Designation: A 983/A 983M – 06

Standard Specification for Continuous Grain Flow Forged Carbon and Alloy Steel Crankshafts for Medium Speed Diesel Engines[1]

This standard is issued under the fixed designation A 983/A 983M; 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 continuous grain flow forged carbon and alloy steel crankshafts for medium speed diesel and natural gas engines.

1.2 The steel used in the manufacture of the forgings is required to be vacuum degassed.

1.3 The choice of steel composition grade for a given strength class is normally made by the forging supplier, unless otherwise specified by the purchaser.

1.4 Provision is made for treatment of designated surfaces of the crankshaft to provide enhanced fatigue strength, or wear resistance, or both.

1.5 Except as specifically required in this specification, all provisions of Specification A 788/A 788M apply.

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

1.7 The values stated in either inch-pound units or SI (metric) 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 are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

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

A 503/A 503M Specification for Ultrasonic Examination of Forged Crankshafts

A 788/A 788M Specification for Steel Forgings, General Requirements

A 966/A 966M Test Method for Magnetic Particle Examination of Steel Forgings Using Alternating Current

A 986/A 986M Specification for Magnetic Particle Examination of Continuous Grain Flow Crankshaft Forgings

E 45 Test Methods for Determining the Inclusion Content of Steel

E 112 Test Methods for Determining Average Grain Size

E 340 Test Method for Macroetching Metals and Alloys

2.2 *Other Standards:*

AWS D1.1 Structural Welding Code[3]

DIN 50 602 [4]

JIS G 0555 Microscopic Testing Method for the Non-Metallic Inclusions in Steel[5]

3. Ordering Information

3.1 In addition to the ordering requirements of Specification A 788/A 788M, the following items should be included:

3.2 Choice of mechanical property class from Table 1.

3.3 Choice of chemical composition Grade from Table 2 if this purchaser option is exercised (4.1.3).

3.4 Whether surface hardening in designated areas is required, referencing Supplementary Requirements S10, S11, or S12, and providing the necessary instructions.

3.5 For crankshafts designed to include welded counterweights the purchaser may specify an alternate welding code to AWS D1.1 Structural Welding Code.

3.6 For alternate tensile and hardness test requirements specify Supplementary Requirement S2.

4. Materials and Manufacture

4.1 *Melting Practice*:

4.1.1 The steel making section of Specification A 788/A 788M shall apply together with mandatory vacuum degassing.

4.1.2 Supplementary Requirement S1 may be used if nonmetallic inclusion rating of the steel is required.

[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 American Welding Society, 550 NW Le Jeune Rd., Miami, FL 33126.

[4] Available from Verlag Stahleisen mbh, Postfach 8229, D-4000 Dusseldorf, Germany.

[5] Available from Japanese Standards Association, 1-24 Akasaka 4, Minato-Ku, Tokyo 107, Japan.

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

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TABLE 1 Tensile and Hardness Requirements

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
Tensile Strength, ksi [Mpa] min	80 [550]	100 [690]	110 [760]	120 [830]	130 [900]	140 [965]	150 [1035]
Yield Strength, (0.2% offset), ksi [Mpa] min	45 [310]	70 [485]	80 [550]	90 [620]	100 [690]	110 [760]	120 [830]
Elongation, min % in 2 in. (4D) [% in 62.5 mm] (5D)	20 [18]	18 [16]	18 [16]	17 [15]	16 [14]	15 [13]	14 [12]
Reduction of Area, % min	45	45	45	45	40	40	40
Brinell Hardness, min	163	207	229	248	262	285	302
Brinell Hardness, max	217	255	269	293	302	331	341

TABLE 2 Chemical Requirements Composition %

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 7A	Grade 8	Grade 8A
Carbon	0.43-0.53	0.43-0.52	0.28-0.33	0.38-0.48	0.30-0.48	0.35-0.45	0.28-0.35	0.38–0.48	0.30-0.35	0.38–0.48
Manganese	0.60-1.10	0.75-1.10	0.40-1.00	0.75-1.10	0.65-1.00	0.65-1.00	0.40-1.00	0.40–1.00	0.40-0.80	0.40–0.80
Phosphorous	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max
Sulfur	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max
Silicon	0.15-0.40	0.15-0.40	0.15-0.040	0.15-0.40	0.15-0.40	0.15-0.40	0.15-0.40	0.15–0.40	0.15-0.40	0.15–0.40
Nickel	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1.30-1.70	1.30–1.70
Chromium	. . .	0.20-0.35	0.80-1.20	0.80-1.20	0.80-1.20	0.80-1.20	2.8-3.3	2.8–3.3	1.00-1.40	1.00–1.40
Molybdenum	. . .	0.10 max	0.15-0.25	0.15-0.25	0.15-0.25	0.30-0.50	0.30-0.50	0.30–0.50	0.20-0.35	0.20–0.35
Vanadium	0.10 max	0.10 max	0.10 max	0.10 max	0.10 max	0.10 max	0.10 max	0.10 max	0.15 max	0.15 max

4.1.3 Unless otherwise specified by the purchaser (3.2), the forging supplier shall select the chemical composition grade to be used from Table 2.

