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LEARNING

D1.1 Code Clinic

2015 Edition

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International Standard Book Number:

American Welding Society

8669 NW 36 Street, #130, Miami, Florida 33166

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Chapter 1

Introduction

Introduction.....

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INTRODUCTION

The first iteration of the D1.1 code, *The Code for Fusion Welding and Gas Cutting in Building Construction*, was published by the American Welding Society in 1928. Since that time, the D1.1 has undergone numerous revisions, upgrades, and name changes, ultimately culminating in the latest version: AWS D1.1/ D1.1M:2015, *Structural Welding Code – Steel*. Individuals who seek certification as a Certified Welding Inspector (CWI) need to select a code for the Part C: Code Applications Exam. This Code Clinic Reference Manual (CCRM) is designed to guide individuals through the D1.1/D1.1M:2015 code and provide them with the strategies and skills necessary to competently navigate the D1.1 code in an exam or at work. From here forth, the use of D1.1 implies the D1.1/D1.1M:2015 edition. While many of the techniques and advice provided in this reference manual can be applied to virtually any code and specification, the information contained herein is meant to solely reference the AWS D1.1. This edition of the D1.1 Code Clinic Reference Manual supersedes previous editions of the CCRM.

The skill set obtained through this program, as either part of the AWS Certified Welding Inspector Seminar or through individual self-study, will allow individuals to quickly and accurately identify specifications related to their current code work. The purpose of the D1.1 Code Clinic Reference Manual is both to prepare the individual to sit for the “Code Applications Exam” portion of the Certified Welding Inspector examination or the D1.1 endorsement exam. Endorsements are supplemental inspection credentials available to all AWS Certified Welding Inspectors (CWIs) and Senior Certified Welding Inspectors (SCWIs) to enhance an individual’s credentials. For instance, a CWI or SCWI may demonstrate competency in additional AWS, ASME, or API codes and list this endorsement on their wallet card.

OBJECTIVES

The express purpose of the Code Clinic Reference Manual is to instruct the reader on efficiently and effectively navigating the D1.1 code. By the end of the program the reader should be able to:

- 1) Identify the nine (9) clauses of the D1.1 code and describe the content of each clause.
- 2) Effectively implement the system taught in this reference manual for identifying keywords.
- 3) Utilize the index, table of contents, and list of tables and figures to identify specific areas of the code.
- 4) Differentiate information located in the D1.1 text, tables, and figures.
- 5) Prepare the D1.1 code for a given examination by tabbing and highlighting the appropriate sections.
- 6) Confidently, efficiently, and accurately navigate the D1.1 code.

WHAT THIS BOOK IS NOT

While the D1.1 Code Clinic Reference Manual is designed to provide a thorough examination of navigation techniques and methodologies, the CCRM is **not**:

- 1) A short cut. Simply reviewing this reference manual will not substantially help you pass the exam. Individuals should be able to understand and apply criteria from the D1.1 code.

HOW TO PREPARE?

Preparing for the D1.1 Code Applications Exam, much like the layout of this workbook, is divided into five phases:

- 1) **Understanding** the exam and the code
- 2) **Familiarizing** oneself with the individual clauses
- 3) **Strategizing** techniques for answering questions
- 4) **Preparing** oneself and the authentic copy of the D1.1 code
- 5) **Practicing**, practicing, and practicing

UNDERSTANDING

The Code Clinic Reference Manual begins with an analysis of the D1.1 Code Applications Exam and a basic overview of the code structure, which are the foundation of this program. These topics are reviewed in Chapters 2 and 3 respectively.

Chapter 2 *“Putting the Test into Perspective”* provides a detailed description of the D1.1 Code Applications Exam structure, making a direct connection between the exam’s body of knowledge and how to prepare for it. The chapter enables the readers to:

- See the exam from the test maker’s perspective.
- Understand the way AWS has structured the test, including the type of questions, exam length, and time requirements.
- Develop fundamental testing strategies, such as exam pacing and benchmarking.

Chapter 3 *“The Code: An Overview”* facilitates the utilization of the code by breaking down its structure and major components. The chapter includes:

- A basic top-level overview of each of the 9 major clauses, including the major topics and topic areas.
- A description of the code’s clauses, including their interrelationships, allowing the reader to view the code from a practical perspective and thereby locate information more efficiently and accurately.

FAMILIARIZING

The next 9 chapters, 4 through 12, provide an in-depth description of the 9 clauses in the D1.1 code: General Requirements, Design of Welded Connections, Prequalification of WPSs, Qualification, Fabrication, Inspection, Stud Welding, Strengthening and Repair of Existing Structures, and Tubular Structures. It should be noted that Clause 9, *“Tubular Structures,”* is a new clause for the 23rd edition.

The tubular provisions, tables, and figures were removed from the other clauses and condensed into this new clause, and a corresponding new commentary was created in the Commentary to AWS *Structural Welding Code – Steel* section of the code.

Each chapter focuses on a single clause and identifies:

- The purpose of the clause. *Why is this clause necessary? What information can be found in this clause?*
- The structure of the clause. *What are the major topics? What information is found in the text, tables, and figures?*
- The important topics. *What information is especially relevant to a welding inspector and where is that information located?*

STRATEGIZING

Chapters 13, 14, and 15 will equip the reader with test taking strategies geared specifically to the AWS D1.1 Code Applications Exam. These chapters focus on utilizing the code's structure to the reader's advantage in locating the pertinent information in the most efficient manner.

Chapter 13 "*Attacking the Question*" provides:

- Strategies to help the reader understand the question's prompt. *What is the question really asking?*
- Strategies for identifying the keywords in a question. *What words should the reader use to start looking for an answer?*

Chapter 14 "*Using the Index and Table of Contents*" provides:

- Strategies for locating information efficiently in the code. *What are the most efficient ways to refer to the Index and Table of contents? How does the reader determine whether to refer to the Index or Table of Contents first?*

Chapter 15 "*Text, Tables, and Figures*" provides:

- Strategies for predicting where an answer will be found within a clause. *Should the reader expect the answer to be found in a section of text, table, or figure?*

Together these 3 chapters provide an effective system for quickly locating information in the D1.1 code that will transcend the exam itself, and provide a systematic approach that can be efficiently utilized in the field.

PREPARING

The last chapters of the code clinic, Chapters 16 and 17, focus on helping you prepare yourself and the D1.1 code for the certification examination. Chapter 16, "*Tabbing and Highlighting*," covers the do's and

don'ts on tabbing and highlighting the D1.1 code. Chapter 17, *"Test Taking Tips"*, includes general test taking tips that are critical for any multiple choice exam (the D1.1 exam included) as well as strategies that can be used to put oneself in the right mind-frame before and during the exam.

PRACTICING

The single most important aspect of preparing for the D1.1 Code Applications Exam is practice, practice, practice. The last section of the clinic contains 3 sample D1.1 tests of varying length and complexity that can be used to practice for the exam while simulating a test day environment.

Chapter 2

Putting the Exam into Perspective

What is Being Tested?.....

Exam Pacing.....

It's not about Getting an "A".

Breaking Down the D1.1 Code Applications Exam





Welding inspectors have a wide range of duties, and they play an essential role in welding quality before, during, and after welding. A welding inspector needs to be able to interpret and assess the conformance of documents – such as welding procedure specifications, welding procedure and performance qualification records, material/weld mechanical testing reports, and inspection procedures and reports – to

a set of requirements like the D1.1 code. A “code” is a systematic set of specifications, methods, guidelines, and best practices organized into one standard for a defined range of industrial applications, like steel structures, bridges, pressure vessels, or pipelines. The D1.1 Code Applications Exam assesses the individual’s competencies to navigate, identify, understand, and apply the code using “open book” questions. Individuals are expected to bring and use their own authentic copy of the D1.1 code (which is also improperly referred to as a codebook or code book) while taking the exam. AWS allows test takers to prepare their authentic copy of the D1.1 code in any method they choose prior to taking the D1.1 Code Applications Exam. Chapter 16 of this workbook will provide general methods for tabbing, highlighting, and preparing your code.

The first step in preparing for any examination is putting the exam into perspective by identifying the number of questions on the exam, the time allotted for completion, the required passing rate, and the type(s) of questions.

D1.1 Code Exam Facts

Number of Questions	Time Allotted	Passing Score	Type of Questions
46-60	2 hours	72%	Multiple Choice

Image 2.1

Establishing this baseline of information will allow test takers to develop efficiency and time management strategies, as well as allow them to walk into the exam with a positive mind-frame. Chapter 3 examines the D1.1 Code Applications Exam structure and content at length, providing test takers with a positive first step in the development of a preparation plan.

What is Being Tested?

Preparations for an exam should always begin by asking the simple question: “What is being tested?” Oftentimes, test takers focus too much on the exam topics, and not enough on the “desired outcome.” AWS recognizes that in a real world scenario, welding inspectors would never be expected to memorize the D1.1 code. Therefore, measuring a test taker’s ability to memorize the particulars of the code would not be an accurate representation as to how well they would fulfill their job duties. Instead, AWS designed the D1.1 Code Applications Exam to measure how efficiently the test taker can understand the question being asked, locate the appropriate information, and interpret the code criteria. In other words, it measures how well the test taker can navigate and apply the code.

A test taker's time is better spent developing navigational strategies and understanding the code layout, and learning what sections of what clauses apply to inspectors' duties. Test takers need to pay attention to details as many clause requirements have essential criteria listed in tables, figures, footnotes, or via cross-references. Test takers need to learn how to use the index fast to locate the correct criteria based on the question, interpret the relevant requirements (or criteria), and then carefully select the best answer.

Exam Pacing

While AWS does not provide the exact number of questions that will appear on the D1.1 Code Applications Exam, they do provide a range. As of the printing of this book, the D1.1 exam will contain between 46 and 60 multiple choice questions.



