Designation: A504/A504M – 18 (Reapproved 2023)

Standard Specification for Wrought Carbon Steel Wheels[1]

This standard is issued under the fixed designation A504/A504M; 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 one-wear, two-wear, and multiple-wear wrought carbon steel wheels for locomotives and cars, designated Classes L, A, B, and C, heat-treated, wheels.

1.2 The service for which the various classes are intended is as follows:

1.2.1 Class B or C wheels shall be used for freight cars in interchange service.

1.2.2 Class B or C wheels are recommended for use on locomotives.

1.2.3 For passenger car service, the various classes are intended generally as follows:

1.2.3.1 *Class L*—High speed with more severe braking conditions than other classes and light wheel loads.

1.2.3.2 *Class A*—High speed with more severe braking conditions, but moderate wheel loads.

1.2.3.3 *Class B*—High speed service with severe braking conditions and heavier wheel loads.

1.2.3.4 *Class C*—(*1*) Service with light braking conditions and heavier wheel loads.

1.2.3.5 *Class C*—(*2*) Service with heavier braking conditions where off-tread brakes are employed.

1.3 Supplemental requirements are provided for use where additional testing or additional restrictions are required by the purchaser. Supplementary requirements included in Specification A788/A788M may also be specified by the purchaser for forgings ordered to this specification. Any supplemental requirements apply only when specified in the purchase order.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.5 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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]

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

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E399 Test Method for Linear-Elastic Plane-Strain Fracture Toughness of Metallic Materials

2.2 *SAE Documents:*[3]

SAE J 442 Test Strip, Holder and Gage for Shot Peening

SAE J 443 Recommended Practice for Procedures for Using Standard Shot Peening Test Strip

SAE J 827 Recommended Practice for Cast Steel Shot

SAE J 2277 Shot Peening Coverage Determination

2.3 *AAR Standard:*[4]

AAR M-107/M-208 Wheels, Carbon Steel

[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.

Current edition approved March 15, 2023. Published April 2023. Originally approved in 1964 to replace A57 and A186. Last previous edition approved in 2018 as A504/A504M – 18. DOI: 10.1520/A0504_A0504M-18R23.

[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 SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

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

3. Terminology

3.1 *Definitions*—(The following terminology is unique to the Railroad industry).

3.1.1 *multi-wear wheel, n*—wheel that has sufficient metal in the rim for more than two turnings before it must be replaced.

3.1.2 *one wear wheel, n*—wheel that has only sufficient metal for the tread to be worn once to condemnable high flange or thin rim condition.

3.1.2.1 *Discussion*—There is insufficient metal remaining in the rim to allow turning or truing of the wheel by machining to the standard tread contour and still have enough metal in the rim to support service loads. Wear refers to the amount of metal on the wheel rim when new, in excess of the condemning thickness of the wheel design.

3.1.3 *tape size, n*—railroad method of expressing wheel circumference based on measurement with a steel tape placed around the tread at the taping line.

3.1.3.1 *Discussion*—For each wheel size there is a calibrated tape. Tape size is expressed as the number of one-eighth increments in circumference from the standard tape for the wheel being measured. An AAR approved tape has four lugs to correctly space the tape from the rim so that the tape will measure on the taping line. The tapeline is always $1^{11}/_{16}$ in. from the gage point, which is how the tape gage was designed. Some wheel profiles define the tapeline as $3^{1}/_{16}$ in. from the back rim face; this may not be correct.

3.1.4 *two-wear wheel, n*—wheel that has more metal in the rim than a one-wear wheel so that the tread can be worn to condemnable condition and then be restored by machining to the original tread contour. Thus, two tread wear lives are obtained from this wheel.

4. Ordering Information and General Requirements

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

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

4.2 Orders for wheels under this specification shall include the following additional information as appropriate:

4.2.1 Class (see Table 1),

4.2.2 Full identification of wheel design, including tread and flange contour, and dimensional drawing if required,

4.2.3 Rough bore size,

4.2.4 Wear category,

4.2.5 Alternate magnetic particle acceptance criteria (15.2.3.2),

4.2.6 Intended service (see Section 1),

4.2.7 Supplementary requirements from this specification, if required, and

4.2.8 Supplementary requirements from Specification A788/A788M, if required.

5. Chemical Requirements

5.1 *Heat Analysis:*

5.1.1 The steel shall conform to the requirements for chemical composition shown in Table 1.

6. Manufacture

6.1 *Discard*—Sufficient discard shall be made from each ingot to ensure freedom from piping and undue segregation.

