Designation: A 729 – 93 (Reapproved 1999)

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:*

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

E 112 Test Methods for Determining the Average Grain Size[3]

E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks[4]

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings[3]

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*:

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.

---

[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 A01.06 on Steel Forgings and Billets.

Current edition approved Dec. 15, 1993. Published February 1994. Originally published as A 729–76. Last previous edition A 729–81(1988).

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

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.

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.

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

7.1.2 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.

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*:

TABLE 3 Tensile Requirements

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

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.

8.7.3 *Spurious Ultrasonic Indications from Contour Variations*—Because an axle varies in cross section it is

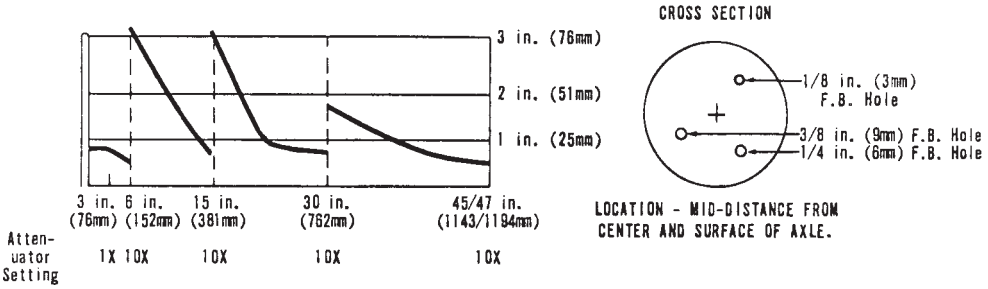
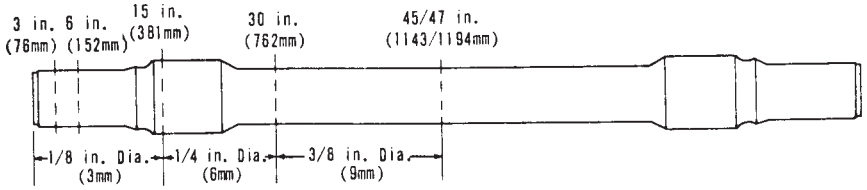


FIG. 1 Typical Distance-Amplitude Curve for Quenched and Tempered Axle as Determined with a Sperry Reflectoscope, Type UM Using a 1⅛ –in. (28.6-mm) Diameter 2.25-MHz Quartz Transducer



Flat Bottom Hole Sizes for Quenched and Tempered Axle

FIG. 2 Showing Location of Reference Holes in Axle

possible to produce spurious indications, particularly at changes of cross section. These must be recognized, and are not reason for rejection. It is not practical to define these indications as responses from axle contours.

8.7.4 *Near-Field Resolution*—It should be recognized that detection of discontinuities near the test surface is limited by the ultrasonic test frequency. In the case of quenched and tempered axles, this is approximately 1 in. (25.4 mm) from the test surface.

9. Dimensional Tolerances

9.1 *Length and Diameter*:

9.1.1 For axles ordered to finished length, the overall length shall not be less than the specified minimum length nor more than 1/16 in. (1.6 mm) over.

9.1.2 For axles ordered for finished-end facing by the purchaser, the overall length shall range from ⅛ in. (3.2 mm) to ¼ in. (6.4 mm) over the specified minimum length.

9.1.3 For any other axles ordered to final length and not covered by the above classifications, the overall length shall not be less than the specified minimum length nor more than ⅛ in. (3.2 mm) over.

9.1.4 The specified minimum length shall be the nominal overall final length less any allowable tolerances.

9.1.5 Rough-machined areas, either the entire axle or designated parts thereof, shall be ⅛ in. (3.2 mm) to ¼ in. (6.4 mm) over the finished diameter; in the case of motor axles having a conglomerate of diameters for the seats for wheel, gear, gear case bearing, and grounding ring the entire area shall be rough machined to a single diameter ⅛ to ¼ in. over the finished diameter of the segment having the largest diameter. Longitudinally ⅛ to ¼ in. of metal shall be allowed at each change of cross section for finish machining.

9.1.6 The smooth-machined body shall be to the specified size with no more than ⅛ in. (3.2 mm) over on the diameters and shall have no more than ⅛ in. allowance longitudinally at each change of cross section.

10. Workmanship and Finish

10.1 Axles shall conform to the size, shape, and finish shown on the purchaser's drawing and unless otherwise specified shall have center holes with clearance drilled for lathe center points and not counterbored. All machining shall be done in a workmanlike manner.

10.2 Where a smooth-machined finish on the body (9.1.6) is specified it shall be to a maximum of 250 µin. (6.35 µm). Rough machining shall be free of excessively rough ridges and coarse chatter marks.

10.3 Finish machined axle surfaces shall be free of injurious imperfections as described in Annex A1.

10.4 The interpretation of injurious imperfections in axles shall comply with Annex A1 to this specification.

11. Inspection

11.1 Inspection of the axles shall be made as agreed upon by the purchaser and seller as part of the purchase contract.

11.2 The inspector representing the purchaser shall have entry, at all times while the work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the axles ordered. The manufacturer shall afford the inspector all reasonable facilities and necessary assistance to satisfy him that the material is being furnished in accordance with their specification. Tests and inspection for acceptance shall be made at the place of manufacture.