AWS certification exams, including the Code Application Exams, are designed by expert volunteers from the welding industry. These volunteers vigilantly monitor exam results and test takers' feedback in order to ensure the most relevant, accurate, and complete tests possible. At times, the volunteer committees may find it necessary to change the parameters of a given exam. Always verify information, such as the question number range, with the certification exam information on AWS's Certification webpage and the information the Certification Department mails to all exam participants.

The D1.1 Code Applications Exam, much like all AWS certification exams, is a timed test. Test takers are provided 2 hours to complete as many questions as possible. Combining the time allotted with the range of possible questions provides test takers with a key piece of information: time allotted per question. Calculating the "time allotted per question" will dictate the testing pace for the exam, ensuring that test takers effectively manage their time.

In order to calculate the "time allotted per question," divide the total time allowed by the number of questions on the test. The answer will be in a decimal format. The whole number equals the number of minutes. Take the remainder and multiply it by 60 to determine the number of seconds. For example, $120 \text{ minutes} \div 46 \text{ questions} = 2.60$. The whole number 2 equals 2 whole minutes. The value of .60 when multiplied by 60 produces the number of seconds. In this case, we have 36 seconds. The total time allotted is 2 minutes and 36 seconds.

Number of Questions	Time Allotted	Minutes per Question
46 Questions	120 min.	2 min 36 seconds
47 Questions	120 min.	2 min 33 seconds
48 Questions	120 min.	2 min 30 seconds
49 Questions	120 min.	2 min 27 seconds
50 Questions	120 min.	2 min 24 seconds
51 Questions	120 min.	2 min 21 seconds
52 Questions	120 min.	2 min 18 seconds

53 Questions	120 min.	2 min 16 seconds
54 Questions	120 min.	2 min 13 seconds
55 Questions	120 min.	2 min 11 seconds
56 Questions	120 min.	2 min 9 seconds
57 Questions	120 min.	2 min 6 seconds
58 Questions	120 min.	2 min 4 seconds
59 Questions	120 min.	2 min 2 seconds
60 Questions	120 min.	2 minutes

Image 2.2

Utilizing the data provided in Image 2.2, a test taker can set testing benchmarks to ensure they keep an appropriate pace. For example, on a 60 question exam, a participant knows that if after 15 minutes he has completed 10 questions, then he is 5 minutes ahead of his ideal pace, allowing him to spend additional time on tougher questions. Conversely, if a participant realizes that after 20 minutes he has only completed 5 questions, then he must adjust his pace or implement a new strategy; otherwise, his chances of obtaining a passing score will decrease substantially.

Does this mean that a test taker cannot allot more time than that on a question?

Test takers can spend as much or as little time as they require answering questions. The D1.1 exam will include questions of varying difficulty. Simple questions may be answered in less time than difficult questions. The time allotted per question data is a simple means of keeping pace during the exam. If a test taker has spent 6 minutes on a question and is not close to locating the answer, it may be beneficial to skip the question. The test taker can return to that question if there is time remaining towards the end of the exam. The central idea behind this information is that of keeping a general pace. However, test takers should not time each individual question. Instead, they should use benchmarks, set at varying intervals, to ensure they have kept pace with the exam.



One of the worst mistakes made by test takers is ignoring the pace, and realizing with minimal time remaining, that they have yet to answer a significant portion for the exam. Test takers must walk a fine line between keeping pace and obsessing over time. Checking their pace after every question will be detrimental to the test taker, as doing so will only use up more of their precious time. Setting a series of benchmarks, like those found in Image 2.3, will allow the test taker to check their pace often enough to ensure they have enough time remaining to answer as many questions as possible, but not too often as to be a detriment.

Time Remaining	Questions Remaining (Ideal Pace)	Questions Remaining (Actual Pace)
120 min.	60	
90 min.	45	
60 min.	30	
30 min.	15	
15 min.	7	

5 min.	2	
--------	---	--

Image 2.3

Additionally, when the time allotted per question data is combined with the information provided in the next section, it becomes clear that a test taker should not spend too much time on any individual question. The ability to keep a pace geared towards passing the exam, as opposed to answering 100% of the questions, will make the D1.1 Code Applications Exam much more manageable.

It's not about getting an "A"



One of the most common mistakes test takers make when sitting for a certification exam is trying to get the "A." While early schooling has taught students to always strive for the "A," this same approach could be detrimental to the test taker trying to pass a certification exam. Consider for a moment that certification exams are graded on a "pass/fail" basis, and that the "pass" or "fail" result is not quantified into categories like "A," "B," "C," "D," or "F." So while at school an "A" is a better grade than a "C," when taking AWS certification exams, a "pass" is a "pass." However, obtaining as high of a score as possible should always be the goal of a test taker.

Calculating the minimum number of correct answers a test taker would need to pass the D1.1 Code Applications Exam does provide tangible and intangible benefits when preparing for the exam. To begin with, test takers can utilize this information to establish general parameters about how they will approach the exam. For example, the longer the exam, the more questions test takers may score incorrectly or skip, and still pass. Shorter exams provide test takers more allotted time per question, but will also provide less leeway with skipped or incorrect answers.

Additionally, understanding that not every question must be answered correctly in order to pass is a great psychological and practical tool for the test taker. Using an example from the previous section, if a test taker has spent 6 minutes trying to answer an individual question, and is not near locating the answer, skipping that question and returning to it if there is time remaining towards the end of the exam would be the correct strategy to implement. Furthermore, if that same test taker was able to recognize after reading the question that he had no real clear means of locating the answer, and decided to move on towards questions he is more comfortable answering, he has saved additional minutes of test time without reducing his chance of passing the exam.

Currently, the minimum passing score for the D1.1 Code Applications Exam is 72%. This percentage translates into a specific number of correct answers needed to pass the exam. The number of correct answers needed to pass is directly proportional to the total number of questions provided, as seen in image 2.4.

In order to calculate the number of correct answers needed to pass, take the total number of questions provided and multiply by .72 (72% converted to a decimal format). For example, an exam with 46 questions would require 33 correct answers to pass. $46 \times .72 = 33.12$ (rounded down to 33).

Number of Questions	Passing Percentage	Operation	Correct Answers Needed to Pass
46	72%	$46 \times .72 \approx$	33 correct
47	72%	$47 \times .72 \approx$	34 correct
48	72%	$48 \times .72 \approx$	35 correct
49	72%	$49 \times .72 \approx$	35 correct
50	72%	$50 \times .72 \approx$	36 correct
51	72%	$51 \times .72 \approx$	37 correct
52	72%	$52 \times .72 \approx$	37 correct
53	72%	$53 \times .72 \approx$	38 correct
54	72%	$54 \times .72 \approx$	39 correct
55	72%	$55 \times .72 \approx$	40 correct
56	72%	$56 \times .72 \approx$	40 correct
57	72%	$57 \times .72 \approx$	41 correct
58	72%	$58 \times .72 \approx$	42 correct
59	72%	$59 \times .72 \approx$	42 correct
60	72%	$60 \times .72 \approx$	43 correct

Image 2.4

Breaking Down the D1.1 Code Applications Exam

The D1.1 code is divided into 9 clauses, each containing the provisions for welding “steel structures that utilize carbon or low alloy steels that are 1/8 inch or thicker with minimum specified yield strength of 100 ksi or less.”¹ Although each of the clauses contain important standards for building steel structures, not all clauses are equally relevant to the welding inspector. As the D1.1 Code Applications Exam is geared towards the welding inspector and not the welding engineer, the number of questions that reference the various clauses are weighed according to their importance to the inspection field.

Simply put, all 9 clauses will not be tested equally. The AWS B5.1, *Specification for the Qualification of Welding Inspectors* breaks down the concentration of questions per topic. These numbers (see Image 2.5) represent the percentage of questions whose answers will be found in a given section.

Code Applications	Percent of Total Questions
Materials and Design	10%
Fabrication	30%
Inspection	25%
Qualification	30%

Image 2.5

¹ AWS D1.1/D1.1 M:2015, 1.2

The Code Applications (Materials and Design, Fabrication, Inspection, and Qualification) match up with the code in such a way that you can expect virtually all of the answers to the exam questions to be located in Clauses 2, 3, 4, 5, 6, or 9. Furthermore, a rudimentary analysis of this information provides some key insights into the design of the exam.

According to the breakdown of questions, test takers can draw some fundamental conclusions that can be utilized to focus their test preparations:

- The industry experts who designed and developed the D1.1 Code Applications Exam placed a great emphasis in areas dealing with welding inspection. Therefore, sections of the listed clauses detailing information critical to the welding inspector should be given emphasis in the code review period of preparation.
- Test takers should familiarize themselves thoroughly with the clauses concerning fabrication, inspection, and qualification, as more than three-fourths of answers to exam questions can be found in these sections.
- When prioritizing time spent reviewing the code, test takers should not focus on the clauses dealing with materials and design to the detriment of fabrication, inspection, and qualification.
- Test takers should still factor in time to review all sections of the code to ensure enough familiarity with each clause, so as not to allow a lack of familiarity to become a hindrance during the exam. The 10% of questions whose answers are found in materials and design could be the difference between passing and failing.
- The total percentage of questions outlined in Image 2.5 is only 95%, indicating that a total of 5% of the questions on the exam will have their answers found either in multiple locations, or outside of the listed areas.

The example found in Image 2.6 illustrates these points even further. If the test taker were taking a D1.1 Code Applications Exam with 50 total questions, then the answer location breakdown would be as follows:

Code Applications	Percentage of Total Questions	Operation	Number of Questions
Materials and Design	10%	$50 \times .10 \approx$	5
Fabrication	30%	$50 \times .30 \approx$	15
Inspection	25%	$50 \times .25 \approx$	12 or 13
Qualification	30%	$50 \times .30 \approx$	15

Image 2.6

In addition to the 9 clauses, the D1.1:2015 code contains Annexes and Commentary that comprise a great bulk of the pages in the code.

