



Designation: ~~A291/A291M – 05 (Reapproved 2010)~~ A291/A291M – 05 (Reapproved 2015)

## Standard Specification for Steel Forgings, Carbon and Alloy, for Pinions, Gears and Shafts for Reduction Gears<sup>1</sup>

This standard is issued under the fixed designation A291/A291M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers normalized and tempered carbon steel and quenched and tempered alloy steel forgings for pinions, gears, and shafts.

1.2 Several grades of steel are covered as follows:

1.2.1 *Grade 1, Class A*, is normalized and tempered carbon steel.

1.2.2 *Grade 2, Class B, Grade 3, Class C, Grade 3A, Class D, Grades 4 to 7, Classes E, F, G, and H, Grade 8, Class I, and Grade 9, Class J*, are liquid quenched and tempered alloy steel.

1.3 All grades and classes are considered weldable under proper conditions. Welding technique is of fundamental importance and it is presupposed that welding procedure and inspection shall be in accordance with approved methods for the class of material used.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

[A275/A275M Practice for Magnetic Particle Examination of Steel Forgings](#)

[A388/A388M Practice for Ultrasonic Examination of Steel Forgings](#)

[A788/A788M Specification for Steel Forgings, General Requirements](#)

### 3. Ordering Information

3.1 Instructions for purchasing forgings to this specification should be in accordance with Specification [A788/A788M](#). In addition, a detailed drawing, sketch, or written description of the forging should be included with the inquiry or order.

3.2 Supplementary requirements are provided and shall apply only when specified in the purchase order.

### 4. Heat Treatment

4.1 *Preliminary Heat Treatment:*

4.1.1 The forgings shall be given such preliminary heat treatment as is proper for the design and composition. The forgings shall be heated to a suitable temperature for a sufficient length of time for austenitization and shall be suitably cooled to bring about complete transformation.

4.1.2 Forgings may be immediately treated for mechanical properties after preliminary heat treatment or may be rough turned prior to treatment for mechanical properties.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.06 on Steel Forgings and Billets.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard

4.2 *Heat Treatment for Mechanical Properties*—The forging shall be reheated to a temperature above the upper critical temperature and held a sufficient length of time for complete austenitization. Grade 1 shall be air cooled while Grades 2 through 9 shall be liquid quenched.

4.3 *Tempering*—The forgings shall be tempered to develop the specified properties. Minimum tempering temperatures shall be as follows:

Grade	Class	Minimum Tempering Temperature	
		°F	[°C]
1 and 2	A and B	1150	[620]
3, 3A, and 4	C, D, and E	1075	[580]
5, 6, 7	F, G, and H	1050	[565]
8	I	1100	[595]
9	J	1000	[540]

The charge shall be cooled under uniform conditions in the furnace at a maximum rate of 100°F [55°C] per h to 600°F [315°C].

4.4 *Stress Relief*—If the manufacturer elects to heat treat for mechanical properties prior to machining, the forgings shall be stress relieved after machining (see 4.5) at a temperature that is 50 to 100°F [30 to 55°C] below the last previous tempering temperature but in no case below 1000°F [540°C]. The forgings shall be cooled under uniform conditions in the furnace at a maximum rate of 100°F [55°C]/h to 600°F [315°C].

4.5 *Machining:*

4.5.1 Rough machining before heat treatment for mechanical properties may be performed at the option of the manufacturer.

4.5.2 If the producer elects to heat treat for mechanical properties prior to machining, the forgings shall be stress relieved after machining.

4.5.3 *Boring*—Forgings, after being heat treated for mechanical properties and subsequently bored, shall be stress relieved.

**5. General Requirements**

5.1 Unless otherwise specified herein, the requirements of Specification **A788/A788M** shall apply to forgings supplied to this specification.

**6. Chemical Requirements**

6.1 The steel shall conform to the requirements for chemical composition prescribed in **Table 1**.

6.2 The limits for elements other than carbon, manganese, phosphorus, sulfur, and silicon in Grade 2 alloy shall be agreed upon between the manufacturer and purchaser.

**7. Mechanical Requirements**

7.1 *Tensile and Impact Requirements:*

7.1.1 The material shall conform to the requirements for tensile and impact properties prescribed in **Table 2** and impact properties (see S2) when agreed upon between the purchaser and the supplier.

7.1.2 *Classification*—The nominal or specified rough-machined diameter or thickness of solid forgings, disregarding large ends, collars and flanges, or the nominal rough-machined wall thickness of bored forgings shall determine the size classification.

7.1.3 *Number, Location, and Orientation of Test Specimens:*

**TABLE 1 Chemical Requirements**

Element	Composition, %						
	Grade 1	Grade 2	Grade 3	Grade 3A	Grades 4 to 7 Classes E, F, G, and H	Grade 8	Grade 9
	Class A	Class B	Class C	Class D		Class I	Class J
Carbon	0.55 max	0.50 max	0.45 max	0.45 max	0.35–0.50	0.38–0.45	0.25–0.39
Manganese	0.60–0.90	0.40–0.90	0.40–0.90	0.40–0.90	0.40–0.90	0.40–0.70	0.20–0.60
Phosphorus, max	0.040	0.040	0.040	0.040	0.040	0.040	0.015
Sulfur, max	0.040	0.040	0.040	0.040	0.040	0.040	0.015
Silicon <sup>A</sup> , max	0.35	0.35	0.35	0.35	0.35	0.40	0.35
Nickel	0.30 max	<sup>B</sup>	0.50 max	1.00–3.00	1.65 min	0.30 max	3.25–4.00
Chromium	0.25 max	<sup>B</sup>	1.25 max	1.50 max	0.60 min	1.40–1.80	1.25–1.75
Molybdenum	0.10 max	<sup>B</sup>	0.15 min	0.15 min	0.20–0.60	0.30–0.45	0.30–0.70
Vanadium, max	0.06	0.10	0.05	0.10	0.10	0.03	0.05–0.15
Copper, max	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Aluminum	...	...	...	...	...	0.85–1.30	...

<sup>A</sup> When vacuum carbon deoxidation is used, silicon maximum shall be 0.10 %.

<sup>B</sup> Optional with manufacturer and purchaser.