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Designation: A 729 – 05

Standard Specification for Alloy Steel Axles, Heat-Treated, for Mass Transit and Electric Railway Service[1]

This standard is issued under the fixed designation A 729; 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 quenched and tempered alloy steel axles for mass transit and commuter cars in electric railway service.

1.2 This specification is for solid design roller bearing axles with machined bodies.

1.3 Various axle designs are used for this service including motor and nonmotor with either inboard or outboard journals.

1.4 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.

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

E 112 Test Methods for Determining the Average Grain Size

E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks

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

NOTE 1—References to analysis standards are for guidance only; other methods of equivalent accuracy may be used.

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity.

3.1.2 Purchaser's drawing showing complete details pertaining to dimensions, tolerances if more restrictive than those contained in this specification, degree of finish and location of stamping and any other information that will aid the manufacturer to furnish a satisfactory product.

3.1.3 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*—A sufficient discard shall be made to assure freedom from piping and undue segregation.

4.3 *Forging Practice*—The axle may be made direct from the ingot or from blooms, the total reduction from ingot or strand cast blooms to forging being not 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 that will prevent internal bursts and overheating.

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

4.4.4 Axles 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*:

[1] 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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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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4.5.1 *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.

4.5.2 *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.

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

4.6 *Straightening*—Straightening shall be done before machining and preferably at a temperature not lower than 950°F (510°C). Straightening performed at temperatures lower than 950°F shall be followed by stress relieving or applicable heat treatment.

5. Chemical Requirements

5.1 *Chemical Composition*—The steel shall conform to the chemical requirements specified in Table 1 or to the composition agreed upon by the manufacturer and the purchaser.

5.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorus, sulfur, and silicon. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements of 5.1.

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 ⅝-in. (16-mm) diameter drill or turnings may be taken from a tension test specimen.

6. Metallurgical Requirements

6.1 A specimen, representing 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.

6.2 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.

6.3 The entire specimen shall show a uniform, fine-grained structure of no. 5 or finer as measured in accordance with Test Methods E 112.

TABLE 1 Chemical Requirements

Element	Composition, %
Carbon, max	0.60
Manganese	1.30–1.70
Phosphorus, max	0.045
Sulfur, max	0.050
Silicon, min	0.15

TABLE 2 Permissible Variations for Product Analysis (for Cross Section 100 in.^{2}(645 cm^2) and Under)

NOTE—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	0.06
Phosphorus	0.008
Sulfur	0.008
Silicon	0.02

7. Tension Test Requirements

7.1 Tension tests shall be made in accordance with Test Methods A 370.

7.1.1 Axles shall conform to the requirements in Table 3.

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

7.1.3 The yield strength prescribed in Table 3 shall be determined by a strain gage or extensometer reading to 0.0002 in. (0.005 mm). Yield strength 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 Test Methods 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.

7.1.4 Tests shall be made only after final heat treatment.

7.1.5 *Tension Test Specimens*:

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

7.1.5.2 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.

7.1.5.3 The tension test specimen shall be machined to the form and dimensions shown in Fig. 6 of Test Methods A 370 covering the standard round tension test specimen with a 2-in. (50-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 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 *Number of Tests*:

7.3.1 Unless otherwise specified by the purchaser, mechanical tests shall be made as covered in 7.3.2 and 7.3.3.

7.3.2 Where batch-type furnaces are used, one test per heat per size classification is required, but each test shall represent no more than 70 axles. The axles represented by this test shall be called a heat-treatment lot.

7.3.3 Where continuous heat-treating furnaces are used, one test per heat per size classification is required, but each test shall represent no more than 70 axles. The axles represented by this test shall be called a heat-treatment lot.

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TABLE 3 Tensile Requirements

Test Prolongation Diameter									
Over		Not Over		Tensile Strength, min		Yield Strength, min		Elongation in 2 in or 50 mm, min, %	Reduction of Area, min, %
in.	mm	in.	mm	ksi	MPa	ksi	MPa		
4	102	7	178	100	690	65	450	20	45

7.3.4 If any test specimen fails because of a mechanical condition of the testing apparatus it may be discarded and another specimen taken.

7.4 *Retest*:

7.4.1 If the results of the mechanical tests of any lot do not conform to the requirements specified because a flaw developed in the test specimen during testing, a retest shall be allowed if the defect is not caused by ruptures, cracks, or flakes in the steel.

7.4.2 If the results of the mechanical tests of any lot do not conform to the requirements specified, the axles may be retreated, but not more than three additional times, and retests shall be made in accordance with Section 7.