The D1.1 code contains 2 types of Annexes, normative and informative. Normative Annexes “contain information that is considered a part of the standard.”² Informative Annexes “are not considered part of the standard and are provided for informational purposes only.”³ The Commentary is prepared “to generate better understanding in the application of the code to welding in steel construction.”⁴

When you combine the concentration of questions on inspection-related code applications and exclude most of the Annexes and Commentary, the relevant D1.1 code criteria shrinks down to a much more manageable size.

² AWS D1.1/D1.1 M:2015, Annexes

³ AWS D1.1/D1.1 M:2015, Annexes

⁴ AWS D1.1/D1.1 M:2015, Foreword to Commentary

Chapter 3

The Code – An Overview

The History

The Sequence

Review



D1.1 code is the American National Standard for welding statically and dynamically loaded steel structures. However, there are some limitations for the range (broad and narrow) of structures to which it applies. The 2 variables that determine application are the types of materials and the amount of pressure. The D1.1 code is limited to welded steel structures that utilize:

1. Carbon or low-alloy steels,
2. Steels that are 1/8 inch or thicker, and
3. Steels with a specific yield strength of 100 ksi (kilopound per square inch) or less.

Outside of the limitation on materials and pressure, the code *may* be used. However, this is a determination that has to be made by the Engineer and must include a written stipulation of any changes made to the requirements of the code *within* the contract. The Engineer is also advised to refer to other codes and standards that have bearing over structures that involve materials and pressures outside of the limitations of D1.1.

THE HISTORY

The foreword in the D1.1 code, shown below, provides a brief history of the evolution of this document.

The first edition of the *Code for Fusion Welding and Gas Cutting in Building Construction* was published by the American Welding Society in 1928 and called Code 1 Part A. It was revised in 1930 and 1937 under the same title. It was revised again in 1941 and given the designation D1.0. D1.0 was revised again in 1946, 1963, 1966, and 1969. The 1963 edition published an amended version in 1965, and the 1966 edition published an amended version in 1967. The code was combined with D2.0, *Specifications for Welding Highway and Railway Bridges*, in 1972, given the designation D1.1, and retitled *AWS Structural Welding Code*. D1.1 was revised again in 1975, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1988, 1990, 1992, 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008 and 2010. A second printing of D1.1:2010 was published in 2011. From 1972 to 1988, the D1.1 code covered the welding of both buildings and bridges. In 1988, AWS published its first edition of AASHTO/AWS D1.5, *Bridge Welding Code*; coincident with this, the D1.1 code changed references of buildings and bridges to statically loaded and dynamically loaded structures, respectively, in order to make the document applicable to a broader range of structural applications. After the publishing of the 2010 edition, it was decided that the *AWS Structural Welding Code—Steel* would be published on a five year revision cycle instead of a two year revision cycle. This was done in order to sync the publication cycle of AWS Structural Welding Code-Steel with the publication cycles of the AISC Steel Building Specification and the International Building Code. This 2015 edition is the 23rd edition of D1.1.

Image 3.1

The D1.1 code is a fluid document that has undergone numerous revisions and updates since it was first published in 1928. As welding technologies continue to evolve, so too will the D1.1 code. This constant revision process necessitates a means of tracking changes from one edition of the code to another. For this reason, the authors of D1.1:2015 underlined the changes that are implemented in the code from the previous edition in 2010. Changes in the code can range from editorial corrections, to several subclauses of new provisions and information that have been added since the last addition. The following (See Images 3.2 and 3.3) are some examples as to how the authors of the D1.1:2015 have indicated changes.

3.1	Approved Base Metals for Prequalified WPSs	49
3.2	Filler Metals for Matching Strength for Table 3.1, Groups I, II, III, and IV Materials	53
3.3	Prequalified Minimum Preheat and Interpass Temperature	57

Image 3.2

5.19 Splices

5.19.1 Subassembly Splices. All welded subassembly splices in each component part of a cover-plated beam or built-up member shall be made before the component part is welded to other component parts of the member.

5.19.1.1 Shop Splice Location. Shop splices of webs and flanges in built-up girders may be located in a single transverse plane or multiple transverse planes.

5.19.1.2 Cyclically Loaded Splices. For cyclically loaded members, the fatigue stress provisions of the general specifications shall apply.

5.19.2 Member Splices. Long girders or girder sections may be made by welding subassemblies. Splices between sections of rolled beams or built-up girders shall be made in a single transverse plane, when practicable.

Image 3.3

THE SEQUENCE

The D1.1 code is laid out in 9 clauses that follow a logical sequence relevant to both the Engineer and the Inspector. When analyzed, the sequence of clauses closely resembles a “construction building sequence,” or the sequence of events that constitute the construction of a fabricated structure. Individuals preparing for the exam are encouraged to use this analogy to familiarize themselves with the general layout of the D1.1 code, as well as to establish a broad understanding of the type of information contained in each clause. The benefit of understanding this information will become obvious while answering practice questions.

Clause 1 – General Requirements

The first clause of the code lays out the foundations for interpreting the code. When considering the “construction building sequence” and the fact that the D1.1 code is written as a legal document, one can logically predict that the first clause would define the responsibilities of the “major players” (i.e., Contractor, Contractor’s Inspector, Verification Inspector, and Original Equipment Manufacturer) in the construction process. Clause 1 also defines the scope of the code as well as:

- 1.2 Limitations
- 1.4 Responsibilities

- 1.7 Safety Precautions

Clause 2 – Design of Welded Connections

Keeping with the construction analogy, after the major players that are in charge of construction are defined, as well as the scope of the project and code, the actual work has to begin. Before welding together the foundation of the building, those welds must undergo the design process.

Clause 2 includes common requirements in designing weld connections for statically and dynamically loaded structures. Expect to find provisions for weld variables that are required of all welds regardless of the particular circumstances. Important sections of Clause 2 include:

- Part A – Common Requirements for Design of Welded Connections (Nontubular and Tubular Members)
 - Subclauses 2.2–2.4
- Part B – Specific Requirements for Design of Nontubular Connections (Statically or Cyclically Loaded)
 - Subclauses 2.5–2.12
- Part C – Specific Requirements for Design of Nontubular Connections (Cyclically Loaded)
 - Subclauses 2.13–2.19

Clause 3 – Prequalification of WPSs

The process of designing and testing welds is both costly and time consuming. The D1.1 code offers specific weld combinations that are prequalified and do not require destructive or nondestructive testing to be approved. These combinations include the welding process, base metal, weld filler metal, gases, etc. Thus, Clause 3 offers the construction team a way of economizing the qualification process by having numerous prequalified welds to choose from. Important sections of Clause 3 include:

- 3.2 Welding Processes
- 3.3 Base Metal/Filler Metal Combinations
- 3.5 Minimum Preheat and Interpass Temperature Requirements
- 3.6 Limitation of WPS Variables
- 3.9 Fillet Weld Requirements
- 3.11 Common Requirements of PJP and CJP Groove Welds
- 3.12 PJP Requirements
- 3.13 CJP Groove Weld Requirements

Clause 4 – Qualification

Even though many of the prequalified welds can be utilized in the design of the new building, some specific weld designs may need to be created and tested by the Engineer. Clause 4 specifies the process for the qualification of welds and welding personnel (an exception is made for those welds that are already prequalified). Clause 4 contains instructions for testing of WPSs as well as performance qualification tests for the welders. Major sections of Clause 4 include:

- Part A – General Requirements
 - Subclauses 4.2–4.3
- Part B – Welding Procedure Specification (WPS) Qualification
 - Subclauses 4.4–4.14
- Part C – Performance Qualification
 - Subclauses 4.15–4.24
- Part D – Requirements for CVN Testing
 - Subclauses 4.25–4.30

Clause 5 – Fabrication

After the design process is completed with the development/qualification (as required) of WPSs and the qualification of the welding personnel, the actual construction may begin. Clause 5 contains provisions that cover the entire fabrication process, including: preheating, welding passes, repairs, and weld cleaning. Major sections of Clause 5 include:

- 5.3 Welding Consumables and Electrode Requirements
- 5.5 WPS Variables
- 5.6 Preheat and Interpass Temperatures
- 5.9 Backing
- 5.11 Welding Environment
- 5.13 Minimum Fillet Weld Sizes
- 5.17 Tack Welds and Construction Aids
- 5.21 Tolerance of Joint Dimensions
- 5.25 Repairs
- 5.26 Peening
- 5.27 Caulking

Clause 6 – Inspection

Once welds begin to be produced, so too must the inspection process begin. Qualified Welding Inspectors must inspect the work of the welding team, examine the workmanship and weld quality, and ultimately approve or reject the welds. Accordingly, “Clause 6 contains all requirements for the

Inspector's qualifications and responsibilities, acceptance criteria for discontinuities, and procedures for NDT [nondestructive testing]."⁵ Major sections of Clause 6 include:

- Part A – General Requirements
 - Subclauses 6.1–6.5
- Part B – Contractor Responsibilities
 - Subclause 6.6
- Part C – Acceptance Criteria
 - Subclauses 6.7–6.13
- Part D – NDT Procedures
 - Subclauses 6.14–6.15
- Part E – Radiographic Testing (RT)
 - Subclauses 6.16–6.18
- Part F – Ultrasonic Testing (UT) of Groove Welds
 - Subclauses 6.19–6.31
- Part G – Other Examination Methods
 - Subclauses 6.32–6.35

Clause 7 – Stud Welding

Clause 7 is a departure somewhat from the construction analogy, as it contains provisions for stud welding and can be viewed as a small parenthetical break from the *sequence* in order to stipulate instructions on welding studs. In some ways, this clause is like a miniature “construction sequence” in that it contains provisions for stud welding for all phases: materials, qualification, testing, fabrication, and inspection. Important sections of Clause 7 include:

- 7.3 Mechanical Requirements
- 7.4 Workmanship/Fabrication
- 7.8 Fabrication and Verification Inspection Requirements
- 7.9 Manufacturer's Stud Base Qualification Requirements

Clause 8 – Strengthening and Repairing Existing Structures

The last step of the construction process is strengthening or repairing all the welds identified by the Inspector as not meeting the standards. All modifications must meet design requirements as specified by the Engineer, as well as the specification contained in this clause. Important sections of Clause 8 include:

- 8.2 Base Metal

⁵ AWS D1.1/D1.1 M:2015, 6.1

- 8.3 Design for Strengthening and Repair
- 8.4 Fatigue Life Enhancement
- 8.5 Workmanship and Technique
- 8.6 Quality

Clause 9 – Tubular Structures

The 2015 edition of the code has been reorganized to make it easier to fabricate plate versus tubular structures. Additionally, the requirements of all other clauses apply to tubulars, unless specifically noted otherwise. The tubular provisions, tables, and figures previously located throughout the code are now mostly contained within Clause 9. The reorganization required numerous reference changes and renumbering of the subclauses, tables, and figures. Many of the tables in Clause 4 contained provisions for plate as well as pipe or tubing. The tables have been divided to only include plate if contained in Clause 4 and pipe or tubing if contained in Clause 9. This separation of the information contained in the tables also resulted in many changes to the footnotes delineated in the tables. Clauses 1, 7, and 8 have only been slightly impacted by the reorganization. However, Clauses 2, 3, 4, 5, and 6 have been greatly impacted by the reorganization. Important sections of Clause 9 include:

- Part A – Design of Tubular Connections
 - Subclauses 9.2–9.8
- Part B – Prequalification of Welding Procedure Specifications
 - 9.9 Fillet Weld Requirements
 - 9.10 PJP Requirements
 - 9.11 CJP Groove Weld Requirements
- Part C – Welding Procedure Specification (WPS) Qualification
 - Subclauses 9.12–9.16
- Part D – Performance Qualification
 - Subclauses 9.17–9.22
- Part E – Fabrication
 - Subclauses 9.23–9.24
- Part F – Inspection
 - Subclauses 9.25–9.30

Review

The construction sequence outlined above is a learning tool meant to facilitate an understanding of the D1.1 structure, but it also reflects the real-world application of the document. The order of the D1.1 code is not accidental; it was designed to be used in the field. Utilizing this sequence to maintain a general understanding of the D1.1 structure and layout will prove invaluable when taking a timed exam.

The valuable seconds saved by knowing the information contained in each clause will add up, and eventually culminate in a less stressful testing experience.

Although a general understanding of the code structure may seem enough to tackle a code application exam, a familiarity with each clause is also paramount to success because, ultimately, test takers will be asked to delve into the code and locate specific pieces of information. Chapters 4 through 12 will provide a thorough breakdown of each clause and identify subclauses that are important to the welding Inspector.

Chapter 4

Clause 1: General Requirements

Introduction.....

Text.....



INTRODUCTION

Clause 1 contains the general requirements for the D1.1 code, such as: the scope and limitations for the code, key definitions, and the major responsibility of the key personnel in the fabrication process.

Clause 1 is all but 3 pages long. However, in this small portion of the code, there are several universally important provisions that lay the groundwork for the rest of the standard. The clause is divided into 9 subclauses, each detailing requirements that apply to the whole of D1.1: Scope, Limitations, Definitions, Responsibilities, Approval, Welding Symbols, Safety Precautions, Standard Units of Measurement, and Reference Documents.

TEXT

Clause 1 has no tables and figures, making it the second smallest clause in the code, second only to Clause 8. This section provides an overview of the general structure of the text in Clause 1. This section also reviews several important subclauses. The following is a list of Clause 1 subclauses from the Table of Contents.

1. General Requirements	1
1.1 Scope	1
1.2 Limitations	1
1.3 Definitions	1
1.4 Responsibilities	2
1.5 Approval	3
1.6 Welding Symbols	3
1.7 Safety Precautions	3
1.8 Standard Units of Measurement	3
1.9 Reference Documents	3

Image 4.1

Clause 1 is not further subdivided into parts like Clauses 2, 4 and 6, nor is it as extensive as Clauses 2, 3, 4, 5, or 6. Therefore, each of the 9 subclauses are concise enough to be treated as their own entity.

The following section highlights important information contained in Clause 1, accompanied by the subclauses they fall under.

1.1 Scope

This subclause stipulates that the D1.1 code contains requirements for fabricating and erecting welded steel structures. When a contract specifies use of the code, all of its provisions are mandatory, unless the contract documents or the authority having jurisdiction modifies or exempts them. The D1.1 code is divided as follows:

-
- Clause 1 – *General Requirements* – Basic information on the scope and limitations of the code, key definitions, and the major responsibilities of the parties involved in steel fabrication.
 - Clause 2 – *Design of Welded Connections* – Requirements for designing welded connections between tubular and/or nontubular product form members.
 - Clause 3 – *Prequalification of WPSs* – Requirements for exempting Welding Procedure Specifications (WPSs) from this code's qualification testing requirements.
 - Clause 4 – *Qualification* – Requirement for the qualification of welding procedures and the welding personnel necessary to perform work to code requirements.
 - Clause 5 – *Fabrication* – Requirements for base metals, welding consumables, welding technique, welded details, material preparation and assembly, workmanship, weld repair, and other requirements for fabrication and erection of welded steel structures.
 - Clause 6 – *Inspection* – Criteria for qualification and responsibilities of welding Inspectors, acceptance of welds, procedures for visual inspection, RT, UT, and other NDT requirements.
 - Clause 7 – *Stud Welding* – Requirements for the welding of studs to structural steel.
 - Clause 8 – *Strengthening and Repairing Existing Structures* – Provisions for design and welding to modify or repair existing structures.
 - Clause 9 – *Tubular Structures* – This new clause is in the 2015 edition and contains exclusive tubular requirements. Additionally, the requirements of all other clauses apply to tubulars, unless specifically noted otherwise.

1.2 Limitations

AWS D1.1 was specifically developed for welded steel structures that utilize carbon or low-alloy steels that are 1/8 inch [3 mm] or thicker with a minimum specified yield strength of 100 ksi [690 MPa] or less. Although the code may be suitable to govern structural fabrications outside of this scope, the Engineer should evaluate such suitability and modify the contract documents accordingly. The Structural Welding Committee encourages the Engineer to consider the applicability of other AWS D1 codes for applications involving aluminum (AWS D1.2), sheet steel equal to or less than 3/16 inch [5 mm] thick (AWS D1.3), reinforcing steel (AWS D1.4), stainless steel (AWS D1.6), strengthening and repair of existing structures (AWS D1.7), seismic supplement (AWS D1.8), and titanium (AWS D1.9). The AASHTO/AWS D1.5, *Bridge Welding Code* was specifically developed for welding highway bridge components and is recommended for those applications.

1.3 Definitions

Defines keywords and the major players of the fabrication process:

- 1.3.1 Engineer: The duly designated individual who acts for, and in behalf of, the Owner on all matters within the scope of the code.
 - 1.3.2 Contractor: Any company, or individual representing a company, responsible for the fabrication, erection, manufacturing, or welding, in conformance with the provisions of this code.
 - 1.3.3 Defines the types of Inspectors.
 - 1.3.3.1 Contractor's Inspector: The person who acts on behalf of the contractor for inspection purposes within the contract limits.
-

-
- 1.3.3.2 Verification Inspector: The person who acts on behalf of the Owner or Engineer for inspection purposes within the contract limits.
 - 1.3.3.3 When the unqualified terms “inspection” or “Inspector” are used, they shall apply equally to fabrication and erection Inspections and to verification inspections, within the limits of responsibility defined in 6.1.2.
 - 1.3.5 Owner: The individual or company that exercises legal ownership of the product or structural assembly produced under the code.

1.4 Responsibilities

- 1.4.1 Engineer’s Responsibilities
- 1.4.2 Contractor’s Responsibilities
- 1.4.3 Inspector’s Responsibilities
 - 1.4.3.1 Contractor Inspection
 - 1.4.3.2 Verification Inspection

1.7 Safety Precaution

Refers the reader to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* and to other pertinent documents. If these documents are mandatory in the context of the project, they are incorporated by reference into AWS D1.1. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing a safety program.

1.8 Standard Units of Measure

Notes that AWS D1.1/D1.1M is 2 codes in 1. AWS D1.1 contains values stated in U.S. Customary (inch-pound) units; AWS D1.1M contains values stated in SI (metric) units. The U.S. Customary values appear first, followed by the SI units in brackets, but the SI units are an approximation of the corresponding U.S. customary units. The reader must use 1 system or the other, and not combine or commingle them in a project.

1.9 References

Refers reader to Annex S for a list of all documents referenced in the code.

Chapter 5

Clause 2: Design of Welded Connections

Introduction.....

Text.....

Tables

Figures



INTRODUCTION

According to the D1.1 code, Clause 2 contains the “requirements for design of welded connections.”⁶ This clause is a compilation of requirements that are necessary for all welded connections regardless of application, materials, or process – except for the specific requirements for the design of tubular connections (statically and cyclically loaded), which have been relocated to Clause 9. Clause 2 includes common requirements for the design of tubular and nontubular connections that are either statically or cyclically loaded, specific requirements for the design of nontubular connections that are either statically or cyclically loaded, and specific requirements for the design of nontubular connections that are cyclically loaded.

Clause 2 is the first step in the construction process. It lays out all the common requirements for erecting welded structures that fall within the scope of the code. Clause 2 is the framework for all welding done according to the D1.1 code regardless of the variety of metals, the architecture of the structure, or even the type of welding process that the construction team will use.

TEXT

The text portion of Clause 2 is distributed amongst 19 subclauses. This section reviews the general structure of the text in Clause 2 as well as some of the important subclauses. The following is a list of all the subclauses in Clause 2, as listed in the Table of Contents.