4.2 *Forging*:

4.2.1 The use of bar from starting stock produced by slitting a rectangular section is not permitted.

4.2.2 The procedure used in forging the crankshaft shall ensure that the centerline of the starting forged or rolled bar will follow the centerline contour of the main bearings, webs, and crankpins of the crankshaft.

4.2.3 The grain flow present between adjacent main bearing journals, webs, and the intervening crankpin shall be demonstrated for the first article testing of a new crankshaft design by a given forging facility. This need not be repeated for other crankshafts of the same design that differ from the first article crankshaft by the number of crankpin throws or, by agreement with the purchaser, for V-Cylinder configurations of the same engine. The axial grain flow shown after etching a centerline longitudinal section of the *main bearing-web-crankpin-web-main bearing* section shall be approved by the purchaser. Etching shall be done in accordance with Test Method E 340. Using Supplementary Requirement S2, additional grain flow sections may be taken by agreement between the manufacturer and purchaser.

4.3 *Heat Treatment for Mechanical Properties*:

4.3.1 Heat treatment of crankshaft forgings may be done either before or after rough machining, at the manufacturer's option. By the use of Supplementary Requirement S3 the purchaser can specify that heat treatment be done after rough machining.

4.3.2 When counterweights are to be attached to the crankshaft by welding (see 4.3.4), then the heat treatment for mechanical properties shall follow after completion of the welding. Intermediate post weld heat treatment may be applied to the assembly at the manufacturer's option.

4.3.3 Heat treatment for mechanical properties shall consist of normalizing followed by tempering at a subcritical temperature, or austenitizing, liquid quenching and subcritical tempering. A normalizing cycle may precede the austenitizing stage.

4.3.3.1 The minimum tempering temperature shall be 1100°F [595°C].

4.3.4 If the crankshaft design includes attaching counterweights to the webs by welding, then the manufacturer shall qualify the weld procedure and welders in accordance with a written procedure acceptable to the purchaser. The procedure shall incorporate AWS specifications.

4.3.5 If forgings receive thermal stress relief after completion of heat treatment, then the stress relieving temperature shall not exceed (T-50)°F [(T-30)°C] where T is the tempering temperature. If this stress relieving temperature is exceeded, then the mechanical testing required in Section 6 shall be repeated.

4.3.6 If crankshaft counterweights are to be welded to the webs, then the welding shall be done to a written, and qualified procedure conforming to AWS D1.1 Structural Welding Code or another similar welding code acceptable to the purchaser. This procedure shall contain instructions concerning repair of counterweight welds, including preheat and post weld heat treatment requirements.

5. Chemical Composition

5.1 *Heat Analysis*—The heat analysis obtained after sampling in accordance with Specification A 788/A 788M shall comply with Table 2 for the chosen grade, and the requirements agreed upon by Supplementary Requirement S4 if this was selected.

6. Mechanical Requirements

6.1 *Tension Testing*:

6.1.1 The heat treated forging shall comply with the requirements of Table 1 for the selected grade when tested in accordance with this section. See also Test Methods and Definitions A 370. It should be noted that when the SI system

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is specified the gauge length for the tension test shall be measured over a length of 5D.

6.1.2 *Test Material*—An integral test prolongation equal in diameter to that of the starting bar diameter shall be provided at one end of each crankshaft subject to mechanical testing.

6.1.3 *Sampling*—The longitudinal axis of the axially oriented tension test specimen shall be located at the mid-radius position in the integral crankshaft test prolongation. Supplementary Requirement S5 provides for a tension test prolongation to be provided at both ends of the heat treated crankshaft, and Supplementary Requirement S6 provides for testing of each crankshaft in lieu of the test frequency specified in Supplementary Requirement S5.

6.1.4 *Orientation*—Longitudinal tension test specimens shall be taken from the crankshaft prolongation.

