metals and 10% for all other P-Number metals.

(3) The ratio of heat input between subsequent layers shall be maintained until a minimum of $\frac{3}{16}$ in. (5 mm) of weld metal has been deposited over the base metal.

(4) For qualifications where the basis for acceptance is impact testing and the filler metal is exempt from temper bead qualification, the heat input may not exceed 50% above the heat input qualified for the remaining fill passes.

(5) For qualifications where the basis for acceptance is hardness testing, a decrease of more than 20% in heat input for the remainder of the fill passes.

(b) Heat input and volume of weld metal per unit length of weld shall be measured using the following methods:

(1) For machine or automatic GTAW or PAW, an increase or decrease of 10% in the power ratio measured as:

$$\text{Power Ratio} = \frac{\text{Amperage} \times \text{Voltage}}{[(\text{WFS/TS}) \times A_f]}$$

where

A_f = the cross-section area of the filler metal wire

TS = the welding travel speed
WFS = the filler metal wire feed speed

(2) For processes other than machine or automatic GTAW or PAW, heat input shall be measured by the method of QW-409.1

Volume of Weld Metal = an increase in bead size or a decrease in length of weld bead per unit length of electrode.

(3) If manual GTAW or PAW is used for making in-process repairs in accordance with QW-290.5, a record of bead size shall be made.

QW-410 TECHNIQUE

QW-410.1 For manual or semiautomatic welding, a change from the stringer bead technique to the weave bead technique, or vice versa.

QW-410.2 A change in the nature of the flame, oxidizing to reducing, or vice versa.

QW-410.3 A change in the orifice, cup, or nozzle size.

QW-410.4 A change in the welding technique, forehand to backhand, or vice versa.

QW-410.5 A change in the method of initial and interpass cleaning (brushing, grinding, etc.).

QW-410.6 A change in the method of back gouging.

QW-410.7 For the machine or automatic welding process, a change in width, frequency, or dwell time of oscillation technique.

QW-410.8 A change in the contact tube to work distance.

(10) **QW-410.9** A change from multipass per side to single pass per side. This variable does not apply when a WPS is qualified with a PWHT above the upper transformation temperature or when an austenitic or P-No. 10H material is solution annealed after welding.

(10) **QW-410.10** A change from single electrode to multiple electrode, or vice versa, for machine or automatic welding only. This variable does not apply when a WPS is qualified with a PWHT above the upper transformation temperature or when an austenitic or P-No. 10H material is solution annealed after welding.

QW-410.11 A change from closed chamber to out-of-chamber conventional torch welding in P-No. 51 through P-No. 53 metals, but not vice versa.

QW-410.12 A change from the melt-in technique to the keyhole technique of welding, or vice versa, or the inclusion of both techniques though each has been individually qualified.

QW-410.14 A change in the angle of the axis of the beam relative to the workpiece.

QW-410.15 A change in the spacing of multiple electrodes for machine or automatic welding.

QW-410.17 A change in the type or model of the welding equipment.

QW-410.18 An increase in the absolute pressure of the vacuum welding environment beyond that qualified.

QW-410.19 Any change in filament type, size, or shape.

QW-410.20 The addition of a wash pass.

QW-410.21 A change of welding from one side to welding from both sides, or vice versa.

QW-410.22 A change in either of the following stud welding parameters: a change of stud gun model; a change in the lift more than $\pm \frac{1}{32}$ in. (0.8 mm).

QW-410.25 A change from manual or semiautomatic to machine or automatic welding and vice versa.

QW-410.26 The addition or deletion of peening.

QW-410.27 A change in the rotational speed producing a change in the outside surface velocity [ft/min (m/min)] greater than ±10% of the outside surface velocity qualified.

QW-410.28 A change in the thrust load greater than ±10% of the thrust load qualified.

QW-410.29 A change in the rotational energy greater than ±10% of the rotational energy qualified.

QW-410.30 Any change in upset dimension (overall loss in length of parts being joined) greater than ±10% of the upset qualified.

QW-410.31 A change in the method of preparing the base metal prior to welding (e.g., changing from mechanical cleaning to chemical cleaning or to abrasive cleaning, or vice versa).

QW-410.32 A change of more than 10% in the holding (forging) pressure prior to or after welding. A change of more than 10% in the electrode holding time (electrode duration sequence).

QW-410.33 A change from one welding type to another, or modification of equipment, including Manufacturer, control panel, model number, electrical rating or capacity, type of electrical energy source, or method of applying pressure.

QW-410.34 Addition or deletion of an electrode cooling medium and where it is used.

QW-410.35 A change in the distance between arms or a change in the throat depth.

QW-410.37 A change from single to multiple pass or vice versa.

QW-410.38 A change from multiple-layer to single layer cladding/hardsurfacing, or vice versa.

QW-410.39 A change in the torch type or tip size.

QW-410.40 For submerged-arc welding and electroslag welding, the deletion of a supplementary device for controlling the magnetic field acting on the weld puddle.

QW-410.41 A change of more than 15% in the travel speed range recorded on the PQR.

QW-410.43 For the torch or workpiece, a change of more than 10% in the travel speed range qualified.

QW-410.44 A change of more than 15% in the spray-torch to workpiece distance qualified.

QW-410.45 A change in the method of surface preparation of the base metal to be hard-faced (example: sandblasting versus chemical cleaning).

QW-410.46 A change in the spray-torch model or tip orifice size.

QW-410.47 A change of more than 10% in the fusing temperature range qualified. A change in the rate of cooling from the fusing temperature of more than 50°F/hr (28°C/hr), a change in the fusing method (e.g., torch, furnace, induction).

QW-410.48 A change in the constricted arc from transferable to nontransferable or vice versa.

QW-410.49 A change in the diameter of the plasma torch-arc constricting orifice.

QW-410.50 A change in the number of electrodes acting on the same welding puddle.

QW-410.52 A change in the method of delivering the filler metal to the molten pool, such as from the leading or trailing edge of the torch, the sides of the torch, or through the torch.

QW-410.53 A change of more than 20% in the center-to-center weld bead distance.

QW-410.54 A change in the upset length or force of more than 10%.

QW-410.55 A change in the distance between the clamping dies of more than 10% or a change in the surface preparation of the clamping area.

QW-410.56 A change in the clamping force by more than 10%.

QW-410.57 A change in more than 10% of the forward or reverse speed.

QW-410.58 The deletion of surface temper beads (see figure QW-462.12) or a change from surface temper beads that cover the weld surface to beads that are only deposited along the toes of the weld.

QW-410.59 A change from machine or automatic welding to manual or semiautomatic welding.

QW-410.60 The addition of thermal methods to prepare the surface to be welded unless the WPS requires that the metal be ground to bright metal before welding.

QW-410.61 The distance, *S*, from the toe of the weld to the edge of any tempering bead shall be limited to the distance measured on the test coupon $\pm\frac{1}{16}$ in. (±1.5 mm) (see figure QW-462.12). Alternatively, a range for *S* may be established by locating temper beads at various distances from the toe of the weld followed by hardness traverses or impact testing, as applicable. Temper reinforcing beads shall not be permitted to touch the toe of the weld. In addition, the ratios of heat input described in QW-409.29 shall apply to temper beads.

QW-410.62 The method of removal of surface temper bead reinforcing layer when it will be removed, including provisions to prevent overheating of the weld surface.

QW-410.63 For weld beads against the base metal and for each tempering bead layer, the range of bead width, *b*, relative to overlap of the previous bead width, *a*, as shown in figure QW-462.13, shall be specified on the WPS. Overlap between 25% and 75% does not require qualification.

(a) Overlap greater than 75% shall be qualified by welding a test coupon using the desired overlap. The overlap qualified shall be the maximum overlap permitted and the minimum overlap shall be 50%.

(b) Overlap less than 25% shall be qualified by welding a test coupon using the desired overlap. The overlap qualified shall be the minimum overlap permitted and the maximum overlap shall be 50%.

QW-410.64 For vessels or parts of vessels constructed with P-No. 11A and P-No. 11B 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-410.65 The addition or deletion of grinding beyond that required to clean the surface or remove minor surface flaws (i.e., use or nonuse of half-bead technique or similar technique).

QW-416
WELDING VARIABLES
Welder Performance

Paragraph[1]		Brief of Variables	Essential					
			OFW QW-352	SMAW QW-353	SAW QW-354	GMAW[2] QW-355	GTAW QW-356	PAW QW-357
QW-402 Joints	.4	− Backing		X		X	X	X
	.7	+ Backing	X					
QW-403 Base Metal	.2	Maximum qualified	X					
	.16	ϕ Pipe diameter		X	X	X	X	X
	.18	ϕ P-Number	X	X	X	X	X	X
QW-404 Filler Metals	.14	± Filler	X				X	X
	.15	ϕ F-Number	X	X	X	X	X	X
	.22	± Inserts					X	X
	.23	t Solid or metal-cored to flux-cored					X	X
	.30	ϕ t Weld deposit		X	X	X	X	X
	.31	ϕ t Weld deposit	X					
	.32	t Limit (s. cir. arc)				X		
QW-405 Positions	.1	+ Position	X	X	X	X	X	X
	.3	ϕ ↑ ↓ Vert. welding		X		X	X	X
QW-408 Gas	.7	ϕ Type fuel gas	X					
	.8	− Inert backing				X	X	X
QW-409 Electrical	.2	ϕ Transfer mode				X		
	.4	ϕ Current or polarity					X	

Welding Processes:

OFW	Oxyfuel gas welding
SMAW	Shielded metal-arc welding
SAW	Submerged-arc welding
GMAW	Gas metal-arc welding
GTAW	Gas tungsten-arc welding
PAW	Plasma-arc welding

Legend:

ϕ Change	t Thickness
+ Addition	↑ Uphill
− Deletion	↓ Downhill

NOTES:
(1) For description, see Section IV.
(2) Flux-cored arc welding as shown in QW-355, with or without additional shielding from an externally supplied gas or gas mixture, is included.

(10) QW-420 BASE METAL GROUPINGS

P-Numbers are assigned to base metals for the purpose of reducing the number of welding and brazing procedure qualifications required.

P-Numbers are alphanumeric designations: accordingly, each P-Number shall be considered a separate P-Number (e.g., base metals assigned P-No. 5A are considered a separate P-Number from those assigned P-No. 5B or P-No. 5C).

In addition, ferrous base metals have been assigned Group Numbers creating subsets of P-Numbers that are used when WPSs are required to be qualified by impact testing by other Sections or Codes. These assignments are based essentially on comparable base metal characteristics, such as composition, weldability, brazeability, and mechanical properties, where this can logically be done. These assignments do not imply that base metals may be indiscriminately substituted for a base metal that was used in the qualification test without consideration of compatibility from the standpoint of metallurgical properties, postweld heat treatment, design, mechanical properties, and service requirements. The following table shows the assignment groups for various alloy systems:

Base Metal	Welding	Brazing
Steel and steel alloys	P-No. 1 through P-No. 15F	P-No. 101 through P-No. 103
Aluminum and aluminum-base alloys	P-No. 21 through P-No. 26	P-No. 104 and P-No. 105
Copper and copper-base alloys	P-No. 31 through P-No. 35	P-No. 107 and P-No. 108
Nickel and nickel-base alloys	P-No. 41 through P-No. 49	P-No. 110 through P-No. 112
Titanium and titanium-base alloys	P-No. 51 through P-No. 53	P-No. 115
Zirconium and zirconium-base alloys	P-No. 61 and P-No. 62	P-No. 117

If an unlisted base metal has the same UNS number designation as a base metal listed in table QW/QB-422, it shall be considered as assigned to that P-Number or P-Number plus Group Number. However, only base metals listed in table QW/QB-422 with minimum tensile strength values may be used for procedure qualification test coupons.

The values given in the column heading "Minimum Specified Tensile" of table QW/QB-422 are the acceptance values for the tensile tests of the welding or brazing procedure qualification, except as otherwise allowed in QW-153 or QB-153.

Materials listed in QW/QB-422 without a minimum specified tensile value shall not be used for the purpose of groove weld procedure qualification.

In 2009, S-Numbers were removed from table QW/QB-422. S-Numbers were assigned to materials that were acceptable for use by the ASME B31 Code for Pressure Piping, or by selected Boiler and Pressure Vessel Code Cases, but which were not included within ASME Boiler and Pressure Vessel Code Material Specifications (Section II). Base metals previously assigned S-Numbers were reassigned the corresponding P-Numbers or P-Numbers plus Group Numbers.

There are instances where materials assigned to one P- or S-Number or Group Number have been reassigned to a different P- or S-Number or Group Number in later editions. Procedure and performance qualifications that were qualified under the previous P- or S-Numbers or Group Number assignment may continue to be used under the new P-Number or Group Number assignment, see QW-200.2(c), provided the WPS is revised to limit the materials qualified for welding to those assigned to the new P- or S-number(s) and Group number(s) for the specific material(s) originally used for the procedure qualification test coupon. Other materials from the original P- or S-Number and Group Number must be reassigned to the same P- or S-Number or Group Number to be considered qualified for welding under the revised WPS.

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS
Grouping of Base Metals for Qualification

Ferrous

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-36	. . .	K02600	58 (400)	1	1	101	11.1	C–Mn–Si	Plate, bar & shapes
SA-53	Type F	. . .	48 (330)	1	1	101	11.1	C	Furnace welded pipe
SA-53	Type S, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Smls. pipe
SA-53	Type E, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Resistance welded pipe
SA-53	Type E, Gr. B	K03005	60 (415)	1	1	101	11.1	C–Mn	Resistance welded pipe
SA-53	Type S, Gr. B	K03005	60 (415)	1	1	101	11.1	C–Mn	Smls. pipe
SA-105	. . .	K03504	70 (485)	1	2	101	11.1	C	Flanges & fittings
SA-106	A	K02501	48 (330)	1	1	101	1.1	C–Si	Smls. pipe
SA-106	B	K03006	60 (415)	1	1	101	11.1	C–Mn–Si	Smls. pipe
SA-106	C	K03501	70 (485)	1	2	101	11.1	C–Mn–Si	Smls. pipe
A 108	1015 CW	G10150	. . .	1	1	101	1.1	C	Bar
A 108	1018 CW	G10180	. . .	1	1	101	1.1	C	Bar
A 108	1020 CW	G10200	. . .	1	1	101	1.1	C	Bar
A 108	8620 CW	G86200	. . .	3	3	102	4.1	0.5Ni–0.5Cr–Mo	Bar
SA-134	SA283 Gr. A	. . .	45 (310)	1	1	101	1.1	C	Welded pipe
SA-134	SA283 Gr. B	. . .	50 (345)	1	1	101	1.1	C	Welded pipe
SA-134	SA283 Gr. C	K02401	55 (380)	1	1	101	1.1	C	Welded pipe
SA-134	SA283 Gr. D	K02702	60 (415)	1	1	101	1.1	C	Welded pipe
SA-134	SA285 Gr. A	K01700	45 (310)	1	1	101	1.1	C	Welded pipe
SA-134	SA285 Gr. B	K02200	50 (345)	1	1	101	1.1	C	Welded pipe
SA-134	SA285 Gr. C	K02801	55 (380)	1	1	101	11.1	C	Welded pipe
SA-135	A	. . .	48 (330)	1	1	101	1.1	C	E.R.W. pipe
SA-135	B	. . .	60 (415)	1	1	101	11.1	C	E.R.W. pipe
A 139	A	. . .	48 (330)	1	1	101	1.1	C	Welded pipe
A 139	B	K03003	60 (415)	1	1	101	1.1	C	Welded pipe
A 139	C	K03004	60 (415)	1	1	101	11.1	C	Welded pipe
A 139	D	K03010	60 (415)	1	1	101	11.1	C	Welded pipe
A 139	E	K03012	66 (455)	1	1	101	11.1	C	Welded pipe
A 167	Type 302B	S30215	75 (515)	8	1	102	8.1	18Cr–8Ni–2Si	Plate, sheet & strip
A 167	Type 308	S30800	75 (515)	8	2	102	8.2	20Cr–10Ni	Plate, sheet & strip
A 167	Type 309	S30900	75 (515)	8	2	102	8.2	23Cr–12Ni	Plate, sheet & strip
A 167	Type 310	S31000	75 (515)	8	2	102	8.2	25Cr–20Ni	Plate, sheet & strip
SA-178	A	K01200	47 (325)	1	1	101	1.1	C	E.R.W. tube
SA-178	C	K03503	60 (415)	1	1	101	11.1	C	E.R.W. tube
SA-178	D	. . .	70 (485)	1	2	101	11.1	C–Mn–Si	E.R.W. tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-179	. . .	K01200	47 (325)	1	1	101	1.1	C	Smls. tube
SA-181	Cl. 60	K03502	60 (415)	1	1	101	11.1	C–Si	Pipe flange & fittings
SA-181	Cl. 70	K03502	70 (485)	1	2	101	11.1	C–Si	Pipe flange & fittings
SA-182	F12, Cl. 1	K11562	60 (415)	4	1	102	5.1	1Cr–0.5Mo	Forgings
SA-182	F12, Cl. 2	K11564	70 (485)	4	1	102	5.1	1Cr–0.5Mo	Forgings
SA-182	F11, Cl. 2	K11572	70 (485)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-182	F11, Cl. 3	K11572	75 (515)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-182	F11, Cl. 1	K11597	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-182	F2	K12122	70 (485)	3	2	101	4.2	0.5Cr–0.5Mo	Forgings
SA-182	F1	K12822	70 (485)	3	2	101	1.1	C–0.5Mo	Forgings
SA-182	F22, Cl. 1	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	Forgings
SA-182	F22, Cl. 3	K21590	75 (515)	5A	1	102	5.2	2.25Cr–1Mo	Forgings
SA-182	FR	K22035	63 (435)	9A	1	101	9.1	2Ni–1Cu	Forgings
SA-182	F21	K31545	75 (515)	5A	1	102	5.2	3Cr–1Mo	Forgings
SA-182	F3V	K31830	85 (585)	5C	1	102	6.2	3Cr–1Mo–V–Ti–B	Forgings
SA-182	F3VCb	. . .	85 (585)	5C	1	102	6.2	3Cr–1Mo–0.25V–Cb–Ca	Forgings
SA-182	F22V	K31835	85 (585)	5C	1	102	6.2	2.25Cr–1Mo–V	Forgings
SA-182	F5	K41545	70 (485)	5B	1	102	5.3	5Cr–0.5Mo	Forgings
SA-182	F5a	K42544	90 (620)	5B	1	102	5.3	5Cr–0.5Mo	Forgings
SA-182	F9	K90941	85 (585)	5B	1	102	5.4	9Cr–1Mo	Forgings
SA-182	F91	K90901	85 (585)	15E	1	102	6.4	9Cr–1Mo–V	Forgings
SA-182	F6a, Cl. 1	S41000	70 (485)	6	1	102	7.2	13Cr	Forgings
SA-182	F6a, Cl. 2	S41000	85 (585)	6	3	102	7.2	13Cr	Forgings
SA-182	FXM–19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Forgings
SA-182	FXM–11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Forgings
SA-182	F304	S30400	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings > 5 in. (127 mm)
SA-182	F304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-182	F304L	S30403	65 (450)	8	1	102	8.1	18Cr–8Ni	Forgings > 5 in. (127 mm)
SA-182	F304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-182	F304H	S30409	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings > 5 in. (127 mm)
SA-182	F304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-182	F304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Forgings
SA-182	F304LN	S30453	70 (485)	8	1	102	8.1	18Cr–8Ni–N	Forgings > 5 in. (127 mm)
SA-182	F304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Forgings
SA-182	F46	S30600	78 (540)	8	1	102	8.1	18Cr–15Ni–4Si	Forgings
SA-182	F45	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Forgings

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-182	F310	S31000	70 (485)	8	2	102	8.2	25Cr–20Ni	Forgings > 5 in. (127 mm)
SA-182	F310	S31000	75 (515)	8	2	102	8.2	25Cr–20Ni	Forgings
SA-182	F310MoLN	S31050	78 (540)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Forgings
SA-182	F50	S31200	100 (690)	10H	1	102	10.2	25Cr–6Ni–Mo–N	Forgings
SA-182	F44	S31254	94 (650)	8	4	102	8.2	20Cr–18Ni–6Mo	Forgings
SA-182	F316	S31600	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Forgings > 5 in. (127 mm)
SA-182	F316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Forgings
SA-182	F316L	S31603	65 (450)	8	1	102	8.1	16Cr–12Ni–2Mo	Forgings > 5 in. (127 mm)
SA-182	F316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Forgings
SA-182	F316H	S31609	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Forgings > 5 in. (127 mm)
SA-182	F316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Forgings
SA-182	F316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Forgings
SA-182	F316LN	S31653	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Forgings > 5 in. (127 mm)
SA-182	F316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Forgings
SA-182	F317	S31700	70 (485)	8	1	102	8.1	18Cr–13Ni–3Mo	Forgings > 5 in. (127 mm)
SA-182	F317	S31700	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Forgings
SA-182	F317L	S31703	65 (450)	8	1	102	8.1	18Cr–13Ni–3Mo	Forgings > 5 in. (127 mm)
SA-182	F317L	S31703	70 (485)	8	1	102	8.1	18Cr–13Ni–3Mo	Forgings
SA-182	F51	S31803	90 (620)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Forgings
SA-182	F321	S32100	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Forgings > 5 in. (127 mm)
SA-182	F321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Forgings
SA-182	F321H	S32109	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Forgings > 5 in. (127 mm)
SA-182	F321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Forgings
SA-182	F55	S32760	109 (750)	10H	1	102	10.1	25Cr–8Ni–3Mo–W–Cu–N	Forgings
SA-182	F10	S33100	80 (550)	8	2	102	8.1	20Ni–8Cr	Forgings
SA-182	F49	S34565	115 (795)	8	4	102	8.3	24Cr-17Ni-6Mn-4.5Mo-N	Forgings
SA-182	F347	S34700	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings > 5 in. (127 mm)
SA-182	F347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings
SA-182	F347H	S34709	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings > 5 in. (127 mm)
SA-182	F347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings
SA-182	F348	S34800	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings > 5 in. (127 mm)
SA-182	F348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings
SA-182	F348H	S34809	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings > 5 in. (127 mm)
SA-182	F348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings
SA-182	F6b	S41026	110 (760)	6	3	102	7.2	13Cr–0.5Mo	Forgings
SA-182	F6NM	S41500	115 (795)	6	4	102	7.2	13Cr–4.5Ni–Mo	Forgings

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-182	F429	S42900	60 (415)	6	2	102	7.2	15Cr	Forgings
SA-182	F430	S43000	60 (415)	7	2	102	7.1	17Cr	Forgings
SA-182	FXM–27Cb	S44627	60 (415)	10I	1	102	7.1	27Cr–1Mo	Forgings
SA-182	F53	S32750	116 (800)	10H	1	102	10.2	25Cr–7Ni–4Mo–N	Forgings
SA-182	F54	S39274	116 (800)	10H	1	102	10.2	25Cr–7Ni–3Mo–2W–Cu–N	Forgings
SA-182	F60	S32205	95 (655)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Forgings
A 182	F6a, Cl. 3	S41000	110 (760)	6	3	102	7.2	13Cr	Forgings
A 182	F6a, Cl. 4	S41000	130 (895)	6	3	102	7.2	13Cr	Forgings
SA-192	...	K01201	47 (325)	1	1	101	1.1	C–Si	Smls. tube
A199	T11	K11597	60(415)	4	1	102	5.1	1.25Cr-0.5Mo-Si	Smls. tube
A199	T22	K21590	60(415)	5A	1	102	5.2	2.25Cr-1Mo	Smls. tube
A199	T21	K31545	60(415)	5A	1	102	...	3Cr-1Mo	Smls. tube
A199	T5	K41545	60(415)	5B	1	102	5.3	5Cr-0.5Mo	Smls. tube
A199	T9	K81590	60(415)	5B	1	102	5.4	9Cr-1Mo	Smls. tube
SA-202	A	K11742	75 (515)	4	1	101	4.2	0.5Cr–1.25Mn–Si	Plate
SA-202	B	K12542	85 (585)	4	1	101	4.2	0.5Cr–1.25Mn–Si	Plate
SA-203	A	K21703	65 (450)	9A	1	101	9.1	2.5Ni	Plate
SA-203	B	K22103	70 (485)	9A	1	101	9.1	2.5Ni	Plate
SA-203	D	K31718	65 (450)	9B	1	101	9.2	3.5Ni	Plate
SA-203	E	K32018	70 (485)	9B	1	101	9.2	3.5Ni	Plate
SA-203	F	...	75 (515)	9B	1	101	9.2	3.5Ni	Plate > 2 in. (51 mm)
SA-203	F	...	80 (550)	9B	1	101	9.2	3.5Ni	Plate, 2 in. (51 mm) & under
SA-204	A	K11820	65 (450)	3	1	101	1.1	C–0.5Mo	Plate
SA-204	B	K12020	70 (485)	3	2	101	1.1	C–0.5Mo	Plate
SA-204	C	K12320	75 (515)	3	2	101	1.2	C–0.5Mo	Plate
SA-209	T1b	K11422	53 (365)	3	1	101	1.1	C–0.5Mo	Smls. tube
SA-209	T1	K11522	55 (380)	3	1	101	1.1	C–0.5Mo	Smls. tube
SA-209	T1a	K12023	60 (415)	3	1	101	1.1	C–0.5Mo	Smls. tube
SA-210	A–1	K02707	60 (415)	1	1	101	11.1	C–Si	Smls. tube
SA-210	C	K03501	70 (485)	1	2	101	11.1	C–Mn–Si	Smls. tube
A 211	A570-30	K02502	49 (340)	1	1	101	1.1	C	Welded pipe
A 211	A570-33	K02502	52 (360)	1	1	101	1.1	C	Welded pipe
A 211	A570-40	K02502	55 (380)	1	1	101	1.1	C	Welded pipe
SA-213	T2	K11547	60 (415)	3	1	101	4.2	0.5Cr–0.5Mo	Smls. tube
SA-213	T12	K11562	60 (415)	4	1	102	5.1	1Cr–0.5Mo	Smls. tube
SA-213	T11	K11597	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Smls. tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-213	T17	K12047	60 (415)	10B	1	102	4.1	1Cr–V	Smls. tube
SA-213	T22	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	Smls. tube
SA-213	T21	K31545	60 (415)	5A	1	102	5.2	3Cr–1Mo	Smls. tube
SA-213	T5c	K41245	60 (415)	5B	1	102	5.3	5Cr–0.5Mo–Ti	Smls. tube
SA-213	T5	K41545	60 (415)	5B	1	102	5.3	5Cr–0.5Mo	Smls. tube
SA-213	T5b	K51545	60 (415)	5B	1	102	5.3	5Cr–0.5Mo–Si	Smls. tube
SA-213	T9	K90941	60 (415)	5B	1	102	5.4	9Cr–1Mo	Smls. tube
SA-213	T91	K90901	85 (585)	5B	2	102	6.4	9Cr–1Mo–V	Smls. tube
SA-213	TP201	S20100	95 (655)	8	3	102	8.3	17Cr–4Ni–6Mn	Smls. tube
SA-213	TP202	S20200	90 (620)	8	3	102	8.3	18Cr–5Ni–9Mn	Smls. tube
SA-213	XM-19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Smls. tube
SA-213	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Smls. tube
SA-213	TP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Smls. tube
SA-213	TP304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Smls. tube
SA-213	TP304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Smls. tube
SA-213	TP304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Smls. tube
SA-213	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Smls. tube
SA-213	TP309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Smls. tube
SA-213	TP309H	S30909	75 (515)	8	2	102	8.2	23Cr–12Ni	Smls. tube
SA-213	TP309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Smls. tube
SA-213	TP309HCb	S30941	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Smls. tube
SA-213	TP310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Smls. tube
SA-213	TP310H	S31009	75 (515)	8	2	102	8.2	25Cr–20Ni	Smls. tube
SA-213	TP310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Smls. tube
SA-213	TP310HCb	S31041	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Smls. tube
SA-213	TP310HCbN	S31042	95 (655)	8	3	102	8.2	25Cr–20Ni–Cb–N	Smls. tube
SA-213	TP310MoLN	S31050	78 (540)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Smls. tube, $t > \frac{1}{4}$ in. (6 mm)
SA-213	TP310MoLN	S31050	84 (580)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Smls. tube, $t \leq \frac{1}{4}$ in. (6 mm)
SA-213	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. tube
SA-213	TP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. tube
SA-213	TP316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. tube
SA-213	TP316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Smls. tube
SA-213	TP316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Smls. tube
SA-213	S31725	S31725	75 (515)	8	4	102	8.1	19Cr–15Ni–4Mo	Smls. tube
SA-213	S31726	S31726	80 (550)	8	4	102	8.1	19Cr–15.5Ni–4Mo	Smls. tube
SA-213	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. tube
SA-213	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. tube

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-213	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Smls. tube
SA-213	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. tube
SA-213	TP347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. tube
SA-213	TP347HFG	S34710	80 (550)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. tube
SA-213	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. tube
SA-213	TP348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. tube
SA-213	XM–15	S38100	75 (515)	8	1	102	8.1	18Cr–18Ni–2Si	Smls. tube
SA-213	S32615	S32615	80 (550)	8	1	102	8.1	18Cr–20Ni–5.5Si	Smls. tube
SA-214	. . .	K01807	47 (325)	1	1	101	1.1	C	E.R.W. tube
SA-216	WCA	J02502	60 (415)	1	1	101	1.1	C–Si	Castings
SA-216	WCC	J02503	70 (485)	1	2	101	1.1	C–Mn–Si	Castings
SA-216	WCB	J03002	70 (485)	1	2	101	1.1	C–Si	Castings
SA-217	WC6	J12072	70 (485)	4	1	102	5.1	1.25Cr–0.5Mo	Castings
SA-217	WC4	J12082	70 (485)	4	1	101	9.1	1Ni–0.5Cr–0.5Mo	Castings
SA-217	WC1	J12524	65 (450)	3	1	101	1.1	C–0.5Mo	Castings
SA-217	WC9	J21890	70 (485)	5A	1	102	5.2	2.25Cr–1Mo	Castings
SA-217	WC5	J22000	70 (485)	4	1	101	4.2	0.75Ni–1Mo–0.75Cr	Castings
SA-217	C5	J42045	90 (620)	5B	1	102	5.3	5Cr–0.5Mo	Castings
SA-217	C12	J82090	90 (620)	5B	1	102	5.4	9Cr–1Mo	Castings
SA-217	CA15	J91150	90 (620)	6	3	102	7.2	13Cr	Castings
A 217	C12A	J84090	85 (585)	15E	1	102	6.4	9Cr–1Mo–V	Castings
SA-225	D	K12004	75 (515)	10A	1	101	2.1	Mn–0.5Ni–V	Plate > 3 in. (76 mm)
SA-225	D	K12004	80 (550)	10A	1	101	2.1	Mn–0.5Ni–V	Plate, 3 in. (76 mm) & under
SA-225	C	K12524	105 (725)	10A	1	101	4.1	Mn–0.5Ni–V	Plate
SA-234	WPB	K03006	60 (415)	1	1	101	11.1	C–Mn–Si	Piping fittings
SA-234	WPC	K03501	70 (485)	1	2	101	11.1	C–Mn–Si	Piping fittings
SA-234	WP11, Cl. 1	. . .	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Piping fittings
SA-234	WP12, Cl. 1	K12062	60 (415)	4	1	101	5.1	1Cr–0.5Mo	Piping fittings
SA-234	WP1	K12821	55 (380)	3	1	101	11.2	C–0.5Mo	Piping fittings
SA-234	WP22, Cl. 1	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	Piping fittings
SA-234	WPR	K22035	63 (435)	9A	1	101	9.1	2Ni–1Cu	Piping fittings
SA-234	WP5, Cl. 1	K41545	60 (415)	5B	1	102	5.3	5Cr–0.5Mo	Piping fittings
SA-234	WP9, Cl. 1	K90941	60 (415)	5B	1	102	5.4	9Cr–1Mo	Piping fittings
SA-234	WP91	K90901	85 (585)	15E	1	102	6.4	9Cr–1Mo–V	Piping fittings
A 234	WP11, Cl. 3	. . .	75 (515)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Piping Fittings

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
A 234	WP12, Cl. 2	K12062	70 (485)	4	1	101	5.1	1Cr–0.5Mo	Piping Fittings
A 234	WP22, Cl. 3	K21590	75 (515)	5A	1	102	5.2	2.25Cr–1Mo	Piping Fittings
A 234	WP5, Cl. 3	K41545	75 (515)	5B	1	102	5.3	5Cr–0.5Mo	Piping Fittings
A 234	WP9, Cl. 3	K90941	75 (515)	5B	1	102	5.4	9cr–1Mo	Piping Fittings
SA-240	Type 201-1	S20100	75 (515)	8	3	102	8.3	17Cr–4Ni–6Mn	Plate, sheet & strip
SA-240	Type 201-2	S20100	95 (655)	8	3	102	8.3	17Cr–4Ni–6Mn	Plate, sheet & strip
SA-240	Type 201LN	S20153	95 (655)	8	3	...	8.3	16Cr–4Ni–6Mn	Plate, sheet & strip
SA-240	Type 202	S20200	90 (620)	8	3	102	8.3	18Cr–5Ni–9Mn	Plate, sheet & strip
SA-240	...	S20400	95 (655)	8	3	102	8.3	16Cr–9Mn–2Ni–N	Plate, sheet & strip
SA-240	Type XM–19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Plate
SA-240	Type XM–19	S20910	105 (725)	8	3	102	8.3	22Cr–13Ni–5Mn	Sheet & strip
SA-240	Type XM–17	S21600	90 (620)	8	3	102	8.3	19Cr–8Mn–6Ni–Mo–N	Plate
SA-240	Type XM–17	S21600	100 (690)	8	3	102	8.3	19Cr–8Mn–6Ni–Mo–N	Sheet & strip
SA-240	Type XM–18	S21603	90 (620)	8	3	102	8.3	19Cr–8Mn–6Ni–Mo–N	Plate
SA-240	Type XM–18	S21603	100 (690)	8	3	102	8.3	19Cr–8Mn–6Ni–Mo–N	Sheet & strip
SA-240	S21800	S21800	95 (655)	8	3	102	8.1	18Cr–8Ni–4Si–N	Plate, sheet & strip
SA-240	Type XM–29	S24000	100 (690)	8	3	102	8.3	18Cr–3Ni–12Mn	Plate, sheet & strip
SA-240	Type 301	S30100	75 (515)	8	1	102	8.1	17Cr–7Ni	Plate, sheet & strip
SA-240	Type 302	S30200	75 (515)	8	1	102	8.1	18Cr–8Ni	Plate, sheet & strip
SA-240	Type 304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Plate, sheet & strip
SA-240	Type 304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Plate, sheet & strip
SA-240	Type 304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Plate, sheet & strip
SA-240	Type 304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Plate, sheet & strip
SA-240	Type XM–21	S30452	85 (585)	8	1	102	8.1	18Cr–8Ni–N	Plate
SA-240	Type XM–21	S30452	90 (620)	8	1	102	8.1	18Cr–8Ni–N	Sheet & strip
SA-240	Type 304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Plate, sheet & strip
SA-240	Type 305	S30500	75 (515)	8	1	102	8.1	18Cr–11Ni	Plate, sheet & strip
SA-240	S30600	S30600	78 (540)	8	1	102	8.1	18Cr–15Ni–4Si	Plate, sheet & strip
SA-240	S30601	S30601	78 (540)	8	1	102	8.1	17.5Cr–17.5Ni–5.3Si	Plate, sheet & strip
SA-240	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Plate, sheet & strip
SA-240	S32615	S32615	80 (550)	8	1	102	8.1	18Cr–20Ni–5.5Si	Plate, sheet & strip
SA-240	Type 309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Plate, sheet & strip
SA-240	Type 309H	S30909	75 (515)	8	2	102	8.2	23Cr–12Ni	Plate, sheet & strip
SA-240	Type 309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Plate, sheet & strip
SA-240	Type 309HCb	S30941	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Plate, sheet & strip
SA-240	Type 310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Plate, sheet & strip
SA-240	Type 310H	S31009	75 (515)	8	2	102	8.2	25Cr–20Ni	Plate, sheet & strip

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-240	Type 310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Plate, sheet & strip
SA-240	Type 310HCb	S31041	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Plate, sheet & strip
SA-240	Type 310MoLN	S31050	80 (550)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Plate, sheet & strip
SA-240	S31200	S31200	100 (690)	10H	1	102	10.2	25Cr–6Ni–Mo–N	Plate, sheet & strip
SA-240	S31254	S31254	94 (650)	8	4	102	8.2	20Cr–18Ni–6Mo	Plate, sheet & strip
SA-240	S31260	S31260	100 (690)	10H	1	102	10.2	25Cr–6.5Ni–3Mo–N	Plate, sheet & strip
SA-240	S31277	S31277	112 (770)	45	. . .	111	8.2	27Ni–22Cr–7Mo–Mn–Cu	Plate, sheet & strip
SA-240	Type 316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Plate, sheet & strip
SA-240	Type 316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Plate, sheet & strip
SA-240	Type 316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Plate, sheet & strip
SA-240	Type 316Ti	S31635	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–Ti	Plate, sheet & strip
SA-240	Type 316Cb	S31640	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–Cb	Plate, sheet & strip
SA-240	Type 316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Plate, sheet & strip
SA-240	Type 316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Plate, sheet & strip
SA-240	Type 317	S31700	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Plate, sheet & strip
SA-240	Type 317L	S31703	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Plate, sheet & strip
SA-240	S31725	S31725	75 (515)	8	4	102	8.1	19Cr–15Ni–4Mo	Plate, sheet & strip
SA-240	S31726	S31726	80 (550)	8	4	102	8.1	19Cr–15.5Ni–4Mo	Plate, sheet & strip
SA-240	S31753	S31753	80 (550)	8	1	102	8.1	18Cr–13Ni–3Mo–N	Plate, sheet & strip
SA-240	S31803	S31803	90 (620)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Plate, sheet & strip
SA-240	Type 321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Plate, sheet & strip
SA-240	Type 321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Plate, sheet & strip
SA-240	2205	S32205	95 (655)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Plate, sheet & strip
SA-240	S32550	S32550	110 (760)	10H	1	102	10.2	25Cr–5Ni–3Mo–2Cu	Plate, sheet & strip
SA-240	S32750	S32750	116 (800)	10H	1	102	10.2	25Cr–7Ni–4Mo–N	Plate, sheet & strip
SA-240	S32760	S32760	108 (745)	10H	1	102	10.2	25Cr–8Ni–3Mo–W–Cu–N	Plate, sheet & strip
SA-240	Type 329	S32900	90 (620)	10H	1	102	10.2	26Cr–4Ni–Mo	Plate, sheet & strip
SA-240	S32906	S32906	109 (750)	10H	1	102	10.2	29Cr–6.5Ni–2Mo–N	Plate, sheet & strip ≥ 0.40 in. (10 mm)
SA-240	S32906	S32906	116 (800)	10H	1	102	10.2	29Cr–6.5Ni–2Mo–N	Plate, sheet & strip < 0.40 in. (10 mm)
SA-240	S32950	S32950	100 (690)	10H	1	102	10.2	26Cr–4Ni–Mo–N	Plate, sheet & strip
SA-240	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Plate, sheet & strip
SA-240	Type 347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Plate, sheet & strip
SA-240	Type 347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Plate, sheet & strip
SA-240	Type 348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Plate, sheet & strip
SA-240	Type 348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Plate, sheet & strip
SA-240	Type XM-15	S38100	75 (515)	8	1	102	8.1	18Cr–18Ni–2Si	Plate, sheet & strip
SA-240	Type 405	S40500	60 (415)	7	1	102	7.1	12Cr–1Al	Plate, sheet & strip

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-240	Type 409	S40910	55 (380)	7	1	102	7.1	11Cr–Ti	Plate, sheet & strip
SA-240	Type 409	S40920	55 (380)	7	1	102	7.1	11Cr–Ti	Plate, sheet & strip
SA-240	Type 409	S40930	55 (380)	7	1	102	7.1	11Cr–Ti	Plate, sheet & strip
SA-240	Type 410	S41000	65 (450)	6	1	102	7.2	13Cr	Plate, sheet & strip
SA-240	Type 410S	S41008	60 (415)	7	1	102	7.2	13Cr	Plate, sheet & strip
SA-240	S41500	S41500	115 (795)	6	4	102	7.2	13Cr–4.5Ni–Mo	Plate, sheet & strip
SA-240	Type 429	S42900	65 (450)	6	2	102	7.2	15Cr	Plate, sheet & strip
SA-240	Type 430	S43000	65 (450)	7	2	102	7.1	17Cr	Plate, sheet & strip
SA-240	Type 439	S43035	60 (415)	7	2	102	7.1	18Cr–Ti	Plate, sheet & strip
SA-240	S44400	S44400	60 (415)	7	2	102	7.1	18Cr–2Mo	Plate, sheet & strip
SA-240	Type XM–33	S44626	68 (470)	10I	1	102	7.1	27Cr–1Mo–Ti	Plate, sheet & strip
SA-240	Type XM–27	S44627	65 (450)	10I	1	102	7.1	27Cr–1Mo	Plate, sheet & strip
SA-240	S43932	S43932	60 (415)	7	2	102	. . .	18Cr–Ti–Cb	Plate, sheet & strip
SA-240	S44635	S44635	90 (620)	10I	1	102	7.1	25Cr–4Ni–4Mo–Ti	Plate, sheet & strip
SA-240	S44660	S44660	85 (585)	10K	1	102	7.1	26Cr–3Ni–3Mo	Plate, sheet & strip
SA-240	S44700	S44700	80 (550)	10J	1	102	7.1	29Cr–4Mo	Plate, sheet & strip
SA-240	S44800	S44800	80 (550)	10K	1	102	7.1	29Cr–4Mo–2Ni	Plate, sheet & strip
SA-249	TP201	S20100	95 (655)	8	3	102	8.3	17Cr–4Ni–6Mn	Welded tube
SA-249	TP202	S20200	90 (620)	8	3	102	8.3	18Cr–5Ni–9Mn	Welded tube
SA-249	TPXM–19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Welded tube
SA-249	TPXM–29	S24000	100 (690)	8	3	102	8.3	18Cr–3Ni–12Mn	Welded tube
SA-249	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Welded tube
SA-249	TP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Welded tube
SA-249	TP304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Welded tube
SA-249	TP304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Welded tube
SA-249	TP304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Welded tube
SA-249	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Welded tube
SA-249	TP309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Welded tube
SA-249	TP309H	S30909	75 (515)	8	2	102	8.2	23Cr–12Ni	Welded tube
SA-249	TP309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Welded tube
SA-249	TP309HCb	S30941	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Welded tube
SA-249	TP310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Welded tube
SA-249	TP310H	S31009	75 (515)	8	2	102	8.2	25Cr–20Ni	Welded tube
SA-249	TP310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Welded tube
SA-249	TP310HCb	S31041	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Welded tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-249	TP310MoLN	S31050	78 (540)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Welded tube, $t > \frac{1}{4}$ in. (6 mm)
SA-249	TP310MoLN	S31050	84 (580)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Welded tube, $t \leq \frac{1}{4}$ in. (6 mm)
SA-249	S31254	S31254	95 (655)	8	4	102	8.2	20Cr–18Ni–6Mo	Welded tube, $t > \frac{3}{16}$ in. (5 mm)
SA-249	S31254	S31254	98 (675)	8	4	102	8.2	20Cr–18Ni–6Mo	Welded tube, $t \leq \frac{3}{16}$ in. (5 mm)
SA-249	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Welded tube
SA-249	TP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Welded tube
SA-249	TP316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Welded tube
SA-249	TP316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Welded tube
SA-249	TP316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Welded tube
SA-249	TP317	S31700	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Welded tube
SA-249	TP317L	S31703	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Welded tube
SA-249	S31725	S31725	75 (515)	8	4	102	8.1	19Cr–15Ni–4Mo	Welded tube
SA-249	S31726	S31726	80 (550)	8	4	102	8.1	19Cr–15.5Ni–4Mo	Welded tube
SA-249	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Welded tube
SA-249	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Welded tube
SA-249	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded tube
SA-249	TP347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded tube
SA-249	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded tube
SA-249	TP348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded tube
SA-249	TPXM–15	S38100	75 (515)	8	1	102	8.1	18Cr–18Ni–2Si	Welded tube
SA-250	T1b	K11422	53 (365)	3	1	101	1.1	C–0.5Mo	E.R.W. tube
SA-250	T1	K11522	55 (380)	3	1	101	1.1	C–0.5Mo	E.R.W. tube
SA-250	T2	K11547	60 (415)	3	1	101	4.2	0.5Cr–0.5Mo	E.R.W. tube
SA-250	T11	K11597	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	E.R.W. tube
SA-250	T1a	K12023	60 (415)	3	1	101	1.1	C–0.5Mo	E.R.W. tube
SA-250	T12	K11562	60 (415)	4	1	102	5.1	1Cr–0.5Mo	E.R.W. tube
SA-250	T22	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	E.R.W. tube
A 254	Cl.1	K01001	42 (290)	...	...	101	NA	C	Cu brazed tube
A 254	Cl.2	K01001	42 (290)	...	...	101	NA	C	Cu brazed tube
SA-266	4	K03017	70 (485)	1	2	101	11.1	C–Mn–Si	Forgings
SA-266	1	K03506	60 (415)	1	1	101	11.1	C–Si	Forgings
SA-266	2	K03506	70 (485)	1	2	101	11.1	C–Si	Forgings
SA-266	3	K05001	75 (515)	1	2	101	11.2	C–Si	Forgings
SA-268	TP405	S40500	60 (415)	7	1	102	7.1	12Cr–1Al	Smls. & welded tube
SA-268	S40800	S40800	55 (380)	7	1	102	7.1	12Cr–Ti	Smls. & welded tube
SA-268	TP409	S40900	55 (380)	7	1	102	7.1	11Cr–Ti	Smls. & welded tube

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-268	TP410	S41000	60 (415)	6	1	102	7.2	13Cr	Smls. & welded tube
SA-268	S41500	S41500	115 (795)	6	4	102	7.2	13Cr–4.5Ni–Mo	Smls. & welded tube
SA-268	TP429	S42900	60 (415)	6	2	102	7.2	15Cr	Smls. & welded tube
SA-268	TP430	S43000	60 (415)	7	2	102	7.1	17Cr	Smls. & welded tube
SA-268	TP430Ti	S43036	60 (415)	7	2	102	...	18Cr–Ti	Smls. & welded tube
SA-268	TP439	S43035	60 (415)	7	2	102	7.1	18Cr–Ti	Smls. & welded tube
SA-268	18Cr–2Mo	S44400	60 (415)	7	2	102	7.1	18Cr–2Mo	Smls. & welded tube
SA-268	TP446–2	S44600	65 (450)	10I	1	102	7.1	27Cr	Smls. & welded tube
SA-268	TP446–1	S44600	70 (485)	10I	1	102	7.1	27Cr	Smls. & welded tube
SA-268	TPXM–33	S44626	68 (470)	10I	1	102	7.1	27Cr–1Mo–Ti	Smls. & welded tube
SA-268	TPXM–27	S44627	65 (450)	10I	1	102	7.1	27Cr–1Mo	Smls. & welded tube
SA-268	25–4–4	S44635	90 (620)	10I	1	102	7.1	25Cr–4Ni–4Mo–Ti	Smls. & welded tube
SA-268	26–3–3	S44660	85 (585)	10K	1	102	7.1	26Cr–3Ni–3Mo	Smls. & welded tube
SA-268	29–4	S44700	80 (550)	10J	1	102	7.1	29Cr–4Mo	Smls. & welded tube
SA-268	S44735	S44735	75 (515)	10J	1	102	7.1	29Cr–4Mo–Ti	Smls. & welded tube
SA-268	29–4–2	S44800	80 (550)	10K	1	102	7.1	29Cr–4Mo–2Ni	Smls. & welded tube
A 269	TP316	S31600	...	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded tube
A 269	TP316L	S31603	...	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded tube
A 269	TP304	S30400	...	8	1	102	8.1	18Cr–8Ni	Smls. & welded tube
A 269	TP304L	S30403	...	8	1	102	8.1	18Cr–8Ni	Smls. & welded tube
A 276	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Bar
A 276	TP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Bar
A 276	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Bar
A 276	TP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Bar
A 276	S32205	S32205	95 (655)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Bar
A 276	TP410	S41000	65 (450)	6	1	102	7.2	13Cr	Bar
SA-283	A	K01400	45 (310)	1	1	101	1.1	C	Plate
SA-283	B	K01702	50 (345)	1	1	101	1.1	C	Plate
SA-283	C	K02401	55 (380)	1	1	101	1.1	C	Plate
SA-283	D	K02702	60 (415)	1	1	101	1.1	C	Plate
SA-285	A	K01700	45 (310)	1	1	101	1.1	C	Plate
SA-285	B	K02200	50 (345)	1	1	101	1.1	C	Plate
SA-285	C	K02801	55 (380)	1	1	101	11.1	C	Plate
SA-299	A	K02803	75 (515)	1	3	101	11.1	C–Mn–Si	Plate
SA-299	B	K02803	80 (550)	1	3	101	11.1	C–Mn–Si	Plate

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-302	A	K12021	75 (515)	3	2	101	1.1	Mn–0.5Mo	Plate
SA-302	B	K12022	80 (550)	3	3	101	1.2	Mn–0.5Mo	Plate
SA-302	C	K12039	80 (550)	3	3	101	. . .	Mn–0.5Mo–0.5Ni	Plate
SA-302	D	K12054	80 (550)	3	3	101	. . .	Mn–0.5Mo–0.75Ni	Plate
SA-312	TPXM-19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Smls. & welded pipe
SA-312	TPXM-11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Smls. & welded pipe
SA-312	TPXM-29	S24000	100 (690)	8	3	102	8.3	18Cr–3Ni–12Mn	Smls. & welded pipe
SA-312	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Smls. & welded pipe
SA-312	TP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Smls. & welded pipe
SA-312	TP304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Smls. & welded pipe
SA-312	TP304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Smls. & welded pipe
SA-312	TP304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Smls. & welded pipe
SA-312	S30600	S30600	78 (540)	8	1	102	8.1	18Cr–15Ni–4Si	Smls. & welded pipe
SA-312	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Smls. & welded pipe
SA-312	S32615	S32615	80 (550)	8	1	102	8.1	18Cr–20Ni–5.5Si	Smls. & welded pipe
SA-312	TP309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Smls. & welded pipe
SA-312	TP309H	S30909	75 (515)	8	2	102	8.2	23Cr–12Ni	Smls. & welded pipe
SA-312	TP309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Smls. & welded pipe
SA-312	TP309HCb	S30941	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Smls. & welded pipe
SA-312	TP310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Smls. & welded pipe
SA-312	TP310H	S31009	75 (515)	8	2	102	8.2	25Cr–20Ni	Smls. & welded pipe
SA-312	TP310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Smls. & welded pipe
SA-312	TP310HCb	S31041	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Smls. & welded pipe
SA-312	TP310MoLN	S31050	78 (540)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Smls. & welded pipe, $t > \frac{1}{4}$ in. (6 mm)
SA-312	TP310MoLN	S31050	84 (580)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Smls. & welded pipe, $t \leq \frac{1}{4}$ in. (6 mm)
SA-312	S31254	S31254	95 (655)	8	4	102	8.2	20Cr–18Ni–6Mo	Smls. & welded pipe, $t > \frac{3}{16}$ in. (5 mm)
SA-312	S31254	S31254	98 (675)	8	4	102	8.2	20Cr–18Ni–6Mo	Smls. & welded pipe, $t \leq \frac{3}{16}$ in. (5 mm)
SA-312	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded pipe
SA-312	TP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded pipe
SA-312	TP316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded pipe
SA-312	TP316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Smls. & welded pipe
SA-312	TP316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Smls. & welded pipe
SA-312	TP317	S31700	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Smls. & welded pipe
SA-312	TP317L	S31703	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Smls. & welded pipe
SA-312	S31725	S31725	75 (515)	8	4	102	8.1	19Cr–15Ni–4Mo	Smls. & welded pipe
SA-312	S31726	S31726	80 (550)	8	4	102	8.1	19Cr–15.5Ni–4Mo	Smls. & welded pipe

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding		Brazing	ISO 15608 Group	Nominal Composition	Product Form
				P-No.	Group No.	P-No.			
SA-312	TP321	S32100	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe > 3/8 in. (10 mm)
SA-312	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe ≤ 3/8 in. (10 mm)
SA-312	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe
SA-312	TP321H	S32109	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe > 3/8 in. (10 mm)
SA-312	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe ≤ 3/8 in. (10 mm)
SA-312	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Welded pipe
SA-312	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Smls & welded pipe
SA-312	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TP347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TP348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TPXM–15	S38100	75 (515)	8	1	102	8.1	18Cr–18Ni–2Si	Smls. & welded pipe
SA-333	6	K03006	60 (415)	1	1	101	11.1	C–Mn–Si	Smls. & welded pipe
SA-333	1	K03008	55 (380)	1	1	101	11.1	C–Mn	Smls. & welded pipe
SA-333	10	. . .	80 (550)	1	3	101	11.1	C–Mn–Si	Smls. & welded pipe
SA-333	4	K11267	60 (415)	4	2	102	4.1	0.75Cr–0.75Ni–Cu–Al	Smls. & welded pipe
SA-333	7	K21903	65 (450)	9A	1	101	9.1	2.5Ni	Smls. & welded pipe
SA-333	9	K22035	63 (435)	9A	1	101	9.1	2Ni–1Cu	Smls. & welded pipe
SA-333	3	K31918	65 (450)	9B	1	101	9.2	3.5Ni	Smls. & welded pipe
SA-333	8	K81340	100 (690)	11A	1	101	9.3	9Ni	Smls. & welded pipe
SA-334	6	K03006	60 (415)	1	1	101	11.1	C–Mn–Si	Welded tube
SA-334	1	K03008	55 (380)	1	1	101	11.1	C–Mn	Welded tube
SA-334	7	K21903	65 (450)	9A	1	101	9.1	2.5Ni	Welded tube
SA-334	9	K22035	63 (435)	9A	1	101	9.1	2Ni–1Cu	Welded tube
SA-334	3	K31918	65 (450)	9B	1	101	9.2	3.5Ni	Welded tube
SA-334	8	K81340	100 (690)	11A	1	101	9.3	9Ni	Welded tube
SA-335	P1	K11522	55 (380)	3	1	101	1.1	C–0.5Mo	Smls. pipe
SA-335	P2	K11547	55 (380)	3	1	101	4.2	0.5Cr–0.5Mo	Smls. pipe
SA-335	P12	K11562	60 (415)	4	1	102	5.1	1Cr–0.5Mo	Smls. pipe
SA-335	P15	K11578	60 (415)	3	1	101	. . .	1.5Si–0.5Mo	Smls. pipe
SA-335	P11	K11597	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Smls. pipe
SA-335	P22	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	Smls. pipe
SA-335	P21	K31545	60 (415)	5A	1	102	5.2	3Cr–1Mo	Smls. pipe
SA-335	P5c	K41245	60 (415)	5B	1	102	5.3	5Cr–0.5Mo–Ti	Smls. pipe
SA-335	P5	K41545	60 (415)	5B	1	102	5.3	5Cr–0.5Mo	Smls. pipe
SA-335	P5b	K51545	60 (415)	5B	1	102	5.3	5Cr–0.5Mo–Si	Smls. pipe

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-335	P9	K90941	60 (415)	5B	1	102	5.4	9Cr–1Mo	Smls. pipe
SA-335	P91	K90901	85 (585)	15E	1	102	6.4	9Cr–1Mo–V	Smls. pipe
SA-336	F3VCb	. . .	85 (585)	5C	1	102	6.2	3Cr–1Mo–0.25V–Cb–Ca	Forgings
SA-336	F6	S41000	85 (585)	6	3	102	7.2	13Cr	Forgings
SA-336	F12	K11564	70 (485)	4	1	102	5.1	1Cr–0.5Mo	Forgings
SA-336	F11, Cl. 1	K11597	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-336	F11, Cl. 2	K11572	70 (485)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-336	F11, Cl. 3	K11572	75 (515)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-336	F1	K12520	70 (485)	3	2	101	1.1	C–0.5Mo	Forgings
SA-336	F22, Cl. 1	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	Forgings
SA-336	F22, Cl. 3	K21590	75 (515)	5A	1	102	5.2	2.25Cr–1Mo	Forgings
SA-336	F21, Cl. 1	K31545	60 (415)	5A	1	102	5.2	3Cr–1Mo	Forgings
SA-336	F21, Cl. 3	K31545	75 (515)	5A	1	102	5.2	3Cr–1Mo	Forgings
SA-336	F3V	K31830	85 (585)	5C	1	102	6.2	3Cr–1Mo–V–Ti–B	Forgings
SA-336	F22V	K31835	85 (585)	5C	1	102	6.2	2.25Cr–1Mo–V	Forgings
SA-336	F5	K41545	60 (415)	5B	1	102	5.3	5Cr–0.5Mo	Forgings
SA-336	F5A	K42544	80 (550)	5B	1	102	5.3	5Cr–0.5Mo	Forgings
SA-336	F9	K90941	85 (585)	5B	1	102	5.4	9Cr–1Mo	Forgings
SA-336	F91	K90901	85 (585)	15E	1	102	6.4	9Cr–1Mo–V	Forgings
SA-350	LF1	K03009	60 (415)	1	1	101	11.1	C–Mn–Si	Forgings
SA-350	LF2	K03011	70 (485)	1	2	101	11.1	C–Mn–Si	Forgings
SA-350	LF5, Cl. 1	K13050	60 (415)	9A	1	101	9.1	1.5Ni	Forgings
SA-350	LF5, Cl. 2	K13050	70 (485)	9A	1	101	9.1	1.5Ni	Forgings
SA-350	LF9	K22036	63 (435)	9A	1	101	9.1	2Ni–1Cu	Forgings
SA-350	LF3	K32025	70 (485)	9B	1	101	9.2	3.5Ni	Forgings
SA-351	CF3	J92500	70 (485)	8	1	102	8.1	18Cr–8Ni	Castings
SA-351	CF3A	J92500	77 (530)	8	1	102	8.1	18Cr–8Ni	Castings
SA-351	CF8	J92600	70 (485)	8	1	102	8.1	18Cr–8Ni	Castings
SA-351	CF8A	J92600	77 (530)	8	1	102	8.1	18Cr–8Ni	Castings
SA-351	CF8C	J92710	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Castings
SA-351	CF3M	J92800	70 (485)	8	1	102	8.1	18Cr–12Ni–2Mo	Castings
SA-351	CF8M	J92900	70 (485)	8	1	102	8.1	18Cr–12Ni–2Mo	Castings
SA-351	CF10	J92590	70 (485)	8	1	102	8.1	19Cr–9Ni–0.5Mo	Castings
SA-351	CF10M	J92901	70 (485)	8	1	102	8.1	19Cr–9Ni–2Mo	Castings
SA-351	CG8M	J93000	75 (515)	8	1	102	8.1	19Cr–10Ni–3Mo	Castings
SA-351	CK3MCuN	J93254	80 (550)	8	4	102	8.2	20Cr–18Ni–6Mo	Castings

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-351	CD3MWCuN	J93380	100 (690)	10H	1	102	10.2	25Cr–8Ni–3Mo–W–Cu–N	Castings
SA-351	CH8	J93400	65 (450)	8	2	102	8.2	25Cr–12Ni	Castings
SA-351	CH20	J93402	70 (485)	8	2	102	8.2	25Cr–12Ni	Castings
SA-351	CG6MMN	J93790	85 (585)	8	3	102	8.3	22Cr–12Ni–5Mn	Castings
SA-351	CK20	J94202	65 (450)	8	2	102	8.2	25Cr–20Ni	Castings
SA-351	CN7M	N08007	62 (425)	45	...	111	8.2	28Ni–19Cr–Cu–Mo	Castings
SA-351	CT15C	N08151	63 (435)	45	...	111	45	32Ni–45Fe–20Cr–Cb	Castings
SA-351	CN3MN	J94651	80 (550)	45	...	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Castings
A 351	CA15	...	90 (620)	6	3	102	7.2	13Cr	Castings
A 351	CE20N	...	80 (550)	8	2	102	8.2	25Cr–8Ni–N	Castings
A 351	CF10MC	J92971	70 (485)	8	1	102	8.1	16Cr–14Ni–2Mo	Castings
A 351	CH10	J93401	70 (485)	8	2	102	8.2	25Cr–12Ni	Castings
A 351	HK30	J94203	65 (450)	8	2	102	8.2	25Cr–20Ni–0.5Mo	Castings
A 351	HK40	J94204	62 (425)	8	2	102	8.2	25Cr–20Ni–0.5Mo	Castings
A 351	HT30	N08603	65 (450)	45	...	111	45	35Ni–15Cr–0.5Mo	Castings
SA-352	LCA	J02504	60 (415)	1	1	101	11.1	C–Si	Castings
SA-352	LCC	J02505	70 (485)	1	2	101	11.1	C–Mn–Si	Castings
SA-352	LCB	J03003	65 (450)	1	1	101	1.1	C–Si	Castings
SA-352	LC1	J12522	65 (450)	3	1	101	1.1	C–0.5Mo	Castings
SA-352	LC2	J22500	70 (485)	9A	1	101	9.1	2.5Ni	Castings
SA-352	LC3	J31550	70 (485)	9B	1	101	9.3	3.5Ni	Castings
SA-352	LC4	J41500	70 (485)	9C	1	101	9.3	4.5Ni	Castings
SA-352	LC2–1	J42215	105 (725)	11A	5	102	9.2	3Ni–1.5Cr–0.5Mo	Castings
SA-352	CA6NM	J91540	110 (760)	6	4	102	7.2	13Cr–4Ni	Castings
SA-353	...	K81340	100 (690)	11A	1	101	9.3	9Ni	Plate
A 356	1	J03502	70 (485)	1	2	101	11.1	C–Si	Castings
A 356	2	J12523	65 (450)	3	1	101	...	C–0.5Mo	Castings
A 356	6	J12073	70 (485)	4	1	102	5.1	1.25Cr–0.5Mo	Castings
A 356	8	J11697	80 (550)	4	1	102	...	1Cr–1Mo–V	Castings
A 356	9	J21610	85 (585)	4	1	102	...	1Cr–1Mo–V	Castings
A 356	10	J22090	85 (585)	5A	1	102	5.2	2.25Cr–1Mo	Castings
A 356	12A	J80490	85 (585)	15E	1	102	6.4	9Cr–1Mo–V	Castings
SA-358	XM–19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Fusion welded pipe
SA-358	XM–29	S24000	100 (690)	8	3	102	8.3	18Cr–3Ni–12Mn	Fusion welded pipe
SA-358	304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Fusion welded pipe
SA-358	304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Fusion welded pipe

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-358	304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Fusion welded pipe
SA-358	304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Fusion welded pipe
SA-358	304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Fusion welded pipe
SA-358	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Fusion welded pipe
SA-358	309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Fusion welded pipe
SA-358	309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Fusion welded pipe
SA-358	310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Fusion welded pipe
SA-358	310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Fusion welded pipe
SA-358	S31254	S31254	94 (650)	8	4	102	8.2	20Cr–18Ni–6Mo	Fusion welded pipe
SA-358	316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Fusion welded pipe
SA-358	316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Fusion welded pipe
SA-358	316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Fusion welded pipe
SA-358	316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Fusion welded pipe
SA-358	316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Fusion welded pipe
SA-358	S31725	S31725	75 (515)	8	4	102	8.1	19Cr–15Ni–4Mo	Fusion welded pipe
SA-358	S31726	S31726	80 (550)	8	4	102	8.1	19Cr–15.5Ni–4Mo	Fusion welded pipe
SA-358	321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Fusion welded pipe
SA-358	347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Fusion welded pipe
SA-358	348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Fusion welded pipe
SA-369	FPA	K02501	48 (330)	1	1	101	1.1	C–Si	Forged pipe
SA-369	FPB	K03006	60 (415)	1	1	101	1.1	C–Mn–Si	Forged pipe
SA-369	FP1	K11522	55 (380)	3	1	101	1.1	C–0.5Mo	Forged pipe
SA-369	FP2	K11547	55 (380)	3	1	101	4.2	0.5Cr–0.5Mo	Forged pipe
SA-369	FP12	K11562	60 (415)	4	1	102	5.1	1Cr–0.5Mo	Forged pipe
SA-369	FP11	K11597	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forged pipe
SA-369	FP22	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	Forged pipe
SA-369	FP21	K31545	60 (415)	5A	1	102	5.2	3Cr–1Mo	Forged pipe
SA-369	FP5	K41545	60 (415)	5B	1	102	5.3	5Cr–0.5Mo	Forged pipe
SA-369	FP9	K90941	60 (415)	5B	1	102	5.4	9Cr–1Mo	Forged pipe
SA-369	FP91	K90901	85 (585)	15E	1	102	6.4	9Cr–1Mo–V	Forged pipe
SA-372	A	K03002	60 (415)	1	1	101	11.1	C–Si	Forgings
SA-372	B	K04001	75 (515)	1	2	101	11.1	C–Mn–Si	Forgings
SA-376	16–8–2H	S16800	75 (515)	8	1	102	8.1	16Cr–8Ni–2Mo	Smls. pipe
SA-376	TP304	S30400	70 (485)	8	1	102	8.1	18Cr–8Ni	Smls. pipe ≥ 0.812 in. (21 mm)
SA-376	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Smls. pipe < 0.812 in. (21 mm)
SA-376	TP304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Smls. pipe

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-376	TP304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Smls. pipe
SA-376	TP304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Smls. pipe
SA-376	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. pipe
SA-376	TP316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. pipe
SA-376	TP316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Smls. pipe
SA-376	TP316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Smls. pipe
SA-376	S31725	S31725	75 (515)	8	4	102	8.1	19Cr–15Ni–4Mo	Smls. pipe
SA-376	S31726	S31726	80 (550)	8	4	102	8.1	19Cr–15.5Ni–4Mo	Smls. pipe
SA-376	TP321	S32100	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. pipe > $^3/_8$ in. (10 mm)
SA-376	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. pipe ≤ $^3/_8$ in. (10 mm)
SA-376	TP321H	S32109	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. pipe > $^3/_8$ in. (10 mm)
SA-376	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. pipe ≤ $^3/_8$ in. (10 mm)
SA-376	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Smls. pipe
SA-376	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. pipe
SA-376	TP347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. pipe
SA-376	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. pipe
A 381	Y35	K03013	60 (415)	1	1	101	1.1	C	Welded pipe
A 381	Y42	. . .	60 (415)	1	1	101	1.2	C	Welded pipe
A 381	Y48	. . .	62 (425)	1	1	101	1.2	C	Welded pipe > $^3/_8$ in. (10 mm)
A 381	Y46	. . .	63 (435)	1	1	101	1.2	C	Welded pipe
A 381	Y50	. . .	64 (440)	1	1	101	1.2	C	Welded pipe > $^3/_8$ in. (10 mm)
A 381	Y52	. . .	66 (455)	1	2	101	1.2	C	Welded pipe > $^3/_8$ in. (10 mm)
A 381	Y56	. . .	71 (490)	1	2	101	1.3	C	Welded pipe > $^3/_8$ in. (10 mm)
A 381	Y60	. . .	75 (515)	1	2	101	1.3	C	Welded pipe > $^3/_8$ in. (10 mm)
SA-387	12, Cl. 1	K11757	55 (380)	4	1	102	5.1	1Cr–0.5Mo	Plate
SA-387	12, Cl. 2	K11757	65 (450)	4	1	102	5.1	1Cr–0.5Mo	Plate
SA-387	11, Cl. 1	K11789	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Plate
SA-387	11, Cl. 2	K11789	75 (515)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Plate
SA-387	Gr. 2, Cl. 1	K12143	55 (380)	3	1	101	4.2	0.5Cr–0.5Mo	Plate
SA-387	Gr. 2, Cl. 2	K12143	70 (485)	3	2	101	4.2	0.5Cr–0.5Mo	Plate
SA-387	22, Cl. 1	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	Plate
SA-387	22, Cl. 2	K21590	75 (515)	5A	1	102	5.2	2.25Cr–1Mo	Plate
SA-387	21, Cl. 1	K31545	60 (415)	5A	1	102	5.2	3Cr–1Mo	Plate
SA-387	21, Cl. 2	K31545	75 (515)	5A	1	102	5.2	3Cr–1Mo	Plate
SA-387	5, Cl. 1	K41545	60 (415)	5B	1	102	5.3	5Cr–0.5Mo	Plate
SA-387	5, Cl. 2	K41545	75 (515)	5B	1	102	5.3	5Cr–0.5Mo	Plate

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-387	Gr. 91, Cl. 2	K90901	85 (585)	15E	1	102	5.4	9Cr–1Mo–V	Plate
SA-403	WPXM–19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Wrought piping fittings
SA-403	WP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Wrought piping fittings
SA-403	WP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Wrought piping fittings
SA-403	WP304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Wrought piping fittings
SA-403	WP304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Wrought piping fittings
SA-403	WP304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Wrought piping fittings
SA-403	WP309	S30900	75 (515)	8	2	102	8.2	23Cr–12Ni	Wrought piping fittings
SA-403	WP310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Wrought piping fittings
SA-403	WP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Wrought piping fittings
SA-403	WP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Wrought piping fittings
SA-403	. . .	S31254	94 (650)	8	4	102	8.2	20Cr–18Ni–6Mo	Wrought piping fittings
SA-403	WP316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Wrought piping fittings
SA-403	WP316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Wrought piping fittings
SA-403	WP316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Wrought piping fittings
SA-403	WP317	S31700	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Wrought piping fittings
SA-403	WP317L	S31703	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Wrought piping fittings
SA-403	WP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Wrought piping fittings
SA-403	WP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Wrought piping fittings
SA-403	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Wrought piping fittings
SA-403	WP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Wrought piping fittings
SA-403	WP347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Wrought piping fittings
SA-403	WP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Wrought piping fittings
SA-403	WP348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Wrought piping fittings
SA-409	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Welded pipe
SA-409	TP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Welded pipe
SA-409	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Welded pipe
SA-409	TP309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Welded pipe
SA-409	TP309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Welded pipe
SA-409	TP310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Welded pipe
SA-409	TP310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Welded pipe
SA-409	S31254	S31254	94 (650)	8	4	102	8.2	20Cr–18Ni–6Mo	Welded pipe
SA-409	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Welded pipe
SA-409	TP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Welded pipe
SA-409	TP317	S31700	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Welded pipe
SA-409	S31725	S31725	75 (515)	8	4	102	8.1	19Cr–15Ni–4Mo	Welded pipe

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)

				Welding		Brazing			
Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	P-No.	Group No.	P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-409	S31726	S31726	80 (550)	8	4	102	8.1	19Cr–15.5Ni–4Mo	Welded pipe
SA-409	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Welded pipe
SA-409	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded pipe
SA-409	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Welded pipe
SA-409	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded pipe
SA-414	A	K01501	45 (310)	1	1	101	1.1	C	Sheet
SA-414	B	K02201	50 (345)	1	1	101	1.1	C	Sheet
SA-414	C	K02503	55 (380)	1	1	101	1.1	C	Sheet
SA-414	D	K02505	60 (415)	1	1	101	1.1	C–Mn	Sheet
SA-414	E	K02704	65 (450)	1	1	101	11.1	C–Mn	Sheet
SA-414	F	K03102	70 (485)	1	2	101	11.1	C–Mn	Sheet
SA-414	G	K03103	75 (515)	1	2	101	11.1	C–Mn	Sheet
SA-420	WPL6	K03006	60 (415)	1	1	101	11.1	C–Mn–Si	Piping fitting
SA-420	WPL9	K22035	63 (435)	9A	1	101	9.1	2Ni–1Cu	Piping fitting
SA-420	WPL3	K31918	65 (450)	9B	1	101	9.2	3.5Ni	Piping fitting
SA-420	WPL8	K81340	100 (690)	11A	1	101	9.3	9Ni	Piping fitting
SA-423	1	K11535	60 (415)	4	2	102	5.1	0.75Cr–0.5Ni–Cu	Smls. & welded tube
SA-423	2	K11540	60 (415)	4	2	102	5.1	0.75Ni–0.5Cu–Mo	Smls. & welded tube
SA-426	CP15	J11522	60 (415)	3	1	101	1.1	C–0.5Mo–Si	Centrifugal cast pipe
SA-426	CP2	J11547	60 (415)	3	1	101	4.2	0.5Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP12	J11562	60 (415)	4	1	102	5.1	1Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP11	J12072	70 (485)	4	1	102	5.1	1.25Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP1	J12521	65 (450)	3	1	101	1.1	C–0.5Mo	Centrifugal cast pipe
SA-426	CP22	J21890	70 (485)	5A	1	102	5.2	2.25Cr–1Mo	Centrifugal cast pipe
SA-426	CP21	J31545	60 (415)	5A	1	102	5.2	3Cr–1Mo	Centrifugal cast pipe
SA-426	CP5	J42045	90 (620)	5B	1	102	5.3	5Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP5b	J51545	60 (415)	5B	1	102	5.3	5Cr–1.5Si–0.5Mo	Centrifugal cast pipe
SA-426	CP9	J82090	90 (620)	5B	1	102	5.4	9Cr–1Mo	Centrifugal cast pipe
SA-426	CPCA15	J91150	90 (620)	6	3	102	7.2	13Cr	Centrifugal cast pipe
SA-451	CPF8	J92600	70 (485)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe
SA-451	CPF8A	J92600	77 (530)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe
SA-451	CPF8C	J92710	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Centrifugal cast pipe
SA-451	CPF8M	J92900	70 (485)	8	1	102	8.1	18Cr–12Ni–2Mo	Centrifugal cast pipe
SA-451	CPF3	J92500	70 (485)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe
SA-451	CPF3M	J92800	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Centrifugal cast pipe
SA-451	CPF3A	J92500	77 (530)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-451	CPH8	J93400	65 (450)	8	2	102	8.2	25Cr–12Ni	Centrifugal cast pipe
SA-451	CPH20	J93402	70 (485)	8	2	102	8.2	25Cr–12Ni	Centrifugal cast pipe
SA-451	CPK20	J94202	65 (450)	8	2	102	8.2	25Cr–20Ni	Centrifugal cast pipe
A 451	CPF10MC	J92971	70 (485)	8	1	102	8.1	16Cr–14Ni–2Mo	Centrifugal cast pipe
A 451	CPE20N	. . .	80 (550)	8	2	102	8.2	25Cr–8Ni–N	Centrifugal cast pipe
SA-455	. . .	K03300	70 (485)	1	2	101	11.2	C–Mn–Si	Plate > 0.580 in.–0.750 in. (15 mm–19 mm)
SA-455	. . .	K03300	73 (505)	1	2	101	11.2	C–Mn–Si	Plate > 0.375 in.–0.580 in. (10 mm–15 mm)
SA-455	. . .	K03300	75 (515)	1	2	101	11.2	C–Mn–Si	Plate, up to 0.375 in. (10 mm)
SA-479	XM–19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Bars & shapes
SA-479	XM–17	S21600	90 (620)	8	3	102	8.3	19Cr–8Mn–6Ni–Mo–N	Bars & shapes
SA-479	XM–18	S21603	90 (620)	8	3	102	8.3	19Cr–8Mn–6Ni–Mo–N	Bars & shapes
SA-479	S21800	S21800	95 (655)	8	3	102	8.1	18Cr–8Ni–4Si–N	Bars & shapes
SA-479	XM–11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Bars & shapes
SA-479	XM–29	S24000	100 (690)	8	3	102	8.3	18Cr–3Ni–12Mn	Bars & shapes
SA-479	302	S30200	75 (515)	8	1	102	8.1	18Cr–8Ni	Bars & shapes
SA-479	304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Bars & shapes
SA-479	304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Bars & shapes
SA-479	304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Bars & shapes
SA-479	304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Bars & shapes
SA-479	304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Bars & shapes
SA-479	S30600	S30600	78 (540)	8	1	102	8.1	18Cr–15Ni–4Si	Bars & shapes
SA-479	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Bars & shapes
SA-479	309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Bars & shapes
SA-479	309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Bars & shapes
SA-479	310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Bars & shapes
SA-479	310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Bars & shapes
SA-479	S31254	S31254	95 (655)	8	4	102	8.2	20Cr–18Ni–6Mo	Bars & shapes
SA-479	316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Bars & shapes
SA-479	316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Bars & shapes
SA-479	316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Bars & shapes
SA-479	316Ti	S31635	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–Ti	Bars & shapes
SA-479	316Cb	S31640	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–Cb	Bars & shapes
SA-479	316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Bars & shapes
SA-479	316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Bars & shapes

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-479	S31725	S31725	75 (515)	8	4	102	8.1	19Cr–15Ni–4Mo	Bars & shapes
SA-479	S31726	S31726	80 (550)	8	4	102	8.1	19Cr–15.5Ni–4Mo	Bars & shapes
SA-479	. . .	S31803	90 (620)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Bars & shapes
SA-479	321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Bars & shapes
SA-479	321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Bars & shapes
SA-479	2205	S32205	95 (655)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Bars & shapes
SA-479	S32550	S32550	110 (760)	10H	1	102	10.2	25Cr–5Ni–3Mo–2Cu	Bars & shapes
SA-479	S32615	S32615	80 (550)	8	1	102	8.1	18Cr–20Ni–5.5Si	Bars & shapes
SA-479	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Bars & shapes
SA-479	347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Bars & shapes
SA-479	347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Bars & shapes
SA-479	348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Bars & shapes
SA-479	348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Bars & shapes
SA-479	403	S40300	70 (485)	6	1	102	7.1	12Cr	Bars & shapes
SA-479	405	S40500	60 (415)	7	1	102	7.1	12Cr–1Al	Bars & shapes
SA-479	410	S41000	70 (485)	6	1	102	7.2	13Cr	Bars & shapes
SA-479	414	S41400	115 (795)	6	4	102	7.2	12.5Cr–2Ni–Si	Bars & shapes
SA-479	S41500	S41500	115 (795)	6	4	102	7.2	13Cr–4.5Ni–Mo	Bars & shapes
SA-479	430	S43000	70 (485)	7	2	102	7.1	17Cr	Bars & shapes
SA-479	439	S43035	70 (485)	7	2	102	7.1	18Cr–Ti	Bars & shapes
SA-479	S44400	S44400	60 (415)	7	2	102	7.1	18Cr–2Mo	Bars & shapes
SA-479	XM–27	S44627	65 (450)	10I	1	102	7.1	27Cr–1Mo	Bars & shapes
SA-479	S44700	S44700	70 (485)	10J	1	102	7.1	29Cr–4Mo	Bars & shapes
SA-479	S44800	S44800	70 (485)	10K	1	102	7.1	29Cr–4Mo–2Ni	Bars & shapes
SA-487	Gr. 16, Cl. A	J31200	70 (485)	1	2	101	1.1	Low C–Mn–Ni	Castings
SA-487	Gr. 1, Cl. A	J13002	85 (585)	10A	1	101	2.1	Mn–V	Castings
SA-487	Gr. 1, Cl. B	J13002	90 (620)	10A	1	101	2.1	Mn–V	Castings
SA-487	Gr. 2, Cl. A	J13005	85 (585)	3	3	101	2.1	Mn–0.25Mo–V	Castings
SA-487	Gr. 2, Cl. B	J13005	90 (620)	3	3	101	2.1	Mn–0.25Mo–V	Castings
SA-487	Gr. 4, Cl. A	J13047	90 (620)	3	3	101	3.1	0.5Ni–0.5Cr–0.25Mo–V	Castings
SA-487	Gr. 4, Cl. B	J13047	105 (725)	11A	3	101	3.1	0.5Ni–0.5Cr–0.25Mo–V	Castings
SA-487	Gr. 4, Cl. E	J13047	115 (795)	11A	3	101	3.1	0.5Ni–0.5Cr–0.25Mo–V	Castings
SA-487	Gr. 8, Cl. A	J22091	85 (585)	5C	1	102	5.2	2.25Cr–1Mo	Castings
SA-487	Gr. 8, Cl. C	J22091	100 (690)	5C	4	102	5.2	2.25Cr–1Mo	Castings
SA-487	Gr. 8, Cl. B	J22091	105 (725)	5C	4	102	5.2	2.25Cr–1Mo	Castings
SA-487	CA15M Cl. A	J91151	90 (620)	6	3	102	7.2	13Cr–Mo	Castings

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-487	CA15 Cl. C	J91150	90 (620)	6	3	102	7.2	13Cr	Castings
SA-487	CA15 Cl. B	J91171	90 (620)	6	3	102	7.2	13Cr	Castings
SA-487	CA15 Cl. D	J91171	100 (690)	6	3	102	7.2	13Cr	Castings
SA-487	CA6NM Cl. B	J91540	100 (690)	6	4	102	7.2	13Cr–4Ni	Castings
SA-487	CA6NM Cl. A	J91540	110 (760)	6	4	102	7.2	13Cr–4Ni	Castings
SA-494	CX2MW	N26022	80 (550)	43	...	111	44	59Ni–22Cr–14Mo–4Fe–3W	Castings
A 494	CW-6M	N30107	72 (495)	44	...	112	44	56Ni–19Mo–18Cr–2Fe	Castings
A 500	C	K02705	62 (425)	1	1	101	11.1	C	Tube
A 500	B	K03000	58 (400)	1	1	101	11.1	C	Tube
A 501	...	K03000	58 (400)	1	1	101	11.1	C	Tube
SA-508	3, Cl. 1	K12042	80 (550)	3	3	101	3.1	0.75Ni–0.5Mo–Cr–V	Forgings
SA-508	3, Cl. 2	K12042	90 (620)	3	3	102	3.1	0.75Ni–0.5Mo–Cr–V	Forgings
SA-508	2, Cl. 1	K12766	80 (550)	3	3	101	3.1	0.75Ni–0.5Mo–0.3Cr–V	Forgings
SA-508	2, Cl. 2	K12766	90 (620)	3	3	101	3.1	0.75Ni–0.5Mo–0.3Cr–V	Forgings
SA-508	1	K13502	70 (485)	1	2	101	11.1	C	Forgings
SA-508	1A	K13502	70 (485)	1	2	101	11.1	C	Forgings
SA-508	22, Cl. 3	K21590	85 (585)	5C	1	102	5.2	2.25Cr–1Mo	Forgings
SA-508	4N, Cl. 3	K22375	90 (620)	3	3	102	3.1	3.5Ni–1.75Cr–0.5Mo–V	Forgings
SA-508	4N, Cl. 1	K22375	105 (725)	11A	5	102	3.1	3.5Ni–1.75Cr–0.5Mo–V	Forgings
SA-508	4N, Cl. 2	K22375	115 (795)	11B	10	102	3.1	3.5Ni–1.75Cr–0.5Mo–V	Forgings
SA-508	3V	K31830	85 (585)	5C	1	102	6.2	3Cr–1Mo–V–Ti–B	Forgings
SA-508	3VCb	...	85 (585)	5C	1	102	6.2	3Cr–1Mo–0.25V–Cb–Ca	Forgings
SA-508	5, Cl. 1	K42365	105 (725)	11A	5	102	3.1	3.5Ni–1.75Cr–0.5Mo–V	Forgings
SA-508	5, Cl. 2	K42365	115 (795)	11B	10	102	3.1	3.5Ni–1.75Cr–0.5Mo–V	Forgings
SA-513	1008	G10080	42 (290)	1	1	101	1.1	C	Tube
SA-513	1010	G10100	45 (310)	1	1	101	1.1	C	Tube
SA-513	1015	G10150	48 (330)	1	1	101	1.1	C	Tube
A 513	1015 CW	G10150	...	1	1	101	1.1	C	Tube
A 513	1020 CW	G10200	...	1	2	101	1.1	C	Tube
A 513	1025 CW	G10250	...	1	2	101	1.2	C	Tube
A 513	1026 CW	G10260	...	1	3	101	11.1	C	Tube
A 514	F	K11576	110 (760)	11B	3	101	3.1	0.75Ni–0.5Cr–0.5Mo–V	Plate, $2\frac{1}{2}$ in. (64 mm) max.
A 514	B	K11630	110 (760)	11B	4	101	3.1	0.5Cr–0.2Mo–V	Plate, $1\frac{1}{4}$ in. (32 mm) max.
A 514	A	K11856	110 (760)	11B	1	101	3.1	0.5Cr–0.25Mo–Si	Plate, $1\frac{1}{4}$ in. (32 mm) max.
A 514	E	K21604	100 (690)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate > $2\frac{1}{2}$ in.–6 in. (64 mm–152 mm), incl.