⁶ AWS D1.1/D1.1 M:2015, 2.1

2. Design of Welded Connections	5
2.1 Scope	5
<i>Part A—Common Requirements for Design of Welded Connections (Nontubular and Tubular Members)</i>	5
2.2 General	5
2.3 Contract Plans and Specifications	5
2.4 Effective Areas	6
<i>Part B—Specific Requirements for Design of Nontubular Connections (Statically or Cyclically Loaded)</i>	8
2.5 General	8
2.6 Stresses	8
2.7 Joint Configuration and Details	10
2.8 Joint Configuration and Details—Groove Welds	10
2.9 Joint Configuration and Details—Fillet Welded Joints	11
2.10 Joint Configuration and Details—Plug and Slot Welds	11
2.11 Filler Plates	12
2.12 Built-Up Members	12
<i>Part C—Specific Requirements for Design of Nontubular Connections (Cyclically Loaded)</i>	12
2.13 General	12
2.14 Limitations	13
2.15 Calculation of Stresses	13
2.16 Allowable Stresses and Stress Ranges	13
2.17 Detailing, Fabrication, and Erection	14
2.18 Prohibited Joints and Welds	15
2.19 Inspection	15

Image 5.1

As indicated above, Clause 2 is divided into 3 main parts, A, B, and C, which contain all common design requirements and specific design requirements for nontubular connections. The scope introduces the general structure of the clause, which is as follows:

Part A – Common Requirements for Design of Welded Connections (Nontubular and Tubular Members)

Part B – Specific Requirements for Design of Nontubular Connections (Statically or Cyclically Loaded)

Part C – Specific Requirements for Design of Nontubular Connections (Cyclically Loaded)

Part A – Common Requirements for Design of Welded Connections (Nontubular and Tubular Members)

Part A specifies the requirements applicable to the design of all welded connections of nontubular and tubular structures, independent of loading. It contains important subclauses for the Inspector. Part A begins on subclause 2.2 and ends on subclause 2.4.

2.3 Contract Plans and Specifications

Requires that contract plans and specifications indicate the base metal designation as well as the location, type, size, and extent of all welds.

- 2.3.1 Defines design drawings as contract documents. The Engineer is required to specify field welds. Additionally, this subclause requires that contract plans and specifications indicate the base metal specification designation as well as the location, type, size, and extent of all welds.
- 2.3.2 Specifies notch toughness requirements. It is the Engineer's responsibility to specify the minimum absorbed energy requirements, the test temperature, and the requirements for weld and heat-affected zone (HAZ) tests.
- 2.3.3 Requires both the Engineer and the Contractor to specify assembly order, welding sequence, welding technique, or other special precautions, if necessary.
- 2.3.5 Covers drawing requirements, PJP groove welds, fillet welds, and welds in skewed T-joints, symbols, and prequalified detail dimensions.

2.4 Effective Areas – Groove and Fillet Welds

- 2.4.1.2 Discusses effective size of CJP groove welds.
 - 2.4.1.3 States the minimum size of PJP groove welds.
 - 2.4.2.6 Covers the calculation for effective throat.
 - 2.4.2.9 Sets the formula for maximum weld size in lap joints. Refers to Figure 2.1, Detail A and B.
 - 2.4.3 Covers skewed T-joints.
 - 2.4.3.1 Defines skewed T-joints as those T-joints in which the angle between the joined parts is greater than 100 degrees or less than 80 degrees.
 - 2.4.3.5 States that the effective length of a skewed T-joint shall be the overall length of the full size weld.
 - 2.4.3.6 States that the minimum weld size for skewed T-joints shall be the same as that of the requirements for all fillet welds in 2.4.2.8.
 - 2.4.3.8 Defines the effective area of skewed T-joints as the effective throat multiplied by the effective length.
-

Part B – Specific Requirements for Design of Nontubular Connections (Statically or Cyclically Loaded)

Part B's requirements for statically loaded nontubular connections apply in conjunction with the requirements of Part A. However, for cyclically loaded nontubular connections, the requirements for Part A and B apply *except* as modified by Part C. Part B starts on subclause 2.5 and ends on 2.12.

2.6 Stresses

- 2.6.1 Calculated Stresses.
 - 2.6.2 Calculated Stresses Due to Eccentricity.
 - 2.6.3 Allowable Base Metal Stresses.
 - 2.6.4 Allowable Weld Metal Stresses.
-

-
- 2.6.4.1 Stress in Fillet Welds.
 - 2.6.4.2 Alternative Allowable Fillet Weld Stresses.

2.7 Joint Configuration and Details

- 2.7.3 Cautions the designer to provide joints that minimize the stress intensity in the through-thickness direction. The designer is also advised that specifying weld sizes larger than necessary to transmit calculated stresses shall be avoided.

2.8 Joint Configuration and Details – Groove Welds

- 2.8.1 Covers transitions in thickness and widths. Refers to Figure 2.3 for transition requirements.

2.9 Joint Configuration and Details – Fillet Welded Joints

- 2.9.1.2 Covers minimum overlap. Refers to Figure 2.4.
- 2.9.3.5 Requires fillet welds on the opposite sides of a common plane to be interrupted at the corner common to both welds. Refers to Figure 2.8.

2.10 Joint Configuration and Details – Plug and Slot Welds

- 2.10.1 Defines the minimum center-to-center spacing of plug welds.
- 2.10.2 Defines the minimum center-to-center spacing of slot welds.
- 2.10.4 Prohibits plug and slot welds in quenched and tempered steels.

2.11 Filler Plates

Covers the use of filler plates used to transfer applied force.

2.12 Built-Up Members

Covers the use of 2 or more plates or rolled shapes to build up a member.

Part C – Specific Requirements for Design of Nontubular Connections (Cyclically Loaded)

Part C applies only to nontubular members and connections subject to cyclical load when the effects of repeated stress cause cracking or fatigue.

2.14 Limitations

Provides that fatigue resistance evaluation is not necessary if the load stress range is less than the threshold stress range.

2.15 Calculation of Stresses

2.16 Allowable Stresses and Stress Ranges

2.19 Inspection

Requires CJP welds that are subject to cyclic transverse applied stress into the tensile range to be inspected using RT or UT.

TABLES

The 5 tables in Clause 2 are arranged in the List of Tables by their respective titles and page numbers. From an Inspector's perspective, the design requirements found in the tables are typically not the responsibility of an Inspector except where dimensional requirements are defined for the welded connections. These dimensional details are often better defined by Clause 2 figures. In this section, a brief review of a few important tables and their respective references within the text in Clause 2 are discussed. Below is the List of Tables for Clause 2.

2.1	Effective Size of Flare-Groove Welds Filled Flush.....	16
2.2	Z Loss Dimension (Nontubular)	16
2.3	Allowable Stresses	17
2.4	Equivalent Strength Coefficients for Obliquely Loaded Fillet Welds.....	18
2.5	Fatigue Stress Design Parameters	19

Image 5.2

Table 2.3 – Allowable Stresses. This table provides the variances for allowable stresses as they differ for CJP and PJP groove, fillet, plug, and slot welds. Below is a preview of Table 2.3.

Table 2.3 Allowable Stresses (see 2.6.4 and 2.16.1)		
Type of Applied Stress	Allowable Stress	Required Filler Metal Strength Level
CJP Groove Welds		
Tension normal to the effective area ^a	Same as base metal	Matching filler metal shall be used ^b
Compression normal to effective area	Same as base metal	Filler metal with a strength level equal to or one classification (10 ksi [70 MPa]) less than matching filler metal may be used.
Tension or compression parallel to axis of the weld ^c	Not a welded joint design consideration	Filler metal with a strength level equal to or less than matching filler metal may be used
Shear on effective area	0.30 × classification tensile strength of filler metal except shear on the base metal shall not exceed 0.40 × yield strength of the base metal	
PJP Groove Welds		
Tension normal to the effective area	0.30 × classification tensile strength of filler metal	Filler metal with a strength level equal to or less than matching filler metal may be used
Compression normal to effective area of weld in joints designed to bear	0.90 × classification tensile strength of filler metal, but not more than 0.90 × yield strength of the connected base metal	
Compression normal to effective area of weld in joints not designed to bear	0.75 × classification tensile strength of filler metal	
Tension or compression parallel to axis of the weld ^c	Not a welded joint design consideration	
Shear parallel to axis of effective area	0.30 × classification tensile strength of filler metal except shear on the base metal shall not exceed 0.40 × yield strength of the base metal	

Image 5.3

Table 2.5 – Fatigue Stress Design Parameters. This table is referenced by subclause 2.14 as the threshold for determining whether or not an evaluation of fatigue resistance is necessary for a cyclically loaded nontubular connection. Table 2.5 spans 17 pages. Below is a preview of the first page.

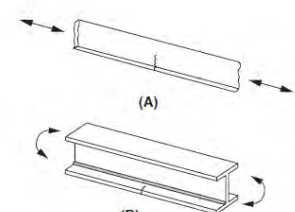
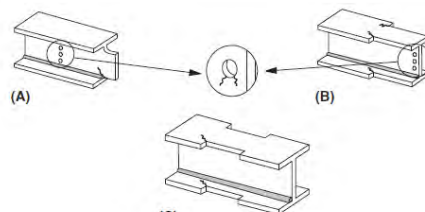
Table 2.5 Fatigue Stress Design Parameters (see 2.14.1)					
Description	Stress Category	Constant C_f	Threshold F_{TH} ksi [MPa]	Potential Crack Initiation Point	Illustrative Examples
Section 1—Plain Material Away from Any Welding					
1.1 Base metal, except non-coated weathering steel, with as-rolled or cleaned surfaces. Thermal cut edges with surface roughness value of 1000 μin [25 μm] or less, but without reentrant corners.	A	250×10^8	24 [165]	Away from all welds or structural connections	1.1/1.2 
1.2 Non-coated weathering steel base metal with as-rolled or cleaned surfaces. Thermal cut edges with surface roughness value of 1000 μin [25 μm] or less, but without reentrant corners.	B	120×10^8	16 [110]	Away from all welds or structural connections	
1.3 Member with reentrant corners at copes, cuts, block-outs or other geometrical discontinuities, except weld access holes. $R \geq 1$ in [25 mm] with radius formed by predrilling, subpunching and reaming or thermally cut and ground to a bright metal surface $R \geq 3/8$ in [10 mm] and the radius need not be ground to a bright metal surface	C E'	44×10^8 3.9×10^8	10 [69] 2.6 [18]	At any external edge or at hole perimeter	1.3 

Image 5.4

FIGURES

The 12 figures in Clause 2 are arranged in the List of Figures by their respective titles and page numbers. In this section a brief review of some important figures and their respective references within the text in Clause 2 are discussed. Below is the List of Figures for Clause 2.

