CASTI Guidebook to
ASME Section IX -
Welding Qualifications
(Covering the 2001 Code Edition)
Third Edition

CASTI Guidebook Series - Vol. 2

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Published By:
CASTI Publishing Inc.
10566 - 114 Street
Edmonton, Alberta, T5H 3J7, Canada
Tel: (780) 424-2552 Fax: (780) 421-1308
E-mail: casti@casti.ca
Web Site: www.casti.ca

ISBN 1-894038-64-9
Printed in Canada
FROM THE PUBLISHER

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The ASME Boiler & Pressure Vessel Code, Section IX is not an easy document to use. I have worked with Section IX for nearly forty years and have been on the Section IX Subcommittee (SCIX) for nearly thirty years. I have learned a good deal about the difficulties of using Section IX by reviewing the numerous inquiries received by the Subcommittee IX and during many years of providing instruction to Code users. I have also learned by working with many other welding and construction codes throughout the world.

I have always had empathy for the Code users. The Code is not a “how-to” guide but rather is a minimum set of rules for the qualification of welders and procedures. The Code does not address all aspects of construction activities. It allows the Code user flexibility in the control of qualifications, and therefore the rules are presented in a general manner.

I have always wanted to write a book about Section IX. Having been on Subcommittee IX longer than anyone else, I feel compelled to write the book, in part, to preserve the historical perspective Section IX. But I also wanted to write the book for the many Code users who have not had the opportunity to attend and benefit from the Subcommittee IX meetings for the past 30 years. I feel I can give users the basis for a sound understanding of how to use Section IX.

Many Code users are specialists in various crafts and have a sincere desire to do everything correctly. Section IX is just one more set of rules in the paper work trail which must be integrated into their specialty. I have prepared this book for those Code users whose specialty is not welding. I hope the book is presented in a clear and concise manner, so those Code users can walk their way through some of their basic welding qualification requirements more easily. This book also has details and interpretations to provide clarity, even to the experienced Code user. Some Section IX rules, unfortunately, remain hidden in the Interpretations, which may not be readily accessible to the general public. This book looks beyond the specific words of the Code, recalling Interpretations when necessary, to provide guidance where even a close study may not produce a clear conclusion.

Joining pressure retaining metals by welding was first permitted in the ASME Boiler & Pressure Vessel Codes in 1935. Each code section committee formed its own rules for the qualification of welding procedure specifications and welders. In 1941, Subcommittee IX was formed as a joint committee of AWS and ASME personnel. The structure of the 1941 edition of Section IX was similar to the current edition. There were sixteen variables for the qualification of welding procedure specifications (WPS) and four variables for the qualification of the welder’s performance. There was a mandatory narrative WPS form which required the Code user to fill in the blanks. Those WPS form blanks were sequential and required the Code user to fill in the base metal preparation, cleaning, back gouging, peening, etc. One of the original committee members, George Fratcher, once said, “The 1941 Code was perfect. You qualified the variables on the WPS and if you changed anything, you had to requalify for the changed variables. The problem was, controlling minor variable changes was not practical nor enforceable.”
The WPS form was revised to a recommended form in 1952, and were finally put into a nonmandatory appendix. Nonessential variables were introduced in the 1974 rewrite of Section IX. The 1974 edition of Section IX stated that the purpose of the WPS was to provide directions for the welder to make the weld. The purpose of the procedure qualification record (PQR) was to demonstrate the properties of the weld under the conditions proposed in the WPS. The purpose of the welders performance qualification (WPQ) test was to demonstrate the welder's ability to deposit sound welds using a qualified WPS. Subcommittee IX clarified that changes in an essential variable on a WPS required a new PQR to support these changes. Subcommittee IX also clarified that a change in a nonessential variables required a revision to the WPS, but did not require a new PQR to support the change. The 1974 edition of the Code also removed those variables which affected the notch-toughness properties of a weldment and placed them in a separate listing as supplemental essential variables, required only for notch-toughness applications. The 1974 changes were practical and a great benefit to the Code user.

The 1998 edition of Section IX has more than 200 variables, many with multiple conditions, for 13 welding processes and special processes. This tremendous addition of processes and variables has been a conscious attempt to further clarify the Code for the user. It may be useful for the Code user to know that the many complicated aspects of the current edition were introduced to make welding qualifications easier. This guide has been prepared to help the Code user understand many of these complex conditions and variables.

Michael J. Houle
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Chapter 1

INTRODUCTION

Scope

Section IX of the ASME Boiler and Pressure Vessel Code is a standard, prepared by the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Committee. ASME standards have been adopted as law by most States, Provinces, some Cities, and by company policy, which makes it mandatory for these standards to be followed in the fabrication and repair of pressure retaining items.

Section IX specifies the requirements for the qualification of welders and the welding procedure specifications employed when welding in accordance with the ASME Boiler and Pressure Code, and the ASME B31 Code for Pressure Piping.

Qualification of welders and the welding procedure specifications they will use in code construction involves a great many factors that are difficult to outline in a code or standard. The CASTI Guidebook to ASME Section IX - Welding Qualifications, is a guide to the requirements of the ASME Boiler and Pressure Vessel Code Section IX - Welding and Brazing Qualifications.

Note: The Preface of Section IX contains an informative historical perspective on the development of the current code rules.

There are three steps involved in qualifying welders and welding procedure specifications for Code construction.

- The first step requires the Code user to prepare welding procedure specifications (WPS). The WPS must contain the minimum requirements that are specified by the reference code. The WPS is intended to provide guidance for welding by specifying ranges for each variable. The WPS must be supported by a procedure qualification record (PQR). See the second step and Chapter 6.

- The second step requires the Code user to qualify the WPS by welding procedure qualification test coupons. The Code user must record the variables and tests used, and must certify the tests and test results on a PQR. See Chapter 7.

- The third step requires the Code user to qualify the performance of the welders by welding performance qualification test coupons. The Code user must record the variables and tests used, specify the variable ranges qualified, and must certify the tests and tests results on a welders performance qualification (WPQ) record. See Chapter 10.

The majority of the rules in Section IX involve one of these three documents, the WPS, PQR or WPQ. The authors have found the biggest source of confusion with Section IX, is the mixing of the rules between these three documents. This guide uses four-column tables to outline how each topic, example, or application applies to the WPS, PQR, or WPQ. See Table 1.1. A given topic, example, or application may
apply to all three documents, while others may only apply to one or two of the documents. The user of
this guide is advised to review and understand each of these documents, and always keep in mind which
document is being addressed. See Table 1.2 for an overview of each of these three documents, and how
they apply to a welding application.

Table 1.1 Basics For Welding - Before You Strike An Arc

<table>
<thead>
<tr>
<th>Welding Application</th>
<th>WPS</th>
<th>PQR</th>
<th>WPQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Specify:</td>
<td>Record:</td>
<td>Record</td>
</tr>
<tr>
<td></td>
<td>Variable ranges</td>
<td>Actual variables</td>
<td>Actual variables</td>
</tr>
<tr>
<td></td>
<td>Essential variables</td>
<td>Essential variables</td>
<td>Specify Ranges</td>
</tr>
<tr>
<td></td>
<td>Nonessential variables</td>
<td>Tests and results</td>
<td>Qualified</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tests and results</td>
</tr>
</tbody>
</table>

**Example 1.1.1**

**Step 1**
The following steps should be followed when the welding application specifies welding per ASME Section IX. The term Code user includes the manufacturer, contractor, assembler, or installer, the owner/user or the repair firm responsible for controlling the welding application.

**Step 2**
QW-250 lists the essential and nonessential variables that must be specified on each Welding Procedure Specification (WPS) for each process. The Code user shall prepare a WPS to cover each application. Welding shall be done following the direction of the WPS. Each WPS shall be supported by one or more PQR’s.

**Step 3**
QW-250 lists the essential variables, by process for qualifying each WPS. The Code user must supervise the welding of the PQR test coupon following the variables of a WPS. The Code user must record each essential variable, tests, and the test results on a PQR form.

**Step 4**
QW-350 lists the variables, by process for qualifying each welder’s performance. The welder is qualified by welding a test coupon following a WPS. The Code user shall supervise this welding, record the variables, the tests, test results, and the ranges qualified on a WPQ form.

**Step 5**
An Authorized Inspector shall verify that each WPS, for each welding application is properly prepared and supported by a valid PQR and that each welder to be used has been properly qualified in accordance with Section IX.

The Authorized Inspector should document this concurrence prior to the start of any new construction or for repairs by welding.

**Step 6**
The Code user must describe on a WPS the details to guide the welder on how each weld is to be made.

The WPS shall specify an allowable range for each variable.

The WPS shall be used to provide direction for the welder and to control each of the variables for each welding process used.

**Step 7**
The Code user may perform the required tests, or testing may be subcontracted to a testing lab. The PQR is intended to prove weldability of the base metal, filler metal, and welding process combinations.

The Code user in each case must certify the PQR thereby accepting responsibility for the results.

**Step 8**
Test coupons shall be mechanically tested or examined by radiography. The tests and examinations may be subcontracted, but the WPQ must be certified by the Code user.

The Code user shall maintain each welder’s qualification using a document that verifies the welder has used the process at least every six months.

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Example 1.1.1. Table 1.1 illustrates a basic path that a Code user may follow to meet the requirements of Section IX. These steps are the basic concept of a video prepared for the State of Wisconsin titled Before You Strike an Arc. The State of Wisconsin required all contractors to review this video before starting construction, which requires Section IX qualifications.

The authors cannot overemphasize the importance of keeping in mind the document that is being addressed. Most mistakes are made when the Code user is working with one of the three documents, while applying a requirement from one of the other documents.

The ASME Code writing committees would do a great service to industry if they would produce three separate Codes:

- The first for the “preparation” of the welding procedure specification (WPS),
- The second for the “qualification” of the WPS and the documentation of that qualification on a Procedure Qualification Record (PQR),
- The third for the “qualification” of the welder’s performance and the documentation of that qualification on a Welder Performance Qualification (WPQ) record.

These three documents, however, are intermixed within Section IX. The Code user must know which of these three documents is being considered at all times. Mixing of the rules for one document with another is the biggest source of confusion when using Section IX.

Another source of confusion is the common use of the word, “procedure.” When someone refers to “the procedure,” or “welding procedure,” it is not certain if they are referring to the welding procedure specification (WPS) or the procedure qualification record (PQR). The Code user may avoid this source of confusion if the proper terms are always used.

Special Note: Standard Welding Procedure Specifications (SWPS) are covered in Article V of Section IX and are described in Chapter 15 of this guide. SWPSs have been recently added to Section IX and are handled by separate rules of Chapter 15 and Section IX.