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
A 514	E	K21604	110 (760)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate, 2½ in. (64 mm) max.
A 514	P	K21650	100 (690)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
A 514	P	K21650	110 (760)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate, 2½ in. (64 mm) max.
A 514	Q	. . .	100 (690)	11B	9	102	3.1	1.3Ni–1.3Cr–0.5Mo–V	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
A 514	Q	. . .	110 (760)	11B	9	102	3.1	1.3Ni–1.3Cr–0.5Mo–V	Plate, 2½ in. (64 mm) max.
SA-515	60	K02401	60 (415)	1	1	101	1.1	C	Plate
SA-515	65	K02800	65 (450)	1	1	101	11.1	C–Si	Plate
SA-515	70	K03101	70 (485)	1	2	101	11.1	C–Si	Plate
SA-516	55	K01800	55 (380)	1	1	101	1.1	C–Si	Plate
SA-516	60	K02100	60 (415)	1	1	101	1.1	C–Mn–Si	Plate
SA-516	65	K02403	65 (450)	1	1	101	1.1	C–Mn–Si	Plate
SA-516	70	K02700	70 (485)	1	2	101	11.1	C–Mn–Si	Plate
SA-517	F	K11576	115 (795)	11B	3	101	3.1	0.75Ni–0.5Cr–0.5Mo–V	Plate ≤ 2½ in. (64 mm)
SA-517	B	K11630	115 (795)	11B	4	101	3.1	0.5Cr–0.2Mo–V	Plate ≤ 1¼ in. (32 mm)
SA-517	A	K11856	115 (795)	11B	1	101	3.1	0.5Cr–0.25Mo–Si	Plate ≤ 1¼ in. (32 mm)
SA-517	E	K21604	105 (725)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
SA-517	E	K21604	115 (795)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate ≤ 2½ in. (64 mm)
SA-517	P	K21650	105 (725)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate > 2½ in.–4 in. (64 mm–102 mm), incl.
SA-517	P	K21650	115 (795)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate ≤ 2½ in. (64 mm)
A 519	1018 HR	G10180	. . .	1	1	101	1.1	C	Tube
A 519	1018 CW	G10180	. . .	1	2	101	1.1	C	Tube
A 519	1020 HR	G10200	. . .	1	1	101	1.1	C	Tube
A 519	1020 CW	G10200	. . .	1	2	101	1.1	C	Tube
A 519	1022 HR	G10220	. . .	1	1	101	1.1	C	Tube
A 519	1022 CW	G10220	70 (485)	1	2	101	1.1	C	Tube
A 519	1025 HR	G10250	55 (380)	1	1	101	1.1	C	Tube
A 519	1025 CW	G10250	75 (515)	1	2	101	1.2	C	Tube
A 519	1026 HR	G10260	55 (380)	1	1	101	11.1	C	Tube
A 519	1026 CW	G10260	75 (515)	1	2	101	11.1	C	Tube
SA-522	Type II	K71340	100 (690)	11A	1	101	9.3	8Ni	Forgings
SA-522	Type I	K81340	100 (690)	11A	1	101	9.3	9Ni	Forgings

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-524	II	K02104	55 (380)	1	1	101	1.1	C–Mn–Si	Smls. pipe
SA-524	I	K02104	60 (415)	1	1	101	1.1	C–Mn–Si	Smls. pipe
SA-533	Type A, Cl. 1	K12521	80 (550)	3	3	101	3.1	Mn–0.5Mo	Plate
SA-533	Type A, Cl. 2	K12521	90 (620)	3	3	101	3.1	Mn–0.5Mo	Plate
SA-533	Type A, Cl. 3	K12521	100 (690)	11A	4	101	3.1	Mn–0.5Mo	Plate
SA-533	Type D, Cl. 1	K12529	80 (550)	3	3	101	3.1	Mn–0.5Mo–0.25Ni	Plate
SA-533	Type D, Cl. 2	K12529	90 (620)	3	3	101	3.1	Mn–0.5Mo–0.25Ni	Plate
SA-533	Type D, Cl. 3	K12529	100 (690)	11A	4	101	3.1	Mn–0.5Mo–0.25Ni	Plate
SA-533	Type B, Cl. 1	K12539	80 (550)	3	3	101	3.1	Mn–0.5Mo–0.5Ni	Plate
SA-533	Type B, Cl. 2	K12539	90 (620)	3	3	101	3.1	Mn–0.5Mo–0.5Ni	Plate
SA-533	Type B, Cl. 3	K12539	100 (690)	11A	4	101	3.2	Mn–0.5Mo–0.5Ni	Plate
SA-533	Type C, Cl. 1	K12554	80 (550)	3	3	101	3.1	Mn–0.5Mo–0.75Ni	Plate
SA-533	Type C, Cl. 2	K12554	90 (620)	3	3	101	3.1	Mn–0.5Mo–0.75Ni	Plate
SA-533	Type C, Cl. 3	K12554	100 (690)	11A	4	101	3.2	Mn–0.5Mo–0.75Ni	Plate
SA-537	Cl. 1	K12437	65 (450)	1	2	101	1.2	C–Mn–Si	Plate > 2½ in.–4 in. (64 mm–102 mm), incl.
SA-537	Cl. 1	K12437	70 (485)	1	2	101	1.2	C–Mn–Si	Plate, 2½ in. (64 mm) & under
SA-537	Cl. 2	K12437	70 (485)	1	3	101	1.2	C–Mn–Si	Plate > 4 in.–6 in. (102 mm–152 mm), incl.
SA-537	Cl. 2	K12437	75 (515)	1	3	101	1.2	C–Mn–Si	Plate > 2½ in.–4 in. (64 mm–102 mm), incl.
SA-537	Cl. 2	K12437	80 (550)	1	3	101	1.2	C–Mn–Si	Plate, 2½ in. (64 mm) & under
SA-537	Cl. 3	K12437	70 (485)	1	3	101	1.2	C–Mn–Si	Plate > 4 in. (102 mm)
SA-537	Cl. 3	K12437	75 (515)	1	3	101	1.2	C–Mn–Si	Plate, 2½ in. < $t \leq$ 4 in. (64 mm < $t \leq$ 102 mm)
SA-537	Cl. 3	K12437	80 (550)	1	3	101	1.2	C–Mn–Si	Plate ≤ 2½ in. (64 mm)
SA-541	1	K03506	70 (485)	1	2	101	11.1	C–Si	Forgings
SA-541	1A	K03020	70 (485)	1	2	101	11.1	C–Mn–Si	Forgings
SA-541	11, Cl. 4	K11572	80 (550)	4	1	102	5.2	1.25Cr–0.5Mo–Si	Forgings
SA-541	3, Cl. 1	K12045	80 (550)	3	3	101	4.1	0.5Ni–0.5Mo–V	Forgings
SA-541	3, Cl. 2	K12045	90 (620)	3	3	101	4.1	0.5Ni–0.5Mo–V	Forgings
SA-541	2, Cl. 1	K12765	80 (550)	3	3	101	4.2	0.75Ni–0.5Mo–0.3Cr–V	Forgings
SA-541	2, Cl. 2	K12765	90 (620)	3	3	101	4.2	0.75Ni–0.5Mo–0.3Cr–V	Forgings
SA-541	22, Cl. 3	K21390	85 (585)	5C	1	102	5.2	2.25Cr–1Mo	Forgings
SA-541	22, Cl. 4	K21390	105 (725)	5C	4	102	5.2	2.25Cr–1Mo	Forgings
SA-541	22, Cl. 5	K21390	115 (795)	5C	5	102	5.2	2.25Cr–1Mo	Forgings

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-541	3V	K31830	85 (585)	5C	1	102	6.2	3Cr–1Mo–V–Ti–B	Forgings
SA-541	3VCb	. . .	85 (585)	5C	1	102	6.2	3Cr–1Mo–0.25V–Cb–Ca	Forgings
SA-541	22V	K31835	85 (585)	5C	1	102	5.2	2.25Cr–1Mo–V	Forgings
SA-542	B, Cl. 4a	K21590	85 (585)	5C	1	102	5.2	2.25Cr–1Mo	Plate
SA-542	B, Cl. 4	K21590	85 (585)	5C	1	102	5.2	2.25Cr–1Mo	Plate
SA-542	A, Cl. 4	K21590	85 (585)	5C	1	102	5.2	2.25Cr–1Mo	Plate
SA-542	A, Cl. 4a	K21590	85 (585)	5C	1	102	5.2	2.25Cr–1Mo	Plate
SA-542	A, Cl. 3	K21590	95 (655)	5C	3	102	5.2	2.25Cr–1Mo	Plate
SA-542	B, Cl. 3	K21590	95 (655)	5C	3	102	5.2	2.25Cr–1Mo	Plate
SA-542	A, Cl. 1	K21590	105 (725)	5C	4	102	5.2	2.25Cr–1Mo	Plate
SA-542	B, Cl. 1	K21590	105 (725)	5C	4	102	5.2	2.25Cr–1Mo	Plate
SA-542	B, Cl. 2	K21590	115 (795)	5C	5	102	5.2	2.25Cr–1Mo	Plate
SA-542	A, Cl. 2	K21590	115 (795)	5C	5	102	5.2	2.25Cr–1Mo	Plate
SA-542	C, Cl. 4	K31830	85 (585)	5C	1	102	6.2	3Cr–1Mo–V–Ti–B	Plate
SA-542	C, Cl. 4a	K31830	85 (585)	5C	1	102	6.2	3Cr–1Mo–V–Ti–B	Plate
SA-542	C, Cl. 3	K31830	95 (655)	5C	3	102	6.2	3Cr–1Mo–V–Ti–B	Plate
SA-542	C, Cl. 1	K31830	105 (725)	5C	4	102	6.2	3Cr–1Mo–V–Ti–B	Plate
SA-542	C, Cl. 2	K31830	115 (795)	5C	5	102	6.2	3Cr–1Mo–V–Ti–B	Plate
SA-542	D, Cl. 4a	K31835	85 (585)	5C	1	102	6.3	2.25Cr–1Mo–V	Plate
SA-542	E, Cl. 4a	. . .	85 (585)	5C	1	102	6.2	3Cr–1Mo–0.25V–Cb–Ca	Plate
SA-543	B, Cl. 3	K42339	90 (620)	3	3	102	3.1	3Ni–1.75Cr–0.5Mo	Plate
SA-543	B, Cl. 1	K42339	105 (725)	11A	5	102	3.1	3Ni–1.75Cr–0.5Mo	Plate
SA-543	B, Cl. 2	K42339	115 (795)	11B	10	102	3.1	3Ni–1.75Cr–0.5Mo	Plate
SA-543	C, Cl. 3	. . .	90 (620)	3	3	102	3.1	2.75Ni–1.5Cr–0.5Mo	Plate
SA-543	C, Cl. 1	. . .	105 (725)	11A	5	102	3.1	2.75Ni–1.5Cr–0.5Mo	Plate
SA-543	C, Cl. 2	. . .	115 (795)	11B	10	102	3.1	2.75Ni–1.5Cr–0.5Mo	Plate
SA-553	II	K71340	100 (690)	11A	1	101	9.3	8Ni	Plate
SA-553	I	K81340	100 (690)	11A	1	101	9.3	9Ni	Plate
SA-556	A2	K01807	47 (325)	1	1	101	1.1	C	Smls. tube
SA-556	B2	K02707	60 (415)	1	1	101	11.1	C–Si	Smls. tube
SA-556	C2	K03006	70 (485)	1	2	101	11.1	C–Mn–Si	Smls. tube
SA-557	A2	K01807	47 (325)	1	1	101	1.1	C	E.R.W. tube
SA-557	B2	K03007	60 (415)	1	1	101	11.1	C	E.R.W. tube
SA-557	C2	K03505	70 (485)	1	2	101	11.1	C–Mn	E.R.W. tube
SA-562	. . .	K11224	55 (380)	1	1	101	1.1	C–Mn–Ti	Plate
A 572	42	. . .	60 (415)	1	1	101	1.2	C–Mn–Si	Plate & shapes

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
A 572	50	...	65 (450)	1	1	101	1.2	C–Mn–Si	Plate & shapes
A 572	60	...	75 (515)	1	2	101	11.1	C–Mn–Si	Plate & shapes
A 573	58	...	58 (400)	1	1	101	11.1	C	Plate
A 573	65	...	65 (450)	1	1	101	11.1	C	Plate
A 573	70	...	70 (485)	1	2	101	11.1	C	Plate
A 575	M 1008	...	...	1	1	101	1.1	C	Bar
A 575	M 1010	...	...	1	1	101	1.1	C	Bar
A 575	M 1012	...	...	1	1	101	1.1	C	Bar
A 575	M 1015	...	...	1	1	101	1.1	C	Bar
A 575	M 1017	...	...	1	1	101	1.1	C	Bar
A 575	M 1020	...	...	1	1	101	11.1	C	Bar
A 575	M 1023	...	...	1	1	101	11.1	C	Bar
A 575	M 1025	...	...	1	1	101	11.1	C	Bar
A 576	G10080	...	...	1	1	101	1.1	C	Bar
A 576	G10100	...	...	1	1	101	1.1	C	Bar
A 576	G10120	...	...	1	1	101	1.1	C	Bar
A 576	G10150	...	...	1	1	101	1.1	C	Bar
A 576	G10160	...	...	1	1	101	1.1	C	Bar
A 576	G10170	...	...	1	1	101	1.1	C	Bar
A 576	G10180	...	...	1	1	101	1.1	C	Bar
A 576	G10190	...	...	1	1	101	1.1	C	Bar
A 576	G10200	...	...	1	1	101	1.1	C	Bar
A 576	G10210	...	...	1	1	101	11.1	C	Bar
A 576	G10220	...	...	1	1	101	11.1	C	Bar
A 576	G10230	...	...	1	1	101	11.1	C	Bar
A 576	G10250	...	...	1	1	101	11.1	C	Bar
SA-587	...	K11500	48 (330)	1	1	101	1.1	C	E.R.W. pipe
A 588	A, a	K11430	63 (435)	3	1	101	1.4	Mn–0.5Cr–0.3Cu–Si–V	Plate & bar
A 588	A, b	K11430	67 (460)	3	1	101	1.4	Mn–0.5Cr–0.3Cu–Si–V	Plate & bar
A 588	A, c	K11430	70 (485)	3	1	101	1.4	Mn–0.5Cr–0.3Cu–Si–V	Plate & shapes
A 588	B, a	K12043	63 (435)	3	1	101	1.4	Mn–0.6Cr–0.3Cu–Si–V	Plate & bar
A 588	B, b	K12043	67 (460)	3	1	101	1.4	Mn–0.6Cr–0.3Cu–Si–V	Plate & bar
A 588	B, c	K12043	70 (485)	3	1	101	1.4	Mn–0.6Cr–0.3Cu–Si–V	Plate & shapes
SA-592	F	K11576	105 (725)	11B	3	101	3.1	0.75Ni–0.5Cr–0.5Mo–V	Forgings, 2½ in.–4 in. (64 mm–102 mm), incl.
SA-592	F	K11576	115 (795)	11B	3	101	3.1	0.75Ni–0.5Cr–0.5Mo–V	Forgings, 2½ in. (64 mm) & under

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-592	E	K11695	105 (725)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Forgings, 2½ in.–4 in. (64 mm–102 mm), incl.
SA-592	E	K11695	115 (795)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Forgings, 2½ in. (64 mm) & under
SA-592	A	K11856	115 (795)	11B	1	101	3.1	0.5Cr–0.25Mo–Si	Forgings, 1½ in. (38 mm) & under
SA-612	. . .	K02900	81 (560)	10C	1	101	1.3	C–Mn–Si	Plate > ½ in.–1 in. (13 mm–25 mm)
SA-612	. . .	K02900	83 (570)	10C	1	101	1.3	C–Mn–Si	Plate, ½ in. (13 mm) & under
A 618	Ia	. . .	67 (460)	1	2	101	. . .	Mn–Cu–V	Tube > ¾ in.–1½ in. (19 mm–38 mm)
A 618	Ia	. . .	70 (485)	1	2	101	. . .	Mn–Cu–V	Tube ≤ ¾ in. (19 mm)
A 618	Ib	K02601	67 (460)	1	2	101	. . .	Mn–Cu–V	Tube > ¾ in.–1½ in. (19 mm–38 mm)
A 618	Ib	K02601	70 (485)	1	2	101	. . .	Mn–Cu–V	Tube ≤ ¾ in. (19 mm)
A 618	II	K12609	67 (460)	1	2	101	1.2	Mn–Cu–V	Tube > ¾ in.–1½ in. (19 mm–38 mm)
A 618	II	K12609	70 (485)	1	2	101	1.2	Mn–Cu–V	Tube, ¾ in. (19 mm) & under
A 618	III	K12700	65 (450)	1	1	101	1.2	Mn–V	Tube
A 633	A	K01802	63 (435)	1	1	101	1.1	Mn–Cb	Plate & shapes
A 633	C	K12000	65 (450)	1	1	101	1.1	Mn–Cb	Plate > 2½ in.–4 in. (64 mm–102 mm), shapes
A 633	C	K12000	70 (485)	1	2	101	1.1	Mn–Cb	Plate to 2½ in. (64 mm), shapes
A 633	D	K12037	65 (450)	1	1	101	1.1	C–Mn–Si	Plate > 2½ in.–4 in. (64 mm–102 mm), shapes
A 633	D	K12037	70 (485)	1	2	101	1.1	C–Mn–Si	Plate to 2½ in. (64 mm), shapes
A 633	E	K12202	80 (550)	1	3	101	4.1	C–Mn–Si–V	Plate & shapes
SA-645	A	K41583	95 (655)	11A	2	101	9.2	5Ni–0.25Mo	Plate
SA-656	T3, Gr. 50	. . .	60 (345)	1	1	101	. . .	C–Mn–Si–V–Cb	Plate
SA-656	T3, Gr. 60	. . .	70 (415)	1	2	101	. . .	C–Mn–Si–V–Cb	Plate
SA-656	T3, Gr. 70	. . .	80 (485)	1	3	101	. . .	C–Mn–Si–V–Cb	Plate
SA-656	T3, Gr. 80	. . .	90 (550)	1	4	101	. . .	C–Mn–Si–V–Cb	Plate
SA-656	T7, Gr. 50	. . .	60 (345)	1	1	101	. . .	C–Mn–Si–V–Cb	Plate
SA-656	T7, Gr. 60	. . .	70 (415)	1	2	101	. . .	C–Mn–Si–V–Cb	Plate
SA-656	T7, Gr. 70	. . .	80 (485)	1	3	101	. . .	C–Mn–Si–V–Cb	Plate
SA-656	T7, Gr. 80	. . .	90 (550)	1	4	101	. . .	C–Mn–Si–V–Cb	Plate
SA-660	WCA	J02504	60 (415)	1	1	101	11.1	C–Si	Centrifugal cast pipe
SA-660	WCC	J02505	70 (485)	1	2	101	11.1	C–Mn–Si	Centrifugal cast pipe
SA-660	WCB	J03003	70 (485)	1	2	101	1.1	C–Si	Centrifugal cast pipe
SA-662	A	K01701	58 (400)	1	1	101	1.1	C–Mn–Si	Plate
SA-662	C	K02007	70 (485)	1	2	101	1.1	C–Mn–Si	Plate
SA-662	B	K02203	65 (450)	1	1	101	1.1	C–Mn–Si	Plate

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
A 663	...	...	...	1	1	101	1.1	C	Bar
SA-666	201-1	S20100	75 (515)	8	3	102	8.3	17Cr–4Ni–6Mn	Plate, sheet & strip
SA-666	201-2	S20100	95 (655)	8	3	102	8.3	17Cr–4Ni–6Mn	Plate, sheet & strip
SA-666	XM-11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Plate, sheet & strip
SA-666	302	S30200	75 (515)	8	1	102	8.1	18Cr–8Ni	Plate, sheet & strip
SA-666	304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Plate, sheet & strip
SA-666	304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Plate, sheet & strip
SA-666	304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Plate, sheet & strip
SA-666	304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Plate, sheet & strip
SA-666	316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Plate, sheet & strip
SA-666	316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Plate, sheet & strip
SA-666	316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Plate, sheet & strip
SA-671	CC60	K02100	60 (415)	1	1	101	1.1	C–Mn–Si	Fusion welded pipe
SA-671	CE55	K02202	55 (380)	1	1	101	11.1	C	Fusion welded pipe
SA-671	CD70	K12437	70 (485)	1	2	101	1.2	C–Mn–Si	Fusion welded pipe
SA-671	CD80	K12437	80 (550)	1	3	101	1.2	C–Mn–Si	Fusion welded pipe
SA-671	CB60	K02401	60 (415)	1	1	101	1.1	C	Fusion welded pipe
SA-671	CE60	K02402	60 (415)	1	1	101	11.1	C–Mn–Si	Fusion welded pipe
SA-671	CC65	K02403	65 (450)	1	1	101	1.1	C–Mn–Si	Fusion welded pipe
SA-671	CC70	K02700	70 (485)	1	2	101	11.1	C–Mn–Si	Fusion welded pipe
SA-671	CB65	K02800	65 (450)	1	1	101	11.1	C–Si	Fusion welded pipe
SA-671	CA55	K02801	55 (380)	1	1	101	11.1	C	Fusion welded pipe
SA-671	CK75	K02803	75 (515)	1	2	101	11.1	C–Mn–Si	Fusion welded pipe
SA-671	CB70	K03101	70 (485)	1	2	101	11.1	C–Si	Fusion welded pipe
SA-672	A45	K01700	45 (310)	1	1	101	1.1	C	Fusion welded pipe
SA-672	C55	K01800	55 (380)	1	1	101	1.1	C–Si	Fusion welded pipe
SA-672	B55	K02001	55 (380)	1	1	101	1.1	C–Si	Fusion welded pipe
SA-672	C60	K02100	60 (415)	1	1	101	1.1	C–Mn–Si	Fusion welded pipe
SA-672	A50	K02200	50 (345)	1	1	101	1.1	C	Fusion welded pipe
SA-672	E55	K02202	55 (380)	1	1	101	11.1	C	Fusion welded pipe
SA-672	D70	K12437	70 (485)	1	2	101	1.2	C–Mn–Si	Fusion welded pipe
SA-672	D80	K12437	80 (550)	1	3	101	1.2	C–Mn–Si	Fusion welded pipe
SA-672	B60	K02401	60 (415)	1	1	101	1.1	C	Fusion welded pipe
SA-672	E60	K02402	60 (415)	1	1	101	11.1	C–Mn–Si	Fusion welded pipe
SA-672	C65	K02403	65 (450)	1	1	101	1.1	C–Mn–Si	Fusion welded pipe
SA-672	C70	K02700	70 (485)	1	2	101	11.1	C–Mn–Si	Fusion welded pipe
SA-672	B65	K02800	65 (450)	1	1	101	11.1	C–Si	Fusion welded pipe

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
Ferrous (CONT'D)									
SA-672	A55	K02801	55 (380)	1	1	101	11.1	C	Fusion welded pipe
SA-672	N75	K02803	75 (515)	1	2	101	11.1	C–Mn–Si	Fusion welded pipe
SA-672	B70	K03101	70 (485)	1	2	101	11.1	C–Si	Fusion welded pipe
SA-672	L65	K11820	65 (450)	3	1	101	1.1	C–0.5Mo	Fusion welded pipe
SA-672	L70	K12020	70 (485)	3	2	101	1.2	C–0.5Mo	Fusion welded pipe
SA-672	H75	K12021	75 (515)	3	2	101	1.1	Mn–0.5Mo	Fusion welded pipe
SA-672	H80	K12022	80 (550)	3	3	101	1.2	Mn–0.5Mo	Fusion welded pipe
SA-672	L75	K12320	75 (515)	3	2	101	1.2	C–0.5Mo	Fusion welded pipe
SA-672	J100	K12521	100 (690)	11A	4	101	3.2	Mn–0.5Mo	Fusion welded pipe
SA-672	J80	...	80 (550)	3	3	101	3.1	Mn–0.5Mo–0.75Ni	Fusion welded pipe
SA-672	J90	...	90 (620)	3	3	101	3.1	Mn–0.5Mo–0.75Ni	Fusion welded pipe
SA-675	45	...	45 (310)	1	1	101	1.1	C	Bar
SA-675	50	...	50 (345)	1	1	101	1.1	C	Bar
SA-675	55	...	55 (380)	1	1	101	1.1	C	Bar
SA-675	60	...	60 (415)	1	1	101	1.1	C	Bar
SA-675	65	...	65 (450)	1	1	101	1.1	C	Bar
SA-675	70	...	70 (485)	1	2	101	1.1	C	Bar
A 675	75	...	75 (515)	...	...	101	...	C	Bar
SA-688	XM–29	S24000	100 (690)	8	3	102	8.3	18Cr–3Ni–12Mn	Welded tube
SA-688	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Welded tube
SA-688	TP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Welded tube
SA-688	TP304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Welded tube
SA-688	TP304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Welded tube
SA-688	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Welded tube
SA-688	TP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Welded tube
SA-688	TP316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Welded tube
SA-688	TP316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Welded tube
SA-691	CMSH–70	K12437	65 (450)	1	2	101	1.2	C–Mn–Si	Fusion welded pipe > $2\frac{1}{2}$ in.–4 in. (64 mm–102 mm)
SA-691	CMSH–70	K12437	70 (485)	1	2	101	1.2	C–Mn–Si	Fusion welded pipe ≤ $2\frac{1}{2}$ in. (64 mm)
SA-691	CMSH–80	K12437	75 (515)	1	3	101	1.2	C–Mn–Si	Fusion welded pipe > $2\frac{1}{2}$ in.–4 in. (64 mm–102 mm)
SA-691	CMSH–80	K12437	80 (550)	1	3	101	1.2	C–Mn–Si	Fusion welded pipe ≤ $2\frac{1}{2}$ in. (64 mm)
SA-691	CMS–75	K02803	75 (515)	1	2	101	11.1	C–Mn–Si	Fusion welded pipe

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-691	1CR, Cl. 1	K11757	55 (380)	4	1	102	5.1	1Cr–0.5Mo	Fusion welded pipe
SA-691	1CR, Cl. 2	K11757	65 (450)	4	1	102	5.1	1Cr–0.5Mo	Fusion welded pipe
SA-691	1.25CR, Cl. 1	K11789	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Fusion welded pipe
SA-691	1.25CR, Cl. 2	K11789	75 (515)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Fusion welded pipe
SA-691	CM–65	K11820	65 (450)	3	1	101	1.1	C–0.5Mo	Fusion welded pipe
SA-691	CM–70	K12020	70 (485)	3	2	101	1.2	C–0.5Mo	Fusion welded pipe
SA-691	0.5CR, Cl. 1	K12143	55 (380)	3	1	101	4.2	0.5Cr–0.5Mo	Fusion welded pipe
SA-691	0.5CR, Cl. 2	K12143	70 (485)	3	2	101	4.2	0.5Cr–0.5Mo	Fusion welded pipe
SA-691	CM–75	K12320	75 (515)	3	2	101	1.2	C–0.5Mo	Fusion welded pipe
SA-691	2.25CR, Cl. 1	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	Fusion welded pipe
SA-691	2.25CR, Cl. 2	K21590	75 (515)	5A	1	102	5.2	2.25Cr–1Mo	Fusion welded pipe
SA-691	3CR, Cl. 1	K31545	60 (415)	5A	1	102	5.2	3Cr–1Mo	Fusion welded pipe
SA-691	3CR, Cl. 2	K31545	75 (515)	5A	1	102	5.2	3Cr–1Mo	Fusion welded pipe
SA-691	5CR, Cl. 1	K41545	60 (415)	5B	1	102	5.3	5Cr–0.5Mo	Fusion welded pipe
SA-691	5CR, Cl. 2	K41545	75 (515)	5B	1	102	5.3	5Cr–0.5Mo	Fusion welded pipe
A 691	91	K91560	85 (585)	15E	1	102	6.4	9Cr-1Mo-V	Fusion welded pipe
A 694	F42	K03014	60 (415)	1	1	101	11.1	C–Mn	Forgings
A 694	F46	K03014	60 (415)	1	1	101	11.1	C–Mn	Forgings
A 694	F52	K03014	66 (455)	1	1	101	11.1	C–Mn	Forgings
A 694	F56	K03014	68 (470)	1	2	101	11.1	C–Mn	Forgings
A 694	F60	K03014	75 (515)	1	2	101	11.1	C–Mn	Forgings
A 694	F65	K03014	77 (530)	1	2	101	11.1	C–Mn	Forgings
A 694	F70	K03014	82 (565)	1	3	101	11.1	C–Mn	Forgings
SA-695	Type B, Gr. 35	K03504	60 (415)	1	1	101	11.1	C	Bar
SA-695	Type B, Gr. 40	K03504	70 (485)	1	2	101	11.1	C	Bar
SA-696	B	K03200	60 (415)	1	1	101	11.1	C–Mn–Si	Bar
SA-696	C	K03200	70 (485)	1	2	101	11.1	C–Mn–Si	Bar
A 707	L1, Cl. 1	K02302	. . .	1	1	101	1.2	C–Mn	Forgings
A 707	L1, Cl. 2	K02302	. . .	1	1	101	1.2	C–Mn	Forgings
A 707	L2, Cl. 1	K03301	. . .	1	1	101	11.1	C–Mn	Forgings
A 707	L2, Cl. 2	K03301	. . .	1	1	101	11.1	C–Mn	Forgings
A 707	L2, Cl. 3	K03301	. . .	1	2	101	11.1	C–Mn	Forgings
A 707	L3, Cl. 1	K12510	. . .	1	1	101	1.2	C–Mn–V–N	Forgings
A 707	L3, Cl. 2	K12510	. . .	1	1	101	1.2	C–Mn–V–N	Forgings
A 707	L3, Cl. 3	K12510	. . .	1	2	101	1.3	C–Mn–V–N	Forgings

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
A 714	Gr. V, Tp. E	K22035	65 (450)	9A	1	102	9.1	2Ni–1Cu	Smls. & welded pipe
A 714	Gr. V	K22035	65 (450)	9A	1	102	9.1	2Ni–1Cu	Smls. & welded pipe
SA-724	A	K11831	90 (620)	1	4	101	3.1	C–Mn–Si	Plate
SA-724	B	K12031	95 (655)	1	4	101	3.1	C–Mn–Si	Plate
SA-724	C	K12037	90 (620)	1	4	101	1.1	C–Mn–Si	Plate
SA-727	. . .	K02506	60 (415)	1	1	101	11.1	C–Mn–Si	Forgings
SA-731	S41500	S41500	115 (795)	6	4	102	7.2	13Cr–4.5Ni–Mo	Smls. & welded pipe
SA-731	TP439	S43035	60 (415)	7	2	102	7.1	18Cr–Ti	Smls. & welded pipe
SA-731	18Cr–2Mo	S44400	60 (415)	7	2	102	7.1	18Cr–2Mo	Smls. & welded pipe
SA-731	TPXM–33	S44626	65 (450)	10I	1	102	7.1	27Cr–1Mo–Ti	Smls. & welded pipe
SA-731	TPXM–27	S44627	65 (450)	10I	1	102	7.1	27Cr–1Mo	Smls. & welded pipe
SA-731	S44660	S44660	85 (585)	10K	1	102	7.1	26Cr–3Ni–3Mo	Smls. & welded pipe
SA-731	S44700	S44700	80 (550)	10J	1	102	7.1	29Cr–4Mo	Smls. & welded pipe
SA-731	S44800	S44800	80 (550)	10K	1	102	7.1	29Cr–4Mo–2Ni	Smls. & welded pipe
SA-737	B	K12001	70 (485)	1	2	101	11.1	C–Mn–Si–Cb	Plate
SA-737	C	K12202	80 (550)	1	3	101	4.1	C–Mn–Si–V	Plate
SA-738	A	K12447	75 (515)	1	2	101	11.1	C–Mn–Si	Plate
SA-738	B	K12007	85 (585)	1	3	101	11.1	C–Mn–Si–Cb	Plate
SA-738	C	K02008	70 (485)	1	3	101	11.1	C–Mn–Si	Plate > 4 in.–6 in. (102 mm–152 mm), incl.
SA-738	C	K02008	75 (515)	1	3	101	11.1	C–Mn–Si	Plate > $2\frac{1}{2}$ in.–4 in. (64 mm–102 mm), incl.
SA-738	C	K02008	80 (550)	1	3	101	11.1	C–Mn–Si	Plate, $2\frac{1}{2}$ in. (64 mm) & under
SA-739	B11	K11797	70 (485)	4	1	102	5.1	1.25Cr–0.5Mo	Bar
SA-739	B22	K21390	75 (515)	5A	1	102	5.2	2.25Cr–1Mo	Bar
SA-765	I	K03046	60 (415)	1	1	101	11.1	C–Mn–Si	Forgings
SA-765	II	K03047	70 (485)	1	2	101	11.1	C–Mn–Si	Forgings
SA-765	III	K32026	70 (485)	9B	1	101	9.2	3.5Ni	Forgings
SA-765	IV	K02009	80 (550)	1	3	101	1.1	C–Mn–Si	Forgings
SA-789	S31200	S31200	100 (690)	10H	1	102	10.2	25Cr–6Ni–Mo–N	Smls. & welded tube
SA-789	S31260	S31260	100 (690)	10H	1	102	10.2	25Cr–6.5Ni–3Mo–N	Smls. & welded tube
SA-789	S31500	S31500	92 (635)	10H	1	102	10.1	18Cr–5Ni–3Mo–N	Smls. & welded tube
SA-789	S31803	S31803	90 (620)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Smls. & welded tube
SA-789	S32205	S32205	95 (655)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Smls. & welded tube
SA-789	S32304	S32304	87 (600)	10H	1	102	10.1	23Cr–4Ni–Mo–Cu–N	Smls. & welded tube > 1 in. (25 mm)
SA-789	S32304	S32304	100 (690)	10H	1	102	10.1	23Cr–4Ni–Mo–Cu–N	Smls. & welded tube ≤ 1 in. (25 mm)

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-789	S32550	S32550	110 (760)	10H	1	102	10.2	25Cr–5Ni–3Mo–2Cu	Smls. & welded tube
SA-789	S32750	S32750	116 (800)	10H	1	102	10.2	25Cr–7Ni–4Mo–N	Smls. & welded tube
SA-789	S32900	S32900	90 (620)	10H	1	102	10.2	26Cr–4Ni–Mo	Smls. & welded tube
SA-789	S32906	S32906	109 (750)	10H	1	102	10.2	29Cr–6.5Ni–2Mo–N	Smls. & welded tube ≥ 0.40 in. (10 mm)
SA-789	S32906	S32906	116 (800)	10H	1	102	10.2	29Cr–6.5Ni–2Mo–N	Smls. & welded tube < 0.40 in. (10 mm)
SA-789	S32950	S32950	100 (690)	10H	1	102	10.2	26Cr–4Ni–Mo–N	Smls. & welded tube
SA-789	S32760	S32760	109 (750)	10H	1	102	10.2	25Cr–8Ni–3Mo–W–Cu–N	Smls. & welded tube
SA-789	S39274	S39274	116 (800)	10H	1	102	10.2	25Cr–7Ni–3Mo–2W–Cu–N	Smls. & welded tube
SA-790	S31200	S31200	100 (690)	10H	1	102	10.2	25Cr–6Ni–Mo–N	Smls. & welded pipe
SA-790	S31260	S31260	100 (690)	10H	1	102	10.2	25Cr–6.5Ni–3Mo–N	Smls. & welded pipe
SA-790	S31500	S31500	92 (635)	10H	1	102	10.1	18Cr–5Ni–3Mo–N	Smls. & welded pipe
SA-790	S31803	S31803	90 (620)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Smls. & welded pipe
SA-790	S32205	S32205	95 (655)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Welded pipe
SA-790	S32304	S32304	87 (600)	10H	1	102	10.1	23Cr–4Ni–Mo–Cu–N	Smls. & welded pipe
SA-790	S32550	S32550	110 (760)	10H	1	102	10.2	25Cr–5Ni–3Mo–2Cu	Smls. & welded pipe
SA-790	S32750	S32750	116 (800)	10H	1	102	10.2	25Cr–7Ni–4Mo–N	Smls. & welded tube
SA-790	S32900	S32900	90 (620)	10H	1	102	10.2	26Cr–4Ni–Mo	Smls. & welded pipe
SA-790	S32906	S32906	109 (750)	10H	1	102	10.2	29Cr–6.5Ni–2Mo–N	Smls. & welded pipe ≥ 0.40 in. (10 mm)
SA-790	S32906	S32906	116 (800)	10H	1	102	10.2	29Cr–6.5Ni–2Mo–N	Smls. & welded pipe < 0.40 in. (10 mm)
SA-790	S32950	S32950	100 (690)	10H	1	102	10.2	26Cr–4Ni–Mo–N	Smls. & welded pipe
SA-790	S32760	S32760	109 (750)	10H	1	102	10.2	25Cr–8Ni–3Mo–W–Cu–N	Smls. & welded pipe
SA-790	S39274	S39274	116 (800)	10H	1	102	10.2	25Cr–7Ni–3Mo–2W–Cu–N	Smls. & welded pipe
SA-803	TP439	S43035	60 (415)	7	2	102	7.1	18Cr–Ti	Welded tube
SA-803	26–3–3	S44660	85 (585)	10K	1	102	7.1	26Cr–3Ni–3Mo	Welded tube
SA-813	TPXM–19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Welded pipe
SA-813	TPXM–11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Welded pipe
SA-813	TPXM–29	S24000	100 (690)	8	3	102	8.3	18Cr–3Ni–12Mn	Welded pipe
SA-813	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Welded pipe
SA-813	TP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Welded pipe
SA-813	TP304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Welded pipe
SA-813	TP304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Welded pipe
SA-813	TP304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Welded pipe
SA-813	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Welded pipe
SA-813	TP309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Welded pipe
SA-813	TP309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Welded pipe
SA-813	TP310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Welded pipe

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-813	TP310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Welded pipe
SA-813	S31254	S31254	94 (650)	8	4	102	8.2	20Cr–18Ni–6Mo	Welded pipe
SA-813	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Welded pipe
SA-813	TP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Welded pipe
SA-813	TP316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Welded pipe
SA-813	TP316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Welded pipe
SA-813	TP316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Welded pipe
SA-813	TP317	S31700	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Welded pipe
SA-813	TP317L	S31703	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Welded pipe
SA-813	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Welded pipe
SA-813	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Welded pipe
SA-813	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded pipe
SA-813	TP347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded pipe
SA-813	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded pipe
SA-813	TP348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded pipe
SA-813	TPXM–15	S38100	75 (515)	8	1	102	8.1	18Cr–18Ni–2Si	Welded pipe
SA-814	TPXM–19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Cold worked welded pipe
SA-814	TPXM–11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Cold worked welded pipe
SA-814	TPXM–29	S24000	100 (690)	8	3	102	8.3	18Cr–3Ni–12Mn	Cold worked welded pipe
SA-814	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Cold worked welded pipe
SA-814	TP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Cold worked welded pipe
SA-814	TP304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Cold worked welded pipe
SA-814	TP304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Cold worked welded pipe
SA-814	TP304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Cold worked welded pipe
SA-814	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Cold worked welded pipe
SA-814	TP309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Cold worked welded pipe
SA-814	TP309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Cold worked welded pipe
SA-814	TP310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Cold worked welded pipe
SA-814	TP310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Cold worked welded pipe
SA-814	S31254	S31254	94 (650)	8	4	102	8.2	20Cr–18Ni–6Mo	Cold worked welded pipe
SA-814	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Cold worked welded pipe
SA-814	TP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Cold worked welded pipe
SA-814	TP316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Cold worked welded pipe
SA-814	TP316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Cold worked welded pipe
SA-814	TP316LN	S31653	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Cold worked welded pipe
SA-814	TP317	S31700	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Cold worked welded pipe

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-814	TP317L	S31703	75 (515)	8	1	102	8.1	18Cr–13Ni–3Mo	Cold worked welded pipe
SA-814	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Cold worked welded pipe
SA-814	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Cold worked welded pipe
SA-814	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Cold worked welded pipe
SA-814	TP347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Cold worked welded pipe
SA-814	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Cold worked welded pipe
SA-814	TP348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Cold worked welded pipe
SA-814	TPXM–15	S38100	75 (515)	8	1	102	8.1	18Cr–18Ni–2Si	Cold worked welded pipe
SA-815	S31803	S31803	90 (620)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Fittings
SA-815	S41500	S41500	110 (760)	6	4	102	7.2	13Cr–4.5Ni–Mo	Fittings
SA-815	S32760	S32760	109 (750)	10H	1	102	10.2	25Cr–8Ni–3Mo–W–Cu–N	Fittings
SA-815	S32205	S32205	95(655)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Welded pipe
SA-832	21V	K31830	85 (585)	5C	1	102	6.2	3Cr–1Mo–V–Ti–B	Plate
SA-832	22V	K31835	85 (585)	5C	1	102	6.2	2.25Cr–1Mo–V	Plate
SA-832	23V	...	85 (585)	5C	1	102	6.2	3Cr–1Mo–0.25V–Cb–Ca	Plate
SA-836	...	...	55 (380)	1	1	101	1.1	C–Si–Ti	Forgings
SA-841	A, Cl. 1	...	70 (485)	1	2	...	1.2	C–Mn–Si	Plate
SA-841	B, Cl. 2	...	80 (550)	1	3	...	1.3	C–Mn–Si	Plate
A 890	CD3MWCuN	J93380	...	10H	1	102	10.2	25Cr–8Ni–3Mo–W–Cu–N	Castings
A 928	...	S32760	109 (750)	10H	1	102	10.2	25Cr–8Ni–3Mo–W–Cu–N	Welded pipe
A 928	S32205	S32205	90 (620)	10H	1	102	10.1	22Cr–5Ni–3Mo–N	Welded pipe
SA-965	F46	S30600	78 (540)	8	1	102	8.1	18Cr–15Ni–4Si	Forgings
SA-965	FXM–19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Forgings
SA-965	FXM–11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Forgings
SA-965	F304	S30400	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-965	F304L	S30403	65 (450)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-965	F304H	S30409	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-965	F304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Forgings
SA-965	F304LN	S30453	70 (485)	8	1	102	8.1	18Cr–8Ni–N	Forgings
SA-965	F310	S31000	75 (515)	8	2	102	8.2	25Cr–20Ni	Forgings
SA-965	F316	S31600	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Forgings
SA-965	F316L	S31603	65 (450)	8	1	102	8.1	16Cr–12Ni–2Mo	Forgings
SA-965	F316H	S31609	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Forgings
SA-965	F316N	S31651	80 (550)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Forgings
SA-965	F316LN	S31653	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo–N	Forgings

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-965	F321	S32100	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Forgings
SA-965	F321H	S32109	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Forgings
SA-965	F347	S34700	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings
SA-965	F347H	S34709	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings
SA-965	F348	S34800	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings
SA-965	F348H	S34809	65 (450)	8	1	102	8.1	18Cr–10Ni–Cb	Forgings
A 992	...	...	65 (450)	1	1	101	1.1	C–Mn–Si	Shapes
SA-995	2A	J93345	95 (655)	10H	1	102	10.2	24Cr–10Ni–4Mo–N	Castings
SA-995	1B	J93372	100 (690)	10H	1	102	10.2	25Cr–5Ni–3Mo–2Cu	Castings
SA-1008	CS Type A	...	40 (275)	1	1	101	1.1	C	Sheet
SA-1008	CS Type B	...	40 (275)	1	1	101	1.1	C	Sheet
A 1008	DS Type B	...	40 (275)	1	1	101	1.1	C	Sheet & strip
SA-1010	40	S41003	66 (455)	7	1	102	...	12CR–1Ni	Plate, sheet & strip
SA-1010	50	S41003	70 (485)	7	1	102	...	12CR–1Ni	Plate, sheet & strip
A 1011	CS Type B	...	40 (275)	1	1	101	1.1	C	Sheet & strip
A 1011	DS Type B	...	40 (275)	1	1	101	1.1	C	Sheet & strip
API 5L	A25, Cl. I	...	45 (310)	1	1	101	1.1	C–Mn	Smls. & welded pipe & tube
API 5L	A25, Cl. II	...	45 (310)	1	1	101	1.1	C–Mn	Smls. & welded pipe & tube
API 5L	A	...	48 (330)	1	1	101	1.1	C–Mn	Smls. & welded pipe & tube
API 5L	B	...	60 (415)	1	1	101	1.1	C–Mn	Smls. & welded pipe & tube
API 5L	X42	...	60 (415)	1	1	101	1.2	C–Mn	Smls. & welded pipe & tube
API 5L	X46	...	63 (435)	1	1	101	1.2	C–Mn	Smls. & welded pipe & tube
API 5L	X52	...	66 (455)	1	1	101	1.2	C–Mn	Smls. & welded pipe & tube
API 5L	X56	...	71 (490)	1	2	101	1.3	C–Mn	Smls. & welded pipe & tube
API 5L	X60	...	75 (515)	1	2	101	1.3	C–Mn	Smls. & welded pipe & tube
API 5L	X65	...	77 (530)	1	2	101	1.3	C–Mn	Smls. & welded pipe & tube
API 5L	X70	...	82 (565)	1	3	101	1.3	C–Mn	Smls. & welded pipe & tube
API 5L	X80	...	90 (620)	1	4	101	1.3	C–Mn	Smls. & welded pipe & tube
MSS SP-75	WPHY-42	...	60 (415)	1	1	101	1.1	C–Mn	Smls./welded fittings
MSS SP-75	WPHY-46	...	63 (435)	1	1	101	1.1	C–Mn	Smls./welded fittings
MSS SP-75	WPHY-52	...	66 (455)	1	1	101	1.1	C–Mn	Smls./welded fittings
MSS SP-75	WPHY-56	...	71 (490)	1	2	101	1.1	C–Mn	Smls./welded fittings
MSS SP-75	WPHY-60	...	75 (515)	1	2	101	1.1	C–Mn	Smls./welded fittings
MSS SP-75	WPHY-65	...	77 (530)	1	2	101	1.1	C–Mn	Smls./welded fittings

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)										
			Minimum Specified	Welding		Brazing				
Spec. No.	Type or Grade	UNS No.	Tensile, ksi (MPa)	P-No.	Group No.	P-No.	ISO 15608 Group	Nominal Composition	Product Form
MSS SP-75	WPHY-70	...	82 (565)	1	3	101	1.1	C–Mn	Smls./welded fittings
SA/AS 1548	PT430	...	62.5 (430)	1	1	101	1.1	C	Plate
SA/AS 1548	PT460	...	66.5 (460)	1	1	101	1.1	C	Plate
SA/AS 1548	PT490	...	71 (490)	1	2	101	1.1	C	Plate
SA/CSA-G40.21	Gr. 38W	...	60 (415)	1	1	101	1.1	C–Mn–Si	Plate, bar & shapes
SA/CSA-G40.21	Gr. 44W	...	60 (415)	1	1	101	1.1	C–Mn–Si	Plate, bar & shapes
SA/EN 10025-2	S235JR	...	52(360)	1	1	...	1.1	C	Plate
SA/EN 10028-2	13CrMoSi5-5+QT	...	71 (490)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Plate > 4–10 in. (100 mm–250 mm) incl.
SA/EN 10028-2	13CrMoSi5-5+QT	...	72.5 (500)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Plate > 2.4–4 in. (60 mm–100 mm) incl.
SA/EN 10028-2	13CrMoSi5-5+QT	...	74 (510)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Plate ≤ 2.4 in. (60 mm)
SA/EN 10028-2	P295GH	...	64 (440)	1	1	101	1.1	C–Mn–Si	Plate > 4 in. ≤ 6 in. (>102 mm ≤ 152 mm)
SA/EN 10028-2	P295GH	...	67 (460)	1	1	101	1.1	C–Mn–Si	Plate ≤ 4 in. (102 mm)
SA/EN 10028-2	P295GH	...	62.5 (430)	1	1	101	...	C–Mn–Si	Plate > 6 in. ≤ 10 in. (>152 mm ≤ 254 mm)
SA/EN 10028-2	P355GH	...	68 (470)	1	2	101	1.2	C–Mn–Si	Plate > 6 in. ≤ 10 in. (150 mm–250 mm)
SA/EN 10028-2	P355GH	...	69.5 (480)	1	2	101	1.2	C–Mn–Si	Plate > 4 in. ≤ 6 in. (102 mm–150 mm)
SA/EN 10028-2	P355GH	...	71 (490)	1	2	101	1.2	C–Mn–Si	Plate > 2.5 in. ≤ 4 in. (63 mm–102 mm)
SA/EN 10028-2	P355GH	...	74 (510)	1	2	101	1.2	C–Mn–Si	Plate ≤ 2.5 in. (63 mm)
SA/EN 10028-3	P275NH	...	51 (350)	1	1	101	1.1	C	Plate > 6 in. ≤ 10 in. (152 mm–254 mm)
SA/EN 10028-3	P275NH	...	52 (360)	1	1	101	1.1	C	Plate > 4 in. ≤ 6 in. (102 mm–152 mm)
SA/EN 10028-3	P275NH	...	53.5 (370)	1	1	101	1.1	C	Plate > 2 in. ≤ 4 in. (51 mm–102 mm)
SA/EN 10028-3	P275NH	...	56.5 (390)	1	1	101	1.1	C	Plate ≤ 2 in. (51 mm)
SA/EN 10028-4	X8Ni9	...	93 (640)	11A	1	...	9.3	9Ni	Plate
SA/EN 10028-4	X7Ni9	...	99 (680)	11A	1	...	9.3	9Ni	Plate
SA/EN 10028-7	X5CrNi18–10	...	75 (520)	8	1	102	...	18Cr–8Ni	Plate
SA/EN 10028-7	X5CrNiMo17–12–2	...	75 (520)	8	1	102	...	16Cr–12Ni–2Mo	Plate
SA/EN 10088-2	X6CrNiMoTi17–12–2	...	78 (540)	8	1	...	8.1	16Cr–12Ni–2Mo–Ti	Plate, sheet & strip
SA/EN 10216-2	P235GH	...	52 (360)	1	1	...	1.1	C	Smls. tube
SA/EN 10216-2	P265GH	...	59.5 (410)	1	1	...	1.1	C	Smls. tube
SA/EN 10216-2	16Mo3	...	65.5 (450)	3	1	...	1.1	C–0.5Mo	Smls. tube
SA/EN 10216-2	13CrMo4–5	...	64 (440)	4	1	...	5.1	1Cr–0.5Mo	Smls. tube
SA/EN 10216-2	10CrMo9–10	...	69.5 (480)	5A	1	...	5.2	2½Cr–1Mo	Smls. tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA/EN 10216-2	X10CrMoVNb9-1	...	91.5 (630)	15E	1	...	6.4	9Cr-1Mo-V	Smls. tube
SA/EN 10217-1	P235TR2	...	52 (360)	1	1	...	1.1	C	E.R.W. tube
SA/EN 10222-2	P280GH	...	66.5 (460)	1	1	101	1.2	C-Mn-Si	Forgings
SA/EN 10222-2	P305GH	...	71 (490)	1	2	101	1.2	C-Mn-Si	Forgings
SA/EN 10222-2	13CrMo4-5	...	64 (440)	4	1	102	5.1	1Cr-0.5Mo	Forgings ≤ 10 in. (≤ 250 mm)
SA/EN 10222-2	13CrMo4-5	...	61 (420)	4	1	102	5.1	1Cr-0.5Mo	Forgings > 10 in. ≤ 20 in. (>250 mm ≤ 500 mm)
SA/EN 10222-2	11CrMo9-10	...	75.5 (520)	5A	1	102	5.2	2.25Cr-1Mo	Forgings ≤ 8 in. (≤ 200 mm
SA/EN 10222-2	11CrMo9-10	...	65.5 (450)	5A	1	102	5.2	2.25Cr-1Mo	Forgings > 8 in. ≤ 20 in. (>200 mm ≤ 500 mm)
SA/EN 10222-2	X10CrMoVNb9-1	...	91.5 (630)	15E	1	102	6.4	9Cr-1Mo-V	Forgings
SA/GB 6654	16MnR	...	65 (450)	1	1	101	...	C-Mn	Plate > 4-5 in. (100-120 mm), incl.
SA/GB 6654	16MnR	...	67 (460)	1	1	101	...	C-Mn	Plate > 2.4-4 in. (60-100 mm), incl.
SA/GB 6654	16MnR	...	68 (470)	1	1	101	...	C-Mn	Plate > 1.5-2.4 in. (36-60 mm), incl.
SA/GB 6654	16MnR	...	71 (490)	1	2	101	...	C-Mn	Plate > 0.65-1.5 in. (16-36 mm), incl.
SA/GB 6654	16MnR	...	74 (510)	1	2	101	...	C-Mn	Plate 0.25-0.65 in. (6-16 mm), incl.
SA/JIS G3118	SGV480	...	70 (485)	1	2	101	1.2	C-Mn-Si	Plate
SA/JIS G4303	SUS 302	S30200	75 (515)	8	1	102	...	18Cr-8Ni	Bars & shapes
SA/JIS G4303	SUS 304	S30400	75 (515)	8	1	102	...	18Cr-8Ni	Bars & shapes
SA/JIS G4303	SUS 304L	S30403	70 (485)	8	1	102	...	18Cr-8Ni	Bars & shapes
SA/JIS G4303	SUS 309S	S30908	75 (515)	8	2	102	...	23Cr-12Ni	Bars & shapes
SA/JIS G4303	SUS 310S	S31008	75 (515)	8	2	102	...	25Cr-20Ni	Bars & shapes
SA/JIS G4303	SUS 316	S31600	75 (515)	8	1	102	...	16Cr-12Ni-2Mo	Bars & shapes
SA/JIS G4303	SUS 316L	S31603	70 (485)	8	1	102	...	16Cr-12Ni-2Mo	Bars & shapes
SA/JIS G4303	SUS 321	S32100	75 (515)	8	1	102	...	18Cr-10Ni-Ti	Bars & shapes
SA/JIS G4303	SUS 347	S34700	75 (515)	8	1	102	...	18Cr-10Ni-Cb	Bars & shapes
SA/JIS G4303	SUS 405	S40500	60 (415)	7	1	102	...	12Cr-1Al	Bars & shapes

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
B 16	C36000	...	48 (330)	...	107	NA	65Cu–Zn–3Pb	Rod ≤ 1 in. (25 mm)
B 16	C36000	...	44 (305)	...	107	NA	65Cu–Zn–3Pb	Rod > 1 in.–2 in. (25 mm–51 mm), incl.
B 16	C36000	...	40 (275)	...	107	NA	65Cu–Zn–3Pb	Rod > 2 in. (51 mm)
B 16	C36000	...	44 (305)	...	107	NA	65Cu–Zn–3Pb	Bar ≤ 1 in. (25 mm)
B 16	C36000	...	40 (275)	...	107	NA	65Cu–Zn–3Pb	Bar > 1 in. (25 mm)
B 26	A24430	...	17 (115)	26	...	24.1	Al–Si	Castings
B 26	A03560	T71	25 (170)	26	...	24.1	Al–Si	Castings
B 26	A03560	T6	30 (205)	26	...	24.1	Al–Si	Castings
SB-42	C10200	...	30 (205)	31	107	31	99.95Cu–P	Smls. pipe
SB-42	C12000	...	30 (205)	31	107	31	99.9Cu–P	Smls. pipe
SB-42	C12200	...	30 (205)	31	107	31	99.9Cu–P	Smls. pipe
SB-43	C23000	...	40 (275)	32	107	32.1	85Cu–15Zn	Smls. pipe
SB-61	C92200	...	30 (205)	...	107	NA	88Cu–Sn–Zn–Pb	Castings
SB-62	C83600	...	28 (195)	...	107	NA	85Cu–5Sn–5Zn–5Pb	Castings
B 68	C10200	102	30 (205)	31	107	31	99.95Cu–P	Tube
B 68	C12000	120	30 (205)	31	107	31	99.9Cu–P	Tube
B 68	C12200	122	30 (205)	31	107	31	99.9Cu–P	Tube
SB-75	C10200	...	30 (205)	31	107	31	99.95Cu–P	Smls. tube
SB-75	C12000	...	30 (205)	31	107	31	99.9Cu–P	Smls. tube
SB-75	C12200	...	30 (205)	31	107	31	99.9Cu–P	Smls. tube
B 88	C10200	102	30 (205)	31	107	31	99.95Cu–P	Tube
B 88	C12000	120	30 (205)	31	107	31	99.9Cu–P	Tube
B 88	C12200	122	30 (205)	31	107	31	99.9Cu–P	Tube
SB-96	C65500	...	50 (345)	33	107	37	97Cu–3Si	Plate, sht, strip & bar
SB-98	C65100	...	40 (275)	33	107	37	98.5Cu–1.5Si	Rod, bar & shapes
SB-98	C65500	...	52 (360)	33	107	37	97Cu–3Si	Rod, bar & shapes
SB-98	C66100	...	52 (360)	33	107	37	94Cu–3Si	Rod, bar & shapes
SB-111	C10200	...	30 (205)	31	107	31	99.95Cu–P	Smls. tube
SB-111	C12000	...	30 (205)	31	107	31	99.9Cu–P	Smls. tube
SB-111	C12200	...	30 (205)	31	107	31	99.9Cu–P	Smls. tube
SB-111	C14200	...	30 (205)	31	107	31	99.4Cu–As–P	Smls. tube
SB-111	C19200	...	38 (260)	31	107	31	99.7Cu–Fe–P	Smls. tube
SB-111	C23000	...	40 (275)	32	107	32.1	85Cu–15Zn	Smls. tube
SB-111	C28000	...	50 (345)	32	107	32.1	60Cu–40Zn	Smls. tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)								
Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-111	C44300	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06As	Smls. tube
SB-111	C44400	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06Sb	Smls. tube
SB-111	C44500	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06P	Smls. tube
SB-111	C60800	...	50 (345)	35	108	35	95Cu–5Al	Smls. tube
SB-111	C68700	...	50 (345)	32	108	32.2	78Cu–20Zn–2Al	Smls. tube
SB-111	C70400	...	38 (260)	34	107	34	95Cu–5Ni	Smls. tube
SB-111	C70600	...	40 (275)	34	107	34	90Cu–10Ni	Smls. tube
SB-111	C71000	...	45 (310)	34	107	34	80Cu–20Ni	Smls. tube
SB-111	C71500	...	52 (360)	34	107	34	70Cu–30Ni	Smls. tube
SB-111	C72200	...	45 (310)	34	107	34	80Cu–16Ni–0.75Fe–0.5Cr	Smls. tube
SB-127	N04400	...	70 (485)	42	110	42	67Ni–30Cu	Plate, sheet & strip
SB-135	C23000	...	40 (275)	32	107	32.1	85Cu–15Zn	Smls. tube
SB-148	C95200	...	65 (450)	35	108	35	88Cu–9Al–3Fe	Castings
SB-148	C95400	...	75 (515)	35	108	35	85Cu–11Al–4Fe	Castings
B 148	C95300	...	65 (450)	35	108	35	89Cu–10Al–1Fe	Castings
B 148	C95500	...	90 (620)	35	108	35	82Cu–11Al–4Fe–3Mn	Castings
B 148	C95600	...	60 (415)	35	108	35	90Cu–7Al–3Si	Castings
SB-150	C61400	...	70 (485)	35	108	35	90Cu–7Al–3Fe	Rod & bar
SB-150	C62300	...	75 (515)	35	108	35	88Cu–9Al–3Fe	Rod (round)
SB-150	C63000	...	85 (585)	35	108	35	81Cu–10Al–5Ni–3Fe	Rod & bar
SB-150	C64200	...	70 (485)	35	108	35	91Cu–7Al–2Si	Rod & bar
SB-151	C70600	...	38 (260)	34	107	34	90Cu–10Ni	Rod & bar
SB-152	C10200	...	30 (205)	31	107	31	99.95Cu–P	Plt, sht, strip & bar
SB-152	C10400	...	30 (205)	31	107	31	99.95Cu + Ag	Plt, sht, strip & bar
SB-152	C10500	...	30 (205)	31	107	31	99.95Cu + Ag	Plt, sht, strip & bar
SB-152	C10700	...	30 (205)	31	107	31	99.95Cu + Ag	Plt, sht, strip & bar
SB-152	C11000	...	30 (205)	31	107	31	99.90Cu	Plt, sht, strip & bar
SB-152	C12200	...	30 (205)	31	107	31	99.9Cu–P	Plt, sht, strip & bar
SB-152	C12300	...	30 (205)	31	107	31	99.9Cu–P	Plt, sht, strip & bar
SB-152	C14200	...	30 (205)	31	107	31	99.4Cu–As–P	Plt, sht, strip & bar
SB-160	N02200	...	55 (380)	41	110	41	99.0Ni	Rod & bar
SB-160	N02201	...	50 (345)	41	110	41	99.0Ni–Low C	Rod & bar
SB-161	N02200	...	55 (380)	41	110	41	99.0Ni	Smls. pipe & tube
SB-161	N02201	...	50 (345)	41	110	41	99.0Ni–Low C	Smls. pipe & tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-162	N02200	...	55 (380)	41	110	41	99.0Ni	Plate, sheet & strip
SB-162	N02201	...	50 (345)	41	110	41	99.0Ni–Low C	Plate, sheet & strip
SB-163	N02200	...	55 (380)	41	110	41	99.0Ni	Smls. tube
SB-163	N02201	...	50 (345)	41	110	41	99.0Ni–Low C	Smls. tube
SB-163	N04400	...	70 (485)	42	110	42	67Ni–30Cu	Smls. tube
SB-163	N06600	...	80 (550)	43	111	43	72Ni–15Cr–8Fe	Smls. tube
SB-163	N06601	...	80 (550)	43	111	43	60Ni–23Cr–12Fe–Al	Smls. tube
SB-163	N06690	...	85 (585)	43	111	43	58Ni–29Cr–9Fe	Smls. tube
SB-163	N08120	...	90 (620)	45	111	45	37Ni–33Fe–25Cr	Smls. tube
SB-163	N08800	...	75 (515)	45	111	45	33Ni–42Fe–21Cr	Smls. tube
SB-163	N08801	...	65 (450)	45	111	45	32Ni–45Fe–20.5Cr–Ti	Smls. tube
SB-163	N08810	...	65 (450)	45	111	45	33Ni–42Fe–21Cr	Smls. tube
SB-163	N08811	...	65 (450)	45	111	45	33Ni–42Fe–21Cr–Al–Ti	Smls. tube
SB-163	N08825	...	85 (585)	45	111	45	42Ni–21.5Cr–3Mo–2.3Cu	Smls. tube
SB-164	N04400	...	70 (485)	42	110	42	67Ni–30Cu	Rod, bar & wire
SB-164	N04405	...	70 (485)	42	110	42	67Ni–30Cu	Rod, bar & wire
SB-165	N04400	...	70 (485)	42	110	42	67Ni–30Cu	Smls. pipe & tube
SB-166	N06045	...	90 (620)	46	111	45	46Ni–27Cr–23Fe–2.75Si	Rod, bar & wire
SB-166	N06600	...	80 (550)	43	111	43	72Ni–15Cr–8Fe	Rod, bar & wire
SB-166	N06601	...	80 (550)	43	111	43	60Ni–23Cr–12Fe–Al	Rod, bar & wire
SB-166	N06617	...	95 (655)	43	111	46	52Ni–22Cr–13Co–9Mo	Rod, bar & wire
SB-166	N06690	...	85 (585)	43	111	43	58Ni–29Cr–9Fe	Rod, bar & wire
SB-167	N06045	...	90 (620)	46	111	45	46Ni–27Cr–23Fe–2.75Si	Smls. pipe & tube
SB-167	N06600	...	75 (515)	43	111	43	72Ni–15Cr–8Fe	Smls. pipe & tube
SB-167	N06601	...	80 (550)	43	111	43	60Ni–23Cr–12Fe–Al	Smls. pipe & tube
SB-167	N06617	...	95 (655)	43	111	46	52Ni–22Cr–13Co–9Mo	Smls. pipe & tube
SB-167	N06690	...	75 (515)	43	111	43	58Ni–29Cr–9Fe	Smls. pipe & tube
SB-168	N06045	...	90 (620)	46	111	45	46Ni–27Cr–23Fe–2.75Si	Plate, sheet & strip
SB-168	N06600	...	80 (550)	43	111	43	72Ni–15Cr–8Fe	Plate, sheet & strip
SB-168	N06601	...	80 (550)	43	111	43	60Ni–23Cr–12Fe–Al	Plate, sheet & strip
SB-168	N06617	...	95 (655)	43	111	46	52Ni–22Cr–13Co–9Mo	Plate, sheet & strip
SB-168	N06690	...	85 (585)	43	111	43	58Ni–29Cr–9Fe	Plate, sheet & strip
SB-169	C61400	...	72 (495)	35	108	35	90Cu–7Al–3Fe	Plt, sht, strip & bar ≤ ½ in. (13 mm)
SB-169	C61400	...	70 (485)	35	108	35	90Cu–7Al–3Fe	Plt, sht, strip & bar > ½ in.–2 in. (13 mm–51 mm)
SB-169	C61400	...	65 (450)	35	108	35	90Cu–7Al–3Fe	Plt, sht, strip & bar > 2 in.–5 in. (51 mm–127 mm)

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-171	C36500	...	40 (275)	32	107	32.2	60Cu–39Zn–Pb	Plate & sheet
SB-171	C44300	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06As	Plate & sheet
SB-171	C44400	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06Sb	Plate & sheet
SB-171	C44500	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06P	Plate & sheet
SB-171	C46400	...	50 (345)	32	107	32.2	60Cu–39Zn–Sn	Plate & sheet
SB-171	C46500	...	50 (345)	32	107	32.2	60Cu–39Zn–As	Plate & sheet
SB-171	C61400	...	65 (450)	35	108	35	90Cu–7Al–3Fe	Plate & sheet > 2 in.–5 in. (51 mm–127 mm), incl.
SB-171	C61400	...	70 (485)	35	108	35	90Cu–7Al–3Fe	Plate & sheet ≤ 2 in. (51 mm)
SB-171	C63000	...	80 (550)	35	108	35	81Cu–10Al–5Ni–3Fe	Plate & sheet > 3½ in.–5 in. (89 mm–127 mm), incl.
SB-171	C63000	...	85 (585)	35	108	35	81Cu–10Al–5Ni–3Fe	Plate & sheet > 2 in.–3.5 in. (51 mm–89 mm), incl.
SB-171	C63000	...	90 (620)	35	108	35	81Cu–10Al–5Ni–3Fe	Plate & sheet ≤ 2 in. (51 mm)
SB-171	C70600	...	40 (275)	34	107	34	90Cu–10Ni	Plate & sheet
SB-171	C71500	...	45 (310)	34	107	34	70Cu–30Ni	Plate & sheet > 2.5 in.–5 in. (64 mm–127 mm), incl.
SB-171	C71500	...	50 (345)	34	107	34	70Cu–30Ni	Plate & sheet ≤ 2.5 in. (64 mm)
SB-187	C10200	060	28 (195)	31	107	31	99.95Cu–P	Rod & bar
SB-187	C11000	060	28 (195)	31	107	31	99.9Cu	Rod & bar
SB-209	A91060	1060	8 (55)	21	104	21	99.60Al	Plate & sheet
SB-209	A91100	1100	11 (76)	21	104	21	99.0Al–Cu	Plate & sheet
SB-209	A93003	3003	14 (97)	21	104	22.1	Al–Mn–Cu	Plate & sheet
SB-209	A93004	3004	22 (150)	22	104	22.2	Al–Mn–Mg	Plate & sheet
SB-209	A95052	5052	25 (170)	22	105	22.3	Al–2.5Mg	Plate & sheet
SB-209	A95083	5083	36 (250)	25	105	22.4	Al–4.4Mg–Mn	Plate & sheet > 7 in.–8 in. (178 mm–203 mm), incl.
SB-209	A95083	5083	37 (255)	25	105	22.4	Al–4.4Mg–Mn	Plate & sheet > 5 in.–7 in. (127 mm–178 mm), incl.
SB-209	A95083	5083	38 (260)	25	105	22.4	Al–4.4Mg–Mn	Plate & sheet > 3 in.–5 in. (76 mm–127 mm), incl.
SB-209	A95083	5083	39 (270)	25	105	22.4	Al–4.4Mg–Mn	Plate & sheet > 1.5 in.–3 in. (38 mm–76 mm), incl.
SB-209	A95083	5083	40 (275)	25	105	22.4	Al–4.4Mg–Mn	Plate & sheet > 0.05 in.–1.5 in. (1.3 mm–38 mm), incl.
SB-209	A95086	5086	34 (235)	25	105	22.4	Al–4.0Mg–Mn	Plate & sheet > 2 in.–3 in. (51 mm–76 mm), incl.
SB-209	A95086	5086	35 (240)	25	105	22.4	Al–4.0Mg–Mn	Plate & sheet > 0.05 in.–2 in. (1.3 mm–51 mm), incl.
SB-209	A95154	5154	30 (205)	22	105	22.4	Al–3.5Mg	Plate & sheet
SB-209	A95254	5254	30 (205)	22	105	22.4	Al–3.5Mg	Plate & sheet
SB-209	A95454	5454	31 (215)	22	105	22.3	Al–2.7Mg–Mn	Plate & sheet
SB-209	A95456	5456	38 (260)	25	105	22.4	Al–5.1Mg–Mn	Plate & sheet > 7 in.–8 in. (178 mm–203 mm), incl.
SB-209	A95456	5456	39 (270)	25	105	22.4	Al–5.1Mg–Mn	Plate & sheet > 5 in.–7 in. (127 mm–178 mm), incl.
SB-209	A95456	5456	40 (275)	25	105	22.4	Al–5.1Mg–Mn	Plate & sheet > 3 in.–5 in. (76 mm–127 mm), incl.
SB-209	A95456	5456	41 (285)	25	105	22.4	Al–5.1Mg–Mn	Plate & sheet > 1.5 in.–3 in. (38 mm–76 mm), incl.