2.1	Maximum Fillet Weld Size Along Edges in Lap Joints.....	36
2.2	Transition of Butt Joints in Parts of Unequal Thickness (Cyclically Loaded Nontubular)	37
2.3	Transition of Thicknesses (Statically Loaded Nontubular).....	38
2.4	Transversely Loaded Fillet Welds.....	38
2.5	Minimum Length of Longitudinal Fillet Welds at End of Plate or Flat Bar Members.....	39
2.6	Termination of Welds Near Edges Subject to Tension.....	39
2.7	End Return at Flexible Connections	40
2.8	Fillet Welds on Opposite Sides of a Common Plane	40
2.9	Thin Filler Plates in Splice Joint	41
2.10	Thick Filler Plates in Splice Joint	41
2.11	Allowable Stress Range for Cyclically Applied Load (Fatigue) in Nontubular Connections (Graphical Plot of Table 2.5).....	42
2.12	Transition of Width (Cyclically Loaded Nontubular)	43

Image 5.5

All these figures have important dimensional requirements that could show up on the D1.1 Code Applications Exam. It is highly recommended that the reader review each figure and be sure they understand the dimensional requirements. Several important figures are discussed below.

Figure 2.1 – Maximum Fillet Weld Size Along Edges in Lap Joints. This figure, shown below, is referred to in subclause 2.4.2.9 to be used in conjunction with the requirements for maximum size of fillet welds in lap joints. The fillet weld size can be equal to or less than the plate thickness for materials less than $\frac{1}{4}$ inch. The weld size is $\frac{1}{16}$ inch [2 mm] less than the thickness of the base metal for metals $\frac{1}{4}$ inch [6 mm] or more in thickness, unless the weld is designated on the shop drawing to be built out to obtain full throat thickness for a leg size equal to the base metal thickness. In the as-welded condition, the distance between the edge of the base metal and the toe of the weld may be less than $\frac{1}{16}$ inch [2 mm] provided the weld size is clearly verifiable.

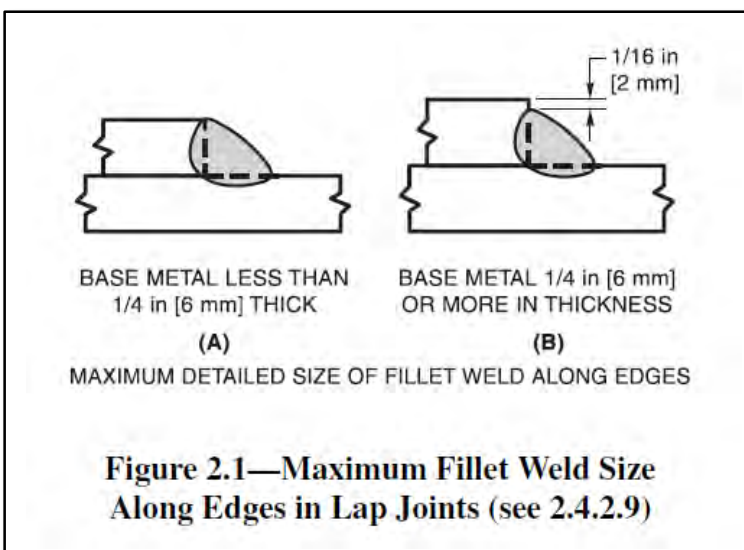


Image 5.6

Figure 2.9 – Thin Filler Plates in Splice Joint and **Figure 2.10 – Thick Filler Plates in Splice Joint.** These are important figures. Filler plates are used to transfer applied force. These 2 figures show the use of thin and thick plates in splice joints. The note in Figure 2.9, shown below, defines the rule for the weld size.

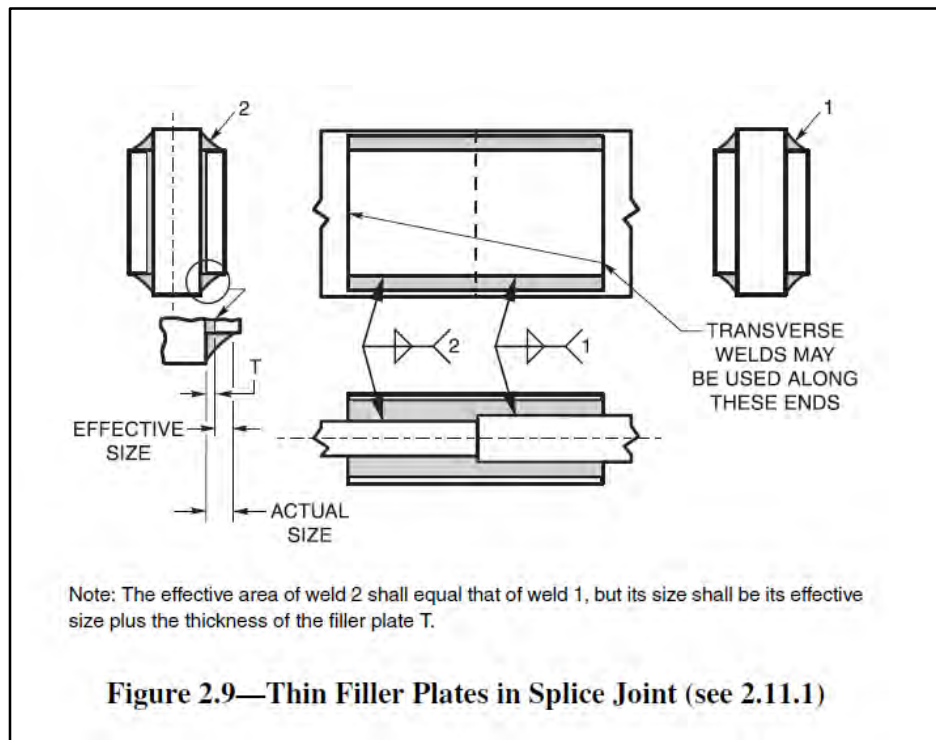


Image 5.7

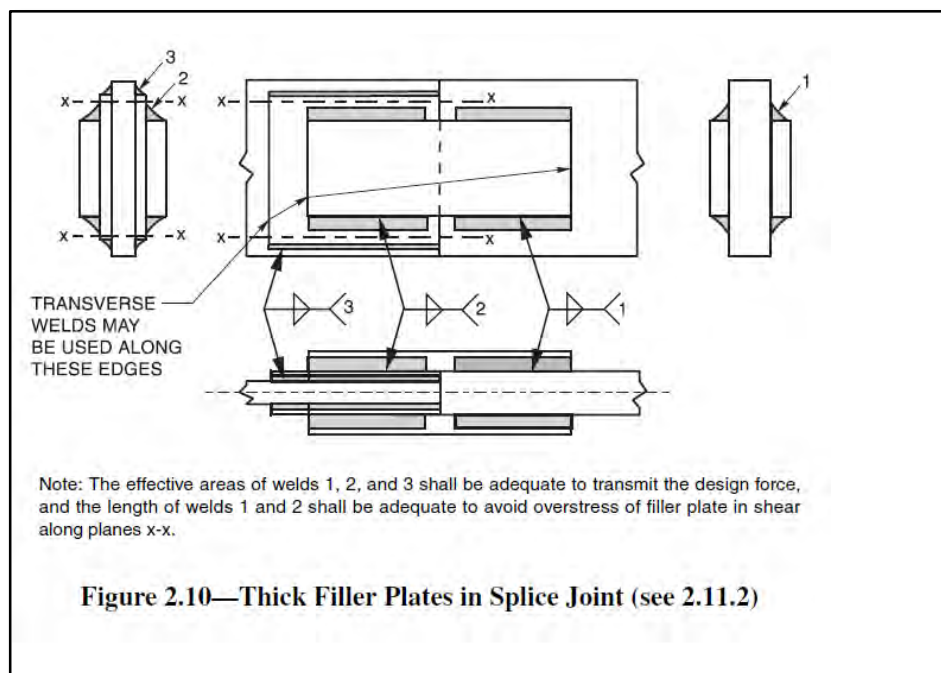


Image 5.8

Chapter 6

Clause 3: Prequalification of WPSs

Introduction.....

Text.....

Tables

Figures



INTRODUCTION

Welding is a special process in that the quality of the weld cannot always be determined by nondestructive inspection alone. Yes, the soundness (detection of discontinuities) of a weld can be determined by visual, surface, and/or volumetric nondestructive inspection, but the metallurgy and the weld's mechanical properties cannot be nondestructively verified by inspection. For this reason, welding processes are controlled by using qualified welders/welding operators and qualified welding procedures. Procedure qualification testing typically requires fabrication of weld test samples that are subjected to a range of nondestructive and destructive (bend, tensile, impact, etc.) tests that determine whether the welding procedure produces acceptable welds.

However, some welding procedure combinations (process, filler, joint design, parameters, etc.) have been tested and used so many times that the D1 code committee has defined conditions that are prequalified. According to the D1.1 code, Clause 3 provides the requirements for prequalified Welding Procedure Specifications (WPSs), which are defined as those WPSs that “are exempt from the WPS qualification testing required in Clause 4.”⁷ All prequalified WPSs shall be written.

In order for a WPS to be prequalified, conformance with all of the applicable requirements of Clause 3 shall be required. WPSs that do not conform to the requirements of Clause 3 may be qualified by tests in conformance with Clause 4. For convenience, Annex P lists provisions to be included in a prequalified WPS, which should be addressed in the Contractor's welding program. Welders, welding operators, and tack welders that use prequalified WPSs shall be qualified in conformance with Clause 4, Part C or Clause 9, Part D for tubulars.