Forward

The Code user should be aware of the Foreword in each of the ASME Code Sections. The Foreword explains that one of the functions of the Boiler and Pressure Vessel Committee is to interpret the rules of the Code when questions arise regarding their intent. The Foreword further states “only the Boiler and Pressure Vessel Committee has the authority to provide official interpretations of this Code”. This guide is not intended to provide, and does not portray any of the statements herein to be an official interpretation of the Code. CAUTION: The reader is advised that guidance should be obtained from the Jurisdictional Authority where the welding is to be performed or registered.

Anyone may make a formal inquiry to the ASME Code Committees, following the rules in the mandatory appendix for each code. The Code committees review all inquiries and prepare the official replies of the ASME Boiler and Pressure Vessel Committee following formal committee rules. This guide uses frequent references to these official Interpretations of the ASME Boiler and Pressure Vessel Code Committees. When referenced, the ASME Interpretations will be contained in square brackets [].

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Interpretations

The ASME Boiler and Pressure Vessel Committee publish Interpretations twice a year. The first eleven volumes were each issued by ASME with Interpretations for Sections I through XI contained in a single booklet. Volume 1 covered replies dated January 1, 1977 through June 30, 1977. Volumes 1 through 5 were published in white covers, while volumes 6 through 11 were published in green covers.

Beginning with volume 12, the Interpretations were issued separately for each code section, loose leaf printed. ASME numbered these individual code section Interpretations beginning with volume 12 as page number 1. Each issue of interpretations contains a complete numerical index and subject index for all volumes. These indices also reference the page on which the Interpretation may be found, beginning with volume 12. The first eleven volumes are not included in these indices. When this guide refers to an ASME Interpretation from volume 12 or higher, only the interpretation number is given. When this guide refers to an Interpretation prior to volume 12, the volume number is also included for quick reference. Each of the interpretations referred in this guide have been reproduced in Appendix 4. There is an ASME Interpretation Index for those interpretations used in this guide.

Chapter 14 makes reference to [Interpretations IX-80-04, IX-80-10, IX-89-100 and IX-92-87]. This guide has additional information on each of these Interpretations to explain how editorial corrections, revisions, rearrangement of paragraphs, and what ASME does if duplicate interpretations are issued.

The cover sheet which comes with these interpretations states “Interpretations are not part of the Code or the Addenda”. While this is true, this guide has used liberal references to these Interpretations as the best method of helping the Code user to understand the intent of the ASME Boiler and Pressure Vessel Committees.

The following is a brief description of the Interpretation designation system, using IX-83-172 as an example. This Interpretation applies to the documentation of the use of a consumable insert as required by QW-404.22 for the GTAW process, and the weld pass thickness as required by QW-403.9 for the SMAW process, on both the WPS and PQR. The identification is applied as follows:

- IX indicates that the Interpretation relates to ASME Section IX.
- -83 indicates the year of the Code Edition to which the response was made.
- -172 indicates that this Interpretation was the 172nd Interpretation published against the 1983 Edition of ASME Section IX

Revisions

The foreword of Section IX also notes that after ASME approves Code revisions, the revisions may be used beginning with the date of issuance. Revisions become mandatory 6 months after such date of issuance. This guide is based upon the July 1, 2001 Edition of Section IX. The Code user should be aware that ASME publishes annual addenda, which may change the structure and the rules of Section IX, and possibly affect some of the information in this guide.

SI Units

The 2001 Edition of the ASME Boiler & Pressure Vessel Code contains both U. S. Customary and SI Units. When used, the measurements are made first using the US Customary system, followed by the SI Units in parenthesis. In all cases, the U.S. Customary units are the standard and the SI units are provided for the convenience of the Code user.
The U.S. Customary numbers and the SI Unit numbers are presented without dimensions in some of the Section IX tables. For example, in QW-451.1, an entry may be shown in a column as ¾ (19) to less than 1½ (38). However, the notation in the header of the column in QW451.1 indicates; “Thickness of Test Coupon Welded, in. (mm).”

There are some major tables, for example QW/QB-422, which uses only the U.S. Customary system for the Minimum Specified Tensile, ksi, column, but uses the dual unit system under Product Form; Plate > 2 in. (51mm). Note: Section IX generally uses the abbreviation; “in.” rather than “inch.”

There are some cases where the conversion factors differ, when the value is changed from fractions to decimals. For example, the designation for 1½ inch (38 mm) is reported in another location as 1.50 inch (38.1mm).

There are numerous areas in Section IX, which use the dual system, and the U.S. Customary units are the only dimensions used.

There are some examples used in this guide, which will not work precisely with the dual system without compromise. For example, Section IX lists ½ inch (13 mm); and 1 inch (25 mm). These are “very soft” conversions. For example, a production application thickness of 1 inch (25 mm) requires a test coupon of ½ inch (13 mm). Or should it be a test coupon of ⅓ inch (12.5 mm)? Or should it be a test coupon of 12.7 mm? This guide suggests the Code user take the most conservative approach, which, in this example, would be to use a 13 mm test coupon, or the “hard” conversion of 12.7 mm. The adoption of the dual dimension system may well be the cause of a large number of inquiries to the ASME Code Committees.

No one can predict the future direction of Section IX. This Guide, however, has been prepared on the basis that the use of both U.S. Customary and SI Units will continue to be used in Section IX. This Guide will attempt to use both the U.S. Customary and SI Units in this Guide wherever possible. The space in some of the tables is quite restricted, in which case; this Guide will use only the US Standard system. There are some examples wherein this Guide will use the exact dimensions, as published in Section IX, so the Code user can more easily follow Section IX with this Guide.

Note: See the table titled Commonly Used Conversion Factors (from 2001 Edition of ASME Section IX) in Appendix 2 of this Guide. See also the table titled Conversion of U.S. Customary Units to SI Units as Used in the CASTI Guidebook to ASME Section IX - Welding Qualifications in Appendix 2.

Purpose

This guide is intended to be an instructive reference to help Section IX Code users understand how to meet the minimum requirements of the Code and to provide insight on the intent of the Code regarding the qualification of welders and welding procedure specifications. This guide also provides examples of how to meet these Code requirements along with checklists to assist in assessing if Code requirements have been met.

Finally, this guide provides a means to verify that welding documentation is in full accord with the minimum requirements of the Code. As active participants in the development and maintenance of the Code, the authors provide valuable insights into the nuances of the Code and how it has evolved into its current form. However, following this guide or the Code itself cannot ensure that welding procedure specifications or welders are capable of producing welds that will meet the specific requirements of any product for the intended service life of the product.
This guide has been prepared to assist Code users in understanding and interpreting the ASME Section IX. This guide, however, does not replace Section IX. This guide is not intended to assist in the proper selection of processes, welding procedure specifications, joint design, filler metal, preheat, post weld treatment, or other variables. Nor is it intended to assist the Code user in making better welds or in verifying that a welding procedure specification is acceptable for any specific application.

The Foreword states that the Code does not address all activities of Code construction. “The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment” by knowledgeable designers experienced in the application of the Code. This guide may be helpful, but requires sound input from welding, metallurgical, process, and design engineers in concert with welders and inspectors who understand and appreciate the intent of the Boiler and Pressure Vessel Code. The application, service, and life of the item must be carefully engineered. Code users should provide proper techniques, training, and education for all personnel.

This guide contains information about Code paragraphs, variables, figures, tables, and graphics, as well as information from other codes and standards (ASTM, AWS, etc.) for discussion herein. It also contains many examples that integrate pertinent references in one place, in a logical manner, to clarify and provide continuity to a specific topic. This does not imply that the Code follows this same sequence, and neither does it imply that the Code is deficient by not following this format. Code paragraphs referenced in this guide may contain additional comments, clarifications, interpretations, or opinions. Also, some Code paragraphs have been restated in this guide, because they are very important and are difficult to review merely by reference to Section IX. In each case, Section IX and the appropriate construction codes must be available for referral when using this guide so the tables, charts, figures, and comments in the guide can be compared to the current code requirements. The current codes must be used for actual qualifications, testing, documentation, etc. At no time may any portion of this guide be used in place of the Code, this guide is intended to be used in concert with the Code.

This guide normally makes references without notation of the chapter where the reference is located. It is not necessary to note which chapter the reference is from because the first number in the reference is the number of the chapter where the table, figure, or example is located.

Tables and Figures

Tables and figures are sequentially numbered beginning with the number of the chapter. For example, Table 1.1 is the first table in chapter 1. Figure 2.1 is the first figure in chapter 2. Examples are usually associated with a table, and are sequentially numbered beginning with the table number. For instance, Example 4.3.1 is the first example in Table 4.3 found in chapter 4. Other examples may simply be a stated example, contained within the paragraph being covered. Figures may appear within a table, e.g. Example 4.16.1 references Figure 4.10 in Table 4.16.

ASME Numbering System

This guide references the ASME code sections using the ASME identification system. For example, for Section IX, ASME uses “Q” as the leading identifier for all paragraphs, tables, charts, etc. The Q represents the scope of ASME Section IX, which is the “qualification” of welders and the “qualification” of welding procedure specifications for code construction. For Section VIII, ASME uses “U” as the leading identifier for “unfired” pressure vessels. For the purposes of this guide, the word Code with a capital “C” refers to ASME Section IX, while the word code with a lower case “c” refers to a code other than Section IX. ASME Section IX is a service Code, in that it is referenced by ASME construction codes and other international codes and standards.
Chapter 2

WELDING DOCUMENTATION FORMS

This chapter discusses the documentation and application of the welding forms found in Nonmandatory Appendix B of ASME Section IX.

The scope of ASME Section IX is the qualification of welders and the welding procedure specifications they employ in welding according to the ASME Boiler and Pressure Vessel Code and the ASME B31 codes for pressure piping. This guide covers four documents, specifically,

- QW-482, Format for the Welding Procedure Specification (WPS) (Figure 2.1),
- QW-483, Format for the Procedure Qualification Record (PQR) (Figure 2.2),
- QW-484, Format A for the Welder Performance Qualification Record (WPQ) (Figure 2.3),
- QW-485, Format for the Demonstration Test Record (DTR) (Figure 2.5).

The rules that apply to these three documents cover the majority of the requirements of Section IX. This chapter is intended to familiarize the Code user with the Code requirements for recording or specifying details for the WPS, QW-482, the PQR, QW-483 and the WPQ, QW-484.

QW-484, Format B, a Welding Operator Performance Qualifications (WOPQ) form is shown in Figure 2.4. The rules for Welding Operators are discussed in Chapter 13.

QW-485, a Demonstration Test Record of Standard Welding Procedure Specifications (DTR) form is shown in (Figure 2.5). The rules for Standard Welding Procedure Specifications (SWPS) are discussed in Chapter 15.

