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SURFACE VEHICLE STANDARD

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An American National Standard

(R) AUTOMOTIVE DUCTILE (NODULAR) IRON CASTINGS

1. ***Scope—***This SAE Standard covers the hardness and microstructure requirements for ductile iron castings used in automotive and allied industries. Castings may be specified in the as-cast or heat treated condition.

The Appendix provides general information on the application of ductile iron castings and their chemical composition to meet hardness microstructure and other properties needed for particular service conditions. The mechanical properties in the Appendix are provided for design purposes.

2. ***References***

2.1 **Applicable Publications—**The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the lastest revision of SAE publications shall apply

2.1.1 ASTM PUBLICATION—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

ASTM E10—Test for Brinell Hardness of Metallic Materials
STP-455—Gray, Ductile, and Malleable Iron Castings Current Capabilities

2.1.2 OTHER PUBLICATION

Metals Handbook, Vol. 1, 2, and 5, 8th Edition, American Society for Metals, Metals Park, OH
Gray and Ductile Iron Castings Handbook, Gray and Ductile Iron Founder Society, Cleveland, OH
H. D. Angus, Physical Engineering Properties of Cast Iron, British Cast Iron Research Association, Birmingham, England

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3. ***Grades—***The specified grades, hardness range, and metallurgical description are shown in Table 1.

TABLE 1—GRADES OF DUCTILE IRON

Grade	Casting Hardness Range	Description
D4018	170 HB max or as agreed (4.6 BID, min)	Ferritic
D4512	156–217 HB or as agreed (4.80–4.10 BID)	Ferritic-pearlitic
D5506	187–255 HB or as agreed (4.4–3.8 BID)	Ferritic-pearlitic
D7003	241–302 HB or as agreed (3.90–3.50 BID)	Pearlitic
DQ&T	Range specific	Martensitic

NOTE— Brinell impression diameter (BID) is the diameter in millimeters (mm) of the impression of a 10 mm ball at 3000 kg load.

4. ***Hardness***

4.1 The area or areas on the castings where hardness is to be checked should be established by agreement between supplier and purchaser.

4.2 The foundry shall exercise the necessary controls and inspection techniques to insure compliance with the specified hardness range. Brinell hardness shall be determined according to ASTM E 10, Test for Brinell Hardness of Metallic Materials, after sufficient material has been removed from the casting surface to insure representative hardness readings. The 10 mm ball and 3000 kg load shall be used unless otherwise agreed upon.

5. ***Heat Treatment***

5.1 Unless otherwise specified, castings may be heat treated to the appropriate hardness range.

5.2 Appropriate heat treatment for removal of residual stresses, or to improve machinability may be specified by agreement between supplier and purchaser.

6. ***Microstructure—***The graphite component of the microstructure shall consist of at least 80% spheroidal graphite conforming to Types I and II in Figure 1. The matrix microstructure shall consist of either ferrite, ferrite and pearlite, pearlite, tempered pearlite, or tempered martensite or a combination of these. The microstructure shall be substantially free of primary cementite.

