



SURFACE VEHICLE STANDARD

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Automotive Gray Iron Castings

RATIONALE

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1. **Scope**—This SAE Standard covers the hardness, tensile strength, and microstructure and special requirements of gray iron sand molded castings used in the automotive and allied industries. Specific requirements are provided for hardness of castings. Test bar tensile strength/Brinell hardness (t/h) ratio requirements are provided to establish a consistent tensile strength-hardness relationship for each grade to facilitate prediction and control of tensile strength in castings. Provision is made for specification of special additional requirements of gray iron automotive castings where needed for particular applications and service conditions.

NOTE—This document was revised in 1993 to provide grade specific t/h control. In 1999 the document was revised to make SI metric units primary. To better align the grading system with long established production methods and grades produced, the previous system of grading by fixed combinations of tensile strength and hardness was changed in 1999 to a system of grading by variable combinations of test bar t/h ratio and casting hardness grades. The number of hardness grades was increased relative to the number of previously available ranges to facilitate centering of casting mean hardness in the specification range so that dependence of cost optimization on controlling near the low or high sides of specification ranges is minimized.

2. References

- 2.1 **Applicable Publications**—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J417—Hardness Tests and Hardness Number Conversions

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 48—Specification for Gray Iron Castings

ASTM A 247—Recommended Practice for Evaluating the Microstructure of Graphite in Iron Castings

ASTM A 438—Transverse Testing of Gray Cast Iron

ASTM E 10—Test for Brinell Hardness of Metallic Materials

ASTM E 562—Determining Volume Fraction by Systematic Manual Point Count

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document. Additional information concerning gray iron castings, their properties, and use can be obtained from:

1. Metals Handbook, Vol. 1, 10th Edition, ASM International, Materials Park, OH
2. Cast Metals Handbook, American Foundrymen's Society, Des Plaines, IL
3. 1981 Iron Castings Handbook, Iron Castings Society, Inc., Cleveland, OH
4. H.D. Angus, "Physical and Engineering Properties of Cast Iron," British Cast Iron Research Association, Birmingham, England, 2nd Edition, 1976
5. "Gray, Ductile, and Malleable Iron Castings Current Capabilities," STP-455, American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959
6. G.N.J. Gilbert, "Engineering Data on Grey Cast Iron," BCIRA (1977), Alvechurch, Birmingham, England
7. "Tables for Normal Tolerance Limits, Sampling Plans and Screening," R.E. Odeh and D.B. Owen, Marcel Dekker, Inc., New York and Basel, 1980
8. "Fatigue Properties of Gray Cast Iron," L.E. Tucker and D.R. Olberts, SAE Paper 690471

3. Grade definition and Designation.

3.1 Iron Grade—Gray iron grades, defined by their minimum test bar t/h ratio, are designated by the letter G followed by a number equaling the defining minimum test bar t/h ratio multiplied by 100. The units used for this purpose are MPa for both tensile strength and hardness. The t/h ratio is dimensionless.

EXAMPLE—G10 designates a gray iron having minimum test bar t/h = 0.100.

3.2 Hardness Grade—Hardness grades, defined by minimum hardness exhibited in castings, are designated by the letter H followed by a number equaling the minimum casting hardness divided by 100. The casting hardness unit used for this purpose is the MPa.

EXAMPLE—H18 designates minimum casting hardness of 1800 MPa.

3.3 Casting Grade—SAE gray iron casting grades are defined and designated by combining the iron grade and the hardness grade designations.

EXAMPLE—G10H18 designates iron in castings with minimum test bar t/h of 0.100 MPa/MPa and minimum casting hardness of 1800 MPa.

3.4 Special Requirements—Special requirements, defined for special applications, are designated by a lowercase suffix letter placed at the end of the casting grade designation.

EXAMPLE—11H20b designates iron meeting special requirements of special service brakedrums.

3.5 Equivalency and Conversion—Equivalency information for engineering purposes, between this and other standards, is provided in A.4.1, A.4.6, and A.4.7. Grades of this document can have multiple equivalents with grades of previous SAE and most other standards as exemplified by grades G3000 and G4000. Determination of current grade equivalent for castings established in production under previous SAE or other documents, shall be by the producer, in accordance with 5.5.3, based on historical or current test data from the established process, and reported to and approved by the purchaser. When the producer does not have access to the applicable historical data, grade determination shall be based on samples provided by producer and approved by purchaser.

4. Grades

4.1 Iron Grades—Iron grades and their t/h lower limit requirements are shown in Table 1.

TABLE 1—IRON GRADES

Grade	Test Bar t/h Ratio Lower Limit ⁽¹⁾ MPa/MPa ⁽²⁾	Test Bar t/h Ratio Lower Limit ⁽¹⁾ psi/HB ⁽³⁾⁽⁴⁾
G7	0.070	100
G9	0.090	128
G10	0.100	142
G11	0.110	156
G12	0.120	171
G13	0.130	185

1. Statistically defined
2. Both tensile and hardness in MPA units
3. For reference only. The MPa/MPa SI metric values are primary. See Section 1.
4. Units of HB are kgf per mm².