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-209	A95456	5456	42 (290)	25	105	22.4	Al–5.1Mg–Mn	Plate & sheet > 0.05 in.–1.5 in. (1.3 mm–38 mm), incl.
SB-209	A95652	5652	25 (170)	22	105	22.3	Al–2.5Mg	Plate & sheet
SB-209	A96061	6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Plate & sheet
SB-209	...	Alclad 3003	13 (90)	21	104	22.1	Al–Mn–Cu	Plate & sheet > 0.05 in. < 0.5 in. (> 1.3 mm < 13 mm)
SB-209	...	Alclad 3003	14 (97)	21	104	22.1	Al–Mn–Cu	Plate & sheet ≥ 0.5 in.–3 in. (13 mm–76 mm), incl.
SB-209	...	Alclad 3004	21 (145)	22	104	22.2	Al–Mn–Mg	Plate & sheet > 0.05 in. < 0.5 in. (> 1.3 mm < 13 mm)
SB-209	...	Alclad 3004	22 (150)	22	104	22.2	Al–Mn–Mg	Plate & sheet ≥ 0.5 in.–3 in. (13 mm–76 mm), incl.
SB-209	...	Alclad 6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Plate & sheet
B 209	A95050	5050	18 (125)	21	105	22.1	Al–1.5Mg	Plate & sheet
SB-210	A91060	1060	8.5 (59)	21	104	21	99.60Al	Smls. tube
SB-210	...	Alclad 3003	13 (90)	21	104	22.1	Al–Mn–Cu	Smls. tube
SB-210	A93003	3003	14 (97)	21	104	22.1	Al–Mn–Cu	Smls. tube
SB-210	A95052	5052	25 (170)	22	105	22.3	Al–2.5Mg	Smls. tube
SB-210	A95154	5154	30 (205)	22	105	22.4	Al–3.5Mg	Smls. tube
SB-210	A96061	6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Smls. tube
SB-210	A96063	6063	17 (115)	23	105	23.1	Al–Mg–Si	Smls. tube
B 210	A95083	5083	39 (270)	25	105	22.4	Al–4.4Mg–Mn	Smls. tube
B 210	A95086	5086	35 (240)	25	105	22.4	Al–4.0Mg–Mn	Smls. tube
B 210	A95456	5456	41 (285)	25	105	22.4	Al–5.1Mg–Mn	Smls. tube
SB-211	A96061	6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Bar, rod & wire
SB-221	A91060	1060	8.5 (59)	21	104	21	99.60Al	Bar, rod & shapes
SB-221	A91100	1100	11 (76)	21	104	21	99.0Al–Cu	Bar, rod & shapes
SB-221	A93003	3003	14 (97)	21	104	22.1	Al–Mn–Cu	Bar, rod & shapes
SB-221	A95083	5083	39 (270)	25	105	22.4	Al–4.4Mg–Mn	Bar, rod & shapes
SB-221	A95154	5154	30 (205)	22	105	22.4	Al–3.5Mg	Bar, rod & shapes
SB-221	A95454	5454	31 (215)	22	105	22.3	Al–2.7Mg–Mn	Bar, rod & shapes
SB-221	A95456	5456	41 (285)	25	105	22.4	Al–5.1Mg–Mn	Bar, rod & shapes
SB-221	A96061	6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Bar, rod & shapes
SB-221	A96063	6063	17 (115)	23	105	23.1	Al–Mg–Si	Bar, rod & shapes
SB-234	A91060	1060	8.5 (59)	21	104	21	99.60Al	Smls. tube
SB-234	...	Alclad 3003	13 (90)	21	104	22.1	Al–Mn–Cu	Smls. tube
SB-234	A93003	3003	14 (97)	21	104	22.1	Al–Mn–Cu	Smls. tube
SB-234	A95052	5052	25 (170)	22	105	22.3	Al–2.5Mg	Smls. tube

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-234	A95454	5454	31 (215)	22	105	22.3	Al–2.7Mg–Mn	Smls. tube
SB-234	A96061	6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Smls. tube
SA-240	S31277	. . .	112 (770)	45	111	8.2	27Ni–22Cr–7Mo–Mn–Cu	Plate, sheet & strip
SB-241	A91060	1060	8.5 (59)	21	104	21	99.60Al	Smls. pipe & tube
SB-241	A91100	1100	11 (76)	21	104	21	99.0Al–Cu	Smls. pipe & tube
SB-241	. . .	Alclad 3003	13 (90)	21	104	22.1	Al–Mn–Cu	Smls. pipe & tube
SB-241	A93003	3003	14 (97)	21	104	22.1	Al–Mn–Cu	Smls. pipe & tube
SB-241	A95052	5052	25 (170)	22	105	22.3	Al–2.5Mg	Smls. pipe & tube
SB-241	A95083	5083	39 (270)	25	105	22.4	Al–4.4Mg–Mn	Smls. pipe & tube
SB-241	A95086	5086	35 (240)	25	105	22.4	Al–4.0Mg–Mn	Smls. pipe & tube
SB-241	A95454	5454	31 (215)	22	105	22.3	Al–2.7Mg–Mn	Smls. pipe & tube
SB-241	A95456	5456	41 (285)	25	105	22.4	Al–5.1Mg–Mn	Smls. pipe & tube
SB-241	A96061	6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Smls. pipe & tube
SB-241	A96063	6063	17 (115)	23	105	23.1	Al–Mg–Si	Smls. pipe & tube
SB-247	A93003	3003	14 (97)	21	104	22.1	Al–Mn–Cu	Forgings
SB-247	A95083	5083	38 (260)	25	105	22.4	Al–4.4Mg–Mn	Forgings
SB-247	A96061	6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Forgings
SB-265	R50250	1	35 (240)	51	115	51	Ti	Plate, sheet & strip
SB-265	R50400	2	50 (345)	51	115	51	Ti	Plate, sheet & strip
SB-265	R50400	2H	58 (400)	51	115	. . .	Ti	Plate, sheet & strip
SB-265	R50550	3	65 (450)	52	115	52	Ti	Plate, sheet & strip
SB-265	R52250	11	35 (240)	51	115	51	Ti–Pd	Plate, sheet & strip
SB-265	R52252	17	35 (240)	51	. . .	51	Ti–Pd	Plate, sheet & strip
SB-265	R52254	27	35 (240)	51	115	51	Ti–Ru	Plate, sheet & strip
SB-265	R52400	7	50 (345)	51	115	51	Ti–Pd	Plate, sheet & strip
SB-265	R52400	7H	58 (400)	51	115	. . .	Ti–Pd	Plate, sheet & strip
SB-265	R52402	16	50 (345)	51	115	51	Ti–Pd	Plate, sheet & strip
SB-265	R52402	16H	58 (400)	51	115	. . .	Ti–Pd	Plate, sheet & strip
SB-265	R52404	26	50 (345)	51	115	51	Ti–Ru	Plate, sheet & strip
SB-265	R52404	26H	58 (400)	51	115	. . .	Ti–Ru	Plate, sheet & strip
SB-265	R53400	12	70 (485)	52	115	52	Ti–0.3Mo–0.8Ni	Plate, sheet & strip
SB-265	R56320	9	90 (620)	53	115	53	Ti–3Al–2.5V	Plate, sheet & strip
SB-265	R56323	28	90 (620)	53	115	53	Ti–3Al–2.5V–0.1Ru	Plate, sheet & strip
SB-271	C95200	. . .	65 (450)	35	108	35	88Cu–9Al–3Fe	Castings
SB-271	C95400	. . .	75 (515)	35	108	35	85Cu–11Al–4Fe	Castings
B 280	C10200	102	30 (205)	31	107	31	99.95Cu–P	Smls. tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
B 280	C12000	120	30 (205)	31	107	31	99.9Cu–P	Smls. tube
B 280	C12200	122	30 (205)	31	107	31	99.9Cu–P	Smls. tube
B 283	C11000	Cu	33 (230)	31	107	31	99.9Cu	Forgings
B 283	C37700	Forging brass	46 (315)	...	107	NA	60Cu–38Zn–2Pb	Forgings > 1.5 in. (38 mm)
B 283	C37700	Forging brass	50 (345)	...	107	NA	60Cu–38Zn–2Pb	Forgings ≤ 1.5 in. (38 mm)
B 283	C46400	Naval brass	64 (440)	32	107	32.2	60Cu–39Zn–Sn	Forgings
B 283	C65500	High Si bronze	52 (360)	33	107	31	97Cu–3Si	Forgings
B 283	C67500	Mn bronze	72 (495)	32	107	32.2	59Cu–39Zn–Fe–Sn	Forgings
B 302	C12000	...	36 (250)	31	107	31	99.9Cu–P	Pipe
B 302	C12200	...	36 (250)	31	107	31	99.9Cu–P	Pipe
SB-308	A96061	6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Shapes
SB-315	C65500	...	50 (345)	33	107	33	97Cu–3Si	Smls. pipe & tube
SB-333	N10001	...	100 (690)	44	112	44	62Ni–28Mo–5Fe	Plate, sheet & strip ≥ 0.1875 in.–2.5 in. (4.8 mm–64 mm), incl.
SB-333	N10001	...	115 (795)	44	112	44	62Ni–28Mo–5Fe	Plate, sheet & strip < 0.1875 in. (48 mm)
SB-333	N10629	...	110 (760)	44	112	44	66Ni–28Mo–3Fe–1.3Cr–0.25Al	Plate, sheet & strip
SB-333	N10665	...	110 (760)	44	112	44	65Ni–28Mo–2Fe	Plate, sheet & strip
SB-333	N10675	...	110 (760)	44	112	44	65Ni–29.5Mo–2Fe–2Cr	Plate, sheet & strip
SB-335	N10001	...	100 (690)	44	112	44	62Ni–28Mo–5Fe	Rod > 1.5 in.–3.5 in. (38 mm–89 mm), incl.
SB-335	N10001	...	115 (795)	44	112	44	62Ni–28Mo–5Fe	Rod ≥ 0.3125 in.–1.5 in. (8 mm–38 mm), incl.
SB-335	N10629	...	110 (760)	44	112	44	66Ni–28Mo–3Fe–1.3Cr–0.25Al	Rod
SB-335	N10665	...	110 (760)	44	112	44	65Ni–28Mo–2Fe	Rod
SB-335	N10675	...	110 (760)	44	112	44	65Ni–29.5Mo–2Fe–2Cr	Rod
SB-338	R50250	1	35 (240)	51	115	51	Ti	Smls. & welded tube
SB-338	R50400	2	50 (345)	51	115	51	Ti	Smls. & welded tube
SB-338	R50400	2H	58 (400)	51	115	...	Ti	Smls. & welded tube
SB-338	R50550	3	65 (450)	52	115	52	Ti	Smls. & welded tube
SB-338	R52400	7	50 (345)	51	115	51	Ti–Pd	Smls. & welded tube
SB-338	R52400	7H	58 (400)	51	115	...	Ti–Pd	Smls. & welded tube
SB-338	R52402	16	50 (345)	51	115	51	Ti–Pd	Smls. & welded tube
SB-338	R52402	16H	58 (400)	51	115	...	Ti–Pd	Smls. & welded tube
SB-338	R52404	26	50 (345)	51	115	51	Ti–Ru	Smls. & welded tube
SB-338	R52404	26H	58 (400)	51	115	...	Ti–Ru	Smls. & welded tube
SB-338	R53400	12	70 (485)	52	115	52	Ti–0.3Mo–0.8Ni	Smls. & welded tube
SB-338	R56320	9	90 (620)	53	115	53	Ti–3Al–2.5V	Smls. & welded tube
SB-338	R56323	28	90 (620)	53	115	53	Ti–3Al–2.5V–0.1Ru	Smls. & welded tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
B 345	A91060	1060	8.5 (59)	21	104	21	99.60Al	Smls. pipe & tube
B 345	A93003	3003	14 (97)	21	104	22.1	Al–Mn–Cu	Smls. pipe & tube
B 345	A95083	5083	39 (270)	25	105	22.4	Al–4.4Mg–Mn	Smls. pipe & tube
B 345	A95086	5086	37 (255)	25	105	22.4	Al–4.0Mg–Mn	Smls. pipe & tube
B 345	A96061	6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Smls. pipe & tube
B 345	A96063	6063	17 (115)	23	105	23.1	Al–Mg–Si	Smls. pipe & tube
SB-348	R50250	1	35 (240)	51	115	51	Ti	Bars & billets
SB-348	R50400	2	50 (345)	51	115	51	Ti	Bars & billets
SB-348	R50400	2H	58 (400)	51	115	. . .	Ti	Bars & billets
SB-348	R50550	3	65 (450)	52	115	52	Ti	Bars & billets
SB-348	R52400	7	50 (345)	51	115	51	Ti–Pd	Bars & billets
SB-348	R52400	7H	58 (400)	51	115	. . .	Ti–Pd	Bars & billets
SB-348	R52402	16H	58 (400)	51	115	. . .	Ti–Pd	Bars & billets
SB-348	R52404	26	50 (345)	51	115	51	Ti–Ru	Bars & billets
SB-348	R52404	26H	58 (400)	51	115	. . .	Ti–Ru	Bars & billets
SB-348	R53400	12	70 (485)	52	115	52	Ti–0.3Mo–0.8Ni	Bars & billets
SB-348	R52402	16	50 (345)	51	115	51	Ti–Pd	Bars & billets
SB-348	R56320	9	90 (620)	53	115	53	Ti–3Al–2.5V	Bars & billets
SB-348	R56323	28	90 (620)	53	115	53	Ti–3Al–2.5V–0.1Ru	Bars & billets
A 351	N08603	HT30	65 (450)	45	111	45	35Ni–15Cr–0.5Mo	Castings
SA-351	J94651	CN3MN	80 (550)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Castings
SA-351	N08007	CN7M	62 (425)	45	111	8.2	28Ni–19Cr–Cu–Mo	Castings
SA-351	N08151	CT15C	63 (435)	45	111	45	32Ni–45Fe–20Cr–Cb	Castings
SB-359	C12200	. . .	30 (205)	31	107	31	99.9Cu–P	Smls. tube
SB-359	C44300	. . .	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06As	Smls. tube
SB-359	C44400	. . .	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06Sb	Smls. tube
SB-359	C44500	. . .	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06P	Smls. tube
SB-359	C70600	. . .	40 (275)	34	107	34	90Cu–10Ni	Smls. tube
SB-359	C71000	. . .	45 (310)	34	107	34	80Cu–20Ni	Smls. tube
SB-359	C71500	. . .	52 (360)	34	107	34	70Cu–30Ni	Smls. tube
B 361	A91060	WP1060	8 (55)	21	104	21	99.60Al	Fittings
B 361	A91100	WP1100	11 (76)	21	104	21	99.0Al–Cu	Fittings
B 361	. . .	WP Alclad 3003	13 (90)	21	104	22.1	Al–Mn–Cu	Fittings
B 361	A93003	WP3003	14 (97)	21	104	22.1	Al–Mn–Cu	Fittings
B 361	A95083	5083	39 (270)	25	105	22.4	Al–4.4Mg–Mn	Fittings
B 361	A95154	5154	30 (205)	22	105	22.3	Al–3.5Mg	Fittings

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
B 361	A96061	WP6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Fittings
B 361	A96063	WP6063	17 (115)	23	105	23.1	Al–Mg–Si	Fittings
SB-363	R50250	WPT 1	35 (240)	51	115	51	Ti	Smls. & welded fittings
SB-363	R50400	WPT 2	50 (345)	51	115	51	Ti	Smls. & welded fittings
SB-363	R50550	WPT 3	65 (450)	52	115	52	Ti	Smls. & welded fittings
SB-363	R52400	WPT 7	50 (345)	51	115	51	Ti–Pd	Smls. & welded fittings
SB-363	R52400	WPT 7H	58 (400)	51	115	...	Ti–Pd	Smls. & welded fittings
SB-363	R52402	WPT 16	50 (345)	51	115	...	Ti–Pd	Smls. & welded fittings
SB-363	R52402	WPT 16H	58 (400)	51	115	...	Ti–Pd	Smls. & welded fittings
SB-363	R52404	WPT 26	50 (345)	51	115	51	Ti–Ru	Smls. & welded fittings
SB-363	R52404	WPT 26H	58 (400)	51	115	...	Ti–Ru	Smls. & welded fittings
SB-363	R53400	WPT 12	70 (485)	52	115	52	Ti–0.3Mo–0.8Ni	Smls. & welded fittings
SB-363	R56320	WPT 9	90 (620)	53	115	53	Ti–3Al–2.5V	Smls. & welded fittings
SB-363	R56323	WPT 28	90 (620)	53	115	53	Ti–3Al–2.5V–0.1Ru	Smls. & welded fittings
SB-366	N02200	...	55 (380)	41	110	41	99.0Ni	Fittings
SB-366	N02201	...	50 (345)	41	110	41	99.0Ni-Low C	Fittings
SB-366	N04400	...	70 (485)	42	110	42	67Ni–30Cu	Fittings
SB-366	N06002	...	100 (690)	43	111	43	47Ni–22Cr–18Fe–9Mo	Fittings
SB-366	N06007	...	90 (620)	45	111	43	47Ni–22Cr–19Fe–6Mo	Fittings
SB-366	N06022	...	100 (690)	43	111	44	55Ni–21Cr–13.5Mo	Fittings
SB-366	N06030	...	85 (585)	45	111	45	40Ni–29Cr–15Fe–5Mo	Fittings
SB-366	N06035	...	85 (585)	43	111	...	58Ni–33Cr–8Mo	Fittings
SB-366	N06045	...	90 (620)	46	111	45	46Ni–27Cr–23Fe–2.75Si	Fittings
SB-366	N06059	...	100 (690)	43	111	43	59Ni–23Cr–16Mo	Fittings
SB-366	N06200	...	100 (690)	43	111	43	59Ni–23Cr–16Mo–1.6Cu	Fittings
SB-366	N06210	...	100 (690)	43	111	...	60Ni–19Cr–19Mo–1.8Ta	Fittings
SB-366	N06230	...	110 (760)	43	111	43	53Ni–22Cr–14W–Co–Fe–Mo	Fittings
SB-366	N06455	...	100 (690)	43	111	43	61Ni–15Mo–16Cr	Fittings
SB-366	N06600	...	80 (550)	43	111	43	72Ni–15Cr–8Fe	Fittings
SB-366	N06625	...	110 (760)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Fittings
SB-366	N06985	...	90 (620)	45	111	45	47Ni–22Cr–20Fe–7Mo	Fittings
SB-366	N08020	...	80 (550)	45	111	45	35Ni–35Fe–20Cr–Cb	Fittings
SB-366	N08031	...	94 (650)	45	111	45	31Ni–31Fe–27Cr–7Mo	Fittings
SB-366	N08120	...	90 (620)	45	111	45	37Ni–33Fe–25Cr	Fittings
SB-366	N08330	...	70 (485)	46	111	45	35Ni–19Cr–1.25Si	Fittings
SB-366	N08367	...	95 (655)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Fittings > $\frac{3}{16}$ in. (4.8 mm)

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-366	N08367	...	100 (690)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Fittings ≤ $^3\!/_{16}$ in. (4.8 mm)
SB-366	N08800	...	75 (515)	45	111	45	33Ni–42Fe–21Cr	Fittings
SB-366	N08825	...	85 (585)	45	111	45	42Ni–21.5Cr–3Mo–2.3Cu	Fittings
SB-366	N08925	...	87 (600)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Fittings
SB-366	N10001	...	100 (690)	44	112	44	62Ni–28Mo–5Fe	Fittings
SB-366	N10003	...	100 (690)	44	112	44	70Ni–16Mo–7Cr–5Fe	Fittings
SB-366	N10242	...	105 (725)	44	112	44	62Ni–25Mo–8Cr–2Fe	Fittings
SB-366	N10276	...	100 (690)	43	111	43	54Ni–16Mo–15Cr	Fittings
SB-366	N10629	...	110 (760)	44	112	44	66Ni–28Mo–3Fe–1.3Cr–0.25Al	Fittings
SB-366	N10665	...	110 (760)	44	112	44	65Ni–28Mo–2Fe	Fittings
SB-366	N10675	...	110 (760)	44	112	44	65Ni–29.5Mo–2Fe–2Cr	Fittings
SB-366	N12160	...	90 (620)	46	...	46	37Ni–30Co–28Cr–2.7Si	Fittings
SB-366	R20033	...	109 (750)	45	111	45	33Cr–31Ni–32Fe–1.5Mo–0.6Cu–N	Fittings
SB-366	R30556	...	100 (690)	45	111	45	21Ni–30Fe–22Cr–18Co–3Mo–3W	Fittings
B 366	N08926	...	94 (650)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Fittings
SB-367	R50400	Gr. C–2	50 (345)	51	115	51	Ti	Castings
SB-367	R50550	Gr. C–3	65 (450)	52	115	52	Ti	Castings
SB-369	C96200	...	45 (310)	34	107	34	87.5Cu–10Ni–Fe–Mn	Castings
SB-381	R50250	F–1	35 (240)	51	115	51	Ti	Forgings
SB-381	R50400	F–2	50 (345)	51	115	51	Ti	Forgings
SB-381	R50400	F-2H	58 (400)	51	115	...	Ti	Forgings
SB-381	R50550	F–3	65 (450)	52	115	52	Ti	Forgings
SB-381	R52400	F–7	50 (345)	51	115	51	Ti–Pd	Forgings
SB-381	R52400	F-7H	58 (400)	51	115	...	Ti–Pd	Forgings
SB-381	R52402	F–16	50 (345)	51	115	51	Ti–Pd	Forgings
SB-381	R52402	F–16H	58 (400)	51	115	...	Ti–Pd	Forgings
SB-381	R52404	F–26	50 (345)	51	115	51	Ti–Ru	Forgings
SB-381	R52404	F–26H	58 (400)	51	115	...	Ti–Ru	Forgings
SB-381	R53400	F–12	70 (485)	52	115	52	Ti–0.3Mo–0.8Ni	Forgings
SB-381	R56320	F–9	90 (620)	53	115	53	Ti–3Al–2.5V	Forgings
SB-381	R56323	F–28	90 (620)	53	115	53	Ti–3Al–2.5V–0.1Ru	Forgings
SB-395	C10200	...	36 (250)	31	107	31	99.95Cu–P	Smls. tube
SB-395	C12000	...	36 (250)	31	107	31	99.9Cu–P	Smls. tube
SB-395	C12200	...	36 (250)	31	107	31	99.9Cu–P	Smls. tube
SB-395	C14200	...	36 (250)	31	107	31	99.4Cu–As–P	Smls. tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-395	C19200	...	38 (260)	31	107	31	99.7Cu–Fe–P	Smls. tube
SB-395	C23000	...	40 (275)	32	107	32.1	85Cu–15Zn	Smls. tube
SB-395	C44300	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06As	Smls. tube
SB-395	C44400	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06Sb	Smls. tube
SB-395	C44500	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06P	Smls. tube
SB-395	C60800	...	50 (345)	35	108	35	95Cu–5Al	Smls. tube
SB-395	C68700	...	50 (345)	32	108	32.2	78Cu–20Zn–2Al	Smls. tube
SB-395	C70600	...	40 (275)	34	107	34	90Cu–10Ni	Smls. tube
SB-395	C71000	...	45 (310)	34	107	34	80Cu–20Ni	Smls. tube
SB-395	C71500	...	52 (360)	34	107	34	70Cu–30Ni	Smls. tube
SB-407	N08120	...	90 (620)	45	111	45	37Ni–33Fe–25Cr	Smls. pipe & tube
SB-407	N08800	...	75 (515)	45	111	45	33Ni–42Fe–21Cr	Smls. pipe & tube
SB-407	N08801	...	65 (450)	45	111	45	32Ni–45Fe–20.5Cr–Ti	Smls. pipe & tube
SB-407	N08810	...	65 (450)	45	111	45	33Ni–42Fe–21Cr	Smls. pipe & tube
SB-407	N08811	...	65 (450)	45	111	45	33Ni–42Fe–21Cr–Al–Ti	Smls. pipe & tube
SB-408	N08120	...	90 (620)	45	111	45	37Ni–33Fe–25Cr	Rod & bar
SB-408	N08800	...	75 (515)	45	111	45	33Ni–42Fe–21Cr	Rod & bar
SB-408	N08810	...	65 (450)	45	111	45	33Ni–42Fe–21Cr	Rod & bar
SB-408	N08811	...	65 (450)	45	111	45	33Ni–42Fe–21Cr–Al–Ti	Rod & bar
SB-409	N08120	...	90 (620)	45	111	45	37Ni–33Fe–25Cr	Plate, sheet & strip
SB-409	N08800	...	75 (515)	45	111	45	33Ni–42Fe–21Cr	Plate, sheet & strip
SB-409	N08810	...	65 (450)	45	111	45	33Ni–42Fe–21Cr	Plate, sheet & strip
SB-409	N08811	...	65 (450)	45	111	45	33Ni–42Fe–21Cr–Al–Ti	Plate, sheet & strip
SB-423	N08825	...	75 (515)	45	111	45	42Ni–21.5Cr–3Mo–2.3Cu	Smls. pipe & tube
SB-424	N08825	...	85 (585)	45	111	45	42Ni–21.5Cr–3Mo–2.3Cu	Plate, sheet & strip
SB-425	N08825	...	85 (585)	45	111	45	42Ni–21.5Cr–3Mo–2.3Cu	Rod & bar
SB-434	N10003	...	100 (690)	44	112	44	70Ni–16Mo–7Cr–5Fe	Plate, sheet & strip
SB-434	N10242	...	105 (725)	44	112	44	62Ni–25Mo–8Cr–2Fe	Plate, sheet & strip
SB-435	N06002	...	95 (655)	43	111	43	47Ni–22Cr–9Mo–18Fe	Plate, sheet & strip
SB-435	N06230	...	110 (760)	43	111	43	53Ni–22Cr–14W–Co–Fe–Mo	Plate, sheet & strip
SB-435	N12160	...	90 (620)	46	...	46	37Ni–30Co–28Cr–2.7Si	Plate, sheet, & strip
SB-435	R30556	...	100 (690)	45	111	45	21Ni–30Fe–22Cr–18Co–3Mo–3W	Plate, sheet & strip
SB-443	N06625	2	100 (690)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Plate, sheet & strip
SB-443	N06625	1	110 (760)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Plate, sheet & strip

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)								
Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-444	N06625	1	120 (825)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Smls. pipe & tube
SB-444	N06625	2	100 (690)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Smls. pipe & tube
SB-446	N06625	1	120 (825)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Rod & bar
SB-446	N06625	2	100 (690)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Rod & bar
SB-462	N06022	...	100 (690)	43	111	44	55Ni–21Cr–13.5Mo	Forgings
SB-462	N06030	...	85 (585)	45	111	45	40Ni–29Cr–15Fe–5Mo	Forgings
SB-462	N06035	...	85 (585)	43	111	...	58Ni–33Cr–8Mo	Forgings
SB-462	N06045	...	90 (620)	46	111	45	46Ni–27Cr–23Fe–2.75Si	Forgings
SB-462	N06059	...	100 (690)	43	111	43	59Ni–23Cr–16Mo	Forgings
SB-462	N06200	...	100 (690)	43	111	43	59Ni–23Cr–16Mo–1.6Cu	Forgings
SB-462	N06686	...	100 (690)	43	111	43	58Ni–21Cr–16Mo–3.5N	Forgings
SB-462	N08020	...	80 (550)	45	111	45	35Ni–35Fe–20Cr–Cb	Forgings
SB-462	N08031	...	94 (650)	45	111	45	31Ni–33Fe–22Cr–6.5Mo–Cu–N	Forgings
SB-462	N08367	...	95 (655)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Forgings
SB-462	N10276	...	100 (690)	43	111	43	54Ni–16Mo–15Cr	Forgings
SB-462	N10629	...	110 (760)	44	112	44	66Ni–28Mo–3Fe–1.3Cr–0.25Al	Forgings
SB-462	N10665	...	110 (760)	44	112	44	65Ni–28Mo–2Fe	Forgings
SB-462	N10675	...	110 (760)	44	112	44	65Ni–29.5Mo–2Fe–2Cr	Forgings
SB-462	R20033	...	109 (750)	45	111	45	33Cr–31Ni–32Fe–1.5Mo–0.6Cu–N	Forgings
SB-463	N08020	...	80 (550)	45	111	45	35Ni–35Fe–20Cr–Cb	Plate, sheet & strip
SB-463	N08024	...	80 (550)	45	111	45	37Ni–33Fe–23Cr–4Mo	Plate, sheet & strip
SB-463	N08026	...	80 (550)	45	111	45	35Ni–30Fe–24Cr–6Mo–3Cu	Plate, sheet & strip
SB-464	N08020	...	80 (550)	45	111	45	35Ni–35Fe–20Cr–Cb	Welded pipe
SB-464	N08024	...	80 (550)	45	111	45	37Ni–33Fe–23Cr–4Mo	Welded pipe
SB-464	N08026	...	80 (550)	45	111	45	35Ni–30Fe–24Cr–6Mo–3Cu	Welded pipe
SB-466	C70600	...	38 (260)	34	107	34	90Cu–10Ni	Smls. pipe & tube
SB-466	C71000	...	45 (310)	34	107	34	80Cu–20Ni	Smls. pipe & tube
SB-466	C71500	...	52 (360)	34	107	34	70Cu–30Ni	Smls. pipe & tube
SB-467	C70600	...	38 (260)	34	107	34	90Cu–10Ni	Welded pipe > 4.5 in. (114 mm) O.D.
SB-467	C70600	...	40 (275)	34	107	34	90Cu–10Ni	Welded pipe ≤ 4.5 in. (114 mm) O.D.
SB-467	C71500	...	45 (310)	34	107	34	70Cu–30Ni	Welded pipe > 4.5 in. (114 mm) O.D.
SB-467	C71500	...	50 (345)	34	107	34	70Cu–30Ni	Welded pipe ≤ 4.5 in. (114 mm) O.D.
SB-468	N08020	...	80 (550)	45	111	45	35Ni–35Fe–20Cr–Cb	Welded tube
SB-468	N08024	...	80 (550)	45	111	45	37Ni–33Fe–23Cr–4Mo	Welded tube
SB-468	N08026	...	80 (550)	45	111	45	35Ni–30Fe–24Cr–6Mo–3Cu	Welded tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-473	N08020	...	80 (550)	45	111	45	35Ni–35Fe–20Cr–Cb	Bar
B 491	A93003	3003	14 (97)	21	104	22.1	Al–Mn–Cu	Extruded tubes
SB-493	R60702	R60702	55 (380)	61	117	61	99.2Zr	Forgings
SB-493	R60705	R60705	70 (485)	62	117	62	95.5Zr+2.5Cb	Forgings
SA-494	N26022	CX2MW	80 (550)	43	111	44	59Ni–22Cr–14Mo–4Fe–3W	Castings
SB-505	C95200	...	68 (470)	35	108	35	88Cu–9Al–3Fe	Castings
SB-511	N08330	...	70 (485)	46	111	45	35Ni–19Cr–1.25Si	Bars & shapes
SB-514	N08120	...	90 (620)	45	111	45	37Ni–33Fe–25Cr	Welded pipe
SB-514	N08800	...	75 (515)	45	111	45	33Ni–42Fe–21Cr	Welded pipe
SB-514	N08810	...	65 (450)	45	111	45	33Ni–42Fe–21Cr	Welded pipe
SB-515	N08120	...	90 (620)	45	111	45	37Ni–33Fe–25Cr	Welded tube
SB-515	N08800	...	75 (515)	45	111	45	33Ni–42Fe–21Cr	Welded tube
SB-515	N08810	...	65 (450)	45	111	45	33Ni–42Fe–21Cr	Welded tube
SB-515	N08811	...	65 (450)	45	111	45	33Ni–42Fe–21Cr–Al–Ti	Welded tube
SB-516	N06045	...	90 (620)	46	111	45	46Ni–27Cr–23Fe–2.75Si	Welded tube
SB-516	N06600	...	80 (550)	43	111	43	72Ni–15Cr–8Fe	Welded tube
SB-517	N06045	...	90 (620)	46	111	45	46Ni–27Cr–23Fe–2.75Si	Welded pipe
SB-517	N06600	...	80 (550)	43	111	43	72Ni–15Cr–8Fe	Welded pipe
SB-523	R60702	R60702	55 (380)	61	117	61	99.2Zr	Smls. & welded tube
SB-523	R60705	R60705	80 (550)	62	117	62	95.5Zr+2.5Cb	Smls. & welded tube
SB-535	N08330	...	70 (485)	46	111	45	35Ni–19Cr–1.25Si	Smls. pipe
SB-536	N08330	...	70 (485)	46	111	45	35Ni–19Cr–1.25Si	Plate, sheet & strip
SB-543	C12200	...	30 (205)	31	107	31	99.9Cu–P	Welded tube
SB-543	C19400	...	45 (310)	31	107	31	97.5Cu–P	Welded tube
SB-543	C23000	...	40 (275)	32	107	32.1	85Cu–15Zn	Welded tube
SB-543	C44300	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06As	Welded tube
SB-543	C44400	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06Sb	Welded tube
SB-543	C44500	...	45 (310)	32	107	32.2	71Cu–28Zn–1Sn–0.06P	Welded tube
SB-543	C68700	...	50 (345)	32	108	32.2	78Cu–20Zn–2Al	Welded tube
SB-543	C70400	...	38 (260)	34	107	34	95Cu–5Ni	Welded tube
SB-543	C70600	...	40 (275)	34	107	34	90Cu–10Ni	Welded tube
SB-543	C71500	...	52 (360)	34	107	34	70Cu–30Ni	Welded tube
B 547	...	Alclad 3003	13 (90)	21	104	22.1	Al–Mn–Cu	Welded tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
B 547	A93003	3003	14 (97)	21	104	22.1	Al–Mn–Cu	Welded tube
B 547	A95083	5083	40 (275)	25	105	22.4	Al–4.4Mg–Mn	Welded tube
B 547	A95454	5454	31 (215)	22	105	22.3	Al–2.7Mg–Mn	Welded tube
B 547	A96061	6061	24 (165)	23	105	23.1	Al–Mg–Si–Cu	Welded tube
SB-550	R60702	R60702	55 (380)	61	117	61	99.2Zr	Bar & wire
SB-550	R60705	R60705	80 (550)	62	117	62	95.5Zr+2.5Cb	Bar & wire
SB-551	R60702	R60702	55 (380)	61	117	61	99.2Zr	Plate, sheet & strip
SB-551	R60705	R60705	80 (550)	62	117	62	95.5Zr+2.5Cb	Plate, sheet & strip
SB-564	N04400	...	70 (485)	42	110	42	67Ni–30Cu	Forgings
SB-564	N06022	...	100 (690)	43	111	44	55Ni–21Cr–13.5Mo	Forgings
SB-564	N06035	...	85 (585)	43	111	...	58Ni–33Cr–8Mo	Forgings
SB-564	N06045	...	90 (620)	46	111	45	46Ni–27Cr–23Fe–2.75Si	Forgings
SB-564	N06059	...	100 (690)	43	111	43	59Ni–23Cr–16Mo	Forgings
SB-564	N06200	...	100 (690)	43	111	43	59Ni–23Cr–16Mo–1.6Cu	Forgings
SB-564	N06210	...	100 (690)	43	111	...	60Ni–19Cr–19Mo–1.8Ta	Forgings
SB-564	N06230	...	110 (760)	43	111	43	53Ni–22Cr–14W–Co–Fe–Mo	Forgings
SB-564	N06600	...	80 (550)	43	111	43	72Ni–15Cr–8Fe	Forgings
SB-564	N06617	...	95 (655)	43	111	46	52Ni–22Cr–13Co–9Mo	Forgings
SB-564	N06625	...	110 (760)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Forgings > 4 in.–10 in. (102 mm–254 mm), incl.
SB-564	N06686	...	100 (690)	43	111	43	58Ni–21Cr–16Mo–3.5W	Forgings
SB-564	N06625	...	120 (825)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Forgings ≤ 4 in. (102 mm)
SB-564	N06690	...	85 (585)	43	111	43	58Ni–29Cr–9Fe	Forgings
SB-564	N08031	...	94 (650)	45	111	45	31Ni–31Fe–27Cr–7Mo	Forgings
SB-564	N08120	...	90 (620)	45	111	45	37Ni–33Fe–25Cr	Forgings
SB-564	N08367	...	95 (655)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Forgings
SB-564	N08800	...	75 (515)	45	111	45	33Ni–42Fe–21Cr	Forgings
SB-564	N08810	...	65 (450)	45	111	45	33Ni–42Fe–21Cr	Forgings
SB-564	N08811	...	65 (450)	45	111	44	33Ni–42Fe–21Cr–Al–Ti	Forgings
SB-564	N08825	...	85 (585)	45	111	45	42Ni–21.5Cr–3Mo–2.3Cu	Forgings
SB-564	N10242	...	105 (725)	44	112	44	62Ni–25Mo–8Cr–2Fe	Forgings
SB-564	N10276	...	100 (690)	43	111	43	54Ni–16Mo–15Cr	Forgings
SB-564	N10629	...	110 (760)	44	112	44	66Ni–28Mo–3Fe–1.3Cr–0.25Al	Forgings
SB-564	N10665	...	110 (760)	44	112	...	65Ni–28Mo–2Fe	Forgings
SB-564	N10675	...	110 (760)	44	112	44	65Ni–29.5Mo–2Fe–2Cr	Forgings
SB-564	R20033	...	109 (750)	45	111	45	33Cr–31Ni–32Fe–1.5Mo–0.6Cu–N	Forgings
SB-564	N12160	...	90 (620)	46	...	46	37Ni–30Co–28Cr–2.7Si	Forgings

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-572	N06002	...	95 (655)	43	111	43	47Ni–22Cr–9Mo–18Fe	Rod
SB-572	N06230	...	110 (760)	43	111	43	53Ni–22Cr–14W–Co–Fe–Mo	Rod
SB-572	N12160	...	90 (620)	46	...	46	37Ni–30Co–28Cr–2.7Si	Rod
SB-572	R30556	...	100 (690)	45	111	45	21Ni–30Fe–22Cr–18Co–3Mo–3W	Rod
SB-573	N10003	...	100 (690)	44	112	44	70Ni–16Mo–7Cr–5Fe	Rod
SB-573	N10242	...	105 (725)	44	112	44	62Ni–25Mo–8Cr–2Fe	Rod
SB-574	N06022	...	100 (690)	43	111	44	55Ni–21Cr–13.5Mo	Rod
SB-574	N06035	...	85 (585)	43	111	...	58Ni–33Cr–8Mo	Rod
SB-574	N06059	...	100 (690)	43	111	43	59Ni–23Cr–16Mo	Rod
SB-574	N06200	...	100 (690)	43	111	43	59Ni–23Cr–16Mo–1.6Cu	Rod
SB-574	N06210	...	100 (690)	43	111	...	60Ni–19Cr–19Mo–1.8Ta	Rod
SB-574	N06455	...	100 (690)	43	111	43	61Ni–16Mo–16Cr	Rod
SB-574	N06686	...	100 (690)	43	111	43	58Ni–21Cr–16Mo–3.5W	Rod
SB-574	N10276	...	100 (690)	43	111	43	54Ni–16Mo–15Cr	Rod
SB-575	N06022	...	100 (690)	43	111	44	55Ni–21Cr–13.5Mo	Plate, sheet & strip
SB-575	N06035	...	85 (585)	43	111	...	58Ni–33Cr–8Mo	Plate, sheet & strip
SB-575	N06059	...	100 (690)	43	111	43	59Ni–23Cr–16Mo	Plate, sheet & strip
SB-575	N06200	...	100 (690)	43	111	43	59Ni–23Cr–16Mo–1.6Cu	Plate, sheet & strip
SB-575	N06210	...	100 (690)	43	111	...	60Ni–19Cr–19Mo–1.8Ta	Plate, sheet & strip
SB-575	N06455	...	100 (690)	43	111	43	61Ni–16Mo–16Cr	Plate, sheet & strip
SB-575	N06686	...	100 (690)	43	111	43	58Ni–21Cr–16Mo–3.5W	Plate, sheet & strip
SB-575	N10276	...	100 (690)	43	111	43	54Ni–16Mo–15Cr	Plate, sheet & strip
SB-581	N06007	...	85 (585)	45	111	43	47Ni–22Cr–19Fe–6Mo	Rod > 0.75 in.–3.5 in. (19 mm–89 mm), incl.
SB-581	N06007	...	90 (620)	45	111	43	47Ni–22Cr–19Fe–6Mo	Rod, 0.3125 in.–0.75 in. (8 mm–19 mm), incl.
SB-581	N06030	...	85 (585)	45	111	45	40Ni–29Cr–15Fe–5Mo	Rod
SB-581	N06975	...	85 (585)	45	111	45	49Ni–25Cr–18Fe–6Mo	Rod
SB-581	N06985	...	85 (585)	45	111	45	47Ni–22Cr–20Fe–7Mo	Rod > 0.75 in.–3.5 in. (19 mm–89 mm), incl.
SB-581	N06985	...	90 (620)	45	111	45	47Ni–22Cr–20Fe–7Mo	Rod, 0.3125 in.–0.75 in. (8 mm–19 mm), incl.
SB-581	N08031	...	94 (650)	45	111	45	31Ni–31Fe–27Cr–7Mo	Rod
SB-582	N06007	...	85 (585)	45	111	43	47Ni–22Cr–19Fe–6Mo	Plate, sheet & strip > 0.75 in.–2.5 in. (19 mm–64 mm), incl.
SB-582	N06007	...	90 (620)	45	111	43	47Ni–22Cr–19Fe–6Mo	Plate, sheet & strip ≤ 0.75 in. (19 mm)
SB-582	N06030	...	85 (585)	45	111	45	40Ni–29Cr–15Fe–5Mo	Plate, sheet & strip
SB-582	N06975	...	85 (585)	45	111	45	49Ni–25Cr–18Fe–6Mo	Plate, sheet & strip
SB-582	N06985	...	85 (585)	45	111	45	47Ni–22Cr–20Fe–7Mo	Plate, sheet & strip > 0.75 in.–2.5 in. (19 mm–64 mm), incl.
SB-582	N06985	...	90 (620)	45	111	45	47Ni–22Cr–20Fe–7Mo	Plate, sheet & strip ≤ 0.75 in. (19 mm)

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-599	N08700	...	80 (550)	45	111	8.2	25Ni–47Fe–21Cr–5Mo	Plate, sheet & strip
SB-619	N06002	...	100 (690)	43	111	43	47Ni–22Cr–9Mo–18Fe	Welded pipe
SB-619	N06007	...	90 (620)	45	111	43	47Ni–22Cr–19Fe–6Mo	Welded pipe
SB-619	N06022	...	100 (690)	43	111	44	55Ni–21Cr–13.5Mo	Welded pipe
SB-619	N06030	...	85 (585)	45	111	45	40Ni–29Cr–15Fe–5Mo	Welded pipe
SB-619	N06035	...	85 (585)	43	111	...	58Ni–33Cr–8Mo	Welded pipe
SB-619	N06059	...	100 (690)	43	111	43	59Ni–23Cr–16Mo	Welded pipe
SB-619	N06200	...	100 (690)	43	111	43	59Ni–23Cr–16Mo–1.6Cu	Welded pipe
SB-619	N06210	...	100 (690)	43	111	...	60Ni–19Cr–19Mo–1.8Ta	Welded pipe
SB-619	N06230	...	110 (760)	43	111	43	53Ni–22Cr–14W–Co–Fe–Mo	Welded pipe
SB-619	N06455	...	100 (690)	43	111	43	61Ni–16Mo–16Cr	Welded pipe
SB-619	N06686	...	100 (690)	43	111	43	58Ni–21Cr–16Mo–3.5W	Welded pipe
SB-619	N06975	...	85 (585)	45	111	45	49Ni–25Cr–18Fe–6Mo	Welded pipe
SB-619	N06985	...	90 (620)	45	111	45	47Ni–22Cr–20Fe–7Mo	Welded pipe
SB-619	N08031	...	94 (650)	45	111	45	31Ni–31Fe–27Cr–7Mo	Welded pipe
SB-619	N08320	...	75 (515)	45	111	8.2	26Ni–22Cr–5Mo–Ti	Welded pipe
SB-619	N10001	...	100 (690)	44	112	44	62Ni–28Mo–5Fe	Welded pipe
SB-619	N10242	...	105 (725)	44	112	44	62Ni–25Mo–8Cr–2Fe	Welded pipe
SB-619	N10276	...	100 (690)	43	111	43	54Ni–16Mo–15Cr	Welded pipe
SB-619	N10629	...	110 (760)	44	112	44	66Ni–28Mo–3Fe–1.3Cr–0.25Al	Welded pipe
SB-619	N10665	...	110 (760)	44	112	44	65Ni–28Mo–2Fe	Welded pipe
SB-619	N10675	...	110 (760)	44	112	44	65Ni–29.5Mo–2Fe–2Cr	Welded pipe
SB-619	N12160	...	90 (620)	46	...	46	37Ni–30Co–28Cr–2.7Si	Welded pipe
SB-619	R20033	...	109 (750)	45	111	45	33Cr–31Ni–32Fe–1.5Mo–0.6Cu–N	Welded pipe
SB-619	R30556	...	100 (690)	45	111	45	21Ni–30Fe–22Cr–18Co–3Mo–3W	Welded pipe
SB-620	N08320	...	75 (515)	45	111	8.2	26Ni–22Cr–5Mo–Ti	Plate, sheet & strip
SB-621	N08320	...	75 (515)	45	111	8.2	26Ni–22Cr–5Mo–Ti	Rod
SB-622	N06002	...	100 (690)	43	111	43	47Ni–22Cr–9Mo–18Fe	Smls. pipe & tube
SB-622	N06007	...	90 (620)	45	111	43	47Ni–22Cr–19Fe–6Mo	Smls. pipe & tube
SB-622	N06022	...	100 (690)	43	111	44	55Ni–21Cr–13.5Mo	Smls. pipe & tube
SB-622	N06030	...	85 (585)	45	111	45	40Ni–29Cr–15Fe–5Mo	Smls. pipe & tube
SB-622	N06035	...	85 (585)	43	111	...	58Ni–33Cr–8Mo	Smls. pipe & tube
SB-622	N06059	...	100 (690)	43	111	43	59Ni–23Cr–16Mo	Smls. pipe & tube
SB-622	N06200	...	100 (690)	43	111	43	59Ni–23Cr–16Mo–1.6Cu	Smls. pipe & tube
SB-622	N06210	...	100 (690)	43	111	...	60Ni–19Cr–19Mo–1.8Ta	Smls. pipe & tube
SB-622	N06230	...	110 (760)	43	111	43	53Ni–22Cr–14W–Co–Fe–Mo	Smls. pipe & tube

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QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-622	N06455	...	100 (690)	43	111	43	61Ni–16Mo–16Cr	Smls. pipe & tube
SB-622	N06686	...	100 (690)	43	111	43	58Ni–21Cr–16Mo–3.5W	Smls. pipe & tube
SB-622	N06975	...	85 (585)	45	111	45	49Ni–25Cr–18Fe–6Mo	Smls. pipe & tube
SB-622	N06985	...	90 (620)	45	111	45	47Ni–22Cr–20Fe–7Mo	Smls. pipe & tube
SB-622	N08031	...	94 (650)	45	111	45	31Ni–31Fe–27Cr–7Mo	Smls. pipe & tube
SB-622	N08320	...	75 (515)	45	111	8.2	26Ni–22Cr–5Mo–Ti	Smls. pipe & tube
SB-622	N10001	...	100 (690)	44	112	44	62Ni–28Mo–5Fe	Smls. pipe & tube
SB-622	N10242	...	105 (725)	44	112	44	62Ni–25Mo–8Cr–2Fe	Smls. pipe & tube
SB-622	N10276	...	100 (690)	43	111	43	54Ni–16Mo–15Cr	Smls. pipe & tube
SB-622	N10629	...	110 (760)	44	112	44	66Ni–28Mo–3Fe–1.3Cr–0.25Al	Smls. pipe & tube
SB-622	N10665	...	110 (760)	44	112	44	65Ni–28Mo–2Fe	Smls. pipe & tube
SB-622	R20033	...	109 (750)	45	111	45	33Cr–31Ni–32Fe–1.5Mo–0.6Cu–N	Smls. pipe & tube
SB-622	R30556	...	100 (690)	45	111	45	21Ni–30Fe–22Cr–18Co–3Mo–3W	Smls. pipe & tube
SB-622	N10675	...	110 (760)	44	112	44	65Ni–29.5Mo–2Fe–2Cr	Smls. pipe & tube
SB-622	N12160	...	90 (620)	46	...	46	37Ni–30Co–28Cr–2.7Si	Smls. pipe & tube
B 625	N08926	...	94 (650)	45	111	8.2	25Ni–20Cr–6Mo–Co–N	Plate, sheet & strip
SB-625	N08031	...	94 (650)	45	111	45	31Ni–31Fe–27Cr–7Mo	Plate, sheet & strip
SB-625	N08904	...	71 (490)	45	111	8.2	44Fe–25Ni–21Cr–Mo	Plate, sheet & strip
SB-625	N08925	...	87 (600)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Plate, sheet & strip
SB-625	R20033	...	109 (750)	45	111	45	33Cr–31Ni–32Fe–1.5Mo–0.6Cu–N	Plate, sheet & strip
SB-626	N06002	...	100 (690)	43	111	43	47Ni–22Cr–9Mo–18Fe	Welded tube
SB-626	N06007	...	90 (620)	45	111	43	47Ni–22Cr–19Fe–6Mo	Welded tube
SB-626	N06022	...	100 (690)	43	111	44	55Ni–21Cr–13.5Mo	Welded tube
SB-626	N06030	...	85 (585)	45	111	45	40Ni–29Cr–15Fe–5Mo	Welded tube
SB-626	N06035	...	85 (585)	43	111	...	58Ni–33Cr–8Mo	Welded tube
SB-626	N06059	...	100 (690)	43	111	43	59Ni–23Cr–16Mo	Welded tube
SB-626	N06200	...	100 (690)	43	111	43	59Ni–23Cr–16Mo–1.6Cu	Welded tube
SB-626	N06210	...	100 (690)	43	111	...	60Ni–19Cr–19Mo–1.8Ta	Welded tube
SB-626	N06230	...	110 (760)	43	111	43	53Ni–22Cr–14W–Co–Fe–Mo	Welded tube
SB-626	N06455	...	100 (690)	43	111	43	61Ni–16Mo–16Cr	Welded tube
SB-626	N06686	...	100 (690)	43	111	43	58Ni–21Cr–16Mo–3.5W	Welded tube
SB-626	N06975	...	85 (585)	45	111	45	49Ni–25Cr–18Fe–6Mo	Welded tube
SB-626	N06985	...	90 (620)	45	111	45	47Ni–22Cr–20Fe–7Mo	Welded tube
SB-626	N08031	...	94 (650)	45	111	45	31Ni–31Fe–27Cr–7Mo	Welded tube
SB-626	N08320	...	75 (515)	45	111	8.2	26Ni–22Cr–5Mo–Ti	Welded tube
SB-626	N10001	...	100 (690)	44	112	44	62Ni–28Mo–5Fe	Welded tube

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-626	N10242	...	105 (725)	44	112	44	62Ni–25Mo–8Cr–2Fe	Welded tube
SB-626	N10276	...	100 (690)	43	111	43	54Ni–16Mo–15Cr	Welded tube
SB-626	N10629	...	110 (760)	44	112	44	66Ni–28Mo–3Fe–1.3Cr–0.25Al	Welded tube
SB-626	N10665	...	110 (760)	44	112	44	65Ni–28Mo–2Fe	Welded tube
SB-626	R20033	...	109 (750)	45	111	45	33Cr–31Ni–32Fe–1.5Mo–0.6Cu–N	Welded tube
SB-626	R30556	...	100 (690)	45	111	45	21Ni–30Fe–22Cr–18Co–3Mo–3W	Welded tube
SB-626	N10675	...	110 (760)	44	112	44	65Ni–29.5Mo–2Fe–2Cr	Welded tube
SB-626	N12160	...	90 (620)	46	...	46	37Ni–30Co–28Cr–2.7Si	Welded tube
B 649	N08926	...	94 (650)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Bar & wire
SB-649	N08904	...	71 (490)	45	111	8.2	44Fe–25Ni–21Cr–Mo	Bar & wire
SB-649	N08925	...	87 (600)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Bar & wire
SB-649	R20033	...	109 (750)	45	111	45	33Cr–31Ni–32Fe–1.5Mo–0.6Cu–N	Bar & wire
B-653	R60702	R60702	55 (380)	61	117	...	99.2Zr	Seamless & welded fittings
SB-658	R60702	R60702	55 (380)	61	117	61	99.2Zr	Smls. & welded pipe
SB-658	R60705	R60705	80 (550)	62	117	62	95.5Zr+2.5Cb	Smls. & welded pipe
SB-668	N08028	...	73 (505)	45	111	45	31Ni–31Fe–29Cr–Mo	Smls. tube
SB-672	N08700	...	80 (550)	45	111	8.2	25Ni–47Fe–21Cr–5Mo	Bar & wire
B 673	N08926	...	94 (650)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Welded pipe
SB-673	N08904	...	71 (490)	45	111	8.2	44Fe–25Ni–21Cr–Mo	Welded pipe
SB-673	N08925	...	87 (600)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Welded pipe
SB-674	N08904	...	71 (490)	45	111	8.2	44Fe–25Ni–21Cr–Mo	Welded tube
SB-674	N08925	...	87 (600)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Welded tube
B 674	N08926	...	94 (650)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Welded tube
SB-675	N08367	...	95 (655)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Welded pipe > $^3/_{16}$ in. (4.8 mm)
SB-675	N08367	...	100 (690)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Welded pipe ≤ $^3/_{16}$ in. (4.8 mm)
SB-676	N08367	...	95 (655)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Welded tube > $^3/_{16}$ in. (4.8 mm)
SB-676	N08367	...	100 (690)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Welded tube ≤ $^3/_{16}$ in. (4.8 mm)
B 677	N08926	...	94 (650)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Smls. pipe & tube
SB-677	N08904	...	71 (490)	45	111	8.2	44Fe–25Ni–21Cr–Mo	Smls. pipe & tube
SB-677	N08925	...	87 (600)	45	111	8.2	25Ni–20Cr–6Mo–Cu–N	Smls. pipe & tube
SB-688	N08367	...	95 (655)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Plate, sheet & strip > $^3/_{16}$ in. (4.8 mm)
SB-688	N08367	...	100 (690)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Plate, sheet & strip ≤ $^3/_{16}$ in. (4.8 mm)

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-690	N08367	...	95 (655)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Smls. pipe & tube > $^3/_{16}$ in. (4.8 mm)
SB-690	N08367	...	100 (690)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Smls. pipe & tube ≤ $^3/_{16}$ in. (4.8 mm)
SB-691	N08367	...	95 (655)	45	111	8.2	46Fe–24Ni–21Cr–6Mo–Cu–N	Rod, bar & wire
SB-704	N06625	...	120 (825)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Welded tube
SB-704	N08825	...	85 (585)	45	111	45	42Ni–21.5Cr–3Mo–2.3Cu	Welded tube
SB-705	N06625	...	120 (825)	43	111	43	60Ni–22Cr–9Mo–3.5Cb	Welded pipe
SB-705	N08825	...	85 (585)	45	111	45	42Ni–21.5Cr–3Mo–2.3Cu	Welded pipe
SB-709	N08028	...	73 (505)	45	111	45	31Ni–31Fe–29Cr–Mo	Plate, sheet & strip
SB-710	N08330	...	70 (485)	46	111	45	35Ni–19Cr–1.25Si	Welded pipe
SB-729	N08020	...	80 (550)	45	111	45	35Ni–35Fe–20Cr–Cb	Smls. pipe & tube
B 725	N02200	...	55 (380)	41	110	41	99.0Ni	Welded pipe
SB-815	R31233	...	120 (825)	49	...	...	Co–26Cr–9Ni–5Mo–3Fe–2W	Rod
SB-818	R31233	...	120 (825)	49	...	...	Co–26Cr–9Ni–5Mo–3Fe–2W	Plate, sheet & strip
B 819	C12200	C12200	30 (205)	...	107	NA	99.9Cu–P	Wrought pipe
SB-861	R50250	1	35 (240)	51	115	51	Ti	Smls. pipe
SB-861	R50400	2	50 (345)	51	115	51	Ti	Smls. pipe
SB-861	R50400	2H	58 (400)	51	115	...	Ti	Smls. pipe
SB-861	R50550	3	65 (450)	52	115	52	Ti	Smls. pipe
SB-861	R52400	7	50 (345)	51	115	51	Ti–Pd	Smls. pipe
SB-861	R52400	7H	58 (400)	51	115	...	Ti–Pd	Smls. pipe
SB-861	R52402	16	50 (345)	51	115	...	Ti–Pd	Smls. pipe
SB-861	R52402	16H	58 (400)	51	115	...	Ti–Pd	Smls. pipe
SB-861	R52404	26	50 (345)	51	115	51	Ti–Ru	Smls. pipe
SB-861	R52404	26H	58 (400)	51	115	...	Ti–Ru	Smls. pipe
SB-861	R53400	12	70 (485)	52	115	52	Ti–0.3Mo–0.8Ni	Smls. pipe
SB-861	R56320	9	90 (620)	53	115	53	Ti–3Al–2.5V	Smls. pipe
SB-861	R56323	28	90 (620)	53	115	53	Ti–3Al–2.5V–0.1Ru	Smls. pipe
SB-862	R50250	1	35 (240)	51	115	51	Ti	Welded pipe
SB-862	R50400	2	50 (345)	51	115	51	Ti	Welded pipe
SB-862	R50400	2H	58 (400)	51	115	...	Ti	Welded pipe
SB-862	R50550	3	65 (450)	52	115	52	Ti	Welded pipe
SB-862	R52400	7	50 (345)	51	115	51	Ti–Pd	Welded pipe
SB-862	R52400	7H	58 (400)	51	115	...	Ti–Pd	Welded pipe

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Nonferrous (CONT'D)

Spec No.	UNS No.	Alloy, Type, or Grade	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SB-862	R52402	16	50 (345)	51	115	...	Ti–Pd	Welded pipe
SB-862	R52402	16H	58 (400)	51	115	...	Ti–Pd	Welded pipe
SB-862	R52404	26	50 (345)	51	115	51	Ti–Ru	Welded pipe
SB-862	R52404	26H	58 (400)	51	115	...	Ti–Ru	Welded pipe
SB-862	R53400	12	70 (485)	52	115	52	Ti–0.3Mo–0.8Ni	Welded pipe
SB-862	R56320	9	90 (620)	53	115	53	Ti–3Al–2.5V	Welded pipe
SB-862	R56323	28	90 (620)	53	115	53	Ti–3Al–2.5V–0.1Ru	Welded pipe
SB-928	A95083	5083	39 (270)	25	105	22.4	Al–4.4Mg–Mn	Plate & sheet > 1.5 in.–3 in. (38 mm–76 mm), incl.
SB-928	A95086	5086	35 (240)	25	105	22.4	Al–4.0Mg–Mn	Plate & sheet > 0.05 in.–2 in. (1.3 mm–51 mm), incl.
SB-928	A95456	5456	41 (285)	25	105	22.4	Al–5.1Mg–Mn	Plate & sheet > 1.5 in.–3 in. (38 mm–76 mm), incl.
SB-956	C70600	...	40 (275)	34	107	...	90Cu–10Ni	Finned welded tube
SB-956	C71500	...	52 (360)	340	107	...	70Cu–30Ni	Finned welded tube
SB/EN 1706	...	EN AC 43000	21.8 (150)	26	104	...	Al–10Si–Mg	Casting
B 16.18	C83600	...	40 (275)	...	107	NA	5Sn–5Zn–5Pb	Cast fittings
B 16.18	C83800	...	40 (275)	...	107	NA	4Sn–6.5Zn–6Pb	Cast fittings
B 16.18	C84400	...	40 (275)	...	107	NA	2.5Sn–8.5Zn–7Pb	Cast fittings
B 16.22	C10200	...	30 (205)	...	107	NA	99.95Cu–P	Wrought pipe fittings
B 16.22	C12000	...	30 (205)	...	107	NA	99.9Cu–P	Wrought pipe fittings
B 16.22	C12200	...	30 (205)	...	107	NA	99.9Cu–P	Wrought pipe fittings
B 16.22	C23000	...	30 (205)	...	107	NA	85Cu–15Zn	Wrought pipe fittings
B 16.50	C10200	...	30 (205)	...	107	...	99.95Cu–P	Wrought pipe fittings
B 16.50	C12000	...	30 (205)	...	107	...	99.9Cu–P	Wrought pipe fittings
B 16.50	C12200	...	30 (205)	...	107	...	99.9Cu–P	Wrought pipe fittings
B 16.50	C23000	...	30 (205)	...	107	...	85Cu–15Zn	Wrought pipe fittings

QW-423 Alternate Base Materials for Welder Qualification

QW-423.1 Base metal used for welder qualification may be substituted for the metal specified in the WPS in accordance with the following table. When a base metal shown in the left column is used for welder qualification, the welder is qualified to weld all combinations of base metals shown in the right column, including unassigned metals of similar chemical composition to these metals.

Base Metals for Welder Qualification	Qualified Production Base Metals
P-No. 1 through P-No. 15F, P-No. 34, and P-No. 41 through P-No. 49	P-No. 1 through P-No. 15F, P-No. 34, and P-No. 41 through P-No. 49
P-No. 21 through P-No. 26	P-No. 21 through P-No. 26
P-No. 51 through P-No. 53 or P-No. 61 and P-No. 62	P-No. 51 through P-No. 53 and P-No. 61 and P-No. 62

QW-423.2 Metals used for welder qualification conforming to national or international standards or specifications may be considered as having the same P-Number as an assigned metal provided it meets the mechanical and chemical requirements of the assigned metal. The base metal specification and corresponding P-Number shall be recorded on the qualification record.

QW-424 Base Metals Used for Procedure Qualification

QW-424.1 Base metals are assigned P-Numbers in table QW/QB-422; metals that do not appear in table QW/QB-422 are considered to be unassigned metals except as otherwise defined for base metals having the same UNS numbers. Unassigned metals shall be identified in the WPS and on the PQR by specification, type and grade, or by chemical analysis and mechanical properties. The minimum tensile strength shall be defined by the organization that specified the unassigned metal if the tensile strength of that metal is not defined by the material specification.

Base Metal(s) Used for Procedure Qualification Coupon	Base Metals Qualified
One metal from a P-Number to any metal from the same P-Number	Any metals assigned that P-Number
One metal from P-No. 15E to any metal from P-No. 15E	Any P-No. 15E or 5B metal to any metal assigned P-No. 15E or 5B
One metal from a P-Number to any metal from any other P-Number	Any metal assigned the first P-Number to any metal assigned the second P-Number
One metal from P-No. 15E to any metal from any other P-Number	Any P-No. 15E or 5B metal to any metal assigned the second P-Number
One metal from P-No. 3 to any metal from P-No. 3	Any P-No. 3 metal to any metal assigned P-No. 3 or 1
One metal from P-No. 4 to any metal from P-No. 4	Any P-No. 4 metal to any metal assigned P-No. 4, 3, or 1
One metal from P-No. 5A to any metal from P-No. 5A	Any P-No. 5A metal to any metal assigned P-No. 5A, 4, 3, or 1
One metal from P-No. 5A to a metal from P-No. 4, or P-No. 3, or P-No. 1	Any P-No. 5A metal to any metal assigned to P-No. 4, 3, or 1
One metal from P-No. 4 to a metal from P-No. 3 or P-No. 1	Any P-No. 4 metal to any metal assigned to P-No. 3 or 1
Any unassigned metal to the same unassigned metal	The unassigned metal to itself
Any unassigned metal to any P-Number metal	The unassigned metal to any metal assigned to the same P-Number as the qualified metal
Any unassigned metal to any metal from P-No. 15E	The unassigned metal to any metal assigned P-No. 15E or 5B
Any unassigned metal to any other unassigned metal	The first unassigned metal to the second unassigned metal

QW-430 F-NUMBERS

QW-431 General

The following F-Number grouping of electrodes and welding rods in table QW-432 is based essentially on their usability characteristics, which fundamentally determine the ability of welders to make satisfactory welds with a given filler metal. This grouping is made to reduce the number of welding procedure and performance qualifications, where this can logically be done. The grouping does not imply that base metals or filler metals within a group may be indiscriminately substituted for a metal that was used in the qualification test without consideration of the compatibility of the base and filler metals from the standpoint of metallurgical properties, postweld heat treatment design and service requirements, and mechanical properties.

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Steel and Steel Alloys	
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...
1	SFA-5.1	EXX27	...
1	SFA-5.1	EXX28	...
1	SFA-5.4	EXXX(X)-26	...
1	SFA-5.5	EXX20-X	...
1	SFA-5.5	EXX27-X	...
2	SFA-5.1	EXX12	...
2	SFA-5.1	EXX13	...
2	SFA-5.1	EXX14	...
2	SFA-5.1	EXX19	...
2	SFA-5.5	E(X)XX13-X	...
3	SFA-5.1	EXX10	...
3	SFA-5.1	EXX11	...
3	SFA-5.5	E(X)XX10-X	...
3	SFA-5.5	E(X)XX11-X	...
4	SFA-5.1	EXX15	...
4	SFA-5.1	EXX16	...
4	SFA-5.1	EXX18	...
4	SFA-5.1	EXX18M	...
4	SFA-5.1	EXX48	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	...
4	SFA-5.5	E(X)XX15-X	...
4	SFA-5.5	E(X)XX16-X	...
4	SFA-5.5	E(X)XX18-X	...
4	SFA-5.5	E(X)XX18M	...
4	SFA-5.5	E(X)XX18M1	...
4	SFA-5.5	E(X)XX45	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	...
6	SFA-5.2	All classifications	...
6	SFA-5.9	All classifications	...
6	SFA-5.17	All classifications	...
6	SFA-5.18	All classifications	...
6	SFA-5.20	All classifications	...
6	SFA-5.22	All classifications	...
6	SFA-5.23	All classifications	...
6	SFA-5.25	All classifications	...
6	SFA-5.26	All classifications	...
6	SFA-5.28	All classifications	...
6	SFA-5.29	All classifications	...
6	SFA-5.30	INMs-X	...
6	SFA-5.30	IN5XX	...
6	SFA-5.30	IN3XX(X)	...

QW-432
F-NUMBERS (CONT'D)
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Aluminum and Aluminum Alloys	
21	SFA-5.3	E1100	A91100
21	SFA-5.3	E3003	A93003
21	SFA-5.10	ER1100	A91100
21	SFA-5.10	ER1188	A91188
21	SFA-5.10	R1100	A91100
21	SFA-5.10	R1188	A91188
22	SFA-5.10	ER5183	A95183
22	SFA-5.10	ER5356	A95356
22	SFA-5.10	ER5554	A95554
22	SFA-5.10	ER5556	A95556
22	SFA-5.10	ER5654	A95654
22	SFA-5.10	R5183	A95183
22	SFA-5.10	R5356	A95356
22	SFA-5.10	R5554	A95554
22	SFA-5.10	R5556	A95556
22	SFA-5.10	R5654	A95654
23	SFA-5.3	E4043	A94043
23	SFA-5.10	ER4009	A94009
23	SFA-5.10	ER4010	A94010
23	SFA-5.10	ER4043	A94043
23	SFA-5.10	ER4047	A94047
23	SFA-5.10	ER4145	A94145
23	SFA-5.10	ER4643	A94643
23	SFA-5.10	R4009	A94009
23	SFA-5.10	R4010	A94010
23	SFA-5.10	R4011	A94011
23	SFA-5.10	R4043	A94043
23	SFA-5.10	R4047	A94047
23	SFA-5.10	R4145	A94145
23	SFA-5.10	R4643	A94643
24	SFA-5.10	R-A356.0	A13560
24	SFA-5.10	R-A357.0	A13570
24	SFA-5.10	R-C355.0	A33550
24	SFA-5.10	R206.0	A02060
24	SFA-5.10	R357.0	A03570
25	SFA-5.10	ER2319	A92319
25	SFA-5.10	R2319	A92319
		Copper and Copper Alloys	
31	SFA-5.6	ECu	W60189
31	SFA-5.7	ERCu	C18980
32	SFA-5.6	ECuSi	W60656
32	SFA-5.7	ERCuSi-A	C65600
33	SFA-5.6	ECuSn-A	W60518
33	SFA-5.6	ECuSn-C	W60521
33	SFA-5.7	ERCuSn-A	WC51800
33	SFA-5.7	ERCuSn-C	C52100
34	SFA-5.6	ECuNi	W60715
34	SFA-5.7	ERCuNi	C71580
34	SFA-5.30	IN67	C71581
35	SFA-5.8	RBCuZn-A	C47000

QW-432
F-NUMBERS (CONT'D)
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Copper and Copper Alloys (CONT'D)	
35	SFA-5.8	RBCuZn-B	C68000
35	SFA-5.8	RBCuZn-C	C68100
35	SFA-5.8	RBCuZn-D	C77300
36	SFA-5.6	ECuAl-A2	W60614
36	SFA-5.6	ECuAl-B	W60619
36	SFA-5.7	ERCuAl-A1	C61000
36	SFA-5.7	ERCuAl-A2	C61800
36	SFA-5.7	ERCuAl-A3	C62400
37	SFA-5.6	ECuMnNiAl	C60633
37	SFA-5.6	ECuNiAl	C60632
37	SFA-5.7	ERCuMnNiAl	C63380
37	SFA-5.7	ERCuNiAl	C63280
		Nickel and Nickel Alloys	
41	SFA-5.11	ENi-1	W82141
41	SFA-5.14	ERNi-1	N02061
41	SFA-5.30	IN61	N02061
42	SFA-5.11	ENiCu-7	W84190
42	SFA-5.14	ERNiCu-7	N04060
42	SFA-5.14	ERNiCu-8	N05504
42	SFA-5.30	IN60	N04060
43	SFA-5.11	ENiCr-4	W86172
43	SFA-5.11	ENiCrCoMo-1	W86117
43	SFA-5.11	ENiCrFe-1	W86132
43	SFA-5.11	ENiCrFe-2	W86133
43	SFA-5.11	ENiCrFe-3	W86182
43	SFA-5.11	ENiCrFe-4	W86134
43	SFA-5.11	ENiCrFe-7	W86152
43	SFA-5.11	ENiCrFe-9	W86094
43	SFA-5.11	ENiCrFe-10	W86095
43	SFA-5.11	ENiCrFe-12	W86025
43	SFA-5.11	ENiCrMo-2	W86002
43	SFA-5.11	ENiCrMo-3	W86112
43	SFA-5.11	ENiCrMo-4	W80276
43	SFA-5.11	ENiCrMo-5	W80002
43	SFA-5.11	ENiCrMo-6	W86620
43	SFA-5.11	ENiCrMo-7	W86455
43	SFA-5.11	ENiCrMo-10	W86022
43	SFA-5.11	ENiCrMo-12	W86032
43	SFA-5.11	ENiCrMo-13	W86059
43	SFA-5.11	ENiCrMo-14	W86026
43	SFA-5.11	ENiCrMo-17	W86200
43	SFA-5.11	ENiCrMo-18	W86650
43	SFA-5.11	ENiCrMo-19	W86058
43	SFA-5.11	ENiCrWMo-1	W86231
43	SFA-5.14	ERNiCr-3	N06082
43	SFA-5.14	ERNiCr-4	N06072
43	SFA-5.14	ERNiCr-6	N06076
43	SFA-5.14	ERNiCrCoMo-1	N06617
43	SFA-5.14	ERNiCrFe-5	N06062

QW-432
F-NUMBERS (CONT'D)
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Nickel and Nickel Alloys (CONT'D)	
43	SFA-5.14	ERNiCrFe-6	N07092
43	SFA-5.14	ERNiCrFe-7	N06052
43	SFA-5.14	ERNiCrFe-7A	N06054
43	SFA-5.14	ERNiCrFe-8	N07069
43	SFA-5.14	ERNiCrFe-11	N06601
43	SFA-5.14	ERNiCrFe-12	N06025
43	SFA-5.14	ERNiCrFeAl-1	N06693
43	SFA-5.14	ERNiCrMo-2	N06002
43	SFA-5.14	ERNiCrMo-3	N06625
43	SFA-5.14	ERNiCrMo-4	N10276
43	SFA-5.14	ERNiCrMo-7	N06455
43	SFA-5.14	ERNiCrMo-10	N06022
43	SFA-5.14	ERNiCrMo-13	N06059
43	SFA-5.14	ERNiCrMo-14	N06686
43	SFA-5.14	ERNiCrMo-16	N06057
43	SFA-5.14	ERNiCrMo-17	N06200
43	SFA-5.14	ERNiCrMo-18	N06650
43	SFA-5.14	ERNiCrMo-19	N07058
43	SFA-5.14	ERNiCrMo-20	N06660
43	SFA-5.14	ERNiCrMo-21	N06205
43	SFA-5.14	ERNiCrWMo-1	N06231
43	SFA-5.30	IN52	N06052
43	SFA-5.30	IN62	N06062
43	SFA-5.30	IN6A	N07092
43	SFA-5.30	IN82	N06082
43	SFA-5.34	All classifications	. . .
44	SFA-5.11	ENiMo-1	W80001
44	SFA-5.11	ENiMo-3	W80004
44	SFA-5.11	ENiMo-7	W80665
44	SFA-5.11	ENiMo-8	W80008
44	SFA-5.11	ENiMo-9	W80009
44	SFA-5.11	ENiMo-10	W80675
44	SFA-5.11	ENiMo-11	W80675
44	SFA-5.14	ERNiMo-1	N10001
44	SFA-5.14	ERNiMo-2	N10003
44	SFA-5.14	ERNiMo-3	N10004
44	SFA-5.14	ERNiMo-7	N10665
44	SFA-5.14	ERNiMo-8	N10008
44	SFA-5.14	ERNiMo-9	N10009
44	SFA-5.14	ERNiMo-10	N10675
44	SFA-5.14	ERNiMo-11	N10629
44	SFA-5.14	ERNiMo-12	N10242
45	SFA-5.11	ENiCrMo-1	W86007
45	SFA-5.11	ENiCrMo-9	W86985
45	SFA-5.11	ENiCrMo-11	W86030
45	SFA-5.14	ERNiCrMo-1	N06007
45	SFA-5.14	ERNiCrMo-8	N06975
45	SFA-5.14	ERNiCrMo-9	N06985
45	SFA-5.14	ERNiCrMo-11	N06030
45	SFA-5.14	ERNiFeCr-1	N08065
46	SFA-5.11	ENiCrFeSi-1	W86045
46	SFA-5.14	ERNiCrFeSi-1	N06045
46	SFA-5.14	ERNiCoCrSi-1	N12160

QW-432
F-NUMBERS (CONT'D)
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Titanium and Titanium Alloys	
51	SFA-5.16	ERTi-1	R50100
51	SFA-5.16	ERTi-11	R52251
51	SFA-5.16	ERTi-13	R53423
51	SFA-5.16	ERTi-17	R52253
51	SFA-5.16	ERTi-27	R52255
51	SFA-5.16	ERTi-2	R50120
51	SFA-5.16	ERTi-7	R52401
51	SFA-5.16	ERTi-14	R53424
51	SFA-5.16	ERTi-16	R52403
51	SFA-5.16	ERTi-26	R52405
51	SFA-5.16	ERTi-30	R53531
51	SFA-5.16	ERTi-33	R53443
51	SFA-5.16	ERTi-3	R50125
51	SFA-5.16	ERTi-15A	R53416
51	SFA-5.16	ERTi-31	R53533
51	SFA-5.16	ERTi-34	R53444
52	SFA-5.16	ERTi-4	R50130
53	SFA-5.16	ERTi-9	R56320
53	SFA-5.16	ERTi-9ELI	R56321
53	SFA-5.16	ERTi-18	R56326
53	SFA-5.16	ERTi-28	R56324
54	SFA-5.16	ERTi-12	R53400
55	SFA-5.16	ERTi-5	R56400
55	SFA-5.16	ERTi-23	R56408
55	SFA-5.16	ERTi-29	R56414
55	SFA-5.16	ERTi-24	R56415
55	SFA-5.16	ERTi-25	R56413
56	SFA-5.16	ERTi-32	R55112
		Zirconium and Zirconium Alloys	
61	SFA-5.24	ERZr2	R60702
61	SFA-5.24	ERZr3	R60704
61	SFA-5.24	ERZr4	R60705
		Hard-Facing Weld Metal Overlay	
71	SFA-5.13	ECoCr-A	W73006
71	SFA-5.13	ECoCr-B	W73012
71	SFA-5.13	ECoCr-C	W73001
71	SFA-5.13	ECoCr-E	W73021
71	SFA-5.13	ECuAl-A2	W60617
71	SFA-5.13	ECuAl-B	W60619
71	SFA-5.13	ECuAl-C	W60625
71	SFA-5.13	ECuAl-D	W61625
71	SFA-5.13	ECuAl-E	W62625
71	SFA-5.13	ECuMnNiAl	W60633
71	SFA-5.13	ECuNi	W60715
71	SFA-5.13	ECuNiAl	W60632
71	SFA-5.13	ECuSi	W60656
71	SFA-5.13	ECuSn-A	W60518
71	SFA-5.13	ECuSn-C	W60521
71	SFA-5.13	EFe1	W74001

QW-432
F-NUMBERS (CONT'D)
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Hard-Facing Weld Metal Overlay (CONT'D)	
71	SFA-5.13	EFe2	W74002
71	SFA-5.13	EFe3	W74003
71	SFA-5.13	EFe4	W74004
71	SFA-5.13	EFe5	W75110
71	SFA-5.13	EFe6	W77510
71	SFA-5.13	EFe7	W77610
71	SFA-5.13	EFeCr-A1A	W74011
71	SFA-5.13	EFeCr-A2	W74012
71	SFA-5.13	EFeCr-A3	W74013
71	SFA-5.13	EFeCr-A4	W74014
71	SFA-5.13	EFeCr-A5	W74015
71	SFA-5.13	EFeCr-A6	W74016
71	SFA-5.13	EFeCr-A7	W74017
71	SFA-5.13	EFeCr-A8	W74018
71	SFA-5.13	EFeCr-E1	W74211
71	SFA-5.13	EFeCr-E2	W74212
71	SFA-5.13	EFeCr-E3	W74213
71	SFA-5.13	EFeCr-E4	W74214
71	SFA-5.13	EFeMn-A	W79110
71	SFA-5.13	EFeMn-B	W79310
71	SFA-5.13	EFeMn-C	W79210
71	SFA-5.13	EFeMn-D	W79410
71	SFA-5.13	EFeMn-E	W79510
71	SFA-5.13	EFeMn-F	W79610
71	SFA-5.13	EFeMnCr	W79710
71	SFA-5.13	ENiCr-C	W89606
71	SFA-5.13	ENiCrFeCo	W83002
71	SFA-5.13	ENiCrMo-5A	W80002
71	SFA-5.13	EWCX-12/30	. . .
71	SFA-5.13	EWCX-20/30	. . .
71	SFA-5.13	EWCX-30/40	. . .
71	SFA-5.13	EWCX-40	. . .
71	SFA-5.13	EWCX-40/120	. . .
72	SFA-5.21	ERCCoCr-A	W73036
72	SFA-5.21	ERCCoCr-B	W73042
72	SFA-5.21	ERCCoCr-C	W73031
72	SFA-5.21	ERCCoCr-E	W73041
72	SFA-5.21	ERCCoCr-G	W73032
72	SFA-5.21	ERCCuAl-A2	W60618
72	SFA-5.21	ERCCuAl-A3	W60624
72	SFA-5.21	ERCCuAl-C	W60626
72	SFA-5.21	ERCCuAl-D	W61626
72	SFA-5.21	ERCCuAl-E	W62626
72	SFA-5.21	ERCCuSi-A	W60657
72	SFA-5.21	ERCCuSn-A	W60518
72	SFA-5.21	ERCCuSn-D	W60524
72	SFA-5.21	ERCFe-1	W74030
72	SFA-5.21	ERCFe-1A	W74031
72	SFA-5.21	ERCFe-2	W74032
72	SFA-5.21	ERCFe-3	W74033
72	SFA-5.21	ERCFe-5	W74035

QW-432
F-NUMBERS (CONT'D)
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Hard-Facing Weld Metal Overlay (CONT'D)	
72	SFA-5.21	ERCFe-6	W77530
72	SFA-5.21	ERCFe-8	W77538
72	SFA-5.21	ERCFeCr-A	W74531
72	SFA-5.21	ERCFeCr-A1A	W74530
72	SFA-5.21	ERCFeCr-A3A	W74533
72	SFA-5.21	ERCFeCr-A4	W74534
72	SFA-5.21	ERCFeCr-A5	W74535
72	SFA-5.21	ERCFeCr-A9	W74539
72	SFA-5.21	ERCFeCr-A10	W74540
72	SFA-5.21	ERCFeMn-C	W79230
72	SFA-5.21	ERCFeMn-F	W79630
72	SFA-5.21	ERCFeMn-G	W79231
72	SFA-5.21	ERCFeMn-H	W79232
72	SFA-5.21	ERCFeMnCr	W79730
72	SFA-5.21	ERCNiCr-A	W89634
72	SFA-5.21	ERCNiCr-B	W89635
72	SFA-5.21	ERCNiCr-C	W89636
72	SFA-5.21	ERCNiCrFeCo	W83032
72	SFA-5.21	ERCNiCrMo-5A	W80036
72	SFA-5.21	ERCoCr-A	R30006
72	SFA-5.21	ERCoCr-B	R30012
72	SFA-5.21	ERCoCr-C	R30001
72	SFA-5.21	ERCoCr-E	R30021
72	SFA-5.21	ERCoCr-F	R30002
72	SFA-5.21	ERCoCr-G	R30014
72	SFA-5.21	ERCuAl-A2	C61800
72	SFA-5.21	ERCuAl-A3	C62400
72	SFA-5.21	ERCuAl-C	C62580
72	SFA-5.21	ERCuAl-D	C62581
72	SFA-5.21	ERCuAl-E	C62582
72	SFA-5.21	ERCuSi-A	C65600
72	SFA-5.21	ERCuSn-A	C51800
72	SFA-5.21	ERCuSn-D	C52400
72	SFA-5.21	ERFe-1	T74000
72	SFA-5.21	ERFe-1A	T74001
72	SFA-5.21	ERFe-2	T74002
72	SFA-5.21	ERFe-3	T74003
72	SFA-5.21	ERFe-5	T74005
72	SFA-5.21	ERFe-6	T74006
72	SFA-5.21	ERFe-8	T74008
72	SFA-5.21	ERFeCr-A	...
72	SFA-5.21	ERFeCr-A1A	...
72	SFA-5.21	ERFeCr-A3A	...
72	SFA-5.21	ERFeCr-A4	...
72	SFA-5.21	ERFeCr-A5	...
72	SFA-5.21	ERFeCr-A9	...
72	SFA-5.21	ERFeCr-A10	...
72	SFA-5.21	ERFeMn-C	...
72	SFA-5.21	ERFeMn-F	...
72	SFA-5.21	ERFeMn-G	...
72	SFA-5.21	ERFeMn-H	...

QW-432
F-NUMBERS (CONT'D)
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Hard-Facing Weld Metal Overlay (CONT'D)	
72	SFA-5.21	ERFeMnCr	...
72	SFA-5.21	ERNiCr-A	N99644
72	SFA-5.21	ERNiCr-B	N99645
72	SFA-5.21	ERNiCr-C	N99646
72	SFA-5.21	ERNiCr-D	N99647
72	SFA-5.21	ERNiCr-E	N99648
72	SFA-5.21	ERNiCrFeCo	F46100
72	SFA-5.21	ERNiCrMo-5A	N10006
72	SFA-5.21	ERWCX-20/30	...
72	SFA-5.21	ERWCX-30/40	...
72	SFA-5.21	ERWCX-40	...
72	SFA-5.21	ERWCX-40/120	...
72	SFA-5.21	RWCX-20/30	...
72	SFA-5.21	RWCX-30/40	...
72	SFA-5.21	RWCX-40	...
72	SFA-5.21	RWCX-40/120	...

QW-433 Alternate F-Numbers for Welder Performance Qualification

The following tables identify the filler metal or electrode that the welder used during qualification testing as "Qualified With," and the electrodes or filler metals that the welder is qualified to use in production welding as "Qualified For." See table QW-432 for the F-Number assignments.

Qualified With → / Qualified For ↓	F-No. 1 With Backing	F-No. 1 Without Backing	F-No. 2 With Backing	F-No. 2 Without Backing	F-No. 3 With Backing	F-No. 3 Without Backing	F-No. 4 With Backing	F-No. 4 Without Backing	F-No. 5 With Backing	F-No. 5 Without Backing
F-No. 1 With Backing	X	X	X	X	X	X	X	X	X	X
F-No. 1 Without Backing		X								
F-No. 2 With Backing			X	X	X	X	X	X		
F-No. 2 Without Backing				X						
F-No. 3 With Backing					X	X	X	X		
F-No. 3 Without Backing						X				
F-No. 4 With Backing							X	X		
F-No. 4 Without Backing								X		
F-No. 5 With Backing									X	X
F-No. 5 Without Backing										X

Qualified With	Qualified For
Any F-No. 6	All F-No. 6 [Note (1)]
Any F-No. 21 through F-No. 25	All F-No. 21 through F-No. 25
Any F-No. 31, F-No. 32, F-No. 33, F-No. 35, F-No. 36, or F-No. 37	Only the same F-Number as was used during the qualification test
F-No. 34 or any F-No. 41 through F-No. 46	F-No. 34 and all F-No. 41 through F-No. 46
Any F-No. 51 through F-No. 55	All F-No. 51 through F-No. 55
Any F-No. 61	All F-No. 61
Any F-No. 71 through F-No. 72	Only the same F-Number as was used during the qualification test

NOTE:

(1) Deposited weld metal made using a bare rod not covered by an SFA Specification but which conforms to an analysis listed in QW-442 shall be considered to be classified as F-No. 6.

QW-440 WELD METAL CHEMICAL COMPOSITION

QW-441 General

Identification of weld metal chemical composition designated on the PQR and WPS shall be as given in QW-404.5.

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)]					
		C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	. . .	. . .	. . .	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40–0.65	. . .	1.60	1.00
3	Chrome (0.4% to 2%)–Molybdenum	0.15	0.40–2.00	0.40–0.65	. . .	1.60	1.00
4	Chrome (2% to 4%)–Molybdenum	0.15	2.00–4.00	0.40–1.50	. . .	1.60	2.00
5	Chrome (4% to 10.5%)–Molybdenum	0.15	4.00–10.50	0.40–1.50	. . .	1.20	2.00
6	Chrome-Martensitic	0.15	11.00–15.00	0.70	. . .	2.00	1.00
7	Chrome-Ferritic	0.15	11.00–30.00	1.00	. . .	1.00	3.00
8	Chromium–Nickel	0.15	14.50–30.00	4.00	7.50–15.00	2.50	1.00
9	Chromium–Nickel	0.30	19.00–30.00	6.00	15.00–37.00	2.50	1.00
10	Nickel to 4%	0.15	. . .	0.55	0.80–4.00	1.70	1.00
11	Manganese–Molybdenum	0.17	. . .	0.25–0.75	0.85	1.25–2.25	1.00
12	Nickel–Chrome—Molybdenum	0.15	1.50	0.25–0.80	1.25–2.80	0.75–2.25	1.00

NOTE:
(1) Single values shown above are maximum.

QW-450 SPECIMENS

QW-451 Procedure Qualification Thickness Limits and Test Specimens

(10)

QW-451.1
GROOVE-WELD TENSION TESTS AND TRANSVERSE-BEND TESTS

Thickness T of Test Coupon, Welded, in. (mm)	Range of Thickness T of Base Metal, Qualified, in. (mm) [Notes (1) and (2)]		Maximum Thickness t of Deposited Weld Metal, Qualified, in. (mm) [Notes (1) and (2)]	Type and Number of Tests Required (Tension and Guided-Bend Tests) [Note (2)]			
	Min.	Max.		Tension, QW-150	Side Bend, QW-160	Face Bend, QW-160	Root Bend, QW-160
Less than $^1/_{16}$ (1.5)	T	$2T$	$2t$	2	. . .	2	2
$^1/_{16}$ to $^3/_8$ (1.5 to 10), incl.	$^1/_{16}$ (1.5)	$2T$	$2t$	2	Note (5)	2	2
Over $^3/_8$ (10), but less than $^3/_4$ (19)	$^3/_{16}$ (5)	$2T$	$2t$	2	Note (5)	2	2
$^3/_4$ (19) to less than $1^1/_2$ (38)	$^3/_{16}$ (5)	$2T$	$2t$ when $t < {}^3/_4$ (19)	2 [Note (4)]	4	. . .	. . .
$^3/_4$ (19) to less than $1^1/_2$ (38)	$^3/_{16}$ (5)	$2T$	$2T$ when $t \geq {}^3/_4$ (19)	2 [Note (4)]	4	. . .	. . .
$1^1/_2$ (38) to 6 (150), incl.	$^3/_{16}$ (5)	8 (200) [Note (3)]	$2t$ when $t < {}^3/_4$ (19)	2 [Note (4)]	4	. . .	. . .
$1^1/_2$ (38) to 6 (150), incl.	$^3/_{16}$ (5)	8 (200) [Note (3)]	8 (200) [Note (3)] when $t \geq {}^3/_4$ (19)	2 [Note (4)]	4	. . .	. . .
Over 6 (150)	$^3/_{16}$ (5)	$1.33T$	$2t$ when $t < {}^3/_4$ (19)	2 [Note (4)]	4	. . .	. . .
Over 6 (150)	$^3/_{16}$ (5)	$1.33T$	$1.33T$ when $t \geq {}^3/_4$ (19)	2 [Note (4)]	4	. . .	. . .

NOTES:

(1) The following variables further restrict the limits shown in this table when they are referenced in QW-250 for the process under consideration: QW-403.9, QW-403.10, QW-404.32, and QW-407.4. Also, QW-202.2, QW-202.3, and QW-202.4 provide exemptions that supersede the limits of this table.

(2) For combination of welding procedures, see QW-200.4.

(3) For the SMAW, SAW, GMAW, PAW, and GTAW welding processes only; otherwise per Note (1) or $2T$, or $2t$, whichever is applicable.

(4) See QW-151.1, QW-151.2, and QW-151.3 for details on multiple specimens when coupon thicknesses are over 1 in. (25 mm).

(5) Four side-bend tests may be substituted for the required face- and root-bend tests, when thickness T is $^3/_8$ in. (10 mm) and over.

QW-451.2
GROOVE-WELD TENSION TESTS AND LONGITUDINAL-BEND TESTS

	Range of Thickness T of Base Metal Qualified, in. (mm) [Notes (1) and (2)]		Thickness t of Deposited Weld Metal Qualified, in. (mm) [Notes (1) and (2)]	Type and Number of Tests Required (Tension and Guided-Bend Tests) [Note (2)]		
Thickness T of Test Coupon Welded, in. (mm)	Min.	Max.	Max.	Tension, QW-150	Face Bend, QW-160	Root Bend, QW-160
Less than $\frac{1}{16}$ (1.5)	T	$2T$	$2t$	2	2	2
$\frac{1}{16}$ to $\frac{3}{8}$ (1.5 to 10), incl.	$\frac{1}{16}$ (1.5)	$2T$	$2t$	2	2	2
Over $\frac{3}{8}$ (10)	$\frac{3}{16}$ (5)	$2T$	$2t$	2	2	2

NOTES:

(1) The following variables further restrict the limits shown in this table when they are referenced in QW-250 for the process under consideration: QW-403.9, QW-403.10, QW-404.32, and QW-407.4. Also, QW-202.2, QW-202.3, and QW-202.4 provide exemptions that supersede the limits of this table.