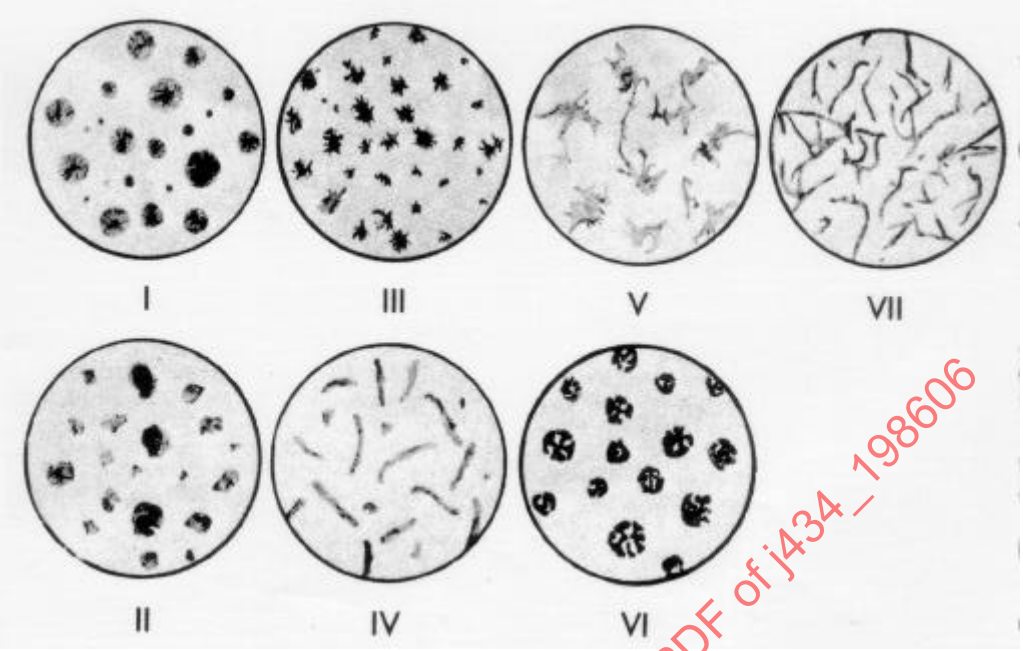

FIGURE 1—CLASSIFICATION OF GRAPHITE SHAPE IN CAST IRONS (FROM ASTM A 247)

7. ***Quality Assurance—***Sampling plans are a matter of agreement between supplier and purchaser. The supplier shall employ adequate equipment and controls to insure that parts conform to the agreed upon requirements.

8. ***General***

8.1 Castings furnished to this standard shall be representative of good foundry practice and shall conform to dimensions and tolerances specified on the casting drawing.

8.2 Minor imperfections usually not associated with the structural functioning may occur in castings. These imperfections are often repairable; however, repairs should be made only in areas and by methods approved by the purchaser.

8.3 Additional casting requirements, such as vendor identification, other casting information, and special tesing, may be agreed upon by the purchaser and supplier. These should appear as additional product requirements on the casting drawing.

9. ***Notes***

9.1 **Marginal Indicia—**The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE IRON AND STEEL TECHNICAL COMMITTEE DIVISION 9—
AUTOMOTIVE IRON AND STEEL CASTINGS

APPENDIX A

DUCTILE (NODULAR) IRON
(A material description not a part of the standard)

A.1 ***Definition And Classification—***Ductile (nodular) iron, also known as spheroidal graphite iron, is cast iron in which the graphite is present as spheroids, instead of flakes as in gray iron or temper carbon nodules as in malleable iron.

Ductile iron castings may be used in the as-cast condition, or may be heat treated.

A.2 ***Chemical Composition—***The typical chemical composition of unalloyed iron generally conforms to the following ranges:

Total carbon	3.20–4.10%
Silicon	1.80–3.00%
Manganese	0.10–1.00%
Phosphorus	0.015–0.10%
Sulfur	0.005–0.035%

Individual foundries will produce to narrower ranges than those shown. The spheroidal graphite structure is produced by alloying the molten iron with small amounts of one or more elements such as magnesium or cerium.

A.3 ***Microstructure***

A.3.1 The microstructure of the various grades of ductile iron consists of spheroidal graphite in a matrix of either ferrite, pearlite, tempered pearlite, tempered martensite, or certain combinations of these. The relative amounts of each of these constituents is dependent upon the grade of material specified, casting design as it affects cooling rate, and heat treatments, if any.

A.3.2 The matrix microstructure of as-cast ductile iron depends to a great extent on the solidification rate and cooling rate of the casting, as shown in Figure A1. If a section solidifies rapidly, especially sections of 0.25 in (6 mm) or less, an appreciable amount of carbide may be present in the casting. If a section cools slowly, as in a massive, heavy casting, a largely ferritic matrix may result.