TEXT

The text portion of Clause 3 is the smallest section of the clause. It is distributed amongst 14 subclauses. In this section, we will cover the general structure of the text in Clause 3 and review some of the important subclauses. The following is a list of all the subclauses in Clause 3, as listed in the Table of Contents.

⁷ AWS D1.1/D1.1 M:2015, 3.1

3. Prequalification of WPSs	45
3.1 Scope	45
3.2 Welding Processes	45
3.3 Base Metal/Filler Metal Combinations	45
3.4 Engineer's Approval for Auxiliary Attachments	46
3.5 Minimum Preheat and Interpass Temperature Requirements	46
3.6 Limitation of WPS Variables	46
3.7 General WPS Requirements	46
3.8 Common Requirements for Parallel Electrode and Multiple Electrode SAW	47
3.9 Fillet Weld Requirements	47
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Image 6.1

Because it's important for an Inspector to be able to examine a prequalified WPS for conformance to the D1.1 code, an Inspector should be familiar with the 14 subclauses in Clause 3. The following section is a review of the important provisions contained in Clause 3, accompanied by the subclauses they fall under.

3.2 Welding Processes

- 3.2.1 Limits the welding processes for prequalified WPSs to SMAW, SAW, GMAW (except GMAW-S), and FCAW. All provisions in Clause 3 shall be met in order for the WPS to be prequalified.
- 3.2.2 States that ESW, EGW, GMAW-S, and GTAW processes are approved for use if qualified as in Clause 4.
- 3.2.3 Indicates that other welding processes may be used with the Engineer's approval and qualification according to Clause 4 requirements.
- 3.2.4 Cautions that only constant voltage power supplies shall be used for GMAW and FCAW prequalified WPSs. *Note: This requirement has become more important in modern welding because new waveform controlled power supplies can change the heat input of the process and the metallurgy of the weld.*

3.3 Base Metal/Filler Metal Combinations

Cautions that only base metals and filler metals listed in Tables 3.1 and 3.2 may be used in prequalified WPSs. These tables will be reviewed later in this section.

3.5 Minimum Preheat and Interpass Temperature Requirements

Specifies that the preheat and interpass temperature shall be sufficient to prevent cracking. It then specifies that Table 3.3 shall be used to determine the minimum preheat and interpass temperatures for steels listed in the code.

-
- 3.5.1 Provides that the minimum preheat or interpass temperature applied to a joint composed of base metals with different minimum preheats from Table 3.3 (based on category and thickness) shall be the highest of these minimum preheats.
- 3.5.2 States that the method set out in 3.5.2 may be adopted to determine the required preheat and interpass temperature for welds made with the SAW process. The use of this option could also establish that for base metals having a minimum specified tensile strength not exceeding 70 ksi [485 MPa], a lower preheat and interpass temperature may be used. In this case, approval of the Engineer is required, and the Vickers hardness of the heat-affected zone must be kept below specified.

3.6 Limitations of WPS Variables

Requires that all prequalified WPSs are prepared as written documents by the manufacturer, fabricator, or contractor. The suggested form is shown as Form M-1 in Annex M.

3.7 General WPS Requirements

- 3.7.1 Specifies that the progression for all passes in vertical position welding shall be upward, with the following exceptions: (1) Undercut may be repaired vertically downwards when preheat is in conformance with Table 3.3, but not lower than 70°F [20°C]. (2) When tubular products are welded, the progression of vertical welding may be upwards or downwards, but only in the direction(s) for which the welder is qualified.
- 3.7.2 Cautions that neither the depth nor the maximum width of weld metal deposited in each pass shall exceed the width of the surface of the weld pass per Figure 3.1.
- 3.7.4 Requires shielding gases for GMAW and FCAW-G to conform to AWS A5.32/A5.32M, and meet 1 of 4 criteria as defined in this subclause.

3.8 Common Requirements for Parallel Electrode and Multiple Electrode SAW

- 3.8.1 Provides that welds may also be made in the root of groove or fillet welds using GMAW, followed by parallel or multiple electrode submerged arcs, provided that the GMAW conforms to the requirements of this section, and providing the spacing between the GMAW arc and the following SAW arc does not exceed 15 inches.

3.9 Fillet Weld Requirements

Directs personnel to Table 5.7 for minimum fillet weld sizes and Figure 3.5 for prequalified fillet weld joint details.

3.10 Plug and Slot Weld Requirements

Limits welding processes to SMAW, FCAW, and GMAW (except GMAW-S) and defines cross-reference requirements that shall be met.

3.11 Common Requirements of PJP and CJP Groove Welds

- 3.11.1 Allows the use of SMAW groove preparations for prequalified GMAW and FCAW.
- 3.11.2 Allows corner joints to be made by preparing either or both joint members provided adequate edge distance is maintained to support the welding operation without excessive melting.
-

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- 3.11.3 Provides that for automatic or machine welding using SAW, GMAW or FCAW, the maximum root opening variation, as fit-up, shall not exceed 1/8 inch.

3.12 PJP Requirements

Requires PJP groove welds to be made using the joint details described in Figure 3.2. The joint dimensional limitations described in 3.12.3 shall apply. Figure 3.2 spans 16 pages of prequalified joint details; it is discussed later in this section.

- 3.12.1 Provides that a PJP groove is defined as a groove joint welded from one side without steel backing or welded from both sides without backgouging.

3.13 CJP Groove Weld Requirements

States that CJP groove welds that may be used without performing the WPS qualification test described in Clause 4 shall be as detailed in Figure 3.3 and are subject to the limitations described in 3.13.1. Figure 3.3 is discussed later in this section.

- 3.13.3 Allows U-grooves and J-grooves and the other side of partially welded double-V-grooves and double-bevel-grooves to be prepared before or after assembly.

3.14 Postweld Heat treatment

Provides that postweld heat treatment (PWHT) shall be prequalified, provided that it is approved by the Engineer and adheres to the rules specified in 3.14.

TABLES

The 7 tables in Clause 3 are arranged in the List of Tables by their respective titles and page numbers. In this section, a brief review of some important tables and their respective references within the text in Clause 3 are discussed. Below is the List of Tables for Clause 3.

3.1	<u>Approved Base Metals for Prequalified WPSs</u>	49
3.2	<u>Filler Metals for Matching Strength for Table 3.1, Groups I, II, III, and IV Materials</u>	53
3.3	<u>Prequalified Minimum Preheat and Interpass Temperature</u>	57
3.4	<u>Filler Metal Requirements for Exposed Bare Applications of Weathering Steels</u>	60
3.5	<u>Minimum Prequalified PJP Weld Size (E)</u>	60
3.6	<u>Prequalified WPS Requirements</u>	61
3.7	<u>Prequalified WPS Variables</u>	62

Image 6.2

Table 3.1 – Approved Base Metals for Prequalified WPSs. This table, shown below, is 4 pages long. It provides the approved Group I, II, III, and IV base metals that can be used with prequalified WPSs. The base metal/filler metal strength relationships shown in Clause 3.3 shall be used in conjunction with Tables 3.1 and 3.2 to determine whether matching or undermatching filler metals are required.

Table 3.1
Approved Base Metals for Prequalified WPSs (see 3.3)

Group	Steel Specification Requirements					
	Steel Specification	Minimum Yield Point/Strength		Tensile Range		
		ksi	MPa	ksi	MPa	
I	ASTM A36	(≤3/4 in [20 mm])	36	250	58–80	400–550
	ASTM A53	Grade B	35	240	60 min.	415 min.
	ASTM A106	Grade B	35	240	60 min.	415 min.
	ASTM A131	Grades A, B, CS, D, DS, E	34	235	58–75	400–520
	ASTM A139	Grade B	35	240	60 min.	415 min.
	ASTM A381	Grade Y35	35	240	60 min.	415 min.
	ASTM A500	Grade A	33	230	45 min.	310 min.
		Grade B	42	290	58 min.	400 min.
		Grade C	46	315	62 min.	425 min.
	ASTM A501	Grade A	36	250	58 min.	400 min.
	ASTM A516	Grade 55	30	205	55–75	380–515
		Grade 60	32	220	60–80	415–550
	ASTM A524	Grade I	35	240	60–85	415–586
		Grade II	30	205	55–80	380–550
	ASTM A573	Grade 65	35	240	65–77	450–530
		Grade 58	32	220	58–71	400–490
	ASTM A709	Grade 36 (≤3/4 in [20 mm])	36	250	58–80	400–550
	ASTM A1008 SS	Grade 30	30	205	45 min.	310 min.
		Grade 33 Type 1	33	230	48 min.	330 min.
		Grade 40 Type 1	40	275	52 min.	360 min.
	ASTM A1011 SS	Grade 30	30	205	49 min.	340 min.
		Grade 33	33	230	52 min.	360 min.
		Grade 36 Type 1	36	250	53 min.	365 min.
		Grade 40	40	275	55 min.	380 min.
		Grade 45	45	310	60 min.	410 min.
	ASTM A1018 SS	Grade 30	30	205	49 min.	340 min.
		Grade 33	33	230	52 min.	360 min.
		Grade 36	36	250	53 min.	365 min.
		Grade 40	40	275	55 min.	380 min.
	API 5L	Grade B	35	241	60	414
		Grade X42	42	290	60	414
	ABS	Grades A, B, D, CS, DS	34	235	58–75	400–520
		Grade E ^b	34	235	58–75	400–520

(Continued)

Image 6.3

Table 3.2 – Filler Metals for Matching Strength for Table 3.1, Groups I, II, III, and IV Materials. This table is 4 pages in length. The first page of Table 3.2, shown below, defines the prequalified filler materials for both SMAW and SAW for all 4 material groups. The second page of Table 3.2 defines the prequalified filler materials for FCAW and GMAW.

