



Standard Specification for Steel Forgings, General Requirements¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification² covers a group of common requirements that, unless otherwise specified in the individual material specification, shall apply to steel forgings under any of the following specifications issued by ASTM:

ASTM Designation	Title
A 266	Forgings, Carbon Steel for Pressure Vessel Components
A 288	Carbon and Alloy Steel Forgings for Magnetic Retaining Rings for Turbine Generators
A 289	Alloy Steel Forgings for Nonmagnetic Retaining Rings for Generators
A 290	Carbon and Alloy Steel Forgings for Rings for Reduction Gears
A 291	Carbon and Alloy Steel Forgings for Pinions and Gears for Reduction Gears
A 336	Steel Forgings, Alloy, for Pressure and High-Temperature Parts
A 372	Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessels
A 427	Wrought Alloy Steel Rolls for Cold and Hot Reduction
A 469	Vacuum-Treated Steel Forgings for Generator Rotors
A 470	Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts
A 471	Vacuum-Treated Alloy Steel Forgings for Turbine Rotor Disks and Wheels
A 508/A 508M	Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings Pressure Vessels
A 521	Steel Closed-Impression Die Forgings for General Industrial Use
A 541/A 541M	Steel Forgings, Carbon and Alloy, Quenched and Tempered, for Pressure Vessel Components
A 579	Superstrength Alloy Steel Forgings
A 592	High-Strength Quenched and Tempered Low-Alloy Steel Forged Fittings and Parts for Pressure Vessels
A 649/A 649M	Forged Steel Rolls Used for Corrugating Paper Machinery
A 668/A 668M	Steel Forgings Carbon and Alloy for General Industrial Use
A 723/A 723M	Alloy Steel Forgings for High-Strength Pressure Component Application

A 765/A 765M	Carbon Steel and Low-Alloy Steel Pressure Vessel Component Forgings with Mandatory Toughness Requirements
A 768	Vacuum-Treated 12 % Chromium Alloy Steel Forgings for Turbine Rotors and Shafts
A 837	Steel Forgings, Alloy, For Carburizing Applications
A 859/A 859M	Steel Forgings, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum Alloy Steel, for Pressure Vessel Components
A 891	Precipitation Hardening Iron Base Superalloy Forgings for Turbine Rotor Disks and Wheels
A 909	Specification for Steel Forgings, Microalloy, for General Industrial Use
A 940	Specification for Vacuum Treated Steel Forgings, Alloy, Differentially Heat Treated, for Turbine Rotors
A 965/A 965M	Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts

1.2 In case of conflict in requirements, the requirements of the individual material specifications shall prevail over those of this specification.

1.3 The purchaser may specify additional requirements (see 4.2.3) that do not negate any of the provisions of either this specification or of the individual material specifications. The acceptance of any such additional requirements shall be dependent on negotiations with the supplier and must be included in the order.

1.4 If, by agreement, forgings are to be supplied in a partially completed condition, that is, all of the provisions of the product specification have not been filled, then the material marking (see Section 17) and certification (see Section 16) shall reflect the extent to which the product specification requirements have been met.

2. Referenced Documents

2.1 ASTM Standards:

- A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings³
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products⁴
- A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings³
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products⁴

¹ This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys, and is the direct responsibility of Subcommittee A1.06 on Steel Forgings and Billets.

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² For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-788 in Section II of that code.

³ Annual Book of ASTM Standards, Vol 01.05.

⁴ Annual Book of ASTM Standards, Vol 01.03.

A 833 Practice for Indentation Hardness of Metallic Materials by Comparison Hardness Testers³

A 939 Test Method for Ultrasonic Examination from Bored Surfaces of Cylindrical Forgings³

A 966/A 966M Test Method for Magnetic Particle Examination of Steel Forgings Using Alternating Current³

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials⁵

E 44 Definitions of Terms Relating to Heat Treatment of Metals⁶

E 112 Test Methods for Determining the Average Grain Size⁵

E 165 Practice for Liquid Penetrant Examination⁷

E 428 Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection⁷

E 813 Test Method for J_{IC} , a Measure of Fracture Toughness⁵

3. Terminology

3.1 Definitions:

3.1.1 *cold-worked forgings*—forgings produced by plastic working well below the temperature range at which recrystallization of the material occurs. Cold-worked forgings must be made from metal previously hot worked by forging or rolling.

