



Designation: A 21 – 94 (Reapproved 1999)

Standard Specification for Carbon Steel Axles, Non-Heat-Treated and Heat-Treated, for Railway Use¹

This standard is issued under the fixed designation A 21; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers nonheat-treated axles up to and including those 6½ in. (165.1 mm) nominal diameter at the center and heat-treated axles of all sizes for freight cars, passenger cars, and locomotives.

1.2 This specification is for axles with machined bodies. For axles with as-forged bodies, see Specification A 383.

1.3 The grades of carbon steel axles are as follows:

1.3.1 *Grade U*—Nonheat-treated.

1.3.2 *Grade F*—Double normalized and tempered. (All freight axles over 6½ in. (165.1 mm) nominal diameter at the center shall be Grade F.)

1.3.3 *Grade G*—Quenched and tempered.

1.3.4 *Grade H*—Normalized, quenched, and tempered.

1.3.5 Grades F, G, and H axles are used in heavy-duty service on locomotives, cars, and other equipment.

1.4 Typical designs for plain and roller bearing axles are shown in the *Manual of Standards and Recommended Practice* of the Association of American Railroads.²

1.5 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.6 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products³

A 383 Specification for Axles, Railway, Carbon Steel, Untreated for Export and General Industrial Use⁴

E 112 Test Methods for Determining Average Grain Size⁵

E 127 Practice for Fabricating and Checking Aluminum

Alloy Ultrasonic Standard Reference Blocks⁶

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings⁵

2.2 Military Standards:

MIL-STD-129 Marking for Shipment and Storage⁷

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage⁷

2.3 Federal Standard:

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)⁷

3. Ordering Information

3.1 The inquiry, order, or contract for material under this specification shall include the following information:

3.1.1 Quantity (number of pieces),

3.1.2 ASTM designation and year of issue,

3.1.3 Grade,

3.1.4 Design and size,

3.1.5 Intended service, and

3.1.6 Supplementary requirements (if any).

4. Manufacture

4.1 *Process*—The steel shall be made by any of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.2 *Discard*—Sufficient discard shall be made to assure freedom from piping and undue segregation.

4.3 *Forging Practice*—The axles may be made direct from the ingot or from blooms. The total reduction from ingot or strand cast bloom to forging shall not be less than 3 to 1, unless otherwise specified.

4.4 Cooling and Heating:

4.4.1 After axle blooms are produced they shall be slow cooled in closed containers, hoods, or furnaces.

4.4.2 Blooms shall be reheated for forging in a manner which will prevent internal bursts and overheating.

4.4.3 After forging, axles shall be slow cooled in closed containers, covered conveyors, or in hoods. If axles (Grades F, G, and H) are heat-treated directly from the forging, they shall be slow cooled following the final heat treatment.

NOTE 1—After slow cooling, Grade U axles may be single normalized

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² Obtainable from the Mechanical Division, Association of American Railroads, 1920 L St. N.W., Washington, DC 20036.

³ *Annual Book of ASTM Standards*, Vol 01.03.

⁴ *Annual Book of ASTM Standards*, Vol 01.04.

⁵ *Annual Book of ASTM Standards*, Vol 03.01.

⁶ *Annual Book of ASTM Standards*, Vol 03.03.

⁷ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

in accordance with 4.4.4 and 4.5.2.

4.4.4 Axles (Grades F, G, and H) that are heat-treated directly from forging (1) shall be cooled below the transformation temperature or to approximately 1000°F (538°C) before any reheating operation and (2) must not be permitted to cool below 500°F (260°C) without slow cooling as defined in 4.4.3.

NOTE 2—As the temperature of the axles approaches the minimum of 500°F (260°C) a supplemental heat source may be necessary to assure an effective slow cooling cycle.

4.4.5 When properly vacuum-degassed steel is used, the slow cooling requirements of 4.4.1, 4.4.3, and 4.4.4 may be omitted but axle blooms must then be pile cooled.

4.5 Heat Treatment:

4.5.1 Axles for heat treatment shall be reheated gradually and uniformly to a suitable temperature to refine the grain structure.

4.5.2 Normalizing—After heating to a suitable temperature the axles shall be withdrawn from the furnace and allowed to cool in air. A furnace charge thus treated is called a normalizing charge. Cooling may be accelerated by increased air circulation which must be controlled to provide reasonably uniform cooling.

4.5.3 Double Normalizing—The procedure shall consist of two separate normalizing treatments. The second shall be performed at a lower temperature than the first treatment. A furnace charge thus treated is termed a double-normalizing charge. Cooling may be accelerated by increased air circulation which must be controlled to provide reasonably uniform cooling.