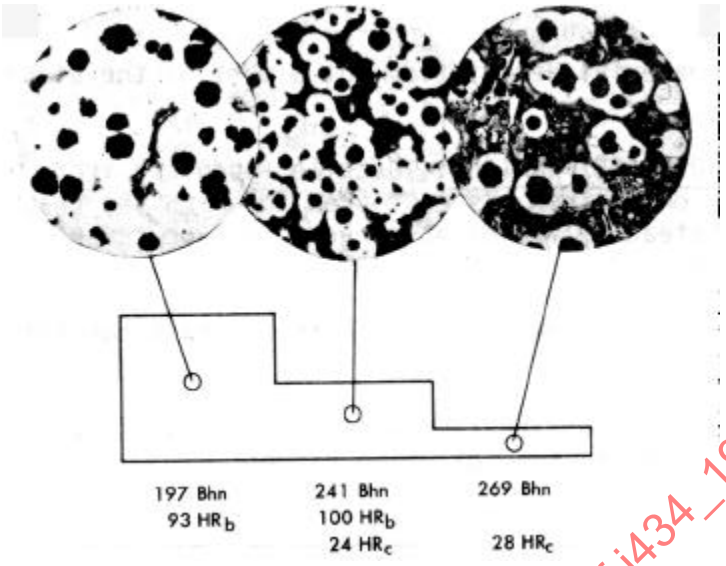

FIGURE A1—EXAMPLE OF MICROSTRUCTURAL VARIATION WHICH MAY OCCUR IN AS-CAST CONDITION AS FUNCTION OF METAL THICKNESS (THAT IS, SOLIDIFICATION RATE)

A.3.3 Alloying elements can also alter the microstructure usually resulting in increased amounts of pearlite. Large variations in structure can be eliminated or minimized by modifying the casting design or the runner system or both, or by controlled cooling, or any combination of these. Primary carbides, and/or pearlite can be decomposed by appropriate heat treatments.

A.3.4 A rim may occur on heat treated castings consisting of a graphite-free layer sometimes containing more or less combined carbon than the underlying material.

A.3.5 Typical microstructure of the grades of ductile iron are as follows:

D4018 is annealed ferritic ductile iron. The annealing time and temperature cycle is such that primary carbides, if present in the as-cast structure, are decomposed, and the resulting matrix is ferritic as shown in Figure A2.

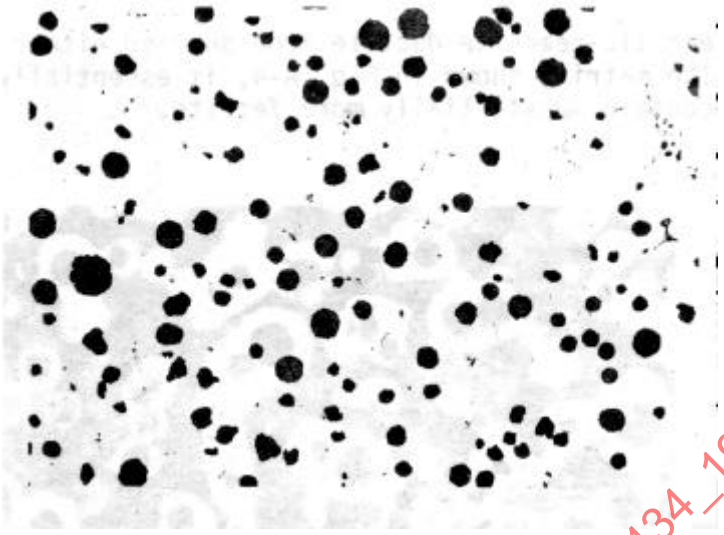

FIGURE A2—D4018, APPROXIMATE 156 HB (100X) TYPICAL MICROSTRUCTURES

D4512 is ferritic ductile iron supplied either as cast or heat treated. The matrix, shown in Figure A3, is essentially ferrite but this grade can contain pearlite, depending on the section size.

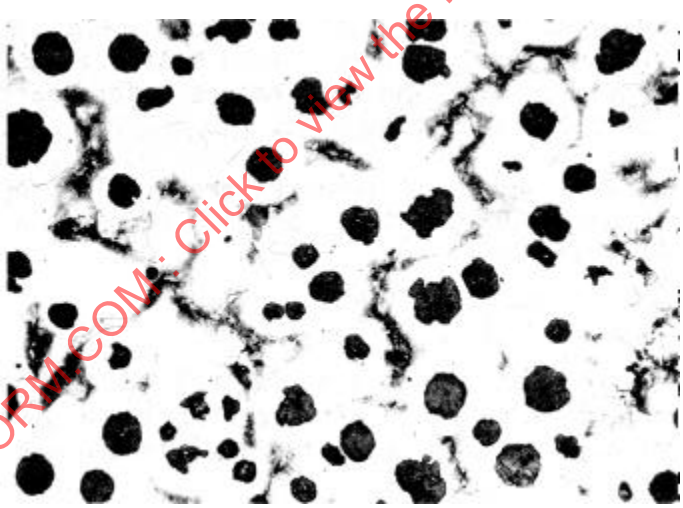

FIGURE A3—D4512, APPROXIMATE 179 HB (100X) TYPICAL MICROSTRUCTURES

D5506 is ferritic-pearlite ductile iron suppied either as-cast or heat treated. The matrix, shown in Figure A4, is essentially pearlite. This grade may contain substantially more ferrite.