The following Code paragraphs (paraphrased and edited) define what is required to be included in the WPS, PQR & WPQ.

Welding Procedure Specification (WPS)

QW-200.1 Each manufacturer (Code user) shall prepare written WPSs (Figure 2.1).

QW-200.1(a) A WPS is a written, qualified, document prepared to provide direction for making production welds to code requirements.

QW-200.1(b) The completed WPS shall describe all of the essential, nonessential, and, when required, supplementary essential variables for each process used in the WPS. The WPS shall reference the supporting Procedure Qualification Record(s) PQR.

QW-200.1(c) Changes may be made in the nonessential variables, without requalification, provided the changes are documented by revision or amendment or by use of a new WPS. Changes in essential or supplementary essential (when required) variables require requalification of the WPS.
The information required to be in a WPS may be in any format as long as every essential, nonessential, and, when required, supplementary essential variable outlined in QW-250 through QW-280 (Table 6.1 QW-253 for SMAW) is included or referenced.

**Procedure Qualification Record (PQR)**

**QW-200.2** Each manufacturer shall prepare a PQR (Figure 2.2).

**QW-103.2** Each manufacturer shall maintain a record of the results obtained in welding procedure qualifications. This paragraph is intended to require Code users to record on a PQR, the results of the procedure qualification tests.

**QW-200.2(a)** A PQR is a record of the welding variables and other welding data used to weld a test coupon, the tests used, and the test results.

**QW-200.2(b)** The completed PQR shall document all essential and, when required, supplementary essential variables for each process used. Other variables and information may be recorded at the Code user’s option. [Interpretations IX 89-73 and IX 92-81 explain some of the Code users responsibility for these qualification requirements.]

**QW-200.2(c)** Changes to the PQR are not permitted, except editorial corrections or an addendum to reflect Code changes. If substantiated as having been part of the original qualification by laboratory record or similar data, additional information may be added to the PQR.

**QW-200.2(d)** The information required to be in a PQR may be in any format provided every essential and, when required, supplementary essential variable, specified by QW-250 through QW-280 (Table 3.3, QW-253 for SMAW) is included. The type, number, and results of the tests shall also be recorded in the PQR.

**Welders Performance Qualification (WPQ)**

**QW-103.2** Each Code user shall maintain a record of the results obtained in welder performance qualifications. This paragraph is intended to require Code users to record the results of the performance qualification test on a WPQ (Figure 2.3) or WOPQ (Figure 2.4) record.

**QW-301.2** Each Code user shall qualify each welder for each welding process to be used in production welding. The performance qualification test shall be welded in accordance with a qualified WPS. Changes beyond which requalification is required are given in QW-351 through QW-357 for welders. Visual, mechanical, and radiographic examination are described in QW-304 for welders.

**QW-301.4** The record of WPQ tests shall include the essential variables (Table 10.1, QW-353 for SMAW), the type of tests, the test results and the ranges qualified for each welder.

**Standard Welding Procedure Specifications (SWPS)**

**QW-100.1** A manufacturer may use an AWS Standard Welding Procedure Specification (SWPS) listed in Appendix E, provided the SWPS has been adopted by that manufacturer in accordance with Article V.

**QW-510(d)** The manufacturer shall weld and test one groove weld demonstration test coupon following that SWPS.
# Welding Documentation Forms  Chapter 2

**QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATIONS (WPS)**  
(See QW-200.1, Section IX, ASME Boiler and Pressure Vessel Code)

<table>
<thead>
<tr>
<th>Company Name</th>
<th>By:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding Procedure Specification No.</td>
<td>Date</td>
</tr>
<tr>
<td>Revision No.</td>
<td>Date</td>
</tr>
<tr>
<td>Welding Process(es)</td>
<td>Type(s)</td>
</tr>
</tbody>
</table>

**JOINTS (QW-402)**

- Joint Design ________________________
- Backing (Yes) ____________________ (No) ________
- Backing Material (Type) ____________

*☐ 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 root spacing and the details of weld groove may be specified.

*(At the option of the Mfr., sketches may be attached to illustrate joint design, weld layers and bead sequences, e.g., for notch toughness procedures, for multiple process procedures, etc.)*

**BASE METALS (QW-403)**

<table>
<thead>
<tr>
<th>P-No.</th>
<th>Group No.</th>
<th>to P-No.</th>
<th>Group No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness Range:</td>
<td>Base Metal</td>
<td>Groove</td>
<td>Fillet</td>
</tr>
</tbody>
</table>

**FILLER METALS (QW-404)**

<table>
<thead>
<tr>
<th>Spec. No. (SFA)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AWS No. (Class)</td>
<td>F-No.</td>
<td>A-No.</td>
<td>Size of Filler Metals</td>
</tr>
<tr>
<td>Weld Metal</td>
<td>Thickness Range:</td>
<td>Groove</td>
<td>Fillet</td>
</tr>
<tr>
<td>Electrode-Flux (Class)</td>
<td>Flux Trade Name</td>
<td>Consumable Insert</td>
<td>Other</td>
</tr>
</tbody>
</table>

*Each base metal-filler metal combination should be recorded individually.*

---

*Figure 2.1 QW-482 Form - Nonmandatory Appendix B (Page 1 of 2)*

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**Figure 2.1 QW-482 Form - Nonmandatory Appendix B (Page 2 of 2)**
Chapter 3

REVIEW OF
ARTICLE I – GENERAL,
ARTICLE II – PROCEDURE,
AND ARTICLE III – PERFORMANCE,

This Chapter provides the Code user with an outline of the first three Articles of Section IX.

Section IX is divided into two parts,

- Part QW Welding
- Part QB Brazing.

Part QW Welding, is divided into five articles,

- Article I – General,
- Article II – Procedure,
- Article III – Performance,
- Article IV – Welding Data,

This chapter outlines the material covered in Part QW, Article I, Article II and Article III of Section IX.

Code users seldom refer to these sections as Articles. They are more likely to refer to the “one hundred section” (QW-100) for general items, the “two hundred section” (QW-200) for items relating to WPS and PQR preparation, the “three hundred section” (QW-300) for items relating to welder’s performance qualification, and the “five hundred section” (QW-500) for items relating to Standard Welding Procedure Specifications.

Article I - General

Table 3.1 provides a convenient outline of Article I showing how each paragraph relates to the welding application, the WPS, the PQR and the WPQ. Each article opens with a General section that defines the scope of the article, as in QW-100 General.

QW-100.1 defines: “the purpose of the WPS and PQR is to determine that the weldment proposed for construction is capable of providing the required properties for its intended application.” This terse opening statement puts the responsibility on the Code user to assure that welding qualifications are suitable for the welding application.
Note: Section IX does not cover the application, service, or life of the component.

QW-100.1 and QW-100.2 provide definitions of the three documents: the WPS, the PQR, and the WPQ.

Table 3.1 Summary of Article I - Welding General Requirements

<table>
<thead>
<tr>
<th>Welding Application</th>
<th>WPS</th>
<th>PQR</th>
<th>WPQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specify:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable ranges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Essential variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonessential variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other directions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Figure 3.1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: This table lists the paragraphs that apply, directly below the production application or below the welding document(s), the WPS, PQR or WPQ to which they apply. This system is used throughout the Guide.

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QW-100.3 covers the WPS, PQR, and WPQ, in more detail. QW-100.3 states that these documents, prepared in accordance with Section IX, may be used in any ASME construction. The second paragraph states that other Sections of the code may have additional requirements, and may provide exemptions from the rules of Section IX. An example of an additional requirement would be when ASME Section VIII, Division I requires impact testing. UG-84(h)(2)(b) requires a change in heat treat condition of the base plate to be handled as an additional supplementary essential variable. An example of an exemption to Section IX would be when, subject to the approval of the owner, ASME B31.1 allows procedures and welders to be qualified by a technically qualified group, under specific conditions, as an exemption to the requirements of QW-201 and QW-300.2.

QW-100.3 also allows the continued use of a WPS, PQR or WPQ, qualified at any time in the past, provided all requirements of the 1962 or later Edition are met. [Interpretations IX-79-30, volume 5, IX-81-45, volume 10 and IX-92-71 are excellent references for the liberal application of these rules]. QW-100.3 does not require a WPS, WPQ or a PQR to be amended to include any variables required by later Editions and Addenda. An example would be the variable QW-403.16, a change in the pipe diameter beyond the range qualified in QW-452, which was added in the 1969 addenda. QW-100.3 allows a welder, qualified in 1962, to continue welding, without additional testing, and without an amendment to the welders WPQ, when QW-403.16 was added in the 1969 addenda. However, it is recommended that Code users react to the addition of such a meaningful variable. Code users should requalify the welder using the new variable QW-403.16 in the performance qualification test.

QW-100.3 does, however, require the qualification of a new WPS or WPQ, or, the requalification of an existing WPS or WPQ to be performed in full accordance with the latest Edition and Addenda of Section IX. For example, a welder qualified in 1962, would have no requirement to be requalified as a result of the 1969 addition of QW-403.16, provided the welder continuously welded using the process. However, if in 1995, the welder lost his qualification because there was a specific reason to question his ability, the welder would have to be requalified using the current Edition and Addenda of the Code, including the new variable of QW-403.16. Another example is: [Interpretation IX-92-71 makes it clear that welders qualified prior to the 1992 addenda do not have to requalify to document their visual examination results.]

Caution: It is recommended that the Code user review each Edition and Addenda of the Code as they are issued. Code users should address all technically sound new requirements. Code users should consider requalification of PQRs and WPQs as variables are revised or added, although Section IX does not require this.

QW-103.1 requires the Code user to conduct the tests used to qualify the welding procedures and welders for welding under this Code. [Interpretations IX-92-09 and IX-92-16 make it clear that this requirement may not be subcontracted.]

QW-110 covers the weld orientation. It is important to recognize that there are test positions, as described in QW-120, and there are welding application positions. See Chapter 4 for a detailed explanation. The test positions in QW-120 and QW-461.3 through 461.8 define a narrow range of positions that are allowed as one of the test positions. The test positions are labeled, for example, as 1G, 2G, 3G, etc. and 1F, 2F, 3F, etc. (see Figures 4.14 and 4.15)

The welding application positions are determined in accordance with QW-461.1 (Figure 4.16) for groove welds and QW-461.2 for fillet welds within the ranges specified in QW-461.9 (Table 4.23). These application positions have a much wider range of latitude. For example, the vertical limitation of a 3G test plate, according to QW-120, is ±15°, while the vertical limitation of a vertical plate welding application may be as much as 75° from vertical as shown in QW-461.1 (Figure 4.16). Make certain you
The following list briefly describes the performance qualification variables for the SMAW process, in the order shown in Table 3.5 (QW-353).