3.1.2 *hot-cold-worked forgings*—forgings worked at elevated temperatures slightly below the recrystallization range to increase mechanical strength. Hot-cold-worked forgings must be made from material previously hot worked by forging or rolling. A hot-cold-worked forging may be produced in one continuous operation wherein the material is first hot worked then hot-cold-worked by control of the finishing temperature.

3.1.2.1 *Discussion*—Because of differences in manufacture hot rolled, or hot rolled and cold finished bars (semi-finished or finished), billets or blooms are not considered to be forgings.

3.1.3 *hot-worked forgings*—forgings produced by working at temperatures above the recrystallization temperature for the material.

3.1.4 *steel forging*—the product of a substantially compressive plastic working operation that consolidates the material and produces the desired shape. The plastic working may be performed by a hammer, press, forging machine, ring rolling machine, or forging rolls, and must deform the material to produce an essentially wrought structure. Forgings may be subdivided into the following three classes on the basis of their forging temperatures:

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *bottom pouring*—steel from a single heat, or from a multiple heat tapped into a common ladle (see 8.1.1 and 8.1.2), introduced into ingot mold(s) such that they are filled from the bottom up. One or more molds can be set up on an individual plate, and more than one plate may be poured in sequence from a heat. The plate is generally constructed such that the molten steel can be ducted through refractory channels to the bottom of each mold on the plate. The steel is poured into a central

spue which is high enough to permit filling the ingot molds to the required level.

3.2.2 *ingot*—the product obtained when molten steel, upon being cast into a mold, is subsequently capable of being wrought in conformance with 3.1. Open-ended molds, that are usually cooled and used, for example, in the continuous casting of steel, are considered to be included in this definition.

3.2.3 *killed steel*—steel deoxidized, either by the addition of strong deoxidizing agents or by vacuum treatment, to reduce the oxygen content to such a level that essentially no reaction occurs between carbon and oxygen during solidification

3.2.3.1 *Discussion*—Vacuum carbon deoxidation (VCD) is a steelmaking process in which primary deoxidation occurs during vacuum treatment as a result of the carbon-oxygen reaction. In order for primary deoxidation to occur during vacuum treatment, deoxidizing agents such as aluminum or silicon are not to be added to the melt in any significant amount prior to the vacuum treatment operation.

3.2.3.2 *Discussion*—Precipitation deoxidation is a steelmaking process in which primary deoxidation is achieved by the addition of strong deoxidizing agents such as aluminum early in the process, and holding the steel in the molten state for sufficient time for the products of deoxidation to separate from the melt to the slag.

3.2.4 *sequential or continuous strand casting*—steel from several heats poured consecutively into a cooled open-ended mold to form a continuous cast product with a change from heat to heat along its length.

3.2.5 *strand casting*—steel from one heat poured into a cooled open-ended mold to form a continuous strand or strands.

4. Ordering Information

4.1 Orders shall include the following information:

4.1.1 Quantity,

4.1.2 Dimensions, including tolerances and surface finishes,

4.1.3 Specification number with type, class, and grade as applicable (including year date), and should include:

4.1.4 Number of copies of the material test report.

4.2 Additional information including the following may be added by agreement with the supplier:

4.2.1 Type of heat treatment when alternative methods are allowed by the material specification,

4.2.2 Supplementary requirements, if any, and

4.2.3 Additional requirements (see 1.4, 16.1.5, and 16.1.6).

4.2.4 Repair welding NOT permitted.

5. Melting Process

5.1 Unless otherwise specified in the material specification, the steel shall be produced by any of the following primary processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction (VIM). The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electro slag remelting (ESR) or vacuum arc remelting (VAR).

5.2 The molten steel may be vacuum-treated prior to or during pouring of the ingot.

⁵ Annual Book of ASTM Standards, Vol 03.01.

⁶ Annual Book of ASTM Standards, Vol 01.02.

⁷ Annual Book of ASTM Standards, Vol 03.03.

5.2.1 When vacuum treatment of the molten steel is required by the material specification the following conditions shall apply:

5.2.1.1 When the vacuum stream degassing process is used, the vacuum system must be of sufficient capacity to effect a blank-off pressure low enough (usually less than 1000 μm), to break up the normal tight, rope-like stream of molten metal into a wide-angled conical stream of relatively small droplets. The capacity of the system must also be sufficiently high to reduce the initial surge pressure at the start of the pour to a low level within 2 min.