4.2 Hardness Grades—Hardness grades and their required lower hardness limits are shown in Table 2.

TABLE 2—HARDNESS GRADES

Grade	Casting Hardness Lower Limit ⁽¹⁾ MPa ⁽²⁾	Casting Hardness Lower Limit ⁽¹⁾ HB ⁽³⁾
H10	1000	102
H11	1100	112
H12	1200	122
H13	1300	133
H14	1400	143
H15	1500	153
H16	1600	163
H17	1700	173
H18	1800	184
H19	1900	194
H20	2000	204
H21	2100	214
H22	2200	224
H23	2300	235
H24	2400	245

1. Statistically Defined.
2. Hardness in MPa = HB multiplied by 9.80665.
3. Units of HB are kgf per mm².

4.3 Special Requirements—Special additional requirements for particular applications and service conditions and their lower case letter designators are shown in Table 3. Special additional requirements shall not change test bar t/h ratio or casting hardness requirements.

TABLE 3—SPECIAL REQUIREMENTS

Designator	Application	Requirements
a	Brake Drums and Discs and Clutch Plates for Special Service	1. Total Carbon 3.4% minimum. 2. Microstructure: Lamellar Pearlite. Ferrite < 15% ⁽¹⁾
b	Brake Drums and Discs and Clutch Plates for Special Service	1. Total Carbon 3.4% minimum. 2. Microstructure: Lamellar Pearlite. Ferrite or carbide < 5%(1)
c	Brake Drums and Discs and Clutch Plates for Special Service	1. Total Carbon 3.5% minimum. 2. Microstructure: Lamellar Pearlite. Ferrite or carbide < 5%(1)
d	Alloy Hardenable Gray Iron Automotive Camshafts ⁽²⁾	1. Chromium shall be 0.85 to 1.50% ⁽³⁾ 2. Molybdenum shall be 0.40 to 0.60%(3) 3. Microstructure of cam nose: Extending to 45 degrees on both sides of cam nose centerline and to minimum depth of 3.2 mm from the surface shall consist of primary carbide (cellular and/or acicular) and graphite in a matrix of fine pearlite. 4. The amount of carbide in the cams and method of checking shall be specified by the purchaser. 5. Casting Hardness check location shall be on a bearing surface.

1. See ASTM E 562.

2. As-cast requirements. Camshafts may be flame or induction hardened to specified hardness and depth on cam surfaces.

3. Ranges for specific castings shall be within the ranges shown.

4.4 Casting Grades—Combination of iron grade, hardness grade, and special requirement designation, if any, defines casting grade. A partial list of casting grades in common production and use, identified as reference grades and considered standard, is given in Table 4 with current and previous SAE designations. Other combinations of iron grade and hardness grade which are established in production and use or become so in the course of application development, or in accordance with 3.5 and 5.5.3, are also considered standard.

TABLE 4—REFERENCE GRADES⁽¹⁾

SAE Casting Grade	Previous SAE Designation ⁽²⁾
G9H12	G1800
G9H17	G2500
G10H18	G3000
G11H18	G3000
G11H20	G3500
G12H21	G4000
G13H19	G4000
G7H16 c	G1800 h ⁽³⁾
G9H17 a	G2500 a
G10H21 c	G3500 c
G11H20 b	G3500 b
G11H24 d	G4000 d

1. Established in production and use and having near equivalents with previous SAE designations.

2. Equivalency based on tensile strength in 30 mm diameter test bars. See Table A4.

3. The h suffix was previously used to designate both t/h and carbon requirements for this grade.

NOTE—For castings successfully established in production and use under previous designations, the current SAE casting grade shall be determined by the producer and approved by the purchaser (see 3.5).

5. Tensile Strength to Hardness Ratio, Hardness, and Casting Tensile Strength

- 5.1 Tensile strength values for the t/h ratio determination shall be obtained as shown in Figure 1 from separately cast 30 mm test bars (type "B") in accordance with ASTM A 48 except sampling frequency shall be as needed for statistical analysis to determine conformance of t/h ratio with requirements of this document. Test specimens shall be at room temperature, defined as between 10 and 35 °C, during tensile testing.