(2) For combination of welding procedures, see QW-200.4.

QW-451.3
FILLET-WELD TESTS

Type of Joint	Thickness of Test Coupons as Welded, in.	Range Qualified	Type and Number of Tests Required [QW-462.4(a) or QW-462.4(d)] Macro
Fillet	Per QW-462.4(a)	All fillet sizes on all base metal thicknesses and all diameters	5
Fillet	Per QW-462.4(d)		4

GENERAL NOTE: A production assembly mockup may be substituted in accordance with QW-181.1.1. When a production assembly mockup is used, the range qualified shall be limited to the fillet weld size, base metal thickness, and configuration of the mockup. Alternatively, multiple production assembly mockups may be qualified. The range of thickness of the base metal qualified shall be no less than the thickness of the thinner member tested and no greater than the thickness of the thicker member tested. The range for fillet weld sizes qualified shall be limited to no less than the smallest fillet weld tested and no greater than the largest fillet weld tested. The configuration of production assemblies shall be the same as that used in the production assembly mockup.

QW-451.4
FILLET WELDS QUALIFIED BY GROOVE-WELD TESTS

Thickness *T* of Test Coupon (Plate or Pipe) as Welded	Range Qualified	Type and Number of Tests Required
All groove tests	All fillet sizes on all base metal thicknesses and all diameters	Fillet welds are qualified when the groove weld is qualified in accordance with either QW-451.1 or QW-451.2 (see QW-202.2)

QW-452 Performance Qualification Thickness Limits and Test Specimens

QW-452.1 Groove-Weld Test. The following tables identify the required type and number of tests and the thickness of weld metal qualified.

QW-452.1(a)
TEST SPECIMENS

Thickness of Weld Metal, in. (mm)	Type and Number of Examinations and Test Specimens Required: Visual Examination per QW-302.4	Side Bend QW-462.2 [Note (1)]	Face Bend QW-462.3(a) or QW-462.3(b) [Notes (1), (2)]	Root Bend QW-462.3(a) or QW-462.3(b) [Notes (1), (2)]
Less than $\frac{3}{8}$ (10)	X	...	1	1
$\frac{3}{8}$ (10) to less than $\frac{3}{4}$ (19)	X	2 [Note (3)]	Note (3)	Note (3)
$\frac{3}{4}$ (19) and over	X	2	...	...

GENERAL NOTE: The "Thickness of Weld Metal" is the total weld metal thickness deposited by all welders and all processes in the test coupon exclusive of the weld reinforcement.

NOTES:

(1) To qualify using positions 5G or 6G, a total of four bend specimens are required. To qualify using a combination of 2G and 5G in a single test coupon, a total of six bend specimens are required. See QW-302.3. The type of bend test shall be based on weld metal thickness.

(2) Coupons tested by face and root bends shall be limited to weld deposit made by one welder with one or two processes or two welders with one process each. Weld deposit by each welder and each process shall be present on the convex surface of the appropriate bent specimen.

(3) One face and root bend may be substituted for the two side bends.

QW-452.1(b)
THICKNESS OF WELD METAL QUALIFIED

Thickness, t, of Weld Metal in the Coupon, in. (mm) [Notes (1) and (2)]	Thickness of Weld Metal Qualified [Note (3)]
All	$2t$
$\frac{1}{2}$ (13) and over with a minimum of three layers	Maximum to be welded

NOTES:

(1) When more than one welder and/or more than one process and more than one filler metal F-Number is used to deposit weld metal in a coupon, the thickness, t, of the weld metal in the coupon deposited by each welder with each process and each filler metal F-Number in accordance with the applicable variables under QW-404 shall be determined and used individually in the "Thickness, t, of Weld Metal in the Coupon" column to determine the "Thickness of Weld Metal Qualified."

(2) Two or more pipe test coupons with different weld metal thickness may be used to determine the weld metal thickness qualified and that thickness may be applied to production welds to the smallest diameter for which the welder is qualified in accordance with QW-452.3.

(3) Thickness of test coupon of $\frac{3}{4}$ in. (19 mm) or over shall be used for qualifying a combination of three or more welders each of whom may use the same or a different welding process.

QW-452.3
GROOVE-WELD DIAMETER LIMITS

Outside Diameter of Test Coupon, in. (mm)	Outside Diameter Qualified, in. (mm) Min.	Max.
Less than 1 (25)	Size welded	Unlimited
1 (25) to $2\frac{7}{8}$ (73)	1 (25)	Unlimited
Over $2\frac{7}{8}$ (73)	$2\frac{7}{8}$ (73)	Unlimited

GENERAL NOTES:
(a) Type and number of tests required shall be in accordance with QW-452.1.
(b) $2\frac{7}{8}$ in. (73 mm) O.D. is the equivalent of NPS $2\frac{1}{2}$ (DN 65).

QW-452.4
SMALL DIAMETER FILLET-WELD TEST

Outside Diameter of Test Coupon, in. (mm)	Minimum Outside Diameter, Qualified, in. (mm)	Qualified Thickness
Less than 1 (25)	Size welded	All
1 (25) to $2\frac{7}{8}$ (73)	1 (25)	All
Over $2\frac{7}{8}$ (73)	$2\frac{7}{8}$ (73)	All

GENERAL NOTES:
(a) Type and number of tests required shall be in accordance with QW-452.5.
(b) $2\frac{7}{8}$ in. (73 mm) O.D. is considered the equivalent of NPS $2\frac{1}{2}$ (DN 65).

QW-452.5 FILLET-WELD TEST

(10)

Type of Joint	Thickness of Test Coupon as Welded, in. (mm)	Qualified Range	Type and Number of Tests Required [QW-462.4(b) or QW-462.4(c)] Macro	Fracture
Tee fillet [Note (1)]	$\frac{3}{16}$ (5) or greater	All base material thicknesses, fillet sizes, and diameters $2\frac{7}{8}$(73) O.D. and over [Note (2)]	1	1
	Less than $\frac{3}{16}$ (5)	T to $2T$ base material thickness, T maximum fillet size, and all diameters $2\frac{7}{8}$ (73) O.D. and over [Note (2)]	1	1

GENERAL NOTE: Production assembly mockups may be substituted in accordance with QW-181.2.1. When production assembly mockups are used, range qualified shall be limited to the fillet sizes, base metal thicknesses, and configuration of the mockup.

NOTE:

(1) Test coupon prepared as shown in QW-462.4(b) for plate or QW-462.4(c) for pipe.

(2) $2\frac{7}{8}$ in. (73 mm) O.D. is considered the equivalent of NPS $2\frac{1}{2}$ (DN 65). For smaller diameter qualifications, refer to QW-452.4 or QW-452.6.

QW-452.6 FILLET QUALIFICATION BY GROOVE-WELD TESTS

Type of Joint	Thickness of Test Coupon as Welded, in. (mm)	Qualified Range	Type and Number of Tests Required
Any groove	All thicknesses	All base material thicknesses, fillet sizes, and diameters	Fillet welds are qualified when a welder/welding operator qualifies on a groove weld test

QW-453
PROCEDURE/PERFORMANCE QUALIFICATION THICKNESS LIMITS AND TEST SPECIMENS FOR HARD-FACING (WEAR-RESISTANT) AND CORROSION-RESISTANT OVERLAYS

	Corrosion-Resistant Overlay [Note (1)]		Hard-facing Overlay (Wear-Resistant) [Note (2)]	
Thickness of Test Coupon (*T*)	Nominal Base Metal Thickness Qualified (*T*)	Type and Number of Tests Required	Nominal Base Metal Thickness Qualified (*T*)	Type and Number of Tests Required
Procedure Qualification Testing				
Less than 1 in. (25 mm) *T*	*T* qualified to unlimited	Notes (4), (5), and (9)	*T* qualified up to 1 in. (25 mm)	Notes (3), (7), (8), and (9)
1 in. (25 mm) and over *T*	1 in. (25 mm) to unlimited	Notes (4), (5), and (9)	1 in. (25 mm) to unlimited	Notes (3), (7), (8), and (9)
Performance Qualification Testing				
Less than 1 in. (25 mm) *T*	*T* qualified to unlimited	Note (6)	*T* qualified to unlimited	Notes (8) and (10)
1 in. (25 mm) and over *T*	1 in. (25 mm) to unlimited	Note (6)	1 in. (25 mm) to unlimited	Notes (8) and (10)

NOTES:

(1) The qualification test coupon shall consist of base metal not less than 6 in. (150 mm) × 6 in. (150 mm). The weld overlay cladding shall be a minimum of $1\frac{1}{2}$ in. (38 mm) wide by approximately 6 in. (150 mm) long. For qualification on pipe, the pipe length shall be a minimum of 6 in. (150 mm), and a minimum diameter to allow the required number of test specimens. The weld overlay shall be continuous around the circumference of the test coupon. For processes (performance qualification only) depositing a weld bead width greater than $\frac{1}{2}$ in. (13 mm) wide, the weld overlay shall consist of a minimum of three weld beads in the first layer.

(2) The test base metal coupon shall have minimum dimensions of 6 in. (150 mm) wide × approximately 6 in. (150 mm) long with a hard-faced layer a minimum of $1\frac{1}{2}$ in. (38 mm) wide × 6 in. (150 mm) long. The minimum hard-faced thickness shall be as specified in the Welding Procedure Specification. Alternatively, the qualification may be performed on a test base metal coupon that represents the size of the production part. For qualification on pipe, the pipe length shall be 6 in. (150 mm) minimum, and of a minimum diameter to allow the required number of test specimens. The weld overlay shall be continuous around the circumference of the test coupon.

(3) The hard-facing surface shall be examined by the liquid penetrant method and shall meet the acceptance standards in QW-195.2 or as specified in the WPS. Surface conditioning prior to liquid penetrant examination is permitted.

(4) The corrosion-resistant surface shall be examined by the liquid penetrant method and shall meet the acceptance standards as specified in QW-195.

(5) Following the liquid penetrant examination, four guided side-bend tests shall be made from the test coupon in accordance with QW-161. The test specimens shall be cut so that there are either two specimens parallel and two specimens perpendicular to the direction of the welding, or four specimens perpendicular to the direction of the welding. For coupons that are less than $\frac{3}{8}$ in. (10 mm) thick, the width of the side-bend specimens may be reduced to the thickness of the test coupon. The side-bend specimens shall be removed from locations specified in QW-462.5(c) or QW-462.5(d).

(6) The test coupon shall be sectioned to make side-bend test specimens perpendicular to the direction of the welding in accordance with QW-161. Test specimens shall be removed at locations specified in QW-462.5(c) or QW-462.5(d).

(7) After surface conditioning to the minimum thickness specified in the WPS, a minimum of three hardness readings shall be made on each of the specimens from the locations shown in QW-462.5(b) or QW-462.5(e). All readings shall meet the requirements of the WPS.

(8) The base metal shall be sectioned transversely to the direction of the hard-facing overlay. The two faces of the hard-facing exposed by sectioning shall be polished and etched with a suitable etchant and shall be visually examined with ×5 magnification for cracks in the base metal or the heat-affected zone, lack of fusion, or other linear defects. The overlay and the base metal shall meet the requirements specified in the WPS. All exposed faces shall be examined. See QW-462.5(b) for pipe and QW-462.5(e) for plate.

(9) When a chemical composition is specified in the WPS, chemical analysis specimens shall be removed at locations specified in QW-462.5(b) or QW-462.5(e). The chemical analysis shall be performed in accordance with QW-462.5(a) and shall be within the range specified in the WPS. This chemical analysis is not required when a chemical composition is not specified on the WPS.

(10) At a thickness greater than or equal to the minimum thickness specified in the WPS, the weld surface shall be examined by the liquid penetrant method and shall meet the acceptance standards in QW-195.2 or as specified in the WPS. Surface conditioning prior to liquid penetrant examination is permitted.

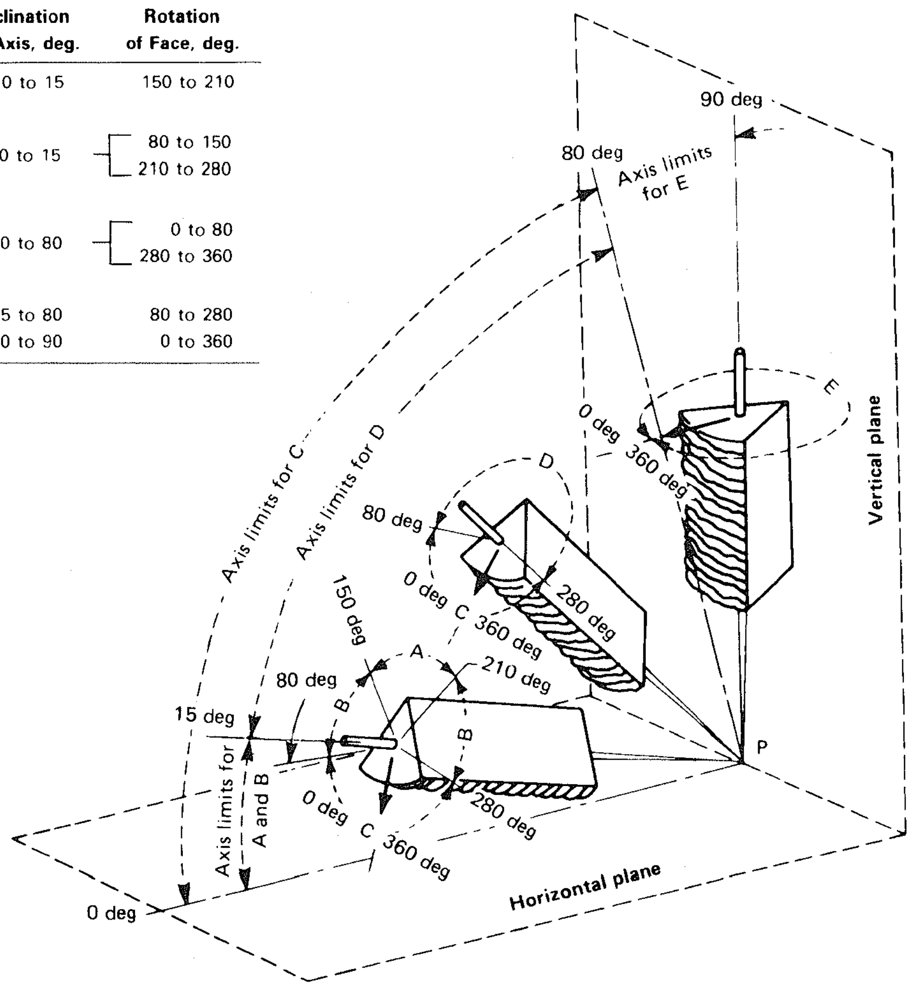
QW-460 GRAPHICS

QW-461 Positions

QW-461.1 POSITIONS OF WELDS — GROOVE WELDS

Tabulation of Positions of Welds

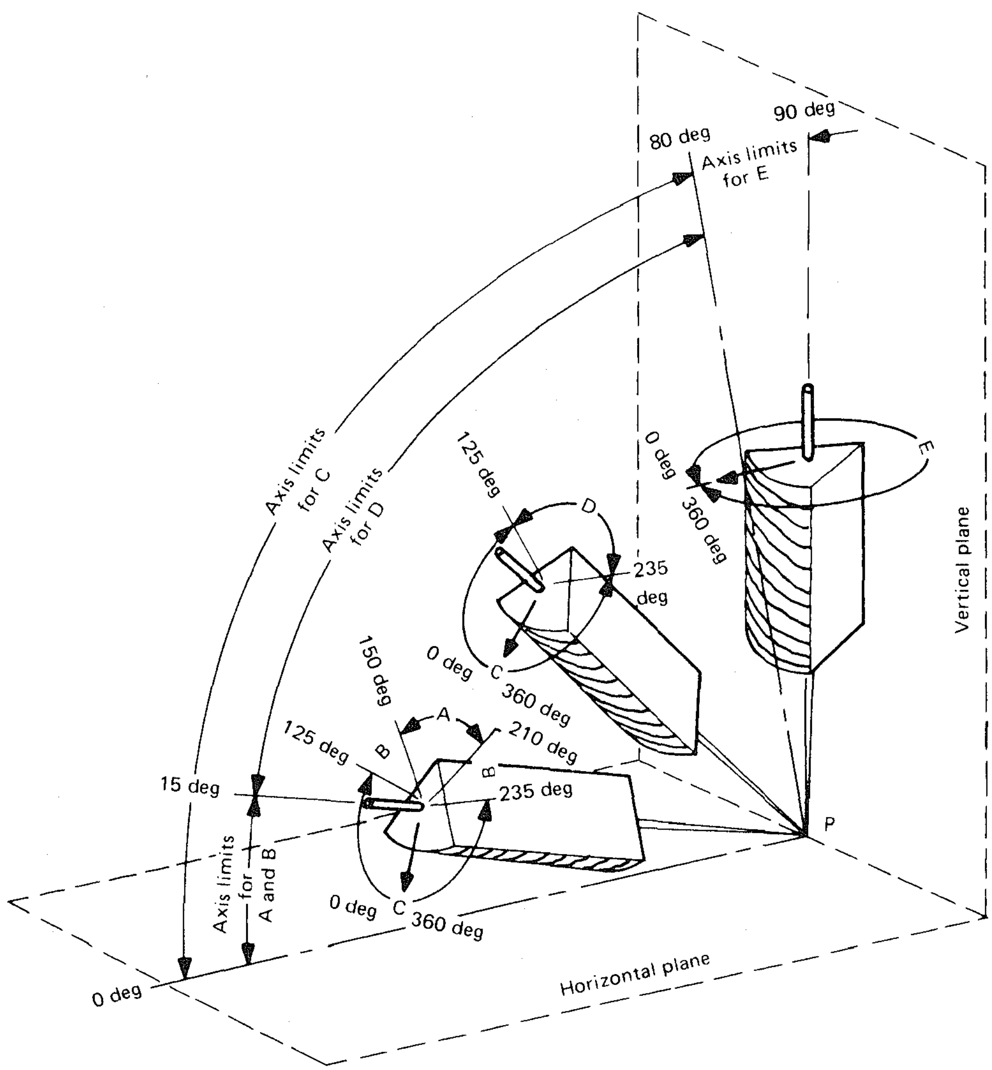
Position	Diagram Reference	Inclination of Axis, deg.	Rotation of Face, deg.
Flat	A	0 to 15	150 to 210
Horizontal	B	0 to 15	80 to 150 210 to 280
Overhead	C	0 to 80	0 to 80 280 to 360
Vertical	D	15 to 80	80 to 280
	E	80 to 90	0 to 360



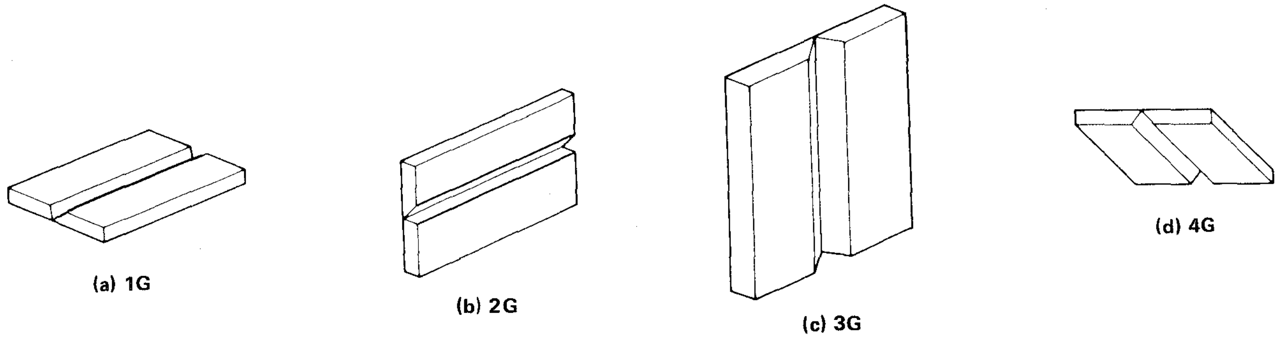
GENERAL NOTE: The horizontal reference plane is taken to lie always below the weld under consideration.
Inclination of axis is measured from the horizontal reference plane toward the vertical.
Angle of rotation of face is measured from a line perpendicular to the axis of the weld and lying in a vertical plane containing this axis. The reference position (0 deg) of rotation of the face invariably points in the direction opposite to that in which the axis angle increases. The angle of rotation of the face of weld is measured in a clockwise direction from this reference position (0 deg) when looking at point *P*.

QW-461.2 POSITIONS OF WELDS — FILLET WELDS

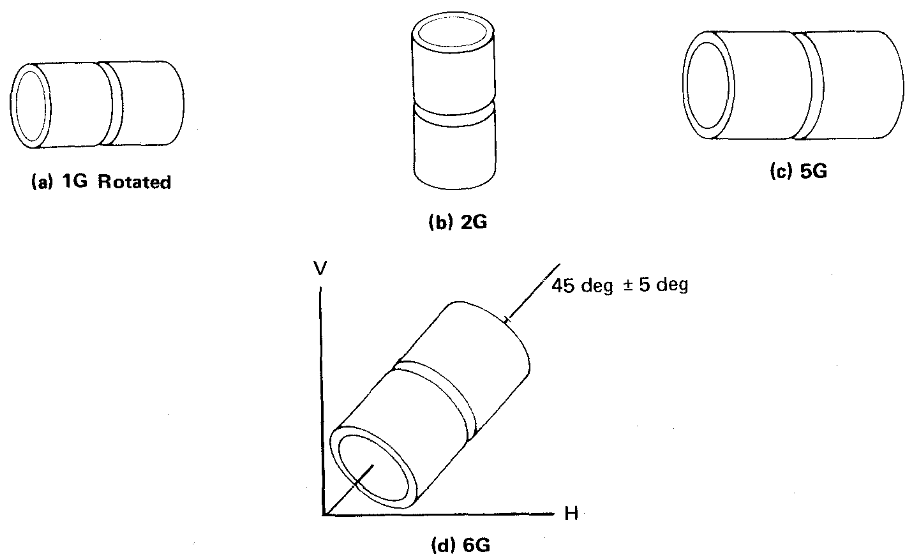
Tabulation of Positions of Fillet Welds			
Position	Diagram Reference	Inclination of Axis, deg.	Rotation of Face, deg.
Flat	A	0 to 15	150 to 210
Horizontal	B	0 to 15	125 to 150 210 to 235
Overhead	C	0 to 80	0 to 125 235 to 360
Vertical	D	15 to 80	125 to 235
	E	80 to 90	0 to 360



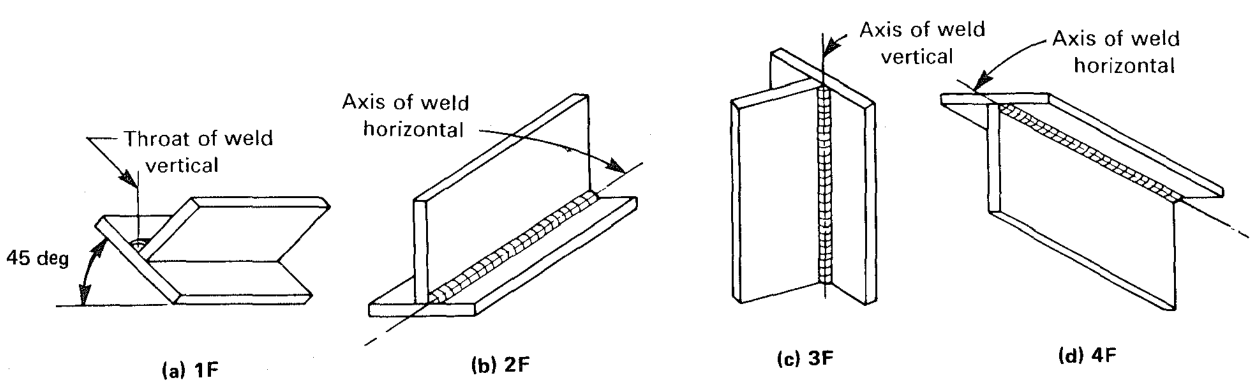
QW-461.3 GROOVE WELDS IN PLATE — TEST POSITIONS



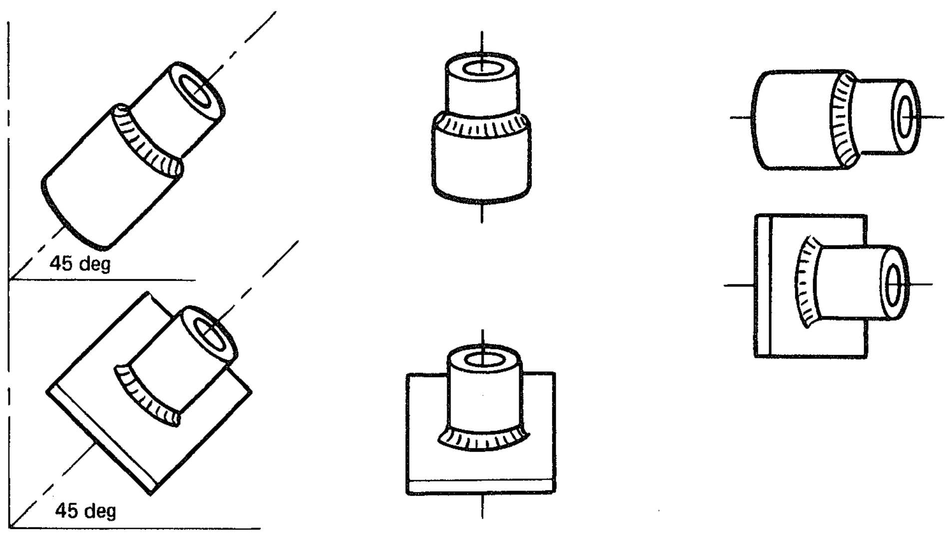
QW-461.4 GROOVE WELDS IN PIPE — TEST POSITIONS



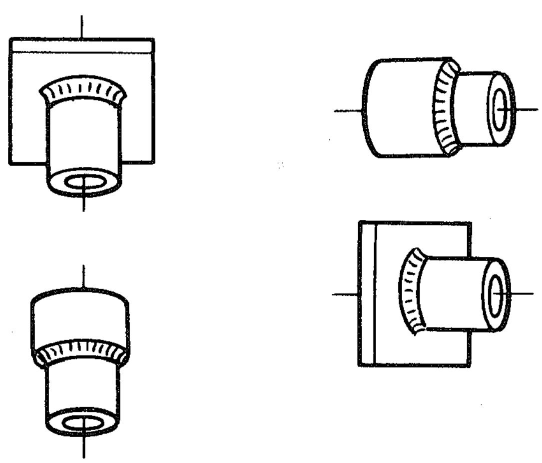
QW-461.5 FILLET WELDS IN PLATE — TEST POSITIONS



QW-461.6 FILLET WELDS IN PIPE — TEST POSITIONS

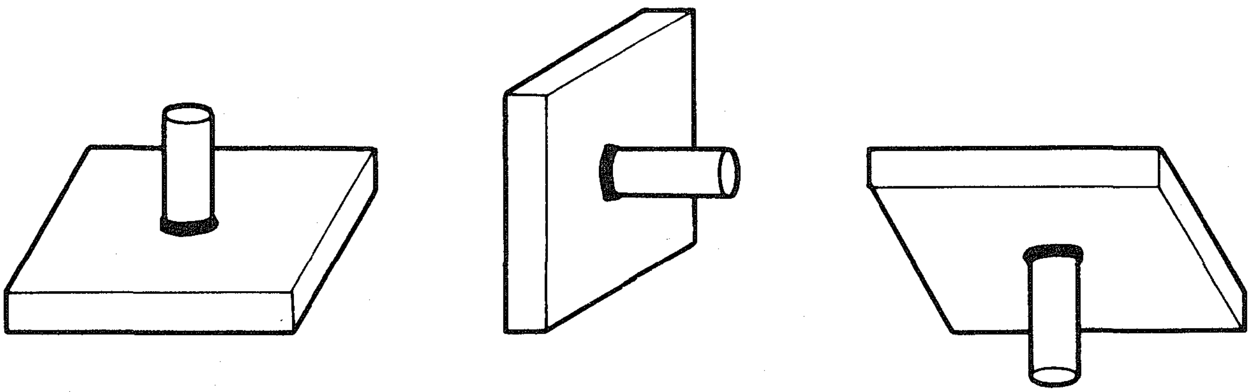


(a) 1F (Rotated) (b) 2F (c) 2FR (Rotated)



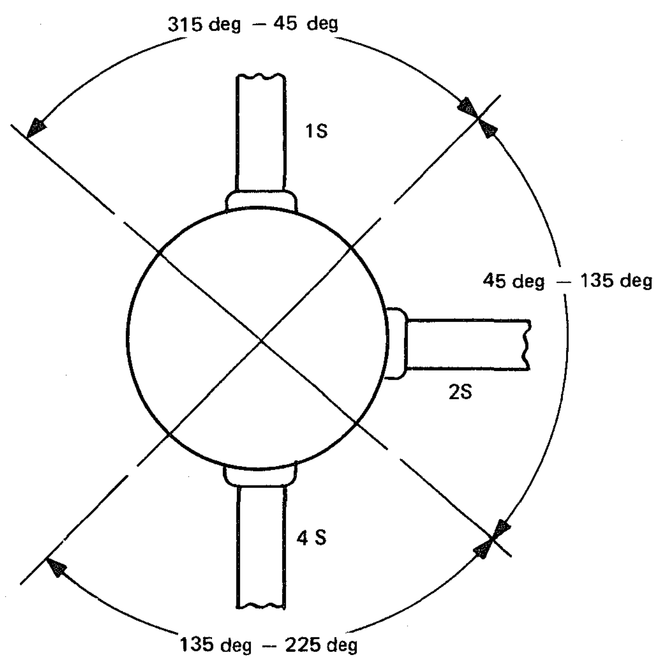
(d) 4F (e) 5F

QW-461.7 STUD WELDS — TEST POSITIONS



(a) 1S (2) 2S (c) 4S

QW-461.8 STUD WELDS — WELDING POSITIONS



QW-461.9
PERFORMANCE QUALIFICATION — POSITION AND DIAMETER LIMITATIONS
(Within the Other Limitations of QW-303)

Qualification Test		Position and Type Weld Qualified [Note (1)]		
		Groove		Fillet
Weld	Position	Plate and Pipe Over 24 in. (610 mm) O.D.	Pipe ≤ 24 in. (610 mm) O.D.	Plate and Pipe
Plate — Groove	1G	F	F [Note (2)]	F
	2G	F,H	F,H [Note (2)]	F,H
	3G	F,V	F [Note (2)]	F,H,V
	4G	F,O	F [Note (2)]	F,H,O
	3G and 4G	F,V,O	F [Note (2)]	All
	2G, 3G, and 4G	All	F,H [Note (2)]	All
	Special Positions (SP)	SP,F	SP,F	SP,F
Plate — Fillet	1F	...	...	F [Note (2)]
	2F	...	...	F,H [Note (2)]
	3F	...	...	F,H,V [Note (2)]
	4F	...	...	F,H,O [Note (2)]
	3F and 4F	...	...	All [Note (2)]
	Special Positions (SP)	...	...	SP,F [Note (2)]
Pipe — Groove [Note (3)]	1G	F	F	F
	2G	F,H	F,H	F,H
	5G	F,V,O	F,V,O	All
	6G	All	All	All
	2G and 5G	All	All	All
	Special Positions (SP)	SP,F	SP,F	SP,F
Pipe — Fillet [Note (3)]	1F	...	...	F
	2F	...	...	F,H
	2FR	...	...	F,H
	4F	...	...	F,H,O
	5F	...	...	All
	Special Positions (SP)	...	...	SP,F

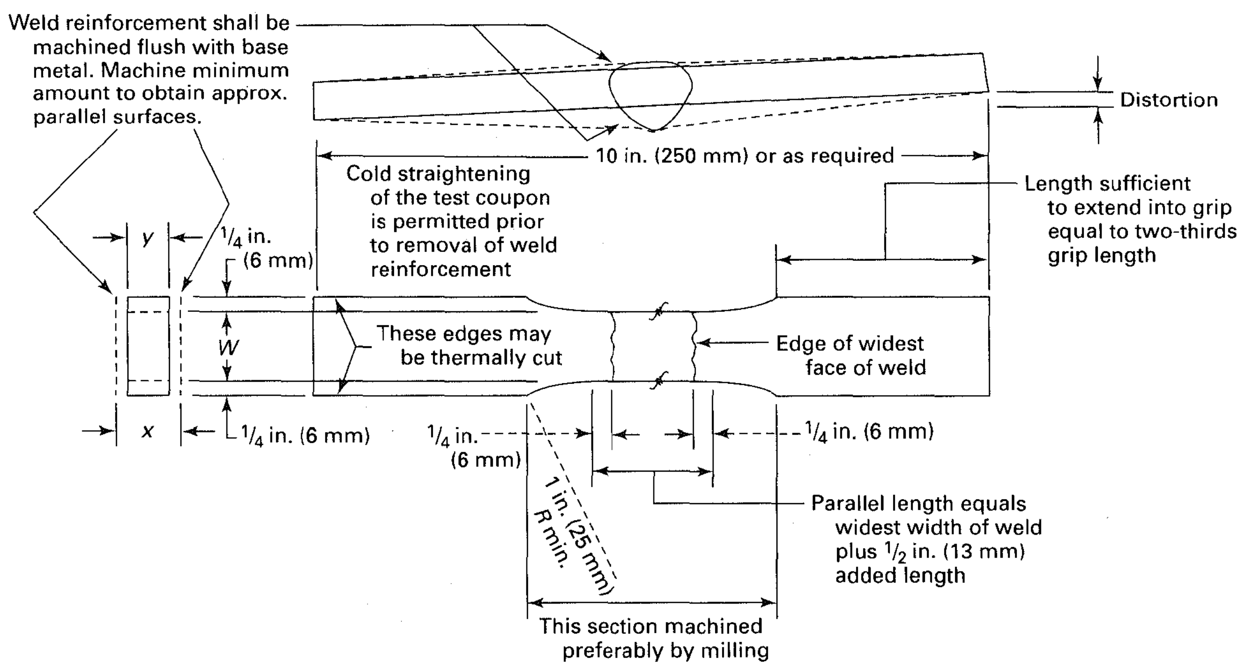
NOTES:
(1) Positions of welding as shown in QW-461.1 and QW-461.2.
F = Flat
H = Horizontal
V = Vertical
O = Overhead
(2) Pipe $2\frac{7}{8}$ in. (73 mm) O.D. and over.
(3) See diameter restrictions in QW-452.3, QW-452.4, and QW-452.6.

QW-462 Test Specimens

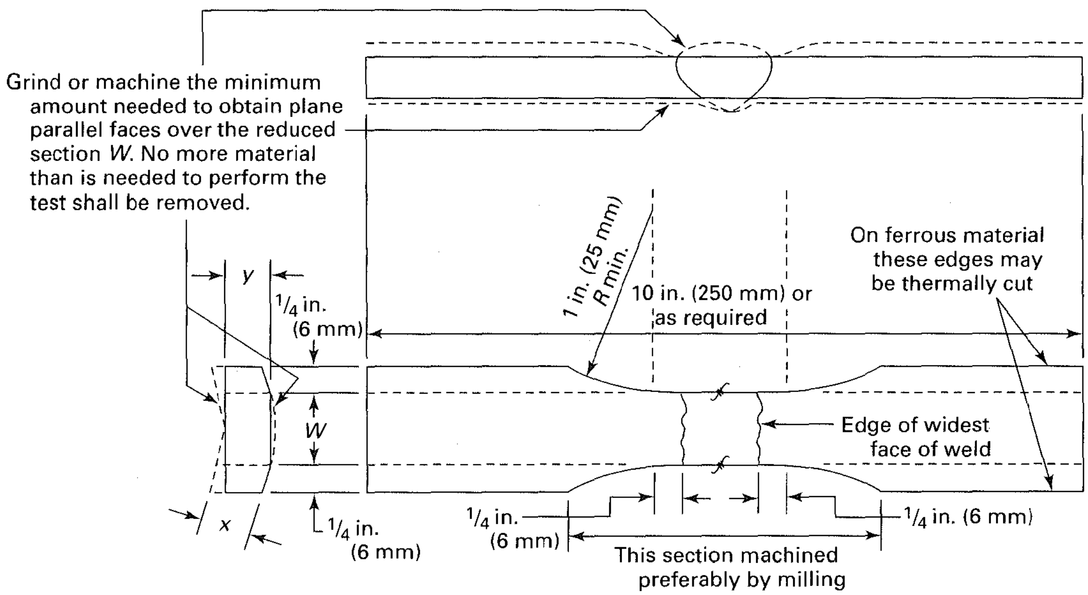
The purpose of the QW-462 figures is to give the manufacturer or contractor guidance in dimensioning test specimens for tests required for procedure and performance qualifications. Unless a minimum, maximum, or tolerance is given in the figures (or as QW-150, QW-160, or QW-180 requires), the dimensions are to be considered approximate. All welding processes and filler material to be qualified must be included in the test specimen.

T = coupon thickness excluding reinforcement
W = specimen width, $\frac{3}{4}$ in. (19 mm)
x = coupon thickness including reinforcement
y = specimen thickness

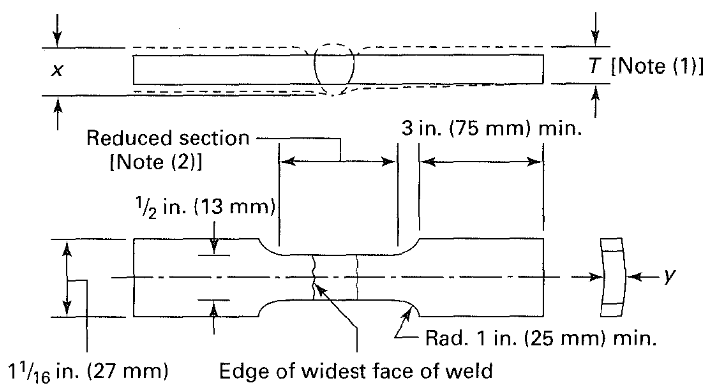
QW-462.1(a) TENSION — REDUCED SECTION — PLATE



QW-462.1(b) TENSION — REDUCED SECTION — PIPE



QW-462.1(c) TENSION — REDUCED SECTION ALTERNATE FOR PIPE

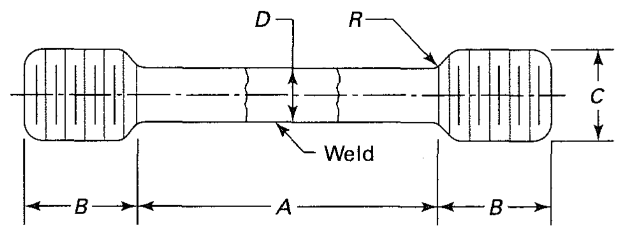


NOTES:

(1) The weld reinforcement shall be ground or machined so that the weld thickness does not exceed the base metal thickness T. Machine minimum amount to obtain approximately parallel surfaces.

(2) The reduced section shall not be less than the width of the weld plus $2y$.

QW-462.1(d) TENSION — REDUCED SECTION — TURNED SPECIMENS



	Standard Dimensions, in. (mm)			
	(a) 0.505 Specimen	(b) 0.353 Specimen	(c) 0.252 Specimen	(d) 0.188 Specimen
A—Length of reduced section	Note (1)	Note (1)	Note (1)	Note (1)
D—Diameter	0.500 ± 0.010 (12.7 ± 0.25)	0.350 ± 0.007 (8.89 ± 0.18)	0.250 ± 0.005 (6.35 ± 0.13)	0.188 ± 0.003 (4.78 ± 0.08)
R—Radius of fillet	$\frac{3}{8}$ (10) min.	$\frac{1}{4}$ (6) min.	$\frac{3}{16}$ (5) min.	$\frac{1}{8}$ (3) min.
B—Length of end section	$1\frac{3}{8}$ (35) approx.	$1\frac{1}{8}$ (29) approx.	$\frac{7}{8}$ (22) approx.	$\frac{1}{2}$ (13) approx.
C—Diameter of end section	$\frac{3}{4}$ (19)	$\frac{1}{2}$ (13)	$\frac{3}{8}$ (10)	$\frac{1}{4}$ (6)

GENERAL NOTES:

(a) Use maximum diameter specimen (a), (b), (c), or (d) that can be cut from the section.

(b) Weld should be in center of reduced section.

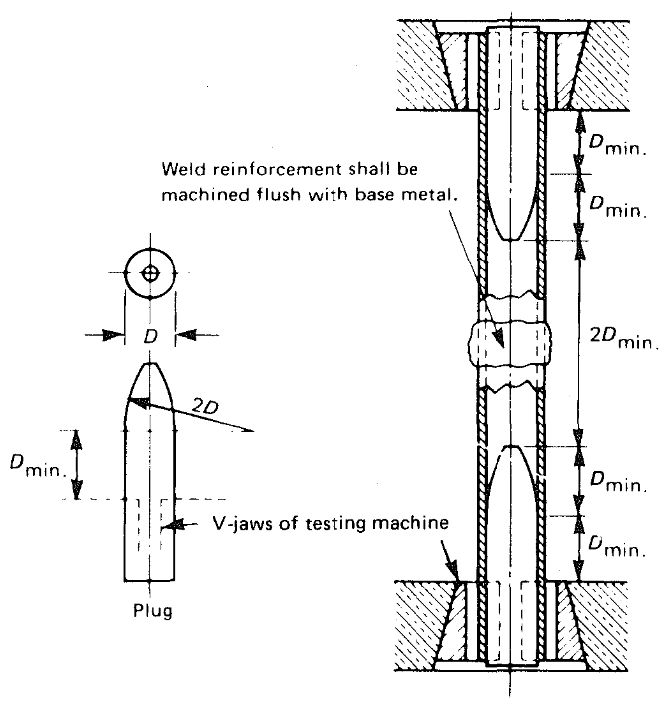
(c) Where only a single coupon is required, the center of the specimen should be midway between the surfaces.

(d) The ends may be of any shape to fit the holders of the testing machine in such a way that the load is applied axially.

NOTE:

(1) Reduced section *A* should not be less than width of weld plus 2*D*.

QW-462.1(e) TENSION — FULL SECTION — SMALL DIAMETER PIPE

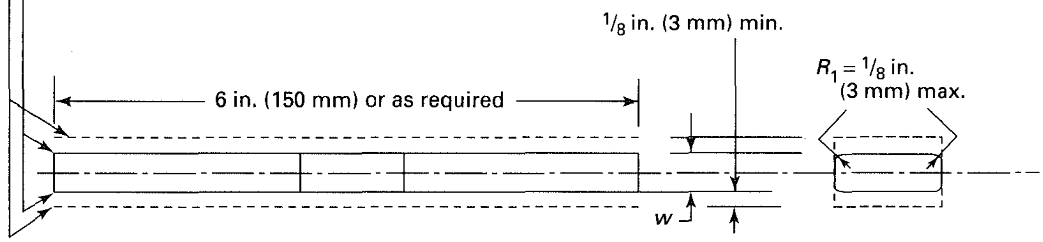


QW-462.2 SIDE BEND

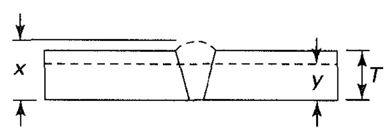
(1a) For procedure qualification of materials other than P-No. 1 in QW-422, if the surfaces of the side bend test specimens are gas cut, removal by machining or grinding of not less than 1/8 in. (3 mm) from the surface shall be required.

(1b) Such removal is not required for P-No. 1 materials, but any resulting roughness shall be dressed by machining or grinding.

(2) For performance qualification of all materials in QW-422, if the surfaces of side bend tests are gas cut, any resulting roughness shall be dressed by machining or grinding.



T, in. (mm)	*y*, in. (mm)	*w*, in. (mm)	
		P-No. 23, F-No. 23, or P-No. 35	All other metals
3/8 to < 1 1/2 (10 to < 38)	*T* [Note (1)]	1/8 (3)	3/8 (10)
≥ 1 1/2 (≥ 38)	Notes (1) and (2)	1/8 (3)	3/8 (10)



GENERAL NOTE: Weld reinforcement and backing strip or backing ring, if any, may be removed flush with the surface of the specimen. Thermal cutting, machining, or grinding may be employed. Cold straightening is permitted prior to removal of the reinforcement.

NOTES:

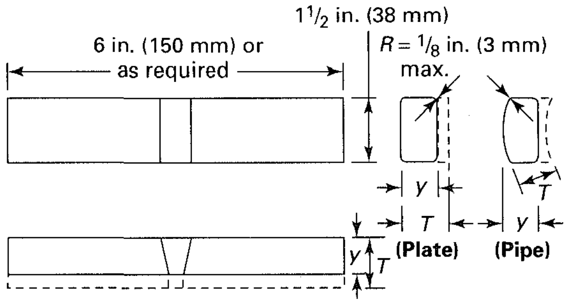
(1) When weld deposit t is less than coupon thickness T, side-bend specimen thickness may be t.

(2) When coupon thickness T equals or exceeds 1½ in. (38 mm), use one of the following:

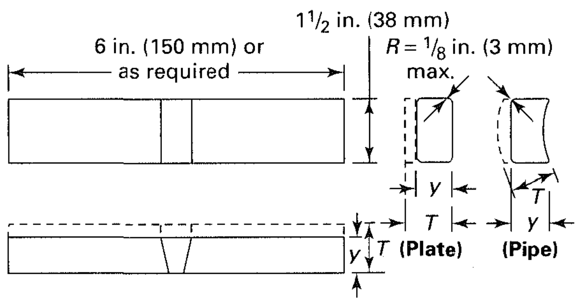
(a) Cut specimen into multiple test specimens of thickness y of approximately equal dimensions [¾ in. (19 mm) to 1½ in. (38 mm)]. y = tested specimen thickness when multiple specimens are taken from one coupon.

(b) The specimen may be bent at full width. See requirements on jig width in QW-466.1.

QW-462.3(a) FACE AND ROOT BENDS — TRANSVERSE



Face-Bend Specimen — Plate and Pipe



Root-Bend Specimen — Plate and Pipe

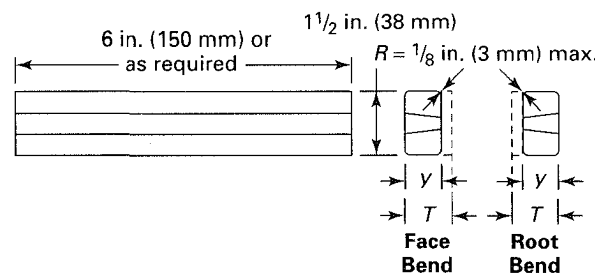
T, in. (mm)	Y, in. (mm) P-No. 23, F-No. 23, or P-No. 35	Y, in. (mm) All Other Metals
$^1/_{16}$ < $^1/_8$ (1.5 < 3)	T	T
$^1/_8$–$^3/_8$ (3–10)	$^1/_8$ (3)	T
>$^3/_8$ (10)	$^1/_8$ (3)	$^3/_8$ (10)

GENERAL NOTES:

(a) Weld reinforcement and backing strip or backing ring, if any, shall be removed flush with the surface of the specimen. If a recessed ring is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the ring, except that in such cases the thickness of the finished specimen shall be that specified above. Do not flame-cut nonferrous material.

(b) If the pipe being tested has a diameter of NPS 4 (DN 100) or less, the width of the bend specimen may be $^3/_4$ in. (19 mm) for pipe diameters NPS 2 (DN 50) to and including NPS 4 (DN 100). The bend specimen width may be $^3/_8$ in. (10 mm) for pipe diameters less than NPS 2 (DN 50) down to and including NPS $^3/_8$ (DN 10) and as an alternative, if the pipe being tested is equal to or less than NPS 1 (DN 25) pipe size, the width of the bend specimens may be that obtained by cutting the pipe into quarter sections, less an allowance for saw cuts or machine cutting. These specimens cut into quarter sections are not required to have one surface machined flat as shown in QW-462.3(a). Bend specimens taken from tubing of comparable sizes may be handled in a similar manner.

QW-462.3(b) FACE AND ROOT BENDS — LONGITUDINAL

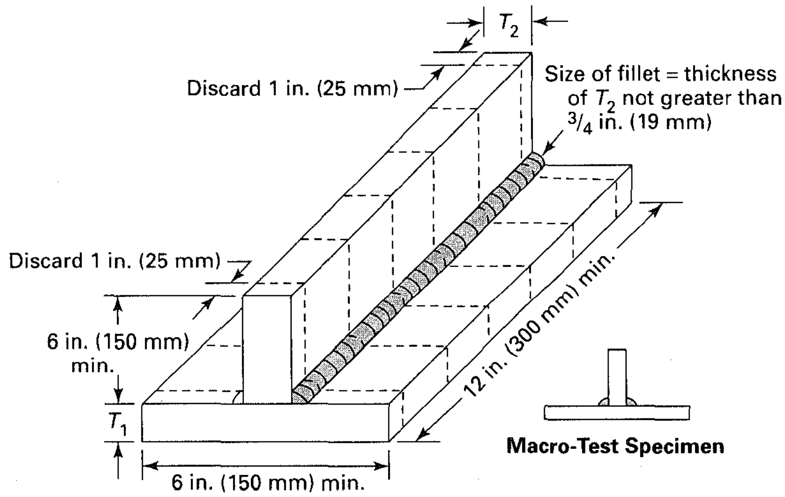


T, in. (mm)	Y, in. (mm) P-No. 23, F-No. 23, or P-No. 35	Y, in. (mm) All Other Metals
$^1/_{16}$ < $^1/_8$ (1.5 < 3)	T	T
$^1/_8$–$^3/_8$ (3–10)	$^1/_8$ (3)	T
>$^3/_8$ (10)	$^1/_8$ (3)	$^3/_8$ (10)

GENERAL NOTE: Weld reinforcements and backing strip or backing ring, if any, shall be removed essentially flush with the undisturbed surface of the base material. If a recessed strip is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the strip, except that in such cases the thickness of the finished specimen shall be that specified above.

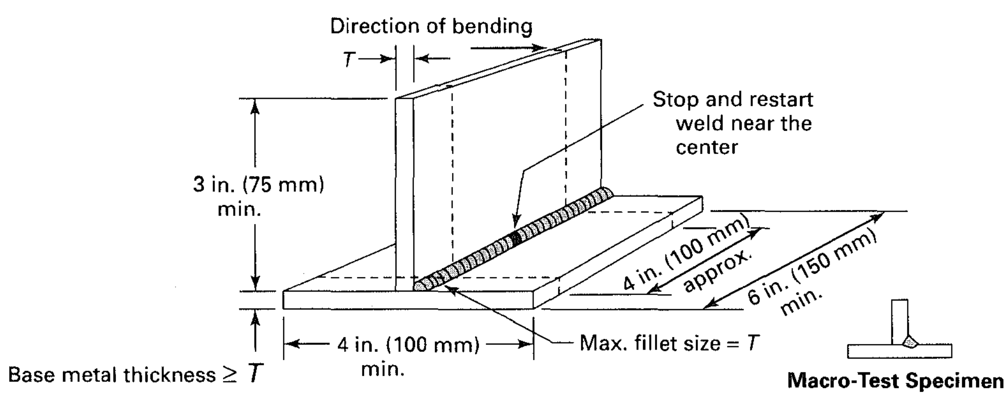
QW-462.4(a) FILLET WELDS IN PLATE — PROCEDURE (10)

T_1	T_2
$^1/_8$ in. (3 mm) and less	T_1
Over $^1/_8$ in. (3 mm)	Equal to or less than T_1, but not less than $^1/_8$ in. (3 mm)



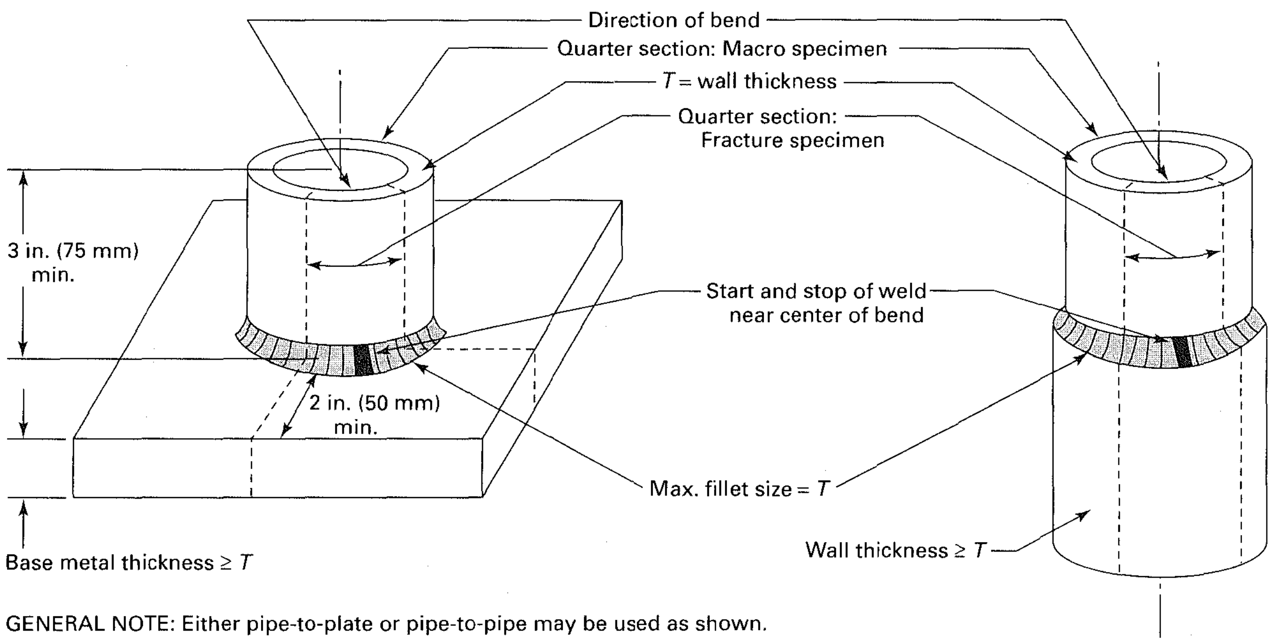
GENERAL NOTE: Macro-test — the fillet shall show fusion at the root of the weld but not necessarily beyond the root. The weld metal and heat-affected zone shall be free of cracks.

QW-462.4(b) FILLET WELDS IN PLATE — PERFORMANCE (10)



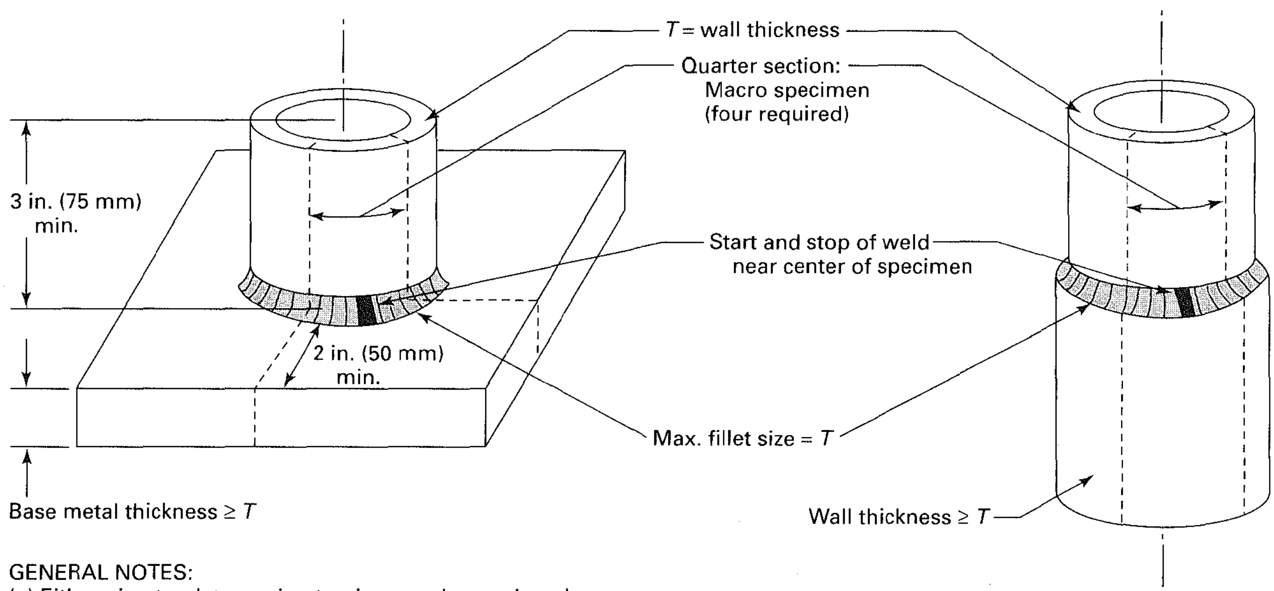
GENERAL NOTE: Refer to QW-452.5 for T thickness/qualification ranges.

QW-462.4(c) FILLET WELDS IN PIPE — PERFORMANCE



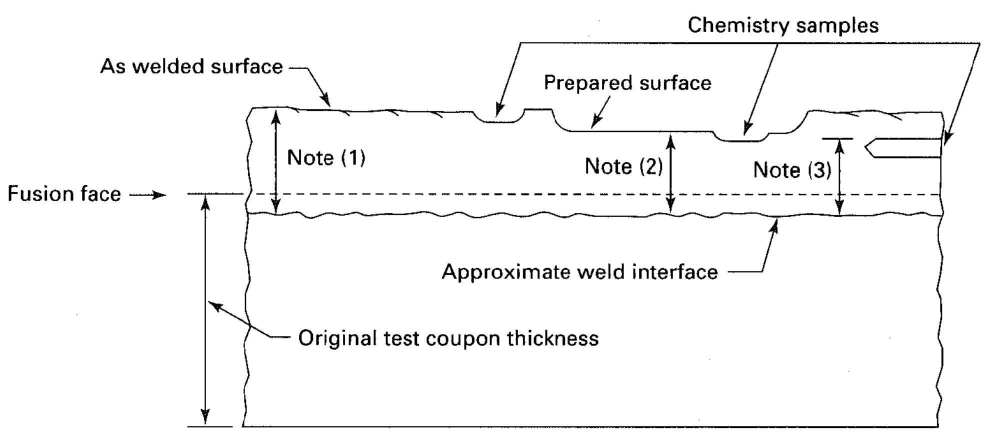
GENERAL NOTE: Either pipe-to-plate or pipe-to-pipe may be used as shown.

QW-462.4(d) FILLET WELDS IN PIPE — PROCEDURE



GENERAL NOTES:
(a) Either pipe-to-plate or pipe-to-pipe may be used as shown.
(b) Macro test:
 (1) The fillet shall show fusion at the root of the weld but not necessarily beyond the root.
 (2) The weld metal and the heat-affected zone shall be free of cracks.

QW-462.5(a) CHEMICAL ANALYSIS AND HARDNESS SPECIMEN CORROSION-RESISTANT AND HARD-FACING WELD METAL OVERLAY



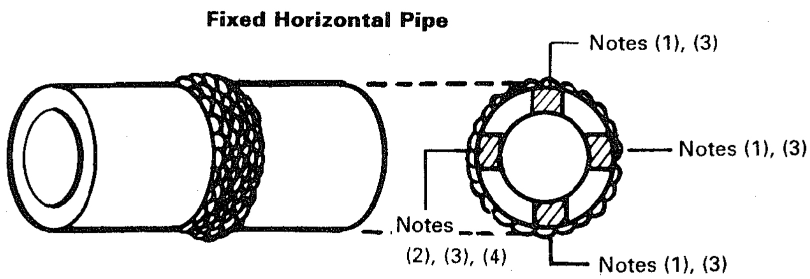
NOTES:

(1) When a chemical analysis or hardness test is conducted on the as welded surface, the distance from the approximate weld interface to the final as welded surface shall become the minimum qualified overlay thickness. The chemical analysis may be performed directly on the as welded surface or on chips of material taken from the as welded surface.

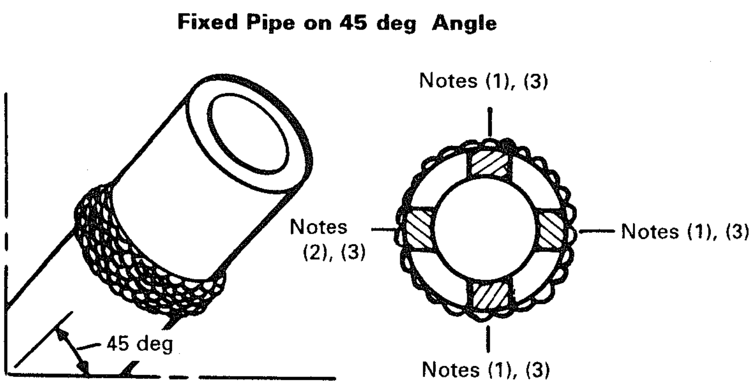
(2) When a chemical analysis or hardness test is conducted after material has been removed from the as welded surface, the distance from the approximate weld interface to the prepared surface shall become the minimum qualified overlay thickness. The chemical analysis may be made directly on the prepared surface or from chips removed from the prepared surface.

(3) When a chemical analysis test is conducted on material removed by a horizontal drilled sample, the distance from the approximate weld interface to the uppermost side of the drilled cavity shall become the minimum qualified overlay thickness. The chemical analysis shall be performed on chips of material removed from the drilled cavity.

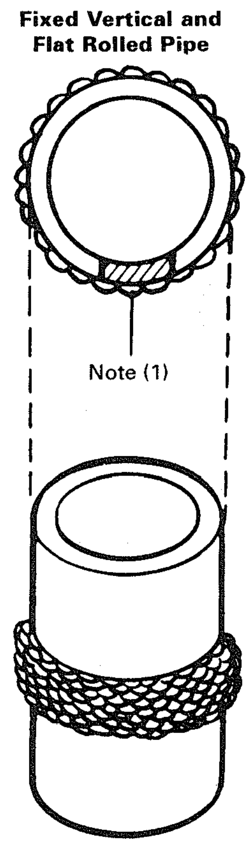
QW-462.5(b) CHEMICAL ANALYSIS SPECIMEN, HARD-FACING OVERLAY HARDNESS, AND MACRO TEST LOCATION(S) FOR CORROSION-RESISTANT AND HARD-FACING WELD METAL OVERLAY



Test Specimen Location for 5G Overlay Qualification
(Specimens Required From a Minimum of Three Locations)



Test Specimen Location for 6G Overlay Qualification
(Specimens Required From a Minimum of Three Locations)



Test Specimen Location for
2G and 1G Rotated Overlay Qualification
(Specimens Required From One Location)

GENERAL NOTE: Overlay may be on the inside or outside of pipe.

NOTES:

(1) Location of required test specimen removal (QW-453). Refer to QW-462.5(a) for chemical analysis and hardness test surface locations and minimum qualified thickness.

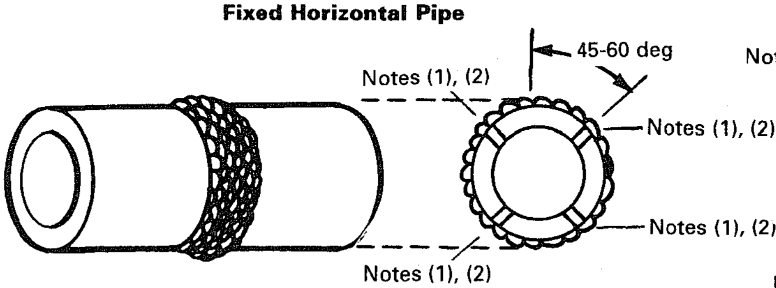
(2) Testing of circumferential hard-facing weld metal on pipe procedure qualification coupons may be limited to a single segment (completed utilizing the vertical, up-hill progression) for the chemical analysis, hardness, and macro-etch tests required in QW-453. Removal is required for a change from vertical down to vertical up-hill progression (but not vice-versa).

(3) Location of test specimens shall be in accordance with the angular position limitations of QW-120.

(4) When overlay welding is performed using machine or automatic welding and the vertical travel direction of adjacent weld beads is reversed on alternate passes, only one chemical analysis or hardness specimen is required to represent the vertical portion. Qualification is then restricted in production to require alternate pass reversal of rotation direction method.

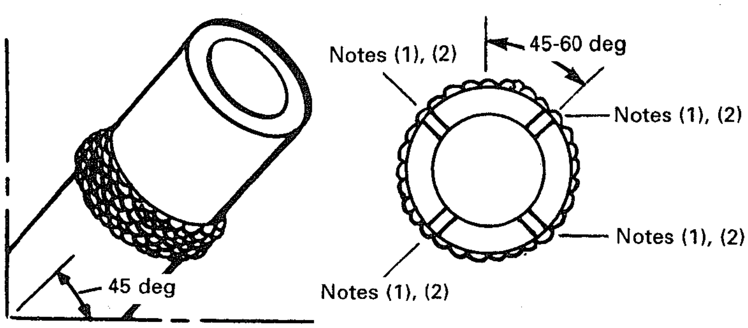
QW-462.5(c) PIPE BEND SPECIMEN — CORROSION-RESISTANT WELD METAL OVERLAY

Fixed Horizontal Pipe



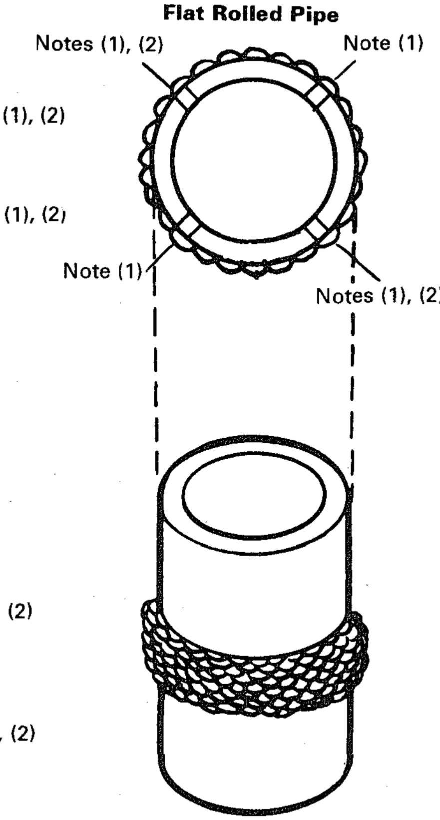
Test Specimen Location for 5G
Overlay Qualification

Fixed Pipe on 45 deg Angle



Test Specimen Location for 6G
Overlay Qualification

Fixed Vertical and
Flat Rolled Pipe

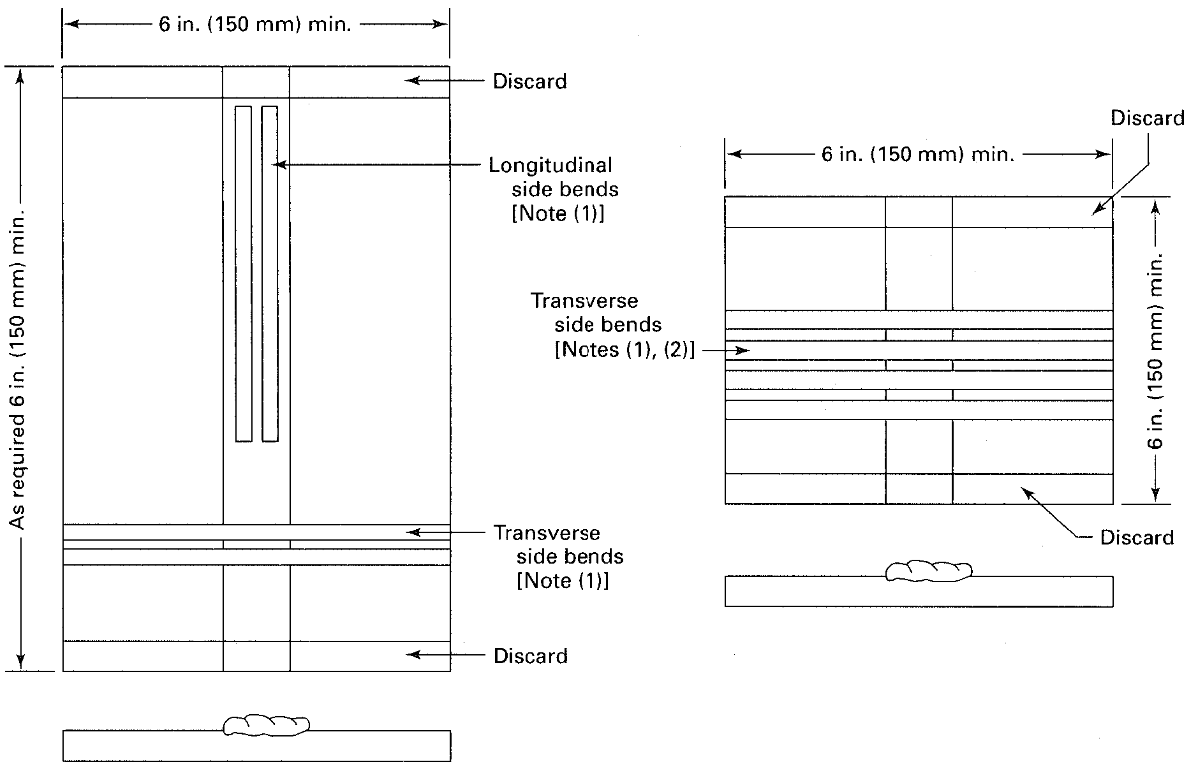


Test Specimen Location for
2G and 1G Rotated
Overlay Qualification

GENERAL NOTE: Overlay may be on the inside or outside of pipe.

NOTES:
(1) Location for required test specimen removal — Procedure (QW-453).
(2) Location for required test specimen removal — Performance (QW-453).

QW-462.5(d) PLATE BEND SPECIMENS — CORROSION-RESISTANT WELD METAL OVERLAY

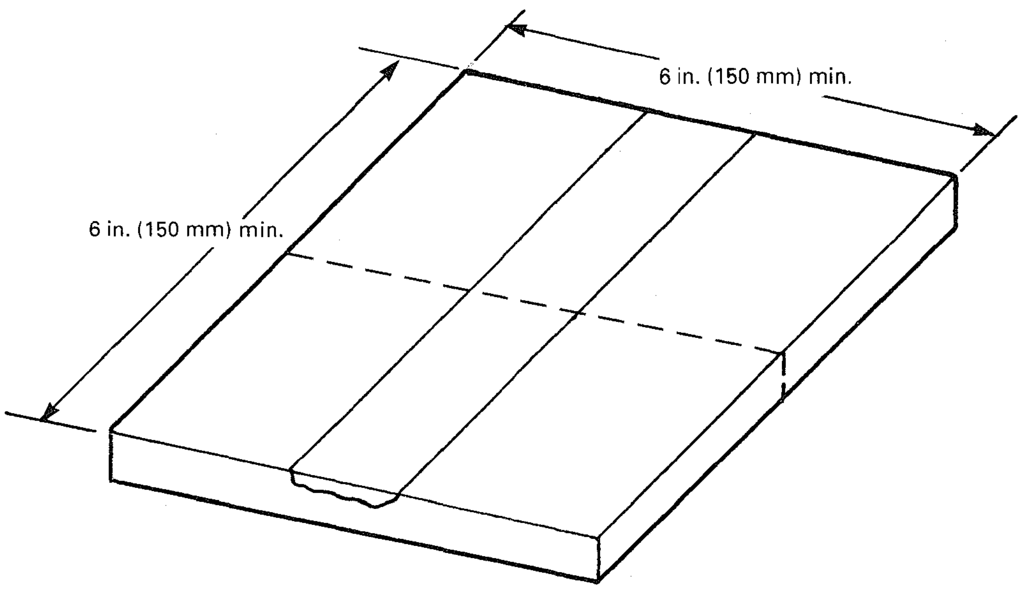


NOTES:

(1) Location for required test specimen removal — Procedure (QW-453). Four-side-bend test specimens are required for each position.

(2) Location for required test specimen removal — Performance (QW-453). Two-side-bend test specimens are required for each position.

QW-462.5(e) PLATE MACRO, HARDNESS, AND CHEMICAL ANALYSIS SPECIMENS — CORROSION-RESISTANT AND HARD-FACING WELD METAL OVERLAY (10)

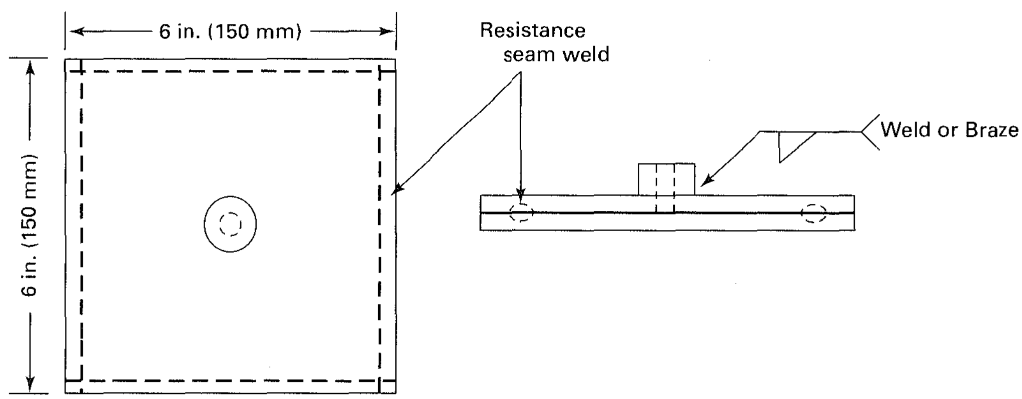


GENERAL NOTES:

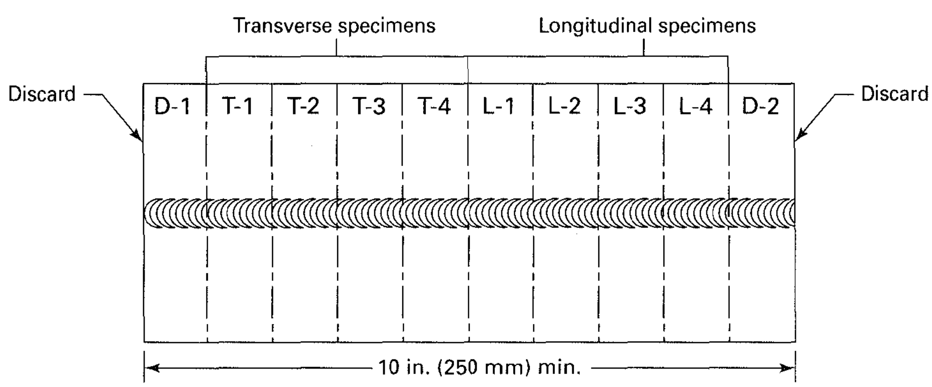
(a) Location of required test specimen removal (QW-453). One required for each position. Refer to QW-462.5(a) for chemical analysis and hardness test surface locations and minimum qualified thickness.

(b) Removal required for a change from vertical up to vertical down and vice versa.

QW-462.7.1 RESISTANCE SEAM WELD TEST COUPON



QW-462.7.2 SEAM WELD SECTION SPECIMEN REMOVAL



GENERAL NOTE: Mark the coupon into ten equal length specimens, label one end of the coupon D-1 the other end D-2. Cut the 10 in. (250 mm) coupon (transverse to the weld length) into pieces 5 in. (125 mm) long each.

(a) Transverse Weld Cross Section Instructions

(1) Cut five specimens each approximately 1 in. (25 mm) in length from the coupon labeled D-1 and discard the piece marked D-1.

(2) Mark the remaining four specimens T-1 through T-4, prepare the specimens as detailed in (b)(2)(a) below for examination, adjacent faces at the cut shall not be used.

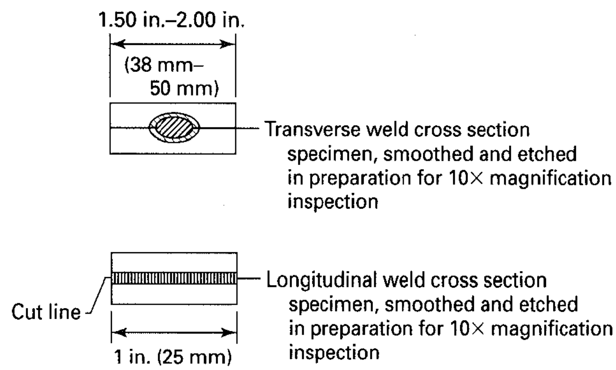
(b) Longitudinal Weld Cross Section Instructions

(1) Cut five specimens each approximately 1 in. (25 mm) in length from the coupon labeled D-2 and discard the piece marked D-2.

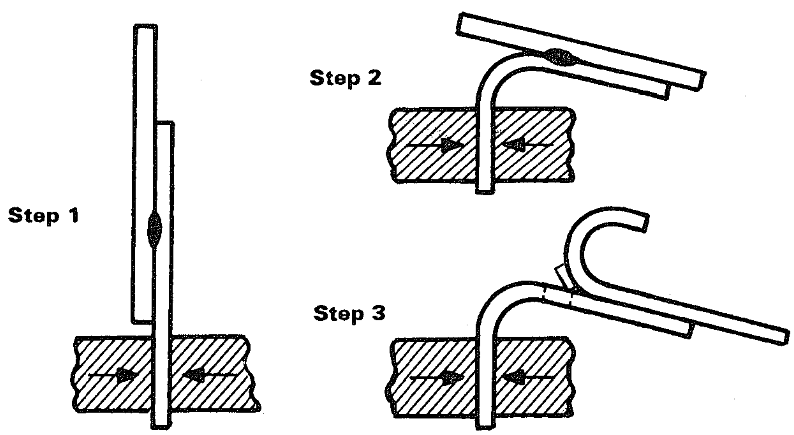
(2) Mark the remaining four specimens L-1 through L-4, cut the specimens at approximately $\frac{1}{3}$ of the weld width from the weld centerline through the length of each specimen in the longitudinal weld direction. Discard the four specimens containing approximately the $\frac{1}{3}$ weld width, the remaining four specimens containing approximately the $\frac{2}{3}$ weld width shall be prepared as detailed in (a) below for examination.

(a) The specimens 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.

QW-462.7.3 RESISTANCE WELD NUGGET SECTION TEST SPECIMENS



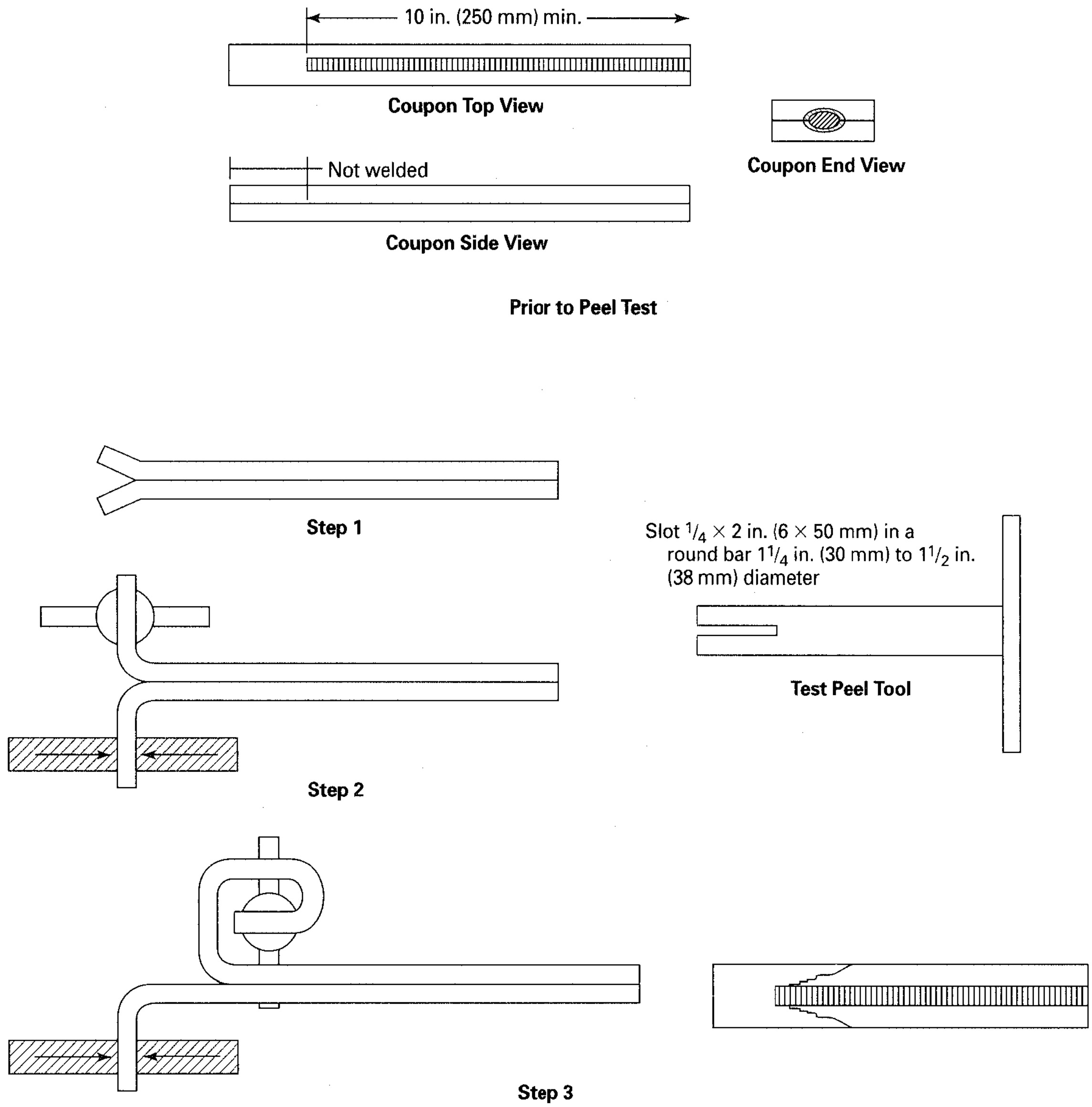
QW-462.8.1 SPOT WELDS IN SHEETS



Peel Test

Step 1 - Grip in vise or other suitable device.
Step 2 - Bend specimen.
Step 3 - Peel pieces apart with pincers or other suitable tool.