Table 3.2 Filler Metals for Matching Strength to Table 3.1, Groups I, II, III, and IV Metals—SMAW and SAW (see 3.3)					
Base Metal Group	AWS Electrode Specification	SMAW		SAW	
		A5.1, Carbon Steel	A5.5 ^a , Low-Alloy Steel	A5.17, Carbon Steel	A5.23 ^c , Low-Alloy Steel
I	AWS Electrode Classification	E60XX	E70XX-X	F6XX-EXXX	F7XX-EXXX-XX
		E70XX		F6XX-ECXXX F7XX-EXXX F7XX-ECXXX	F7XX-ECXXX-XX
II	AWS Electrode Classification	E7015	E7015-X	F7XX-EXXX	F7XX-EXXX-XX
		E7016	E7016-X	F7XX-ECXXX	F7XX-ECXXX-XX
		E7018	E7018-X		
		E7028			
III	AWS Electrode Classification	N/A	E8015-X	N/A	F8XX-EXXX-XX
			E8016-X		F8XX-ECXXX-XX
			E8018-X		
IV	AWS Electrode Classification	N/A	E9015-X	N/A	F9XX-EXXX-XX
			E9016-X		F9XX-ECXXX-XX
			E9018-X		
			E9018M		

(Continued)

Image 6.4

Table 3.2 (Continued)
Filler Metals for Matching Strength to Table 3.1, Groups I Metals—FCAW and GMAW Metal Cored (see 3.3)

WELDING PROCESS(ES)					
Base Metal Group	AWS Electrode Specification	GMAW		FCAW	
		A5.18, Carbon Steel	A5.28 ^a , Low-Alloy Steel	A5.20, Carbon Steel	A5.29 ^d , Low-Alloy Steel
AWS Electrode Classification	ER70S-X E70C-XC E70C-XM (Electrodes with the -GS suffix shall be excluded)	ER70S-X E70C-XC E70C-XM (Electrodes with the -GS suffix shall be excluded)	ER70S-XXX E70C-XXX	E7XT-X E7XT-XC E7XT-XM (Electrodes with the -2C, -2M, -3, -10, -13, -14, and -GS suffix shall be excluded and electrodes with the -11 suffix shall be excluded for thicknesses greater than 1/2 in [12 mm])	E6XTX-X E7XTX-X E6XTX-XC E6XTX-XM E7XTX-XC E7XTX-XM
I					(Flux Cored Electrodes with the T1S, T3S, T10S, T14S, and -GS suffix shall be excluded and electrodes with the T11 suffix shall be excluded for thicknesses greater than 1/2 in [12 mm]) FCAW Low-Alloy Steel E6XTX-XAX-XXX E7XTX-XAX-XXX GMAW-Metal Cored Carbon Steel E7XTX-XAX-CS1 E7XTX-XAX-CS2 (Electrodes with the -GS suffix shall be excluded) GMAW-Metal Cored Low-Alloy Steel E7XTX-XAX-XXX

(Continued)

Image 6.5

Table 3.3 – Prequalified Minimum Preheat and Interpass Temperature. This table relates 4 important weld variables: base metal category, welding process, thickness, and minimum preheat and interpass temperature. For example, if an ASTM A36 (Category A) steel that is 1/4 inch thick is being welded with SMAW using a low-hydrogen electrode, then the minimum preheat and interpass temperature is 32 degrees Fahrenheit or 0 degrees Celsius. Below is Table 3.3.

C a t e g o r y	Steel Specification	Welding Process	Thickness of Thickest Part at Point of Welding		Minimum Preheat and Interpass Temperature	
			in	mm	°F	°C
A	ASTM A36	SMAW with other than low- hydrogen electrodes	1/8 to 3/4 incl.	3 to 20 incl.	32 ^a	0 ^a
	ASTM A53 Grade B					
	ASTM A106 Grade B					
	ASTM A131 Grades A, B, CS, D, DS, E					
	ASTM A139 Grade B					
	ASTM A381 Grade Y35					
	ASTM A500 Grade A					
	Grade B					
	Grade C					
	ASTM A501 Grade A					
	ASTM A516					
	ASTM A524 Grades 1 & II					
	ASTM A573 Grade 65					
	ASTM A709 Grade 36					
	ASTM A1008 SS Grade 30					
	Grade 33 Type 1					
	Grade 40 Type 1					
	ASTM A1011 SS Grade 30					
	Grade 33					
	Grade 36 Type 1					
Grade 40						
Grade 45						
Grade 50						
Grade 55						
ASTM A1018 SS	Grade 30					
Grade 33						
Grade 36						
Grade 40						
API 5L	Grade B					
Grade X42						
ABS	Grades A, B, D, CS, DS					
Grade E						

Image 6.6

Table 3.6 – Prequalified WPS Requirements. This table gives ranges for specific variables that must be met when prequalified welding procedures are employed (maximum electrode diameter, maximum current, maximum root pass thickness, maximum fill pass thickness, maximum single pass fillet weld size, and maximum single pass layer width). Below is Table 3.6.

Table 3.6 Prequalified WPS Requirements ^f (see 3.7)							
Variable	Position	Weld Type	SMAW	SAW ^a			GMAW/ FCAW ^g
				Single	Parallel	Multiple	
Maximum Electrode Diameter	Flat	Fillet ^a	5/16 in [8.0 mm]	1/4 in [6.4 mm]			1/8 in [3.2 mm]
		Groove ^a	1/4 in [6.4 mm]				
		Root pass	3/16 in [4.8 mm]				
	Horizontal	Fillet	1/4 in [6.4 mm]	1/4 in [6.4 mm]			1/8 in [3.2 mm]
		Groove	3/16 in [4.8 mm]	Requires WPS Qualification Test			
	Vertical	All	3/16 in [4.8 mm] ^b				3/32 in [2.4 mm]
	Overhead	All	3/16 in [4.8 mm] ^b				5/64 in [2.0 mm]
Maximum Current	All	Fillet	Within the range of recommended operation by the filler metal manufacturer	1000 A	1200A	Unlimited	Within the range of recommended operation by the filler metal manufacturer
	All	Groove weld root pass with opening		600A	700A		
		Groove weld root pass without opening			900A		
		Groove weld fill passes			1200A		
		Groove weld cap pass		Unlimited			
	Maximum Root Pass Thickness ^d	Flat		All	3/8 in [10 mm]	Unlimited	
Horizontal		5/16 in [8 mm]	5/16 in [8 mm]				
Vertical		1/2 in [12 mm]	1/2 in [12 mm]				
Overhead		5/16 in [8 mm]	5/16 in [8 mm]				
Maximum Fill Pass Thickness	All	All	3/16 in [5 mm]	1/4 in [6 mm]	Unlimited		1/4 in [6 mm]
Maximum Single Pass Fillet Weld Size ^e	Flat	Fillet	3/8 in [10 mm]	Unlimited			1/2 in [12 mm]
	Horizontal		5/16 in [8 mm]	5/16 in [8 mm]	5/16 in [8 mm]	1/2 in [12 mm]	3/8 in [10 mm]
	Vertical		1/2 in [12 mm]				1/2 in [12 mm]
	Overhead		5/16 in [8 mm]				5/16 in [8 mm]
Maximum Single Pass Layer Width	All (for GMAW/ FCAW) F & H (for SAW)	Root opening > 1/2 in [12 mm], or		Split layers	Laterally displaced electrodes or split layer	Split layers	Split layers
		Any layer of width w		Split layers if w > 5/8 in [16 mm]	Split layers with tandem electrodes if w > 5/8 in [16 mm]	If w > 1 in [25 mm], split layers	(Note e)

^a Except root passes.
^b 5/32 in [4.0 mm] for EXX14 and low-hydrogen electrodes.
^c See 3.7.3 for requirements for welding unpainted and exposed ASTM A588.
^d See 3.7.2 for width-to-depth limitations.
^e In the F, H, or OH positions for nontubulars, split layers when the layer width w > 5/8 in [16 mm]. In the vertical position for nontubulars or the flat, horizontal, vertical, and overhead positions for tubulars, split layers when the width w > 1 in [25 mm].
^f Shaded area indicates nonapplicability.
^g GMAW-S shall not be prequalified.

Image 6.7

Table 3.7 – Prequalified WPS Variables. This table shows whether or not a change to welding variables will require a new prequalified WPS to be prepared or require the WPS to be requalified per Clause 4. For example, a change in amperage using SAW that is less than 10% does not require requalification since there is no minimum current in Table 3.6. However, a new prequalified WPS needs to be prepared if the minimum current for SAW is decreased more than 10%. Below is Table 3.7.

Table 3.7
Prequalified WPS Variables (see 3.6 and 3.7)

Prequalified WPS Variable	Process			
	SMAW	SAW	GMAW	FCAW
General				
1) A change in welding process(es) ²	X	X	X	X
2) A change in welding position(s)	X	X	X	X
Base Metal				
3) A change in base metal group number(s) (see Table 3.1)	X	X	X	X
4) A change in the base metal preheat category (see Table 3.3)	X	X	X	X
Filler Metal				
5) A change in electrode classification(s)	X	X	X	X
6) A change in electrode/flux classification(s)		X		
7) A change in nominal electrode diameter(s)	X	X	X	X
8) A change in the number of electrodes		X		
Process Parameters				
9) A change in amperage		> 10% increase or decrease	> 10% increase or decrease	> 10% increase or decrease
10) A change in type of current (ac or dc) or polarity	X	X	X	X
11) A change in the mode of transfer			X	
12) A change in voltage		> 15% increase or decrease	> 15% increase or decrease	> 15% increase or decrease
13) A change in wire feed speed (if not amperage controlled)		> 10% increase or decrease	> 10% increase or decrease	> 10% increase or decrease
14) A change in travel speed		> 25% increase or decrease	> 25% increase or decrease	> 25% increase or decrease
Shielding Gas				
15) A change in the nominal composition of shielding gas			X	X (for FCAW-G only)
16) A decrease in shielding gas flow rate			> 25%	> 25% (for FCAW-G only)
17) An increase in the gas flow rate			> 50%	> 50% (for FCAW-G only)

(Continued)

Image 6.8