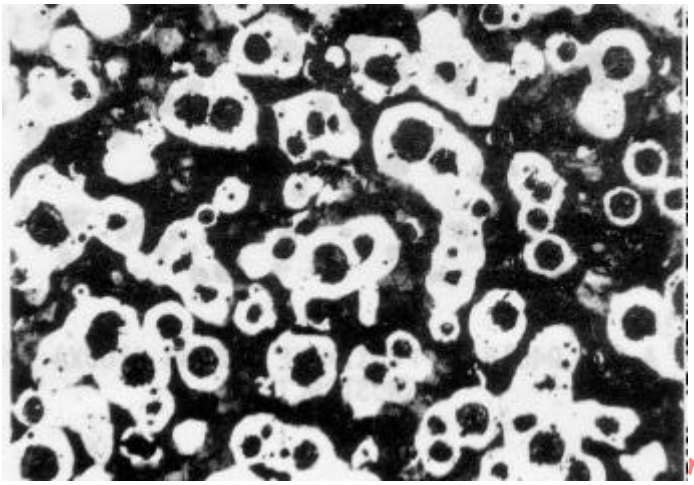

FIGURE A4—D5506, APPROXIMATE 235 HB (100X) TYPICAL MICROSTRUCTURES

D7003 (not shown) is generally air or liquid quenched and tempered to a specified hardness range. The resulting matrix is tempered pearlite or tempered martensite. Time and temperature before hardening can be such that primary carbides are decomposed.

DQ&T is a liquid quenched and tempered grade. The resulting matrix is tempered martensite. The Brinell hardness range is a matter of agreement between supplier and purchaser.

A.4 Mechanical Properties

A.4.1 The mechanical properties listed in Table A1 are intended as guidelines; but, since properties may vary with location in a given casting, the suitability of a particular metal for an intended use is best determined by laboratory or service tests.

TABLE A1—TYPICAL MECHANICAL PROPERTIES FOR DUCTILE IRONS(1)

Grade	Hardness Range(2)	Description	Tensile Strength, psi (MPa)	Yield Strength 0.2% Off-set, psi (MPa)	Elongation, % In 2 In	Modulus of Elasticity, 10^6 psi (GPa)
D4018	170 HB max (4.6 BID min)	Ferritic	60,000 (414)	40,000 (276)	18	22 (152)
D4512	156–217 HB (4.80–4.10 BID)	Ferritic-pearlitic	65,000 (448)	45,000 (310)	12	22 (152)
D5506	187–255 HB (4.4–3.8 BID)	Ferritic-pearlitic	80,000 (552)	55,000 (379)	6	22 (152)
D7003	241–302 HB (3.9-3.5 BID)	Pearlitic	100,000 (689)	70,000 (483)	3	22 (152)
DQ&T	Range specified by agreement	Martensitic	A wide variety of desirable properties will result from liquid quenching and tempering			22 (152)

1. These properties were obtained on separately cast test bars and may vary in various sections of a casting depending on composition and cooling rate.
2. Brinell impression diameter (BID) is the diameter in millimeters (mm) of the impression of a 10 mm ball at 3000 kg load.

A.4.2 The mechanical properties will vary with the microstructure which, especially in the as-cast condition, is dependent on section size as well as chemical composition and some foundry processes.

A.4.3 For optimum mechanical properties in the quenched and tempered grade, section size for unalloyed iron should generally not exceed 3/4 in (19 mm) to insure a uniform, through-hardened structure.

A.5 Typical Applications

A.5.1 D4018 is used in moderately stressed parts requiring high ductility and good machinability, such as automotive suspension parts.

A.5.2 D4512 is used for moderately stressed parts where machinability is less important, such as differential cases and carriers.

A.5.3 D5506 is used for more highly stressed parts, such as automotive crankshafts.

A.5.4 D7003 is used where high strength and/or improved wear resistance are required and where selective hardening is to be employed.

A.5.5 DQ&T is used where the uniformity of a heat treated material is required to control the range of mechanical properties or machinability.