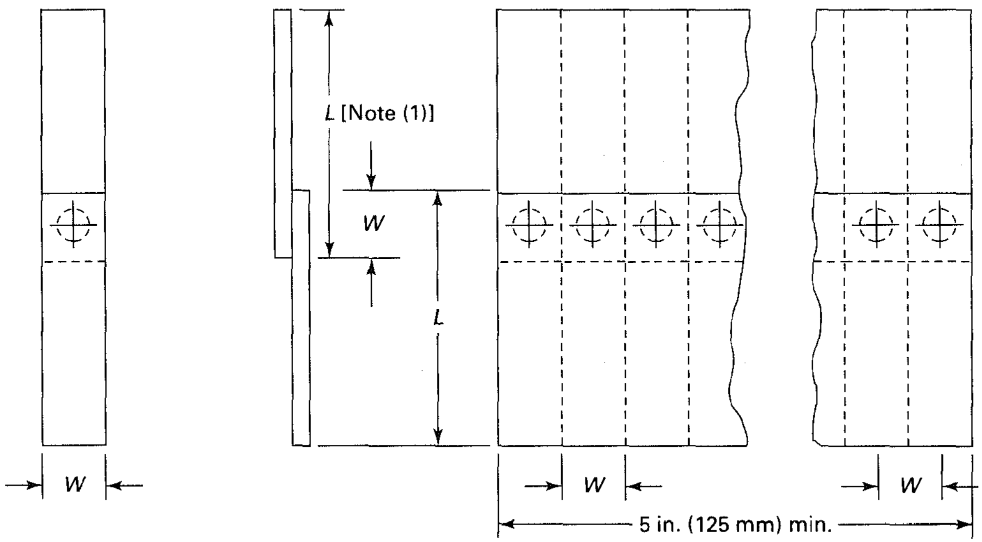
QW-462.8.2 SEAM WELD PEEL TEST SPECIMEN AND METHOD



Peel Test

Step 1 — Separate coupon plies in nonwelded end.
Step 2 — Grip in vise or other suitable device, bend specimen.
Step 3 — Peel pieces apart with pincers or other suitable tool.

QW-462.9 SPOT WELDS IN SHEET



(a) Single Spot Shear Specimen

(b) Multiple Spot Shear Specimen [Note (2)]

Nominal Thickness of Thinner Sheet, in. (mm)	W, in. (mm) Min.
Over 0.008 to 0.030 (0.20 to 0.8)	0.68 (17)
Over 0.030 to 0.100 (0.8 to 2.5)	1.00 (25)
Over 0.100 to 0.130 (2.5 to 3)	1.25 (30)
Over 0.130 (3)	1.50 (38)

NOTES:

(1) *L* shall be not less than 4*W*.

(2) Sketch (b) shall be made of 5 specimens or more.

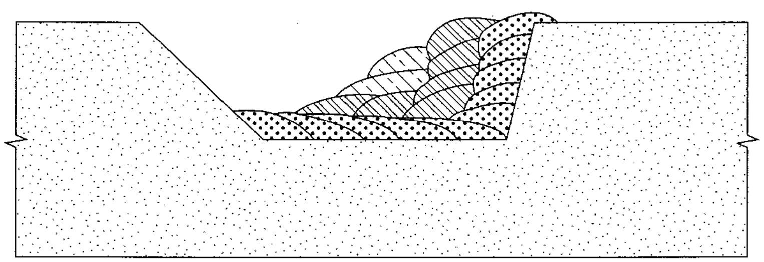
QW-462.10
SHEAR STRENGTH REQUIREMENTS FOR SPOT OR PROJECTION WELD SPECIMENS

Customary Units					SI Units				
P-No. 1 Through P-No. 11 and P-No. 41 Through P-No. 49 Metals					P-No. 1 Through P-No. 11 and P-No. 41 Through P-No. 49 Metals				
	Ultimate Strength 90,000 to 149,000 psi		Ultimate Strength Below 90,000 psi			Ultimate Strength 620 MPa to 1 027 MPa		Ultimate Strength Below 620 MPa	
Nominal Thickness of Thinner Sheet,	lb per Spot		lb per Spot		Nominal Thickness of Thinner Sheet,	kg per Spot		kg per Spot	
in.	Min.	Min. Avg.	Min.	Min. Avg.	mm	Min.	Min. Avg.	Min.	Min. Avg.
0.009	130	160	100	125	0.2	59	73	45	57
0.010	160	195	115	140	0.25	73	88	52	64
0.012	200	245	150	185	0.30	91	111	68	84
0.016	295	365	215	260	0.41	134	166	98	118
0.018	340	415	250	305	0.46	154	188	113	138
0.020	390	480	280	345	0.51	177	218	127	156
0.022	450	550	330	405	0.56	204	249	150	184
0.025	530	655	400	495	0.64	240	297	181	225
0.028	635	785	465	575	0.71	288	356	211	261
0.032	775	955	565	695	0.81	352	433	256	315
0.036	920	1,140	690	860	0.91	417	517	313	390
0.040	1,065	1,310	815	1,000	1.0	483	594	370	454
0.045	1,285	1,585	1,005	1,240	1.1	583	719	456	562
0.050	1,505	1,855	1,195	1,475	1.3	683	841	542	669
0.056	1,770	2,185	1,460	1,800	1.4	803	991	662	816
0.063	2,110	2,595	1,760	2,170	1.6	957	1 177	798	984
0.071	2,535	3,125	2,080	2,560	1.8	1 150	1 418	943	1 161
0.080	3,005	3,705	2,455	3,025	2.0	1 363	1 681	1 114	1 372
0.090	3,515	4,335	2,885	3,560	2.3	1 594	1 966	1 309	1 615
0.100	4,000	4,935	3,300	4,070	2.54	1 814	2 239	1 497	1 846
0.112	4,545	5,610	3,795	4,675	2.84	2 062	2 545	1 721	2 121
0.125	5,065	6,250	4,300	5,310	3.18	2 297	2 835	1 950	2 409

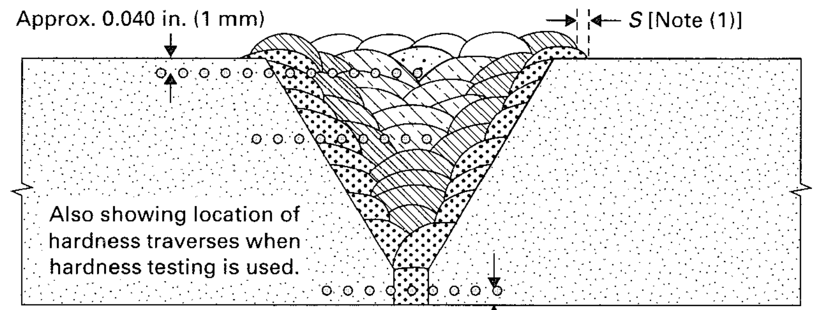
QW-462.11
SHEAR STRENGTH REQUIREMENTS FOR SPOT OR PROJECTION WELD SPECIMENS

U.S. Customary Units							SI Units					
P-No. 21 Through P-No. 25 Aluminum Alloys							P-No. 21 Through P-No. 25 Aluminum Alloys					
Nominal Thickness of Thinner Sheet, in.	Ultimate Strength 35,000 to 55,999 psi, lb per Spot		Ultimate Strength 19,500 to 34,999 psi, lb per Spot		Ultimate Strength Below 19,500 psi, lb per Spot		Nominal Thickness of Thinner Sheet, mm	Ultimate Strength 241 MPa to 386 MPa, kg per Spot		Ultimate Strength 134 MPa to 241 MPa, kg per Spot		Ultimate Strength Below 134 MPa, kg per Spot	
	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.		Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.
0.010	50	65	...	...	...	...	0.25	23	29	...	...	...	...
0.012	65	85	30	40	20	25	0.30	29	39	14	18	9	11
0.016	100	125	70	90	50	65	0.41	45	57	32	41	23	29
0.018	115	145	85	110	65	85	0.46	52	66	39	50	29	39
0.020	135	170	100	125	80	100	0.51	61	77	45	57	36	45
0.022	155	195	120	150	95	120	0.56	70	88	54	68	43	54
0.025	175	200	145	185	110	140	0.64	79	91	66	84	50	64
0.028	205	260	175	220	135	170	0.71	93	118	79	100	61	77
0.032	235	295	210	265	165	210	0.81	107	134	95	120	75	95
0.036	275	345	255	320	195	245	0.91	125	156	116	145	88	111
0.040	310	390	300	375	225	285	1.0	141	177	136	170	102	129
0.045	370	465	350	440	260	325	1.1	168	211	159	200	118	147
0.050	430	540	400	500	295	370	1.3	195	245	181	227	134	168
0.057	515	645	475	595	340	425	1.45	234	293	215	270	154	193
0.063	610	765	570	715	395	495	1.6	277	347	259	324	179	225
0.071	720	900	645	810	450	565	1.8	327	408	293	367	204	256
0.080	855	1,070	765	960	525	660	2.0	388	485	347	435	238	299
0.090	1,000	1,250	870	1,090	595	745	2.3	454	567	395	494	270	338
0.100	1,170	1,465	940	1,175	675	845	2.54	531	665	426	533	306	383
0.112	1,340	1,675	1,000	1,255	735	920	2.84	608	760	454	569	333	417
0.125	1,625	2,035	1,050	1,315	785	985	3.18	737	923	476	596	356	447
0.140	1,920	2,400	...	...	...	...	3.56	871	1 089	...	...	...	...
0.160	2,440	3,050	...	...	...	...	4.06	1 107	1 383	...	...	...	...
0.180	3,000	3,750	...	...	...	...	4.57	1 361	1 701	...	...	...	...
0.190	3,240	4,050	...	...	...	...	4.83	1 470	1 837	...	...	...	...
0.250	6,400	8,000	...	...	...	...	6.35	2 903	3 629	...	...	...	...

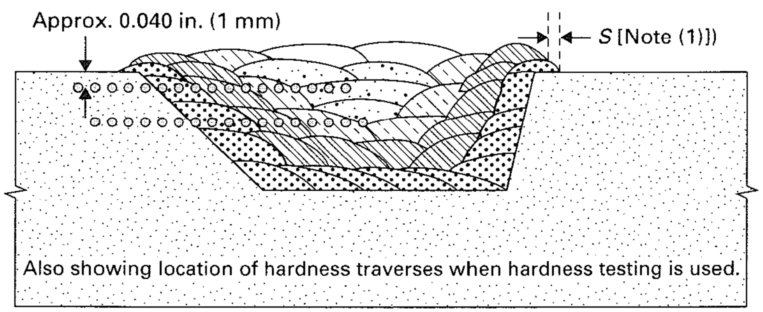
QW-462.12 NOMENCLATURE FOR TEMPER BEAD WELDING



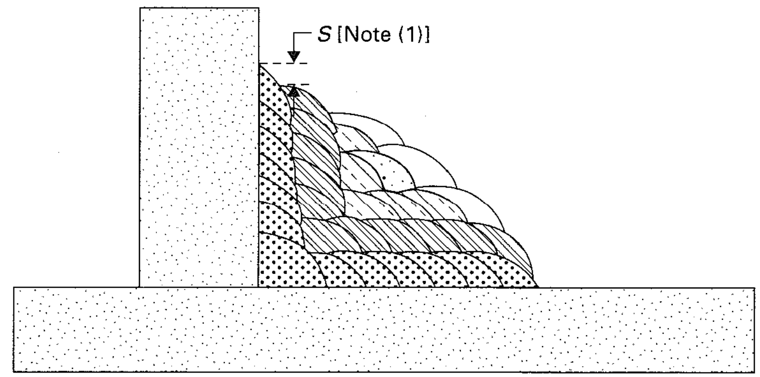
Partially Completed Partial-Penetration Weld



Typical Groove Weld

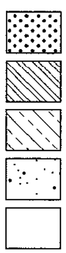


Completed Partial-Penetration Weld



Typical Fillet Weld

LEGEND
See Note (2)



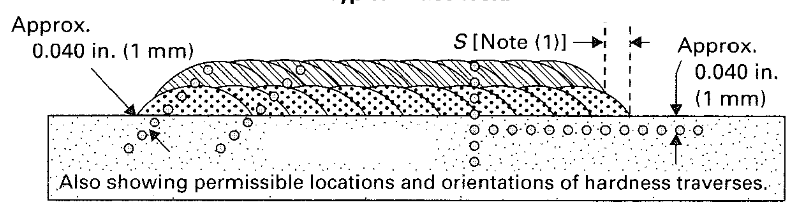
Weld Beads against Base Metal

First Layer Tempering Beads

Second Layer Tempering Beads

Fill Weld Beads

Surface Temper Weld Reinforcing Beads



Overlay Weld

GENERAL NOTES:

(a) Weld beads shown above may be deposited in any sequence that will result in placement of the beads as shown.

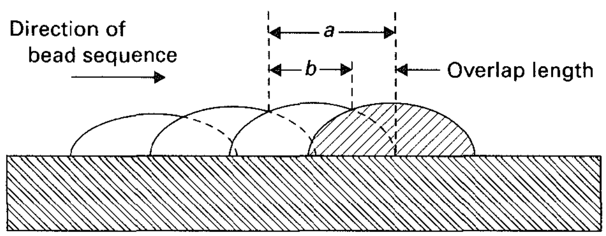
(b) Surface temper reinforcing beads may cover the entire weld surface, or may only be placed at the toe of the weld; they may or may not be mechanically removed.

NOTES:

(1) The distance, *S*, is measured from the toe of the weld to the edge of the temper beads. Measurements shall be made parallel to the base metal surface.

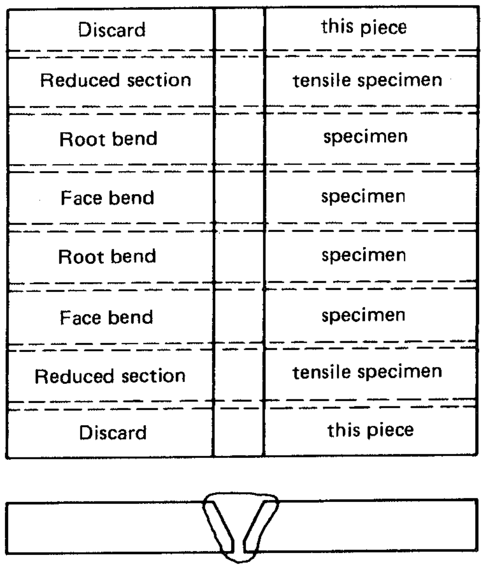
(2) Beads near the finished surface may be both tempering beads and surface temper reinforcing beads.

QW-462.13 MEASUREMENT OF TEMPER BEAD OVERLAP

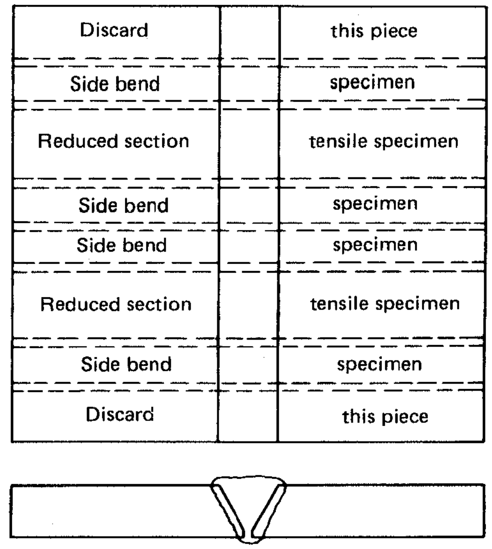


GENERAL NOTE: Measurement of bead overlap – % overlap length = (a–b)/a × 100%. In this figure, the shaded bead overlaps previous bead by 30% to 40%. The distance *a* is measured before the next bead is deposited.

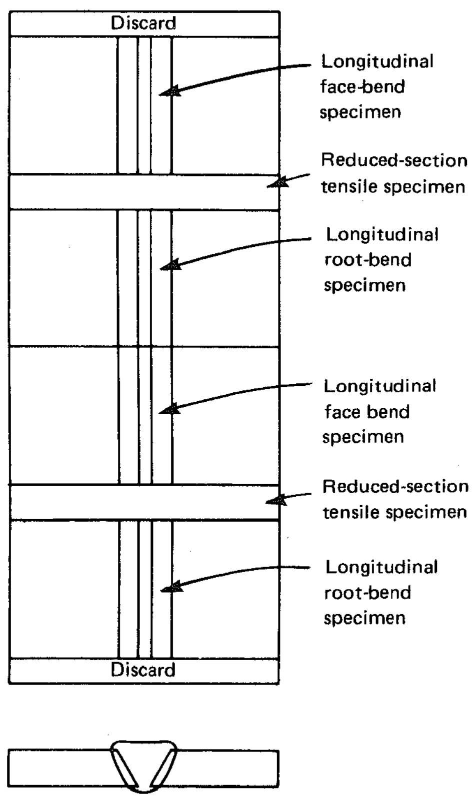
QW-463.1(a) PLATES — LESS THAN $^3/_4$ in. (19 mm) THICKNESS PROCEDURE QUALIFICATION



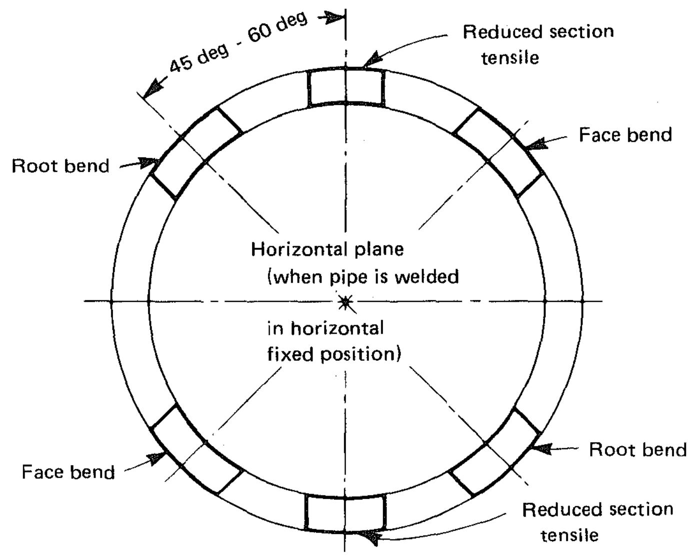
QW-463.1(b) PLATES — $^3/_4$ in. (19 mm) AND OVER THICKNESS AND ALTERNATE FROM $^3/_8$ in. (10 mm) BUT LESS THAN $^3/_4$ in. (19 mm) THICKNESS PROCEDURE QUALIFICATION



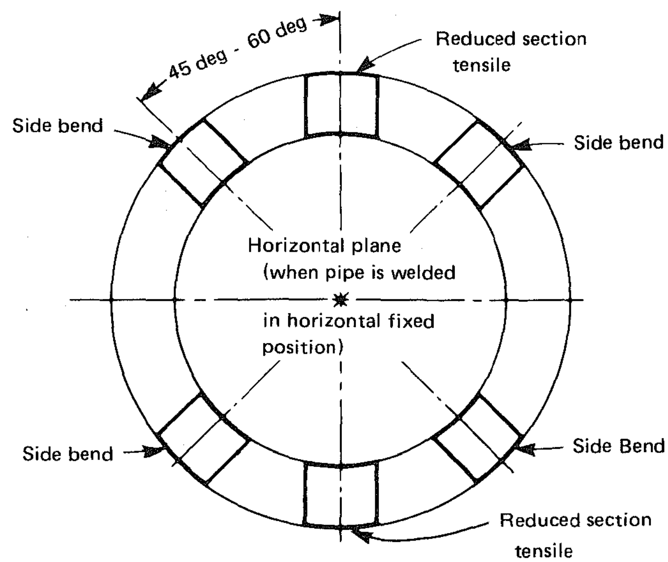
QW-463.1(c) PLATES — LONGITUDINAL PROCEDURE QUALIFICATION



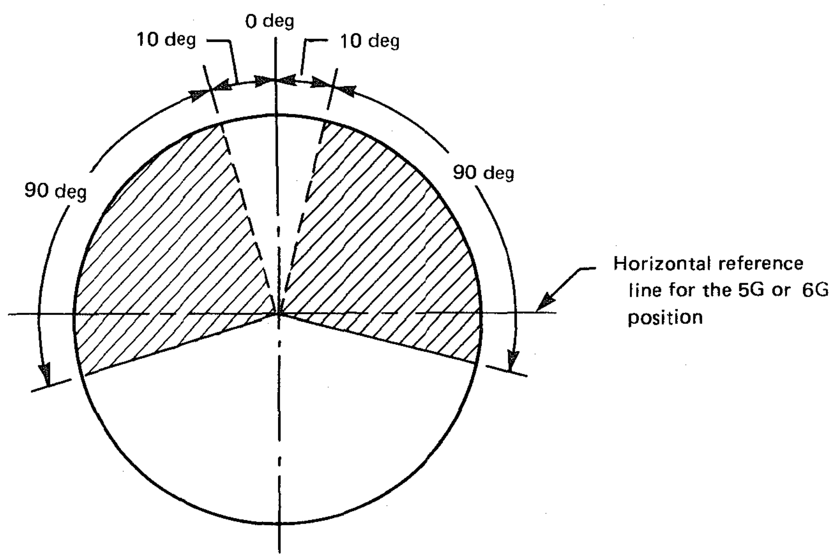
QW-463.1(d) PROCEDURE QUALIFICATION



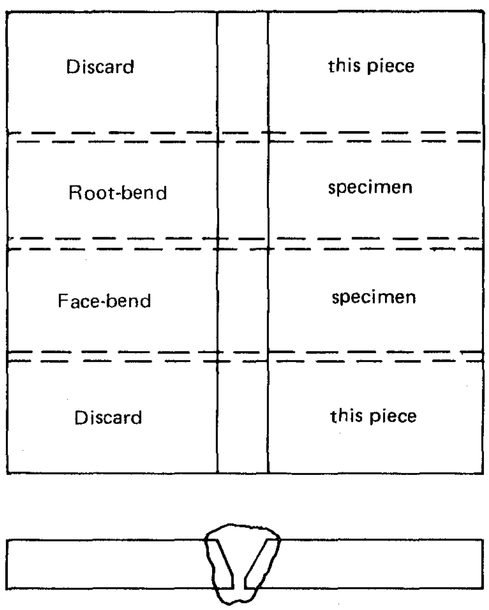
QW-463.1(e) PROCEDURE QUALIFICATION



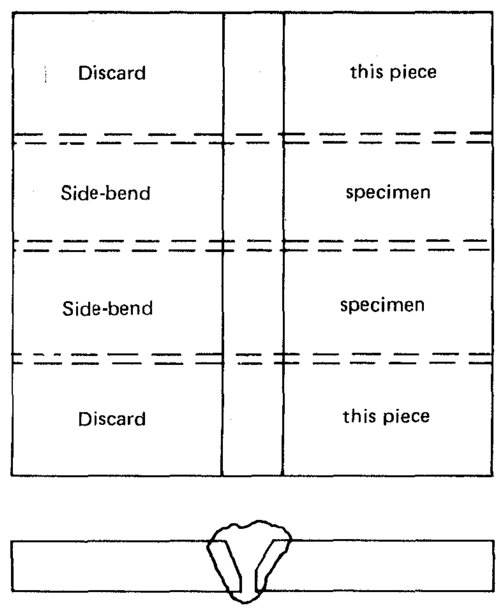
QW-463.1(f) NOTCH-TOUGHNESS TEST SPECIMEN LOCATION



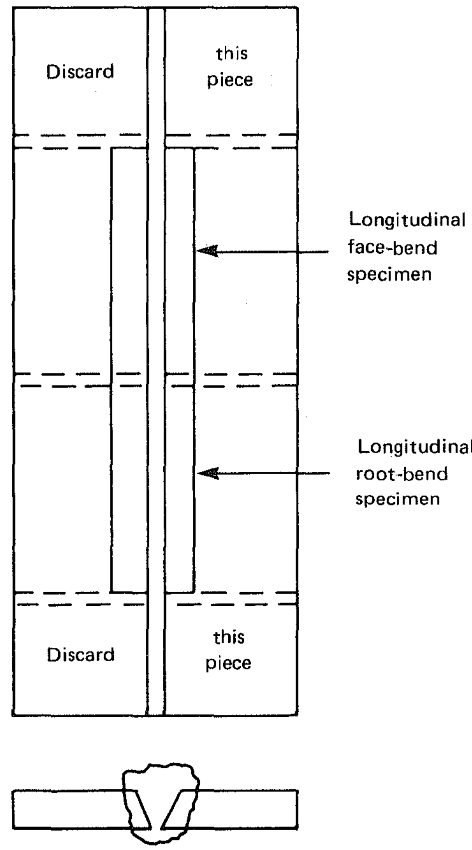
QW-463.2(a) PLATES — LESS THAN 3/4 in. (19 mm) THICKNESS PERFORMANCE QUALIFICATION



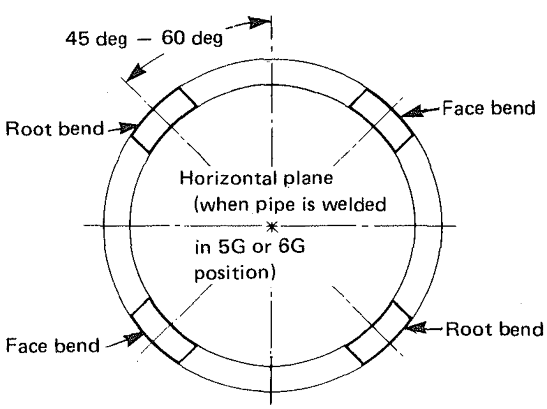
QW-463.2(b) PLATES — 3/4 in. (19 mm) AND OVER THICKNESS AND ALTERNATE FROM 3/8 in. (10 mm) BUT LESS THAN 3/4 in. (19 mm) THICKNESS PERFORMANCE QUALIFICATION



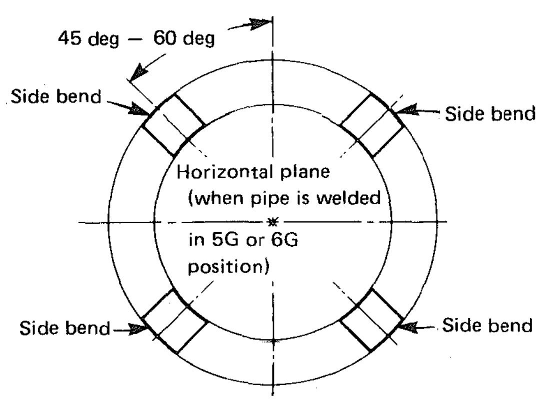
QW-463.2(c) PLATES — LONGITUDINAL PERFORMANCE QUALIFICATION



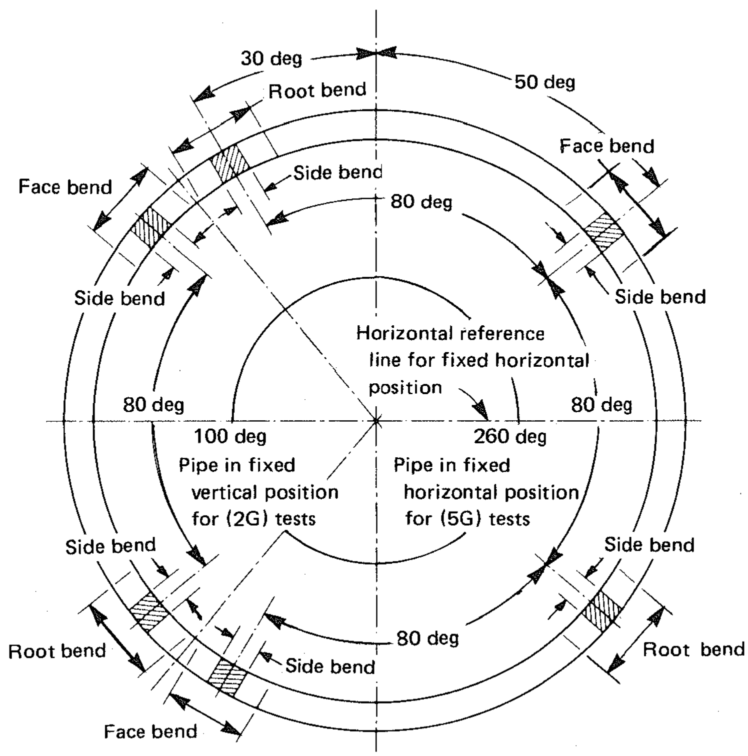
QW-463.2(d) PERFORMANCE QUALIFICATION



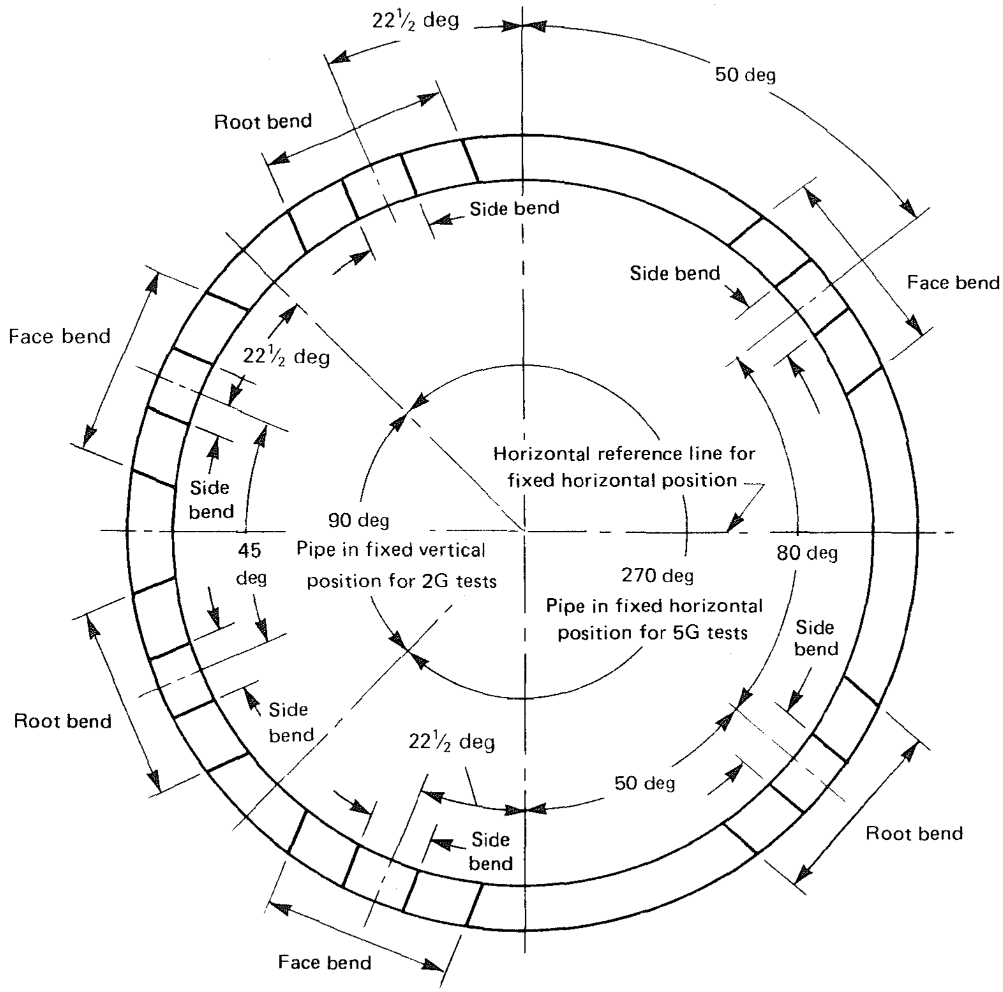
QW-463.2(e) PERFORMANCE QUALIFICATION



QW-463.2(f) PIPE — NPS 10 (DN 250) ASSEMBLY PERFORMANCE QUALIFICATION



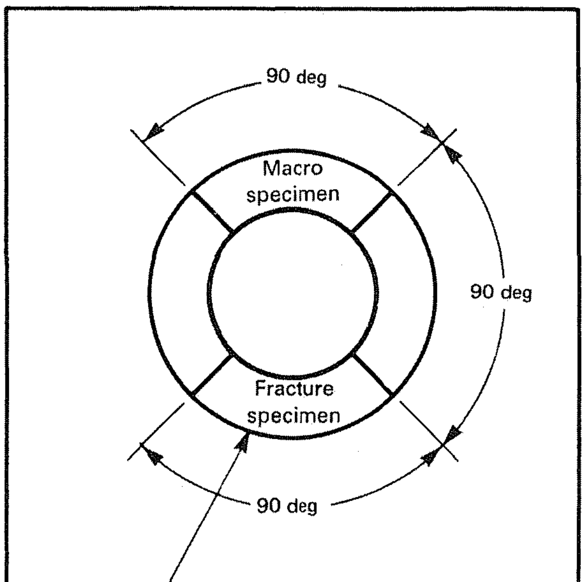
QW-463.2(g) NPS 6 (DN 150) OR NPS 8 (DN 200) ASSEMBLY PERFORMANCE QUALIFICATION



GENERAL NOTE: When side bend tests are made in accordance with QW-452.1 and QW-452.3, they shall be removed as shown in QW-463.2(g) in place of the face and root bends.

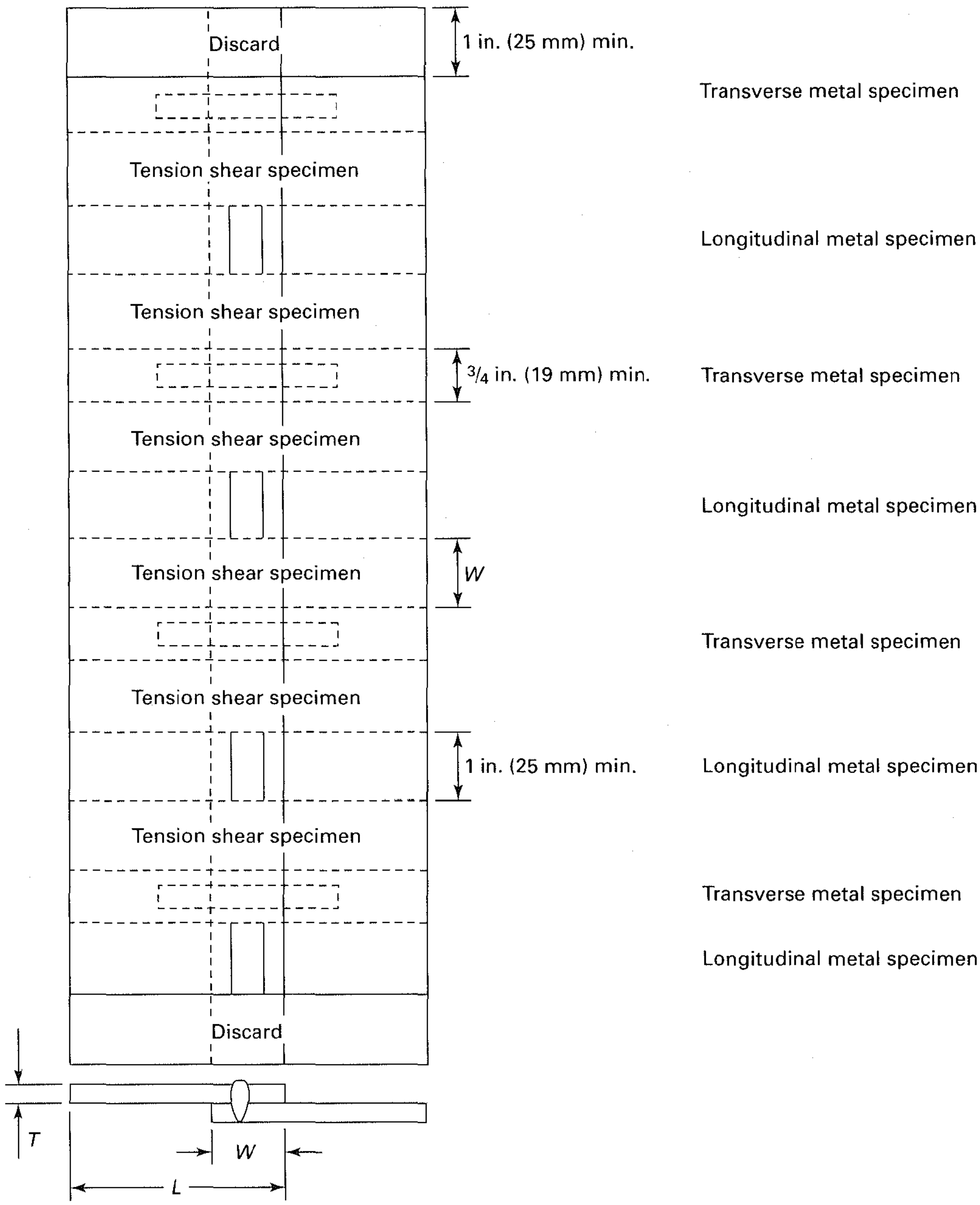
(10)

QW-463.2(h) PERFORMANCE QUALIFICATION



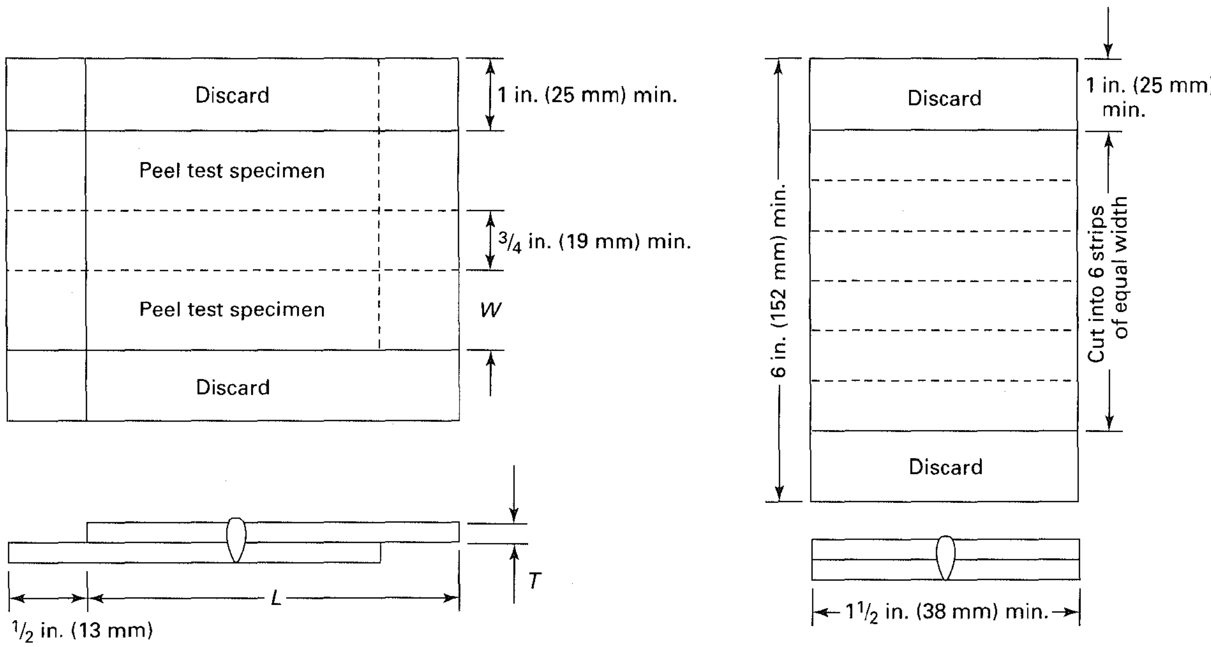
Fracture specimen to be removed from lower 90 deg section in position 5F

QW-464.1 PROCEDURE QUALIFICATION TEST COUPON AND TEST SPECIMENS



Thickness of Thinner, Sheet, T, in. (mm)	Specimen Width, W, in. (mm)	Recommended Length, L, in. (mm)
Up to 0.029 (0.74)	$\frac{5}{8}$ (16)	3 (75)
0.031 to 0.050 (0.79 to 1.2)	$\frac{3}{4}$ (19)	3 (75)
0.051 to 0.100 (1.3 to 2.54)	1 (25)	4 (100)
0.101 to 0.130 (2.57 to 3.30)	$1\frac{1}{4}$ (32)	5 (125)
0.131 to 0.190 (3.33 to 4.83)	$1\frac{1}{2}$ (38)	5 (125)
0.191 (4.85) and over	2 (50)	6 (150)

QW-464.2 PERFORMANCE QUALIFICATION TEST COUPONS AND TEST SPECIMENS

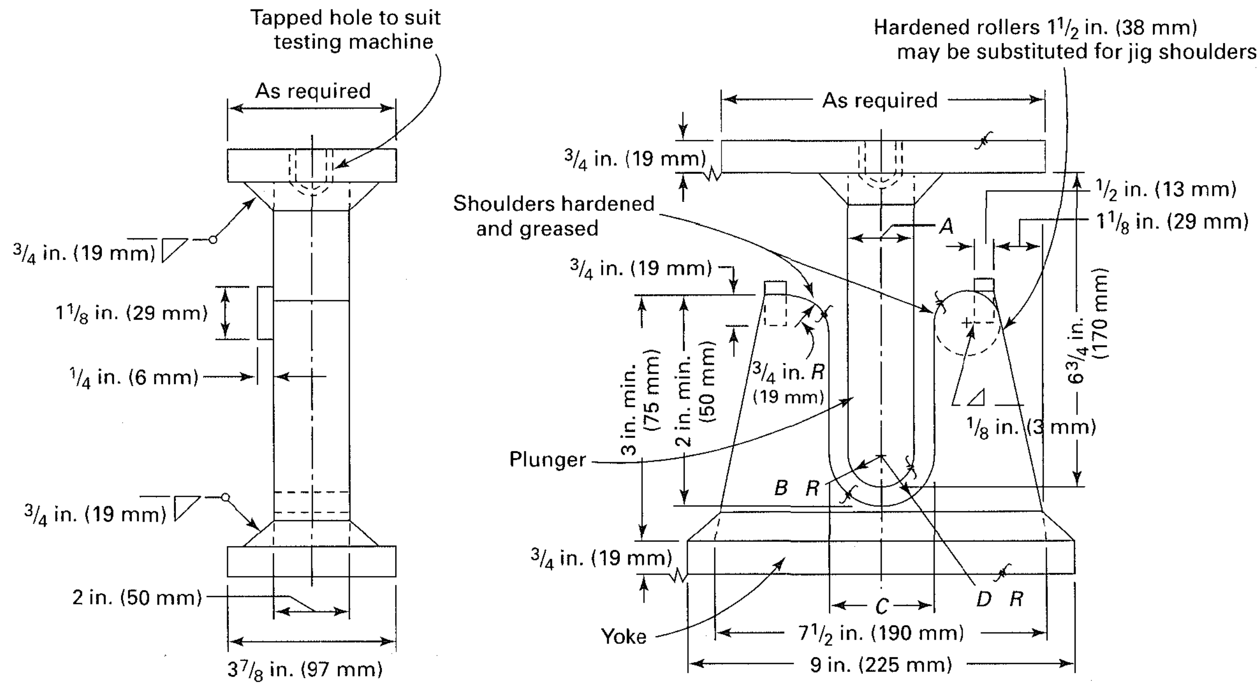


(b) Metallurgical Examination Coupon and Transverse Specimens

Thickness of Thinner Sheet, T, in. (mm)	Specimen Width, W, in. (mm)	Recommended Length, L, in. (mm)
Up to 0.029 (0.74)	$\frac{5}{8}$ (16)	2 (50)
0.030 to 0.058 (0.75 to 1.4)	1 (25)	3 (75)
0.059 to 0.125 (1.5 to 3.2)	$1\frac{1}{2}$ (38)	4 (100)

(a) Peel Test Coupon and Specimens

QW-466.1 TEST JIG DIMENSIONS



Customary Units

Material	Thickness of Specimen, in.	A, in.	B, in.	C, in.	D, in.
P-No. 23 to P-No. 21 through P-No 25; P-No. 21 through P-No. 25 with F-No. 23; P-No. 35; any P-No. metal with F-No. 33, 36, or 37	$\frac{1}{8}$ $t = \frac{1}{8}$ or less	$2\frac{1}{16}$ $16\frac{1}{2}t$	$1\frac{1}{32}$ $8\frac{1}{4}t$	$2\frac{3}{8}$ $18\frac{1}{2}t + \frac{1}{16}$	$1\frac{3}{16}$ $9\frac{1}{4}t + \frac{1}{32}$
P-No. 11; P-No. 25 to P-No. 21 or P-No. 22 or P-No. 25	$\frac{3}{8}$ $t = \frac{3}{8}$ or less	$2\frac{1}{2}$ $6\frac{2}{3}t$	$1\frac{1}{4}$ $3\frac{1}{3}t$	$3\frac{3}{8}$ $8\frac{2}{3}t + \frac{1}{8}$	$1\frac{11}{16}$ $4\frac{1}{3}t + \frac{1}{16}$
P-No. 51; P-No. 49	$\frac{3}{8}$ $t = \frac{3}{8}$ or less	3 $8t$	$1\frac{1}{2}$ $4t$	$3\frac{7}{8}$ $10t + \frac{1}{8}$	$1\frac{15}{16}$ $5t + \frac{1}{16}$
P-No. 52; P-No. 53; P-No. 61; P-No. 62	$\frac{3}{8}$ $t = \frac{3}{8}$ or less	$3\frac{3}{4}$ $10t$	$1\frac{7}{8}$ $5t$	$4\frac{5}{8}$ $12t + \frac{1}{8}$	$2\frac{5}{16}$ $6t + \frac{1}{16}$
All others with greater than or equal to 20% elongation	$\frac{3}{8}$ $t = \frac{3}{8}$ or less	$1\frac{1}{2}$ $4t$	$\frac{3}{4}$ $2t$	$2\frac{3}{8}$ $6t + \frac{1}{8}$	$1\frac{3}{16}$ $3t + \frac{1}{16}$
Materials with 3% to less than 20% elongation	t = [see Note (b)]	$32\frac{7}{8}t$ max.	$16\frac{7}{16}t$ max.	$A + 2t + \frac{1}{16}$ max.	$\frac{1}{2}C + \frac{1}{32}$ max.

QW-466.1 TEST JIG DIMENSIONS (CONT'D)

SI Units

Material	Thickness of Specimen, mm	*A*, mm	*B*, mm	*C*, mm	*D*, mm
P-No. 23 to P-No. 21 through P-No. 25; P-No. 21 through P-No. 25 with F-No. 23; P-No. 35; any P-No. metal with F-No. 33, 36, or 37	3 t = 3 or less	52.4 $16\frac{1}{2}t$	26.2 $8\frac{1}{4}t$	60.4 $18\frac{1}{2}t + 1.6$	30.2 $9\frac{1}{4}t + 0.8$
P-No. 11; P-No.25 to P-No. 21 or P-No. 22 or P-No. 25	10 t = 10 or less	63.5 $6\frac{2}{3}t$	31.8 $3\frac{1}{3}t$	85.8 $8\frac{2}{3}t + 3.2$	42.9 $4\frac{1}{3}t + 1.6$
P-No. 51; P-No. 49	10 t = 10 or less	76.2 $8t$	38.1 $4t$	98.4 $10t + 3.2$	49.2 $5t + 1.6$
P-No. 52; P-No. 53; P-No. 61; P-No. 62	10 t = 10 or less	95.2 $10t$	47.6 $5t$	117.5 $12t + 3.2$	58.7 $6t + 1.6$
All others with greater than or equal to 20% elongation	10 t = 10 or less	38.1 $4t$	19.0 $2t$	60.4 $6t + 3.2$	30.2 $3t + 1.6$
Materials with 3% to less than 20% elongation	t = [see Note (b)]	$32\frac{7}{8}t$ max.	$16\frac{7}{16}t$ max.	$A + 2t + 1.6$ max.	$\frac{1}{2}C + 0.8$ max.

GENERAL NOTES:

(a) For P-Numbers, see QW/QB-422; for F-Numbers, see QW-432.

(b) The dimensions of the test jig shall be such as to give the bend test specimen a calculated percent outer fiber elongation equal to at least that of the base material with the lower minimum elongation as specified in the base material specification.

$$\text{percent outer fiber elongation} = \frac{100t}{A + t}$$

The following formula is provided for convenience in calculating the bend specimen thickness:

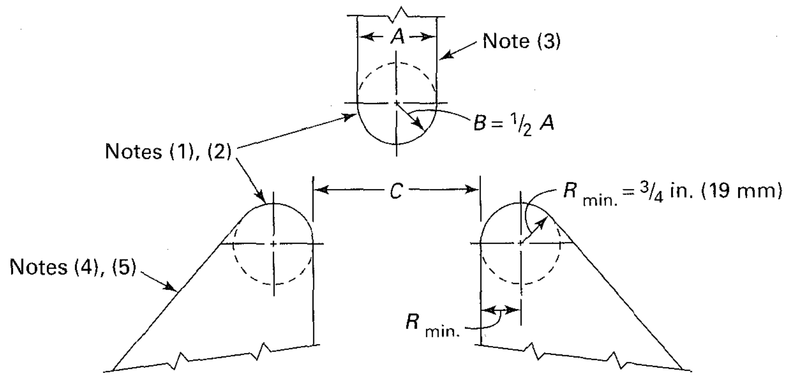
$$\text{thickness of specimen } (t) = \frac{A \times \text{percent elongation}}{[100 - (\text{percent elongation})]}$$

(c) For guided-bend jig configuration, see QW-466.2, QW-466.3, and QW-466.4.

(d) The weld and heat-affected zone, in the case of a transverse weld bend specimen, shall be completely within the bend portion of the specimen after testing.

(e) For materials with less than 3% elongation, a macro-etch specimen shall be used in lieu of bend test at each bend test location. Acceptance criteria shall be in accordance with QW-183(a).

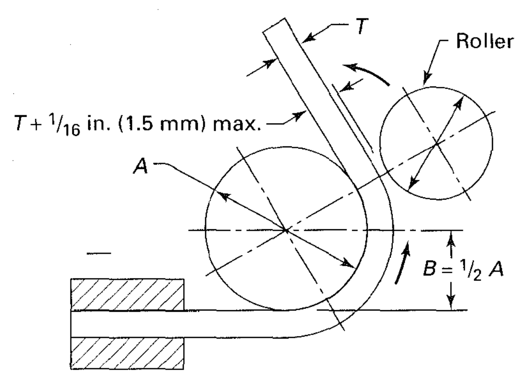
QW-466.2 GUIDED-BEND ROLLER JIG



GENERAL NOTE: See QW-466.1 for jig dimensions and general notes.

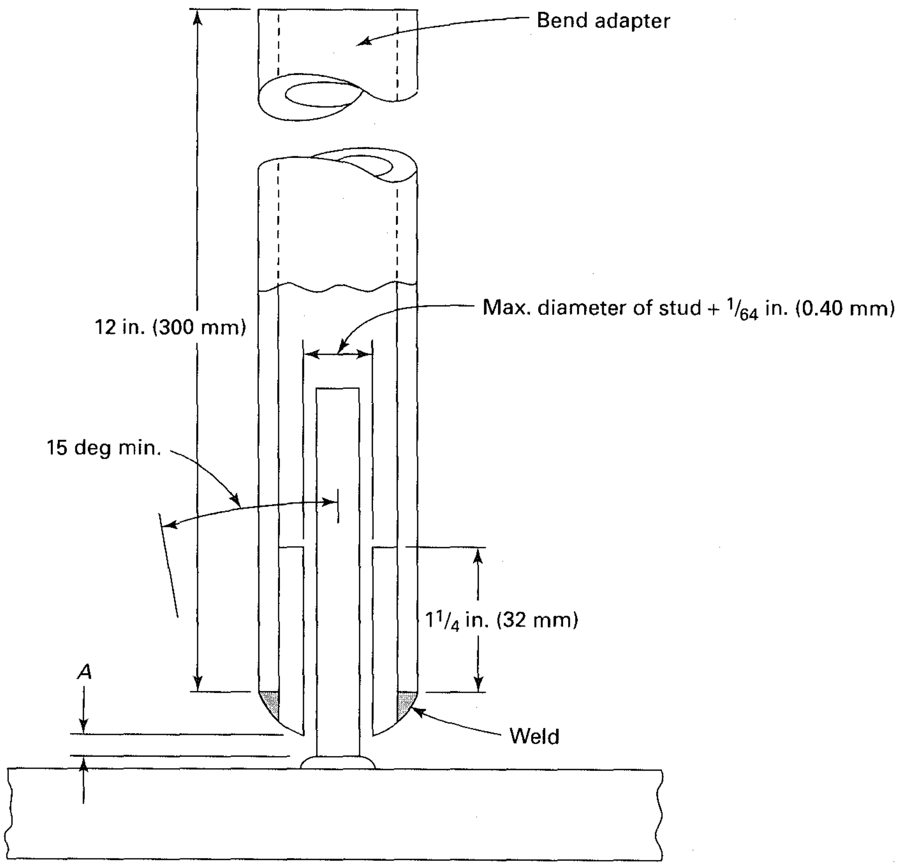
NOTES:
(1) Either hardened and greased shoulders or hardened rollers free to rotate shall be used.
(2) The shoulders or rollers shall have a minimum bearing surface of 2 in. (50 mm) for placement of the specimen. The rollers shall be high enough above the bottom of the jig so that the specimens will clear the rollers when the ram is in the low position.
(3) The ram shall be fitted with an appropriate base and provision made for attachment to the testing machine, and shall be of a sufficiently rigid design to prevent deflection and misalignment while making the bend test. The body of the ram may be less than the dimensions shown in column A of QW-466.1.
(4) If desired, either the rollers or the roller supports may be made adjustable in the horizontal direction so that specimens of *t* thickness may be tested on the same jig.
(5) The roller supports shall be fitted with an appropriate base designed to safeguard against deflection and misalignment and equipped with means for maintaining the rollers centered midpoint and aligned with respect to the ram.

QW-466.3 GUIDED-BEND WRAP AROUND JIG



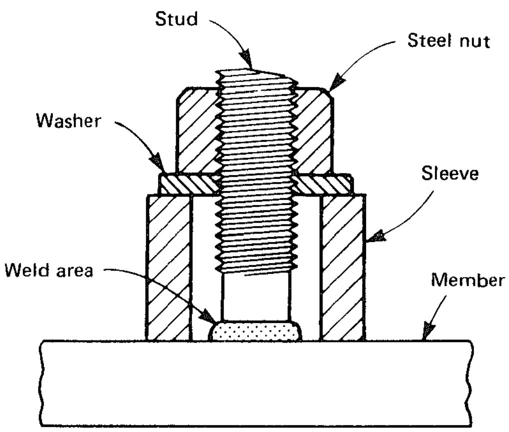
GENERAL NOTES:
(a) See QW-466.1 for jig dimensions and other general notes.
(b) Dimensions not shown are the option of the designer. The essential consideration is to have adequate rigidity so that the jig parts will not spring.
(c) The specimen shall be firmly clamped on one end so that there is no sliding of the specimen during the bending operation.
(d) Test specimens shall be removed from the jig when the outer roll has been removed 180 deg from the starting point.

QW-466.4 STUD-WELD BEND JIG



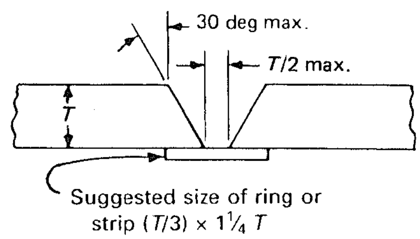
For Stud Diameter, in. (mm)	Use Adapter Gap, A, in. (mm)
1/8 (3)	1/8 (3)
3/16 (5)	1/8 (3)
1/4 (6)	3/16 (5)
3/8 (10)	7/32 (5.5)
1/2 (13)	5/16 (8)
5/8 (16)	11/32 (9)
3/4 (19)	15/32 (12)
7/8 (22)	15/32 (12)
1 (25)	19/32 (15)

QW-466.5 TORQUE TESTING ARRANGEMENT FOR STUD WELDS

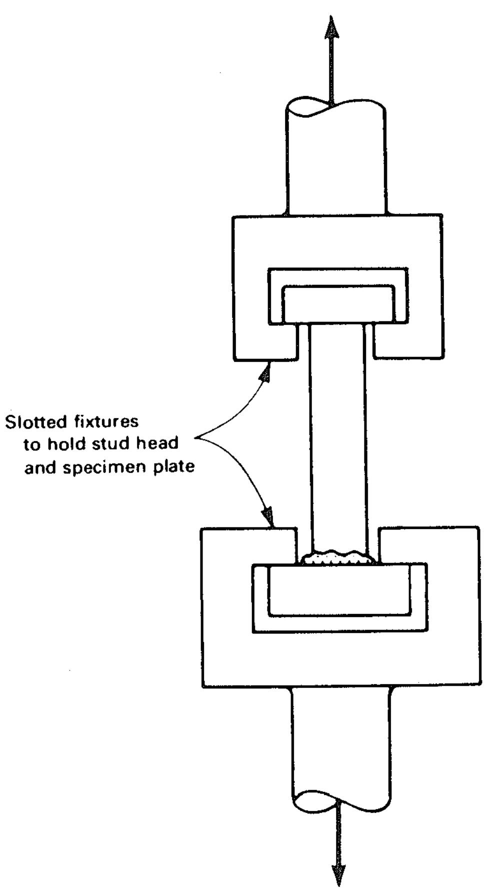


GENERAL NOTES:
(a) Dimensions are appropriate to the size of the stud.
(b) Threads of the stud shall be clean and free of lubricant other than residual cutting oil.

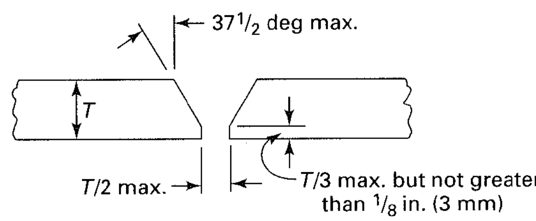
QW-469.1 BUTT JOINT



QW-466.6 SUGGESTED TYPE TENSILE TEST FIGURE FOR STUD WELDS



QW-469.2 ALTERNATIVE BUTT JOINT



QW-470 ETCHING — PROCESSES AND REAGENTS

QW-471 General

The surfaces to be etched should be smoothed by filing, machining, or grinding on metallographic papers. With different alloys and tempers, the etching period will vary from a few seconds to several minutes, and should be continued until the desired contrast is obtained. As a protection from the fumes liberated during the etching process, this work should be done under a hood. After etching, the specimens should be thoroughly rinsed and then dried with a blast of warm air. Coating the surface with a thin clear lacquer will preserve the appearance.

QW-472 For Ferrous Metals

Etching solutions suitable for carbon and low alloy steels, together with directions for their use, are suggested in QW-472.1 through QW-472.4.

QW-472.1 Hydrochloric Acid. Hydrochloric (muriatic) acid and water, equal parts, by volume. The solution should be kept at or near the boiling temperature during the etching process. The specimens are to be immersed in the solution for a sufficient period of time to reveal all lack of soundness that might exist at their cross-sectional surfaces.

QW-472.2 Ammonium Persulfate. One part of ammonium persulfate to nine parts of water, by weight. The solution should be used at room temperature, and should be applied by vigorously rubbing the surface to be etched with a piece of cotton saturated with the solution. The etching process should be continued until there is a clear definition of the structure in the weld.

QW-472.3 Iodine and Potassium Iodide. One part of powdered iodine (solid form), two parts of powdered potassium iodide, and ten parts of water, all by weight. The solution should be used at room temperature, and brushed on the surface to be etched until there is a clear definition or outline of the weld.

QW-472.4 Nitric Acid. One part of nitric acid and three parts of water, by volume.

CAUTION: Always pour the acid into the water. Nitric acid causes bad stains and severe burns.

The solution may be used at room temperature and applied to the surface to be etched with a glass stirring rod. The specimens may also be placed in a boiling solution of the acid, but the work should be done in a well-ventilated room. The etching process should be continued for a sufficient period of time to reveal all lack of soundness that might exist at the cross-sectional surfaces of the weld.

QW-473 For Nonferrous Metals

The following etching reagents and directions for their use are suggested for revealing the macrostructure.

QW-473.1 Aluminum and Aluminum-Base Alloys

Solution	Volume
Hydrochloric acid (concentrated)	15 ml
Hydrofluoric acid (48%)	10 ml
Water	85 ml

This solution is to be used at room temperature, and etching is accomplished by either swabbing or immersing the specimen.

QW-473.2 For Copper and Copper-Base Alloys: Cold Concentrated Nitric Acid. Etching is accomplished by either flooding or immersing the specimen for several seconds under a hood. After rinsing with a flood of water, the process is repeated with a 50-50 solution of concentrated nitric acid and water.

In the case of the silicon bronze alloys, it may be necessary to swab the surface to remove a white (SiO_2) deposit.

QW-473.3 For Nickel and Nickel-Base Alloys

Material	Formula
Nickel	Nitric Acid or Lepito's Etch
Low Carbon Nickel	Nitric Acid or Lepito's Etch
Nickel–Copper (400)	Nitric Acid or Lepito's Etch
Nickel–Chromium–Iron (600 and 800)	Aqua Regia or Lepito's Etch

MAKEUP OF FORMULAS FOR AQUA REGIA AND LEPITO'S ETCH

Solution	Aqua Regia [(1), (2)]	Lepito's Etch [(2), (3)]
Nitric Acid, Concentrated — HNO_3	1 part	3 ml
Hydrochloric Acid, Concentrated — HCL	2 parts	10 ml
Ammonium Sulfate — $(NH_4)_2(SO_4)$	. . .	1.5 g
Ferric Chloride — $FeCl_3$	. . .	2.5 g
Water	. . .	7.5 ml

NOTES:
(1) Warm the parts for faster action.
(2) Etching is accomplished by either swabbing or immersing the specimen.
(3) Mix solution as follows:
(a) Dissolve $(NH_4)_2(SO_4)$ in H_2O.
(b) Dissolve powdered $FeCl_3$ in warm HCl.
(c) Mix (a) and (b) above and add HNO_3.

QW-473.4 For Titanium

Solution	Kroll's Etch	Keller's Etch
Hydrofluoric acid (48%)	1 to 3 ml	½ ml
Nitric acid (concentrated)	2 to 6 ml	2½ ml
Hydrochloric Acid (concentrated)	. . .	1½ ml
Water	To make 100 ml	To make 100 ml

QW-473.5 For Zirconium

Solution	Volume
Hydrofluoric acid	3 ml
Nitric acid (concentrated)	22 ml
Water	22 ml

Apply by swab and rinse in cold water.

These are general purpose etchants which are applied at room temperature by swabbing or immersion of the specimen.

QW-490 DEFINITIONS

QW/QB-491 General

Definitions of the more common terms relating to welding/brazing are defined in QW/QB-492. These are identical to, or substantially in agreement with the definitions of the American Welding Society document, AWS A3.0, Standard Welding Terms and Definitions. There are terms listed that are specific to ASME Section IX and are not presently defined in AWS A3.0. Several definitions have been modified slightly from AWS A3.0 so as to better define the context/intent as used in ASME Section IX.

(10) QW/QB-492 Definitions

arc seam weld: a seam weld made by an arc welding process.

arc spot weld: a spot weld made by an arc welding process.

arc strike: any inadvertent discontinuity resulting from an arc, consisting of any localized remelted metal, heat-affected metal, or change in the surface profile of any metal object. The arc may be caused by arc welding electrodes, magnetic inspection prods, or frayed electrical cable.

arc welding: a group of welding processes wherein coalescence is produced by heating with an arc or arcs, with or without the application of pressure, and with or without the use of filler metal.

as-brazed: adj. pertaining to the condition of brazements after brazing, prior to any subsequent thermal, mechanical,or chemical treatments.

as-welded: adj. pertaining to the condition of weld metal, welded joints, and weldments after welding but prior to any subsequent thermal, mechanical, or chemical treatments.

backgouging: the removal of weld metal and base metal from the weld root side of a welded joint to facilitate complete fusion and complete joint penetration upon subsequent welding from that side.

backhand welding: a welding technique in which the welding torch or gun is directed opposite to the progress of welding.

backing: a material placed at the root of a weld joint for the purpose of supporting molten weld metal so as to facilitate complete joint penetration. The material may or may not fuse into the joint. See also *retainer*.

backing gas: a gas, such as argon, helium, nitrogen, or reactive gas, which is employed to exclude oxygen from the root side (opposite from the welding side) of weld joints.

base metal: the metal or alloy that is welded, brazed, or cut.

bond line (brazing and thermal spraying): the cross section of the interface between a braze or thermal spray deposit and the substrate.

braze: a joint produced by heating an assembly to suitable temperatures and by using a filler metal having a liquidus above 840°F (450°C) and below the solidus of the base materials. The filler metal is distributed between the closely fitted surfaces of the joint by capillary action.

brazer: one who performs a manual or semiautomatic brazing operation.

brazing: a group of metal joining processes which produces coalescence of materials by heating them to a suitable temperature, and by using a filler metal having a liquidus above 840°F (450°C) and below the solidus of the base materials. The filler metal is distributed between the closely fitted surfaces of the joint by capillary action.

brazing, automatic: brazing with equipment which performs the brazing operation without constant observation and adjustment by a brazing operator. The equipment may or may not perform the loading and unloading of the work.

brazing, block (BB): a brazing process that uses heat from heated blocks applied to the joint. This is an obsolete or seldom used process.

brazing, dip (DB): a brazing process in which the heat required is furnished by a molten chemical or metal bath. When a molten chemical bath is used, the bath may act as a flux; when a molten metal bath is used, the bath provides the filler metal.

brazing, furnace (FB): a brazing process in which the workpieces are placed in a furnace and heated to the brazing temperature.

brazing, induction (IB): a brazing process that uses heat from the resistance of the workpieces to induced electric current.

brazing, machine: brazing with equipment which performs the brazing operation under the constant observation and control of a brazing operator. The equipment may or may not perform the loading and unloading of the work.

brazing, manual: a brazing operation performed and controlled completely by hand. See also *automatic brazing* and *machine brazing*.

brazing, resistance (RB): a brazing process that uses heat from the resistance to electric current flow in a circuit of which the workpieces are a part.

brazing, semiautomatic: brazing with equipment which controls only the brazing filler metal feed. The advance of the brazing is manually controlled.

brazing, torch (TB): a brazing process that uses heat from a fuel gas flame.

brazing operator: one who operates machine or automatic brazing equipment.

brazing temperature: the temperature to which the base metal(s) is heated to enable the filler metal to wet the base metal(s) and form a brazed joint.

brazing temperature range: the temperature range within which brazing can be conducted.

build-up of base metal/restoration of base metal thickness: this is the application of a weld material to a base metal so as to restore the design thickness and/or structural integrity. This build-up may be with a chemistry different from the base metal chemistry which has been qualified via a standard butt welded test coupon. Also, may be called base metal repair or buildup.

butt joint: a joint between two members aligned approximately in the same plane.

buttering: the addition of material, by welding, on one or both faces of a joint, prior to the preparation of the joint for final welding, for the purpose of providing a suitable transition weld deposit for the subsequent completion of the joint.

clad brazing sheet: a metal sheet on which one or both sides are clad with brazing filler metal.

coalescence: the growing together or growth into one body of the materials being joined.

complete fusion: fusion which has occurred over the entire base material surfaces intended for welding, and between all layers and beads.

composite: a material consisting of two or more discrete materials with each material retaining its physical identity.

consumable insert: filler metal that is placed at the joint root before welding, and is intended to be completely fused into the root to become part of the weld.

contact tube: a device which transfers current to a continuous electrode.

corner joint: a joint between two members located approximately at right angles to each other in the form of an L.

coupon: see *test coupon*.

crack: a fracture-type discontinuity characterized by a sharp tip and high ratio of length and width to opening displacement.

creep strength enhanced ferritic alloys (CSEF's): a family of ferritic steels whose creep temperature strength is enhanced by the creation of a precise condition of microstructure, specifically martensite or bainite, which is stabilized during tempering by controlled precipitation of temper-resistant carbides, carbo-nitrides, or other stable and/or meta-stable phases.

defect: a discontinuity or discontinuities that by nature or accumulated effect (for example, total crack length) render a part or product unable to meet minimum applicable acceptance standards or specifications. This term designates rejectability. See also *discontinuity* and *flaw*.

direct current electrode negative (DCEN): the arrangement of direct current arc welding leads in which the electrode is the negative pole and the workpiece is the positive pole of the welding arc.

direct current electrode positive (DCEP): the arrangement of direct current arc welding leads in which the electrode is the positive pole and the workpiece is the negative pole of the welding arc.

discontinuity: an interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical, metallurgical, or physical characteristics. A discontinuity is not necessarily a defect. See also *defect* and *flaw*.

double-welded joint: a joint that is welded from both sides.

double-welded lap joint: a lap joint in which the overlapped edges of the members to be joined are welded along the edges of both members.

dwell: the time during which the energy source pauses at any point in each oscillation.

electrode, arc welding: a component of the welding circuit through which current is conducted.

electrode, bare: a filler metal electrode that has been produced as a wire, strip, or bar with no coating or covering other than that incidental to its manufacture or preservation.

electrode, carbon: a nonfiller material electrode used in arc welding and cutting, consisting of a carbon or graphite rod, which may be coated with copper or other materials.

electrode, composite: a generic term of multicomponent filler metal electrodes in various physical forms, such as stranded wires, tubes, and covered electrodes.

electrode, covered : a composite filler metal electrode consisting of a core of a bare electrode or metal-cored electrode to which a covering sufficient to provide a slag layer on the weld metal has been applied. The covering may contain materials providing such functions as shielding from the atmosphere, deoxidation, and arc stabilization, and can serve as a source of metallic additions to the weld.

electrode, electroslag welding: a filler metal component of the welding circuit through which current is conducted between the electrode guiding member and the molten slag.

NOTE: Bare electrodes and composite electrodes as defined under arc welding electrode are used for electroslag welding. A consumable guide may also be used as part of the electroslag welding electrode system.

electrode, emissive: a filler metal electrode consisting of a core of a bare electrode or a composite electrode to which a very light coating has been applied to produce a stable arc.

electrode, flux-cored: a composite filler metal electrode consisting of a metal tube or other hollow configuration containing ingredients to provide such functions as shielding atmosphere, deoxidation, arc stabilization, and slag formation. Alloying materials may be included in the core. External shielding may or may not be used.

electrode, lightly coated: a filler metal electrode consisting of a metal wire with a light coating applied subsequent to the drawing operation, primarily for stabilizing the arc.

electrode, metal: a filler or nonfiller metal electrode used in arc welding and cutting that consists of a metal wire or rod that has been manufactured by any method and that is either bare or covered.

electrode, metal-cored: a composite filler metal electrode consisting of a metal tube or other hollow configuration containing alloying ingredients. Minor amounts of ingredients providing such functions as arc stabilization and fluxing of oxides may be included. External shielding gas may or may not be used.

electrode, resistance welding: the part of a resistance welding machine through which the welding current and, in most cases, force are applied directly to the workpiece. The electrode may be in the form of a rotating wheel, rotating roll, bar, cylinder, plate, clamp, chuck, or modification thereof.

electrode, stranded: a composite filler metal electrode consisting of stranded wires which may mechanically enclose materials to improve properties, stabilize the arc, or provide shielding.

electrode, tungsten: a nonfiller metal electrode used in arc welding, arc cutting, and plasma spraying, made principally of tungsten.

face feed: the application of filler metal to the face side of a joint.

ferrite number: an arbitrary, standardized value designating the ferrite content of an austenitic stainless steel weld metal. It should be used in place of percent ferrite or volume percent ferrite on a direct one-to-one replacement basis. See the latest edition of AWS A4.2, Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal.

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

filler metal, brazing: the metal or alloy used as a filler metal in brazing, which has a liquidus above 840°F (450°C) and below the solidus of the base metal.

filler metal, powder: filler metal in particle form.

filler metal, supplemental: in electroslag welding or in a welding process in which there is an arc between one or more consumable electrodes and the workpiece, a powder, solid, or composite material that is introduced into the weld other than the consumable electrode(s).

fillet weld: a weld of approximately triangular cross section joining two surfaces approximately at right angles to each other in a lap joint, tee joint, or corner joint.

flaw: an undesirable discontinuity. See also *defect*.

flux (welding/brazing): a material used to dissolve, prevent, or facilitate the removal of oxides or other undesirable surface substances. It may act to stabilize the arc, shield the molten pool, and may or may not evolve shielding gas by decomposition.

flux, active (SAW): a flux from which the amount of elements deposited in the weld metal is dependent upon the welding parameters, primarily arc voltage.

flux, alloy (SAW): a flux which provides alloying elements in the weld metal deposit.

flux, neutral (SAW): a flux which will not cause a significant change in the weld metal composition when there is a large change in the arc voltage.

flux cover: metal bath dip brazing and dip soldering. A layer of molten flux over the molten filler metal bath.

forehand welding: a welding technique in which the welding torch or gun is directed toward the progress of welding.

frequency: the completed number of cycles which the oscillating head makes in 1 min or other specified time increment.

fuel gas: a gas such as acetylene, natural gas, hydrogen, propane, stabilized methylacetylene propadiene, and other fuels normally used with oxygen in one of the oxyfuel processes and for heating.

fused spray deposit (thermal spraying): a self-fluxing thermal spray deposit which is subsequently heated to coalescence within itself and with the substrate.

fusion (fusion welding): the melting together of filler metal and base metal, or of base metal only, to produce a weld.

fusion face: a surface of the base metal that will be melted during welding.

fusion line: a non-standard term for weld interface.

gas backing: see *backing gas*.

globular transfer (arc welding): a type of metal transfer in which molten filler metal is transferred across the arc in large droplets.

groove weld: a weld made in a groove formed within a single member or in the groove between two members to be joined. The standard types of groove weld are as follows:

(a) square groove weld
(b) single-Vee groove weld
(c) single-bevel groove weld
(d) single-U groove weld
(e) single-J groove weld
(f) single-flare-bevel groove weld
(g) single-flare-Vee groove weld
(h) double-Vee groove weld
(i) double-bevel groove weld
(j) double-U groove weld
(k) double-J groove weld
(l) double-flare-bevel groove weld
(m) double-flare-Vee groove weld

heat-affected zone: that portion of the base metal which has not been melted, but whose mechanical properties or microstructures have been altered by the heat of welding or cutting.

instantaneous power or *energy*: as used for waveform controlled welding, the determination of power or energy using the product of current and voltage measurements made at rapid intervals which capture brief changes in the welding waveform.

interpass temperature: the highest temperature in the weld joint immediately prior to welding, or in the case of multiple pass welds, the highest temperature in the section of the previously deposited weld metal, immediately before the next pass is started.

joint: the junction of members or the edges of members which are to be joined or have been joined.

joint penetration: the distance the weld metal extends from the weld face into a joint, exclusive of weld reinforcement.

keyhole welding: a technique in which a concentrated heat source penetrates partially or completely through a workpiece, forming a hole (keyhole) at the leading edge of the weld pool. As the heat source progresses, the molten metal fills in behind the hole to form the weld bead.

lap or overlap: the distance measured between the edges of two plates when overlapping to form the joint.

lap joint: a joint between two overlapping members in parallel planes.

layer: a stratum of weld metal consisting of one or more beads. See figures QW/QB-492.1 and QW/QB-492.2.

lower transformation temperature: the temperature at which austenite begins to form during heating.

macro-examination: the process of observing a specimen cross-section by the unaided eye, or at a specified low magnification, with or without the use of smoothing and etching.

melt-in: a technique of welding in which the intensity of a concentrated heat source is so adjusted that a weld pass can be produced from filler metal added to the leading edge of the molten weld metal.

nugget: the volume of weld metal formed in a spot, seam, or projection weld.

oscillation: for a machine or automatic process, an alternating motion relative to the direction of travel of welding, brazing, or thermal spray device. See also *weave bead*.

overlay: a non-standard term, used in Section IX, for surfacing. See also *hard-facing* and *corrosion-resistant overlay*.

overlay, corrosion-resistant weld metal: deposition of one or more layers of weld metal to the surface of a base material in an effort to improve the corrosion resistance properties of the surface. This would be applied at a level above the minimum design thickness as a nonstructural component of the overall wall thickness.

overlay, hard-facing weld metal: deposition of one or more layers of weld metal to the surface of a material in an effort to improve the wear resistance properties of the surface. This would be applied at a level above the minimum design thickness as a nonstructural component of the overall wall thickness.

pass: a single progression of a welding or surfacing operation along a joint, weld deposit, or substrate. The result of a pass is a weld bead or layer.

pass, cover: a final or cap pass(es) on the face of a weld.

pass, wash: pass to correct minor surface aberrations and/or prepare the surface for nondestructive testing.

peel test: a destructive method of testing that mechanically separates a lap joint by peeling.

peening: the mechanical working of metals using impact blows.

performance qualification: the demonstration of a welder's or welding operator's ability to produce welds meeting prescribed standards.

plug weld: a weld made in a circular, or other geometrically shaped hole (like a slot weld) in one member of a lap or tee joint, joining that member to the other. The walls of the hole may or may not be parallel, and the hole may be partially or completely filled with weld metal. (A fillet-welded hole or spot weld should not be construed as conforming to this definition.)

polarity, reverse: the arrangement of direct current arc welding leads with the work as the negative pole and the electrode as the positive pole of the welding arc; a synonym for direct current electrode positive.

polarity, straight: the arrangement of direct current arc welding leads in which the work is the positive pole and the electrode is the negative pole of the welding arc; a synonym for direct current electrode negative.

postbraze heat treatment: any heat treatment subsequent to brazing.

postheating: the application of heat to an assembly after welding, brazing, soldering, thermal spraying, or thermal cutting.

postweld heat treatment: any heat treatment subsequent to welding.

postweld hydrogen bakeout: holding a completed or partially completed weld at elevated temperature below 800°F (425°C) for the purpose of allowing hydrogen diffusion from the weld.

powder: see *filler metal, powder*.

preheat current: an impulse or series of impulses that occurs prior to and is separated from the welding current.

preheat maintenance: practice of maintaining the minimum specified preheat temperature, or some specified higher temperature for some required time interval after welding or thermal spraying is finished or until post weld heat treatment is initiated.

preheat temperature: the minimum temperature in the weld joint preparation immediately prior to the welding; or in the case of multiple pass welds, the minimum temperature in the section of the previously deposited weld metal, immediately prior to welding.

preheating: the application of heat to the base metal immediately before a welding or cutting operation to achieve a specified minimum preheat temperature.

pulsed power welding: any arc welding method in which the power is cyclically programmed to pulse so that effective but short duration values of a parameter can be utilized. Such short duration values are significantly different from the average value of the parameter. Equivalent terms are pulsed voltage or pulsed current welding. See also *pulsed spray welding*.

pulsed spray welding: an arc welding process variation in which the current is pulsed to utilize the advantages of the spray mode of metal transfer at average currents equal to or less than the globular to spray transition current.

rabbet joint: typical design is indicated in figures QB-462.1(c), QB-462.4, QB-463.1(c), and QB-463.2(a).

retainer: nonconsumable material, metallic or nonmetallic, which is used to contain or shape molten weld metal. See also*backing*.

seal weld: any weld designed primarily to provide a specific degree of tightness against leakage.

seam weld: a continuous weld made between or upon overlapping members in which coalescence may start and occur on the faying surfaces, or may have proceeded from the surface of one member. The continuous weld may consist of a single weld bead or a series of overlapping spot welds. See also *resistance welding*.

short-circuiting transfer (gas metal-arc welding): metal transfer in which molten metal from a consumable electrode is deposited during repeated short circuits. See also *globular transfer* and *spray transfer*.

single-welded joint: a joint welded from one side only.

single-welded lap joint: a lap joint in which the overlapped edges of the members to be joined are welded along the edge of one member only.

slag inclusion: nonmetallic solid material entrapped in weld metal or between weld metal and base metal.

specimen: see *test specimen*.

spot weld: a weld made between or upon overlapping members in which coalescence may start and occur on the faying surfaces or may proceed from the outer surface of one member. The weld cross section (plan view) is approximately circular.

spray-fuse: a thermal spraying technique in which the deposit is reheated to fuse the particles and form a metallurgical bond with the substrate.

spray transfer (arc welding): metal transfer in which molten metal from a consumable electrode is propelled axially across the arc in small droplets.