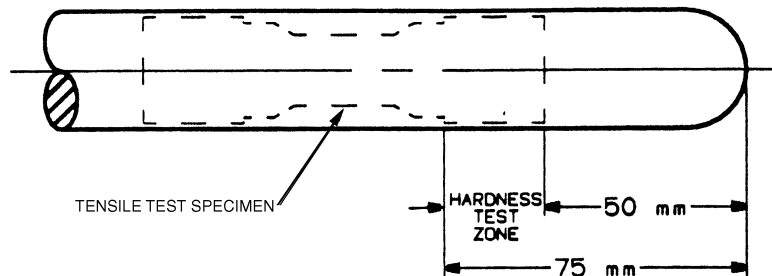


FIGURE 1—TEST BAR HARDNESS LONGITUDINAL TEST ZONE IN RELATION TO TENSILE SPECIMEN

- 5.2 Test bar hardness for the t/h ratio determination shall be taken on the tensile test bar between bar center and midpoint of the as-cast radius, and between 50 and 75 mm from the as-cast bar end as shown in Figures 1 and 2.

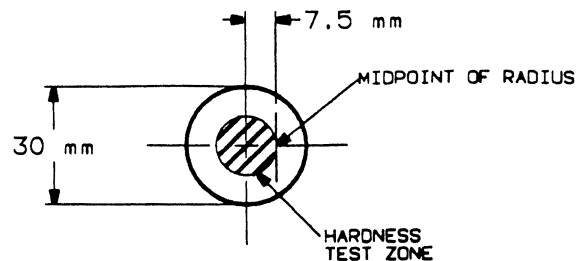


FIGURE 2—TEST BAR HARDNESS RADIAL TEST ZONE

- 5.3 Brinell Hardness is considered standard for test bars and production castings and shall be determined according to ASTM E 10 after sufficient material has been removed from the casting surface to insure representative hardness readings. The 10 mm ball and 3000 kgf load shall be used unless physically precluded by specimen dimensions as given in ASTM E 10. Test specimens shall be at room temperature, defined as between 10 and 35 °C, during hardness testing.
- 5.3.1 When a hardness test other than the Brinell test with 10 mm ball and 3000 kgf load must be used, conversion to the 3000 kgf 10 mm ball equivalent shall be by applicable conversion table in SAE J417 or by on-site calibration using Standard Brinell Bars.

- 5.4** A non-destructive casting hardness test location on the casting for monitoring conformance to grade limits shall be established by agreement between purchaser and producer or determined by producer. It should be readily accessible for convenience in performing the test to ensure adequate quantity, consistency, and accuracy of accumulated data for statistical validity in service of general variance control. Targeting of hardness measurement at service function related locations shall not be considered a requirement unless specified in accordance with 5.4.1.
- 5.4.1** In special cases, casting hardness at particular casting locations considered critical by the designer but difficult to access or requiring casting destruction may be specified by the purchaser with producer agreement. In such cases, hardness grade conformance may be established directly by hardness readings so obtained or indirectly by hardness readings at an accessible location using an agreed method of correlation.
- 5.5** The foundry shall exercise the necessary controls and inspection techniques to ensure compliance with the specified hardness and t/h ratio minimums. When samples exhibit normal variance patterns, conformance with grade requirements for t/h and casting hardness shall be determined by long term analysis of production samples using Normal Curve statistical methods. For sample sizes less than 30, the lower limit shall be taken as 3 standard deviations below the mean. For sample sizes larger than 30, the lower limits for t/h and casting hardness control may be optionally taken as the lower 3 standard deviation limit or the lower 99% population limit of the one-sided normal distribution at 95% confidence calculated by the confidence interval method (see A.1.5).
- 5.5.1** Test bar samples to confirm test bar t/h ratio conformance shall be random samples. Frequency of sampling may be specified by purchaser or determined by producer. Minimum frequency per grade shall be 1 per 8 h shift. Sample period may be any time interval or accumulation of time intervals in which the targeted mean t/h of producer's process control specifications is unchanged.
- 5.5.2** Casting samples to confirm casting hardness conformance shall be random samples. Frequency of sampling may be specified by purchaser or determined by producer. Minimum frequency shall be the least of 5 per 8 h shift or 100% of production. Sample period may be any time interval or accumulation of time intervals during which the targeted mean casting hardness of producer's process control specifications is unchanged.
- 5.5.3** Parts successfully established in production and use under previous SAE or other Standards shall be reclassified under this document, without change in mean test bar t/h or mean casting hardness, by appropriate selection of iron grade from Table 1, casting hardness grade from Table 2, and casting hardness range under 5.6.
- 5.5.4** Casting t/h data obtained by casting hardness tests as described in 5.4 or 5.4.1 and casting tensile tests as described in 5.7, shall be considered informational only and shall not be used for grade conformance assessment.
- 5.5.5** When casting hardness and/or test bar t/h variance patterns have too much skewness or otherwise do not support Normal Curve methods of analysis, an alternate method shall be established by agreement of purchaser and producer which achieves population limit control equivalent to that described in 5.5.
- 5.6** Casting hardness range may be specified by the purchaser to provide a non-statistical upper limit for machinability control. The standard range shall be 600 MPa or 60 HB, taken above the required grade minimum, and this shall be the assumed range when not specified. Purchasers shall not specify narrower ranges than this without prior agreement of the producer. Producers shall not exceed this range without prior agreement of the purchaser.