NOTE 3—A single normalizing treatment shall be permitted when all other requirements for Grade F are met.

4.5.4 Quenching—After heating to a suitable temperature the axles shall be quenched in a suitable medium under reasonably uniform conditions. A furnace charge thus treated is termed a quenching charge.

4.5.5 Tempering—Axles shall be reheated gradually to, and held at, a suitable temperature below the critical range and shall then be allowed to cool under suitable conditions. A furnace charge thus treated is termed a tempering charge.

4.5.6 Heat treatment may be performed in either batch-type furnaces or continuous furnaces.

4.6 Straightening:

4.6.1 Any straightening of axle forgings shall be done before machining and in such a manner as to leave the axle body free of injurious marks.

4.6.2 Straightening shall preferably be performed at a temperature no lower than 950°F (510°C). Straightening performed at a temperature lower than 950°F shall be followed by a furnace stress-relieving procedure or applicable heat treatment.

5. Chemical Requirements

5.1 Chemical Composition—The steel shall conform to the requirements for chemical composition shown in Table 1.

5.2 Cast or Heat Analysis—An analysis of each cast or heat shall be made by the manufacturer to determine the percent-

TABLE 1 Chemical Requirements

Element	Composition, %					
	Nonheat-Treated		Heat-Treated			
	Grade U		Grade F		Grades G and H	
	min	max	min	max	min	max
Carbon	0.40	0.55	0.45	0.59	...	...
Manganese	0.60	0.90	0.60	0.90	0.60	0.90
Phosphorus	...	0.045	...	0.045	...	0.045
Sulfur	...	0.050	...	0.050	...	0.050
Silicon	0.15	...	0.15	...	0.15	...

ages of the elements specified in Table 1. The analysis shall be made from a test sample taken preferably during the pouring of the cast or heat. The chemical composition thus determined shall conform to the requirements in Table 1.

5.3 Product Analysis—An analysis may be made by the purchaser from one axle representing each heat. The chemical composition thus determined shall conform to the requirements of 5.1 subject to tolerances included in Table 2. The sample for these analyses shall be taken from one end of the test axle or full-sized prolongation at a point midway between the center and surface. If drillings are taken, they shall be obtained using a 5/8-in. (16-mm) diameter drill or turnings may be taken from a tension test specimen.

6. Mechanical Requirements and Tests for Nonheat-Treated Axles

6.1 At the option of the manufacturer, either drop tests or tension tests (but normally not both) shall be performed to qualify each heat of steel.

6.2 Drop Test:

6.2.1 The test axle shall be so placed on supports 3 ft (914 mm) apart that the tup will strike it midway between the ends. It shall stand without fracture five blows from a tup of 2240 lb (1016 kg) falling from a height H such that H in feet equals the square of the diameter of the axle at the center in inches, $H = d^2$. The axles shall be rotated through 180° after the first and third blows.

6.2.2 Before the axle is drop tested, the center shall be calipered to the nearest 1/8 in. (3.2 mm) and the height of drop in feet, to the nearest 1/2 ft, shall not be less than the square of the actual diameter at the center in inches.

6.2.3 The permanent set produced by the first blow shall not exceed that given by the following equation in which L = length of axle in inches and d = diameter of axle at center in inches:

$$\text{Permanent set, max, in.} = L/1.9d - d/2 + 1/2$$

6.2.4 The drop test requirements for AAR untreated standard plain bearing axles Classes A to E are shown in Table 3. Drop test requirements for AAR standard roller bearing axles, Classes B to E, are shown in Table 4. Class F and all other plain or roller bearing axles over 6 1/2 in. nominal diameter at center are not subject to drop test (Section 1).

6.2.5 The permanent set is the difference between the distance from a straightedge to the middle point of the axle, measured before the first blow and distance measured in the same manner after the blow. The straightedge shall rest on the end collars or ends of the axle.

TABLE 2 Permissible Variations for Product Analysis (for Cross Section 100 in.² (645 cm²) and Under)

NOTE 1— Product cross-sectional area is defined as either:
(a) maximum cross-sectional area of rough machined forging (excluding boring),
(b) maximum cross-sectional area of the unmachined forging, or
(c) maximum cross-sectional area of the billet, bloom or slab.
Area taken at right angles to the axis of the original ingot or billet.