11.3 The purchaser may make tests to cover the acceptance or rejection of the axles in his own laboratory or elsewhere.

11.4 The purchaser's representative shall examine each axle for workmanship, imperfections, and conformity to the dimensions given on the order or drawing. If imperfections are found in this inspection that the manufacturer can remedy, he may correct such imperfections.

12. Rejection

12.1 Any axle that fails to meet the requirements of this specification shall be rejected.

12.2 Axles that show injurious imperfections subsequent to their original inspection and acceptance at the manufacturer's works, or elsewhere, shall be rejected and the manufacturer shall be notified.

13. Rehearing

13.1 Samples of axles tested in accordance with this specification that represent rejected material shall be held 14 days from the date of the test report. In case of dissatisfaction with the results of the tests the manufacturer may request a rehearing within that time.

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the test results shall be furnished at the time of shipment.

15. Product Marking

15.1 Axles shall be legibly cold-stamped with letters and figures not less than ¼ in. (6.4 mm) high. This stamping shall be on the end face or under cut shoulder at the end of the journal as shown on the purchaser's drawing. It should include month and year made, manufacturer's name or trademark, heat number, and serial number.

15.2 In addition to the above required markings, bar code tags may be applied to the axles. If these tags are applied, it is recommended that Bar Code 39 be used. The size and location of the tags, as well as the information to be included, shall be agreed upon by the purchaser and the manufacturer.

16. Keywords

16.1 axles; rail applications; steel forgings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser. Details shall be agreed upon by the manufacturer and the purchaser.

S1. Macroscopical Tests

S1.1 The prolongation from the largest axle in each heat shall be sawed normal to the axis of the axle and shall then be split longitudinally. The transverse and the longitudinal face shall be etched for macroscopical examination. Reference shall be made to Method E 381.

ANNEX

(Mandatory Information)

A1. INTERPRETATION OF IMPERFECTIONS CONSIDERED INJURIOUS IN AXLES

A1.1 General

A1.1.1 The conditions that have been most difficult for inspectors to evaluate are light lines visible to the normal unaided eye, variously described as actual seams, hairlines, stringers, shadow seams, ghost lines, etc., which appear after the axles have been finish machined and burnished or ground. It is, therefore, advisable to describe these conditions in more detail.

A1.1.2 The interpretation of injurious imperfections as enumerated below is not to be considered as precluding other unforeseen or objectionable conditions not specifically listed. The right of the purchaser is reserved to reject temporarily such axles and make final settlement on the basis of further negotiations between representatives of the manufacturer and the purchaser who are especially qualified to decide such questions.

A1.1.3 Any transverse or circumferential seams, cracks, or laps of indeterminate depth on the axle surfaces other than the discolorations listed in A1.1.4 regardless of their location, are considered to be injurious and are cause for rejection without further machining.

A1.1.4 Ghost lines, shadow marks, or other similar discolorations, visible to the normal unaided eye that are not actual separations in the metal are not considered injurious regardless of location.

A1.1.5 Any longitudinal discontinuity, variously termed hairline, stringer, or fine seam, in machined fillets is considered to be injurious and is cause for rejection without further conditioning.

A1.2 Journals and Dust Guards

A1.2.1 Fine longitudinal discontinuities on the finished (burnished or ground) surfaces variously termed hairlines, stringers, or fine seams are not considered injurious if they meet the following conditions:

A1.2.1.1 Must not extend into fillets.

A1.2.1.2 Must not be over ¾ in. (19.1 mm) long individually in the journal nor ½ in. (12.7 mm) long individually in the dust-guard seat.

A1.2.1.3 Total length of such imperfections over ¼ in. (6.4 mm) long must not exceed 2 in. (50.8 mm) in any one end of the axle.

A1.3 Wheel Seats, Gear Seats, Gear Case Bearing Seat, and Grounding Ring Seats

A1.3.1 Longitudinal discontinuities on the finished-machined surface of wheel and gear seats, variously termed hairlines, stringers, fine seams, tight seams, surface imperfections, etc., are not considered injurious if they meet the following conditions:

A1.3.1.1 Must not extend within 1½ in. (38.1 mm) of either end of the seats covered in this section.

A1.3.1.2 Must not be over ½ in. (12.7 mm) long individually.

A1.3.1.3 Total length of such imperfections, ¼ in. (6.4 mm) to ½ in. (12.7 mm) long, must not exceed 3 in. (76.2 mm) in any one end of the axle.

A1.4 Areas Between Attachment Seats (Body) Specified to Be Smooth Machined

A1.4.1 Longitudinal discontinuities on the smooth machined body, variously termed hairlines, stringers, or fine seams, are not considered injurious if they meet the following conditions:

A1.4.1.1 Must not extend into fillets at the ends of the body.

A1.4.1.2 Must not be over ½ in. (12.7 mm) long individually.

A1.4.1.3 Total length of such imperfections, ¼ in. (6.4 mm) to ½ in. (12.7 mm) long, must not exceed 1½ in. (38.1 mm) in any 12 in. (305 mm) of body length.

A1.4.1.4 Axles containing longitudinal discontinuities in the body in excess of those described in A1.4.1.2 and A1.4.1.3 may be reconditioned by grinding or machining provided the diameter is not reduced below the specified minimum.