Designation: A729/A729M – 17 (Reapproved 2022)

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

This standard is issued under the fixed designation A729/A729M; 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 heat-treated carbon and alloy steel axles for mass transit and commuter cars in electric and locomotive hauled 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 non-motor with either inboard or outboard journals.

1.4 Supplementary requirements including those in the general requirements of Specification A788/A788M 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 Unless the order specifies the applicable "M" specification designation, the axles shall be furnished to the inch-pound units.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A29/A29M Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought

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

E112 Test Methods for Determining Average Grain Size

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E1426 Test Method for Determining the X-Ray Elastic Constants for Use in the Measurement of Residual Stress Using X-Ray Diffraction Techniques

2.2 *Other Standard:*[3]

AAR Manual of Standards and Recommended Practices Wheels and Axles, Section G

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *class*—the set of chemical requirements for the steel to be used for the axles to be supplied.

3.1.2 *grade*—the designation of the specific set of mechanical properties selected for the axle(s) to be supplied. The grade is selected based on the axle design and service requirements.

3.2 Users of this specification are cautioned that the above terms may be used differently in other industry standards and purchaser ordering information. Producers and purchasers should ensure that both parties are in agreement regarding the specific mechanical and chemical requirements for the axles to be supplied.

4. Ordering Information

4.1 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

[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.

[3] Available from Association of American Railroads (AAR), 425 3rd St., SW, Washington, DC 20024, http://www.aar.org.

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

4.1.1 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, then the requirements of this specification shall prevail.

4.2 In addition to the ordering information required by Specification A788/A788M, the purchaser should include with the inquiry and order a detailed drawing, sketch or written description of the axle showing complete details pertaining to dimensions, grade, tolerances if more restrictive than those contained in this specification, degree of finish, and location of stamping.

4.2.1 Unless the purchaser designates a class in the purchase order or contract, the class used shall be at the producer's discretion.

4.3 Supplementary requirements, if needed, including any that are appropriate from Specification A788/A788M.

5. Chemical Requirements

5.1 *Chemical Composition*—The steel shall conform to the chemical requirements specified in Table 1.

5.2 Seven classes of steel are included in Table 1. Unless otherwise specified by the purchaser, the choice of steel class to be used for any given axle grade is at the option of the producer.

5.3 Classes F, G, and H are referenced in the AAR Manual of Standards and Recommended Practices, Section G, Standard M-101 as Grades F, G, and H and unspecified element additions to these classes shall be reported.

5.4 The purchaser may use the requirements of Specification A788/A788M for a product analysis.

6. Manufacture

6.1 *Forging Practice*—The axle may be made direct from the ingot or from blooms, the total reduction in cross-sectional area from ingot or strand cast blooms to axle forging being not less than 3 to 1, unless otherwise specified.

6.2 *Cooling and Heating:*

6.2.1 Blooms and ingots shall be reheated for forging in a manner that will prevent internal bursts and overheating.

6.2.2 Axles that are heat-treated directly from forging shall be cooled below 1000 °F [538 °C] and fully transformed before the start of any reheating operation.

6.3 *Heat Treatment:*

6.3.1 Axles shall be heat-treated in accordance with Table 2.

6.3.2 Grades A and F shall be heat-treated by double normalizing, followed by tempering. After heating to and holding at an appropriate temperature in the austenitic range, the axles shall be cooled in still air to under 500 °F [260 °C]. They shall then be reheated into the austenitic range to the same or a lower temperature and again air cooled to under 500 °F [260 °C]. A furnace charge thus treated is termed a double normalizing charge. After cooling, the axles are then tempered as in 6.3.4.

6.3.3 All other Grades shall be liquid quenched and tempered. After heating to and holding at an appropriate temperature in the austenitic range, the axles shall be quenched in a suitable medium. A furnace charge thus treated is termed a quenching charge. Following quenching, the axles are tempered as in 6.3.4.

6.3.3.1 Grade H axles require a normalizing cycle prior to the quenching heat treatment.

6.3.3.2 At the manufacturer's option for Grade G, a normalizing cycle may precede austenitizing for the liquid quenching operation.

6.3.4 *Tempering*—Axles shall be reheated gradually to and held at an appropriate subcritical temperature, and shall then be allowed to cool under uniform conditions. A furnace charge thus treated is termed a tempering charge.

6.3.4.1 When required by Supplementary Requirement S2, axles that have been rough machined after heat treatment shall be heated to and held for an appropriate time at a temperature that is less than the last tempering temperature by at least 50 °F [10 °C]. Then the axles shall be quenched directly into water with the axle length vertical.