Standard Welding Procedure Specification (SWPS): a welding procedure specification, published by the American Welding Society, that is made available for production welding by companies or individuals without further qualification, and that may be used in Code applications in accordance with the restrictions and limitations of Article V.

stringer bead: a weld bead formed without appreciable weaving.

surface temper bead reinforcing layer: a subset of temper bead welding in which one or more layers of weld metal are applied on or above the surface layers of a component and are used to modify the properties of previously deposited weld metal or the heat-affected zone. Surface layer may cover a surface or only the perimeter of the weld.

surfacing: the application by welding, brazing, or thermal spraying of a layer(s) of material to a surface to obtain desired properties or dimensions, as opposed to making a joint.

tee joint (T): a joint between two members located approximately at right angles to each other in the form of a T.

temper bead welding: a weld bead placed at a specific location in or at the surface of a weld for the purpose of affecting the metallurgical properties of the heat-affected zone or previously deposited weld metal. The bead may be above, flush with, or below the surrounding base metal surface. If above the base metal surface, the beads may cover all or only part of the weld deposit and may or may not be removed following welding.

test coupon: a weld or braze assembly for procedure or performance qualification testing. The coupon may be any product from plate, pipe, tube, etc., and may be a fillet weld, overlay, deposited weld metal, etc.

test specimen: a sample of a test coupon for specific test. The specimen may be a bend test, tension test, impact test, chemical analysis, macrotest, etc. A specimen may be a complete test coupon, for example, in radiographic testing or small diameter pipe tension testing.

thermal cutting (TC): a group of cutting processes that severs or removes metal by localized melting, burning, or vaporizing of the workpieces.

throat, actual (of fillet): the shortest distance from the root of a fillet weld to its face.

throat, effective (of fillet): the minimum distance from the fillet face, minus any convexity, to the weld root. In the case of fillet welds combined with a groove weld, the weld root of the groove weld shall be used.

throat, theoretical (of fillet): the distance from the beginning of the joint root perpendicular to the hypotenuse of the largest right triangle that can be inscribed within the cross-section of a fillet weld. This dimension is based on the assumption that the root opening is equal to zero.

undercut: a groove melted into the base metal adjacent to the weld toe or weld root and left unfilled by weld metal.

upper transformation temperature: the temperature at which transformation of the ferrite to austenite is completed during heating.

usability: a measure of the relative ease of application of a filler metal to make a sound weld or braze joint.

waveform controlled welding: a welding process modification of the voltage and/or current wave shape to control characteristics such as droplet shape, penetration, wetting, bead shape or transfer mode(s).

weave bead: for a manual or semiautomatic process, a weld bead formed using weaving. See also *oscillation*.

weaving: a welding technique in which the energy source is oscillated transversely as it progresses along the weld path.

weld: a localized coalescence of metals or nonmetals produced either by heating the materials to the welding temperature, with or without the application of pressure, or by the application of pressure alone and with or without the use of filler material.

weld, autogenous: a fusion weld made without filler metal.

weld bead: a weld deposit resulting from a pass. See also *stringer bead* and *weave bead*.

weld face: the exposed surface of a weld on the side from which welding was done.

weld interface: the interface between the weld metal and base metal in a fusion weld.

weld metal: metal in a fusion weld consisting of that portion of the base metal and filler metal melted during welding.

weld reinforcement: weld metal on the face or root of a groove weld in excess of the metal necessary for the specified weld size.

weld size: for equal leg fillet welds: the leg lengths of the largest isosceles right triangle which can be inscribed within the fillet weld cross section.

weld size: for unequal leg fillet welds: the leg lengths of the largest right triangle which can be inscribed within the fillet weld cross section.

weld size: groove welds: the depth of chamfering plus any penetration beyond the chamfering, resulting in the strength carrying dimension of the weld.

welder: one who performs manual or semiautomatic welding.

welding, arc stud (SW): an arc welding process that uses an arc between a metal stud, or similar part, and the other workpiece. The process is used without filler metal, with or without shielding gas or flux, with or without partial shielding from a ceramic or graphite ferrule surrounding the stud, and with the application of pressure after the faying surfaces are sufficiently heated.

welding, automatic: welding with equipment which performs the welding operation without adjustment of the controls by a welding operator. The equipment may or may not perform the loading and unloading of the work. See also *machine welding*.

welding, consumable guide electroslag: an electroslag welding process variation in which filler metal is supplied by an electrode and its guiding member.

welding, electrogas (EGW): an arc welding process that uses an arc between a continuous filler metal electrode and the weld pool, employing approximately vertical welding progression with retainers to confine the weld metal. The process is used with or without an externally supplied shielding gas and without the application of pressure. Shielding for use with solid or metal-cored electrodes is obtained from a gas or gas mixture. Shielding for use with flux-cored electrodes may or may not be obtained from an externally supplied gas or gas mixture.

welding, electron beam (EBW): a welding process that produces coalescence with a concentrated beam composed primarily of high velocity electrons,impinging on the joint. The process is used without shielding gas and without the application of pressure.

welding, electroslag (ESW): a welding process producing coalescence of metals with molten slag which melts the filler metal and the surfaces of the work to be welded. The molten weld pool is shielded by this slag which moves along the full cross section of the joint as welding progresses. The process is initiated by an arc which heats the slag. The arc is then extinguished and the conductive slag is maintained in a molten condition by its resistance to electric current passing between the electrode and the work. See electroslag welding electrode and consumable guide electroslag welding.

welding, flux-cored arc (FCAW): a gas metal-arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding gas from a flux contained within the tubular electrode, with or without additional shielding from an externally supplied gas, and without the application of pressure.

welding, friction (FRW): a solid state welding process that produces a weld under compressive force contact of workpieces rotating or moving relative to one another to produce heat and plastically displace material from the faying surfaces.

welding, friction, inertia and continuous drive: processes and types of friction welding (solid state welding process) wherein coalescence is produced after heating is obtained from mechanically induced sliding motion between rubbing surfaces held together under pressure. Inertia welding utilizes all of the kinetic energy stored in a revolving flywheel spindle system. Continuous drive friction welding utilizes the energy provided by a continuous drive source such as an electric or hydraulic motor.

welding, gas metal-arc (GMAW): an arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from an externally supplied gas and without the application of pressure.

welding, gas metal-arc, pulsed arc (GMAW-P): a variation of the gas metal-arc welding process in which the current is pulsed. See also *pulsed power welding*.

welding, gas metal-arc, short-circuiting arc (GMAW-S): a variation of the gas metal-arc welding process in which the consumable electrode is deposited during repeated short circuits. See also *short-circuiting transfer*.

welding, gas tungsten-arc (GTAW): an arc welding process which produces coalescence of metals by heating them with an arc between a tungsten (nonconsumable) electrode and the work. Shielding is obtained from a gas or gas mixture. Pressure may or may not be used and filler metal may or may not be used. (This process has sometimes been called TIG welding, a nonpreferred term.)

welding, gas tungsten-arc, pulsed arc (GTAW-P): a variation of the gas tungsten-arc welding process in which the current is pulsed. See also *pulsed power welding*.

welding, induction (IW): a welding process that produces coalescence of metals by the heat obtained from resistance of the workpieces to the flow of induced high frequencywelding current with or without the application of pressure. The effect of the high-frequency welding current is to concentrate the welding heat at the desired location.

welding, laser beam (LBW): a welding process which produces coalescence of materials with the heat obtained from the application of a concentrated coherent light beam impinging upon the members to be joined.

welding, machine: welding with equipment that has controls that are manually adjusted by the welding operator or adjusted under the welding operator's direction in response to visual observation of the welding, with the torch, gun, or electrode holder held by a mechanical device. See also *welding, automatic*.

welding, manual: welding wherein the entire welding operation is performed and controlled by hand.

welding operator: one who operates machine or automatic welding equipment.

welding, oxyfuel gas (OFW): a group of welding processes which produces coalescence by heating materials with an oxyfuel gas flame or flames, with or without the application of pressure, and with or without the use of filler metal.

welding, plasma-arc (PAW): an arc welding process which produces coalescence of metals by heating them with a constricted arc between an electrode and the workpiece (transferred arc), or the electrode and the constricting nozzle (nontransferred arc). Shielding is obtained from the hot, ionized gas issuing from the torch orifice which may be supplemented by an auxiliary source of shielding gas. Shielding gas may be an inert gas or a mixture of gases. Pressure may or may not be used, and filler metal may or may not be supplied.

welding, projection (PW): a resistance welding process that produces coalescence by the heat obtained from the resistance of the flow of welding current. The resulting welds are localized at predetermined points by projections, embossments, or intersections. The metals to be joined lap over each other.

welding, resistance (RW): a group of welding processes that produces coalescence of the faying surfaces with the heat obtained from resistance of the workpieces to the flow of the welding current in a circuit of which the workpieces are a part, and by the application of pressure.

welding, resistance seam (RSEW): a resistance welding process that produces a weld at the faying surfaces of overlapped parts progressively along a length of a joint. The weld may be made with overlapping weld nuggets, a continuous weld nugget, or by forging the joint as it is heated to the welding temperature by resistance to the flow of the welding current.

welding, resistance spot (RSW): a resistance welding process that produces a weld at the faying surfaces of a joint by the heat obtained from resistance to the flow of welding current through the workpieces from electrodes that serve to concentrate the welding current and pressure at the weld area.

welding, resistance stud: a resistance welding process wherein coalescence is produced by the heat obtained from resistance to electric current at the interface between the stud and the workpiece, until the surfaces to be joined are properly heated, when they are brought together under pressure.

welding, semiautomatic arc: arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.

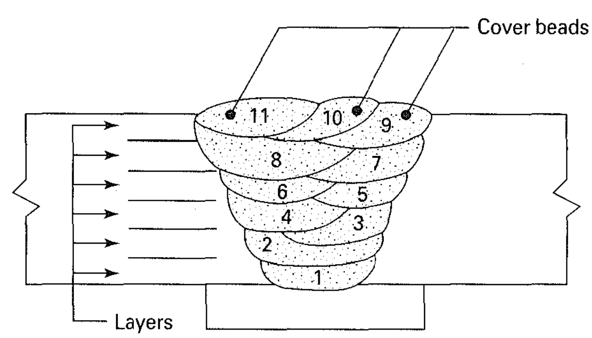
welding, shielded metal-arc (SMAW): an arc welding process with an arc between a covered electrode and the weld pool. The process is used with shielding from the decomposition of the electrode covering, without the application of pressure, and with filler metal from the electrode.

welding, stud: a general term for the joining of a metal stud or similar part to a workpiece. Welding may be accomplished by arc, resistance, friction, or other suitable process with or without external gas shielding.

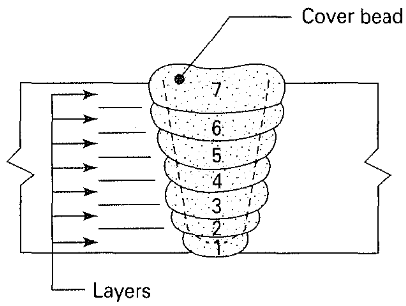
welding, submerged-arc (SAW): an arc welding process that uses an arc or arcs between a bare metal electrode or electrodes and the weld pool. The arc and molten metal are shielded by a blanket of granular flux on the workpieces. The process is used without pressure and with filler metal from the electrode and sometimes from a supplemental source (welding rod, flux, or metal granules).

weldment: an assembly whose constituent parts are joined by welding, or parts which contain weld metal overlay.

QW/QB-492.1 TYPICAL SINGLE AND MULTIBEAD LAYERS



QW/QB-492.2 TYPICAL SINGLE BEAD LAYERS



ARTICLE V
STANDARD WELDING PROCEDURE SPECIFICATIONS (SWPSs)

QW-500 GENERAL

The SWPSs listed in Appendix E are acceptable for construction in which the requirements of the ASME Boiler and Pressure Vessel Code, Section IX are specified. Any requirements of the applicable Construction Code Section regarding SWPS take precedence over the requirements of Section IX. These SWPSs are not permitted for construction where impact testing of the WPS is required by the Construction Code.

Only SWPSs (including edition) that have been accepted in Appendix E within the 1998 Edition or any later edition of Section IX may be used in accordance with this Article. Adoption of SWPSs (including edition) shall be in accordance with the current edition (see Foreword) and addenda of Section IX.

QW-510 ADOPTION OF SWPSs

Prior to use, the manufacturer or contractor that will be responsible for and provide operational control over production welding shall comply with the following for each SWPS that it intends to use, except as noted in QW-520.

(a) Enter the name of the manufacturer or contractor on the SWPS.

(b) An employee of that manufacturer or contractor shall sign and date the SWPS.

(c) The applicable Code Section(s) (Section VIII, B31.1, etc.) and/or any other fabrication document (contract, specification, etc.) that must be followed during welding shall be listed on the SWPS.

(d) The manufacturer or contractor shall weld and test one groove weld test coupon following that SWPS. The following information shall be recorded:

(1) the specification, type, and grade of the base metal welded

(2) groove design

(3) initial cleaning method

(4) presence or absence of backing

(5) The ASME or AWS specification and AWS classification of electrode or filler metal used and manufacturer's trade name

(6) size and classification of tungsten electrode for GTAW

(7) size of consumable electrode or filler metal

(8) shielding gas and flow rate for GTAW and GMAW

(9) preheat temperature

(10) position of the groove weld and, if applicable, the progression

(11) if more than one process or electrode type is used, the approximate weld metal deposit thickness for each process or electrode type

(12) maximum interpass temperature

(13) post weld heat treatment used, including holding time and temperature range

(14) visual inspection and mechanical testing results

(15) the results of radiographic examination when permitted as an alternative to mechanical testing by QW-304

(e) The coupon shall be visually examined in accordance with QW-302.4 and mechanically tested in accordance with QW-302.1 or radiographically examined in accordance with QW-302.2. If visual examination, radiographic examination, or any test specimen fails to meet the required acceptance criteria, the test coupon shall be considered as failed and a new test coupon shall be welded before the organization may use the SWPS.

QW-511 Use of Demonstrated SWPSs

Code Sections or fabrication documents that are required to be referenced by QW-510(c) may be added or deleted from a demonstrated SWPS without further demonstrations.

QW-520 USE OF SWPSs WITHOUT DISCRETE DEMONSTRATION

Once an SWPS has been demonstrated, additional SWPSs that are similar to the SWPS that was demonstrated may be used without further demonstration. Such additional SWPSs shall be compared to the SWPS that was used for the demonstration, and the following limitations shall not be exceeded:

(*a*) a change in the welding process.

(*b*) a change in the P-Number.

(*c*) a change from the as-welded condition to the heat-treated condition. This limitation also applies for SWPSs that allow use in both conditions (e.g., SWPS B2.1-021 allows production welding with or without heat treatment; if the demonstration was performed without heat treatment, production welding with heat treatment is not permitted). Once heat treatment has been demonstrated for any SWPS, this limitation no longer applies.

(*d*) a change from a gas-shielded flux-cored wire or solid wire to a self-shielded flux-cored wire or vice versa.

(*e*) a change from spray, globular, or pulsed transfer mode to short-circuiting transfer mode or vice-versa.

(*f*) a change in the F-Number of the welding electrode.

(*g*) the addition of preheat above ambient temperature.

(*h*) a change from an SWPS that is identified as for sheet metal to one that is not and vice versa.

QW-530 FORMS

A suggested Form QW-485 for documenting the welding variables and test results of the demonstration is provided in Nonmandatory Appendix B.

QW-540 PRODUCTION USE OF SWPSs

As with any WPS, welding that is done following an SWPS shall be done in strict accordance with the SWPS. In addition, the following requirements apply to the use of SWPSs:

(*a*) The manufacturer or contractor may not deviate from the welding conditions specified on the SWPS.

(*b*) SWPSs may not be supplemented with PQRs or revised in any manner except for reference to the applicable Code Section or other fabrication documents as provided by QW-511.

(*c*) Only the welding processes shown on an SWPS shall be used in given production joint. When a multi-process SWPS is selected, the processes shown on the SWPS shall be used in the order and manner specified on the SWPS.

(*d*) SWPSs shall not be used in the same production joint together with WPSs qualified by the manufacturer or contractor.

(*e*) The manufacturer or contractor may supplement an SWPS by attaching additional instructions to provide the welder with further direction for making production welds to Code or other requirements. When SWPSs are supplemented with instructions that address any condition shown on the SWPS, such instructions shall be within the limits of the SWPS. For example, when an SWPS permits use of several electrode sizes, supplemental instructions may direct the welder to use only one electrode size out of those permitted by the SWPS; however, the supplemental instructions may not permit the welder to use a size other than one or more of those permitted by the SWPS.

(*f*) SWPSs may not be used until the demonstration of QW-510 has been satisfactorily welded, tested, and certified.

(*g*) The identification number of the Supporting Demonstration shall be noted on each SWPS that it supports prior to using the SWPS.

(*h*) The certified Supporting Demonstration Record shall be available for review by Authorized Inspector.

PART QB BRAZING

ARTICLE XI
BRAZING GENERAL REQUIREMENTS

QB-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.

QB-100.1 The purpose of the Brazing Procedure Specification (BPS) and Procedure Qualification Record (PQR) is to determine that the brazement proposed for construction is capable of providing the required properties for its intended application. It is presupposed that the brazer or brazing operator performing the brazing procedure qualification test is a skilled workman. That is, the brazing procedure qualification test establishes the properties of the brazement, not the skill of the brazer or brazing operator. Briefly, a BPS lists the variables, both essential and nonessential, and the acceptable ranges of these variables when using the BPS. The BPS is intended to provide direction for the brazer or brazing operator. The PQR lists what was used in qualifying the BPS and the test results.

QB-100.2 In performance qualification, the basic criterion established for brazer qualification is to determine the brazer's ability to make a sound brazed joint. The purpose of the performance qualification test for the brazing operator is to determine the operator's mechanical ability to operate the brazing equipment.

QB-100.3 Brazing Procedure Specifications (BPS) written and qualified in accordance with the rules of this Section, and brazers and operators of automatic and machine brazing 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 rules under which Section IX requirements are mandatory, in whole or in part, and give additional requirements. The reader is advised to take these provisions into consideration when using this Section.

Brazing Procedure Specifications, Procedure Qualification Records, and Brazer or Brazing Operator Performance Qualifications 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.

Brazing Procedure Specifications, Procedure Qualification Records, and Brazer or Brazing Operator Performance Qualifications 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.

Brazing Procedure Specifications and Brazer/Brazing 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 Brazing Procedure Specifications or Brazers/Brazing Operators and requalification of existing Brazing Procedure Specifications or Brazers/Brazing Operators shall be in accordance with the current Edition (see Foreword) and Addenda of Section IX.

QB-101 Scope

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

QB-102 Terms and Definitions

Some of the more common terms relating to brazing are defined in QW/QB-492. These are in substantial agreement with the definitions of the American Welding Society given in its document, A3.0-89, Standard Welding Terms and Definitions.

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

QB-103 Responsibility

QB-103.1 Brazing. Each manufacturer[1] or contractor[1] is responsible for the brazing done by his organization, and shall conduct the tests required in this Section to qualify the brazing procedures he uses in the construction of the brazed assemblies built under this Code and the performance of brazers and brazing operators who apply these procedures.

QB-103.2 Records. Each manufacturer or contractor shall maintain a record of the results obtained in brazing procedure and brazer or brazing operator performance qualifications. These records shall be certified by a signature or other means as described in the manufacturer's or contractor's Quality Control System and shall be accessible to the Authorized Inspector. Refer to recommended Forms in Nonmandatory Appendix B.

QB-110 BRAZE ORIENTATION

The orientations of brazes with respect to planes of reference are classified in accordance with figure QB-461.1 into four positions[2] (A, B, C, and D in column 1), based on the basic flow of brazing filler metal through joints. These positions are flat flow, vertical downflow, vertical upflow, and horizontal flow.

The maximum permitted angular deviation from the specified flow plane is ±45 deg.

QB-120 TEST POSITIONS FOR LAP, BUTT, SCARF, OR RABBET JOINTS

Brazed joints may be made in test coupons oriented in any of the positions in figure QB-461.2 and as described in the following paragraphs, except that angular deviation from the specified horizontal and vertical flow planes in accordance with column 1 of figure QB-461.2 is permitted during brazing.

QB-121 Flat-Flow Position

The test coupon joints in position suitable for applying brazing filler metal in rod, strip, or other suitable form under the flat-flow conditions are shown in illustrations (1) through (5) of Line A in figure QB-461.2. The maximum permitted angular deviation from the specified flow plane is ±15 deg.

QB-122 Vertical-Downflow Position

The test coupon joints in a position suitable for applying brazing filler metal in rod, strip, or other suitable form under the vertical-downflow conditions are shown in illustrations (1) through (4) of Line B in figure QB-461.2. The brazing filler metal flows by capillary action with the aid of gravity downward into the joint. The maximum permitted angular deviation from the specified flow plane is ±15 deg.

QB-123 Vertical-Upflow Position

The test coupon joints in position suitable for applying brazing filler metal in rod, strip, or other suitable form under the vertical-upflow conditions are shown in illustrations (1) through (4) of Line C in figure QB-461.2. The brazing filler metal flows by capillary action through the joint. The maximum permitted angular deviation from the specified flow plane is ±15 deg.

QB-124 Horizontal-Flow Position

The test coupon joints in a position suitable for applying brazing filler metal in rod, strip, or other suitable form under the horizontal-flow conditions are shown in illustrations (1) and (2) of Line D of figure QB-461.2. The brazing filler metal flows horizontally by capillary action through the joint. The maximum permitted angular deviation from the specified flow plane is ±15 deg.

QB-140 TYPES AND PURPOSES OF TESTS AND EXAMINATIONS

QB-141 Tests

Tests used in brazing procedure and performance qualifications are specified in QB-141.1 through QB-141.6.

QB-141.1 Tension Tests. Tension tests, as described in QB-150, are used to determine the ultimate strength of brazed butt, scarf, lap, and rabbet joints.

QB-141.2 Guided-Bend Tests. Guided-bend tests, as described in QB-160, are used to determine the degree of soundness and ductility of butt and scarf joints.

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

[2] In the following paragraphs the word *position* is synonymous with *flow position*.

QB-141.3 Peel Tests. Peel tests, as described in QB-170, are used to determine the quality of the bond and the amount of defects in lap joints.

QB-141.4 Sectioning Tests. Sectioning tests, i.e., the sectioning of test coupons, as described in QB-180, are used to determine the soundness of workmanship coupons or test specimens. Sectioning tests are also a substitute for the peel test when the peel test is impractical to perform, (e.g., when the strength of brazing filler material is equal to or greater than the strength of the base metals).

QB-141.5 Workmanship Coupons. Workmanship coupons, as described in QB-182, are used to determine the soundness of joints other than the standard butt, scarf, lap, and rabbet joints.

QB-141.6 Visual Examination. Visual examination of brazed joints is used for estimating the soundness by external appearance, such as continuity of the brazing filler metal, size, contour, and wetting of fillet along the joint and, where appropriate, to determine if filler metal flowed through the joint from the side of application to the opposite side.

QB-150 TENSION TESTS

QB-151 Specimens

Tension test specimens shall conform to one of the types illustrated in figures QB-462.1(a) through QB-462.1(f), and shall meet the requirements of QB-153.

QB-151.1 Reduced Section — Plate. Reduced-section specimens conforming to the requirements given in figures QB-462.1(a) and QB-462.1(c) may be used for tension tests on all thicknesses of plate. The specimens may be tested in a support fixture in substantial accordance with figure QB-462.1(f).

(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 thicknesses greater than 1 in. (25 mm), full thickness specimens or multiple specimens may be used, provided QB-151.1(c) and QB-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 brazed joint 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 QB-153.

QB-151.2 Reduced Section — Pipe. Reduced-section specimens conforming to the requirements given in figure QB-462.1(b) may be used for tension tests on all thicknesses of pipe or tube having an outside diameter greater than 3 in. (75 mm). The specimens may be tested in a support fixture in substantial accordance with figure QB-462.1(f).

(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 QB-151.2(c) and QB-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 brazed joint 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 QB-153.

QB-151.3 Full-Section Specimens for Pipe. Tension specimens conforming to the dimensions given in figure QB-462.1(e) may be used for testing pipe with an outside diameter of 3 in. (75 mm) or less.

QB-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 measured before the load is applied.

QB-153 Acceptance Criteria — Tension Tests

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

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

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

(c) if the specimen breaks in the base metal outside of the braze, 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 in the annealed condition.

(d) the specified minimum tensile strength is for full thickness specimens including cladding for Aluminum

Alclad materials (P-No. 104 and P-No. 105) less than $\frac{1}{2}$ in. (13 mm). For Aluminum Alclad materials $\frac{1}{2}$ 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.

QB-160 GUIDED-BEND TESTS

QB-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 designated the first and second surfaces. The specimen thickness and bend radius are shown in figures QB-466.1, QB-466.2, and QB-466.3. Guided-bend specimens are of five types, depending on whether the axis of the joint is transverse or parallel to the longitudinal axis of the specimen, and which surface (first or second) is on the convex (outer) side of the bent specimen. The five types are defined as follows (QB-161.1 through QB-161.6).

QB-161.1 Transverse First Surface Bend. The joint is transverse to the longitudinal axis of the specimen, which is bent so that the first surface becomes the convex surface of the bent specimen. In general, the *first surface* is defined as that surface from which the brazing filler metal is applied and is fed by capillary attraction into the joint. Transverse first surface bend specimens shall conform to the dimensions shown in figure QB-462.2(a). For subsize first surface bends, see QB-161.3.

QB-161.2 Transverse Second Surface Bend. The joint is transverse to the longitudinal axis of the specimen, which is bent so that the second surface becomes the convex surface of the bent specimen. In general, the *second surface* is defined as the surface opposite to that from which the brazing filler metal is placed or fed, but definitely is the surface opposite to that designated as the first surface, irrespective of how the brazing filler metal is fed. Transverse second surface bend specimens shall conform to the dimensions shown in figure QB-462.2(a). For subsize first surface bends, see QB-161.3.

QB-161.3 Subsize Transverse Bend. In those cases where the wall thickness of the tube or pipe is less than $\frac{3}{8}$ in. (10 mm) and the diameter-to-thickness ratio does not permit the preparation of full-size rectangular guided-bend specimens, the $1\frac{1}{2}$ in. (38 mm) wide standard guided-bend specimen shown in figure QB-462.2(a) may be replaced by three subsize specimens having a width of $\frac{3}{8}$ in. (10 mm) or $4t$, whichever is less.

QB-161.4 Longitudinal-Bend Tests. Longitudinal-bend tests may be used in lieu of the transverse-bend tests for testing braze metal or base metal combinations, which differ markedly in bending properties between

(*a*) the two base metals; or

(*b*) the braze metal and the base metal.

QB-161.5 Longitudinal First Surface Bend. The joint is parallel to the longitudinal axis of the specimen, which is bent so that the first surface becomes the convex surface of the bent specimen. The definition of first surface is as given in QB-161.1. Longitudinal first surface bend specimens shall conform to the dimensions given in figure QB-462.2(b).

QB-161.6 Longitudinal Second Surface Bend. The joint is parallel to the longitudinal axis of the specimen, which is bent so that the second surface becomes the convex surface of the specimen. The definition of the second surface is given in QB-161.2. Longitudinal second surface bend specimens shall conform to the dimensions given in figure QB-462.2(b).

QB-162 Guided-Bend Test Procedure

QB-162.1 Jigs. Guided-bend specimens shall be bent in test jigs that are in substantial accordance with QB-466. When using the jigs in accordance with figure QB-466.1 or figure QB-466.2, the side of the specimen turned toward the gap of the jig shall be the first surface for first surface bend specimens (defined in QB-161.1), and the second surface for second surface bend specimens (defined in QB-161.2). 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 mm) diameter wire cannot be inserted between the specimen and the die of figure QB-466.1, or the specimen is bottom ejected, if the roller type of jig (figure QB-466.2) is used.

When using the wrap around jig (figure QB-466.3) the side of the specimen turned toward the roller shall be the first surface for first surface bend specimens, and the second surface for second surface bend specimens.

QB-163 Acceptance Criteria — Bend Tests

The joint of a transverse-bend specimen shall be completely within the bent portion of the specimen after testing.

The guided-bend specimens shall have no open discontinuities exceeding $\frac{1}{8}$ in. (3 mm), measured in any direction on the convex surface of the specimen after bending. Cracks occurring on the corners of the specimen during testing shall not be considered, unless there is definite evidence that they result from flux inclusions, voids, or other internal discontinuities.

QB-170 PEEL TESTS

QB-171 Specimens

The dimensions and preparation of the peel test specimen shall conform to the requirements of figure QB-462.3.

QB-172 Acceptance Criteria — Peel Test

In order to pass the peel test, the specimens shall show evidence of brazing filler metal along each edge of the joint. Specimens shall be separated or peeled either by clamping Section A and striking Section B with a suitable tool such that the bending occurs at the fulcrum point (see figure QB-462.3), or by clamping Section A and Section B in a machine suitable for separating the sections under tension. The separated faying surfaces of joints shall meet the following criteria:

(a) The total area of discontinuities (unbrazed areas, flux inclusions, etc.) shall not exceed 25% of the total area of any individual faying surface.

(b) The sum of the lengths of the discontinuities measured on any one line in the direction of the lap shall not exceed 25% of the lap.

(c) No discontinuity shall extend continuously from one edge of the joint to the other edge, irrespective of its direction.

QB-180 SECTIONING TESTS AND WORKMANSHIP COUPONS

QB-181 Sectioning Test Specimens

The dimensions and configuration of the sectioning test specimens shall conform to the requirements of figure QB-462.4. Each side of the specimen shall be polished and examined with at least a four-power magnifying glass. The sum of the length of unbrazed areas on either side, considered individually, shall not exceed 20% of the length of the joint overlap.

QB-182 Workmanship Coupons

The dimensions and configuration of the workmanship coupon shall conform to the nearest approximation of the actual application. Some typical workmanship coupons are shown in figure QB-462.5. Each side of the specimen shall be polished and examined with at least a four-power magnifying glass. The sum of the length of unbrazed areas on either side, considered individually, shall not exceed 20% of the length of the joint overlap.

ARTICLE XII
BRAZING PROCEDURE QUALIFICATIONS

QB-200 GENERAL

QB-200.1 Each manufacturer or contractor shall prepare written Brazing Procedure Specifications, which are defined as follows.

(a) Brazing Procedure Specification (BPS). A BPS is a written qualified brazing procedure prepared to provide direction for making production brazes to Code requirements. The BPS or other documents [see QB-200.1(e)] may be used to provide direction to the brazer or brazing operator to assure compliance with the Code requirements.

(b) Contents of the BPS. The completed BPS shall describe all of the essential and nonessential variables for each brazing process used in the BPS. These variables are listed in QB-250 and are defined in Article XIV, Brazing Data.

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

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

Changes in essential variables require requalification of the BPS [new or additional PQRs to support the change in essential variable(s)].

(d) Format of the BPS. The information required to be in the BPS may be in any format, written or tabular, to fit the needs of each manufacturer or contractor, as long as every essential and nonessential variable outlined in QB-250 is included or referenced.

Form QB-482 (see Nonmandatory Appendix B) has been provided as a guide for the BPS. It is only a guide and does not list all required data for all brazing processes.

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

QB-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 brazing data used to braze a test coupon. The PQR is a record of variables recorded during the brazing 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 brazing.

(b) Contents of the PQR. The completed PQR shall document all essential variables of QB-250 for each brazing process used during the brazing of the test coupon. Nonessential or other variables used during the brazing 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 brazing of the test coupon. If variables are not monitored during brazing, 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 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 brazing of the test coupon and that the resulting tensile, bend, peel, or section (as required) test results are in compliance with Section IX.

(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 brazing test. Editorial corrections or addenda to the PQR are permitted. An example of an editorial correction is an incorrect P-Number or F-Number that was assigned to a particular base material 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 material or adopt a new filler material 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 QB-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 variable, required by QB-250, is included. Also the type of tests, number of tests, and test results shall be listed in the PQR. Additional sketches or information may be attached or referenced to record the required variables.

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

(f) Multiple BPSs With One PQR/Multiple PQRs With One BPS. Several BPSs may be prepared from the data on a single PQR (e.g., a vertical-upflow pipe PQR may support BPSs for the vertical-upflow and downflow positions on pipe within all other essential variables). A single BPS may cover several essential variable changes as long as a supporting PQR exists for each essential variable.

QB-200.3 To reduce the number of brazing procedure qualifications required, P-Numbers are assigned to base metals dependent on characteristics such as composition, brazability, and mechanical properties, where this can logically be done, and for ferrous and nonferrous metals.

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, postbraze heat treatment, design, mechanical properties, and service requirements.

QB-200.4 Dissimilar Base Metal Thicknesses. A BPS qualified on test coupons of equal thickness shall be applicable for production brazements between dissimilar base metal thicknesses provided the thickness of both base metals are within the qualified thickness range permitted by QB-451. A BPS qualified on test coupons of different thicknesses shall be applicable for production brazements between dissimilar base metal thicknesses provided the thickness of each base metal is within the qualified range of thickness (based on each test coupon thickness) permitted by QB-451.

QB-201 Manufacturer's or Contractor's Responsibility

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

Each manufacturer or contractor shall qualify the BPS by the brazing of test coupons and the testing of specimens (as required in this Code), and the recording of the brazing data and test results in a document known as a Procedure Qualification Record (PQR). The brazers or brazing operators used to produce brazements 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 brazements. It is not permissible for the manufacturer or contractor to have the brazing of the test brazements performed by another organization. It is permissible, however, to subcontract any or all of the work of preparation of test metal for brazing and subsequent work on preparation of test specimens from the completed brazement, 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 brazements to be made in accordance with this Code. If in an organization effective operational control of brazing 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 brazing procedure qualifications are not required, provided all other requirements of Section IX are met.

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

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

QB-201.1 The Code recognizes that manufacturers or contractors may maintain effective operational control of PQRs and BPSs 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 BPSs 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 BPSs and PQRs

(b) the BPSs 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

QB-202 Type of Tests Required

QB-202.1 Tests. The type and number of test specimens which shall be tested to qualify a brazing procedure are given in QB-451, and shall be removed in a manner similar to that shown in QB-463. If any test specimen required by QB-451 fails to meet the applicable acceptance criteria, the test coupon shall be considered as failed.

When it can be determined that the cause of failure is not related to brazing parameters, another test coupon may be brazed using identical brazing parameters. Alternatively, if adequate material of the original test coupon exists, additional test specimens may be removed as close as practicable to the original specimen location to replace the failed test specimens.

When it has been determined that the test failure was caused by an essential variable, a new test coupon may be brazed with appropriate changes to the variable(s) that were determined to cause the test failure. If the new test passes, the essential variables shall be documented on the PQR.

When it is determined that the test failure was caused by one or more brazing related factors other than essential variables, a new test coupon may be brazed with the appropriate changes to brazing related factors that were determined to cause the test failure. If the new test passes, the brazing related factors that were determined to cause the previous test failure shall be addressed by the manufacturer to assure that the required properties are achieved in the production brazement.

QB-202.2 Base Metals. The procedure qualification shall encompass the thickness ranges to be used in production for the base metals to be joined or repaired. The range of thickness qualified is given in QB-451.

QB-203 Limits of Qualified Flow Positions for Procedures (See figures QB-461.1 and QB-461.2)

QB-203.1 For plate, qualification in the flat-flow, vertical-upflow, or horizontal-flow position shall qualify for the vertical-downflow position. For pipe, qualification in the horizontal-flow or vertical-upflow position shall qualify for the vertical-downflow position.

Qualification in pipe shall qualify for plate, but not vice versa. Horizontal-flow in pipe shall also qualify for flat-flow in plate.

QB-203.2 Special Flow Positions. A fabricator who does production brazing in a special orientation may make the tests for procedure qualification in this specific orientation. Such qualifications are valid only for the flow positions actually tested, except that an angular deviation of ±15 deg is permitted in the inclination of the braze plane, as defined in figures QB-461.1 and QB-461.2.

QB-203.3 The brazing process must be compatible, and the brazing filler metals, such as defined in the specifications of Section II, Part C, must be suitable for their use in specific flow positions. A brazer or brazing operator making and passing the BPS qualification test is thereby qualified for the flow position tested (see QB-301.2).

QB-210 PREPARATION OF TEST COUPON

QB-211 Base Metal and Filler Metal

The base metals and filler metals shall be one or more of those listed in the BPS. The dimensions of the test assembly shall be sufficient to provide the required test specimens.

The base metals may consist of either plate, pipe, or other product forms. Qualification in pipe also qualifies for plate brazing, but not vice versa.

QB-212 Type and Dimension of Joints

The test coupon shall be brazed using a type of joint design proposed in the BPS for use in construction.

QB-250 BRAZING VARIABLES

QB-251 General

QB-251.1 Types of Variables for Brazing Procedure Specification (BPS). Brazing variables (listed for each brazing process in tables QB-252 through QB-257) are subdivided into essential and nonessential variables (QB-401).

QB-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 brazement, and shall require requalification of the BPS.

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

QB-252
TORCH BRAZING (TB)

Paragraph	252.1 Essential Variables	252.2 Nonessential Variables
QB-402 Base Metal	QB-402.1	. . .
	QB-402.3	. . .
QB-403 Brazing Filler Metal	QB-403.1	. . .
	QB-403.2	. . .
QB-406 Brazing Flux, Gas, or Atmosphere	QB-406.1	QB-406.3
QB-407 Flow Position	QB-407.1	. . .
QB-408 Joint Design	QB-408.2	. . .
	QB-408.4	. . .
QB-409 Postbraze Heat Treatment	QB-409.1	. . .
	QB-409.2	. . .
	QB-409.3	. . .
QB-410 Technique	. . .	QB-410.1
	. . .	QB-410.2
	. . .	QB-410.3
	. . .	QB-410.4
	. . .	QB-410.5

QB-253
FURNACE BRAZING (FB)

Paragraph	253.1 Essential Variables	253.2 Nonessential Variables
QB-402 Base Metal	QB-402.1	. . .
	QB-402.3	. . .
QB-403 Brazing Filler Metal	QB-403.1	. . .
	QB-403.2	. . .
QB-404 Brazing Temperature	QB-404.1	. . .
QB-406 Brazing Flux, Gas, or Atmosphere	QB-406.1	. . .
	QB-406.2	. . .
QB-407 Flow Position	QB-407.1	. . .
QB-408 Joint Design	QB-408.2	. . .
	QB-408.4	. . .
QB-409 Postbraze Heat Treatment	QB-409.1	. . .
	QB-409.2	. . .
	QB-409.3	. . .
QB-410 Technique	. . .	QB-410.1
	. . .	QB-410.2

QB-254
INDUCTION BRAZING (IB)

Paragraph	254.1 Essential Variables	254.2 Nonessential Variables
ParagraphQB-402 Base Metal	QB-402.1	...
	QB-402.3	...
QB-403 Brazing Filler Metal	QB-403.1	...
	QB-403.2	...
QB-404 Brazing Temperature	QB-404.1	...
QB-406 Brazing Flux, Gas, or Atmosphere	QB-406.1	...
QB-407 Flow Position	QB-407.1	...
QB-408 Joint Design	QB-408.2	...
	QB-408.4	...
QB-409 Postbraze Heat Treatment	QB-409.1	...
	QB-409.2	...
	QB-409.3	...
QB-410 Technique	...	QB-410.1
	...	QB-410.2

QB-255
RESISTANCE BRAZING (RB)

Paragraph	255.1 Essential Variables	255.2 Nonessential Variables
QB-402 Base Metal	QB-402.1	...
	QB-402.3	...
QB-403 Brazing Filler Metal	QB-403.1	...
	QB-403.2	...
QB-404 Brazing Temperature	QB-404.1	...
QB-406 Brazing Flux, Gas, or Atmosphere	QB-406.1	...
QB-407 Flow Position	QB-407.1	...
QB-408 Joint Design	QB-408.2	...
	QB-408.4	...
QB-409 Postbraze Heat Treatment	QB-409.1	...
	QB-409.2	...
	QB-409.3	...
QB-410 Technique	...	QB-410.1
	...	QB-410.2

QB-256
DIP BRAZING — SALT OR FLUX BATH (DB)

Paragraph	256.1 Essential Variables	256.2 Nonessential Variables
QB-402 Base Metal	QB-402.1	...
	QB-402.3	...
QB-403 Brazing Filler Metal	QB-403.1	...
	QB-403.2	...
QB-404 Brazing Temperature	QB-404.1	...
QB-406 Brazing Flux, Gas, or Atmosphere	QB-406.1	...
QB-407 Flow Position	QB-407.1	...
QB-408 Joint Design	QB-408.2	...
	QB-408.4	...
QB-409 Postbraze Heat Treatment	QB-409.1	...
	QB-409.2	...
	QB-409.3	...
QB-410 Technique	...	QB-410.1
	...	QB-410.2

QB-257
DIP BRAZING — MOLTEN METAL BATH (DB)

Paragraph	257.1 Essential Variables	257.2 Nonessential Variables
QB-402 Base Metal	QB-402.1	...
	QB-402.3	...
QB-403 Brazing Filler Metal	QB-403.1	...
	QB-403.2	...
QB-404 Brazing Temperature	QB-404.1	...
QB-406 Brazing Flux, Gas, or Atmosphere	QB-406.1	...
QB-407 Flow Position	QB-407.1	...
QB-408 Joint Design	QB-408.2	...
	QB-408.4	...
QB-409 Postbraze Heat Treatment	QB-409.1	...
	QB-409.2	...
	QB-409.3	...
QB-410 Technique	...	QB-410.1
	...	QB-410.2

ARTICLE XIII
BRAZING PERFORMANCE QUALIFICATIONS

QB-300 GENERAL

QB-300.1 This Article lists the brazing processes separately, with the essential variables which apply to brazer and brazing operator performance qualifications.

The brazer qualification is limited by the essential variables given for each brazing process. These variables are listed in QB-350, and are defined in Article XIV, Brazing Data. The brazing operator qualification is limited by the essential variables given in QB-350 for each brazing process.

QB-300.2

(a) The basic premises of responsibility in regard to brazing are contained within QB-103 and QB-301.2. These paragraphs require that each manufacturer or contractor shall be responsible for conducting tests to qualify the performance of brazers and brazing operators in accordance with one of his qualified Brazing Procedure Specifications, which his organization employs in the construction of brazements built in accordance with the Code. The purpose of this requirement is to ensure that the manufacturer or contractor has determined that his brazers and brazing operators using his procedures are capable of developing the minimum requirements specified for an acceptable brazement. This responsibility cannot be delegated to another organization.

(b) The brazers or brazing operators used to produce such brazements shall be tested under the full supervision and control of the manufacturer or contractor during the production of these test brazements. It is not permissible for the manufacturer or contractor to have the brazing performed by another organization. It is permissible, however, to subcontract any or all of the work of preparation of test materials for brazing, subsequent work on the preparation of test specimens from the completed brazement, and performance of nondestructive examination and mechanical tests, provided the manufacturer or contractor accepts full responsibility for any such work.

(c) The Code recognizes a manufacturer or contractor as the organization which has responsible operational control of the production of the brazement to be made in accordance with this Code. If in an organization effective operational control of the brazer performance qualification for two or more companies of different names exists, the companies involved must establish, to the satisfaction of the ASME Boiler and Pressure Vessel Committee, that the necessary controls are applied, in which case requalification of brazers and brazing operators within the companies of such an organization will not be required, provided all other requirements of Section IX are met.

(d) The Code recognizes that manufacturers or contractors may maintain effective operational control of Brazer/Brazing Operator Performance Qualification (BPQ) records under different ownership than existed during the original Brazer or Brazing Operator qualification. When a manufacturer or contractor or part of a manufacturer or contractor is acquired by a new owner(s), the BPQs may be used by the new owner(s) without requalification, provided all of the following are met:

(1) the new owner(s) takes responsibility for the BPQs

(2) the BPQs reflect the name of the new owner(s)

(3) the Quality Control System/Quality Assurance Program reflects the source of the BPQs as being from the former manufacturer or contractor

QB-300.3 More than one manufacturer or contractor may simultaneously qualify one or more brazers or brazing operators. When simultaneous qualifications are conducted, each participating organization shall be represented by a responsible employee during brazing of the test coupons.

The brazing procedure specifications (BPS) that are followed during simultaneous qualifications shall be compared by the participating organizations. The BPSs shall be identical for all essential variables, except that the flow position, base metal thickness, and overlap lengths need not be identical, but they shall be adequate to permit brazing of the test coupons. Alternatively, the participating organizations shall agree upon the use of a single BPS, provided each participating organization has a PQR(s) to support the BPS covering the range of variables to be followed in the performance qualification. When a single BPS is to be followed, each participating organization shall review and accept that BPS.

Each participating organization's representative shall positively identify each brazer or brazing operator who is being tested. Each organizational representative shall also verify marking of the test coupon with the brazer's or brazing operator's identification, and marking of the top of the test coupon when the orientation must be known in order to remove test specimens.

Each organizational representative shall complete and certify a Record of Brazer or Brazing Operator Qualification (Form QB-484 or equivalent) for each brazer or brazing operator.

When a brazer or brazing operator changes employers, that new participating organization shall verify that the brazer's continuity of qualifications has been maintained as required by QB-322 by previous employers since his qualification date. If the brazer or brazing operator has had his qualification withdrawn for specific reasons, the employing organization shall notify all participating organizations that the brazer's or brazing operator's qualification(s) has been revoked in accordance with QB-322(b). The new organization shall determine that the brazer or brazing operator can perform satisfactory work in accordance with this Section.

When a brazer's or brazing operator's qualifications are renewed in accordance with the provisions of QB-322, each renewing organization shall be represented by a responsible employee and the testing procedures shall follow the rules of this paragraph.

QB-301 Tests

QB-301.1 Intent of Tests. The performance qualification tests are intended to determine the ability of brazers and brazing operators to make sound braze joints.

QB-301.2 Qualification Tests. Each manufacturer or contractor shall qualify each brazer or brazing operator for each brazing process to be used in production brazing. The performance qualification test shall be brazed in accordance with one of any of his qualified Brazing Procedure Specifications (BPS).

The brazer or brazing operator who prepares the BPS qualification test coupons is also qualified within the limits of the performance qualifications, listed in QB-304 for brazers and in QB-305 for brazing operators. He is qualified only for the positions tested in the procedure qualification in accordance with QB-407.

The performance test may be terminated at any stage of the testing procedure, whenever it becomes apparent to the supervisor conducting the tests that the brazer or brazing operator does not have the required skill to produce satisfactory results.

QB-301.3 Identification of Brazers and Brazing Operators. Each qualified brazer and brazing operator shall be assigned an identifying number, letter, or symbol by the manufacturer or contractor, which shall be used to identify the work of that brazer or brazing operator.

QB-301.4 Record of Tests. The record of Brazer or Brazing Operator Performance Qualification (BPQ) tests shall include the essential variables (QB-350), the type of tests and the test results, and the ranges qualified in accordance with QB-452 for each brazer and brazing operator. A suggested form for these records is given in Form QB-484 (see Nonmandatory Appendix B).

QB-302 Type of Test Required

QB-302.1 Test Specimens. The type and number of test specimens required shall be in accordance with QB-452, and shall be removed in a manner similar to that shown in QB-463.

All test specimens shall meet the requirements prescribed in QB-170 or QB-180, as applicable. Tests for brazing operators shall meet the requirements of QB-305.

QB-302.2 Test Coupons in Pipe. For test coupons made in pipe, specimens shall be removed as shown in figure QB-463.2(c) at approximately 180 deg apart.

QB-302.3 Combination of Base Metal Thicknesses. When joints are brazed between two base metals of different thicknesses, a performance qualification shall be made for the applicable combination of thicknesses, even though qualification tests have been made for each of the individual base metals brazed to itself. The range of thickness of each of the base metals shall be determined individually per QB-452.

QB-303 Limits of Qualified Positions (See figures QB-461.1 and QB-461.2)

QB-303.1 For plate, qualification in the flat-flow, vertical-upflow, or horizontal-flow positions shall qualify for the vertical-downflow position.

QB-303.2 For pipe, qualification in either the horizontal-flow or vertical-upflow position shall qualify for the vertical-downflow position.

QB-303.3 Qualification in pipe shall qualify for plate, but not vice versa. Horizontal-flow in pipe shall qualify for flat-flow in plate.

QB-303.4 Special Positions. A fabricator who does production brazing in a special orientation may make the tests for performance qualification in this specific orientation. Such qualifications are valid only for the flow positions actually tested, except that an angular deviation of ±15 deg is permitted in the inclination of the braze plane, as defined in figures QB-461.1 and QB-461.2.

QB-304 Brazers

Each brazer who brazes under the rules of this Code shall have passed the tests prescribed in QB-302 for performance qualifications.

A brazer qualified to braze in accordance with one qualified BPS is also qualified to braze in accordance with other qualified BPSs, using the same brazing process, within the limits of the essential variables of QB-350.

QB-305 Brazing Operators

The brazing operator who prepares brazing procedure qualification test specimens meeting requirements of QB-451 is thereby qualified. Alternatively, each brazing operator who brazes on vessels constructed under the rules of this Code shall be qualified for each combination of essential variables under which brazing is performed using semiautomatic or automatic processes (such as the resistance, induction, or furnace processes) as follows:

(a) A typical joint or workmanship coupon embodying the requirements of a qualified brazing procedure shall be brazed and sectioned. Typical joints are shown in figure QB-462.5.

(b) In order to ensure that the operator can carry out the provisions of the brazing procedure, the test sections required in QB-305(a) shall meet the requirements of QB-452.

QB-310 QUALIFICATION TEST COUPONS

QB-310.1 Test Coupons. The test coupons may be plate, pipe, or other product forms. The dimensions of the test coupon and length of braze shall be sufficient to provide the required test specimens.

QB-310.2 Braze Joint. The dimensions of the braze joint at the test coupon used in making qualification tests shall be the same as those in the Brazing Procedure Specification (BPS).

QB-310.3 Base Metals. When a brazer or brazing operator is to be qualified, the test coupon shall be base metal of the P-Number or P-Numbers to be joined in production brazing.

QB-320 RETESTS AND RENEWAL OF QUALIFICATION

QB-321 Retests

A brazer or brazing operator who fails to meet the requirements for one or more of the test specimens prescribed in QB-452 may be retested under the following conditions.

QB-321.1 Immediate Retest. When an immediate retest is made, the brazer or brazing operator shall make two consecutive test coupons for each position which he has failed, all of which shall pass the test requirements.

QB-321.2 Further Training. When the brazer or brazing operator has had further training or practice, a complete retest shall be made for each position on which he failed to meet the requirements.

QB-322 Renewal of Qualification

Renewal of qualification of a performance qualification is required

(a) when a brazer or brazing operator has not used the specific brazing process for a period of 6 months or more, or

(b) when there is a specific reason to question his ability to make brazes that meet the specification. Renewal of qualification for a specific brazing process under QB-322(a) may be made with specific brazing process by making only one test joint (plate or pipe) with all the essential variables used on any one of the brazer's or brazing operator's previous qualification test joints. This will reestablish the brazer's or brazing operator's qualification for all variables for which he had previously qualified with the specific brazing process.

QB-350 BRAZING VARIABLES FOR BRAZERS AND BRAZING OPERATORS

QB-351 General

A brazer or brazing operator shall be requalified whenever a change is made in one or more of the essential variables for each brazing process, as follows:

(a) Torch Brazing (TB)
(b) Furnace Brazing (FB)
(c) Induction Brazing (IB)
(d) Resistance Brazing (RB)
(e) Dip Brazing (DB)

QB-351.1 Essential Variables — Manual, Semiautomatic, and Machine Brazing

(a) QB-402 Base Metal
  (1) QB-402.2
  (2) QB-402.3
(b) QB-403 Brazing Filler Metal
  (1) QB-403.1
  (2) QB-403.2
(c) QB-407 Flow Position
  (1) QB-407.1
(d) QB-408 Joint Design
  (1) QB-408.1
  (2) QB-408.3
(e) QB-410 Technique
  (1) QB-410.5

QB-351.2 Essential Variables — Automatic

(a) A change from automatic to machine brazing.
(b) A change in brazing process.

ARTICLE XIV
BRAZING DATA

QB-400 VARIABLES

QB-401 General

QB-401.1 Each brazing variable described in this Article is applicable as an essential or nonessential variable for procedure qualification when referenced in QB-250 for each specific process. Essential variables for performance qualification are referenced in QB-350 for each specific brazing process. A change from one brazing process to another brazing process is an essential variable and requires requalification.

QB-402 Base Metal

QB-402.1 A change from a base metal listed under one P-Number in table QW/QB-422 to any of the following:

(a) a metal listed under another P-Number

(b) any other base metal not listed in table QW/QB-422

The brazing of dissimilar metals need not be requalified if each base metal involved is qualified individually for the same brazing filler metal, flux, atmosphere, and process. Similarly, the brazing of dissimilar metals qualifies for the individual base metal brazed to itself and for the same brazing filler metal, flux, atmosphere, and process, provided the requirements of QB-153.1(a) are met.

QB-402.2 A change from a base metal listed under one P-Number in table QW/QB-422 to any of the following:

(a) a metal listed under another P-Number

(b) any other metal not listed in table QW/QB-422

The brazing of dissimilar metals need not be requalified if each base metal involved is qualified individually for the same brazing filler metal, flux, atmosphere, and process. Similarly, the brazing of dissimilar metals qualifies for the individual base metal brazed to itself and for the same brazing filler metal, flux, atmosphere, and process.

QB-402.3 A change in base metal thickness beyond the range qualified in QB-451 for procedure qualification, or QB-452 for performance qualification.

QB-403 Brazing Filler Metal

QB-403.1 A change from one F-Number in table QB-432 to any other F-Number, or to any other filler metal not listed in table QB-432.

QB-403.2 A change in filler metal from one product form to another (for example, from preformed ring to paste).

QB-404 Brazing Temperature

QB-404.1 A change in brazing temperature to a value outside the range specified in the BPS.

QB-406 Brazing Flux, Fuel Gas, or Atmosphere

QB-406.1 The addition or deletion of brazing flux or a change in AWS classification of the flux. Nominal chemical composition or the trade name of the flux may be used as an alternative to the AWS classification.

QB-406.2 A change in the furnace atmosphere from one basic type to another type. For example

(a) reducing to inert

(b) carburizing to decarburizing

(c) hydrogen to disassociated ammonia

QB-406.3 A change in the type of fuel gas(es).

QB-407 Flow Position

QB-407.1 The addition of other brazing positions than those already qualified (see QB-120 through QB-124, QB-203 for procedure, and QB-303 for performance).

(a) If the brazing filler metal is preplaced or facefed from outside the joint, then requalification is required in accordance with the positions defined in figures QB-461.1 and QB-461.2 under the conditions of QB-120 through QB-124.

(b) If the brazing filler metal is preplaced in a joint in a manner that major flow does occur, then requalification is required in accordance with the positions defined in figures QB-461.1 and QB-461.2 under the conditions of QB-120 through QB-124.

(c) If the brazing filler metal is preplaced in a joint so that there is no major flow, then the joint may be brazed in any position without requalification.

QB-408 Joint Design

QB-408.1 A change in the joint type, i.e., from a butt to a lap or socket, from that qualified. For lap or socket joints, an increase in lap length of more than 25% from the overlap used on the brazer performance qualification test coupon (a decrease in overlap is permitted without requalification).

QB-408.2 A change in the joint clearances to a value outside the range specified in the BPS and as recorded in the PQR.

QB-408.3 A change in the joint clearances to a value outside the range specified in the BPS.

QB-408.4 A change in the joint type, e.g., from a butt to a lap or socket, from that qualified. For lap and socket joints, a decrease in overlap length from the overlap used on the procedure qualification test coupon (an increase in overlap is permitted without requalification).

QB-409 Postbraze Heat Treatment

QB-409.1 A separate procedure qualification is required for each of the following:

(a) For P-Nos. 101 and 102 materials, the following postbraze heat treatment conditions apply:

(1) no postbraze heat treatment

(2) postbraze heat treatment below the lower transformation temperature

(3) postbraze heat treatment above the upper transformation temperature (e.g., normalizing)

(4) postbraze heat treatment above the upper transformation temperature followed by heat treatment below the lower transformation temperature (e.g., normalizing or quenching followed by tempering)

(5) postbraze heat treatment between the upper and lower transformation temperatures

(b) For all other materials, the following post weld heat treatment conditions apply:

(1) no postbraze heat treatment

(2) postbraze heat treatment within a specified temperature range

QB-409.2 A change in the postbraze heat treatment (see QB-409.1) temperature and time range requires a PQR.

The procedure qualification test shall be subjected to postbraze heat treatment essentially equivalent to that encountered in the fabrication of production brazements, including at least 80% of the aggregate time at temperature(s). The postbraze heat treatment total time(s) at temperature(s) may be applied in one heating cycle.

QB-409.3 For a procedure qualification test coupon receiving a postbraze heat treatment in which the upper transformation temperature is exceeded, the maximum qualified thickness for production brazements is 1.1 times the thickness of the test coupon.

QB-410 TECHNIQUE

QB-410.1 A change in the method of preparing the base metal, i.e., method of precleaning the joints (for example, from chemical cleaning to cleaning by abrasive or mechanical means).

QB-410.2 A change in the method of postbraze cleaning (for example, from chemical cleaning to cleaning by wire brushing or wiping with a wet rag).

QB-410.3 A change in the nature of the flame (for example, a change from neutral or slightly reducing).

QB-410.4 A change in the brazing tip sizes.

QB-410.5 A change from manual to mechanical torch brazing and vice versa.

QB-420 P-NUMBERS

(See Part QW, Welding — QW-420)

QB-430 F-NUMBERS

QB-431 General

The following F-Number grouping of brazing filler metals in table QB-432 is based essentially on their usability characteristics, which fundamentally determine the ability of brazers and brazing operators to make satisfactory brazements with a given filler metal. This grouping is made to reduce the number of brazing procedure and performance qualifications, where this can logically be done. The grouping does not imply that filler metals within a group may be indiscriminately substituted for a filler metal which was used in the qualification test without consideration of the compatibility from the standpoint of metallurgical properties, design, mechanical properties, postbraze heat treatment, and service requirements.

QB-432
F-NUMBERS
Grouping of Brazing Filler Metals for Procedure and Performance Qualification SFA-5.8

QB	F-No.	AWS Classification No.
432.1	101	BAg-1
		BAg-1a
		BAg-8
		BAg-8a
		BAg-22
		BAg-23
		BVAg-0
		BVAg-8
		BVAg-8b
		BVAg-30
432.2	102	BAg-2
		BAg-2a
		BAg-3
		BAg-4
		BAg-5
		BAg-6
		BAg-7
		BAg-9
		BAg-10
		BAg-13
		BAg-13a
		BAg-18
		BAg-19
		BAg-20
		BAg-21
		BAg-24
		BAg-26
		BAg-27
		BAg-28
		BAg-33
		BAg-34
		BAg-35
		BAg-36
		BAg-37
		BVAg-6b
		BVAg-8
		BVAg-8a
		BVAg-18
		BVAg-29
		BVAg-31
		BVAg-32
432.3	103	BCuP-2
		BCuP-3
		BCuP-4
		BCuP-5
		BCuP-6
		BCuP-7
		BCuP-8
		BCuP-9

QB-432
F-NUMBERS (CONT'D)
Grouping of Brazing Filler Metals for Procedure and Performance Qualification SFA-5.8

QB	F-No.	AWS Classification No.
432.4	104	BAlSi-2
		BAlSi-3
		BAlSi-4
		BAlSi-5
		BAlSi-7
		BAlSi-9
		BAlSi-11
432.5	105	BCu-1
		BCu-1a
		BCu-2
		BCu-3
		BVCu-1a
		BVCu-1b
432.6	106	RBCuZn-A
		RBCuZn-B
		RBCuZn-C
		RBCuZn-D
432.7	107	BNi-1
		BNi-1a
		BNi-2
		BNi-3
		BNi-4
		BNi-5
		BNi-5a
		BNi-5b
		BNi-6
		BNi-7
		BNi-8
		BNi-9
		BNi-10
		BNi-11
		BNi-12
		BNi-13
432.8	108	BAu-1
		BAu-2
		BAu-3
		BAu-4
		BAu-5
		BAu-6
		BVAu-2
		BVAu-3
		BVAu-4
		BVAu-7
		BVAu-8
		BVAu-9
		BVAu-10
432.9	109	BMg-1
432.10	110	BCo-1
432.11	111	BVPd-1

QB-450 SPECIMENS

QB-451 Procedure Qualification Specimens

QB-451.1
TENSION TESTS AND TRANSVERSE-BEND TESTS — BUTT AND SCARF JOINTS

Thickness T of Test Coupon as Brazed, in. (mm)	Range of Thickness of Materials Qualified by Test Plate or Pipe, in. (mm)		Type and Number of Test Specimens Required		
	Min.	Max.	Tension [Note (1)]	First Surface Bend [Note (2)]	Second Surface Bend [Note (2)]
Less than $\frac{1}{8}$ (3)	$0.5T$	$2T$	2	2	2
$\frac{1}{8}$ to $\frac{3}{8}$ (3 to 10), incl.	$\frac{1}{16}$ (1.5)	$2T$	2	2	2
Over $\frac{3}{8}$ (10)	$\frac{3}{16}$ (5)	$2T$	2 [Note (3)]	2	2

NOTES:

(1) For specimen dimensions, see figure QB-462.1(a) for plate specimens, or figure QB-462.1(b) for pipe specimens. For pipe specimens not greater than NPS 3 (DN 75), full section testing may be substituted; see figure QB-462.1(e).

(2) For specimen dimensions, see figure QB-462.2(a). For specimen removal, see figure QB-463.1(a) for plate coupons, or figure QB-463.1(e) for pipe coupons.

(3) See QB-151 for details on multiple specimens when coupon thicknesses are over 1 in. (25 mm).

QB-451.2
TENSION TESTS AND LONGITUDINAL BEND TESTS — BUTT AND SCARF JOINTS

Thickness T of Test Coupon as Brazed, in. (mm)	Range of Thickness of Materials Qualified by Test Plate or Pipe, in. (mm)		Type and Number of Test Specimens Required		
	Min.	Max.	Tension [Note (1)]	First Surface Bend [Note (2)]	Second Surface Bend [Note (2)]
Less than $\frac{1}{8}$ (3)	$0.5T$	$2T$	2	2	2
$\frac{1}{8}$ to $\frac{3}{8}$ (3 to 10), incl.	$\frac{1}{16}$ (1.5)	$2T$	2	2	2
Over $\frac{3}{8}$ (10)	$\frac{3}{16}$ (5)	$2T$	2 [Note (3)]	2	2

NOTES:

(1) For specimen dimensions, see figure QB-462.1(a) for plate specimens, or figure QB-462.1(b) for pipe specimens. For pipe specimens not greater than NPS 3 (DN 75), full section testing may be substituted; see figure QB-462.1(e).

(2) For specimen dimensions, see figures QB-462.2(b) and QB-463.1(b) for specimen removal.

(3) See QB-151 for details on multiple specimens when coupon thicknesses are over 1 in. (25 mm).

(10)

QB-451.3
TENSION TESTS AND PEEL TESTS — LAP JOINTS

Thickness T of Test Coupon as Brazed, in. (mm)	Range of Thickness of Materials Qualified by Test Plate or Pipe, in. (mm)		Type and Number of Test Specimens Required [Note (1)]	
	Min.	Max.	Tension [Note (2)]	Peel [Notes (3) and (4)]
Less than $\frac{1}{8}$ (3)	$0.5T$	$2T$	2	2
$\frac{1}{8}$ to $\frac{3}{8}$ (3 to 10), incl.	$\frac{1}{16}$ (1.5)	$2T$	2	2
Over $\frac{3}{8}$ (10)	$\frac{3}{16}$ (5)	$2T$	2	2

NOTES:

(1) When materials of a representative geometry and thickness are not available to prepare butt or lap joint test coupons, workmanship coupons may be prepared and examined per QB-451.5 to establish the range of thickness of base metal qualified. When this is done, the properties of the joint shall be validated using butt or lap joint test coupons of any thickness.

(2) For specimen dimensions, see figure QB-462.1(c). For pipe specimens not greater than NPS 3 (DN 75), full section testing may be substituted; see figure QB-462.1(e).

(3) For peel specimens, see figure QB-462.3 for specimen dimensions, and figure QB-463.1(d) for specimen removal.

(4) Sectioning tests may be substituted for peel tests. For section specimens, see figure QB-462.4 for specimen dimensions, and figure QB-463.1(c) for specimen removal.

QB-451.4
TENSION TESTS AND SECTION TESTS — RABBET JOINTS

Thickness T of Test Coupon as Brazed, in. (mm)	Range of Thickness of Materials Qualified by Test Plate or Pipe, in. (mm)		Type and Number of Test Specimens Required	
	Min.	Max.	Tension [Note (1)]	Section [Note (2)]
Less than $\frac{1}{8}$ (3)	0.5T	2T	2	2
$\frac{1}{8}$ to $\frac{3}{8}$ (3 to 10), incl.	$\frac{1}{16}$ (1.5)	2T	2	2
Over $\frac{3}{8}$ (10)	$\frac{3}{16}$ (5)	2T	2	2

NOTES:
(1) For specimen dimensions, see figure QB-462.1(c). For pipe specimens not greater than NPS 3 (DN 75), full section testing may be substituted; see figure QB-462.1(e).
(2) For specimen dimensions, see figures QB-462.4 and QB-463.1(c) for specimen removal.

QB-451.5
SECTION TESTS — WORKMANSHIP COUPON JOINTS

Thickness T of Test Coupon as Brazed, in. (mm)	Range of Thickness of Materials Qualified by Test Plate or Pipe, in. (mm)		Type and Number of Test Specimens Required
	Min.	Max.	Section, QB-462.5 [Note (1)]
Less than $\frac{1}{8}$ (3)	0.5T	2T	2
$\frac{1}{8}$ to $\frac{3}{8}$ (3 to 10), incl.	$\frac{1}{16}$ (1.5)	2T	2
Over $\frac{3}{8}$ (10)	$\frac{3}{16}$ (5)	2T	2

NOTE:
(1) This test in itself does not constitute procedure qualification but must be validated by conductance of tests of butt or lap joints as appropriate. For joints connecting tension members, such as the stay or partition type in QB-462.5, the validation data may be based upon butt joints; for joints connecting members in shear, such as saddle or spud joints, the validation data may be based on lap joints.

QB-452 Performance Qualification Specimens

(10)

QB-452.1
PEEL OR SECTION TESTS — BUTT, SCARF, LAP, RABBET JOINTS

Thickness T of Test Coupon as Brazed, in. (mm)	Range of Thickness of Materials Qualified by Test Plate or Pipe, in. (mm)		Type and Number of Test Specimens Required
	Min.	Max.	Peel, QB-462.3 or Section, QB-462.4 [Notes (1), (2), and (3)]
Less than $^1/_8$ (3)	$0.5T$	$2T$	2
$^1/_8$ to $^3/_8$ (3 to 10), incl.	$^1/_{16}$ (1.5)	$2T$	2
Over $^3/_8$ (10)	$^3/_{16}$ (5)	$2T$	2

NOTES:

(1) Sectioning tests may be substituted for the peel test when the peel test is impractical to perform (e.g., when the strength of the brazing filler metal is equal to or greater than the strength of the base metals).

(2) For specimen dimensions, see figure QB-462.3 for peel test specimens or figure QB-462.4 for section specimens.

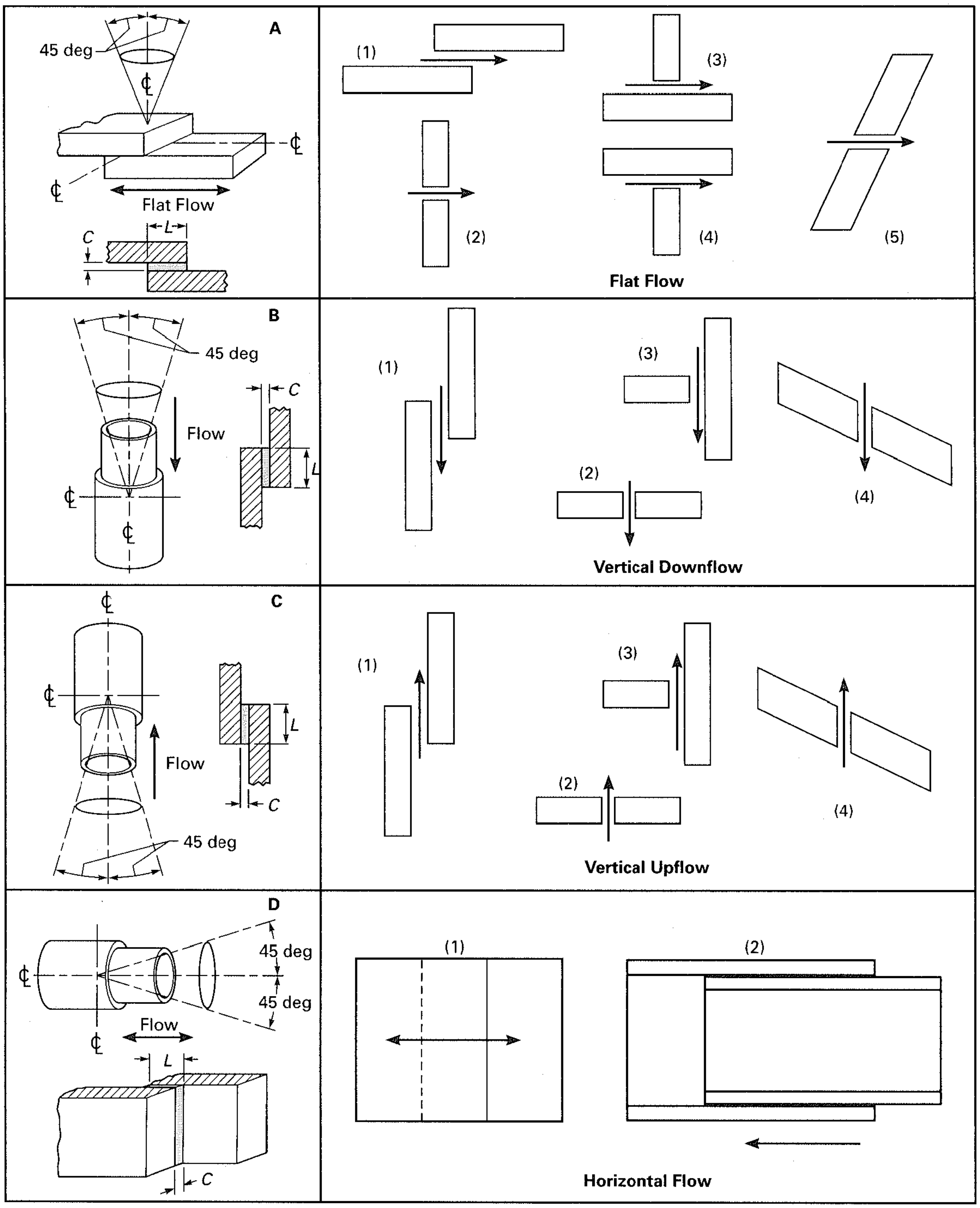
(3) For specimen removal, see figure QB-463.2(a) for section specimens or figure QB-463.2(b) for peel specimens from plate coupons, or figure QB-463.2(c) for pipe coupons.

QB-452.2
SECTION TESTS — WORKMANSHIP SPECIMEN JOINTS

Thickness T of Test Coupon as Brazed, in. (mm)	Range of Thickness of Materials Qualified by Test Plate or Pipe, in. (mm)		Type and Number of Test Specimens Required
	Min.	Max.	Section, QB-462.5
Less than $^1/_8$ (3)	$0.5T$	$2T$	1
$^1/_8$ to $^3/_8$ (3 to 10), incl.	$^1/_{16}$ (1.5)	$2T$	1
Over $^3/_8$ (10)	$^3/_{16}$ (5)	$2T$	1

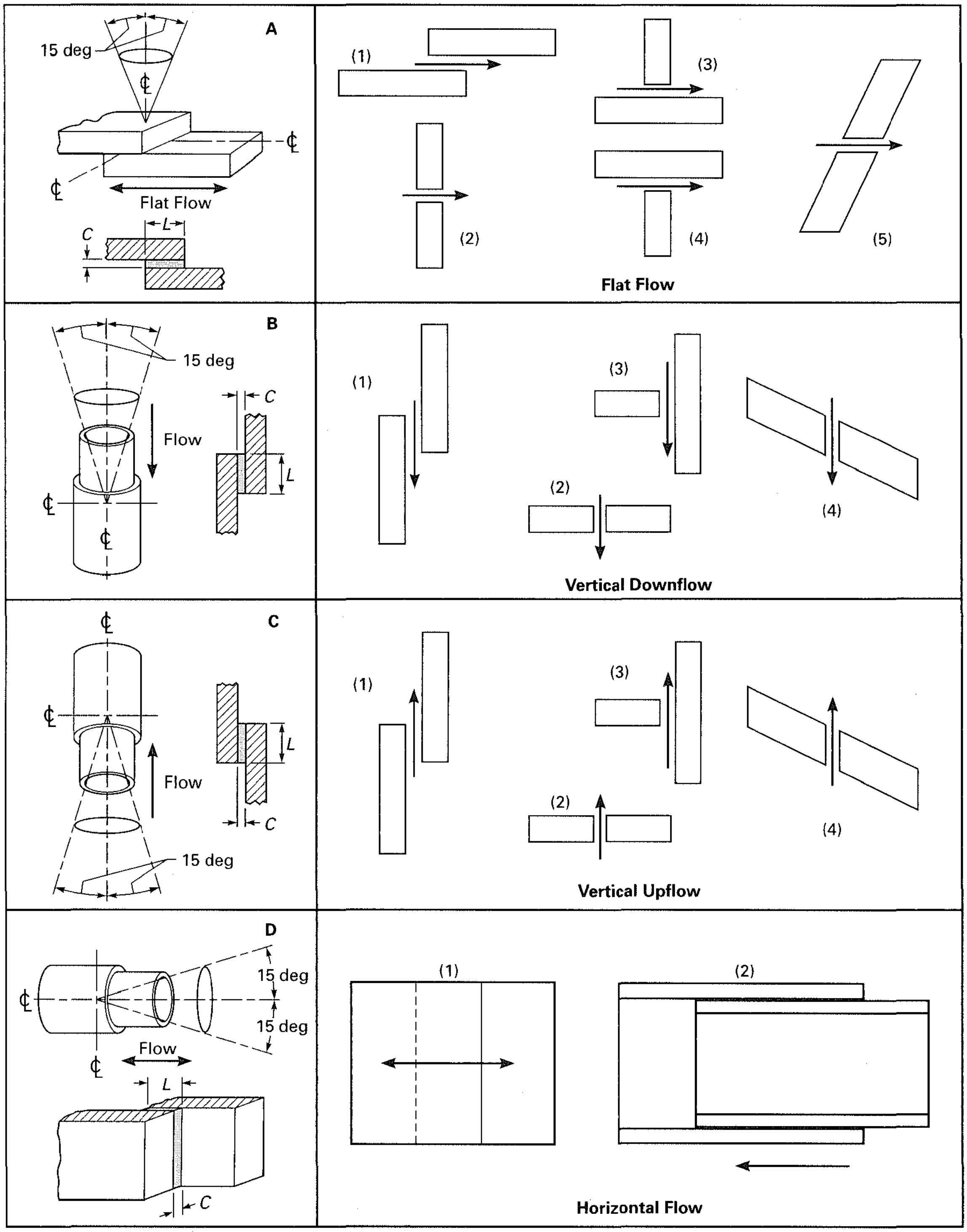
QB-460 GRAPHICS

QB-461.1 FLOW POSITIONS



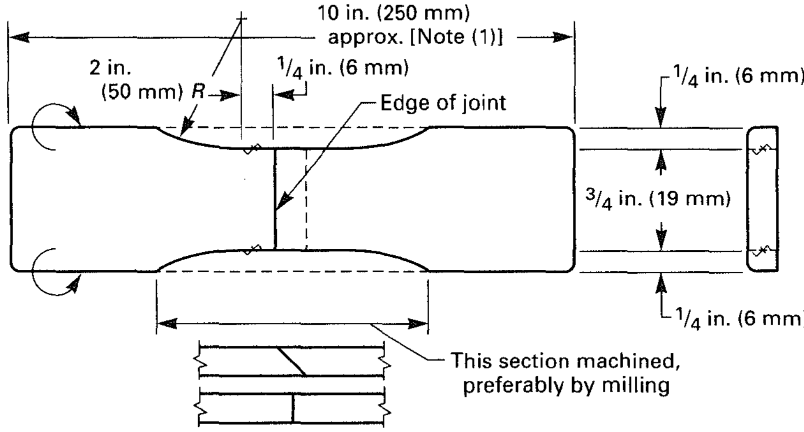
GENERAL NOTES:
(a) C = joint clearance
(b) L = length of lap or thickness

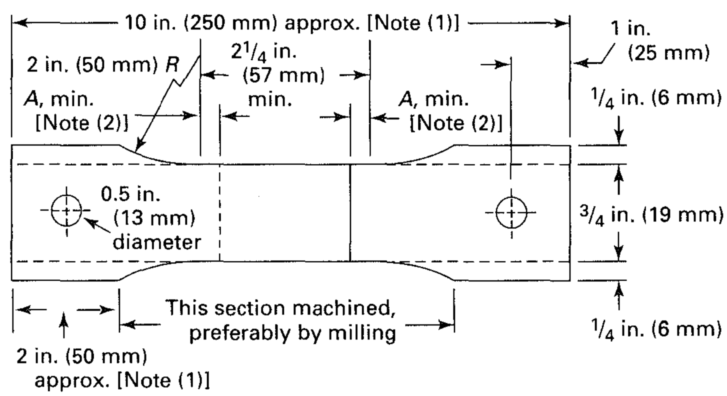
QB-461.2 TEST FLOW POSITIONS



GENERAL NOTES:
(a) C = joint clearance
(b) L = length of lap or thickness

QB-462.1(a) TENSION — REDUCED SECTION FOR BUTT AND SCARF JOINTS — PLATE

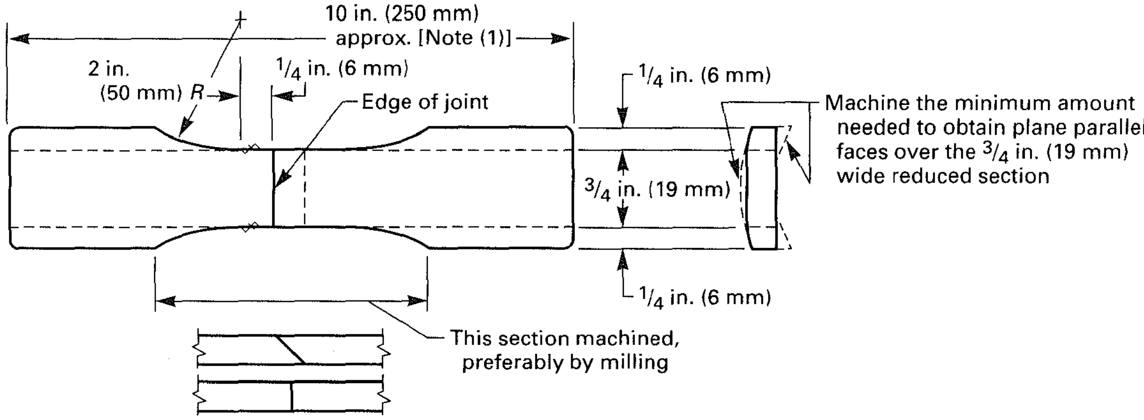


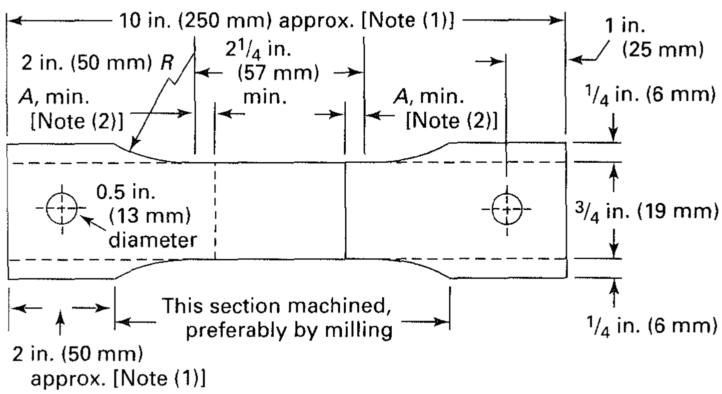


Alternate Pin-Loaded Specimen

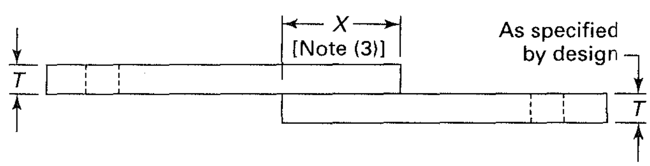
NOTES:
(1) Length may vary to fit testing machine.
(2) A = greater of $\frac{1}{4}$ in. (6 mm) or $2T$

QB-462.1(b) TENSION — REDUCED SECTION FOR BUTT, LAP, AND SCARF JOINTS — PIPE





Alternate Pin-Loaded Specimen



For Lap Joints

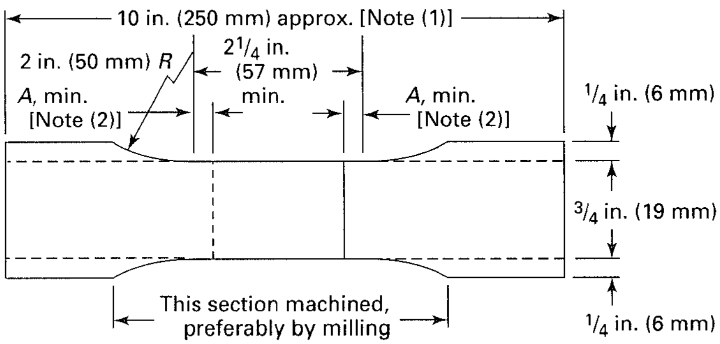
NOTES:

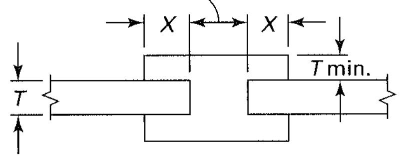
(1) Length may vary to fit testing machine.