6.1.5 *Number of Tests*—Unless Supplementary Requirements S5 or S6, or both, are specified, one tension test specimen shall be tested to the requirements of Table 1, for the selected grade, at a frequency of one test per heat treatment load.

6.2 *Impact Testing*—If Charpy impact testing of the crankshaft is required, Supplementary Requirement S7 shall be specified.

7. Grain Size

7.1 The grain size of the forging following heat treatment shall be ASTM 5 or finer when tested at the tension test location(s) in accordance with Test Methods E 112.

8. Surface Hardening

8.1 When required by the purchaser, and indicated in the crankshaft drawing, the crankshaft shall be surface hardened in designated areas for purposes of wear resistance and, when the bearing fillets are included, enhanced fatigue strength.

8.2 The method and extent of the surface hardening shall be specified by the purchaser by including reference to Supplementary Requirements S9 (nitriding), S10 (induction hardening of the bearing journals), or S11 (full induction hardening of bearing journals and fillets).

9. Nondestructive Examination

9.1 Because ac magnetizing equipment is required to be used, the magnetic particle examination of the crankshaft shall be done on completion of all machining operations. The examination shall be in accordance with Test Method A 966/A 966M.

9.1.1 Acceptance criteria for the magnetic particle examination shall be in accordance with Specification A 986/A 986M.

9.2 Supplementary Requirement S8 shall be specified if ultrasonic examination of the crankshaft bar or the crankshaft forging is required.

10. Workmanship

10.1 In addition to the specific order or drawing requirements for surface finish, the general appearance with respect to soundness and finish shall be consistent with good crankshaft practice, as determined by ordinary visual inspection.

11. Certification

11.1 When certification of a crankshaft includes inspection by a classification agency, the manufacturer shall be notified of this provision, so that arrangements can be made to allow for witnessing of such manufacturing and testing operations as needed.

12. Delivery

12.1 In addition to the requirements of Specification A 788/A 788M, the purchaser shall notify the producer on any special corrosion protection and packing instructions. Supplementary Requirement S12 may be used to call for specific packing instructions, otherwise the producer's normal product protection practices shall apply.

13. Keywords

13.1 crankshafts, continuous grain flow; medium speed diesel engines; steel forgings; surface hardening

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Nonmetallic Inclusion Rating

S1.1 The nonmetallic inclusion rating for steel bars or billets to be used for making CGF crankshafts shall be done in accordance with an agreed upon practice, or one of the following standards: Test Methods E 45—Method D, DIN 50 602, or JIS G 0555.

S1.2 The acceptance criteria for the nonmetallic inclusion rating shall be specified by the purchaser.

S2. Alternate Tensile and Hardness Requirements

S2.1 The purchaser shall specify alternate tensile strength and hardness requirements to those specified in Table 1.

S2.2 The alternate tensile strength values shall be interpolated from the values given in Table 1. For strength levels higher than Class 7 in Table 1 the requirements shall be agreed between the purchaser and the manufacturer.

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S2.3 The alternate hardness values shall be interpolated from the values given in Table 1, but shall be in increments of 0.05 mm.

S3. Machining Before Heat Treatment

S3.1 Forgings shall be rough machined to agreed upon dimensions prior to heat treatment for mechanical properties.

S4. Additional Chemical Elements

S4.1 In addition to the elements specified in Table 2 for a specific grade, additional elements shall be added to the steel within ranges agreed upon between manufacturer and producer.

S4.2 The chemical analysis of the modified grade shall be reported as required by the certification section.

S5. Mechanical Testing

S5.1 For each crankshaft, tension testing at the prolongation mid-radius position shall be done at both ends of the crankshaft. A heat treatment weight, excluding test prolongations, in excess of 6000 lb [3000 kg] may be specified by the purchaser as the point at which testing both ends of the crankshaft is required.

S5.2 The maximum difference in ultimate tensile strength between tests taken at opposite ends of the crankshaft shall be specified by the purchaser.

S6. Test Frequency

S6.1 Instead of the tension testing frequency specified in 6.1.5, each crankshaft shall be tested from an integral prolongation.

S7. Charpy Impact Testing

S7.1 From each crankshaft test prolongation used for tension testing, one set of three longitudinal Charpy V-notch specimens shall be taken at the mid-radius position, for testing at room temperature. The notch shall be oriented at right angles to the surface of the prolongation, that is, radially. The absorbed energy requirements shall be specified by the purchaser.