6.2 *Temperatures*—During the manufacture, necessary care in the regulation of temperature gradients shall be exercised to obtain the mechanical properties to be expected from the chemical composition and mechanical work. Immediately after the last hot fabricating operation (coning or dishing), all wheels shall be allowed to cool to a temperature below the critical range. The cooling shall be controlled to prevent injury by too rapid cooling.

7. Heat Treatment

7.1 Heat treatment shall consist of treatment of the rim only.

7.2 *Rim-Quenching Treatment*—The entire wheel shall be reheated uniformly to the proper temperature to refine the grain

TABLE 1 Chemical Requirements

Element %	Class L	Class A	Class B	Class C
Carbon	0.47 max	0.47–0.57	0.57–0.67	0.67–0.77
Manganese	0.60–0.90	0.60–0.90	0.60–0.90	0.60–0.90
Phosphorous, max	0.030	0.030	0.030	0.030
Sulfur	0.005–0.040	0.005–0.040	0.005–0.040	0.005–0.040
Silicon	0.15–1.00	0.15–1.00	0.15–1.00	0.15–1.00
Nickel, max[A]	0.25	0.25	0.25	0.25
Chromium, max[A]	0.25	0.25	0.25	0.25
Molybdenum, max[A]	0.10	0.10	0.10	0.10
Vanadium, max[A]	0.060	0.060	0.060	0.060
Copper, max	0.35	0.35	0.35	0.35
Aluminum, max	0.060	0.060	0.060	0.060
Titanium, max	0.03	0.03	0.03	0.03
Columbium, max (Niobium)[B]	0.05	0.05	0.05	0.05

[A] The manufacturer may exceed the noted maximum limits for nickel, chromium, molybdenum, or vanadium provided that the following relationship (AAR M-107/M-208) is met:

$$930 - [570 \times \%C] - [80 \times \%Mn] - [20 \times \%Si] - [50 \times \%Cr] - [30 \times \%Ni] - [20 \times (\%Mo + \%V)] > 390$$

[B] Columbium (Cb) and Niobium (Nb) are alternate names for Element 41 in the Periodic Table of the Elements.

and then the rims shall be quenched. Following quenching, the wheel shall be charged into a furnace for tempering to meet the requirements of Section 13, and subsequently cooled under controlled conditions.

7.3 For production of railroad wheels, the flow of water during rim spray quenching shall not be interrupted, once started, until quenching is completed. Similarly, immersion quenching of the rim shall not be interrupted. For non-railroad wheels, water flow may be interrupted per Supplementary Requirement S7.

8. Shot Peening

8.1 *Scope*—The plate surfaces (area between the hub and rim) of all wheels shall be shot-peened in accordance with the following requirements:

8.2 *Requirements:*

8.2.1 *Shot*—The shot shall be No. 660 or larger hardened steel as specified in SAE J 827.

8.2.2 *Shot Size Control*—The peening machines shall be equipped with a separator for continuously removing broken shot. Sufficient new shot shall be added to ensure that a minimum of 85 % of No. 550 or larger shot (retained on a #14 screen as defined by Specification E11) is maintained in the machines at all times.

8.2.3 *Peening Intensity*—The peening intensity shall be sufficient to produce an average arc height of not less than 0.010 Almen C-2 on the front plate near the hub fillet and on the back plate near the rim fillet of wheels of the standard design, and at back plate hub fillet and front plate rim fillet of the reverse plate design. The area to be peened is defined as the plate area extended approximately one half of the way into the hub and rim fillet radii on the front and on the back of the wheel.

8.2.4 *Arc Height Measurement*—Measurements of arc height shall be made in accordance with SAE J 442 or SAE J 443.

8.2.5 *Coverage*—The minimum peening time shall be sufficient to ensure that full coverage is attained on the Almen C strip as defined in the Alternate Procedure of SAE J 2277.

8.2.6 *Sequence*—Shot peening shall be performed on all wheels and after any corrective surface preparation in the plate area. Plate area is defined in 8.2.3. Peening may be performed prior to dimensional inspection and nondestructive examination.