5.2.1.2 When the vacuum-lift process is utilized, the molten metal shall be repeatedly drawn into the evacuated vessel to give a recirculation factor (see Annex A1) of at least 2.5 to ensure thorough degassing and mixing of the entire heat. The evacuation system shall be capable of reducing the pressure surges, which occur each time a new portion of steel is admitted to the vessel to increasingly lower levels, until a blank-off pressure, (usually less than 1000 μm) is achieved signifying the end of the degassing treatment.

5.2.1.3 When the ladle degassing process is used, the evacuation system shall be capable of reducing the system vacuum pressure to a low level (usually less than 1000 μm). The molten metal shall be adequately stirred for a sufficient length of time to maximize exposure to the evacuated atmosphere.

5.2.1.4 Other methods of vacuum treatment may be used if the supplier can demonstrate adequate degassing and acceptable properties in the finished forging to the satisfaction of the purchaser.

6. Forging

6.1 Forgings shall be made in accordance with 3.1.

7. Cooling Prior to Heat Treatment

7.1 After forging and before reheating for heat treatment, the forgings shall be allowed to cool in such a manner as to prevent injury and, in the case of ferritic forgings, to permit substantially complete transformation of austenite.

8. Chemical Composition

8.1 Heat Analysis:

8.1.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of those elements specified in the material specification. This analysis shall be made from a test sample preferably taken during the pouring of the heat and shall conform to the requirements of the material specification.

8.1.2 When multiple heats are tapped into a common ladle, the ladle chemistry shall apply. The chemical composition thus determined shall conform to the requirements of the material specification.

8.1.3 For multiple-heat ingots, either individual heat analyses or a weighted average (see Annex A2) may be taken. The results of the method used shall conform to the requirements of the material specification.

8.1.4 With the exception of the product from multiple heats sequentially cast in strand casting machines (see 8.1.6), if the test sample taken for a heat analysis is lost or declared

inadequate for chemical determinations, the manufacturer may take alternative samples from appropriate locations near the surface of the ingot or forging as necessary to establish the analysis of the heat in question.

8.1.5 Heat Analysis for Remelted Ingots:

8.1.5.1 When consumable remelting processes are used, a chemical analysis taken from one remelted ingot (or the product of one remelted ingot) per heat shall be taken as the heat analysis.

8.1.5.2 When electrodes from different master heats are remelted sequentially, an analysis shall be made in each zone of the remelted ingot corresponding to at least one electrode from each master heat. The resultant chemical analysis of each zone shall conform to the requirements of the material specification. The heat analysis of the remelted ingot shall be represented by a weighted average (see Annex A2) of the individual chemical analyses for each zone.

8.1.5.3 Limits on aluminum content in remelt ingots shall be set as required in the product specification.

8.1.6 For multiple heats sequentially cast in strand casting machines, the heat analysis shall be determined for each individual heat in accordance with 8.1.1, or 8.1.2 if applicable.

8.1.6.1 If, for multiple heats sequentially strand cast, the test sample is lost or declared inadequate for chemical analysis determination, alternative samples, remote from the transition zones, may be taken by the manufacturer from the cast material or product of that heat, as defined in 8.2 or 8.3 as appropriate.

8.2 *Heat Number Assignment for Sequentially Strand Cast Material*—When heats of the same chemical composition are sequentially strand cast, the heat number assigned to the cast product may remain unchanged until all of the steel in the product is from the following heat, except when Supplementary Requirement S3 is invoked.

8.3 *Identification of Material of Different Chemical Composition Ranges, Sequentially Strand Cast*—Because of intermixing in the tundish, separation and identification of the resultant transition material is required when steels of different chemical composition ranges are sequentially strand cast. The supplier shall remove the transition material by any established procedure that positively separates the grades.

8.4 Product Analysis:

8.4.1 An analysis may be made by the purchaser from a forging representing each heat or multiple heat (see 8.1). Samples for analysis may be taken from the forging or from a full-size prolongation at any point from the midradius to the outer surface of disk or other solid forgings or midway between the inner and outer surfaces of hollow or bored forgings. The analysis may also be taken from a mechanical test specimen or the mechanical test location as defined in the material specification.

8.4.2 The chemical composition thus determined shall conform to the requirements of the forging specification subject to the permissible variations specified in Table 1, for those elements listed in the material specification. Limitations on the application of the allowances in Table 1 may be made in the material specification for specified elements.

8.5 *Residual and Unspecified Elements*—Provisions for the limitation of certain residual and unspecified elements have