(2) A = greater of $\frac{1}{4}$ in. (6 mm) or $2T$

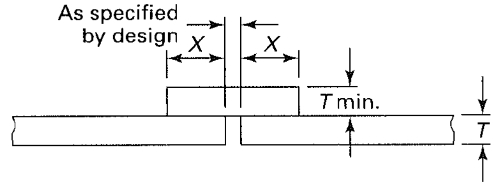
(3) X = test specimen overlap

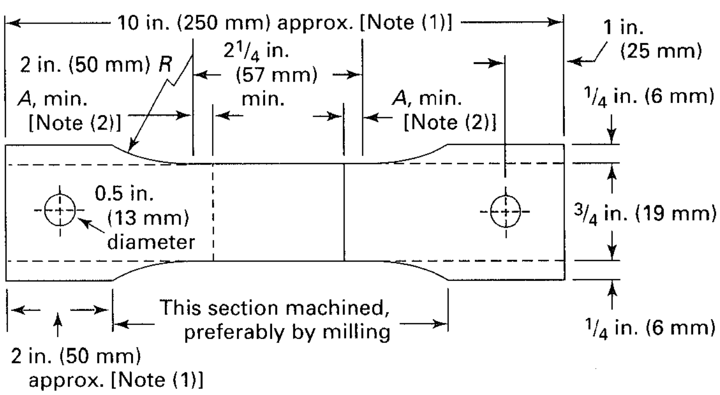
QB-462.1(c) TENSION — REDUCED SECTION FOR LAP AND RABBET JOINTS — PLATE



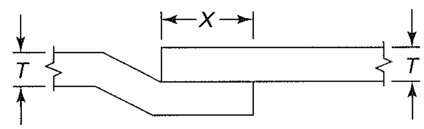


For Rabbet Joints

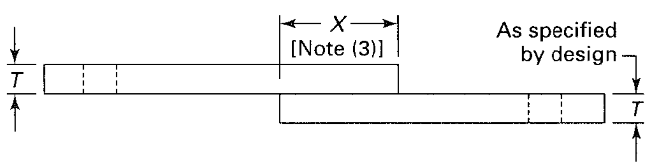




Alternate Pin-Loaded Specimen



Alternate Designs



For Lap Joints

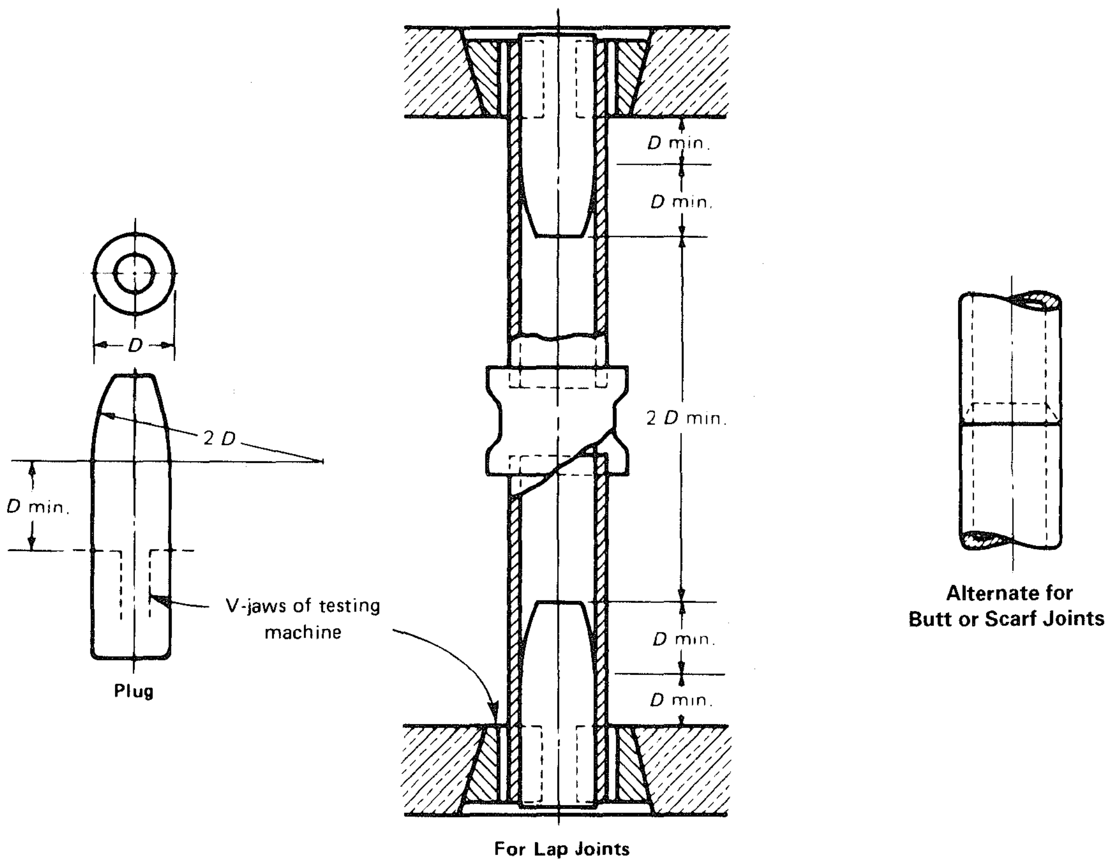
NOTES:

(1) Length may vary to fit testing machine.

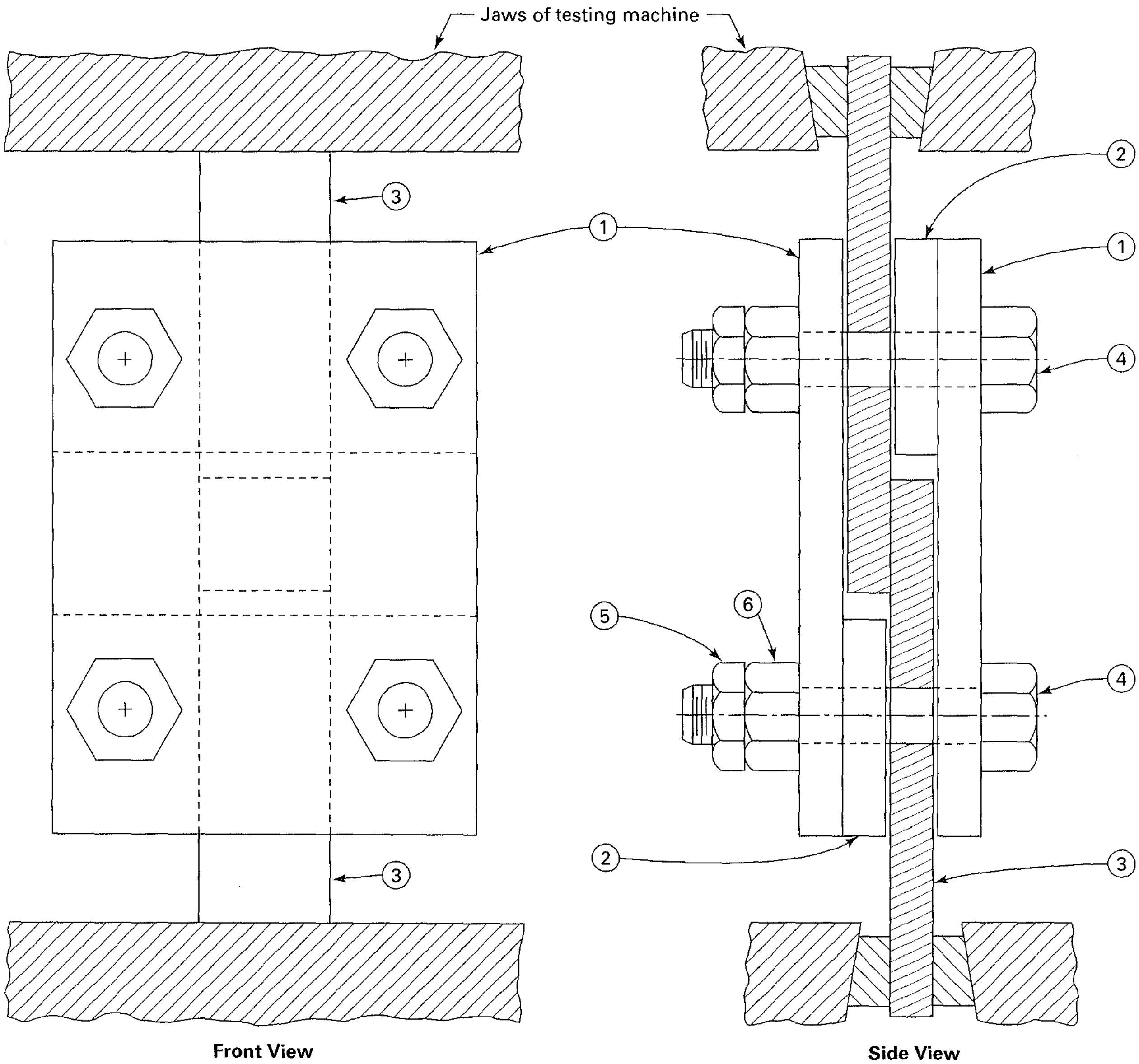
(2) A = greater of ¼ in. (6 mm) or $2T$

(3) X = test specimen overlap

QB-462.1(e) TENSION — FULL SECTION FOR LAP, SCARF, AND BUTT JOINTS — SMALL DIAMETER PIPE



QB-462.1(f) SUPPORT FIXTURE FOR REDUCED-SECTION TENSION SPECIMENS



(1) Restrainer Bars

(2) Spacers

(3) Reduced-Section Tension Specimen

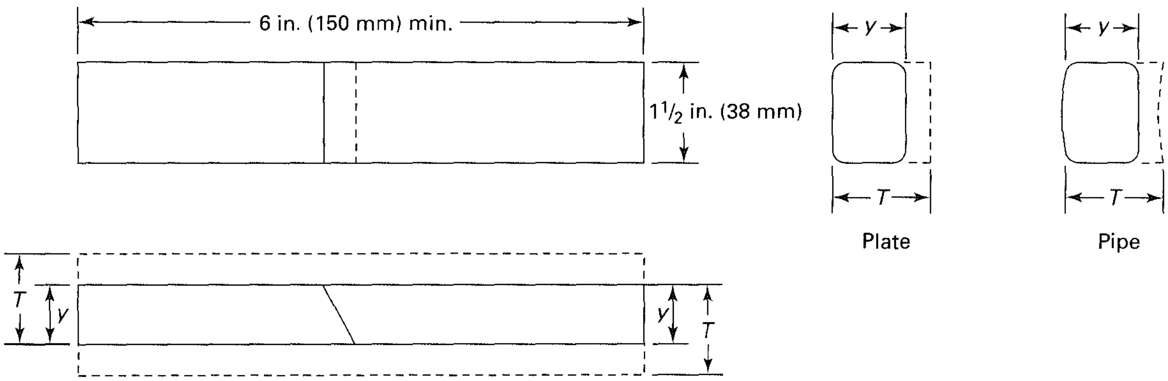
(4) Bolts, Body-Bound

(5) 4 Locknuts

(6) 4 Nuts

GENERAL NOTE: The restraining fixture is intended to provide a snug fit between the fixture and the contour of the tension specimen. The fixture shall be tightened, but only to the point where a minimum of 0.001 in. (0.03 mm) clearance exists between the sides of the fixture and the tension specimen.

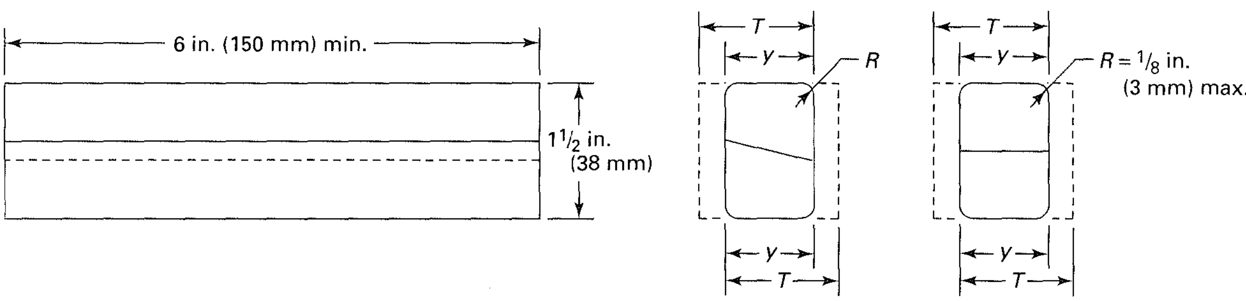
QB-462.2(a) TRANSVERSE FIRST AND SECOND SURFACE BENDS — PLATE AND PIPE



T, in. (mm)	y, in. (mm)
	All ferrous and nonferrous materials
1/16 – 3/8 (1.5–10)	T
>3/8 (>10)	3/8 (10)

GENERAL NOTE: For the first surface bend specimens, machine from the second surface as necessary until the required thickness is obtained. For second surface bend specimens, machine from the first surface as necessary until the required thickness is obtained.

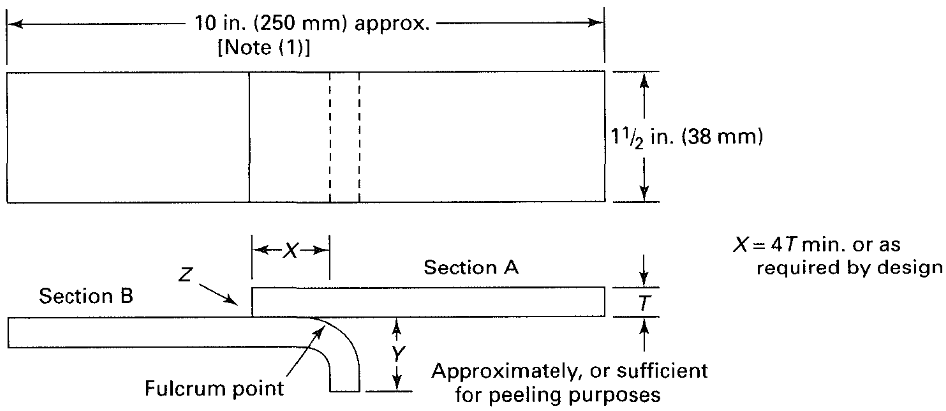
QB-462.2(b) LONGITUDINAL FIRST AND SECOND SURFACE BENDS — PLATE



T, in. (mm)	y, in. (mm)
	All ferrous and nonferrous materials
1/16 – 3/8 (1.5–10)	T
>3/8 (>10)	3/8 (10)

GENERAL NOTE: For the first surface bend specimens, machine from the second surface as necessary until the required thickness is obtained. For second surface bend specimens, machine from the first surface as necessary until the required thickness is obtained.

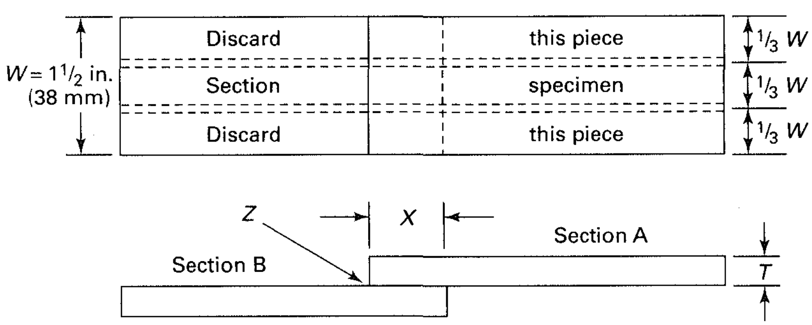
QB-462.3 LAP JOINT PEEL SPECIMEN



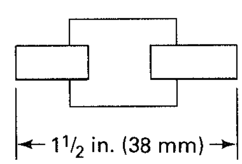
GENERAL NOTES:
(a) Flange Y may be omitted from Section B when "peeling" is to be accomplished in a suitable tension machine.
(b) Specimen shall be brazed from side marked Z.

NOTE:
(1) Length may vary to fit testing machine.

QB-462.4 LAP JOINT SECTION SPECIMEN (See QB-181)



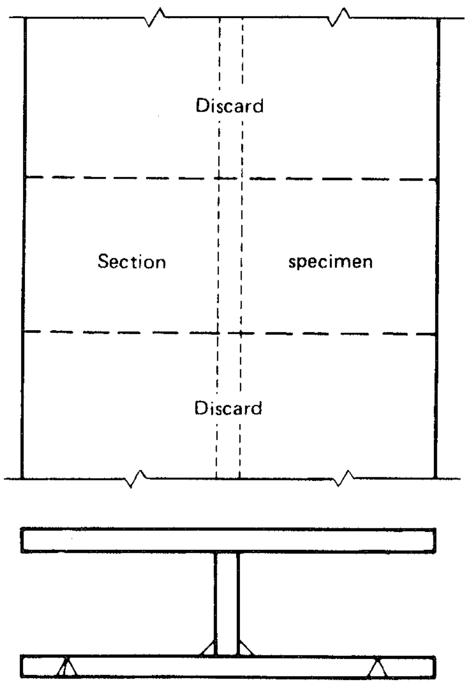
$X = 4T$ min. or as required by design



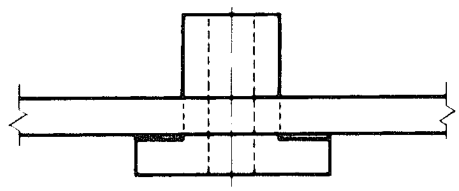
Alternate for Rabbet Joint

GENERAL NOTE: Specimen shall be brazed from the side marked Z.

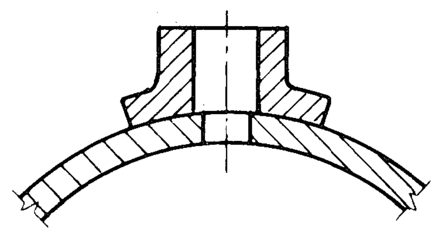
QB-462.5 WORKMANSHIP COUPONS



(a) Typical Stay or Partition Joint
[Note (1)]



(b) Typical Spud Joint
[Note (2)]

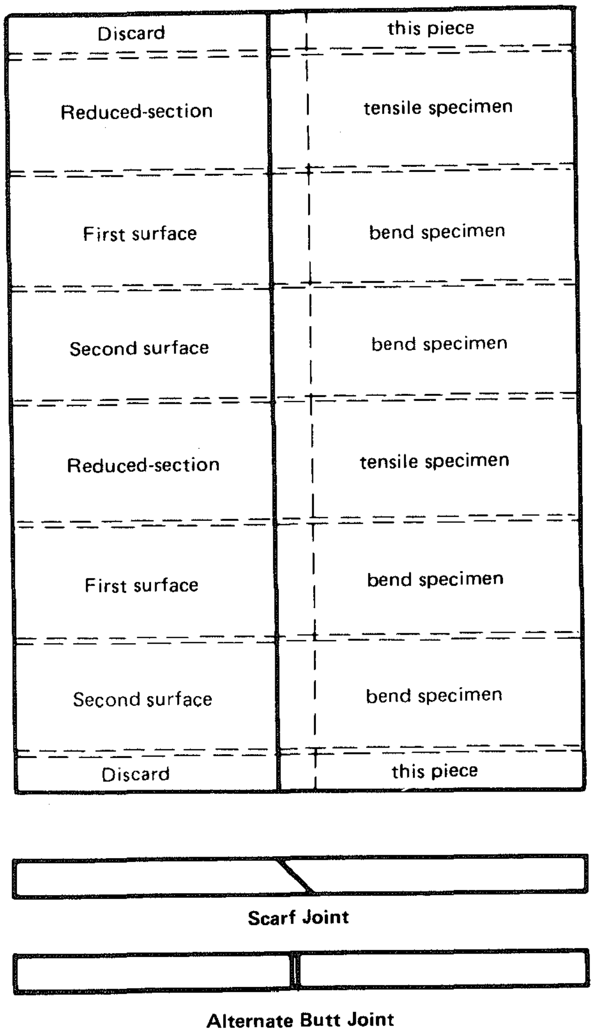


(c) Typical Saddle Joint Sectioned
[Note (2)]

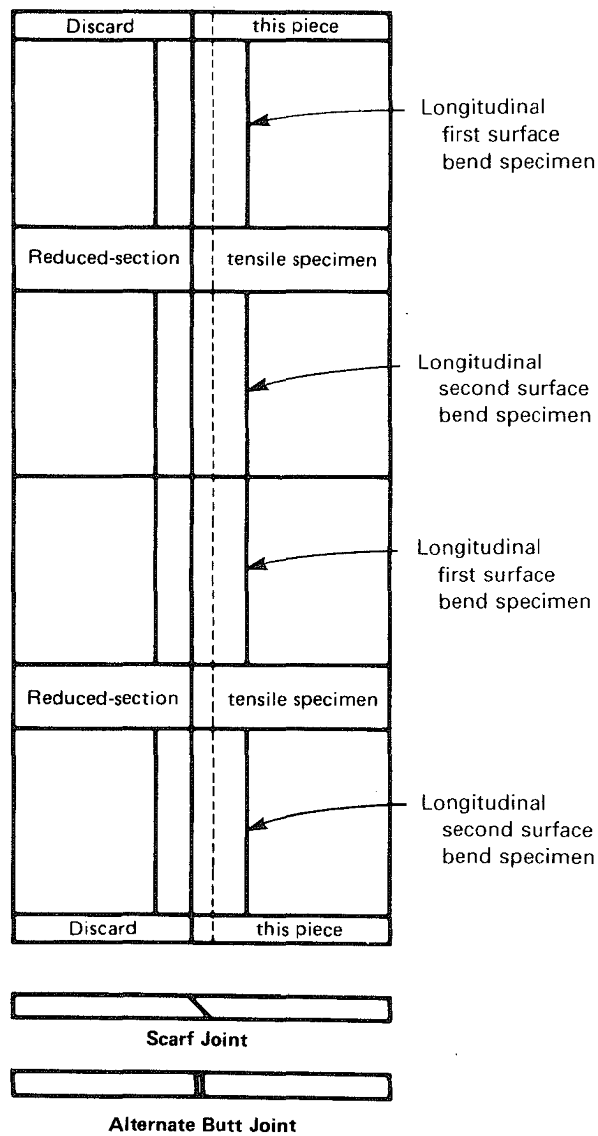
NOTES:
(1) Workmanship coupons shall be 10 in. (250 mm) in length or represent one-half the typical joint, whichever is less.
(2) Circular coupons shall be sectioned in half, and one-half shall be used as the test specimen.

QB-463 Order of Removal

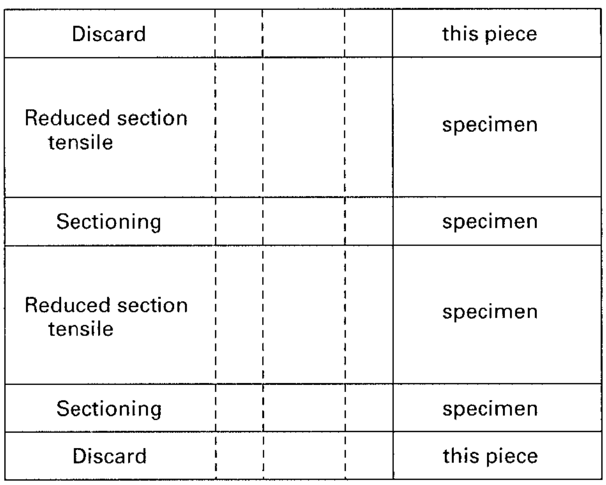
QB-463.1(a) PLATES PROCEDURE QUALIFICATION

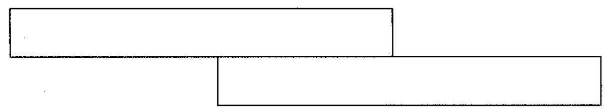


QB-463.1(b) PLATES PROCEDURE QUALIFICATION

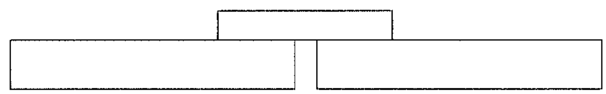


QB-463.1(c) PLATES PROCEDURE QUALIFICATION

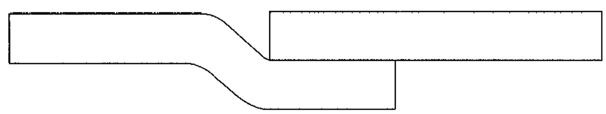




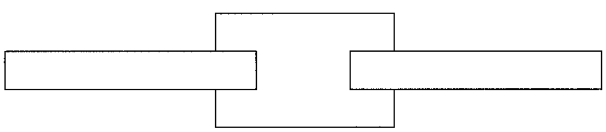
Alternate Lap Joint
[Note (2)]



Alternate Lap Joint
[Note (2)]



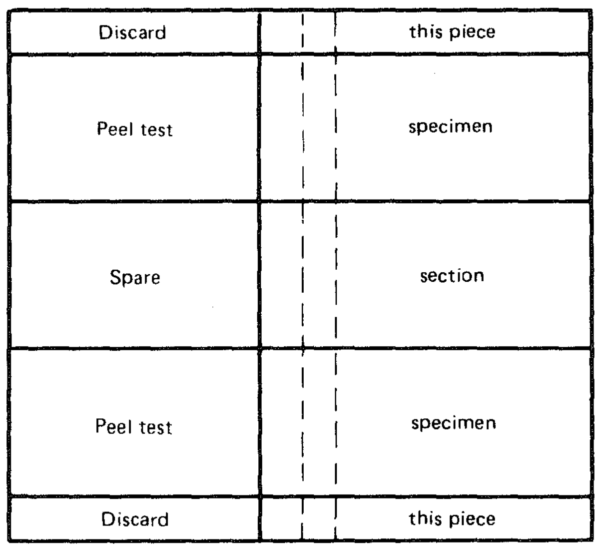
Alternate Lap Joint
[Note (2)]

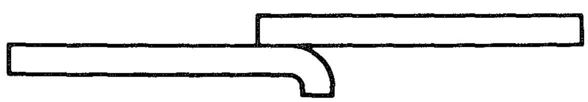


Rabbet Joint
[Note (1)]

NOTES:
(1) Required for rabbet joints.
(2) The sectioning specimen in this view may be used as an alternate to sectioning the peel test specimens of QB-463.1(d) when the peel test cannot be used. This section test specimen should be approximately $^1/_2$ in. (13 mm) wide.

QB-463.1(d) PLATES PROCEDURE QUALIFICATION



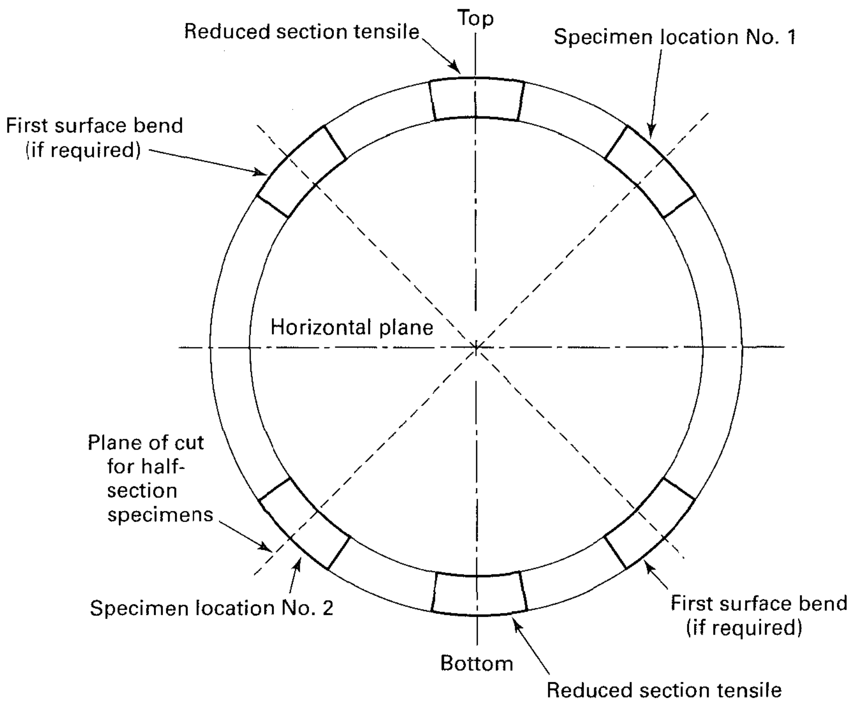


Lap Joint

[Note (1)]

NOTE:
(1) Required when peel test can be used.

QB-463.1(e) PIPE — PROCEDURE QUALIFICATION



GENERAL NOTES:

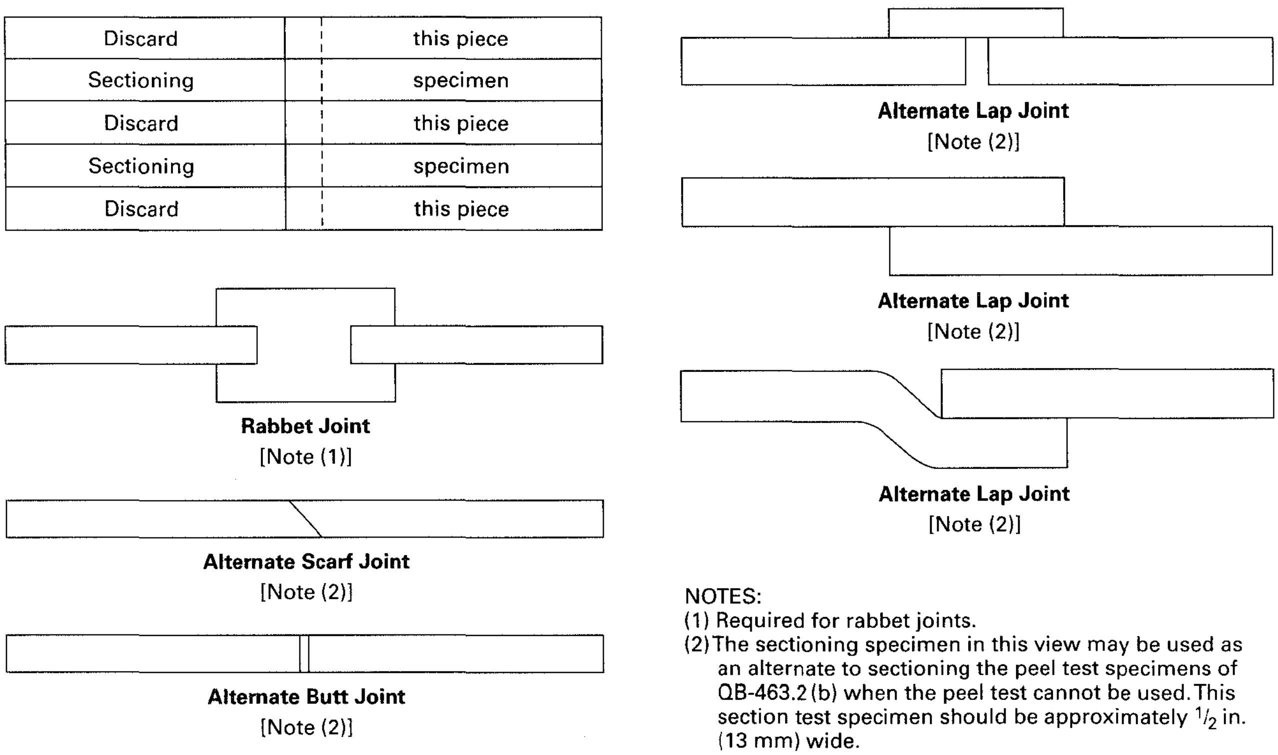
(a) Figure shown is for coupons over 3 in. (75 mm) O.D. Locations No. 1 and 2 are for:
  (1) second surface specimens for butt and scarf joints
  (2) peel or section specimens for lap joints
  (3) section specimens for rabbet joints

(b) For coupons 3 in. (75 mm) O.D. and smaller, two coupons shall be brazed and one specimen shall be removed from each coupon. If brazed in the horizontal flow position, the specimen shall be taken at specimen location No. 1. Alternatively, each coupon shall be cut longitudinally and the specimen shall consist of both sides of one half-section of each coupon.

(c) When coupon is brazed in the horizontal flow position, specimens locations shall be as shown relative to the horizontal plane of the coupon, and for half-section specimens, plane of cut shall be oriented as shown relative to the horizontal plane of the coupon.

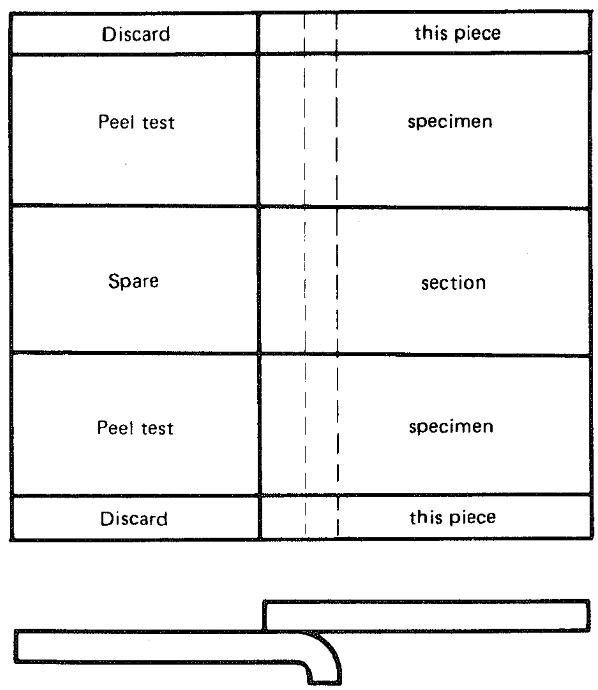
(d) When both ends of a coupling are brazed, each end is considered a separate test coupon.

QB-463.2(a) PLATES PERFORMANCE QUALIFICATION



NOTES:
(1) Required for rabbet joints.
(2) The sectioning specimen in this view may be used as an alternate to sectioning the peel test specimens of QB-463.2(b) when the peel test cannot be used. This section test specimen should be approximately $^1/_2$ in. (13 mm) wide.

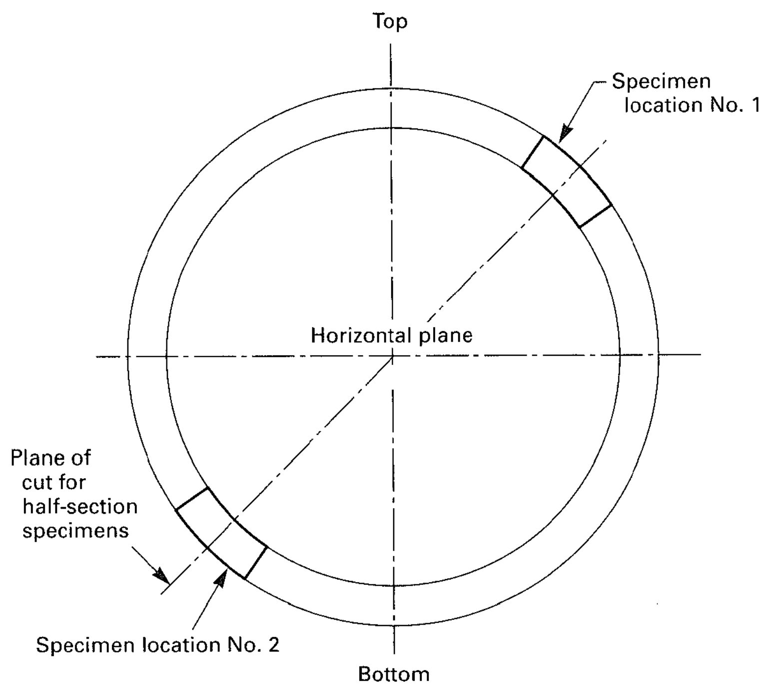
QB-463.2(b) PLATES PERFORMANCE QUALIFICATION



Lap Joint
[Note (1)]

NOTE:
(1) Required when peel test can be used.

QB-463.2(c) PIPE PERFORMANCE QUALIFICATION



GENERAL NOTES:

(a) For coupons over 3 in. (75 mm) O.D., one specimen shall be removed from each location shown.

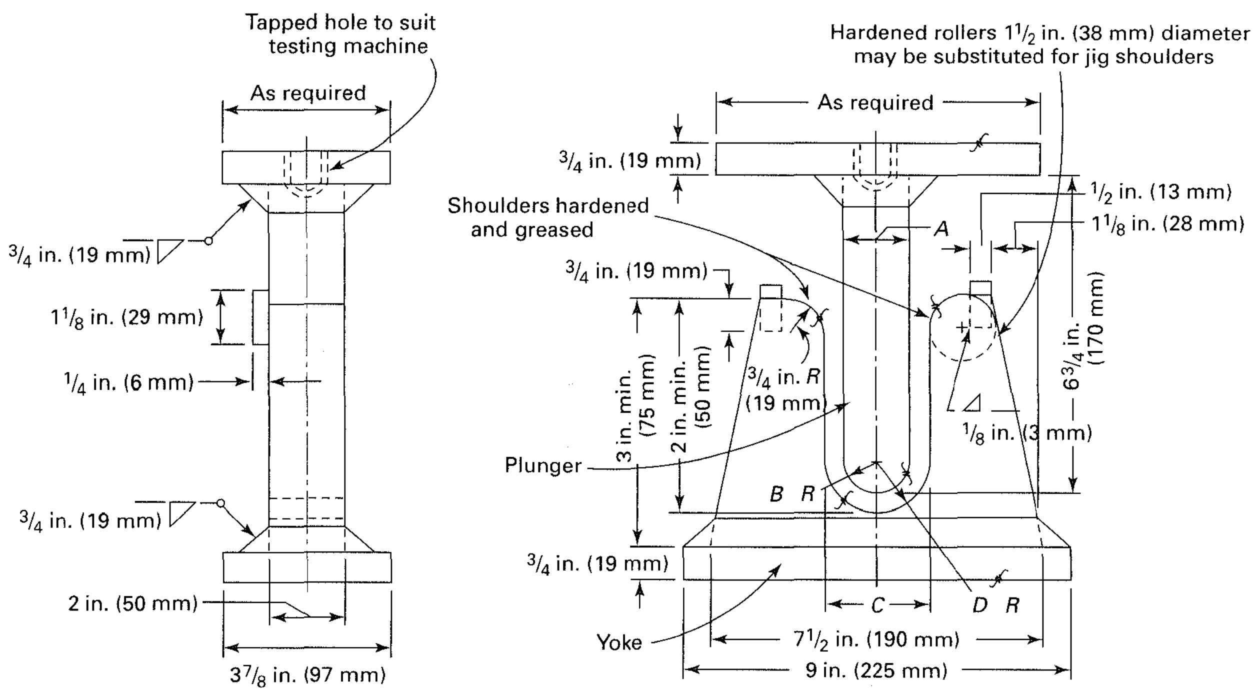
(b) For coupons 3 in. (75 mm) O.D. and smaller, two coupons shall be brazed and one specimen shall be removed from each coupon. If brazed in the horizontal flow position, the specimen shall be taken at specimen location No. 1. Alternatively, each coupon shall be cut longitudinally and the specimen shall be both sides of one half-section of each coupon.

(c) When the coupon is brazed in the horizontal flow position, specimen locations shall be as shown relative to the horizontal plane of the coupon. For half-section specimens, plane of cut shall be oriented as shown relative to the horizontal plane of the coupon.

(d) When both ends of a coupling are brazed, each end is considered a separate test coupon.

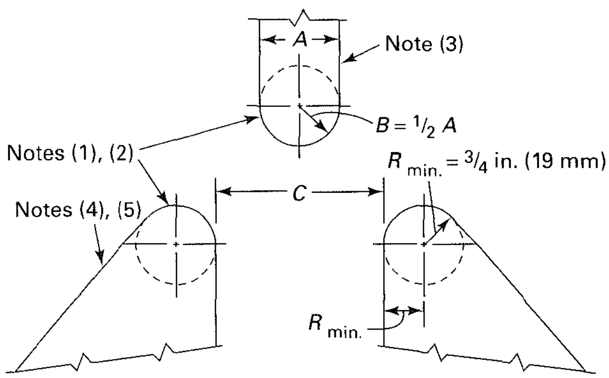
QB-466 Test Jigs

QB-466.1 GUIDED-BEND JIG



Thickness of Specimen, in. (mm)	A, in. (mm)	B, in. (mm)	C, in. (mm)	D, in. (mm)
3/8 (10)	1 1/2 (38)	3/4 (19)	2 3/8 (60)	1 3/16 (30)
t	$4t$	$2t$	$6t + 3.2$	$3t + 1.6$

QB-466.2 GUIDED-BEND ROLLER JIG



Thickness of Specimen, in. (mm)	A, in. (mm)	B, in. (mm)	C, in. (mm)
$\frac{3}{8}$ (10)	$1\frac{1}{2}$ (38)	$\frac{3}{4}$ (19)	$2\frac{3}{8}$ (60)
t	$4t$	$2t$	$6t + \frac{1}{8}$ (3)

GENERAL NOTE: The braze joint in the case of a transverse bend specimen shall be completely within the bend portion of the specimen after testing.

NOTES:

(1) Either hardened and greased shoulders or hardened rollers free to rotate shall be used.

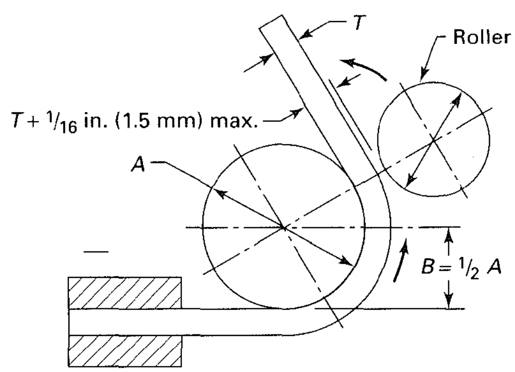
(2) The shoulders of rollers shall have a minimum bearing surface of 2 in. (50 mm) for placement of the specimen. The rollers shall be high enough above the bottom of the jig so that the specimens will clear the rollers when the ram is in the low position.

(3) The ram shall be fitted with an appropriate base and provision made for attachment to the testing machine, and shall be of a sufficiently rigid design to prevent deflection and misalignment while making the bend test. The body of the ram may be less than the dimensions shown in column *A*.

(4) If desired, either the rollers or the roller supports may be made adjustable in the horizontal direction so that specimens of *t* thickness may be tested on the same jig.

(5) The roller supports shall be fitted with an appropriate base designed to safeguard against deflection or misalignment and equipped with means for maintaining the rollers centered midpoint and aligned with respect to the ram.

QB-466.3 GUIDED-BEND WRAP AROUND JIG



Thickness of Specimen, in. (mm)	A, in. (mm)	B, in. (mm)
$\frac{3}{8}$ (10)	$1\frac{1}{2}$ (38)	$\frac{3}{4}$ (19)
t	$4t$	$2t$

GENERAL NOTES:

(a) Dimensions not shown are the option of the designer. The essential consideration is to have adequate rigidity so that the jig parts will not spring.

(b) The specimen shall be firmly clamped on one end so that there is no sliding of the specimen during the bending operation.

(c) Test specimens shall be removed from the jig when the outer roll has been removed 180 deg from the starting point.

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MANDATORY APPENDIX A
SUBMITTAL OF TECHNICAL INQUIRIES TO THE BOILER AND PRESSURE VESSEL COMMITTEE

A-100 INTRODUCTION

(a) This Appendix provides guidance to Code users for submitting technical inquiries to the Committee. See Guideline on the Approval of New Materials Under the ASME Boiler and Pressure Vessel Code in Section II, Parts C and D for additional requirements for requests involving adding new materials to the Code. Technical inquiries include requests for revisions or additions to the Code rules, requests for Code Cases, and requests for Code interpretations, as described in the following:

(1) Code Revisions. Code revisions are considered to accommodate technological developments, address administrative requirements, incorporate Code Cases, or to clarify Code intent.

(2) Code Cases. Code Cases represent alternatives or additions to existing Code rules. Code Cases are written as a question and reply, and are usually intended to be incorporated into the Code at a later date. When used, Code Cases prescribe mandatory requirements in the same sense as the text of the Code. However, users are cautioned that not all jurisdictions or owners automatically accept Code Cases. The most common applications for Code Cases are

(a) to permit early implementation of an approved Code revision based on an urgent need

(b) to permit the use of a new material for Code construction

(c) to gain experience with new materials or alternative rules prior to incorporation directly into the Code

(3) Code Interpretations. Code Interpretations provide clarification of the meaning of existing rules in the Code, and are also presented in question and reply format. Interpretations do not introduce new requirements. In cases where existing Code text does not fully convey the meaning that was intended, and revision of the rules is required to support an interpretation, an Intent Interpretation will be issued and the Code will be revised.

(b) The Code rules, Code Cases, and Code Interpretations established by the Committee are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Code rules.

(c) Inquiries that do not comply with the provisions of this Appendix or that do not provide sufficient information for the Committee's full understanding may result in the request being returned to the inquirer with no action.

A-200 INQUIRY FORMAT

Submittals to the Committee shall include

(a) Purpose. Specify one of the following:

(1) revision of present Code rules

(2) new or additional Code rules

(3) Code Case

(4) Code Interpretation

(b) Background. Provide the information needed for the Committee's understanding of the inquiry, being sure to include reference to the applicable Code Section, Division, Edition, Addenda, paragraphs, figures, and tables. Preferably, provide a copy of the specific referenced portions of the Code.

(c) Presentations. The inquirer may desire or be asked to attend a meeting of the Committee to make a formal presentation or to answer questions from the Committee members with regard to the inquiry. Attendance at a Committee meeting shall be at the expense of the inquirer. The inquirer's attendance or lack of attendance at a meeting shall not be a basis for acceptance or rejection of the inquiry by the Committee.

A-300 CODE REVISIONS OR ADDITIONS

Requests for Code revisions or additions shall provide the following:

(a) Proposed Revisions or Additions. For revisions, identify the rules of the Code that require revision and submit a copy of the appropriate rules as they appear in the Code, marked up with the proposed revision. For additions, provide the recommended wording referenced to the existing Code rules.

(b) Statement of Need. Provide a brief explanation of the need for the revision or addition.

(c) Background Information. Provide background information to support the revision or addition, including any data or changes in technology that form the basis for the request that will allow the Committee to adequately evaluate the proposed revision or addition. Sketches, tables, figures, and graphs should be submitted as appropriate. When applicable, identify any pertinent paragraph in the Code that would be affected by the revision or addition and identify paragraphs in the Code that reference the paragraphs that are to be revised or added.

A-400 CODE CASES

Requests for Code Cases shall provide a Statement of Need and Background Information similar to that defined in A-300(b) and A-300(c), respectively, for Code revisions or additions. The urgency of the Code Case (e.g., project underway or imminent, new procedure, etc.) must be defined and it must be confirmed that the request is in connection with equipment that will be ASME stamped, with the exception of Section XI applications. The proposed Code Case should identify the Code Section and Division, and be written as a *Question* and a *Reply* in the same format as existing Code Cases. Requests for Code Cases should also indicate the applicable Code Editions and Addenda to which the proposed Code Case applies.

A-500 CODE INTERPRETATIONS

(a) Requests for Code Interpretations shall provide the following:

(1) Inquiry. Provide a condensed and precise question, omitting superfluous background information and, when possible, composed in such a way that a "yes" or a "no" *Reply,* with brief provisos if needed, is acceptable. The question should be technically and editorially correct.

(2) Reply. Provide a proposed *Reply* that will clearly and concisely answer the *Inquiry* question. Preferably, the *Reply* should be "yes" or "no," with brief provisos if needed.

(3) Background Information. Provide any background information that will assist the Committee in understanding the proposed *Inquiry* and *Reply.*

(b) Requests for Code Interpretations must be limited to an interpretation of a particular requirement in the Code or a Code Case. The Committee cannot consider consulting type requests such as the following:

(1) a review of calculations, design drawings, welding qualifications, or descriptions of equipment or parts to determine compliance with Code requirements

(2) a request for assistance in performing any Code-prescribed functions relating to, but not limited to, material selection, designs, calculations, fabrication, inspection, pressure testing, or installation

(3) a request seeking the rationale for Code requirements

A-600 SUBMITTALS

Submittals to and responses from the Committee shall meet the following:

(a) Submittal. Inquiries from Code users shall be in English and preferably be submitted in typewritten form. However, legible handwritten inquiries will also be considered. They shall include the name, address, telephone number, fax number, and e-mail address, if available, of the inquirer and be mailed to the following address:

Secretary
ASME Boiler and Pressure Vessel Committee
Three Park Avenue
New York, NY 10016-5990

As an alternative, inquiries may be submitted via e-mail to: SecretaryBPV@asme.org.

(b) Response. The Secretary of the ASME Boiler and Pressure Vessel Committee or of the appropriate Subcommittee shall acknowledge receipt of each properly prepared inquiry and shall provide a written response to the inquirer upon completion of the requested action by the Code Committee.

NONMANDATORY APPENDIX B
WELDING AND BRAZING FORMS

B-100 FORMS

This Nonmandatory Appendix illustrates sample formats for Welding and Brazing Procedure Specifications, Procedure Qualification Records, and Performance Qualification.

B-101 Welding

Form QW-482 is a suggested format for Welding Procedure Specifications (WPS); Form QW-483 is a suggested format for Procedure Qualification Records (PQR). These forms are for the shielded metal-arc (SMAW), submerged-arc (SAW), gas metal-arc (GMAW), and gas tungsten-arc (GTAW) welding processes, or a combination of these processes.

Forms for other welding processes may follow the general format of Forms QW-482 and QW-483, as applicable.

Form QW-484 is a suggested format for Welder/Welding Operator/Performance Qualification (WPQ) for groove or fillet welds.

Form QW-485 is a suggested format for Demonstration of Standard Welding Procedure Specifications.

B-102 Brazing

Form QB-482 is a suggested format for Brazing Procedure Specifications (BPS); Form QB-483 is a suggested format for Procedure Qualifications Records (PQR). These forms are for torch brazing (TB), furnace brazing (FB), induction brazing (IB), resistance brazing (RB), and dip brazing (DB) processes.

Forms for other brazing processes may follow the general format of Forms QB-482 and QB-483, as applicable.

Form QB-484 is a suggested format for Brazer/Brazing Operator/Performance Qualification (BPQ).

QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATIONS (WPS)
(See QW-200.1, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name ________________ By ________________

Welding Procedure Specification No. ________ Date ________ Supporting PQR No.(s) ________

Revision No. ________ Date ________

Welding Process(es) ________________ Type(s) ________________
(Automatic, Manual, Machine, or Semi-Automatic)

JOINTS (QW-402) Details

Joint Design ________

Root Spacing ________

Backing: Yes ________ No ________

Backing Material (Type) ________
(Refer to both backing and retainers)

☐ Metal ☐ Nonfusing Metal

☐ Nonmetallic ☐ Other

Sketches, Production Drawings, Weld Symbols, or Written Description should show the general arrangement of the parts to be welded. Where applicable, the details of weld groove may be specified.

[At the option of the manufacturer, sketches may be attached to illustrate joint design, weld layers, and bead sequence (e.g., for notch toughness procedures, for multiple process procedures, etc.)]

*BASE METALS (QW-403)

P-No. ________ Group No. ________ to P-No. ________ Group No. ________

OR

Specification and type/grade or UNS Number ________

to Specification and type/grade or UNS Number ________

OR

Chem. Analysis and Mech. Prop. ________

to Chem. Analysis and Mech. Prop. ________

Thickness Range:

Base Metal: Groove ________ Fillet ________

Maximum Pass Thickness $\leq 1/2$ in. (13 mm) (Yes) ________ (No) ________

Other ________

*FILLER METALS (QW-404)	1	2
Spec. No. (SFA)		
AWS No. (Class)		
F-No.		
A-No.		
Size of Filler Metals		
Filler Metal Product Form		
Supplemental Filler Metal		
Weld Metal		
Thickness Range:		
Groove		
Fillet		
Electrode-Flux (Class)		
Flux Type		
Flux Trade Name		
Consumable Insert		
Other		

*Each base metal-filler metal combination should be recorded individually.

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QW-482 (Back)

WPS No. ____________ Rev. ____________

POSITIONS (QW-405)
Position(s) of Groove ____________
Welding Progression: Up ____________ Down ____________
Position(s) of Fillet ____________
Other ____________

POSTWELD HEAT TREATMENT (QW-407)
Temperature Range ____________
Time Range ____________
Other ____________

PREHEAT (QW-406)
Preheat Temperature, Minimum ____________
Interpass Temperature, Maximim ____________
Preheat Maintenance ____________
Other ____________
(Continuous or special heating, where applicable, should be recorded)

GAS (QW-408)

	Gas(es)	Percent Composition (Mixture)	Flow Rate
Shielding			
Trailing			
Backing			
Other			

ELECTRICAL CHARACTERISTICS (QW-409)

Weld Pass(es)	Process	Filler Metal		Current Type and Polarity	Amps (Range)	Wire Feed Speed (Range)	Energy or Power (Range)	Volts (Range)	Travel Speed (Range)	Other (e.g., Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, etc.)
		Classification	Diameter							

Amps and volts, or power or energy range, should be recorded for each electrode size, position, and thickness, etc.

Pulsing Current ____________ Heat Input (max.) ____________

Tungsten Electrode Size and Type ____________
(Pure Tungsten, 2% Thoriated, etc.)

Mode of Metal Transfer for GMAW (FCAW) ____________
(Spray Arc, Short Circuiting Arc, etc.)

Other ____________

TECHNIQUE (QW-410)
String or Weave Bead ____________
Orifice, Nozzle, or Gas Cup Size ____________
Initial and Interpass Cleaning (Brushing, Grinding, etc.) ____________

Method of Back Gouging ____________
Oscillation ____________
Contact Tube to Work Distance ____________
Multiple or Single Pass (Per Side) ____________
Multiple or Single Electrodes ____________
Electrode Spacing ____________
Peening ____________
Other ____________

(07/10)

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QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORDS (PQR)
(See QW-200.2, Section IX, ASME Boiler and Pressure Vessel Code)
Record Actual Variables Used to Weld Test Coupon

Company Name ____________________
Procedure Qualification Record No. ____________________ Date ____________________
WPS No. ____________________
Welding Process(es) ____________________
Types (Manual, Automatic, Semi-Automatic) ____________________

JOINTS (QW-402)

Groove Design of Test Coupon
(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal and process used.)

BASE METALS (QW-403)
Material Spec. ____________________
Type/Grade, or UNS Number ____________________
P-No. ______ Group No. ______ to P-No. ______ Group No. ______
Thickness of Test Coupon ____________________
Diameter of Test Coupon ____________________
Maximum Pass Thickness ____________________
Other ____________________

FILLER METALS (QW-404)	1	2
SFA Specification		
AWS Classification		
Filler Metal F-No.		
Weld Metal Analysis A-No.		
Size of Filler Metal		
Filler Metal Product Form		
Supplemental Filler Metal		
Electrode Flux Classification		
Flux Type		
Flux Trade Name		
Weld Metal Thickness		
Other		

POSITION (QW-405)
Position of Groove ____________________
Weld Progression (Uphill, Downhill) ____________________
Other ____________________

PREHEAT (QW-406)
Preheat Temperature ____________________
Interpass Temperature ____________________
Other ____________________

POSTWELD HEAT TREATMENT (QW-407)
Temperature ____________________
Time ____________________
Other ____________________

GAS (QW-408)

	Gas(es)	Percent Composition (Mixture)	Flow Rate
Shielding			
Trailing			
Backing			
Other			

ELECTRICAL CHARACTERISTICS (QW-409)
Current ____________________
Polarity ____________________
Amps. ____________ Volts ____________
Tungsten Electrode Size ____________________
Mode of Metal Transfer for GMAW (FCAW) ____________________
Heat Input ____________________
Other ____________________

TECHNIQUE (QW-410)
Travel Speed ____________________
String or Weave Bead ____________________
Oscillation ____________________
Multipass or Single Pass (Per Side) ____________________
Single or Multiple Electrodes ____________________
Other ____________________

07/10

QW-483 (Back)

PQR No. ____________

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load	Ultimate Unit Stress, (psi or MPa)	Type of Failure and Location

Guided-Bend Tests (QW-160)

Type and Figure No.	Result

Toughness Tests (QW-170)

Specimen No.	Notch Location	Specimen Size	Test Temperature	Impact Values			Drop Weight Break (Y/N)
				ft-lb or J	% Shear	Mils (in.) or mm	

Comments ____________

Fillet-Weld Test (QW-180)

Result — Satisfactory: Yes ________ No ________ Penetration into Parent Metal: Yes ________ No ________

Macro — Results ____________

Other Tests

Type of Test ____________

Deposit Analysis ____________

Other ____________

. . . .

Welder's Name ____________ Clock No. ________ Stamp No. ________

Tests Conducted by ____________ Laboratory Test No. ________

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Manufacturer or Contractor ____________

Date ____________ Certified by ____________

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)

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QW-484A SUGGESTED FORMAT A FOR WELDER PERFORMANCE QUALIFICATIONS (WPQ)
(See QW-301, Section IX, ASME Boiler and Pressure Vessel Code)

Welder's name ______________________ Identification no. ______________________

Test Description

Identification of WPS followed ______________________ ☐ Test coupon ☐ Production weld

Specification and type/grade or UNS Number of base metal(s) ______________________ Thickness ____________

Testing Variables and Qualification Limits

Welding Variables (QW-350)	Actual Values	Range Qualified
Welding process(es)	____________	____________
Type (i.e.; manual, semi-automatic) used	____________	____________
Backing (with/without)	____________	____________
☐ Plate ☐ Pipe (enter diameter if pipe or tube)	____________	____________
Base metal P-Number to P-Number	____________	____________
Filler metal or electrode specification(s) (SFA) (info. only)	____________	
Filler metal or electrode classification(s) (info. only)	____________	
Filler metal F-Number(s)	____________	____________
Consumable insert (GTAW or PAW)	____________	____________
Filler Metal Product Form (solid/metal or flux cored/powder) (GTAW or PAW)	____________	____________
Deposit thickness for each process	____________	____________
Process 1 ________ 3 layers minimum ☐ Yes ☐ No	____________	____________
Process 2 ________ 3 layers minimum ☐ Yes ☐ No	____________	____________
Position qualified (2G, 6G, 3F, etc.)	____________	____________
Vertical progression (uphill or downhill)	____________	____________
Type of fuel gas (OFW)	____________	____________
Inert gas backing (GTAW, PAW, GMAW)	____________	____________
Transfer mode (spray/globular or pulse to short circuit-GMAW)	____________	____________
GTAW current type/polarity (AC, DCEP, DCEN)	____________	____________

RESULTS

Visual examination of completed weld (QW-302.4) ______________________

☐ Transverse face and root bends [QW-462.3(a)] ☐ Longitudinal bends [QW-462.3(b)] ☐ Side bends (QW-462.2)

☐ Pipe bend specimen, corrosion-resistant weld metal overlay [QW-462.5(c)]

☐ Plate bend specimen, corrosion-resistant weld metal overlay [QW-462.5(d)]

☐ Pipe specimen, macro test for fusion [QW-462.5(b)] ☐ Plate specimen, macro test for fusion [QW-462.5(e)]

Type	Result	Type	Result	Type	Result

Alternative Volumetric Examination Results (QW-191): ______________ RT ☐ or UT ☐ (check one)

Fillet weld — fracture test (QW-181.2) ______________ Length and percent of defects ______________

☐ Fillet welds in plate [QW-462.4(b)] ☐ Fillet welds in pipe [QW-462.4(c)]

Macro examination (QW-184)__________ Fillet size (in.) _____ × _____ Concavity/convexity (in.) __________

Other tests ______________________

Film or specimens evaluated by ______________________ Company ______________________

Mechanical tests conducted by ______________________ Laboratory test no. ______________________

Welding supervised by ______________________

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME BOILER AND PRESSURE VESSEL CODE.

Manufacturer or Contractor ______________________

Date ______________ Certified by ______________________

(07/10)

(10)

QW-484B SUGGESTED FORMAT B FOR WELDING OPERATOR PERFORMANCE QUALIFICATIONS (WOPQ)
(See QW-301, Section IX, ASME Boiler and Pressure Vessel Code)

Welding operator's name ______________ Identification no. ______________

Test Description (*Information Only*)

Identification of WPS followed ______________ ☐ Test coupon ☐ Production weld

Specification and type/grade or UNS Number of base metal(s) ______________ Thickness ______________

Base metal P-Number ________ to P-Number ________ Position (2G, 6G, 3F, etc.) ______________

☐ Plate ☐ Pipe (enter diameter, if pipe or tube) ______________

Filler metal (SFA) specification ________ Filler metal or electrode classification ______________

Testing Variables and Qualification Limits When Using Automatic Welding Equipment

Welding Variables (QW-361.1)	Actual Values	Range Qualified
Type of welding (automatic)		
Welding process		
Filler metal used (Yes/No) (EBW or LBW)		
Type of laser for LBW (CO_2 to YAG, etc.)		
Continuous drive or inertia welding (FW)		
Vacuum or out of vacuum (EBW)		

Testing Variables and Qualification Limits When Using Machine Welding Equipment

Welding Variables (QW-361.2)	Actual Values	Range Qualified
Type of welding (Machine)		
Welding process		
Direct or remote visual control		
Automatic arc voltage control (GTAW)		
Automatic joint tracking		
Position qualified (2G, 6G, 3F, etc.)		
Consumable inserts (GTAW or PAW)		
Backing (with/without)		
Single or multiple passes per side		

RESULTS

Visual examination of completed weld (QW-302.4) ______________

☐ Transverse face and root bends [QW-462.3(a)] ☐ Longitudinal bends [QW-462.3(b)] ☐ Side bends (QW-462.2)

☐ Pipe bend specimen, corrosion-resistant weld metal overlay [QW-462.5(c)]

☐ Plate bend specimen, corrosion-resistant weld metal overlay [QW-462.5(d)]

☐ Pipe specimen, macro test for fusion [QW-462.5(b)] ☐ Plate specimen, macro test for fusion [QW-462.5(e)]

Type	Result	Type	Result	Type	Result

Alternative Volumetric Examination Results (QW-191): ______________ RT ☐ or UT ☐ (check one)

Fillet weld — fracture test (QW-181.2) ______________ Length and percent of defects ______________

☐ Fillet welds in plate [QW-462.4(b)] ☐ Fillet welds in pipe [QW-462.4(c)]

Macro examination (QW-184) ________ Fillet size (in.) ________ × ________ Concavity/convexity (in.) ______________

Other tests ______________

Film or specimens evaluated by ______________ Company ______________

Mechanical tests conducted by ______________ Laboratory test no. ______________

Welding supervised by ______________

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Manufacturer or Contractor ______________

Date ______________ Certified by ______________

(07/10)

QW-485 SUGGESTED FORMAT FOR DEMONSTRATION OF STANDARD WELDING PROCEDURE SPECIFICATIONS (SWPS)
(See Article V)

Identification of Standard Welding Procedure Specification Demonstrated ______

Demonstration Welding Variables

Specification and type/grade or UNS Number of Base Metal(s) ______
to Specification and type/grade or UNS Number of Base Metal(s) ______
Base Metal P-Number ______ to Base Metal P-Number ______ Thickness ______

Welding Process(es) used ______
☐ Plate ☐ Pipe (Enter Diameter of Pipe or Tube) ______
Groove Design (Single V, Double V, Single U, etc.) ______
Initial Cleaning Method ______
Backing (with/without) ______
Filler Metal Specification ______
Filler Metal or Electrode Classification ______
Filler Metal or Electrode Trade Name ______
Size of Consumable Electrode or Filler Metal ______
Tungsten Electrode Classification and Size for GTAW ______
Consumable Insert Class and Size for GTAW ______
Shielding Gas Composition and Flow Rate for GTAW or GMAW (FCAW) ______
Preheat Temperature ______
Position (1G, 2G, etc.) of Weld ______
Progression (Uphill or Downhill) ______
Interpass Cleaning Method ______
Measured Maximum Interpass Temperature ______
Approximate Deposit Thickness for Each Process or Electrode Type ______
Current Type/Polarity (AC, DCEP, DCEN) ______
Postweld Heat Treatment Time and Temperature ______

Visual Examination of Completed Weld (QW-302.4) ______ Date of Test ______

Bend Test (QW-302.1) ☐ Transverse Face and Root [QW-462.3(a)] ☐ Side (QW-462.2)

Type	Result	Type	Result	Type	Result

Alternative Radiographic Examination Results (QW-302.2) ______
Specimens Evaluated By ______ Title ______ Company ______
Welding Supervised By ______ Title ______ Company ______
Welder's Name ______ Stamp No. ______
We certify that the statements in this record are correct and that the weld described above was prepared, welded, and tested in accordance with the requirements of Section IX of the ASME BOILER AND PRESSURE VESSEL CODE.

Manufacturer or Contractor ______

Signature ______ Date ______ Demonstration Number ______

(03/08)

QB-482 SUGGESTED FORMAT FOR A BRAZING PROCEDURE SPECIFICATION (BPS)
(See QB-200.1, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name ______ By ______
BPS Number ______ Revision ______ Date Issued ______
Supporting PQRs ______
Brazing Process(es) ______ Type(s) ______ (Automatic, Manual, Machine, or Semi-Automatic)

Joint Design (QB-408)

Joint Design: Type ______ Joint Clearance ______
Overlap: Minimum ______ Maximum ______

Base Metal (QB-402)

P-Number ______
to P-Number ______
Other ______

Base Metal Thickness
Minimum ______
Maximum ______

Brazing Filler Metal (QB-403)

Specification Number ______
AWS Classification ______
F-Number ______
Filler Metal Product Form ______

Brazing Temperature (QB-404)

Brazing Temperature Range ______

Postbraze Heat Treatment (QB-409)

Temperature Range ______
Time Range ______

Brazing Flux, Fuel Gas, or Atmosphere (QB-406)

Flux (AWS Class, Composition, or Trade Name) ______
Fuel Gas ______
Furnace Temperature ______
Atmosphere Type ______
Other ______

Flow Position (QB-407)

Positions Permitted ______
Flow Direction ______

Technique (QB-410) and Other Information

Initial Cleaning ______

Flux Application ______

Nature of Flame (Oxidizing, Neutral, Reducing) ______

Torch Tip Sizes ______

Postbraze Cleaning ______

Inspection ______

(02/07)

QB-483 SUGGESTED FORMAT FOR A BRAZING PROCEDURE QUALIFICATION RECORD (PQR)
(See QB-200.2, Section IX, ASME Boiler and Pressure Vessel Code)
Record of Actual Variables Used to Braze Test Coupon

Company Name ______________________________
BPS Followed During Brazing of Test Coupon ______________________ PQR No. ____________
Brazing Process(es) Used ______________________ Date Coupon Was Brazed ____________

Base Metal (QB-402)
Base Metal Specification ______________ to Base Metal Specification ______________
P-Number ______________ to P-Number ______________
Base Metal Thickness ______________ to Base Metal Thickness ______________
Plate or Pipe/Tube ______________

Brazing Filler Metal (QB-403)
Filler Metal Specification: AWS Classification __________ F-No. ________ Filler Metal Product Form __________

Joint Design (QB-408)
Overlap ________ Joint Type ______________ Joint Clearance ______________

Brazing Temperature (QB-404)
Brazing Temperature Range ______________

Brazing Flux, Fuel Gas, or Atmosphere (QB-406)
Flux (AWS Class., Compostion, Trade Name, or None) ______________ Atmosphere Type ______________
Fuel Gas ______________ Furnace Temperature ______________ Other ______________

Flow Position (QB-407)
Position ______________ Flow Direction ______________

Postbraze Heat Treatment (QB-409)
Temperature ______________ Time ______________

Technique (QB-410)
Cleaning Prior to Brazing ______________________________
Postbraze Cleaning ______________________________
Nature of Flame (Oxidizing, Neutral, Reducing) ______________________________
Other ______________________________

Tensile Tests (QB-150)

Specimen	Width/ Diameter	Thickness	Area	Ultimate Load	UTS (psi or MPa)	Failure Location

Bend Tests (QB-160)

Type	Results	Type	Results

Peel Tests (QB-170) or Section Tests (QB-180)

Type	Results	Type	Results

Other Tests ______________________________
Brazer's/Brazing Operator's Name ______________ ID No. ______________
Brazing of Test Coupon Supervised by ______________
Test Specimens Evaluated by ______________ Company ______________
Laboratory Test Number ______________________________

We hereby certify that the statements in this record are correct and that the test coupons were prepared, brazed, and tested in accordance with the requirements of Section IX of the ASME BOILER AND PRESSURE VESSEL CODE.

Manufacturer ______________________________

Certified by ______________________ Date ______________

(05/07)

QB-484 SUGGESTED FORMAT FOR A BRAZER/BRAZING OPERATOR PERFORMANCE QUALIFICATION (BPQ)
(See QB-301, Section IX, ASME Boiler and Pressure Vessel Code)

Brazer's/Brazing Operator's Name ______________________ Identification No. ______________

Testing Variables and Ranges Qualified

Identification of BPS Followed During Brazing of Test Coupon ______________________
Specification of First Test Coupon Base Metal ______________________
Specification of Second Test Coupon Base Metal ______________________

Brazing Variables (QB-350)	Actual Values	Range Qualified
Brazing Process(es)		
Type of Brazing (Manual, Semi-Automatic, Automatic, Machine)		
Torch Brazing: Manual or Mechanical		
Base Metal P-Number ______ to P-Number		
☐ Plate ☐ Pipe (enter diameter if pipe or tube)		
Base Metal Thickness		
to Base Metal Thickness		
Joint Type (Butt, Lap, Scarf, Socket, etc.)		
If Lap or Socket, Overlap Length		
Joint Clearance		
Filler Metal (SFA) Specification(s) (info. only)		
Filler Metal Classification(s) (info. only)		
Filler Metal/F-Number		
Filler Metal Product Form		
Brazing Flow Positions		

Testing and Results

Visual Examination of Completed Joint (QB-141.6) ______________________ **Date of Test** ______________

Mechanical Test ☐ Peel (QB-462.3) ☐ Section (QB-462.4) ☐ Tension (QB-462.1)
☐ Transverse Bends [QB-462.2(a)] ☐ Longitudinal Bends [QB-462.2(b)]

Position	Result	Position	Result	Position	Result

Mechanical Tests Conducted by ______________________ Company ______________________
Specimens Evaluated by ______________________ Company ______________________
Lab Test No. ______________________

We certify that the statements in this record are correct and that the test coupons were prepared, brazed, and tested in accordance with the requirements of Section IX of the ASME BOILER AND PRESSURE VESSEL CODE.