8.2.7 *Portable Peeners*—A portable peening device may be used to re-peen small reconditioned areas (no larger than about 2 in. by 3 in. [50 mm by 75 mm]) on wheel plate surfaces excluding the critical fillet areas (front hub and back rim). The portable equipment must be capable of peening an Almen C-2 Strip to develop the required average arc height of not less than 0.010 in. [0.203 mm] with a reasonable time of peening. Peening time of wheel plates must be at least as long as the time required to develop the 0.010 in. arc height. The equipment must be tested on an Almen C Strip each 8 h shift that the portable peener is used. A record of the Almen C test results shall be maintained.

8.3 *Quality Assurance Provisions:*

8.3.1 *Wheel Surface Condition*—The peened appearance of rim and hub shall not be cause for rejection.

8.3.2 *Frequency of Test*—Arc height determinations shall be made on Almen strips attached to a test wheel at the beginning and end of each production run but not less than once in each eight operating hours.

8.3.3 *Retest*—If a test fails to meet the arc height requirements of 0.010 Almen C-2, two retests shall be made. These retests shall be averaged with the first determination. The average shall be not less than 0.010 and no more than one value of the three shall be less than 0.010.

8.3.4 *Repeening*—When test values fail to meet the provisions of 8.3.3, corrective action shall be initiated and satisfactory test values secured before proceeding with production peening. If the average Almen value is less than 0.010, all the wheels peened since the last satisfactory test shall be repeened with full exposure.

9. Retreatment

9.1 Any wheel failing to meet the requirements of Section 13 may be retreated and tested in accordance with 13.1 and 13.2.

10. Mating

10.1 Wheels shall be measured and marked to the lower tape number until the next graduation is reached. Wheels shall be shipped in pairs of the same measured tape size.

NOTE 1—The tables of tape sizes may be referred to in the Wheel and Axle Manual of the Association of American Railroads.

11. Permissible Dimensional Variations

11.1 The wheels shall conform to the permissible dimension variations specified in Table 2. When the permissible dimension variations in Table 2 allow a certain percentage of the wheels to vary by a given amount from standard dimensions for tape size, the percentage of such wheels shipped by any manufacturer shall not exceed this percentage during a calendar year. No individual purchaser may receive more than this percentage in daily shipments of such wheels except by agreement with the manufacturer.

12. Finish

12.1 Wheels shall be rough bored and shall not have black spots in the rough bore. The front and back hub faces of wheels shall be parallel to the plane of the vertical reference line and shall be machined.

12.2 Wheels shall be machined and finished smooth without excessive tool chatter.

12.3 Wheels shall be given a thorough surface examination and gauging at the place of manufacture before being offered for inspection. They shall have a workmanlike finish and must be free of conditions likely to develop in or cause removal from service.

12.4 Wheels shall not be covered with any substance to such an extent as to hide defects.

12.5 "As forged" surfaces shall be free of abrupt changes in section or grooves and in a clean condition free of scale prior

TABLE 2 Permissible Variations in Wheel Dimensions

Wheel Dimensions	Narrow Flange Type		Wide Flange Type	
	in.	mm	in.	mm
Flange:				
Height of flange	+1/16 –0	+1.5 –0	+1/16 –0	+1.5 –0
Thickness of flange	+1/16 –0	+1.5 –0	+1/32 –3/32	+0.8 –2.4
Rim:				
Tape sizes, less than 44 in. [110 cm]	+14 –0[A]	+14 –0[A]	+14 –0[A] 5 % –5[B]	+14 –0[A] 5 % –5[B]
Inside diameter (back face of rim)				
(x) maximum governed by rim thickness and tape size	(x) – 3/8	(x) –10	(x) –3/8	(x) –10
Inside diameter (front face of rim)				
Maximum variation from back face diameter	+0 –1/4 [C,D]	+0 –6[C,D]	±1/4 [C,D]	±6[C,D]
Thickness of rim (measured with AAR steel wheel gauge, or equivalent)	1/8	3	1/8	3
Corner at inside diameter of back rim face, radius, max (sharp corner preferable)	1/32	0.8	1/32	0.8
Rotundity, opening in ring gauge, max	±1/8	±3	±1/8	±3
Width of rim				
Plane of back face, distance from straightedge:				
Over entire rim face, max	. . .	. . .	1/16	1.5
Over rim face more than 1 1/4 in. [30 mm] from inside edge, max	1/32	0.8	. . .	. . .
Plate:				
Thickness of plate (may vary)	–0	–0	–0	–0
Hub:				
Diameter of hub	+1 –0	+25 –0	+1 –0	+25–0
Wall thickness maximum variations:				
Outer surface machined	1/8	3	. . .	. . .
Not machined	3/8	10	3/8	10
Length of hub	±1/8	±3	±1/8	±3
Projection of hub (back rim face to back hub face)	±1/8	±3	±1/4	±6
Bore:				
Diameter of bore:				
Rough bore (finished bore not specified)	±1/16	±1.5	±1/16	±1.5
Rough bore (1/4 in. [6 mm] less than finished bore)	+1/16 –1/8	+1.5 –3	+1/16 –1/8	+1.5 –3
Eccentricity of bore—between rough bore and tread, max	1/16 [E]	1.5[E]	1/16 [E]	1.5[E]