- **QW-402.4** The deletion of the backing in single welded groove welds. Double welded groove welds are considered welding with backing. **Note:** The addition of backing is not a variable. Therefore a welder that qualifies without backing is also qualified to weld with backing.

- **QW-403.16** A change in the pipe diameter beyond the range qualified in QW-452. Welding small diameter pipe is the main concern here.

- **QW-403.18** A change in P-Numbers, except as permitted in QW-420.2 and QW-423. While P-number is a variable, section IX allows the welder to be qualified on many different P-numbers simply by welding with one P-number.

- **QW-404.15** A change in F-Numbers of QW-432, except as permitted in QW-433. F-numbers are critical and usually the welder receives qualification for the F-number used during the testing.

- **QW-404.30** A change in weld metal thickness beyond the range qualified in QW-452. Weld metal thickness is the only thickness limitation imposed on a welder. Base metal thickness is not a variable.

- **QW-405.1** The addition of positions other than those already qualified. Proving the ability to weld in all necessary positions is critical for a welder.

- **QW-405.3** A change in the progression of a vertical weld (3G, 5G, 6G, 3F test positions). Read this variable carefully so that the welder can be qualified with the least number of restrictions.

Each of these variables are covered in detail in chapter 10.
Chapter 4

REVIEW OF ARTICLE IV – WELDING DATA

This Chapter provides an overview of ASME Section IX Article IV, Welding Data. Article IV, is commonly referred to as the 400 section. The QW-400 paragraphs define variables, P-Numbers, S-Numbers, F-Numbers, A-Numbers, the type and number of tests, the weld metal and base metal thickness ranges, pipe diameter ranges, welding positions, test positions, welding progression, dimensions of test specimens, order of removal of test specimens, dimensions of test jigs, test rules for all materials, etching processes and reagents, and definitions.

This chapter is intended to explain each type of welding data in the order that they are found in Article IV. Tables, figures and charts are used with examples to explain the purpose of each welding variable. Most examples concentrate on one variable at a time. In every case the Code user must remember that all other variables and details must be considered when evaluating a single change. This detailed explanation of each variable is intended to provide the Code user with a base for evaluating the WPS, PQR and WPQ documentation requirements.

Table 4.1 outlines all the items within Article IV. This table shows the pattern of where each of the paragraphs apply with respect to the Welding Application, WPS, PQR or WPQ. This may help the Code user when considering a given variable. The following bulleted illustration and Table 4.1 illustrate how each paragraph applies quite differently as shown:

- QW-401.1 describes the essential variables which apply to both the WPS and the PQR.
- QW-401.2 describes the essential variables which apply only to the WPQ.
- QW-401.4 describes the nonessential variables which apply only to the WPS.
- QW-402 through QW-410 describe the variables which may apply to the WPS, PQR or WPQ, depending on the welding process.
- QW-420 explains base metal groupings and assigns base metals to P-Numbers, Group numbers, and S-Numbers.
- QW-430 defines filler material grouping in F-Numbers.
- QW-440 defines filler metal assignment by type of deposit as A-Numbers.
- QW-450 specifies type and number of tests to be performed for the PQR and WPQ.
- QW-461.1 defines groove welding positions which apply to the Application and the WPS.
- QW-461.4 illustrates groove welded test positions, which apply to the PQR and WPQ.
- QW-461.9 illustrates the position and diameter limitations for WPQ.
- QW-470 defines etching processes and reagents for various materials.
- QW-492 contains definitions, which apply to the Application and the WPS, PQR and WPQ.
Table 4.1 Article IV - Welding Data

<table>
<thead>
<tr>
<th>Welding Application</th>
<th>WPS</th>
<th>PQR</th>
<th>WPQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill process deposited thickness $t_{in}$</td>
<td>Specify:</td>
<td>Record:</td>
<td>Record:</td>
</tr>
<tr>
<td>Root process deposited thickness $t_{o}$</td>
<td>Variable ranges</td>
<td>Actual values</td>
<td>value range</td>
</tr>
<tr>
<td></td>
<td>Essential variables</td>
<td>Essential variables</td>
<td>tested</td>
</tr>
<tr>
<td></td>
<td>Nonessential variables</td>
<td>Tests and results</td>
<td>qualified</td>
</tr>
<tr>
<td></td>
<td>Other directions</td>
<td>Other data</td>
<td>Record tests and results</td>
</tr>
</tbody>
</table>

- **QW-401.1** Defines essential variables for WPS & PQR.
- **QW-401.2** Defines essential variables for WPQ.
- **QW-401.3** Defines supplementary essential variables for WPS & PQR.
- **QW-401.4** Defines nonessential variables for WPS.
- **QW-402** through **QW-410** Variables, when referenced, may be Essential, Supplementary-Essential or Nonessential for WPS, PQR or WPQ.
- **QW-420.1** Defines P-Nos. & **QW-420.2** defines S-Nos. This section also defines Group Nos. for notch-toughness.
- **QW/QB-422** Lists P-Nos., Group Nos., and S-Nos. by specification, type, grade, UNS No. min. tensile strength, composition & product form.
- **QW-431** Defines F-Numbers and rules for grouping filler metals.
- **QW-432** Lists F-Numbers by types of steels, copper, nickel, etc., with ASME Specification & AWS Classification.
- **QW-441** Identification of ferrous weld metal A-Number analysis as given in **QW-404.5**.
- **QW-442** Lists A-Numbers by type of deposit.
- **QW-451** Lists type & number of tests & ranges of base and weld metal thickness.
- **QW-452** type & number of tests, & range of weld metal thickness.
- **QW-461.1** Defines welding positions as described on the WPS and for production applications as flat (F), horizontal (H), vertical (V), overhead (OH).
- **QW-461.3** through **QW-461.8** shows Test positions as 2G, 3F, and etc.
- **QW-461.9** Lists the type of weld, the test position used and the position and diameter limits.
- **QW-462** Illustrates dimensions and limitations of test specimens.
- **QW-463** Illustrates order of removal of test specimens taken from test coupons.
- **QW-466** Illustrates dimensions of test jigs and rules for each type of material.
- **QW-470** Defines etching processes and reagents for various materials.

**QW-492** Covers definitions which apply to welding applications. They are a very useful reference for Section IX. These definitions may vary slightly from AWS definitions.
Variables

The first item in Article IV is the welding variables. Welding variables may apply to one, two or all three documents (WPS, PQR and WPQ). Welding variables are required only when referenced, by process, in QW-250 for the WPS, in QW-250 for the PQR or in QW-350 for the WPQ. Welding variables may be essential, nonessential and supplementary essential variables. Figure 4.2 (Table 4.2) illustrates a sample application listing typical entries for each group of variables. Table 4.2 outlines how each of the three types of variables apply to the WPS, PQR and WPQ.

The following lists four common variables. The Code user must first determine where each of these variables apply. QW-250 lists the variables for the preparation of the WPS, PQR. QW-350 lists the variables for the preparation of the WPQ. The following illustrates how different variables may apply to one or more of the three welding documents, the WPS, PQR and WPQ.

- **Backing (QW-402.4)**
  
  QW-253 references QW-402.4, backing, FOR the WPS but NOT FOR the PQR.  
  QW-353 references QW-402.4, backing, FOR the WPQ.

- **Base Metal Thickness (Tb) (QW-403.8)**
  
  QW-253 (Table 3.3) references QW-403.8, (base metal thickness) (Tb) FOR the WPS and PQR.  
  QW-353 (Table 3.5) DOES NOT reference QW-403.8, (base metal thickness) (Tb) for the WPQ.

- **Pipe Diameter QW-403.16**
  
  QW-253 DOES NOT reference pipe diameter for either the WPS or the PQR.  
  QW-353 references QW-403.16, (pipe diameter) FOR the WPQ.

- **Weld metal Thickness (td)**
  
  QW-253 references QW-404.30, (the weld metal thickness) (td) for both the WPS and the PQR.  
  QW-353 references QW-404.30, (the weld metal thickness) (td) for the WPQ.

Table 4.3, Figure 4.3 illustrates another simple change in four variables, and how the change affects each of the three documents, the WPS, PQR and WPQ.

| Example 4.3.1 | The change in the groove design affects only the WPS. |
| Example 4.3.2 | The change in the F-Number affects the WPS, PQR and the WPQ. |
| Example 4.3.3 | The change in backing affects only the WPS and the WPQ. |
| Example 4.3.4 | The change in product form from plate to pipe affects only the WPQ. |

These are good illustrations of the need to identify the variables required for each document.

- QW-250 lists the essential and nonessential variables, by process, which must be specified on the WPS.
- QW-250 lists the essential variables, by process, which must be recorded on the PQR.
- QW-350 lists the essential variables, by process, which must be recorded on, and the qualified ranges specified on, the WPQ.
Special Note: Variables are seldom written as complete sentences. Subcommittee IX developed the rules for the preparation of a WPS and the qualification test to be recorded on a PQR using committee member company documents as a model. For example, the committee agreed that a change in the “Type of Joint” was a proper variable, based on their typical company WPS. Since the member’s company documents each had a joint type on their WPS, they agreed that the variable should state: QW-402.1 “A change in the type of groove.” This is not a complete sentence, but it reflects the committee thinking at the time. These variables have changed over the years based upon inquiries from Code users. As a result, the committee later added the examples to QW-402.1 as: “(Vee-groove, U-groove, single-bevel, double-bevel, etc.). Think of variables as though you have your WPS, PQR or WPQ, and “a change, addition or deletion” will require a revision to the document. If the change is an essential variable, the WPS or WPQ will have to be requalified. If the change is a nonessential variable, the WPS will have to be revised.

P-Numbers, Group Numbers and S-Numbers

P-Numbers

Base metals are grouped into P-Numbers for the purpose of Qualification. The complete listing of P-Numbers is found in QW/QB-422. Note that base metals for welding and brazing are combined in this table. QW/QB-422 lists each of the base metals in a numeric sequence based upon the ASTM material specification number. When the ASME codes adopt an ASTM material specification, an A-XXX, ASME designates this acceptance by adding an S to the ASTM specification. The ASME material specification, Section II, Part A, for example, specifies all ASME adopted metals as SA-XXX. The SA marking indicates that the material has been produced in accordance with the ASME SA-XXX specification, which may be identical to the ASTM A-XXX specification, or there may be some exceptions.

QW/QB-422 is a convenient place to find the P-Number when the Code user knows which base metal is being used. Table 4.4 outlines P-Numbers, with examples of how to find a P-Number. Table 4.5 provides a sampling of QW/QB-422.