8. Nondestructive Testing Requirements

8.1 *Ultrasonic Inspection*—The purpose of this inspection is to evaluate the quality of new axles (*1*) by determining end face to end face penetrability, and (*2*) by detecting discontinuities that may be harmful to axle service.

8.2 *Equipment*—Equipment requirements are as follows:

8.2.1 The instrument used must be a pulse echo type.

8.2.2 The instrument shall be operated at a 2¼-MHz frequency for both penetrability and discontinuity detection.

8.2.3 The instrument may use various transducers, namely, quartz 1 in. (25.4 mm) square or 1⅛ in. (28.6 mm) round, or barium titanate ¾ in. (19.1 mm) to 1 in. round. The transducer type is at the option of the axle manufacturer. Other transducers of similar response capability as those described may be used.

8.3 *Time of Inspection*—Inspection shall be made after heat treatment and after the axle ends are machined and centered, or at any subsequent stage of processing.

8.4 *Instrument Sensitivity and Scanning*:

8.4.1 *Instrument Sensitivity*:

8.4.1.1 The instrument sensitivity shall be adjusted to produce an indication of 20 % full screen height (FSH) from a reference test block manufactured from a quench and tempered axle forging having a ⅛-in. (3.18-mm) diameter, 1 in. (25.4 mm) deep, flat-bottomed hole drilled perpendicularly to and at a distance of 15 in. (381 mm) from the test end face of the axle section. The reference blocks shall have a surface finish of 80 to 125 µin. (2.03 to 3.18 µm).

8.4.1.2 At the sensitivity established in 8.4.1.1 the instrument shall detect in reference axles a flat-bottom hole of the size and distance specified in the table below.

Minimum Size (Flat-Bottom Holes) Detectable at Various Distances from End Faces

Test Distance to 15 in. (381 mm)	Test Distance 15 to 30 in. (381 to 762 mm)	Test Distance over 30 in. (762 mm)
⅛ in. (3.18 mm)	¼ in. (6.35 mm)	⅜ in. (9.52 mm)

8.4.2 *Scanning*:

8.4.2.1 Scanning shall be performed from both end faces, which shall have a surface finish of 125 µin. (3.18 µm) maximum. The scanning shall include the maximum end face area obtainable by manual or automated inspection techniques.

8.4.2.2 During scanning the amplitude of the indication from the end face opposite the search unit shall be monitored and the amplitudes of all discontinuity indications shall be evaluated with respect to the distance from the test surface (see 8.4.3 and 8.7.2).

8.4.3 *Distance-Amplitude Correction*— The amplitude of an ultrasonic indication must be considered in relation to its distance from the testing surface to evaluate its significance. This can be accomplished by an electronic device or by distance-amplitude curves (DAC), which are described in 8.7.2.

8.5 *Rejection*:

8.5.1 *Longitudinal Penetration*—Axles that do not produce a 40 % FSH back reflection from the end of face opposite the search unit shall be rejected or made acceptable by heat treatment.

8.5.2 *Discontinuity Test*—The axle shall be rejected if the amplitude of any discontinuity indication exceeds the indication levels obtained from the flat-bottom holes listed in the table under 8.4.1.2 considering the distance-amplitude correction as described in 8.4.3.

8.6 *Marking*—Axles that meet the ultrasonic inspection requirements of this specification shall be stamped with the letter "T" on the end face adjacent to the heat number or serial number.

8.7 *Additional Information*:

8.7.1 *Alternative Reference Standards*— Alternative references may be used to establish the test sensitivity if they are cross referenced with the reference test block described in 8.4.1.1. For example, alternative references for quenched and tempered axles that give equivalent sensitivity: (*1*) a 1-in. (25.4-mm) indication from a No. 1 series "A" Alcoa block, and (*2*) a 1½-in. (38.1-mm) indication from an ASTM Practice E 127 (latest edition) block No. 1-0300.

8.7.2 *Distance-Amplitude Correction*—The amplitude of an ultrasonic indication from a given discontinuity size varies with its distance from the test surface. To compensate for this effect, a distance-amplitude relationship is employed. The relationship can be established by an electronic device or by curves. Because the distance-amplitude relationship is influenced primarily by the ultrasonic transducer and instrument, it is necessary to relate this factor to the specific equipment used. Appropriate distance-amplitude curves shall be developed. A typical example is shown in Fig. 1 as related to the axle in Fig. 2.

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