Element	Permissible Variations, Over the Maximum Limit or Under the Minimum Limit, %
Manganese	0.03
Phosphorus	0.008
Sulfur	0.008
Silicon	0.02

6.2.6 The temperature of the test axle shall be between 40 and 120°F (4 and 49°C).

6.2.7 If a drop test axle fails, a retest shall be permitted when it can be determined that the failure is caused by a mechanical condition of the drop-test machine (this condition must be corrected before a retest can be performed) or when it can be determined a mechanical flaw in the test axle was the reason for failure.

6.2.8 *Drop-Test Machine*—The anvil of the drop-test machine shall be supported on twelve springs, as shown in the AAR drawings,⁸ shall be free to move in a vertical direction, and shall weigh 17 500 lb (7938 kg). The radius of the striking face of the tup and of the supports shall be 5 in. (127 mm).

6.2.9 *Number of Drop Tests*—One axle, selected by the purchaser's inspector from each heat of steel, shall be drop tested; or the manufacturer may furnish a report of a drop test made previously on the same heat.

6.2.10 The manufacturer may substitute Grade F for Grade U axles. Such axles must be marked Grade F and comply with specification requirements for Grade F axles.

6.3 Tension Tests:

6.3.1 Grade U axles (AAR classes B through E) shall be held pending tensile test results and be released if the results conform to.

6.3.2 The yield point in Table 5 for Classes B through E may be determined as outlined in 7.1.4.

6.3.3 Tension test specimens shall be procured as indicated in 7.1.7.

6.3.4 One tension test is required for each untreated heat of axles for qualification of the heat.

6.3.5 If the results of the tension test do not conform to the requirements specified because a flaw developed in the test specimen during testing, a retest is permitted as indicated in 11.1.

6.3.6 If the results of the mechanical tests of any Grade U lot of axles do not conform to the requirements specified, the axle having the prolongation from which the tension specimen was taken will be drop tested. Failure of the drop test axle is covered in 6.2.7.

7. Mechanical Requirements and Tests for Heat Treated Axles

7.1 Tension Tests:

7.1.1 Grades F, G, and H axles shall conform to the requirements in Table 6.

7.1.2 The classification of axle forgings by size shall be determined by the finished diameter of the journal.

7.1.3 The diameter of the test prolongation of axle forgings shall be determined by the forged diameter of the journal.

7.1.4 The yield point in Table 6 for Grade F may be determined by the drop of the beam or halt of the gage of the testing machine or, by use of dividers. Where a definite yield point is not exhibited, the yield point method in 7.1.5 shall be used.

7.1.5 The yield point prescribed in Table 6 for Grades G and H axles shall be determined by a strain gage or extensometer reading to 0.0002 in. (0.005 mm). Yield point may be defined as the stress at 0.6 % total strain under load or as the stress at 0.2 % offset. The method described in Methods and Definitions A 370 shall be followed. After the yield point has been passed the extensometer may then be removed and the test continued to determine the tensile strength.

7.1.6 Tests shall be made only after final heat treatment.

7.1.7 Tension Test Specimens:

7.1.7.1 Tension test specimens shall be taken from the test prolongation or an axle in accordance with the provision in 7.2.

7.1.7.2 Unless otherwise specified, the axis of the specimen shall be located at any point midway between the center and surface of the axle or full-sized prolongation and shall be parallel to the axis of the axle.

7.1.7.3 The tension test specimen shall be machined to the form and dimensions shown in Fig. 5 of Methods and Definitions A 370 covering the standard round tension test specimen with a 2-in. (50.8-mm) gage length.

7.2 Prolongation for Test:

7.2.1 For test purposes, prolongations shall be attached to at least 5 % of the axles in each size classification of each heat in each heat-treating lot.

7.2.2 If axles with prolongations have been expended then axles may be used for test procurement.

7.3 *Microscopical Test*—For heat-treated axles (Grades F, G, and H):

7.3.1 A specimen, representing each size classification of each heat in each heat-treatment lot, shall be taken for microscopical test from the tension test specimen. This section for microscopical test shall be cut from the large undistorted portion of the tension test specimen in such a way as will give a face transverse to the axis of the axle.

7.3.2 The face shall be polished practically free of scratches and shall be etched to define the microstructure. The specimen shall be examined under a magnification of 100 diameters.

7.3.3 The entire specimen shall show a uniform, fine-grained structure, and shall have a grain size of 5 or finer as measured in accordance with Test Methods E 112.

7.4 Number of Tests:

7.4.1 Unless otherwise specified by the purchaser, mechanical tests for grades and sizes shown in Table 6 shall be made upon heat-treated axles as covered in 7.4.2 and 7.4.3.

⁸ Section B of the AAR Mechanical Division *Manual of Standards and Recommended Practices*; see Footnote 2.