

Exploring the Need to Include Cast Carbon Steels in Welding Procedure Specifications

A case is made for adding cast carbon steel grades in prequalified specifications to AWS D1.1

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The United States uses more than 100 million tons of steel products a year, making the ability to weld steel economically and achieve good properties in the fabricated structure key to its prevalence in manufacturing.

The purpose of this article is to shed light on the fact that AWS D1.1 *Structural Welding Code — Steel*, does not currently include cast carbon steel grade specifications. The authors of this article believe it is time that these were added to D1.1.

All steel products start as castings. Steel products today are made mostly from recycled steel and iron melted in electric furnaces. Steel is cast into a variety of shapes and formed by rolling, forging, or machining. Steel can also be cast into its designed shape in custom molds to make complex components.

WPS and PQR Importance

To ensure that the final steel component has the desired properties af-

ter welding, a qualified welding procedure is needed. They are supported by a Welding Procedure Specification (WPS) and Procedure Qualification Record (PQR). The WPS is a document specifying how the welding process must be done to ensure sound and quality welds. It consists of the essential variables and their values that must be followed. A PQR is a record of variables used to produce a test weldment. These results qualify a WPS.

Foundries use welding to meet component requirements in the pro-



Fig. 1 — A propeller is cast in sand in a foundry (left). On the right is the propeller casting with the sand removed.

Table 1 — Proposed Cast Carbon Steel Grades and Some Prequalified Base Metals in AWS D1.1 (Ref. 1) Table 3.1 with Corresponding Chemistry and Mechanical Properties Based on ASTM Standards (Ref. 6) and ASME BPVC Section IX (Ref. 4)

Group No.	Specification	Grade	Product Form (based on AWS B2.1 BMG)	Chemistry, wt-%**		AWS D1.1		ASME
				C	Mn	Min. Yield, ksi	Min. Tensile, ksi	Min. Tensile, ksi
I	ASTM A36	($\leq \frac{3}{4}$ in.)	plate	0.25	—	36	58	58
	ASTM A53	B	resistance welded pipe	0.3	1.2	35	60	60
	ASTM A500	B	seamless and welded tube	0.26	1.35	42	58	58
		C	seamless and welded tube	0.23	1.35	46	62	62
	ASTM A501	A	seamless and welded tube	0.26	—	36	58	58
	ASTM A216*	WCA	casting	0.25	0.7	30**	60**	60
	ASTM A352*	LCA	casting	0.25	0.7	30**	60**	60
		LCB	casting	0.3	1	35**	65**	65
	ASTM A660*	WCA	centrifugal cast pipe	0.25	0.7	30**	60**	60
	II	ASTM A529	50	plate, bar, and shapes	0.27	1.35	50	70
55			plate, bar, and shapes	0.27	1.35	55	70	—
ASTM A572		55	plate, sheet, bar, and shapes	0.25	1.35	55	70	—
ASTM A618		II	tube	0.22	1.25	46	65	67
ASTM A216*		WCB	casting	0.3	1	36**	70**	70
		WCC	casting	0.25	1.2	40**	70**	70
ASTM A352*		LCC	casting	0.25	1.2	40**	70**	70
ASTM A356*		1	casting	0.35	0.7	36**	70**	70
ASTM A660*		WCB	centrifugal cast pipe	0.3	1	36**	70**	70
		WCC	centrifugal cast pipe	0.25	1.2	40**	70**	70

*Unlisted base metals that are proposed to be included in AWS D1.1.

**ASTM Standard, ASM International

duction of castings — Fig. 1. Steel casting producers use production welding to replace areas of the casting that do not meet the purchaser's quality requirements. When ASTM standards are used to purchase the casting, qualified welders are required to use a qualified WPS. ASTM A488 *Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel*, is the ASTM specification imposed by technical delivery standards A703 and A781 for welds on production of castings.