Special Note: Appendix D is a nonmandatory listing of P-Numbers, and lists each of the base metals in a numeric sequence based upon the P-Number. Appendix D is a convenient place to find all the base metals of a given P-Number in one table. Appendix D may be very useful when a Code user is looking for other base metals within a given P-Number for the purpose of qualification.

Example 4.4.1 illustrates how to find the P-Number of an ASME SA-53 Type S, Grade B material, as outlined in Table 4.4. (Also see Table 4.5 which is a sampling of QW/QB442, which includes SA-53 Type S, Grade B material.)

a) under Spec. No. read down to find: SA-53,

b) from SA-53, read across under Type & Grade to find: Type S, Grade B,

c) continue across under UNS No. to find: K03005,

d) continue across under Min. Specified Tensile ksi to find: 60,

e) continue across under Welding,

1) under P-No. to find: 1

2) under Group No. to find: 1

3) under S-No. to find: ...

4) under Group No. to find: ...

f) continue across under Brazing,

1) under P-No. to find: 101,

2) under S-No. to find: ...

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g) continue across under Nominal Composition to find: C-Mn,
h) continue across under Product Form to find: Seamless Pipe.

This search reveals that the ASME SA-53, Type S, Grade B is a P-Number 1, Group Number 1, carbon manganese, seamless pipe, with a UNS Number of K03005, with a minimum specified tensile strength of 60 ksi, with a P-Number for brazing of 101, with no S-Number/Group Numbers assigned.

Table 4.4 defines P-Numbers and example 4.4.1 describes how to find a P-Number.

Figure 4.4 (Table 4.4) illustrates a typical vessel, with a group of base metals in Example 4.4.2, and how each of the three documents addresses P-Numbers. Table 4.4 also illustrates how a P-Number is used in each of the three documents.

### Table 4.4 QW-420.1 - P-Numbers

<table>
<thead>
<tr>
<th>Welding Application</th>
<th>WPS</th>
<th>PQR</th>
<th>WPQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Specify:</td>
<td>Record:</td>
<td>Record:</td>
</tr>
<tr>
<td>Shell SA-516 Gr. 70; P-No. 1 Gr. 2</td>
<td>Variable ranges</td>
<td>Actual values</td>
<td>value range tested qualified</td>
</tr>
<tr>
<td>Head SA-234 WPB; P-No. 1 Gr. 1</td>
<td>Essential variables</td>
<td>Essential variables</td>
<td></td>
</tr>
<tr>
<td>Figure 4.4</td>
<td>Nonessential variables</td>
<td>Tests and results</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other directions</td>
<td>Other data</td>
<td></td>
</tr>
</tbody>
</table>

**QW-420** Families of base metals have been assigned a P-No. based on characteristics, composition, weldability, and other properties.

**How do you find a P-No.?**

QW/QB-422 lists all P-No. materials alpha-numerically by specification number.

**Example 4.4.1** Read down QW/QB-422 (Table 4.5 is a sampling of QW/QB-422) until you find your material by specification, type & grade, then read across to determine the P-No.

From QW/QB-422, find: SA-53 Type S, Gr. B and read across to find: UNS No. K03005, 60 ksi, P-No. 1 Gr. 1, (P-No 101 for brazing), C-Mn composition, Seamless Pipe.

**How do you use a P-No.?**

**Example 4.4.2**

**Base Metals:**

- SA-106 Gr. B, P1 Gr. 1
- SA 105, P1 Gr. 2
- SA-516 Gr. 70, P1 Gr. 2
- SA-234 WPB P1 Gr. 1
- A 192, P1 Gr. 1

**QW-403.11** Base metals specified in the WPS shall be qualified by a procedure qualification test (PQR) made per QW-424.

**QW-403.18** A change in a P-No. as permitted in QW-423.

**When the base metal is P-No. 1**

**QW-403.11** The WPS must specify P-No. 1.

**PQR** must weld a P-No. 1 test coupon.

**WPQ** must weld a P-No. 1 through 11 or P-No. 41 through 47.

**Example 4.4.2**

**Base Metals:**

- SA-106 Gr. B, P1 Gr. 1
- SA 105, P1 Gr. 2
- SA-516 Gr. 70, P1 Gr. 2
- SA-234 WPB P1 Gr. 1
- A 192, P1 Gr. 1

Variable QW-403.11 requires a PQR test coupon to be welded using a P-No. 1 base metal per QW-424 and recorded on the PQR. (Group numbers do not apply unless notch-toughness is invoked).

Variable QW-403.11 requires a PQR test coupon to be welded using any P-No. 1 through P-No. 11, P-No. 34, P-No. 41 through P-No. 47 per QW-423 & recorded on the WPQ. (Group numbers are not a variable for the qualification of a welder’s performance).
Table 4.5 is a brief sampling of base metals, typical of QW/QB-422 for Ferrous P-Numbers and S-Numbers. The P-Numbers are listed alpha-numerically.

Table 4.5 Sampling of QW/QB-422 - Ferrous P-Numbers and S-Numbers.
Grouping of Base Metals for Qualification.

<table>
<thead>
<tr>
<th>Spec. No.</th>
<th>Type &amp; Grade</th>
<th>UNS No.</th>
<th>Minimum Specified Tensile ksi</th>
<th>Welding</th>
<th>Braze</th>
<th>Nominal Comp.</th>
<th>Product Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA-36</td>
<td>...</td>
<td>K02600</td>
<td>58</td>
<td>1</td>
<td>1</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>SA-53</td>
<td>Type E Gr. B</td>
<td>K03005</td>
<td>60</td>
<td>1</td>
<td>1</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>SA-53*</td>
<td>Type S Gr. B</td>
<td>K03005</td>
<td>60</td>
<td>1</td>
<td>1</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>SA-105</td>
<td>...</td>
<td>K03504</td>
<td>70</td>
<td>1</td>
<td>2</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>SA-166</td>
<td>B</td>
<td>K03006</td>
<td>60</td>
<td>1</td>
<td>1</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>A 108</td>
<td>1018 CW</td>
<td>G10180</td>
<td>60</td>
<td>...</td>
<td>1</td>
<td>1</td>
<td>...</td>
</tr>
<tr>
<td>A 134</td>
<td>A 285 B</td>
<td>K02200</td>
<td>50</td>
<td>...</td>
<td>1</td>
<td>1</td>
<td>...</td>
</tr>
<tr>
<td>SA-182b</td>
<td>F11, Cl. 2</td>
<td>K11872</td>
<td>70</td>
<td>4</td>
<td>1</td>
<td>...</td>
<td>102</td>
</tr>
<tr>
<td>SA-182b</td>
<td>P22, Cl. 1</td>
<td>K21590</td>
<td>60</td>
<td>5A</td>
<td>1</td>
<td>...</td>
<td>102</td>
</tr>
<tr>
<td>SA-182b</td>
<td>F360L</td>
<td>S30403c</td>
<td>70</td>
<td>8</td>
<td>1</td>
<td>...</td>
<td>102</td>
</tr>
<tr>
<td>A 211</td>
<td>A 570 Gr. 30</td>
<td>K02502</td>
<td>49</td>
<td>...</td>
<td>1</td>
<td>1</td>
<td>...</td>
</tr>
<tr>
<td>SA-234</td>
<td>WPB</td>
<td>K09006</td>
<td>60</td>
<td>1</td>
<td>1</td>
<td>...</td>
<td>101</td>
</tr>
<tr>
<td>SA-234</td>
<td>WP5</td>
<td>K41545</td>
<td>60</td>
<td>5B</td>
<td>1</td>
<td>...</td>
<td>102</td>
</tr>
<tr>
<td>SA-240</td>
<td>Type 304L</td>
<td>S30403c</td>
<td>70</td>
<td>8</td>
<td>1</td>
<td>...</td>
<td>102</td>
</tr>
<tr>
<td>SA-335</td>
<td>P22</td>
<td>K21590</td>
<td>60</td>
<td>5A</td>
<td>1</td>
<td>...</td>
<td>102</td>
</tr>
<tr>
<td>SA-387</td>
<td>11, Cl. 1</td>
<td>K11789</td>
<td>60</td>
<td>4</td>
<td>1</td>
<td>...</td>
<td>102</td>
</tr>
<tr>
<td>SA-516</td>
<td>Grade 60</td>
<td>K02100</td>
<td>60</td>
<td>1</td>
<td>1</td>
<td>...</td>
<td>101</td>
</tr>
<tr>
<td>API5L</td>
<td>Grade B</td>
<td>...</td>
<td>60</td>
<td>...</td>
<td>1</td>
<td>1</td>
<td>...</td>
</tr>
</tbody>
</table>

a. Both SA-53 specifications have the same UNS Number, but they are different product forms.
b. These SA-182 materials have the same specification number, but have different nominal compositions of material.
c. Both UNS Numbers are the same, but they are from different specifications and product forms.

P-Numbers, S-Numbers and UNS Numbers, may be used in the qualification of the welding procedure specification (Reference QW-424) and the qualification of the welders performance (Reference QW-423). The minimum specified tensile strength is to be used as one of the acceptance standards for the procedure qualification record tension tests (Reference QW-153). The nominal composition and product form are listed in Section IX only as a convenience for the Code user.

QW-253 references QW-403.11 which defines the P-Number limits of the base metals to be used for the qualification of the welding procedure specification (WPS). QW-403.11 refers the Code user to QW-424 to determine the extent of base metals which may be specified on a WPS, based upon the base metal used for the PQR test coupon. QW-424 applies only to the WPS and the PQR.

There are additional rules in QW-403.13 for base metals of P-Number 5, P-Number 9, and P-Number 10. Basically, QW-403.13 reminds the Code user to be aware that each of these P-Numbers have been further divided. For example, P-Number 5 has been divided into P-Number 5A, P-Number 5B, and P-Number 5C, and each must be treated as separate P-Numbers.
For the qualification of welders, QW-353 references QW-403.18 to cover the P-Numbers of the base metals to be used. QW-403.18 refers the Code user to QW-423 to determine the extent of the base metals for which the welder is qualified. QW-423 applies only to the WPQ.

The examples in Table 4.6, illustrate how QW-424.1 may be used for the qualification of the WPS by the PQR tests and, for the same applications, how QW-423.1 may be used for the qualification of the welder and preparation of the WPQ. [Interpretations IX-83-106 and IX-89-05 cover some unique applications of these rules.]

Example 4.6.1 The application is an ASTM A 105 flange to an ASME SA-516 base metal. These are both P-Number 1 base metals (reference Table 4.5; QW/QB-422). Example 4.6.1 illustrates that the WPS may specify base metals of P-Number 1 to P-Number 1. To support this WPS, QW-424 states that the PQR test coupon must be welded using a P-Number 1 base metal to any other P-Number 1 base metal. In Example 4.6.1, two ASME SA-36 plates were chosen as the PQR test coupon. In this case, QW-424 states that this PQR may support any metal assigned to P-Number 1, welded to itself or any other P-Number 1 material.