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

6.4 *Straightening*—Straightening, if necessary, shall be done before machining and at a temperature between 950 °F [510 °C] and 100 °F [55 °C] below the final tempering temperature. Straightening performed at temperatures lower than 950 °F [510 °C] shall be followed by stress relieving or applicable heat treatment. These requirements do not apply to straightening performed prior to final heat treatment.

TABLE 1 Chemical Requirements

	Composition %					
	Class A	Class B	Class C	Class D[A]	Class F	Classes G & H
Carbon	0.43-0.48	0.28-0.33	0.38-0.43	0.28-0.33	0.45-0.59	...
Manganese	0.75-1.00	0.40-0.60	0.75-1.00	0.70 0.90	0.70-1.00	0.60-0.90
Phosphorous	0.035 max	0.035 max	0.035 max	0.035 max	0.035 max	0.035 max
Sulfur	0.040 max	0.040 max	0.040 max	0.040 max	0.040 max	0.040 max
Silicon	0.15-0.35	0.15-0.35	0.15-0.35	0.15-0.35	0.15 min	0.15 min
Nickel	...	...	...	0.40-0.70	B	B
Chromium	0.20-0.35	0.80-1.10	0.80-1.10	0.40-0.60	B	B
Molybdenum	...	0.15-0.25	0.15-0.25	0.15-0.25	B	B
Vanadium	0.08 max	0.08 max	0.08 max	0.08 max	0.02-0.08	B
Aluminum	0.04 max	0.04 max	0.04 max	0.04 max	B	B

[A] Class D meets the requirements of SAE 8630 alloy steel.
[B] The manufacturer may add these elements as necessary to meet the specified mechanical properties after the required heat treatment. The actual chemistry shall be reported.

TABLE 2 Heat Treatment and Tensile Requirements

Grade	Heat Treatment	Size, Solid Diameter or Thickness, in. [mm]		Tensile Strength, psi [MPa], min	Yield Strength at 0.2 %, min, psi [MPa]	Elongation, in 2 in. [50 mm], min	Reduction of Area %, min
		Over	Not Over				
A, F	Double Normalize and Temper	...	8 [200]	88 000 [605]	50 000 [345]	22	37
		8 [200]	12 [300]	86 000 [595]	48 000 [330]	21	35
B, C, D	Quench and Temper	...	4 [100]	105 000 [725]	70 000 [485]	24	45
		4 [100]	7 [175]	100 000 [690]	65 000 [450]	22	45
		7 [175]	10 [250]	85 000 [585]	50 000 [345]	20	40
		10 [250]	...	82 500 [570]	48 000 [330]	19	35
G	Quench and Temper	...	4 [200]	90 000 [620]	55 000 [380]	20	39
		4 [100]	7 [175]	85 000 [585]	50 000 [345]	20	39
		7 [175]	10 [250]	85 000 [585]	50 000 [345]	19	37
H	Normalize, Quench, and Temper	...	7 [175]	115 000 [795]	75 000 [520]	16	35
		7 [175]	10 [250]	105 000 [725]	65 000 [450]	18	35

7. Metallurgical Requirements

7.1 A specimen, representing each heat in each heat-treatment lot, shall be taken for the heat treated grain size determination in accordance with Test Methods E112. This sample section may 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.

7.2 The entire specimen shall show a uniform, fine-grained structure of No. 5 or finer as measured in accordance with Test Methods E112.

7.3 Alternatively, the austenitic fine grain requirements of Specification A29/A29M may be used in lieu of the heat-treated grain size described in 7.1. In this case, the grain refining elements used shall be included in the heat analysis results.

8. Tension Test Requirements

8.1 Tension tests shall be taken from the test prolongation or from an axle in accordance with 8.2.

8.1.1 Axles shall conform to the requirements in Table 2.

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

8.1.3 Tests shall be made only after final heat treatment. Final heat treatment for purposes of this requirement includes the subcritical quench required by Supplementary Requirement S2, but does not include post-straightening stress relief heat treatment per 6.4.

8.1.4 The longitudinal 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.

8.2 *Prolongation:*

8.2.1 To ensure that sufficient material is available for test purposes, prolongations shall be attached to at least 5 % of the axles in each heat in each heat-treating lot.

8.2.2 If axles with prolongations have been expended, then axles without prolongations may be used to prepare test samples. The samples shall be removed from the bearing journal diameter and radially located per 8.1.4.

8.3 *Number of Tests:*

8.3.1 Unless otherwise specified by the purchaser, mechanical tests shall be made as covered in 8.3.2 and 8.3.3.

8.3.2 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.