To minimize qualification testing and establish consistency between welding specifications, the American Welding Society (AWS) along with the Welding Research Council (WRC) developed prequalified WPS or Standard WPS (SWPS). These SWPSs are supported by PQRs solicited from the industry.

AWS D1.1

AWS D1.1 is a welding standard specifically for carbon and low-alloy steels (Ref. 1). Table 3.1 in this standard identifies prequalified base metals that can be used in their prequalified WPS. They are divided into groups depending on their corresponding mechanical properties and weldability. The lower the group number, the lower the yield and tensile strengths are.

The prequalified base metals in AWS D1.1 do not include castings. AWS standard D1.6 (Ref. 2), *Structural Welding Code — Stainless Steel*, recognizes cast grades in its prequalified base metal list, but AWS D1.6 is specifically for stainless steels.

The welding procedure qualification standard of AWS is B2.1 *Specification for Welding Procedure and Performance Qualification* (Ref. 3). This standard presents a base metal grouping from which qualification of any welding procedure is based. B2.1 contains some castings specifications.

The American Society of Mechanical Engineers (ASME) has the *Boiler and Pressure Vessel Code* (BPVC) Section IX (Ref. 4) as its standard on welding boilers and pressure vessels. Like AWS, base materials under Section IX of ASME BPVC are divided into groups and assigned P-numbers based on composition, weldability, and mechanical properties; for example, the P-number of carbon steel is 1. These documents contain some casting specifications.

The base metal grouping assignments for AWS and ASME reduce the number of welding procedure qualifications required. AWS B2.1 M- and group numbers are consistent with P- and group numbers under ASME BPVC Section IX. B2.1 lists base metals that are not listed in the boiler and

pressure code. The mechanical properties in AWS B2.1 match the properties noted in ASME.

Both AWS B2.1 and ASME BPVC Section IX include cast grades in their base metal grouping. This article proposes the addition of cast carbon steel grades recognized by both these standards into AWS D1.1 Table 3.1. The most common structural carbon steel grades are ASTM A36, A53 Grade B, A500 Grades B and C, A501 Grades A and B, and A529 Grades 50 and 55 (Ref. 5). The composition of these proposed cast grades and some of the prequalified base metals in AWS D1.1 Table 3.1 are summarized in Table 1. The compositions of the alloys are based on ASTM standards (Ref. 6), and the mechanical properties for the proposed cast grades noted under the AWS D1.1 column are based on ASTM standards as well. The major alloying content of the cast grades and, thus, the weldability of these cast carbon steels are comparable to the prequalified carbon steel grades. This validates that the cast grades proposed do fit in groups I and II of the prequalified base materials in AWS D1.1.

To further show the compatibility of these proposed cast grades with the grouping of the prequalified base metals, Table 2 shows the group numbers and mechanical properties of cast grades based on AWS B2.1 and ASME

Table 2 — Proposed Cast Carbon Steel Grades and Some Prequalified Base Metals in AWS D1.1 (Ref. 1) Table 3.1 with Corresponding Base Metal Grouping and Mechanical Properties Based on ASTM Standards (Ref. 6), AWS B2.1 (Ref. 3), and ASME BPVC Section IX (Ref. 4)