S8. Ultrasonic Examination

S8.1 Ultrasonic examination of the starting crankshaft bar, or the forged and heat treated crankshaft, or both, shall be done according to the requirements in Specification A 503/A 503M for continuous grain flow crankshafts. In the event that the purchaser does not state in the inquiry or order that ultrasonic examination of the starting bar is required, then only the heat treated crankshaft shall be examined.

S8.2 The acceptance criteria for the ultrasonic examination(s) shall be specified by the purchaser.

S9. Surface Nitriding

S9.1 The surfaces designated in the crankshaft drawing shall be nitrided. Significant details such as the surface hardness, disposition of white layer, case depth, and limitations on localized imperfection removal shall be as agreed upon between the manufacturer and purchaser.

S9.2 Magnetic particle examination of the crankshaft shall follow final grinding or polishing and agreed upon white layer removal.

S9.3 Special identification marking, as instructed by the purchaser, shall be included with the crankshaft marking requirements specified in the drawing or order.

S10. Induction Hardening

S10.1 The crankshaft crankpin and main bearing journal surfaces shall be induction hardened as specified in the crankshaft drawing. The depth of hardening, hardness requirements, and location limits for the hardened zones shall be as specified in the drawing or in written instructions from the purchaser. Unless otherwise specified the producer may temper the crankshaft on completion of hardening to obtain the required hardness.

S10.2 The hardening pattern and the hardness profile through the hardened case shall be established by sectioning test pieces representative of the crankpin and main bearing journals. The material, contour, and diameter of these test pieces shall closely approximate those of the crankshaft so that it can be shown that the hardening process can meet the drawing requirements, including the extent of hardening at the oil holes.

S10.3 Final magnetic particle examination of the crankshaft shall follow finish grinding and polishing of the crankshaft.

S10.4 If required by the purchaser the marking requirements for the crankshaft shall be augmented to denote that the crankshaft has been induction hardened on the bearing surfaces.

S11. Fully Induction Hardened Crankshafts

S11.1 Full induction hardening of a crankshaft indicates that all designated surfaces including bearing fillets have been hardened. The designated surfaces shall be as shown in the crankshaft drawing. The required surface hardness and depth of hardening shall be as described in the crankshaft drawing or as agreed upon between purchaser and producer.

S11.2 The producer shall establish that the required hardness pattern on the crankpin and main bearing journals, and at the oil holes, together with the necessary fillet hardening can be achieved by means of representative test sections that replicate the material, major dimensions, excess stock, and surface finish of the crankshaft at the time of hardening.

S11.3 Magnetic particle examination of the crankshaft shall follow final grinding and polishing of the crankshaft.

S11.4 Marking of the crankshaft may be specified by the purchaser to indicate that the crankshaft has been fully induction hardened.

S12. Special Packaging

S12.1 When specified by the purchaser special packaging shall be done to help preclude corrosion or mechanical damage during shipping and storage.

S13. Additional Macro Examination

S13.1 Additional grain flow macro sections or sections from other forged shapes in the crankshaft shall be taken as agreed upon between manufacturer and purchaser.

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S14. Near Surface Nonmetallic Inclusion Rating

S14.1 Heat qualification based on nonmetallic inclusion rating in accordance with Test Methods E 45 shall be established by sampling according to the following plan, depending on the steel teeming system:

S14.2 For top poured ingots samples representing the top and bottom of the first, middle and last ingots of the heat shall be used.

S14.3 For bottom poured ingots, samples representing the top and bottom of one ingot from the first plate poured, and samples representing the top and bottom of two ingots from each additional plate, shall be examined.

S14.4 For steel bars produced from hot worked continuously cast steel billets or blooms the bars shall be sampled from product representing each strand from the start of the heat and from each 10 tons [9t] thereafter.

S14.5 The samples for inclusion rating shall be located ½ in. [12mm] from the bar surface and oriented parallel to the major direction of working.

S14.6 Acceptance shall be based on the following inclusion ratings:

Type	Rating Units Thin Series	Heavy Series
A	1.5	1.5
B	1.5	1.5
C	1.5	1.5
D	1.5	1.5

S14.6.1 For alternate inclusion rating systems the acceptance criteria shall be specified by the purchaser.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 983/A 983M – 05) that may impact the use of this standard. (Approved Sept. 1, 2006.)

(*1*) Added 4.3.3.1.

Committee A01 has identified the location of selected changes to this standard since the last issue, A 983/A 983M – 04, that may impact the use of this standard. (Approved Oct. 1, 2005.)

(*1*) Added new 1.3, 3.2, 3.3, and 4.1.3 with renumbering of existing clauses.

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