According to QW-423.1, the welder may use any P-Number 1 through P-Number 11, P-Number 34, P-Number 4X and unassigned metals of similar chemical composition to these metals for the WPQ test coupon. The use of any of these base metals for the WPQ test coupons will qualify the welder for welding all base metals of P-Number 1 through P-Number 11, P-Number 34, P-Number 4X, and unassigned metals of similar chemical composition to these metals. Keep in mind, however, the welder will be able to weld each of these base metals, but only with the filler metal(s) used during qualification. The Code user must also have properly qualified WPSs if welding is to be done on Code items.

Note: P-Number 4X refers to the nickel base alloys of P-Number 41 through P-Number 47.

Example 4.6.2 The application is an ASTM A 105 forging welded to an ASME SA-240 type 304 shell which is a P-Number 1 to a P-Number 8 (reference Table 4.5; QW/QB-422) application as shown in Figure 4.5. The WPS could specify P-Number 1 to P-Number 8 base metals, which would require a PQR test coupon of P-Number 1 to P-Number 8 base metals. Example 4.6.2 illustrates that the PQR was an ASME SA-36 plate to an ASME SA-240 type 304 plate test coupon. According to QW-424.1, this PQR test coupon qualifies the WPS for all P-Number 1 to P-Number 8 applications, but does not qualify for either P-Number 1 to P-Number 1 nor P-Number 8 to P-Number 8 base metals. The welder would not have to be requalified for QW-403.18, the welders variable for P-Numbers. QW-403.18 references QW-423.1 which allows the WPQ test coupon of Example 4.6.1 to also qualify the welder for the Example 4.6.2 application.

Example 4.6.3 The application is an ASME SA-106 pipe welded to an ASME SA-335 P11 pipe which is a P-Number 1 to a P-Number 4 (reference Table 4.5; QW/QB-422). According to QW-424.1, a P-Number 4 PQR test coupon (ASME SA-387 Grade 11, Class 1 plate) will qualify the WPS for P-Number 4 to P-Number 4, and P-Number 4 to P-Number 3, and P-Number 4 to P-Number 1 applications. The P-Number 4 test coupon will not, however, qualify the WPS for P-Number 3 to P-Number 3, nor P-Number 1 to P-Number 1, nor P-Number 3 to P-Number 1 applications.

According to QW-423.1, the WPQ test coupon of Example 4.6.1 also qualifies the welder for the Example 4.6.3 as also described in Example 4.6.2.

Example 4.6.4 The application is an AISI 1018 plate material, an unassigned metal, is welded to an ASME SA-106 pipe, which is a P-Number 1 base metal (reference Table 4.5; QW/QB-422). According to QW-424.1, a P-Number 1 to an AISI 1018 PQR test coupon will qualify the WPS for AISI 1018 metals welded to any base metals listed as a P-Number 1 base metal.
Chapter 5

SAMPLE WPS, PQR AND WPQ DOCUMENTATION

This chapter provides sample WPS, PQR, and WPQ, prepared and qualified for a specific application. These documents will be referenced as each rule and variable is described in the chapters which follow. These sample documents provide a reference point as this guide weaves itself through the many complex rules and variables.

The samples are:

- Table 5.1 (WPS # 134), prepared for welding carbon steels with the SMAW process with an E6010 root and an E7018 fill and cover, without PWHT or notch toughness requirements.

- Table 5.2 (PQR # Q134), prepared to qualify the variable ranges of WPS # 134 (Table 5.1).

- Table 5.3 (WPQ # 342), WPQ record prepared for a welder that must use WPS # 134.

The samples list the Code paragraph number of each variable on these documents, providing a ready reference for the Code user. Some companies use this technique for their own reference, since it is difficult to keep track of each of these variables and rules. Others plug in the data without Code paragraph references, making it difficult to find relevant information, and to verify if the documents have been properly prepared. This guide also provides a checklist in Chapter 9 to assist the Code user in verifying existing documentation.

WPS # 134 (Table 5.1) was prepared with the welder in mind. The variables, which are of primary interest to the welder were put on the first page of the WPS. The variables which are not of much interest to the welder were put on the second page. The details specified or recorded in each of these samples is generally the minimum required to address the variable.

Caution: Much more detailed information may be required for each variable for an actual application.

Page 3 of 3 was added at the end of the WPS. The attachment sheet is a convenient manner to specify a family of groove designs, which may frequently be changed.

Figure 5.1, illustrating starting and stopping techniques, was placed on page 1 of WPS # 134 to show how special information, specific to the current job, could be shown on page 1 for the welder.

The WPS, PQR and WPQ may be prepared in any format to fit the needs of each Code user, as long as every essential, nonessential (outlined in QW-250 or QW-350), and when required, supplementary essential variable (outlined in QW-250) for each process is described, addressed or referenced in some manner.
### Table 5.1 WPS # 134, page 1 of 3

**Company Inc.**

**Welding Procedure Specification # 134**

<table>
<thead>
<tr>
<th>Revision</th>
<th>Description</th>
<th>Date: 06Oct98</th>
<th>Supporting PQRs: # Q134</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0-</td>
<td>For welding carbon steels with E6010 &amp; E7018 fillers, without PWHT. (not qualified for notch toughness or impact tested applications)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-1- Authorized for use by: Peat McQuinty</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**QW-401 Welding Processes**

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shielded Metal Arc Welding (SMAW), manual,</td>
<td></td>
</tr>
<tr>
<td>SFA-5.1</td>
<td></td>
</tr>
</tbody>
</table>

**QW-403.11 P-Number**

<table>
<thead>
<tr>
<th>P-Number 1</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain Carbon, Low Carbon or Mild Steels</td>
<td></td>
</tr>
</tbody>
</table>

**QW-403.7 & 403.8 Base metal thickness “T”**

<table>
<thead>
<tr>
<th>Minimum thickness</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/16 in. minimum through 1/8 in. maximum</td>
<td></td>
</tr>
</tbody>
</table>

**QW-402.1 Groove Design**

<table>
<thead>
<tr>
<th>Design</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>As shown on this WPS -or- on the repair plan, or inspection check-off plan.</td>
<td></td>
</tr>
</tbody>
</table>

**QW-402.4 Backing**

<table>
<thead>
<tr>
<th>Backing</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>See page 2 and the repair or check-off plan.</td>
<td></td>
</tr>
</tbody>
</table>

**QW-402.10 Root spacing**

<table>
<thead>
<tr>
<th>Spacing</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>As shown on this WPS -or- on the repair plan, or inspection check-off plan.</td>
<td></td>
</tr>
</tbody>
</table>

**QW-402.11 Retainers**

<table>
<thead>
<tr>
<th>Retainers</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>No ceramic or non-fusing metal retainers</td>
<td></td>
</tr>
</tbody>
</table>

**QW-410.5 Type of cleaning**

<table>
<thead>
<tr>
<th>Cleaning</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brush or grind free of rust, dirt and scale 4 in. from the edge of the weld preparation.</td>
<td></td>
</tr>
</tbody>
</table>

**QW-405.1 Position/ QW-405.3 progression**

<table>
<thead>
<tr>
<th>Position</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>All positions, upward progression.</td>
<td></td>
</tr>
</tbody>
</table>

**QW-406.1 Preheat**

<table>
<thead>
<tr>
<th>Preheat</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>200°F minimum preheat for the E6010</td>
<td></td>
</tr>
<tr>
<td>50°F minimum preheat for the E7018.</td>
<td></td>
</tr>
</tbody>
</table>

**QW-406.2 Preheat maintenance**

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>No preheat maintenance required.</td>
<td></td>
</tr>
</tbody>
</table>

**QW-410.1 Type of weld bead**

<table>
<thead>
<tr>
<th>Bead</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Optional” May use string and/or weave beads</td>
<td></td>
</tr>
</tbody>
</table>

**QW-410.5 Type of back gouging**

<table>
<thead>
<tr>
<th>Gouging</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any mechanical or thermal method</td>
<td></td>
</tr>
</tbody>
</table>

**QW-410.26 Peening**

<table>
<thead>
<tr>
<th>Peening</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not peen the first nor the last pass</td>
<td></td>
</tr>
</tbody>
</table>

**QW-409.4 / QW-409.8 Electrical values**

<table>
<thead>
<tr>
<th>Current</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Current, reverse polarity.</td>
<td></td>
</tr>
</tbody>
</table>

**Filler**

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Amperage</th>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>E6010</td>
<td>1/16 in.</td>
<td>40-80 1. Start travel opposite direction of weld.</td>
</tr>
<tr>
<td>E6010</td>
<td>1/8 in.</td>
<td>75-125 2. Reverse direction when arc initiates.</td>
</tr>
<tr>
<td>E6010</td>
<td>5/32 in.</td>
<td>110-170 3. Weld over start to reduce porosity.</td>
</tr>
<tr>
<td>E7018</td>
<td>1/4 in.</td>
<td>105-165 5. Reverse direction of travel.</td>
</tr>
<tr>
<td>E7018</td>
<td>3/16 in.</td>
<td>150-220 6. To fill crater when breaking arc.</td>
</tr>
</tbody>
</table>

**Figure 5.1**

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Figure 5.2 through 5.5 were included at the end of WPS # 134 to illustrate some methods of bringing specific welding details to the attention of the welder, the supervisor, and the inspector.