Group No.	Specification	Grade	Product Form (based on AWS B2.1 BMG)	AWS B2.1		ASME		AWS D1.1		AWS B2.1		ASME
				M- No.	Group No.	P- No.	Group No.	Min. Yield, ksi	Min. Tensile, ksi	Min. Yield, ksi	Min. Tensile, ksi	Min. Tensile, ksi
I	ASTM A36	($\leq \frac{3}{4}$ in.)	plate	1	1	1	1	36	58	36	58	58
	ASTM A53	B	resistance welded pipe	1	1	1	1	35	60	35	60	60
	ASTM A500	B	seamless and welded tube	1	1	1	1	42	58	42	58	58
		C	seamless and welded tube	1	1	1	1	46	62	46	62	62
	ASTM A501	A	seamless and welded tube	1	1	1	1	36	58	36	58	58
	ASTM A216*	WCA	casting	1	1	1	1	30**	60**	30	60	60
	ASTM A352*	LCA	casting	1	1	1	1	30**	60**	30	60	60
LCB		casting	1	1	1	1	35**	65**	35	65	65	
ASTM A660*	WCA	centrifugal cast pipe	1	1	1	1	30**	60**	30	60	60	
II	ASTM A529	50	plate, bar, and shapes	1	2	-	-	50	70	50	70	-
		55	plate, bar, and shapes	1	2	-	-	55	70	55	70	-
	ASTM A572	55	plate, sheet, bar, and shapes	1	2	-	-	55	70	55	70	-
	ASTM A618	lb, II	tube	1	2	1	2	46	65	46	67	67
	ASTM A216*	WCB	casting	1	2	1	2	36**	70**	36	70	70
		WCC	casting	1	2	1	2	40**	70**	40	70	70
	ASTM A352*	LCC	casting	1	2	1	2	40**	70**	40	70	70
	ASTM A356*	1	casting	1	2	1	2	36**	70**	36	70	70
	ASTM A660*	WCB	centrifugal cast pipe	1	2	1	2	36**	70**	36	70	70
		WCC	centrifugal cast pipe	1	2	1	2	40**	70**	40	70	70

*Unlisted base metals that are proposed to be included in AWS D1.1.

**ASTM Standard, ASM International


BPVC Section IX. These standards identify cast carbon grades as Groups I and II in their base metal grouping. The mechanical properties of these cast grades are also comparable to the prequalified base metals.

The addition of these cast steel grades to AWS D1.1 Table 3.1 would allow its users to use the prequalified procedures to weld castings. This would be similar to the approach used in the ASME BPVC. Section IX of the ASME BPVC allows qualification of alloys with the same P-number regardless of the product form. This allows the fabricator of pressure vessel equipment to use one WPS to join castings to plates, bars, or forgings all having the same P-number. In casting production welding that imposes ASTM A488, the casting producer does not need to requalify the procedure or welder if they are already qualified to a WPS complying with ASME Section IX. Both ASME BPVC Section IX and ASTM A488 allow the qualification of welding of castings using wrought steel in the same P-number group.

Conclusion

Both AWS B2.1, D1.6, and a stringent standard such as ASME BPVC

Section IX recognize cast grades and allow the use of the same WPS as other similar steels in other product forms. AWS D1.1 should add cast grades to Table 3.1. Its users can use prequalified WPS. As previously mentioned, these cast grades are already in AWS B2.1 and ASME BPVC. Since foundries typically use ASME BPVC Section IX or ASTM A488 to qualify welding procedures, the cast grades suggested are already qualified to use the same WPS to weld to the grades already in D1.1 Table 3.1.

Fabrication of parts with complex geometries may involve welding of wrought materials to castings. If a particular alloy grade is only listed in a welding standard as a wrought product, then a qualification procedure must be done before it can be welded to a cast component. This requalification procedure leads to additional cost and time in terms of conducting the tests and evaluating the corresponding PQR and WPS. Expansion of the prequalified carbon and low-alloy steels in AWS D1.1 Table 3.1 to include cast carbon steel grades will be beneficial to anyone who welds steel castings. 

References

1. American Welding Society. 2015.

D1.1:2015, *Structural Welding Code — Steel*.

2. American Welding Society. 2007. D1.6/D1.6M:2007, *Structural Welding Code — Stainless Steel*.

3. American Welding Society. 2014. B2.1/B2.1M:2014, *Specification for Welding Procedure and Performance Qualification*.

4. American Society of Mechanical Engineers. 2010. ASME Boiler Pressure Vessel Code Section IX, *Welding and Brazing Qualifications*.

5. Anderson, M., Carter, C. J., and Schlafly, T. J. February 2012. Are you properly specifying materials? *Modern Steel Construction*.

6. ASTM International. 2015. ASTM Standard.

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