Manufacturer ______________________

Certified by ______________________ Date ______________________

(03/07)

(10)

NONMANDATORY APPENDIX D
P-NUMBER LISTING

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys			
1	1	SA-36	. . .
1	1	SA-53	Type E, Gr. A
1	1	SA-53	Type E, Gr. B
1	1	SA-53	Type F
1	1	SA-53	Type S, Gr. A
1	1	SA-53	Type S, Gr. B
1	1	SA-106	A
1	1	SA-106	B
1	1	A 108	1015CW
1	1	A 108	1018CW
1	1	A 108	1020CW
1	1	SA-134	. . .
1	1	SA-135	A
1	1	SA-135	B
1	1	A 139	A
1	1	A 139	B
1	1	A 139	C
1	1	A 139	D
1	1	A 139	E
1	1	SA-178	A
1	1	SA-178	C
1	1	SA-179	. . .
1	1	SA-181	Cl. 60
1	1	SA-192	. . .
1	1	SA-210	A-1
1	1	A 211	A570-30
1	1	A 211	A570-33
1	1	A 211	A570-40
1	1	SA-214	. . .
1	1	SA-216	WCA
1	1	SA-234	WPB
1	1	SA-266	1
1	1	SA-283	A
1	1	SA-283	B
1	1	SA-283	C
1	1	SA-283	D
1	1	SA-285	A
1	1	SA-285	B
1	1	SA-285	C
1	1	SA-333	1
1	1	SA-333	6
1	1	SA-334	1
1	1	SA-334	6
1	1	SA-350	LF1
Steel and Steel Alloys (CONT'D)			
1	1	SA-352	LCA
1	1	SA-352	LCB
1	1	SA-369	FPA
1	1	SA-369	FPB
1	1	SA-372	A
1	1	A 381	Y35
1	1	A 381	Y42
1	1	A 381	Y46
1	1	A 381	Y48
1	1	A 381	Y50
1	1	SA-414	A
1	1	SA-414	B
1	1	SA-414	C
1	1	SA-414	D
1	1	SA-414	E
1	1	SA-420	WPL6
1	1	A 500	B
1	1	A 500	C
1	1	A 501	K03000
1	1	SA-513	1008
1	1	SA-513	1010
1	1	SA-513	1015
1	1	A 513	1015CW
1	1	SA-515	60
1	1	SA-515	65
1	1	SA-516	55
1	1	SA-516	60
1	1	SA-516	65
1	1	A 519	1018 HR
1	1	A 519	1020 HR
1	1	A 519	1022 HR
1	1	A 519	1025 HR
1	1	A 519	1026 HR
1	1	A 521	Cl. CC
1	1	SA-524	I
1	1	SA-524	II
1	1	SA-556	A2
1	1	SA-556	B2
1	1	SA-557	A2
1	1	SA-557	B2
1	1	SA-562	. . .
1	1	A 572	42
1	1	A 572	50
1	1	A 573	58

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
1	1	A 573	65
1	1	A 575	M1008
1	1	A 575	M1010
1	1	A 575	M1012
1	1	A 575	M1015
1	1	A 575	M1017
1	1	A 575	M1020
1	1	A 575	M1023
1	1	A 575	M1025
1	1	A 576	G10080
1	1	A 576	G10100
1	1	A 576	G10120
1	1	A 576	G10150
1	1	A 576	G10160
1	1	A 576	G10170
1	1	A 576	G10180
1	1	A 576	G10190
1	1	A 576	G10200
1	1	A 576	G10210
1	1	A 576	G10220
1	1	A 576	G10230
1	1	A 576	G10250
1	1	SA-587	. . .
1	1	SA-618	III
1	1	SA-633	A
1	1	SA-633	Cb
1	1	SA-633	Db
1	1	SA-656	Type 3, Gr. 50
1	1	SA-656	Type 7, Gr. 50
1	1	SA-660	WCA
1	1	SA-662	A
1	1	SA-662	B
1	1	SA-663	. . .
1	1	SA-668	Cl. B
1	1	SA-668	Cl. C
1	1	SA-671	CA55
1	1	SA-671	CB60
1	1	SA-671	CB65
1	1	SA-671	CC60
1	1	SA-671	CC65
1	1	SA-671	CE55
1	1	SA-671	CE60
1	1	SA-672	A45
1	1	SA-672	A50
1	1	SA-672	A55
1	1	SA-672	B55
1	1	SA-672	B60
1	1	SA-672	B65
1	1	SA-672	C55
1	1	SA-672	C60
1	1	SA-672	C65
1	1	SA-672	E55
1	1	SA-672	E60
1	1	SA-675	45
Steel and Steel Alloys (CONT'D)			
1	1	SA-675	50
1	1	SA-675	55
1	1	SA-675	60
1	1	SA-675	65
1	1	A 694	F42
1	1	A 694	F46
1	1	A 694	F52
1	1	SA-695	Type B, Gr. 35
1	1	SA-696	B
1	1	A 707	L1, Cl. 1
1	1	A 707	L1, Cl. 2
1	1	A 707	L2, Cl. 1
1	1	A 707	L2, Cl. 2
1	1	A 707	L3, Cl. 1
1	1	A 707	L3, Cl. 2
1	1	SA-727	. . .
1	1	SA-765	I
1	1	SA-836	. . .
1	1	A 992	. . .
1	1	SA-1008	CS Type A
1	1	SA-1008	CS Type B
1	1	A 1008	DS Type B
1	1	A 1011	CS Type B
1	1	A 1011	DS Type B
1	1	API 5L	A
1	1	API 5L	A25, Cl. I
1	1	API 5L	A25, Cl. II
1	1	API 5L	B
1	1	API 5L	X42
1	1	API 5L	X46
1	1	API 5L	X52
1	1	MSS SP-75	WPHY-42
1	1	MSS SP-75	WPHY-46
1	1	MSS SP-75	WPHY-52
1	1	SA/AS 1548	PT430
1	1	SA/AS 1548	PT460
1	1	SA/CSA G40.21	Gr. 38W
1	1	SA/CSA G40.21	Gr. 44W
1	1	SA/EN 10028-2	P295GH
1	1	SA/EN 10028-3	P275NH
1	1	SA/EN 10216-2	P235GH
1	1	SA/EN 10216-2	P265GH
1	1	SA/EN 10222-2	P280GH
1	1	SA/GB 6654	16MnR
1	1	SA/EN 10025-2	S235JR
1	1	SA/EN 10217-1	P235TR2
1	2	SA-105	. . .
1	2	SA-106	C
1	2	SA-178	D
1	2	SA-181	Cl. 70
1	2	SA-210	C
1	2	SA-216	WCB
1	2	SA-216	WCC
1	2	SA-234	WPC
1	2	SA-266	2

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
1	2	SA-266	3
1	2	SA-266	4
1	2	SA-299	A
1	2	SA-350	LF2
1	2	SA-352	LCC
1	2	A 356	1
1	2	SA-372	B
1	2	A 381	Y52
1	2	A 381	Y52
1	2	A 381	Y56
1	2	A 381	Y56
1	2	A 381	Y60
1	2	A 381	Y60
1	2	SA-414	F
1	2	SA-414	G
1	2	SA-455	. . .
1	2	SA-487	Gr. 16, Cl. A
1	2	SA-508	1
1	2	SA-508	1A
1	2	A 513	1020 CW
1	2	A 513	1025 CW
1	2	SA-515	70
1	2	SA-516	70
1	2	A 519	1018 CW
1	2	A 519	1020 CW
1	2	A 519	1022 CW
1	2	A 519	1025 CW
1	2	A 519	1026 CW
1	2	A 521	Cl. CE
1	2	SA-537	Cl. 1
1	2	SA-541	1
1	2	SA-541	1A
1	2	SA-556	C2
1	2	SA-557	C2
1	2	A 572	60
1	2	A 573	70
1	2	A 618	II, a
1	2	A 618	II, b
1	2	A 633	C a
1	2	A 633	D a
1	2	SA-656	Type 3, Gr. 60
1	2	SA-656	Type 7, Gr. 60
1	2	SA-660	WCB
1	2	SA-660	WCC
1	2	SA-662	C
1	2	A 668	Cl. D
1	2	SA-671	CB70
1	2	SA-671	CC70
1	2	SA-671	CD70
1	2	SA-671	CK75
1	2	SA-672	B70
1	2	SA-672	C70
1	2	SA-672	D70
1	2	SA-672	N75
1	2	SA-675	70
1	2	A 675	75
Steel and Steel Alloys (CONT'D)			
1	2	SA-691	CMS-75
1	2	SA-691	CMSH-70
1	2	A 694	F56
1	2	A 694	F60
1	2	A 694	F65
1	2	SA-695	Type B, Gr. 40
1	2	SA-696	C
1	2	A 707	L2, Cl. 3
1	2	A 707	L3, Cl. 3
1	2	SA-737	B
1	2	SA-738	A
1	2	SA-765	II
1	2	API 5L	X56
1	2	API 5L	X60
1	2	API 5L	X65
1	2	MSS SP-75	WPHY-56
1	2	MSS SP-75	WPHY-60
1	2	MSS SP-75	WPHY-65
1	2	SA/AS 1548	PT490
1	2	SA/EN 10028-2	P355GH
1	2	SA/EN 10222-2	P305GH
1	2	SA/GB 6654	16MnR
1	2	SA/JIS G3118	SGV480
1	2	SA-841	A, Cl. 1
1	3	SA-299	B
1	3	SA-333	10
1	3	A 513	1026 CW
1	3	SA-537	Cl. 2
1	3	SA-537	Cl. 3
1	3	A 633	E
1	3	A 668	Cl. Fa
1	3	A 668	Cl. Fb
1	3	SA-656	Type 3, Gr. 70
1	3	SA-656	Type 7, Gr. 70
1	3	SA-671	CD80
1	3	SA-672	D80
1	3	SA-691	CMSH-80
1	3	A 694	F70
1	3	SA-737	C
1	3	SA-738	B
1	3	SA-738	C
1	3	SA-765	IV
1	3	SA-812	65
1	3	SA-841	B, Cl. 2
1	3	API 5L	X70
1	3	MSS SP-75	WPHY-70
1	4	SA-656	Type 3, Gr. 80
1	4	SA-656	Type 7, Gr. 80
1	4	SA-724	A
1	4	SA-724	B
1	4	SA-724	C
1	4	SA-812	80
1	4	API 5L	X80
3	1	SA-204	A
3	1	SA-209	T1

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
3	1	SA-209	T1a
3	1	SA-209	T1b
3	1	SA-213	T2
3	1	SA-217	WC1
3	1	SA-234	WP1
3	1	SA-250	T1
3	1	SA-250	T1a
3	1	SA-250	T1b
3	1	SA-250	T2
3	1	SA-335	P1
3	1	SA-335	P2
3	1	SA-335	P15
3	1	SA-352	LC1
3	1	A 356	2
3	1	SA-369	FP1
3	1	SA-369	FP2
3	1	SA-387	Gr. 2, Cl. 1
3	1	SA-426	CP1
3	1	SA-426	CP2
3	1	SA-426	CP15
3	1	A 588	A, a
3	1	A 588	A, b
3	1	A 588	A, c
3	1	A 588	B, a
3	1	A 588	B, b
3	1	A 588	B, c
3	1	SA-672	L65
3	1	SA-691	½CR
3	1	SA-691	CM-65
3	1	SA/EN 10216-2	16Mo3
3	2	SA-182	F1
3	2	SA-182	F2
3	2	SA-204	B
3	2	SA-204	C
3	2	SA-302	A
3	2	SA-336	F1
3	2	SA-387	Gr. 2, Cl. 2
3	2	SA-672	H75
3	2	SA-672	L70
3	2	SA-672	L75
3	2	SA-691	½CR, Cl. 2
3	2	SA-691	CM-70
3	2	SA-691	CM-75
3	3	A 108	8620 CW
3	3	SA-302	B
3	3	SA-302	C
3	3	SA-302	D
3	3	SA-487	Gr. 2, Cl. A
3	3	SA-487	Gr. 2, Cl. B
3	3	SA-487	Gr. 4, Cl. A
3	3	SA-508	2, Cl. 1
3	3	SA-508	2, Cl. 2
3	3	SA-508	3, Cl. 1
3	3	SA-508	3, Cl. 2
3	3	SA-508	4N, Cl. 3

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
3	3	SA-533	Type A, Cl. 1
3	3	SA-533	Type A, Cl. 2
3	3	SA-533	Type B, Cl. 1
3	3	SA-533	Type B, Cl. 2
3	3	SA-533	Type C, Cl. 1
3	3	SA-533	Type C, Cl. 2
3	3	SA-533	Type D, Cl. 1
3	3	SA-533	Type D, Cl. 2
3	3	SA-541	2, Cl. 1
3	3	SA-541	2, Cl. 2
3	3	SA-541	3, Cl. 1
3	3	SA-541	3, Cl. 2
3	3	SA-543	B Cl. 3
3	3	SA-543	C Cl. 3
3	3	SA-672	H80
3	3	SA-672	J80
3	3	SA-672	J90
4	1	SA-182	F11, Cl. 1
4	1	SA-182	F11, Cl. 2
4	1	SA-182	F11, Cl. 3
4	1	SA-182	F12, Cl. 1
4	1	SA-182	F12, Cl. 2
4	1	A-199	T11
4	1	SA-202	A
4	1	SA-202	B
4	1	SA-213	T11
4	1	SA-213	T12
4	1	SA-217	WC4
4	1	SA-217	WC5
4	1	SA-217	WC6
4	1	SA-234	WP11, Cl. 1
4	1	SA-234	WP12, Cl. 1
4	1	A 234	WP11, Cl. 3
4	1	A 234	WP12, Cl. 2
4	1	SA-250	T11
4	1	SA-250	T12
4	1	SA-335	P11
4	1	SA-335	P12
4	1	SA-336	F11, Cl. 2
4	1	SA-336	F11, Cl. 3
4	1	SA-336	F11, Cl. 1
4	1	SA-336	F12
4	1	A 356	6
4	1	A 356	8
4	1	A 356	9
4	1	SA-369	FP11
4	1	SA-369	FP12
4	1	SA-387	11, Cl. 1
4	1	SA-387	11, Cl. 2
4	1	SA-387	12, Cl. 1
4	1	SA-387	12, Cl. 2
4	1	SA-426	CP11
4	1	SA-426	CP12
4	1	SA-541	11, Cl. 4
4	1	SA-691	1CR

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
4	1	SA-691	$1\frac{1}{4}$ CR
4	1	SA-739	B11
4	1	SA/EN 10028-2	13CrMoSi5-5+QT
4	1	SA/EN 10216-2	13CrMo4-5
4	1	SA/EN 10222-2	13CrMo4-5
4	2	SA-333	4
4	2	SA-423	1
4	2	SA-423	2
4	3	A 148	90-60
4	3	A 668	Cl. K a
4	3	A 668	Cl. K b
4	3	A 668	Cl. L a
4	3	A 668	Cl. L b
4	3	A 668	Cl. L c
5A	1	SA-182	F21
5A	1	SA-182	F22, Cl. 1
5A	1	SA-182	F22, Cl. 3
5A	1	A 199	T21
5A	1	A 199	T22
5A	1	SA-213	T21
5A	1	SA-213	T22
5A	1	SA-217	WC9
5A	1	SA-234	WP22, Cl. 1
5A	1	A 234	WP22, Cl. 3
5A	1	SA-250	T22
5A	1	SA-335	P21
5A	1	SA-335	P22
5A	1	SA-336	F21, Cl. 3
5A	1	SA-336	F21, Cl. 1
5A	1	SA-336	F22, Cl. 3
5A	1	SA-336	F22, Cl. 1
5A	1	A 356	10
5A	1	SA-369	FP21
5A	1	SA-369	FP22
5A	1	SA-387	21, Cl. 1
5A	1	SA-387	21, Cl. 2
5A	1	SA-387	22, Cl. 1
5A	1	SA-387	22, Cl. 2
5A	1	SA-426	CP21
5A	1	SA-426	CP22
5A	1	SA-691	$2\frac{1}{4}$CR
5A	1	SA-691	3CR
5A	1	SA-739	B22
5A	1	SA/EN 10216-2	10CrMo9-10
5A	1	SA/EN 10222-2	11CrMo9-10
5B	1	SA-182	F5
5B	1	SA-182	F5a
5B	1	SA-182	F9
5B	1	A 199	T5
5B	1	A 199	T9
5B	1	SA-213	T5
5B	1	SA-213	T5b
5B	1	SA-213	T5c
5B	1	SA-213	T9
5B	1	SA-217	C5
Steel and Steel Alloys (CONT'D)			
5B	1	SA-217	C12
5B	1	SA-234	WP5
5B	1	SA-234	WP9
5B	1	A 234	WP5, Cl. 3
5B	1	A 234	WP9, Cl. 3
5B	1	SA-335	P5
5B	1	SA-335	P5b
5B	1	SA-335	P5c
5B	1	SA-335	P9
5B	1	SA-336	F5
5B	1	SA-336	F5A
5B	1	SA-336	F9
5B	1	SA-369	FP5
5B	1	SA-369	FP9
5B	1	SA-387	5, Cl. 1
5B	1	SA-387	5, Cl. 2
5B	1	SA-426	CP5
5B	1	SA-426	CP5b
5B	1	SA-426	CP9
5B	1	SA-691	5CR
5C	1	SA-182	F3V
5C	1	SA-182	F3VCb
5C	1	SA-182	F22V
5C	1	SA-336	F3V
5C	1	SA-336	F3VCb
5C	1	SA-336	F22V
5C	1	SA-487	Gr. 8 Cl. A
5C	1	SA-508	3V
5C	1	SA-508	3VCb
5C	1	SA-508	22, Cl. 3
5C	1	SA-541	3V
5C	1	SA-541	3VCb
5C	1	SA-541	22V
5C	1	SA-541	22, Cl. 3
5C	1	SA-542	A, Cl. 4
5C	1	SA-542	A, Cl. 4a
5C	1	SA-542	B, Cl. 4
5C	1	SA-542	B, Cl. 4a
5C	1	SA-542	C, Cl. 4
5C	1	SA-542	C, Cl. 4a
5C	1	SA-542	D, Cl. 4a
5C	1	SA-542	E, Cl. 4a
5C	1	SA-832	21V
5C	1	SA-832	22V
5C	1	SA-832	23V
5C	3	SA-542	A, Cl. 3
5C	3	SA-542	B, Cl. 3
5C	3	SA-542	C, Cl. 3
5C	4	SA-487	Gr. 8 Cl. B
5C	4	SA-487	Gr. 8 Cl. C
5C	4	SA-541	22, Cl. 4
5C	4	SA-542	A, Cl. 1
5C	4	SA-542	B, Cl. 1
5C	4	SA-542	C, Cl. 1
5C	5	SA-541	22, Cl. 5

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
5C	5	SA-542	A, Cl. 2
5C	5	SA-542	B, Cl. 2
5C	5	SA-542	C, Cl. 2
6	1	SA-182	F6a, Cl. 1
6	1	SA-240	410
6	1	SA-268	TP410
6	1	A 276	TP410
6	1	SA-479	403
6	1	SA-479	410
6	2	SA-182	F429
6	2	SA-240	429
6	2	SA-268	TP429
6	3	SA-182	F6a, Cl. 2
6	3	SA-182	F6b
6	3	A 182	F6a, Cl. 3
6	3	A 182	F6a, Cl. 4
6	3	SA-217	CA15
6	3	SA-336	F6
6	3	A 351	CA15
6	3	SA-426	CPCA15
6	3	SA-487	CA15 Cl. B
6	3	SA-487	CA15 Cl. C
6	3	SA-487	CA15 Cl. D
6	3	SA-487	CA15M Cl. A
6	4	SA-182	F6NM
6	4	SA-240	S41500
6	4	SA-268	S41500
6	4	SA-352	CA6NM
6	4	SA-479	414
6	4	SA-479	S41500
6	4	SA-487	CA6NM Cl. A
6	4	SA-487	CA6NM Cl. B
6	4	SA-731	S41500
6	4	SA-815	S41500
7	1	SA-240	Type 405
7	1	SA-240	Type 409
7	1	SA-240	Type 410S
7	1	SA-268	S40800
7	1	SA-268	TP430Ti
7	1	SA-268	TP405
7	1	SA-268	TP409
7	1	SA-268	TP430Ti
7	1	SA-479	405
7	1	SA-1010	40
7	1	SA-1010	50
7	1	SA/JIS G4303	SUS405
7	2	SA-182	F430
7	2	SA-240	S44400
7	2	SA-240	Type 430
7	2	SA-240	Type 439
7	2	SA-240	S43932
7	2	SA-268	18Cr–2Mo
7	2	SA-268	TP430Ti
7	2	SA-268	TP430
7	2	SA-268	TP439
7	2	SA-479	430
Steel and Steel Alloys (CONT'D)			
7	2	SA-479	439
7	2	SA-479	S44400
7	2	SA-731	18Cr-2Mo
7	2	SA-731	TP439
7	2	SA-803	TP439
8	1	A 167	Type 302B
8	1	SA-182	S30600
8	1	SA-182	F304
8	1	SA-182	F304H
8	1	SA-182	F304L
8	1	SA-182	F304LN
8	1	SA-182	F304N
8	1	SA-182	F316
8	1	SA-182	F316H
8	1	SA-182	F316L
8	1	SA-182	F316LN
8	1	SA-182	F316
8	1	SA-182	F317
8	1	SA-182	F317L
8	1	SA-182	F321
8	1	SA-182	F321H
8	1	SA-182	F347
8	1	SA-182	F347H
8	1	SA-182	F348
8	1	SA-182	F348H
8	1	SA-213	TP304
8	1	SA-213	TP304H
8	1	SA-213	TP304L
8	1	SA-213	TP304LN
8	1	SA-213	TP304N
8	1	SA-213	S32615
8	1	SA-213	TP316
8	1	SA-213	TP316H
8	1	SA-213	TP316L
8	1	SA-213	TP316LN
8	1	SA-213	TP316N
8	1	SA-213	TP321
8	1	SA-213	TP321H
8	1	SA-213	TP347
8	1	SA-213	TP347H
8	1	SA-213	TP347HFG
8	1	SA-213	TP348
8	1	SA-213	TP348H
8	1	SA-213	XM-15
8	1	A 269	TP304
8	1	A 269	TP304L
8	1	A 269	TP316
8	1	A 269	TP316L
8	1	A 276	TP304
8	1	A 276	TP304L
8	1	A 276	TP316
8	1	A 276	TP316L
8	1	SA-240	S30500
8	1	SA-240	S30600
8	1	SA-240	S30601

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
8	1	SA-240	S31753
8	1	SA-240	S32615
8	1	SA-240	Type 301
8	1	SA-240	Type 302
8	1	SA-240	Type 304
8	1	SA-240	Type 304H
8	1	SA-240	Type 304L
8	1	SA-240	Type 304LN
8	1	SA-240	Type 304N
8	1	SA-240	Type 316
8	1	SA-240	Type 316Cb
8	1	SA-240	Type 316H
8	1	SA-240	Type 316L
8	1	SA-240	Type 316LN
8	1	SA-240	Type 316N
8	1	SA-240	Type 316Ti
8	1	SA-240	Type 317
8	1	SA-240	Type 317L
8	1	SA-240	Type 321
8	1	SA-240	Type 321H
8	1	SA-240	Type 347
8	1	SA-240	Type 347H
8	1	SA-240	Type 348
8	1	SA-240	Type 348H
8	1	SA-240	Type XM-15
8	1	SA-240	Type XM-21
8	1	SA-249	TP304
8	1	SA-249	TP304H
8	1	SA-249	TP304L
8	1	SA-249	TP304LN
8	1	SA-249	TP304N
8	1	SA-249	TP316
8	1	SA-249	TP316H
8	1	SA-249	TP316L
8	1	SA-249	TP316LN
8	1	SA-249	TP316N
8	1	SA-249	TP317
8	1	SA-249	TP317L
8	1	SA-249	TP321
8	1	SA-249	TP321H
8	1	SA-249	TP347
8	1	SA-249	TP347H
8	1	SA-249	TP348
8	1	SA-249	TP348H
8	1	SA-249	TP XM-15
8	1	A 269	TP304
8	1	A 269	TP304L
8	1	A 269	TP316
8	1	A 269	TP316L
8	1	A 276	TP304
8	1	A 276	TP304L
8	1	A 276	TP316
8	1	A 276	TP316L
8	1	SA-312	S30600
8	1	SA-312	S32615

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
8	1	SA-312	TP304
8	1	SA-312	TP304H
8	1	SA-312	TP304L
8	1	SA-312	TP304LN
8	1	SA-312	TP304N
8	1	SA-312	TP316
8	1	SA-312	TP316H
8	1	SA-312	TP316L
8	1	SA-312	TP316LN
8	1	SA-312	TP316N
8	1	SA-312	TP317
8	1	SA-312	TP317L
8	1	SA-312	TP321
8	1	SA-312	TP321H
8	1	SA-312	TP347
8	1	SA-312	TP347H
8	1	SA-312	TP348
8	1	SA-312	TP348H
8	1	SA-312	TP XM-15
8	1	SA-351	CF3
8	1	SA-351	CF3A
8	1	SA-351	CF3M
8	1	SA-351	CF8
8	1	SA-351	CF8A
8	1	SA-351	CF8C
8	1	SA-351	CF8M
8	1	SA-351	CF10
8	1	SA-351	CF10M
8	1	SA-351	CG8M
8	1	A 351	CF10MC
8	1	SA-358	304
8	1	SA-358	304H
8	1	SA-358	304L
8	1	SA-358	304LN
8	1	SA-358	304N
8	1	SA-358	316
8	1	SA-358	316H
8	1	SA-358	316L
8	1	SA-358	316LN
8	1	SA-358	316N
8	1	SA-358	321
8	1	SA-358	347
8	1	SA-358	348
8	1	SA-376	16-8-2H
8	1	SA-376	TP304
8	1	SA-376	TP304H
8	1	SA-376	TP304LN
8	1	SA-376	TP304N
8	1	SA-376	TP316
8	1	SA-376	TP316H
8	1	SA-376	TP316LN
8	1	SA-376	TP316N
8	1	SA-376	TP321

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
8	1	SA-376	TP321H
8	1	SA-376	TP347
8	1	SA-376	TP347H
8	1	SA-376	TP348
8	1	SA-376	16-8-2H
8	1	SA-403	WP304
8	1	SA-403	WP304H
8	1	SA-403	WP304L
8	1	SA-403	WP304LN
8	1	SA-403	WP304N
8	1	SA-403	WP316
8	1	SA-403	WP316H
8	1	SA-403	WP316L
8	1	SA-403	WP316LN
8	1	SA-403	WP316N
8	1	SA-403	WP317
8	1	SA-403	WP317L
8	1	SA-403	WP321
8	1	SA-403	WP321H
8	1	SA-403	WP347
8	1	SA-403	WP347H
8	1	SA-403	WP348
8	1	SA-403	WP348H
8	1	SA-409	TP304
8	1	SA-409	TP304L
8	1	SA-409	TP316
8	1	SA-409	TP316L
8	1	SA-409	TP317
8	1	SA-409	TP321
8	1	SA-409	TP347
8	1	SA-409	TP348
8	1	SA-451	CPF3
8	1	SA-451	CPF3A
8	1	SA-451	CPF3M
8	1	SA-451	CPF8
8	1	SA-451	CPF8A
8	1	SA-451	CPF8C
8	1	SA-451	CPF8M
8	1	A 451	CPF10MC
8	1	SA-479	302
8	1	SA/JIS G4303	SUS302
8	1	SA/JIS G4303	SUS304
8	1	SA-479	304
8	1	SA-479	304H
8	1	SA-479	304L
8	1	SA/JIS G4303	SUS304L
8	1	SA-479	304LN
8	1	SA-479	304N
8	1	SA-479	316
8	1	SA/JIS G4303	SUS316
8	1	SA-479	316Cb
8	1	SA-479	316H
8	1	SA-479	316L
8	1	SA/JIS G4303	SUS316L

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
8	1	SA-479	316LN
8	1	SA-479	316N
8	1	SA-479	316Ti
8	1	SA-479	321
8	1	SA/JIS G4303	SUS321
8	1	SA-479	321H
8	1	SA-479	347
8	1	SA/JIS G4303	SUS347
8	1	SA-479	347H
8	1	SA-479	348
8	1	SA-479	348H
8	1	SA-479	S30600
8	1	SA-479	S32615
8	1	SA-666	302
8	1	SA-666	304
8	1	SA-666	304L
8	1	SA-666	304LN
8	1	SA-666	304N
8	1	SA-666	316
8	1	SA-666	316L
8	1	SA-666	316N
8	1	SA-688	TP304
8	1	SA-688	TP304L
8	1	SA-688	TP304LN
8	1	SA-688	TP304N
8	1	SA-688	TP316
8	1	SA-688	TP316L
8	1	SA-688	TP316LN
8	1	SA-688	TP316N
8	1	SA-813	TP304
8	1	SA-813	TP304H
8	1	SA-813	TP304L
8	1	SA-813	TP304LN
8	1	SA-813	TP304N
8	1	SA-813	TP316
8	1	SA-813	TP316H
8	1	SA-813	TP316L
8	1	SA-813	TP316LN
8	1	SA-813	TP316N
8	1	SA-813	TP317
8	1	SA-813	TP317L
8	1	SA-813	TP321
8	1	SA-813	TP321H
8	1	SA-813	TP347
8	1	SA-813	TP347H
8	1	SA-813	TP348
8	1	SA-813	TP348H
8	1	SA-813	TPXM-15
8	1	SA-814	TP304
8	1	SA-814	TP304H
8	1	SA-814	TP304L
8	1	SA-814	TP304LN
8	1	SA-814	TP304N
8	1	SA-814	TP316
8	1	SA-814	TP316H

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
8	1	SA-814	TP316L
8	1	SA-814	TP316LN
8	1	SA-814	TP316N
8	1	SA-814	TP317
8	1	SA-814	TP317L
8	1	SA-814	TP321
8	1	SA-814	TP321H
8	1	SA-814	TP347
8	1	SA-814	TP347H
8	1	SA-814	TP348
8	1	SA-814	TP348H
8	1	SA-814	TPXM-15
8	1	SA/EN 10028-7	X5CrNi18-10
8	1	SA/EN 10028-7	X5CrNiMo17-12-2
8	1	SA-965	F304
8	1	SA-965	F304H
8	1	SA-965	F304L
8	1	SA-965	F304LN
8	1	SA-965	F304N
8	1	SA-965	F316
8	1	SA-965	F316H
8	1	SA-965	F316L
8	1	SA-965	F316LN
8	1	SA-965	F316N
8	1	SA-965	F321
8	1	SA-965	F321H
8	1	SA-965	F347
8	1	SA-965	F347H
8	1	SA-965	F348
8	1	SA-965	F348H
8	1	SA/EN 10088-2	X6CrNiMoTi17-12-2
8	2	A 167	Type 308
8	2	A 167	Type 309
8	2	A 167	Type 310
8	2	SA-182	F10
8	2	SA-182	F45
8	2	SA-182	F310
8	2	SA-182	F310MoLN
8	2	SA-213	S30815
8	2	SA-213	TP309Cb
8	2	SA-213	TP309H
8	2	SA-213	TP309S
8	2	SA-213	TP310Cb
8	2	SA-213	TP310S
8	2	SA-213	TP309HCb
8	2	SA-213	TP310H
8	2	SA-213	TP310MoLN
8	2	SA-213	TP310HCb
8	2	SA-240	S30815
8	2	SA-240	Type 309Cb
8	2	SA-240	Type 309H
8	2	SA-240	Type 309HCb
8	2	SA-240	Type 309S
8	2	SA-240	Type 310Cb
8	2	SA-240	Type 310HCb
Steel and Steel Alloys (CONT'D)			
8	2	SA-240	Type 310MoLN
8	2	SA-240	Type 310S
8	2	SA-249	S30815
8	2	SA-249	TP309Cb
8	2	SA-249	TP309H
8	2	SA-249	TP309HCb
8	2	SA-249	TP309S
8	2	SA-249	TP310Cb
8	2	SA-249	TP310H
8	2	SA-249	TP310S
8	2	SA-249	TP310MoLN
8	2	SA-312	S30815
8	2	SA-312	TP309Cb
8	2	SA-312	TP309H
8	2	SA-312	TP309HCb
8	2	SA-312	TP309S
8	2	SA-312	TP310Cb
8	2	SA-312	TP310H
8	2	SA-312	TP310HCb
8	2	SA-312	TP310S
8	2	SA-312	TP310MoLN
8	2	SA-351	CH8
8	2	SA-351	CH20
8	2	SA-351	CK20
8	2	A 351	CE20N
8	2	A 351	CH10
8	2	A 351	HK30
8	2	A 351	HK40
8	2	SA-358	309
8	2	SA-358	309Cb
8	2	SA-358	309S
8	2	SA-358	310Cb
8	2	SA-358	310S
8	2	SA-358	S30815
8	2	SA-403	WP309
8	2	SA-403	WP310S
8	2	SA-409	S30815
8	2	SA-409	TP309Cb
8	2	SA-409	TP309S
8	2	SA-409	TP310Cb
8	2	SA-409	TP310S
8	2	SA-451	CPH8
8	2	SA-451	CPH20
8	2	SA-451	CPK20
8	2	A 451	CPE20N
8	2	SA-479	309Cb
8	2	SA-479	309S
8	2	SA/JIS G4303	SUS309S
8	2	SA-479	310Cb
8	2	SA-479	310S
8	2	SA/JIS G4303	SUS310S
8	2	SA-479	S30815
8	2	SA-813	S30815
8	2	SA-813	TP309Cb
8	2	SA-813	TP309S

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
8	2	SA-813	TP310Cb
8	2	SA-813	TP310S
8	2	SA-814	S30815
8	2	SA-814	TP309Cb
8	2	SA-814	TP309S
8	2	SA-814	TP310Cb
8	2	SA-814	TP310S
8	2	SA-965	F310
8	3	SA-182	FXM-11
8	3	SA-182	FXM-19
8	3	SA-213	TP201
8	3	SA-213	TP202
8	3	SA-213	XM-19
8	3	SA-213	S31042
8	3	SA-240	S20100
8	3	SA-240	S21800
8	3	SA-240	S20100
8	3	SA-240	S20153
8	3	SA-240	Type 202
8	3	SA-240	S20400
8	3	SA-240	Type XM-17
8	3	SA-240	Type XM-18
8	3	SA-240	Type XM-19
8	3	SA-240	Type XM-29
8	3	SA-249	TP201
8	3	SA-249	TP202
8	3	SA-249	TPXM-19
8	3	SA-249	TPXM-29
8	3	SA-312	TPXM-11
8	3	SA-312	TPXM-19
8	3	SA-312	TPXM-29
8	3	SA-351	CG6MMN
8	3	SA-358	XM-19
8	3	SA-358	XM-29
8	3	SA-403	WPXM-19
8	3	SA-479	S21800
8	3	SA-479	XM-11
8	3	SA-479	XM-17
8	3	SA-479	XM-18
8	3	SA-479	XM-19
8	3	SA-479	XM-29
8	3	SA-666	201
8	3	SA-666	XM-11
8	3	SA-688	XM-29
8	3	SA-813	TPXM-11
8	3	SA-813	TPXM-19
8	3	SA-813	TPXM-29
8	3	SA-814	TPXM-11
8	3	SA-814	TPXM-19
8	3	SA-814	TPXM-29
8	3	SA-965	FXM-11
8	3	SA-965	FXM-19
8	4	SA-182	F44
8	4	SA-182	S34565
8	4	A 182	S34565

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
8	4	SA-213	S31725
8	4	SA-213	S31726
8	4	SA-213	S34565
8	4	SA-240	S31254
8	4	SA-240	S31725
8	4	SA-240	S31726
8	4	SA-240	S34565
8	4	A 240	S34565
8	4	SA-249	S31254
8	4	SA-249	S31725
8	4	SA-249	S31726
8	4	SA-249	S34565
8	4	SA-312	S31254
8	4	SA-312	S31725
8	4	SA-312	S31726
8	4	SA-312	S34565
8	4	A 312	S34565
8	4	SA-351	J93254
8	4	SA-358	S31254
8	4	SA-358	S31725
8	4	SA-358	S31726
8	4	SA-376	S31725
8	4	SA-376	S31726
8	4	SA-376	S34565
8	4	SA-403	S31254
8	4	SA-403	S34565
8	4	A 403	S34565
8	4	SA-409	S31254
8	4	SA-409	S31725
8	4	SA-409	S31726
8	4	SA-409	S34565
8	4	SA-479	S31254
8	4	SA-479	S31725
8	4	SA-479	S31726
8	4	SA-479	S34565
8	4	SA-813	S31254
8	4	SA-814	S31254
8	4	SA-965	F46
9A	1	SA-182	FR
9A	1	SA-203	A
9A	1	SA-203	B
9A	1	SA-234	WPR
9A	1	SA-333	7
9A	1	SA-333	9
9A	1	SA-334	7
9A	1	SA-334	9
9A	1	SA-350	LF5, Cl. 1
9A	1	SA-350	LF5, Cl. 2
9A	1	SA-350	LF9
9A	1	SA-352	LC2
9A	1	SA-420	WPL9
9A	1	A 714	Gr. V
9A	1	A 714	Gr. V, Tp. E
9B	1	SA-203	D

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
9B	1	SA-203	E
9B	1	SA-203	F
9B	1	SA-333	3
9B	1	SA-334	3
9B	1	SA-350	LF3, Cl. 2
9B	1	SA-352	LC3
9B	1	SA-420	WPL3
9B	1	SA-765	III
9C	1	SA-352	LC4
10A	1	SA-225	C
10A	1	SA-225	D
10A	1	SA-487	Gr. 1, Cl. A
10A	1	SA-487	Gr. 1, Cl. B
10B	1	SA-213	T17
10C	1	SA-612	. . .
10H	1	SA-182	F53
10H	1	SA-182	F50
10H	1	SA-182	F51
10H	1	SA-182	F54
10H	1	SA-182	F55
10H	1	SA-182	F60
10H	1	A 182	F60
10H	1	SA-240	S31200
10H	1	SA-240	S31260
10H	1	SA-240	S31803
10H	1	SA-240	S32550
10H	1	SA-240	S32750
10H	1	SA-240	S32760
10H	1	SA-240	S32906
10H	1	SA-240	S32950
10H	1	SA-240	Type 329
10H	1	SA-240	S32205
10H	1	A 240	S32205
10H	1	A 276	S32205
10H	1	SA-351	CD3MWCuN
10H	1	SA-479	S31803
10H	1	SA-479	S32205
10H	1	SA-479	S32550
10H	1	SA-789	S31200
10H	1	SA-789	S31260
10H	1	SA-789	S31500
10H	1	SA-789	S31803
10H	1	SA-789	S32205
10H	1	SA-789	S32304
10H	1	SA-789	S32550
10H	1	SA-789	S32750
10H	1	SA-789	S32760
10H	1	SA-789	S32900
10H	1	SA-789	S32906
10H	1	SA-789	S32950
10H	1	SA-789	S39274
10H	1	A 789	S32205
10H	1	SA-790	S31200
10H	1	SA-790	S31260
10H	1	SA-790	S31500

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
10H	1	SA-790	S31803
10H	1	SA-790	S32205
10H	1	A 790	S32205
10H	1	SA-790	S32304
10H	1	SA-790	S32550
10H	1	SA-790	S32750
10H	1	SA-790	S32760
10H	1	SA-790	S32900
10H	1	SA-790	S32906
10H	1	SA-790	S32950
10H	1	SA-790	S39274
10H	1	SA-815	S31803
10H	1	SA-815	S32205
10H	1	A 815	S32205
10H	1	SA-815	S32760
10H	1	A 890	CD3MWCuN
10H	1	A 928	S32760
10H	1	A 928	S32205
10H	1	SA-995	2A
10H	1	SA-995	1B
10I	1	SA-182	FXM-27Cb
10I	1	SA-240	S44635
10I	1	SA-240	Type XM-27
10I	1	SA-240	Type XM-33
10I	1	SA-268	25-4-4
10I	1	SA-268	TP446-1
10I	1	SA-268	TP446-2
10I	1	SA-268	TPXM-27
10I	1	SA-268	TPXM-33
10I	1	SA-336	FXM-27Cb
10I	1	SA-479	XM-27
10I	1	SA-731	TPXM-27
10I	1	SA-731	TPXM-33
10J	1	SA-240	S44700
10J	1	SA-268	S44700
10J	1	SA-268	S44735
10J	1	SA-479	S44700
10J	1	SA-731	S44700
10K	1	SA-240	S44660
10K	1	SA-240	S44800
10K	1	SA-268	S44660
10K	1	SA-268	S44800
10K	1	SA-479	S44800
10K	1	SA-731	S44660
10K	1	SA-731	S44800
10K	1	SA-803	S44660
11A	1	SA-333	8
11A	1	SA-334	8
11A	1	SA-353	. . .
11A	1	SA-420	WPL8
11A	1	SA-522	Type I
11A	1	SA-522	Type II
11A	1	SA-553	Type I
11A	1	SA-553	Type II

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Steel and Steel Alloys (CONT'D)			
11A	2	SA-645	A
11A	3	SA-487	Gr. 4, Cl. B
11A	3	SA-487	Gr. 4, Cl. E
11A	4	SA-533	Type A, Cl. 3
11A	4	SA-533	Type B, Cl. 3
11A	4	SA-533	Type C, Cl. 3
11A	4	SA-533	Type D, Cl. 3
11A	4	SA-672	J100
11A	5	SA-352	LC2-1
11A	5	SA-508	4N, Cl. 1
11A	5	SA-508	5, Cl. 1
11A	5	SA-543	B Cl. 1
11A	5	SA-543	C Cl. 1
11A	1	SA/EN 10028-4	X8Ni9
11A	1	SA/EN 10028-4	X7Ni9
11B	1	A 514	A
11B	1	SA-517	A
11B	1	SA-592	A
11B	2	A 514	E
11B	2	SA-517	E
11B	2	SA-592	E
11B	3	A 514	F
11B	3	SA-517	F
11B	3	SA-592	F
11B	4	A 514	B
11B	4	SA-517	B
11B	8	A 514	P
11B	8	SA-517	P
11B	9	A 514	Q
11B	10	SA-508	4N, Cl. 2
11B	10	SA-508	5, Cl. 2
11B	10	SA-543	B Cl. 2
11B	10	SA-543	C Cl. 2
15E	1	SA-182	F91
15E	1	SA-213	T91
15E	1	A 217	C12A
15E	1	SA-234	WP91
15E	1	SA-335	P91
15E	1	SA-336	F91
15E	1	A 356	12A
15E	1	SA-369	FP91
15E	1	A 691	9Cr, Cl. 2
15E	1	A 691	91
15E	1	SA-387	Gr. 91, Cl. 2
15E	1	SA-10222-2	X10CrMoVNb9-1
15E	1	SA/EN 10216-2	X10CrMoVNb9-1
Aluminum and Aluminum-Base Alloys			
21	...	B 26	A03560
21	...	B 26	A24430
21	...	SB-209	A91060
21	...	SB-209	A91100
21	...	SB-209	A93003
21	...	B 209	A95050

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Aluminum and Aluminum-Base Alloys (CONT'D)			
21	...	SB-210	A91060
21	...	SB-210	A93003
21	...	SB-221	A91060
21	...	SB-221	A91100
21	...	SB-221	A93003
21	...	SB-234	A91060
21	...	SB-234	A93003
21	...	SB-241	A91060
21	...	SB-241	A91100
21	...	SB-241	A93003
21	...	SB-247	A93003
21	...	B 345	A91060
21	...	B 345	A93003
21	...	B 361	WP Alclad 3003
21	...	B 361	A91060
21	...	B 361	A91100
21	...	B 361	A93003
21	...	B 491	A93003
21	...	B 547	A93003
21	...	B 547	Alclad 3003
22	...	SB-209	A93004
22	...	SB-209	A95052
22	...	SB-209	A95154
22	...	SB-209	A95254
22	...	SB-209	A95454
22	...	SB-209	A95652
22	...	SB-210	A95052
22	...	SB-210	A95154
22	...	SB-221	A95154
22	...	SB-221	A95454
22	...	SB-234	A95052
22	...	SB-234	A95454
22	...	SB-241	A95052
22	...	SB-241	A95454
22	...	B 361	A95154
22	...	B 547	A95454
23	...	SB-209	A96061
23	...	SB-210	A96061
23	...	SB-210	A96063
23	...	SB-211	A96061
23	...	SB-221	A96061
23	...	SB-221	A96063
23	...	SB-234	A96061
23	...	SB-241	A96061
23	...	SB-241	A96063
23	...	SB-247	A96061
23	...	SB-308	A96061
23	...	B 345	A96061
23	...	B 345	A96063
23	...	B 361	A96061
23	...	B 361	A96063
23	...	B 547	A96061
25	...	SB-209	A95083
25	...	SB-209	A95086
25	...	SB-209	A95456

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Aluminum and Aluminum-Base Alloys (CONT'D)			
25	...	B 210	A95083
25	...	B 210	A95086
25	...	B 210	A95456
25	...	SB-221	A95083
25	...	SB-221	A95456
25	...	SB-241	A95083
25	...	SB-241	A95086
25	...	SB-241	A95456
25	...	SB-247	A95083
25	...	B 345	A95083
25	...	B 345	A95086
25	...	B 361	A95083
25	...	B 547	A95083
25	...	SB-928	A95083
25	...	SB-928	A95086
25	...	SB-928	A95456
26	...	B 26	A24430
26	...	B 26	A03560
26	...	SB/EN 1706	EN AC 43000
Copper and Copper-Base Alloys			
31	...	SB-42	C10200
31	...	SB-42	C12000
31	...	SB-42	C12200
31	...	B 68	C10200
31	...	B 68	C12000
31	...	B 68	C12200
31	...	SB-75	C10200
31	...	SB-75	C12000
31	...	SB-75	C12200
31	...	SB-75	C14200
31	...	B 88	C10200
31	...	B 88	C12000
31	...	B 88	C12200
31	...	SB-111	C10200
31	...	SB-111	C12000
31	...	SB-111	C12200
31	...	SB-111	C14200
31	...	SB-111	C19200
31	...	SB-152	C10200
31	...	SB-152	C10400
31	...	SB-152	C10500
31	...	SB-152	C10700
31	...	SB-152	C11000
31	...	SB-152	C12200
31	...	SB-152	C12300
31	...	SB-152	C14200
31	...	SB-187	C10200
31	...	SB-187	C11000
31	...	B 280	C10200
31	...	B 280	C12000
31	...	B 280	C12200
31	...	B 283	C11000
31	...	B 302	C12000
Copper and Copper-Base Alloys (CONT'D)			
31	...	SB-359	C10200
31	...	SB-359	C12000
31	...	SB-359	C12200
31	...	SB-359	C14200
31	...	SB-359	C19200
31	...	SB-395	C10200
31	...	SB-395	C12000
31	...	SB-395	C12200
31	...	SB-395	C14200
31	...	SB-395	C19200
31	...	SB-543	C12200
31	...	SB-543	C19400
32	...	SB-43	C23000
32	...	SB-111	C23000
32	...	SB-111	C28000
32	...	SB-111	C44300
32	...	SB-111	C44400
32	...	SB-111	C44500
32	...	SB-111	C68700
32	...	SB-135	C23000
32	...	SB-171	C36500
32	...	SB-171	C44300
32	...	SB-171	C44400
32	...	SB-171	C44500
32	...	SB-171	C46400
32	...	SB-171	C46500
32	...	B 283	C67500
32	...	B 283	C46400
32	...	SB-359	C23000
32	...	SB-359	C44300
32	...	SB-359	C44400
32	...	SB-359	C44500
32	...	SB-359	C68700
32	...	SB-395	C23000
32	...	SB-395	C44300
32	...	SB-395	C44400
32	...	SB-395	C44500
32	...	SB-395	C68700
32	...	SB-543	C23000
32	...	SB-543	C44300
32	...	SB-543	C44400
32	...	SB-543	C44500
32	...	SB-543	C68700
33	...	SB-96	C65500
33	...	SB-98	C65100
33	...	SB-98	C65500
33	...	SB-98	C66100
33	...	B 283	C65500
33	...	SB-315	C65500
34	...	SB-111	C70400
34	...	SB-111	C70600
34	...	SB-111	C71000
34	...	SB-111	C71500
34	...	SB-111	C71640
34	...	SB-111	C72200

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Copper and Copper-Base Alloys (CONT'D)			
34	...	SB-151	C70600
34	...	SB-171	C70600
34	...	SB-171	C71500
34	...	SB-359	C70400
34	...	SB-359	C70600
34	...	SB-359	C71000
34	...	SB-359	C71500
34	...	SB-369	C96200
34	...	SB-395	C70600
34	...	SB-395	C71000
34	...	SB-395	C71500
34	...	SB-466	C70600
34	...	SB-466	C71000
34	...	SB-466	C71500
34	...	SB-467	C70600
34	...	SB-467	C71500
34	...	SB-543	C70400
34	...	SB-543	C70600
34	...	SB-543	C71500
34	...	SB-543	C71640
34	...	SB-956	C70600
34	...	SB-956	C71500
35	...	SB-111	C60800
35	...	SB-148	C95200
35	...	SB-148	C95400
35	...	B 148	C95300
35	...	B 148	C95500
35	...	B 148	C95600
35	...	SB-150	C61400
35	...	SB-150	C62300
35	...	SB-150	C63000
35	...	SB-150	C64200
35	...	SB-169	C61400
35	...	SB-171	C61400
35	...	SB-171	C63000
35	...	SB-271	C95200
35	...	SB-271	C95400
35	...	SB-359	C60800
35	...	SB-395	C60800
35	...	SB-505	C95200
Nickel and Nickel-Base Alloys			
41	...	SB-160	N02200
41	...	SB-160	N02201
41	...	SB-161	N02200
41	...	SB-161	N02201
41	...	SB-162	N02200
41	...	SB-162	N02201
41	...	SB-163	N02200
41	...	SB-163	N02201
41	...	SB-366	N02200
41	...	SB-366	N02201
41	...	B 725	N02200

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Nickel and Nickel-Base Alloys (CONT'D)			
42	...	SB-127	N04400
42	...	SB-163	N04400
42	...	SB-164	N04400
42	...	SB-164	N04405
42	...	SB-165	N04400
42	...	SB-366	N04400
42	...	SB-564	N04400
43	...	SB-163	N06600
43	...	SB-163	N06601
43	...	SB-163	N06690
43	...	SB-166	N06600
43	...	SB-166	N06601
43	...	SB-166	N06617
43	...	SB-166	N06690
43	...	SB-167	N06600
43	...	SB-167	N06601
43	...	SB-167	N06617
43	...	SB-167	N06690
43	...	SB-168	N06600
43	...	SB-168	N06601
43	...	SB-168	N06617
43	...	SB-168	N06690
43	...	SB-366	N06002
43	...	SB-366	N06022
43	...	SB-366	N06035
43	...	SB-366	N06059
43	...	SB-366	N06200
43	...	SB-366	N06210
43	...	SB-366	N06230
43	...	SB-366	N06455
43	...	SB-366	N06600
43	...	SB-366	N06625
43	...	SB-366	N10276
43	...	SB-435	N06002
43	...	SB-435	N06230
43	...	SB-443	N06625
43	...	SB-444	N06625
43	...	SB-446	N06625
43	...	SB-462	N06022
43	...	SB-462	N06035
43	...	SB-462	N06059
43	...	SB-462	N06200
43	...	SB-462	N06686
43	...	SB-462	N10276
43	...	SA-494	N26022
43	...	SB-516	N06600
43	...	SB-517	N06600
43	...	SB-564	N06022
43	...	SB-564	N06035
43	...	SB-564	N06059
43	...	SB-564	N06200
43	...	SB-564	N06210
43	...	SB-564	N06230
43	...	SB-564	N06600
43	...	SB-564	N06617

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Nickel and Nickel-Base Alloys (CONT'D)			
43	...	SB-564	N06625
43	...	SB-564	N06686
43	...	SB-564	N06690
43	...	SB-564	N10276
43	...	SB-572	N06002
43	...	SB-572	N06230
43	...	SB-574	N06022
43	...	SB-574	N06035
43	...	SB-574	N06059
43	...	SB-574	N06200
43	...	SB-574	N06210
43	...	SB-574	N06455
43	...	SB-574	N06686
43	...	SB-574	N10276
43	...	SB-575	N06022
43	...	SB-575	N06035
43	...	SB-575	N06059
43	...	SB-575	N06200
43	...	SB-575	N06210
43	...	SB-575	N06455
43	...	SB-575	N06686
43	...	SB-575	N10276
43	...	SB-619	N06002
43	...	SB-619	N06022
43	...	SB-619	N06035
43	...	SB-619	N06059
43	...	SB-619	N06200
43	...	SB-619	N06210
43	...	SB-619	N06230
43	...	SB-619	N06455
43	...	SB-619	N06686
43	...	SB-619	N10276
43	...	SB-622	N06002
43	...	SB-622	N06022
43	...	SB-622	N06035
43	...	SB-622	N06059
43	...	SB-622	N06200
43	...	SB-622	N06210
43	...	SB-622	N06230
43	...	SB-622	N06455
43	...	SB-622	N06686
43	...	SB-622	N10276
43	...	SB-626	N06002
43	...	SB-626	N06022
43	...	SB-626	N06035
43	...	SB-626	N06059
43	...	SB-626	N06200
43	...	SB-626	N06210
43	...	SB-626	N06230
43	...	SB-626	N06455
43	...	SB-626	N06686
43	...	SB-626	N10276
43	...	SB-704	N06625
43	...	SB-705	N06625
Nickel and Nickel-Base Alloys (CONT'D)			
44	...	SB-333	N10001
44	...	SB-333	N10629
44	...	SB-333	N10665
44	...	SB-333	N10675
44	...	SB-335	N10001
44	...	SB-335	N10629
44	...	SB-335	N10665
44	...	SB-335	N10675
44	...	SB-366	N10001
44	...	SB-366	N10003
44	...	SB-366	N10242
44	...	SB-366	N10629
44	...	SB-366	N10665
44	...	SB-366	N10675
44	...	SB-434	N10003
44	...	SB-434	N10242
44	...	SB-462	N10629
44	...	SB-462	N10665
44	...	SB-462	N10675
44	...	A 494	N30107
44	...	SB-564	N10242
44	...	SB-564	N10629
44	...	SB-564	N10665
44	...	SB-564	N10675
44	...	SB-573	N10003
44	...	SB-573	N10242
44	...	SB-619	N10001
44	...	SB-619	N10242
44	...	SB-619	N10629
44	...	SB-619	N10665
44	...	SB-619	N10675
44	...	SB-622	N10001
44	...	SB-622	N10242
44	...	SB-622	N10629
44	...	SB-622	N10665
44	...	SB-622	N10675
44	...	SB-626	N10001
44	...	SB-626	N10242
44	...	SB-626	N10629
44	...	SB-626	N10665
44	...	SB-626	N10675
45	...	SA-240	S31277
45	...	SB-163	N08120
45	...	SB-163	N08800
45	...	SB-163	N08801
45	...	SB-163	N08810
45	...	SB-163	N08811
45	...	SB-163	N08825
45	...	SA-351	CN3MN
45	...	SA-351	N08007
45	...	SA-351	N08151
45	...	A 351	N08603
45	...	SB-366	N06007

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Nickel and Nickel-Base Alloys (CONT'D)			
45	...	SB-366	N06030
45	...	SB-366	N06985
45	...	SB-366	N08020
45	...	SB-366	N08031
45	...	SB-366	N08120
45	...	SB-366	N08367
45	...	SB-366	N08800
45	...	SB-366	N08825
45	...	SB-366	N08925
45	...	SB-366	R20033
45	...	SB-366	R30556
45	...	B 366	N08926
45	...	SB-407	N08120
45	...	SB-407	N08800
45	...	SB-407	N08801
45	...	SB-407	N08810
45	...	SB-407	N08811
45	...	SB-408	N08120
45	...	SB-408	N08800
45	...	SB-408	N08810
45	...	SB-408	N08811
45	...	SB-409	N08120
45	...	SB-409	N08800
45	...	SB-409	N08810
45	...	SB-409	N08811
45	...	SB-423	N08825
45	...	SB-424	N08825
45	...	SB-425	N08825
45	...	SB-435	R30556
45	...	SB-462	N06030
45	...	SB-462	N08020
45	...	SB-462	N08031
45	...	SB-462	N08367
45	...	SB-462	R20033
45	...	SB-463	N08020
45	...	SB-463	N08024
45	...	SB-463	N08026
45	...	SB-464	N08020
45	...	SB-464	N08024
45	...	SB-464	N08026
45	...	SB-468	N08020
45	...	SB-468	N08024
45	...	SB-468	N08026
45	...	SB-473	N08020
45	...	SB-514	N08120
45	...	SB-514	N08800
45	...	SB-514	N08810
45	...	SB-515	N08120
45	...	SB-515	N08800
45	...	SB-515	N08810
45	...	SB-515	N08811
45	...	SB-564	N08031
45	...	SB-564	N08120
45	...	SB-564	N08367
45	...	SB-564	N08800

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Nickel and Nickel-Base Alloys (CONT'D)			
45	...	SB-564	N08810
45	...	SB-564	N08811
45	...	SB-564	N08825
45	...	SB-564	R20033
45	...	SB-572	R30556
45	...	SB-581	N06007
45	...	SB-581	N06030
45	...	SB-581	N06975
45	...	SB-581	N06985
45	...	SB-581	N08031
45	...	SB-582	N06007
45	...	SB-582	N06030
45	...	SB-582	N06975
45	...	SB-582	N06985
45	...	SB-599	N08700
45	...	SB-619	N06007
45	...	SB-619	N06030
45	...	SB-619	N06975
45	...	SB-619	N06985
45	...	SB-619	N08031
45	...	SB-619	N08320
45	...	SB-619	R20033
45	...	SB-619	R30556
45	...	SB-620	N08320
45	...	SB-621	N08320
45	...	SB-622	N06007
45	...	SB-622	N06030
45	...	SB-622	N06975
45	...	SB-622	N06985
45	...	SB-622	N08031
45	...	SB-622	N08320
45	...	SB-622	R20033
45	...	SB-622	R30556
45	...	SB-625	N08031
45	...	SB-625	N08904
45	...	SB-625	N08925
45	...	SB-625	R20033
45	...	B 625	N08926
45	...	SB-626	N06007
45	...	SB-626	N06030
45	...	SB-626	N06975
45	...	SB-626	N06985
45	...	SB-626	N08031
45	...	SB-626	N08320
45	...	SB-626	R20033
45	...	SB-626	R30556
45	...	SB-649	N08904
45	...	SB-649	N08925
45	...	SB-649	R20033
45	...	B 649	N08926
45	...	SB-668	N08028
45	...	SB-672	N08700
45	...	SB-673	N08904
45	...	SB-673	N08925

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Nickel and Nickel-Base Alloys (CONT'D)			
45	...	SB-673	N08926
45	...	SB-674	N08904
45	...	SB-674	N08925
45	...	B 674	N08926
45	...	SB-675	N08367
45	...	SB-676	N08367
45	...	SB-677	N08904
45	...	SB-677	N08925
45	...	B 677	N08926
45	...	SB-688	N08367
45	...	SB-690	N08367
45	...	SB-691	N08367
45	...	SB-704	N08825
45	...	SB-705	N08825
45	...	SB-709	N08028
45	...	SB-729	N08020
46	...	SB-166	N06045
46	...	SB-167	N06045
46	...	SB-168	N06045
46	...	SB-366	N06045
46	...	SB-366	N08330
46	...	SB-366	N12160
46	...	SB-435	N12160
46	...	SB-462	N06045
46	...	SB-511	N08330
46	...	SB-516	N06045
46	...	SB-517	N06045
46	...	SB-535	N08330
46	...	SB-536	N08330
46	...	SB-564	N06045
46	...	SB-564	N12160
46	...	SB-572	N12160
46	...	SB-619	N12160
46	...	SB-622	N12160
46	...	SB-626	N12160
46	...	SB-710	N08330
49	...	SB-815	R31233
49	...	SB-818	R31233
Titanium and Titanium-Base Alloys			
51	...	SB-265	R50250
51	...	SB-265	R50400
51	...	SB-265	R52250
51	...	SB-265	R52252
51	...	SB-265	R52254
51	...	SB-265	R52400
51	...	SB-265	R52402
51	...	SB-265	R52404
51	...	SB-338	R50250
51	...	SB-338	R50400
51	...	SB-338	R52400
51	...	SB-338	R52402
51	...	SB-338	R52404
51	...	SB-348	R50250

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Titanium and Titanium-Base Alloys (CONT'D)			
51	...	SB-348	R50400
51	...	SB-348	R50402
51	...	SB-348	R52400
51	...	SB-348	R52404
51	...	SB-363	R50250
51	...	SB-363	R50400
51	...	SB-363	R52400
51	...	SB-363	R52404
51	...	SB-367	R50400
51	...	SB-381	R50250
51	...	SB-381	R50400
51	...	SB-381	R50402
51	...	SB-381	R52400
51	...	SB-381	R52404
51	...	SB-861	R50250
51	...	SB-861	R50400
51	...	SB-861	R52400
51	...	SB-861	R52404
51	...	SB-862	R50250
51	...	SB-862	R50400
51	...	SB-862	R52400
51	...	SB-862	R52404
52	...	SB-265	R50550
52	...	SB-265	R53400
52	...	SB-338	R50550
52	...	SB-338	R53400
52	...	SB-348	R50550
52	...	SB-348	R53400
52	...	SB-363	R50550
52	...	SB-363	R53400
52	...	SB-367	R50550
52	...	SB-381	R50550
52	...	SB-381	R53400
52	...	SB-861	R50550
52	...	SB-861	R53400
52	...	SB-862	R50550
52	...	SB-862	R53400
53	...	SB-265	R56320
53	...	SB-338	R56320
53	...	SB-348	R56320
53	...	SB-363	R56320
53	...	SB-381	R56320
53	...	SB-861	R56320
53	...	SB-862	R56320
53	...	SB-265	R56323
53	...	SB-338	R56323
53	...	SB-348	R56323
53	...	SB-363	R56323
53	...	SB-381	R56323
53	...	SB-861	R56323
53	...	SB-862	R56323
Zirconium and Zirconium-Base Alloys			
61	...	SB-493	R60702
61	...	SB-523	R60702

P-No.	Grp. No.	Spec. No.	Type, Grade, or UNS No.
Zirconium and Zirconium-Base Alloys (CONT'D)			
61	...	SB-550	R60702
61	...	SB-551	R60702
61	...	SB-653	R60702
61	...	SB-658	R60702
62	...	SB-493	R60705
62	...	SB-523	R60705
62	...	SB-550	R60705
62	...	SB-551	R60705
62	...	SB-658	R60705

(10)

MANDATORY APPENDIX E
PERMITTED SWPSs

The following AWS Standard Welding Procedure Specifications may be used under the requirements given in Article V.

Specification	Designation
Carbon Steel	
Shielded Metal Arc Welding	
Standard Welding Procedure Specification for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E7018, As-Welded or PWHT Condition	B2.1-1-016-94 (R05)
Standard Welding Procedure Specification for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E6010, As-Welded or PWHT Condition	B2.1-1-017-94 (R05)
Standard Welding Procedure Specification for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E6010 (Vertical Uphill) Followed by E7018, As-Welded or PWHT Condition	B2.1-1-022-94 (R05)
Standard Welding Procedure Specification for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E6010 (Vertical Downhill) Followed by E7018, As-Welded or PWHT Condition	B2.1-1-026-94 (R05)
Combination GTAW and SMAW	
Standard Welding Procedure Specification for Gas Tungsten Arc Welding Followed by Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, ER70S-2 and E7018, As-Welded or PWHT Condition	B2.1-1-021-94 (R05)
Flux Cored Arc Welding	
Standard Welding Procedure Specification (WPS) for CO_2 Shielded Flux Cored Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E70T-1 and E71T-1, As-Welded Condition	B2.1-1-019-94 (R05)
Standard Welding Procedure Specification (WPS) for 75% Ar/25% CO_2 Shielded Flux Cored Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E70T-1 and E71T-1, As-Welded or PWHT Condition	B2.1-1-020-94 (R05)
Carbon Steel — Primarily Pipe Applications	
Shielded Metal Arc Welding	
Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $\frac{3}{4}$ inch Thick, E6010 (Vertical Uphill) Followed by E7018 (Vertical Uphill), As-Welded Condition, Primarily Pipe Applications	B2.1-1-201-96 (R07)
Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $\frac{3}{4}$ inch Thick, E6010 (Vertical Downhill) Followed by E7018 (Vertical Uphill), As-Welded Condition, Primarily Pipe Applications	B2.1-1-202-96 (R07)
Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $\frac{3}{4}$ inch Thick, E6010 (Vertical Uphill), As-Welded Condition, Primarily Pipe Applications	B2.1-1-203-96 (R07)
Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $\frac{3}{4}$ inch Thick, E6010 (Vertical Downhill Root with the Balance Vertical Uphill), As-Welded Condition, Primarily Pipe Applications	B2.1-1-204-96 (R07)
Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E6010 (Vertical Uphill) Followed by E7018 (Vertical Uphill), As-Welded or PWHT Condition, Primarily Pipe Applications	B2.1-1-205-96 (R07)
Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E6010 (Vertical Downhill) Followed by E7018 (Vertical Uphill), As-Welded or PWHT Condition, Primarily Pipe Applications	B2.1-1-206-96 (R07)

Specification	Designation
Carbon Steel — Primarily Pipe Applications (CONT'D)	
Shielded Metal Arc Welding (CONT'D)	
Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E7018, As-Welded or PWHT Condition, Primarily Pipe Applications	B2.1-1-208-96 (R07)
Gas Tungsten Arc Welding	
Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, ER70S-2, As-Welded or PWHT Condition, Primarily Pipe Applications	B2.1-1-207-96 (R07)
Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding with Consumable Insert Root of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, INMs-1 and ER70S-2, As-Welded or PWHT Condition, Primarily Pipe Applications	B2.1-1-210: 2001
Flux Cored Arc Welding	
Standard Welding Procedure Specification (SWPS) for Argon plus 25% Carbon Dioxide Shielded Flux Cored Arc Welding of Carbon Steel (M-1/P-1/S-1, Groups 1 and 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E7XT-X, As-Welded or PWHT Condition, Primarily Pipe Applications	B2.1-1-234: 2006
Gas Metal Arc Welding — Spray Transfer	
Standard Welding Procedure Specification (SWPS) for Argon plus 2% Oxygen Shielded Gas Metal Arc Welding (Spray Transfer Mode) of Carbon Steel (M-1/P-1/S-1, Groups 1 and 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E70S-3, Flat Position Only, As-Welded or PWHT Condition, Primarily Pipe Applications	B2.1-1-235: 2006
Combination GTAW and SMAW	
Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding Followed by Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, ER70S-2 and E7018, As-Welded or PWHT Condition, Primarily Pipe Applications	B2.1-1-209-96 (R07)
Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding with Consumable Insert Root followed by Shielded Metal Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, INMs-1, ER70S-2, and E7018, As-Welded or PWHT Condition, Primarily Pipe Applications	B2.1-1-211: 2001
Austenitic Stainless Steel Plate and Pipe	
Shielded Metal Arc Welding	
Standard Welding Procedure Specification for Shielded Metal Arc Welding of Austenitic Stainless Steel (M-8/P-8/S-8, Group 1), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, As-Welded Condition	B2.1-8-023-94 (R05)
Gas Tungsten Arc Welding	
Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding of Austenitic Stainless Steel (M-8/P-8/S-8, Group 1), $\frac{1}{16}$ through $1\frac{1}{2}$ inch Thick, ER3XX, As-Welded Condition, Primarily Plate and Structural Applications	B2.1-8-024: 2001
Combination GTAW and SMAW	
Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding Followed by Shielded Metal Arc Welding of Austenitic Stainless Steel (M-8/P-8/S-8, Group 1), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, ER3XX and 3XX-XX, As-Welded Condition, Primarily Plate and Structural Applications	B2.1-8-025: 2001
Austenitic Stainless Steel Primarily Pipe Applications	
Shielded Metal Arc Welding	
Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Austenitic Stainless Steel (M-8/P-8/S-8, Group 1), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E3XX-XX, As-Welded Condition, Primarily Pipe Applications	B2.1-8-213-97 (R07)
Gas Tungsten Arc Welding	
Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding of Austenitic Stainless Steel (M-8/P-8/S-8, Group 1), $\frac{1}{16}$ through $1\frac{1}{2}$ inch Thick, ER3XX, As-Welded Condition, Primarily Pipe Applications	B2.1-8-212: 2001
Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding with Consumable Insert of Austenitic Stainless Steel (M-8/P-8/S-8, Group 1), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, IN3XX and ER3XX, As-Welded Condition, Primarily Pipe Applications	B2.1-8-215: 2001

Specification	Designation
Austenitic Stainless Steel Primarily Pipe Applications (CONT'D)	
Combination GTAW and SMAW	
Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding Followed by Shielded Metal Arc Welding of Austenitic Stainless Steel (M-8/P-8/S-8, Group 1), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, ER3XX and E3XX-XX, As-Welded Condition, Primarily Pipe Applications	B2.1-8-214: 2001
Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding with Consumable Insert Root followed by Shielded Metal Arc Welding of Austenitic Stainless Steel (M-8/P-8/S-8, Group 1), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, IN3XX, ER3XXX, and E3XX-XX, As-Welded Condition, Primarily Pipe Applications	B2.1-8-216: 2001
Carbon Steel to Austenitic Stainless Steel	
Gas Tungsten Arc Welding	
Standard Welding Procedure Specification (SWPS) for Gas Tungsten Arc Welding of Carbon Steel to Austenitic Stainless Steel (M-1/P-1/S-1, Groups 1 and 2 Welded to M-8/P-8/S-8, Group 1), $\frac{1}{16}$ through $1\frac{1}{2}$ inch Thick, ER309(L), As-Welded Condition, Primarily Pipe Applications	B2.1-1/8-227: 2002
Standard Welding Procedure Specification (SWPS) for Gas Tungsten Arc Welding with Consumable Insert Root of Carbon Steel to Austenitic Stainless Steel (M-1/P-1/S-1, Gruops 1 and 2 Welded to M-8/P-8/S-8, Group 1), $\frac{1}{16}$ through $1\frac{1}{2}$ inch Thick, IN309 and R309(L), As-Welded Condition, Primarily Pipe Applications	B2.1-1/8-230: 2002
Shielded Metal Arc Welding	
Standard Welding Procedure Specification (SWPS) for Shielded Metal Arc Welding of Carbon Steel to Austenitic Stainless Steel (M-1/P-1/S-1, Groups 1 and 2 Welded to M-8/P-8/S-8, Group 1), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, E309(L)-15, -16, or -17, As-Welded Condition, Primarily Pipe Applications	B2.1-1/8-228: 2002
Combination GTAW and SMAW	
Standard Welding Procedure Specification (SWPS) for Gas Tungsten Arc Welding Followed by Shielded Metal Arc Welding of Carbon Steel to Austenitic Stainless Steel (M-1/P-1/S-1 Groups 1 and 2 Welded to M-8/P-8/S-8, Group 1), $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, ER309(L) and E309(L)-15, -16, or -17, As-Welded Condition, Primarily Pipe Applications	B2.1-1/8-229: 2002
Standard Welding Procedure Specification (SWPS) for Gas Tungsten Arc Welding with Consumable Insert Root, Followed by Shielded Metal Arc Welding of Carbon Steel to Austenitic Stainless Steel (M-1/P-1/S-1 Groups 1 and 2 Welded to M-8/P-8/S-8, Group 1) $\frac{1}{8}$ through $1\frac{1}{2}$ inch Thick, IN309, ER309(L), and E309(L)-15, -16, -17, As-Welded Condition, Primarily Pipe Applications	B2.1-1/8-231: 2002

MANDATORY APPENDIX F
STANDARD UNITS FOR USE IN EQUATIONS

TABLE F-100
STANDARD UNITS FOR USE IN EQUATIONS

Quantity	U.S. Customary Units	SI Units
Linear dimensions (e.g., length, height, thickness, radius, diameter)	inches (in.)	millimeters (mm)
Area	square inches (in.^{2})	square millimeters (mm^2)
Volume	cubic inches (in.^{3})	cubic millimeters (mm^3)
Section modulus	cubic inches (in.^{3})	cubic millimeters (mm^3)
Moment of inertia of section	inches^4 (in.^{4})	millimeters^4 (mm^4)
Mass (weight)	pounds mass (lbm)	kilograms (kg)
Force (load)	pounds force (lbf)	newtons (N)
Bending moment	inch-pounds (in.-lb)	newton-millimeters (N·mm)
Pressure, stress, stress intensity, and modulus of elasticity	pounds per square inch (psi)	megapascals (MPa)
Energy (e.g., Charpy impact values)	foot-pounds (ft-lb)	joules (J)
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)
Absolute temperature	Rankine (R)	kelvin (K)
Fracture toughness	ksi square root inches (ksi$\sqrt{\text{in.}}$)	MPa square root meters (MPa$\sqrt{\text{m}}$)
Angle	degrees or radians	degrees or radians
Boiler capacity	Btu/hr	watts (W)

NONMANDATORY APPENDIX G GUIDANCE FOR THE USE OF U.S. CUSTOMARY AND SI UNITS IN THE ASME BOILER AND PRESSURE VESSEL CODE

G-100 USE OF UNITS IN EQUATIONS

The equations in this Nonmandatory Appendix are suitable for use with either the U.S. Customary or the SI units provided in Mandatory Appendix F, or with the units provided in the nomenclature associated with that equation. It is the responsibility of the individual and organization performing the calculations to ensure that appropriate units are used. Either U.S. Customary or SI units may be used as a consistent set. When necessary to convert from one system of units to another, the units shall be converted to at least three significant figures for use in calculations and other aspects of construction.

G-200 GUIDELINES USED TO DEVELOP SI EQUIVALENTS

The following guidelines were used to develop SI equivalents:

(a) SI units are placed in parentheses after the U.S. Customary units in the text.

(b) In general, separate SI tables are provided if interpolation is expected. The table designation (e.g., table number) is the same for both the U.S. Customary and SI tables, with the addition of suffix "M" to the designator for the SI table, if a separate table is provided. In the text, references to a table use only the primary table number (i.e., without the "M"). For some small tables, where interpolation is not required, SI units are placed in parentheses after the U.S. Customary unit.

(c) Separate SI versions of graphical information (charts) are provided, except that if both axes are dimensionless, a single figure (chart) is used.

(d) In most cases, conversions of units in the text were done using hard SI conversion practices, with some soft conversions on a case-by-case basis, as appropriate. This was implemented by rounding the SI values to the number of significant figures of implied precision in the existing U.S. Customary units. For example, 3,000 psi has an implied precision of one significant figure. Therefore, the conversion to SI units would typically be to 20 000 kPa. This is a difference of about 3% from the "exact" or soft conversion of 20 684.27 kPa. However, the precision of the conversion was determined by the Committee on a case-by-case basis. More significant digits were included in the SI equivalent if there was any question. The values of allowable stress in Section II, Part D generally include three significant figures.

(e) Minimum thickness and radius values that are expressed in fractions of an inch were generally converted according to the following table:

Fraction, in.	Proposed SI Conversion, mm	Difference, %
1/32	0.8	−0.8
3/64	1.2	−0.8
1/16	1.5	5.5
3/32	2.5	−5.0
1/8	3	5.5
5/32	4	−0.8
3/16	5	−5.0
7/32	5.5	1.0
1/4	6	5.5
5/16	8	−0.8
3/8	10	−5.0
7/16	11	1.0
1/2	13	−2.4
9/16	14	2.0
5/8	16	−0.8
11/16	17	2.6
3/4	19	0.3
7/8	22	1.0
1	25	1.6

(f) For nominal sizes that are in even increments of inches, even multiples of 25 mm were generally used. Intermediate values were interpolated rather than converting and rounding to the nearest mm. See examples in the following table. [Note that this table does not apply to nominal pipe sizes (NPS), which are covered below.]

Size, in.	Size, mm
1	25
1⅛	29
1¼	32
1½	38
2	50
2¼	57
2½	64
3	75
3½	89
4	100
4½	114
5	125
6	150
8	200
12	300
18	450
20	500
24	600
36	900
40	1 000
54	1 350
60	1 500
72	1 800

Size or Length, ft	Size or Length, m
3	1
5	1.5
200	60

(g) For nominal pipe sizes, the following relationships were used:

U.S. Customary Practice	SI Practice	U.S. Customary Practice	SI Practice
NPS ⅛	DN 6	NPS 20	DN 500
NPS ¼	DN 8	NPS 22	DN 550
NPS ⅜	DN 10	NPS 24	DN 600
NPS ½	DN 15	NPS 26	DN 650
NPS ¾	DN 20	NPS 28	DN 700
NPS 1	DN 25	NPS 30	DN 750
NPS 1¼	DN 32	NPS 32	DN 800
NPS 1½	DN 40	NPS 34	DN 850
NPS 2	DN 50	NPS 36	DN 900
NPS 2½	DN 65	NPS 38	DN 950
NPS 3	DN 80	NPS 40	DN 1000
NPS 3½	DN 90	NPS 42	DN 1050
NPS 4	DN 100	NPS 44	DN 1100
NPS 5	DN 125	NPS 46	DN 1150
NPS 6	DN 150	NPS 48	DN 1200
NPS 8	DN 200	NPS 50	DN 1250
NPS 10	DN 250	NPS 52	DN 1300
NPS 12	DN 300	NPS 54	DN 1350
NPS 14	DN 350	NPS 56	DN 1400
NPS 16	DN 400	NPS 58	DN 1450
NPS 18	DN 450	NPS 60	DN 1500

(h) Areas in square inches (in.^{2}) were converted to square mm (mm^2) and areas in square feet (ft^2) were converted to square meters (m^2). See examples in the following table:

Area (U.S. Customary)	Area (SI)
1 in.^{2}	650 mm^2
6 in.^{2}	4 000 mm^2
10 in.^{2}	6 500 mm^2
5 ft^2	0.5 m^2

(i) Volumes in cubic inches (in.^{3}) were converted to cubic mm (mm^3) and volumes in cubic feet (ft^3) were converted to cubic meters (m^3). See examples in the following table:

Volume (U.S. Customary)	Volume (SI)
1 in.^{3}	16 000 mm^3
6 in.^{3}	100 000 mm^3
10 in.^{3}	160 000 mm^3
5 ft^3	0.14 m^3

(j) Although the pressure should always be in MPa for calculations, there are cases where other units are used in the text. For example, kPa is used for small pressures. Also, rounding was to one significant figure (two at the most) in most cases. See examples in the following table. (Note that 14.7 psi converts to 101 kPa, while 15 psi converts to 100 kPa. While this may seem at first glance to be an anomaly, it is consistent with the rounding philosophy.)

Pressure (U.S. Customary)	Pressure (SI)
0.5 psi	3 kPa
2 psi	15 kPa
3 psi	20 kPa
10 psi	70 kPa
14.7 psi	101 kPa
15 psi	100 kPa
30 psi	200 kPa
50 psi	350 kPa
100 psi	700 kPa
150 psi	1 MPa
200 psi	1.5 MPa
250 psi	1.7 MPa
300 psi	2 MPa
350 psi	2.5 MPa
400 psi	3 MPa
500 psi	3.5 MPa
600 psi	4 MPa
1,200 psi	8 MPa
1,500 psi	10 MPa

(k) Material properties that are expressed in psi or ksi (e.g., allowable stress, yield and tensile strength, elastic modulus) were generally converted to MPa to three significant figures. See example in the following table:

Strength (U.S. Customary)	Strength (SI)
95,000 psi	655 MPa

(l) In most cases, temperatures (e.g., for PWHT) were rounded to the nearest 5°C. Depending on the implied precision of the temperature, some were rounded to the nearest 1°C or 10°C or even 25°C. Temperatures colder than 0°F (negative values) were generally rounded to the

nearest 1°C. The examples in the table below were created by rounding to the nearest 5°C, with one exception:

Temperature, °F	Temperature, °C
70	20
100	38
120	50
150	65
200	95
250	120
300	150
350	175
400	205
450	230
500	260
550	290
600	315
650	345
700	370
750	400
800	425
850	455
900	480
925	495
950	510
1,000	540
1,050	565
1,100	595
1,150	620
1,200	650
1,250	675
1,800	980
1,900	1 040
2,000	1 095
2,050	1 120

G-300 SOFT CONVERSION FACTORS

The following table of "soft" conversion factors is provided for convenience. Multiply the U.S. Customary value by the factor given to obtain the SI value. Similarly, divide the SI value by the factor given to obtain the U.S. Customary value. In most cases it is appropriate to round the answer to three significant figures.

U.S. Customary	SI	Factor	Notes
in.	mm	25.4	...
ft	m	0.3048	...
$in.^2$	mm^2	645.16	...
ft^2	m^2	0.09290304	...
$in.^3$	mm^3	16,387.064	...
ft^3	m^3	0.02831685	...
U.S. gal	m^3	0.003785412	...
U.S. gal	liters	3.785412	...
psi	MPa (N/mm^2)	0.0068948	Used exclusively in equations
psi	kPa	6.894757	Used only in text and for nameplate
psi	bar	0.06894757	...
ft-lb	J	1.355818	...
°F	°C	$\frac{5}{9} \times$ (°F − 32)	Not for temperature difference
°F	°C	$\frac{5}{9}$	For temperature differences only
R	K	$\frac{5}{9}$	Absolute temperature
lbm	kg	0.4535924	...
lbf	N	4.448222	...
in.-lb	N·mm	112.98484	Use exclusively in equations
ft-lb	N·m	1.3558181	Use only in text
ksi$\sqrt{in.}$	MPa$\sqrt{m}$	1.0988434	...
Btu/hr	W	0.2930711	Use for boiler rating and heat transfer
lb/ft^3	kg/m^3	16.018463	...

NONMANDATORY APPENDIX H WAVEFORM CONTROLLED WELDING (10)

H-100 BACKGROUND

Advances in microprocessor controls and welding power source technology have resulted in the ability to develop waveforms for welding that improve the control of droplet shape, penetration, bead shape and wetting. Some welding characteristics that were previously controlled by the welder or welding operator are controlled by software or firmware internal to the power source. It is recognized that the use of controlled waveforms in welding can result in improvements in productivity and quality. The intention of this Code is to enable their use with both new and existing procedure qualifications.

The ASME Section IX heat input measurement methods in QW-409.1(a) and QW-409.1(b), were developed at a time when welding power source output was relatively constant. The heat input of welds made using waveform controlled power sources is not accurately represented by QW-409.1(a) due to the rapidly-changing outputs, phase shifts, and synergic changes, but is correctly represented by QW-409.1(b) or QW-409.1(c). During waveform controlled welding, current and voltage and values observed on the equipment meters no longer are valid for heat input determination, and must be replaced by instantaneous energy (joules) or power (joules/second or watts) to correctly calculate heat input. QW-409.1(c) more accurately reflects heat input changes when performing waveform controlled welding, but is also suitable for nonwaveform controlled (conventional) welding.

H-200 WAVEFORM CONTROLLED WELDING AND HEAT INPUT DETERMINATION

Power sources that support rapidly pulsing processes (e.g., GMAW-P) are the most common waveform controlled power sources. Power sources that are marketed as synergic, programmable, or microprocessor controlled are generally capable of waveform controlled welding. In these cases, heat input is calculated by the methods outlined in either QW-409.1(b) or QW-409.1(c) when performing procedure qualification or to determine compliance with a qualified procedure. If any doubt exists on whether waveform controlled welding is being performed, the welding equipment manufacturer should be consulted. It is recognized that waveform controls may not be active for all of the welding processes or equipment settings for a particular power source. When the waveform control features of the equipment are not used, the heat input determination methods of either QW-409.1(a), QW-409.1(b), or QW-409.1(c) are used.

When the welding equipment does not display instantaneous energy or power, an external meter with high frequency sampling capable of displaying instantaneous energy or power is typically used, or the welding equipment is upgraded or modified to display instantaneous energy or power.

The equation shown in QW-409.1(c)(1) uses the unit of joules (J) for energy. Other conveniently obtained units of energy such as calories or British thermal units (Btu) may be used with the appropriate conversion factors. The equation shown in QW-409.1(c)(2) uses the unit of joules/second(J/s) or watts (W) for power. One J/s is equal to 1 W. Other conveniently obtained units of power, such as horsepower (HP or kilowatts (kW) may be used with the appropriate conversion factors.

H-300 NEW PROCEDURES QUALIFICATIONS

When qualifying a new procedure using waveform controlled welding, the instantaneous energy or power range is used in lieu of the current (amperage) and voltage ranges to determine the heat input per QW-409.1(c).

When qualifying a new procedure using nonwaveform controlled welding, either the current and voltage is recorded and heat input determined using the methods of QW-409.1(a) or QW-409.1(b), as previously required, or the instantaneous energy or power is recorded and the heat input determined by the method in QW-409.1(c).

H-400 EXISTING QUALIFIED PROCEDURES

Welding procedures previously qualified using nonwaveform controlled welding and heat input determined by QW-409.1(a) may continue to be used for waveform controlled welding, provided they are amended to require heat input determination for production welds using the methods of QW-409.1(c). Welding procedures previously qualified using nonwaveform controlled welding and heat input determined by QW-409.1(b) continue to be applicable for waveform controlled welding without changes to the heat input determination method.

(a) To determine if the heat input of a waveform controlled production weld meets the heat input range of a welding procedure qualified with nonwaveform controlled welding with heat input determined using QW-409.1(a)

(1) the heat input of the production weld is determined using instantaneous power or energy per the method of QW-409.1(c)

(2) the heat input of the production weld is compared to the heat input range of the welding procedure specification

(b) to determine if the heat input of a nonwaveform controlled production weld meets the heat input range of a welding procedure qualified with waveform controlled welding with heat input determined using QW-409.1(c)

(1) the heat input of the production weld is determined using QW-409.1(a) or QW-409.1(c)

(2) the heat input of the production weld is compared to the heat input range of the welding procedure specification

H-500 PERFORMANCE QUALIFICATIONS

Separate performance qualifications are not required for waveform controlled welding. However, it is recognized that a welder or welding operator may require instruction on proper use of the equipment. The extent of such instruction is best determined by the manufacturer or fabricator, as needed to understand how to properly set up and adjust the equipment for welding and conformance to the WPS requirements.

Power sources capable of waveform controlled welding often have additional operator settings that are typically not used during nonwaveform controlled welding. It is important for a welder to be familiar with other equipment parameters that can influence the overall welding performance. These can include the mode, arc control, program, cable length, wire feed speed, trim, and other machine and software settings.

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FOREWORD

General Information

This publication includes all written interpretations issued between the indicated dates by the ASME Staff on behalf of the ASME Boiler and Pressure Vessel Committee in response to inquiries concerning interpretations of the ASME Boiler and Pressure Vessel Code. A contents is also included which lists subjects specific to the interpretations covered in the individual volume.

These interpretations are taken verbatim from the original letters, except for a few typographical and editorial corrections made for the purpose of improved clarity. In some instances, a review of the interpretation revealed a need for corrections of a technical nature. In these cases, a revised interpretation is presented bearing the original interpretation number with the suffix R and the original file number with an asterisk. Following these revised interpretations, new interpretations and revisions to them issued during the indicated dates are assigned interpretation numbers in chronological order. Interpretations applying to more than one Code Section appear with the interpretations for each affected Section.

ASME procedures provide for reconsideration of these interpretations when or if additional information is available which the inquirer believes might affect the interpretation. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. As stated in the Statement of Policy in the Code documents, ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

An interpretation applies either to the Edition and Addenda in effect on the date of issuance of the interpretation or the Edition and Addenda stated in the interpretation. Subsequent revisions to the Code may supersede the interpretation.

For detailed instructions on preparation of technical inquiries to the ASME Boiler and Pressure Vessel Committee, refer to Appendix A.

Subject and Numerical Indexes

Subject and numerical indexes have been prepared to assist the user in locating interpretations by subject matter or by location in the Code. They cover interpretations issued from Volume 12 up to and including the present volume, and will be updated with each volume.

SECTION IX

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QW-181.2.1 and QW-452.5	IX-10-05	09-1596
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QW/QB-422	IX-07-14	09-486

Interpretation: IX-07-14

Subject: QW/QB-422

Date Issued: June 4, 2009

File: 09-486

Question: Does the assignment of P-No. 8, Group No. 3 to SA-479, Type XM-19, UNS S20910 include all three of the heat treatment conditions (annealed, hot-rolled, and strain-hardened) specified by SA-479?

Reply: Yes.

Interpretation: IX-10-01

Subject: QW-302.1 and QW-302.2 — Article III

Date Issued: August 18, 2009

File: 09-567

Question (1): If radiographic examination per QW-302.2 is done for qualification of two welders on a single pipe coupon welded in the 6G position, must each welder complete the entire circumference of the pipe coupon?

Reply (1): Yes.

Question (2): If mechanical testing per QW-302.1 is done for qualification of two welders on a single pipe coupon welded in the 6G position, must each welder complete the entire circumference of the pipe coupon in order to remove the required bend specimens in accordance with QW-463.2(d) or QW-463.2(e)?

Reply (2): Yes.

Interpretation: IX-10-02

Subject: QW-300.2(b)

Date Issued: August 18, 2009

File: 09-747

Question: Is the manufacturer or contractor required to provide full supervision during the performance qualification testing, so that issues such as the essential variables and inspections during the test can be verified and satisfied for each welder or welding operator qualified?

Reply: Yes.

Interpretation: IX-10-03

Subject: QW-304 and QW-355 — FCAW

Date Issued: August 18, 2009

File: 09-1012

Question (1): May radiographic examination meeting the requirements of QW-304 be used to qualify a welder using the flux-cored arc welding (FCAW) process, provided the transfer mode is not the short circuiting mode?

Reply (1): Yes.

Question (2): When qualifying a welder in accordance with the essential variables listed in QW-355 for the gas metal-arc welding (GMAW) process and the requirements of QW-304 are met, is the welder also qualified for the flux-cored arc welding (FCAW) process if the essential variables are unchanged?

Reply (2): Yes.

Interpretation: IX-10-04

Subject: QW-100.3 and QW-420.1

Date Issued: November 12, 2009

File: 09-490

Background: A later edition/addenda of Section IX assigns a P-number different from that assigned by the edition/addenda of Section IX that was in effect at the time of qualification.

Question (1): Is it required that the WPS be revised or a new WPS be written to identify the new P-number when the applicable code edition/addenda lists the material under the new P-number?

Reply (1): Yes.

Question (2): Is it required that the WPS be revised or a new WPS be written to identify the new P-number when the applicable code edition/addenda lists the material under the old P-number?

Reply (2): No.

Question (3): Is it required that a supporting PQR be amended to show the new P-number assignment?

Reply (3): No.

Question (4): May a supporting PQR be amended to show the new P-number assignment?

Reply (4): Yes.

Question (5): May a supporting PQR be amended to show both the old and the new P-number assignments?

Reply (5): Yes.

Background: A later edition/addenda of Section IX assigns an F-number different from that assigned by the edition/addenda of Section IX that was in effect at the time of qualification.

Question (6): Is it required that the WPS or PQR be amended to reflect the new filler metal F-No. assignment?

Reply (6): No.

Question (7): May the WPS or PQR be amended to reflect the new filler metal F-No. assignment?

Reply (7): Yes.

Interpretation: IX-10-05

Subject: QW-181.2.1 and QW-452.5

Date Issued: December 2, 2009

File: 09-1596

Background: A fillet weld performance qualification test is performed using a production assembly mockup.

Question: Must a welder or a welding operator using a production mockup assembly be qualified for a change in fillet size, base material thickness, or configuration of the mockup?

Reply: Yes.

Interpretation: IX-10-06

Subject: QW-452.5

Date Issued: December 11, 2009

File: 08-210

Question: Is it the intent of QW-452.5 to permit welder or welding operator fillet weld performance qualification testing to be conducted using test coupon thicknesses greater than $\frac{3}{8}$ in. thick?

Reply: Yes.

Interpretation: IX-10-07

Subject: QW-250

Date Issued: December 31, 2009

File: 09-588

Question (1): Is it the intent of the Code that Variables QW-403.6, QW-406.3, QW-409.1, QW-410.9, and QW-410.10 apply when specified in QW-250 for P-No. 10H materials?

Reply (1): No.

Question (2): Is it the intent of the Code that Variable QW-407.4 applies when specified in QW-250 for P-No. 10H materials?

Reply (2): Yes.

Interpretation: IX-07-07E

Subject: QW-404.22, Use of Consumable Inserts

Date Issued: February 12, 2008

File: 08-40

Background: QW-356 lists the essential variables for Welder Performance Qualification for manual GTAW. QW-404.22, the use of consumable inserts, is an essential variable for Welder Performance Qualification within QW-356.

An individual performs the following two qualification tests:

(a) groove weld using the GTAW-machine process on a NPS 6 (DN 150) Schedule 40 pipe coupon with a consumable insert

(b) groove weld using the GTAW-manual process on a NPS 6 (DN 150) Schedule 40 pipe coupon with an open root

Each qualification test is performed independently and welded full thickness by the process used to make the root weld.

Question (1): Is this individual qualified to weld a NPS 6 (DN 150) Schedule 40 pipe groove weld by making the root weld with the GTAW-machine process with a consumable insert and then completing the weld using the GTAW-manual process?

Reply (1): Yes.

Question (2): Is this individual qualified to make non-through-wall weld repairs using the GTAW-manual process to a NPS 6 (DN 150) Schedule 40 pipe groove weld that was originally performed using the GTAW-machine process with a consumable insert?

Reply (2): Yes.

Question (3): Is this individual qualified to make through-wall repairs using the GTAW-manual process to the root of a NPS 6 (DN 150) Schedule 40 pipe groove weld that was originally performed using the GTAW-machine process with a consumable insert if the defect removal results in a repair cavity with an open root?

Reply (3): Yes.

NOTE: This interpretation originally appeared in Volume 59. The word "machine" in paragraph (b) of "Background" has been corrected by errata to read "manual."

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