Table 5.1  WPS # 134  page 2 of 3

<table>
<thead>
<tr>
<th>Revision -0-</th>
<th>Supporting PQRs: # Q134</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date: 01 Aug 1987</td>
<td>Page 2 of 3</td>
</tr>
<tr>
<td><strong>Company Inc.</strong></td>
<td><strong>Welding Procedure Specification # 134</strong></td>
</tr>
<tr>
<td><strong>Revision -1- Authorized for use by: Peat McSquinty</strong></td>
<td><strong>Date: 06Oct98</strong></td>
</tr>
<tr>
<td><strong>QW-402.4 Backing</strong></td>
<td>Qualified for welding with or without backing. The backing shall be a P-Number 1 base metal, or weld metal of one of the filler metals on this WPS. Also qualified for fillet welds, partial penetration groove welds and weld metal buildup of base metals.</td>
</tr>
<tr>
<td><strong>QW-403.13 P-Numbers (5 / 9 /10)</strong></td>
<td>This WPS is applicable only for P-Number 1 base metals. QW-403.13 is not applicable</td>
</tr>
<tr>
<td><strong>QW-403 Pipe diameter</strong></td>
<td>1 inch minimum outside diameter for butt welds. There is no minimum diameter for fillet welds.</td>
</tr>
<tr>
<td>This is not a variable required by Section IX, but is a limitation of Co. Inc.</td>
<td></td>
</tr>
<tr>
<td><strong>QW-403.9 Single pass weld metal thickness &quot;t_d&quot;</strong></td>
<td>Not qualified to deposit more than $\frac{1}{2}$ inch thick weld metal in a single weld pass.</td>
</tr>
<tr>
<td><strong>QW-407.1 Post Weld Heat Treatment</strong></td>
<td>PWHT shall not be applied.</td>
</tr>
<tr>
<td><strong>QW-407.4 PWHT above the Upper TT</strong></td>
<td>Not applicable (No PWHT applied).</td>
</tr>
</tbody>
</table>

![Figure 5.2](image-url)
Chapter 6

HOW TO PREPARE AND REVIEW A WPS

This Chapter provides the Code user with detailed instructions for preparing a Welding Procedure Specification (WPS). This will also assist the Code user that must review WPSs to assure that they are properly prepared, appropriate for the application, and properly supported by a Procedure Qualification Record (PQR) (Chapter 7).

The following list provides basic information for preparing and reviewing a WPS.

The Code User shall:

- be responsible for having a WPS prepared.
- be responsible for all of the contents of the WPS, but may have the preparation of a WPS subcontracted,
- follow all the rules of the ASME Code Section IX.
- prepare each WPS to provide direction for “what the Code User intends to weld”.
- prepare each WPS to provide direction for the welder, inspector, and supervisor.
- specify ranges for each welding variable as required by QW-250 and other details as required by Section IX. Section IX lists the welding variables for each process in QW-250. [See Interpretation IX-89-03, question #1 for more details.]
- qualify each WPS by welding of test coupons under the supervision of the Code user. These tests and the test results shall be recorded on one or more PQRs.
- list the supporting PQR(s) on the WPS.

A reviewer of a WPS should verify that:

- each WPS has an entry for every essential, (supplementary essential variable when required) and nonessential variable, as listed for the process in QW-250.
- the WPS covers the ranges for the welding application for each variable listed for each process, as specified in QW-250.
- the WPS meets all other requirements of Section IX.
- the WPS meets all requirements of the construction code or contract of record.
- every variable range on the WPS is being followed during fabrication or repairs.

Figure 6.1 covers some of the basic requirements for the Code user identification block of an ASME Section IX WPS form using circled numbers on the form with the corresponding requirements described below. There are no rules for any entry in the Code user identification block, nor for any arrangement of the information (QW-200.1(d)). Figure 6.1 is patterned after QW-482 (Figure 2.1) since most WPS forms use a similar identification block.

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Figure 6.1 Code user identification block.

1. The Code user should use the same name that the Code user has in the quality control manual. This would normally be the name used when obtaining the certificate of authorization from ASME or the National Board. This Code user name may be used on numerous documents and items, so it is prudent to use the shortest possible version of the Code user name. (Table 5.1, WPS # 134, Company Inc.)

2. QW-482 (Figure 2.1) has always had a space on the form after the company name entitled “By:”. This was intended to be for the Code user’s authorization or certification to use the WPS. The quality program for most organizations requires one or more signatures authorizing a WPS for use in its intended application. Section IX, however, has no rules that the WPS be certified. A WPS is a vital document, which provides direction for making Code welds, and it is strongly recommended that Code users establish a protocol for the review, certification, and authorization of the WPS. (In Table 5.1, WPS # 134, the certification block is near the top of page 1 of 3 and was signed by Peat McSquinty.)

3. There are no rules in Section IX for a WPS numbering system. A good quality program, however, should require a unique identification be assigned for each WPS. Keeping computers in mind, the numbering system may be sequential, such as 1, 2, 3, or may be related to the contents as used in Table 5.1 (WPS # 134) as shown below:

   WPS # 134:  
   1 = ASME P-No. 1 (Carbon Steel Base Metals)  
   3 = F-No. 3  
   4 = F-No. 4  
   (E6010) SMAW  
   (E7018) SMAW

4. The date that the WPS was certified or authorized in 2 is normally used in this space.

5. QW-200.1(c) allows changes to be made to a WPS provided such changes are documented by revision or amendment. When a WPS is amended it should be documented including a revision level.

6. The revision or amendment should be dated on the WPS per QW-200.1.(c).

7. The revision or amendment should be certified or authorized as detailed in 2. (Table 5.1, WPS # 134, listed the revision level at the top in the company identification block).

8. QW-200.1(b) requires the WPS to reference its supporting PQRs. The supporting PQRs are normally noted in this identification block. (Table 5.1, WPS # 134, listed the supporting PQR # Q134, at the bottom of page 1 of 3 on the certification line.) Note: It may take more than one PQR to support all the essential variable ranges specified in a WPS.
The welding process is not listed as an essential variable in QW-253 (Table 6.1), but is noted as an essential variable in QW-401. The welding process is shown on QW-482 (Figure 2.1) in the identification block, and in Table 5.1, WPS # 134, as the first variable listed.

QW-410.25 is a nonessential variable “type of process”, that must be described on the WPS. The type of welding is normally noted with the welding process, in the identification block. (Table 5.1, WPS # 134, listed “manual” as the process type on page 2, on the line, QW-410.25).

Each welding process may be one or more of the following: manual, semi-automatic, machine, or automatic. The following illustrates some of the common welding processes and the types of processes that are normally associated with welders and welding operators. A part all of the Section IX definition is stated first, with additional comments in parenthesis.

Welder: One who performs a manual or semiautomatic welding operation. (A welder holds and has manipulative control of the welding torch or the electrode holder).

Welding operator: One who operates machine or automatic welding equipment. (A welder becomes a welding operator when the welding equipment holds the welding torch).

Machine Welding: Welding with equipment, which performs the welding operation under the constant observation and control of a welding operator. (The welding operator controls machine welding, where adjustments may be made while welding).

Automatic Welding: Welding with equipment, which performs the welding operation without adjustment of the controls by a welding operator. (The welding is considered automatic when the welding operator cannot make adjustments while welding).

<table>
<thead>
<tr>
<th>Welder or Operator</th>
<th>Process</th>
<th>Process Type</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welder</td>
<td>SMAW, GTAW</td>
<td>manual</td>
<td>hand held torches or electrode holders</td>
</tr>
<tr>
<td>Welder</td>
<td>GMAW, FCAW, SAW</td>
<td>semi-automatic</td>
<td>wire fed hand held torches</td>
</tr>
<tr>
<td>Welding Operator</td>
<td>GMAW, FCAW, GTAW, SAW</td>
<td>machine</td>
<td>adjustments can be made by welding operator</td>
</tr>
<tr>
<td>Welding Operator</td>
<td>GMAW, FCAW, GTAW, SAW</td>
<td>automatic</td>
<td>adjustments can not be made by welding operator</td>
</tr>
</tbody>
</table>

There is no specified requirement for a description of what the WPS covers, but these descriptions are very helpful after the Code user has established a procedure qualification program with multiple WPSs. When a Code user has prepared dozens of WPSs, they all begin to look alike. A brief description may prove to be very beneficial when retrieving or assigning WPSs. (Table 5.1, WPS # 134 noted “For welding carbon steels with E6010 & E7018 without PWHT, (not qualified for notch-toughness or impact tested applications.”) This block may be used for any description needed by the Code user for a convenient, quick reference.

The balance of this chapter is a review of the requirements of a WPS, using the SMAW process for applications where notch-toughness is not a requirement. This chapter therefore, will not cover the supplementary essential variables. See Chapter 14 for supplementary essential variable conditions.

This chapter uses the variables as required by QW-253 (Table 3.3) for the SMAW process. To simplify this basic review of a WPS, Table 6.1 was prepared using the same information as Table 3.3 (QW-253). The supplementary essential variables have been removed. QW-200.1(b) requires that each essential and nonessential variable listed for the process be addressed on a completed WPS. Hence, for the SMAW process (when supplementary essential variables are not required), each variable as shown in Table 6.1 must be addressed on the WPS.
WPS # 134 (Table 5.1) is used as the model for each example throughout this chapter, with the exception of the identification block, Figure 6.1, which used the QW-482 sample format.

This chapter shows various methods of addressing the variables in a WPS. There is no consideration given to the qualification of these variables, simply how to address the variable on the WPS. A Code user simply specifies in a WPS the application ranges needed for each variable. A Code user must then evaluate the essential variables required to qualify the application ranges specified in the WPS. Chapter 7, How to Prepare or Review a PQR, shows how to record each essential variable on a PQR, and gives various methods of addressing the qualification rules for each of the variables.

Table 6.1 lists all the variables for the SMAW process by groups of variables. Table 6.2 lists the first group of variables, QW-402, Joints. In Table 6.2 the first variable, QW-402.1 has been shaded. Shadings high light that QW-402.1 will be discussed following Table 6.2. The basics of QW-402.1 are stated, followed by examples of how to apply the variable. Each new variable, or group of variables, begins with a bolded title, such as: QW-402-Joints, Groove Design, for Table 6.2. Table 6.3 specifically describes QW-402.4 Backing, QW-402.10 Root Spacing and QW-402.11 Retainers.

### Table 6.1 QW-253, Essential and Nonessential Variables for SMAW

<table>
<thead>
<tr>
<th>Paragraph</th>
<th>Brief of Variables</th>
<th>Essential</th>
<th>Nonessential</th>
</tr>
</thead>
<tbody>
<tr>
<td>QW-402 Joints</td>
<td>.1 Groove design</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.4 Backing</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.10 Root spacing</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.11 Retainers</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td>QW-403 Base Metals</td>
<td>.7 T/t limits &gt; 8 inch (203 mm)</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>.8 T qualified</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>.9 t pass &gt; ½ in.</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>.11 P-No. qualified</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>.13 P-No. 5/9/10</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td>QW-404 Filler Metals</td>
<td>.4 F-Number</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>.5 A-Number</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>.6 Diameter</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.30 t</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>.33 AWS class</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td>QW-405 Positions</td>
<td>.1 Position</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.3 Vertical welding</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td>QW-406 Preheat</td>
<td>.1 Decrease &gt; 100°F (56°C)</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>.2 Preheat maintenance</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td>QW-407 PWHT</td>
<td>.1 PWHT</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>.4 T limits</td>
<td>E</td>
<td>...</td>
</tr>
<tr>
<td>QW-409 Electrical</td>
<td>.4 Current or polarity</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.8 I &amp; E range</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td>QW-410 Technique</td>
<td>.1 String / weave</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.5 Method cleaning</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.6 Method back gouge</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.9 Multiple to single pass/side</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.25 Manual or automatic</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.26 Peening</td>
<td>...</td>
<td>NE</td>
</tr>
</tbody>
</table>
The first rule for determining how each variable is applied, is to review the specific variable of QW-253 (Tables 3.3 and 6.1), such as QW-402.1, φ Groove Design. Do not attempt to comprehend the details of a variable from the description noted in the “Brief of Variables” column. Read the actual variable, such as QW-402.1, “A change in the type of groove (Vee-groove, U-groove, single-bevel, double-bevel, etc.).” Errors are made when the Code user implements a variable based upon the “Brief of Variables” description.