[A] Tape sizes are not in inches or millimetres. The tables of tape sizes may be referred to in the Wheel and Axle Manual of the Association of American Railroads, latest edition.
[B] No shipment shall exceed this percentage except by agreement with the manufacturer.
[C] This does not apply when the design incorporates unequal front and back rim IDs.
[D] Ninety-five percent shall not be less than specified. Five percent may be 1/8 in. [3 mm] less than specified. One hundred percent shall not vary more than 1/8 in. [3.2 mm] on any two radii in any one wheel.
[E] Five percent of wheels delivered may be over 1/16 in. [1.5 mm] total dial indicator reading (TDIR), and these must not exceed 3/32 in. [2.25 mm] TDIR.

to final inspection. Where corrective machining or grinding has been employed, such surfaces shall not exceed a roughness of 500 µin. [12.7 µm] prior to final shot peening, and a uniform transition from the machined or ground surface into the plane of the "as forged" surface must be provided.

13. Mechanical Requirements

13.1 The Brinell hardness of the rim, when measured in accordance with the requirements of 13.2, shall show the values as listed in Table 3.

13.2 *Method of Measurement*—Measurement shall be made on the front face of the rim with the edge of the impression not less than 3/16 in. [5 mm] from the radius joining face and tread. Before making the impression, surface decarburization shall be removed from the front face of the rim at the point chosen for measurement. The surface of the wheel rim shall be properly prepared to permit accurate determination of hardness.

TABLE 3 Rim Hardness Values

Class	Minimum Hardness, HB	Maximum Hardness, HB
L	197	277
A	255	321
B	302	341
C	321	363

13.3 *Number of Tests:*

13.3.1 Where continuous heat-treating furnaces are used, Brinell hardness measurements shall be made on 10 % of the wheels from each heat. Where batch-type heat-treating furnaces are used, Brinell hardness measurements shall be made on 10 % of the wheels from each heat-treatment lot, provided that at least one wheel is selected for test from each heat represented in the heat treatment lot. For either process, when there are less than 20 wheels from a heat, a minimum of two wheels shall be checked for hardness except when there is only one wheel from a heat, in which case a Brinell hardness measurement shall be made on the one wheel.

13.3.2 If all the wheels tested meet the requirements of Section 13, all of the wheels represented shall be accepted.

13.3.3 If any wheel tested fails to meet the requirements of Section 13, it shall be checked by making two additional hardness measurements, one on each side of the point first measured and each approximately 1 in. [25.4 mm] from that point. If both of these check measurements meet the requirements of Section 13, the wheel shall be considered to have met the requirements of Section 13.

13.3.4 When continuous heat-treating furnaces are used, should any of the wheels tested fail on check test to meet the requirements of Section 13, the manufacturer may test for individual hardness measurements all of the wheels of that heat in the lot submitted for inspection and those meeting the requirements of Section 13 shall be accepted. Where batch heat-treating furnaces are used, should any of the wheels tested fail on check test to meet the requirements of Section 13, the manufacturer may test all of the wheels in the heat-treatment lot for individual hardness measurement and those meeting the requirements of Section 13 shall be accepted.

14. Inspection

14.1 The gauges and tapes shall conform to and be used as required by the standards of the Mechanical Division, Association of American Railroads. Gauges not defined by the standards of the Mechanical Division, Association of American Railroads may be used provided the gauges are proven to detect rejectable conditions and are certified and traceable to NIST standards.