8.3.3 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.

8.4 *Retest:*

8.4.1 If the results of the mechanical tests of any lot do not conform to the requirements specified, the axles may be

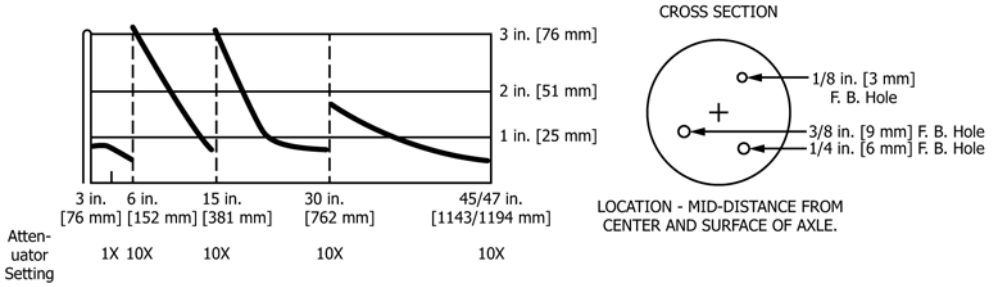

FIG. 1 Typical Distance-Amplitude Curve for a Heat-Treated Axle Using a 1⅛ in. [28.6 mm] Diameter 2.25 MHz Quartz Transducer

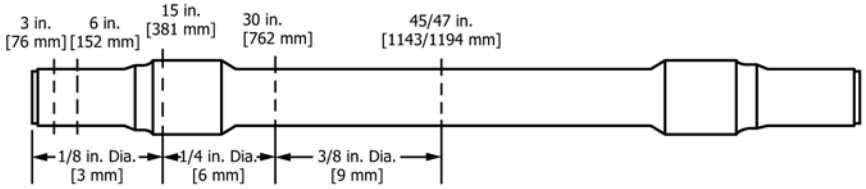

FIG. 2 Location of Reference Holes in an Axle—Flat Bottom Hole Sizes for a Heat-Treated Axle

retreated, but not more than three additional times and retests shall be made in accordance with Section 8.

9. Nondestructive Testing Requirements

9.1 *Ultrasonic Examination*—The purpose of this examination 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.

9.2 *Method*—The axle examination shall conform to Practice A388/A388M.

9.3 *Time of Examination*—Examination shall be made after heat treatment and after the axle end faces have been machined square, and preferably before being centered.

9.4 *Instrument Sensitivity and Scanning:*

9.4.1 *Instrument Sensitivity:*

9.4.1.1 The instrument sensitivity shall be adjusted to produce an indication of 20 % full screen height (FSH) from a reference test block manufactured from a representative heat-treated axle forging having a ⅛ in. [3.20 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 µin. to 125 µin. [2.03 µm to 3.20 µm] and detect in reference axles a flat-bottom hole of the size and distance specified in the table below.

9.4.1.2 At the sensitivity established in 9.4.1.1, the instrument shall be capable of detecting a flat-bottom hole of the size and distance specified below:

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

Test Distance to 15 in. [381 mm]	Test Distance 15 in. to 30 in. [381 mm to 762 mm]	Test Distance over 30 in. [762 mm]
⅛ in. [3.20 mm]	¼ in. [6.35 mm]	⅜ in. [9.52 mm]

9.4.2 *Scanning:*

9.4.2.1 Scanning shall be performed from both end faces, which shall have a surface finish of 125 µin. [3.20 µm] maximum, and from the outside diameter (OD). The scanning shall include the maximum end face area obtainable by manual or automated inspection techniques.

9.4.2.2 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 9.4.3 and 9.7.2).

9.4.3 *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 9.7.2.

9.4.4 In addition to the reportable conditions of Practice A388/A388M, indications exceeding the resulting back reflection shall be reported.

9.5 *Acceptance:*

9.5.1 *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.

9.5.2 *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 9.4.1.2 considering the distance-amplitude correction as described in 9.4.3.

9.5.3 *Radial Scan*—An axle forging shall be unacceptable if from the radial scan from the OD one or more reflections are present producing indications accompanied by complete loss of back reflection not attributable to geometric configuration. For this purpose, a back reflection of less than 5 % of full screen height shall be considered loss of back reflection.

9.6 *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.

9.7 *Additional Information:*

9.7.1 *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.

9.7.2 *Spurious Ultrasonic Indications from Contour Variations*—Because an axle varies in cross section it is possible to produce spurious indications, particularly at