**QW-402 Joints – Groove Design**

<table>
<thead>
<tr>
<th>Paragraph</th>
<th>Brief of Variables</th>
<th>Essential</th>
<th>Nonessential</th>
</tr>
</thead>
<tbody>
<tr>
<td>QW-402 Joints</td>
<td>.1 φ Groove design</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.4 - Backing</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.10 φ Root spacing</td>
<td>...</td>
<td>NE</td>
</tr>
<tr>
<td></td>
<td>.11 ± Retainers</td>
<td>...</td>
<td>NE</td>
</tr>
</tbody>
</table>

Table 6.2 will be used to demonstrate how variables can be addressed on a WPS. Table 6.2 represents the QW-402 Joints group of variables for the SMAW process. Table 6.2 contains only essential and nonessential variables. The supplementary essential variables column has been removed. Code user finds the first application variable for the process, QW-402.1, φ Groove design. This variable has been shaded in Table 6.2. Variable QW-402.1 states: “A change in the type of groove (Vee-groove, U-groove, single bevel, double bevel, etc.).”

When preparing the WPS, it does not matter if the variable is essential or nonessential. The WPS must address each variable listed for the process. QW-402.1 may be addressed by stating on the WPS which types of grooves may be used with the WPS.

WPS # 134 (Table 5.1) addressed this groove design variable on page 1 of 3 by stating: “QW-402.1 Groove Design - As shown on this WPS (Note: this would permit the application to be welded using any of those groove designs shown on WPS # 134 in Figure 5.2 on page 2 of 3, and Figures 5.3 through 5.5 on page 3 of 3, but could not use any other groove design, unless) -or- on the repair plan, or inspection check off plan. (Note: this note extends the groove design to any specified on the repair plan or inspection check off plan.) The names of the documents, which may be used to specify groove designs, are not important, so long as they are referenced for use by the WPS.

**Example 6.2.1** Groove details may also be specified by reference on the WPS to:

- production drawings
- fabrication plans
- shop sketches

provided the joint design is available for reference by the:

- welder
- inspector (Code user’s)
- supervisor
- Authorized Inspector (AI, NBCI, or API 510 Inspectors)
ASME SFA-5.1 (AWS A5.1)  
Specification For Covered Carbon Steel Arc Welding Electrodes (Excerpt)  

1. Scope—This specification prescribes requirements for the classification of covered carbon steel electrodes for shielded metal-arc welding.  

2. Classification  

2.1 The welding materials covered by this specification are classified according to the following criteria:  

(1) Type of current.  
(2) Type of covering.  
(3) Welding position of the electrode.  
(4) Mechanical properties.  

2.2 Materials classified under one classification shall not be classified under any other classification of this specification.  

3. Acceptance—Acceptance of electrodes shall be in accordance with AWS A5.01.  

4. Certification—The AWS specification and classification on the packaging certifies that the manufacturer has met this specification.  

6. Tests—This specification defines all the tests the manufacturer of the electrode must make when required by the purchaser in accordance with AWS A5.01.  

22. Electrode Identification  
23. Packaging  
24. Marking  

The following is an excerpt from the ASME SFA-5.1 (AWS A5.1) Appendix - Guide to Classification of Carbon Steel Covered Arc Welding Electrodes. Similar guides are found in the other ASME SFA-5.X (AWS A5.X) specifications. These guides will assist in meeting the requirements of QW-404.33.

ASME SFA-5.1 (AWS A5.1)  
Guide to Classification of Carbon Steel Covered Arc Welding Electrodes (Excerpt)  

A1 Introduction  

This guide was intended to correlate electrode classifications with applications as examples rather than a complete listing of the filler metal / base metal combinations.

A2 Classification System  

A2.1 The classification system used in the specification follows the established pattern for AWS filler metal specifications. The letter E designates an electrode. The first two digits, 60, for example, designate tensile strength of at least 60 ksi of the deposited metal, weld metal in the as-welded condition. The third digit indicates the position in which satisfactory welds can be made with the electrode. Thus, “1” (as in E6010) means that the electrode is satisfactory for use in all positions (flat, vertical, overhead, and horizontal). The “2” (as in E6020) indicates that the electrode is suitable for the flat position and also for making fillet welds in the horizontal position. The last two digits taken together indicate the type of current with which the electrode can be used and the type of covering on the electrode, as listed in Table 1.
A2.2  Optional designators are also used in this specification to identify electrodes that have met the mandatory classification requirements and certain supplementary requirements as agreed between the supplier and the purchaser. For example the \( \cdot J \) in an E7018-1 identifies an electrode, which meets optional supplemental impact requirements at a lower temperature than is required for the plain E7018 electrode. Other designators are \( R \) for moisture resistant, \( HZ \) for diffusible hydrogen content, \( M \) for all of the above.

A6  Welding Considerations

A6.3  Hydrogen is another factor involved. Weld metals, other than those from low hydrogen electrodes (E7015, E7016, E7018, E7028, and E7048) contain significant quantities of hydrogen for some period of time after they have been deposited. This hydrogen gradually escapes. After two to four weeks at room temperature or in 24 to 48 hours at 200 to 220 degrees F (95 to 105 degrees C), most of it has escaped. As a result of this change in hydrogen content the yield, tensile, and impact strength remain relatively unchanged, but the ductility of the weld metal increases toward its inherent value.

A6.4  When weld deposits are given a post weld heat treatment, the temperature and time at temperature are very important. The following points from SFA-5.1 Appendix: Guide to...concerning post weld heat treatment (stress relief, in this case) should be kept in mind. The tensile and yield strengths generally are decreased as stress relief temperature and time at temperature are increased.

A6.11.1  Hydrogen can have adverse effects on welds in some steel under certain conditions. One source of this hydrogen is moisture in the electrode coverings. For this reason the proper storage, treatment, and handling of electrodes are necessary.

A6.11.4  Cellulose coverings for E6010 electrodes have moisture levels of 3% to 7%; therefore, storage or conditioning above ambient temperature may dry them too much and may adversely affect their operation.

A7  Description and Intended Use of Electrodes

A7.1.1  E6010 Classification electrodes are characterized by a deeply penetrating, forceful, spray type arc and readily removable, thin friable slag, which may not seem to completely cover the deposit. Fillet welds are usually relatively flat in profile and have a rather coarse, unevenly spaced ripple.

A7.1.2  These electrodes are recommended for all-position work, particularly on multiple pass applications in the vertical and overhead positions and where welds of radiographic soundness are required.

A7.1.3  The majority of applications for these electrodes is in joining carbon steel. However, they have been used to advantage on galvanized plate and on some low alloy steels. Typical applications include shipbuilding, structures such as buildings and bridges, storage tanks, piping, and pressure vessel fittings.

A7.8.1  Electrodes of the low hydrogen classifications are made with inorganic coverings that contain minimal moisture.

A7.8.3  In order to maintain low hydrogen, electrodes should be stored and handled with considerable care. Electrodes exposed to moisture may lose their characteristics. Reconditioning may restore the low hydrogen characteristics.

A7.8.4  Low hydrogen electrodes designed to resist moisture are designated \( \cdot R \).
ASME Section VIII, Division 1, UW-32(a) requires base metals to be cleaned prior to welding. OSHA requires the area be cleaned 4 in. from the edge of the weld joint preparation. Whatever is specified on the WPS must be followed, so make certain everyone understands what is required.

Another example where the construction code specifies requirements in addition to Section IX is ASME Section VIII, Division 1 UW-39 (a) which states that it is not permitted to peen the first or the last pass of a weld unless the weldment is subsequently given a PWHT. Removal of slag is not considered peening [Interpretation VIII-1-83-255]. The work hardening effect of peening may be minimized, however, by the use of flapper wheels, rotary wire wheels, needle scalers or shot blast for removing weld slag. Some of these nonessential variables may require detailed descriptions in order to meet the requirements of the construction code.
Chapter 7

HOW TO PREPARE AND REVIEW A PQR

This chapter provides the Code user with detailed instructions for preparing a procedure qualification record (PQR). This chapter will also assist the Code user who must review PQRs to assure that they are properly prepared, that the tests and tests results are satisfactory, and that the PQR(s) properly supports the welding procedure specification WPS(s).

The Code User wishing to qualify a WPS(s) must:

- prepare a PQR by welding a test coupon and recording the essential variables on the PQR, for each process used. Ensure the test coupon is cut into specimens and be tested. The test results shall be recorded on a PQR to provide a record of “what was welded, tested and the test results.”
- record the actual ranges used for each essential variable as required by QW-250 for each welding process used. Additional nonessential variables or any other reference information may be recorded on a PQR, but a PQR is only governed by the essential variables (QW-200.2(b)).
- be responsible for supervising the welding of all PQR test coupons (QW-201).
- be responsible for the results of the PQR tests (QW-201). The testing of PQR test coupons may be subcontracted.
- prepare each PQR following all the rules of ASME Section IX and the construction code.
- prepare one or more PQRs to support each WPS.

A reviewer of a PQR should verify that:

- each PQR covers the ranges for the intended WPS it is supporting, that the actual range used is recorded for each essential variable for each process, as specified in QW-250, and that the PQR has the proper tests and test results documented, and the PQR has been certified by the Code user.
- the Code user's identification block on the PQR form has the proper Code user name and other details as defined for WPS (See Figure 6.1).
- the PQR is certified by the Code user (QW-201, last paragraph).

Caution: Be aware of additional variables that may be required by Section IX or the construction code.

Variables

This chapter reviews the requirements for a PQR, with most examples related to welding using the SMAW process for applications where notch-toughness is not a requirement. Therefore, the supplementary essential variables are not applicable (see Chapter 14 for supplementary essential variables and notch-toughness requirements). This chapter uses the variables as required by QW-253 (Table 3.3) for the SMAW process. To simplify this basic review of a PQR, Table 7.1 was prepared with the same information contained in Table 3.3 (QW-253), but has had the nonessential and supplementary essential variables removed. (Table 7.1 therefore represents a simplified version of QW-253 (Table 3.3),