15. Nondestructive Examination Requirements

15.1 *Ultrasonic Examination:*

15.1.1 Wheels shall be ultrasonically examined in accordance with applicable procedures of Practice A388/A388M.

15.1.2 The ultrasonic examination shall be performed after final thermal processing.

15.1.3 *Calibration:*

15.1.3.1 Calibration shall be conducted using a reference standard of a wheel or portion of a wheel rim containing reference reflectors. The instrument sensitivity level should be adjusted to produce an approximate ½ full-scale reflection from the reference standards of 15.1.3.2, 15.1.3.3, or 15.1.3.4, if this option is used.

15.1.3.2 For axial testing the reference standard shall be a ⅛ in. [3 mm] diameter flat-bottom hole drilled perpendicular to the rim face and to a depth of 1 in. [25 mm] to 1½ in. [40 mm] at the mid-thickness of the rim (Fig. 1).

15.1.3.3 For radial testing the reference standard shall be a ⅛ in. [3 mm] diameter flat-bottom hole drilled from the inside diameter of the rim essentially parallel to the rim face. It shall be a minimum of 1¼ in. [30 mm] from the tread surface (Fig. 2).

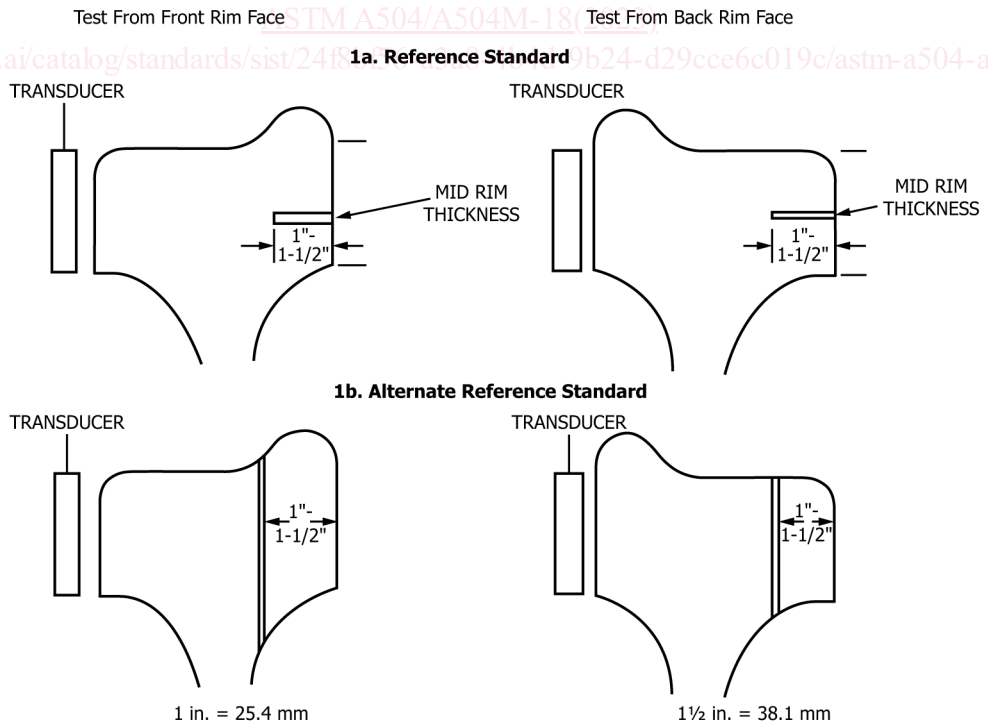
15.1.3.4 The side of a small-diameter hole from 1/16 in. [1.5 mm] to ⅛ in. [3 mm] diameter may be used when it is drilled the same distance from the testing surface. For the axial scan the hole is shown in Fig. 1(b), and for the radial scan the hole is shown in Fig. 2(b). The instrument shall be adjusted to give an equal test value to that of a ⅛ in. diameter flat-bottom hole. This practice is an alternative for the reference standards of 15.1.3.2 (Fig. 1(b)) and 15.1.3.3 (Fig. 2(a)).

15.1.3.5 Reference standards for the inspection of wheels shall be fabricated from heat-treated test wheels. The reference standard need not be the same design as the wheels being inspected.

15.1.4 *Scanning:*

15.1.4.1 Wheels shall be inspected axially from either the front or the back rim face and radially from the tread surface.

15.1.4.2 One or more transducers shall be designed and located to give maximum coverage of the rim section, both radially and axially.



Note—SI Units: 1 in. [25 mm]; 1½ in. [38 mm].

FIG. 1 Typical Reference Standards for Rim Face Test (Axial Testing)