Designation: A 799/A799M – 04

Standard Practice for Steel Castings, Stainless, Instrument Calibration, for Estimating Ferrite Content[1]

This standard is issued under the fixed designation A 799/A799M; 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 practice covers the procedure for calibration of instruments to be used for estimating the ferrite content of the microstructure of cast stainless steels by magnetic response or measurement of permeability. This procedure covers both primary and secondary instruments.

1.1.1 A primary instrument is one that has been calibrated using National Institute of Standards and Technology-Standard Reference Material (NIST-SRM) thickness coating standards. It is a laboratory tool to be used with test specimens. Some primary instruments may be used to directly measure the ferrite content of castings.

1.1.2 A secondary instrument is one that has been calibrated by the use of secondary standards that have been measured by a calibrated primary instrument. Secondary instruments are to be used to directly measure the ferrite content of castings.

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

1.3 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

B 499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

E 562 Practice for Determining Volume Fraction by Systematic Manual Point Count

2.2 *NIST Standard:*

NIST-SRM Coating Thickness Standards

NOTE 1—The specific coating thickness standards previously referenced in this practice are no longer available. Similar ones are now available from NIST.

3. Terminology

3.1 *Definitions:* The definitions in Terminology A 941 are applicable to this standard.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ferrite, n*—the body-centered cubic microconstituent in stainless steel.

3.2.2 *ferrite percentage, n*—a value designating the ferrite content of stainless steels.

3.2.2.1 *Discussion*—The Steel Founders' Society of America (SFSA) has assigned ferrite percentages to the series of NIST coating thickness standards[3]. This assignment was based on the magnetic attraction for a standard magnet by the coating standards when compared with the magnetic attraction of the same magnet by a series of cast stainless steels whose ferrite content had been determined by an accurate metallographic point count. A similar assignment based on magnetic permeability was also established. Algebraic equations have now been derived from a plot of the thickness of these standards and the assigned ferrite percentages. By the use of these equations, any primary instrument will have its calibration traceable to the SFSA's instruments or any other calibrated instrument and thus afford comparable reproducible ferrite percentages. It also allows traceability to NIST.

3.2.3 *secondary standards, n*—a piece of cast stainless steel whose ferrite percentage has been determined by a calibrated primary instrument.

[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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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] Aubrey, L.S., Weiser, P.F., Pollard, W.J., and Schoefer, E.A., "Ferrite Measurement and Control in Cast Duplex Stainless Steels," *Stainless Steel Castings, ASTM STP 756*, ASTM, 1982, p 126.

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

3.2.3.1 *Discussion*—Secondary statements are used to calibrate secondary instruments (see Calibration of Secondary Instruments).

4. Significance and Use

4.1 The amount of ferrite present in an austenitic stainless steel has been shown to influence the strength, toughness and corrosion resistance of this type of cast alloy. The amount of ferrite present tends to correlate well with the magnetic permeability of the steel. The methods described in this standard cover calibration practice for estimating ferrite by the magnetic permeability of the steel. The practice is inexpensive to use over large areas of the cast part and is non-destructive.

4.2 This practice has been used for research, alloy development, quality control, and manufacturing control.

4.2.1 Many instruments are available having different designs, and different principles of operation. When the probe is placed on the material being investigated, a closed magnetic circuit is formed allowing measurement of the magnetic permeability. When calibrated with standards having known ferrite content, this permeability indicates the ferrite content of the material being analyzed. The estimated ferrite content is read from a calibrated dial or from a digital-readout dial. Follow the manufacturer's instructions for proper calibration of the instrument.

4.3 Since this practice measures magnetic attraction and not ferrite directly, it is subject to all of the variables that affect magnetic permeability, such as the shape, size, orientation, and composition of the ferrite phase. These in turn are affected by thermal history. Ferrite measurements by magnetic methods have also been found to be affected by the surface finish of the material being analyzed.

4.4 Magnetic methods should not be used for arbitration of conflicts on ferrite content except when agreed upon between manufacturer and purchaser.

5. Apparatus

5.1 One primary instrument that uses magnetic attraction consists of a spring-loaded balance arm from which a rod-shaped magnet is suspended.[4] The opposite end of the balance arm from the magnet has counterweights that balance most but not all of the weight of the magnet.

5.1.1 When this instrument is used, the spring load is relaxed sufficiently to allow the magnet to make contact with the material being tested.

5.1.2 The spring is then wound until the force of the coiled spring overcomes the magnetic attraction of the magnet for the material being tested, causing the magnet to break contact and the lever arm to rise.

5.1.3 The amount of force that the coiled spring has developed is determined from a marked dial securely attached to the shaft that is used to coil or uncoil the spring.

5.1.3.1 A weighted number 2 is used with this instrument, U5-0664W.

5.2 When using a Feritscope,[5] follow the manufacturer's instructions for calibration. When traceability is required, confirm the calibration using the appropriate NIST standards.

5.2.1 Newer versions of this instrument have a single-point probe while older versions have a two-point probe as the sensing device. When this probe is placed on the material being investigated, a closed magnetic circuit is formed and energized by a low-frequency magnetic field. The voltage induced in the probe coil by this field is a measure of the permeability. When calibrated with standards having known ferrite content, this permeability indicates the ferrite content of the material being analyzed. The estimated ferrite content is read from a calibrated dial or from a digital-readout dial.

5.3 One secondary instrument consists of a balance arm that has a rod-shaped magnet attached to one end.[6] The opposite end is counterweighted to balance the magnet.

5.3.1 This arm with its magnet and counterweight is enclosed in a transparent box. The top face of this container has a threaded hole directly over the magnet. Into this hole are screwed-marked inserts that have metal plates on their bottom face. These plates have different strengths of attraction for the magnet.

5.3.2 In use, the bottom end of the magnet is touched to the material being investigated. The other end of the magnet is in contact with the metal plate on the bottom of the insert. The container is then raised. If the material being measured has a greater attraction for the magnet than does the plate on the bottom of the insert, the magnet will be pulled away from the insert. If not, the magnet will pull away from the material being measured. The insert buttons are changed until the ones that are just weaker and also stronger than the material being investigated are found.

5.3.3 The results of a measurement with this instrument are reported as less than A and greater than B.

5.4 NIST-SRM Coating Thickness Standards. These are mild steel plates that are covered by an electroplated copper layer which in turn is covered by a flash coat of chromium. The thickness of the copper coat varies from standard to standard and is certified by NIST. The strength of the magnetic attraction of each standard varies with the thickness of the coating. These are primary standards for calibration.

5.5 Other instruments such as the Elcometer[7] may be used.

6. Calibration

6.1 Calibrate primary instruments that use magnetic attraction as criterion as follows:

6.1.1 When calibrating magnetic instruments, make sure there is no magnetic material within the area that could affect the calibration. This includes beneath the surface on which the instrument rests.

6.1.2 *Magnet*—Use weighted standard No. 2 magnet for measurement of ferrite content of cast stainless steel.

[4] Magne Gage, produced by Magne Gage Sales and Service Co., Inc., 629 Packer Street, Avoca, PA 18641; http://www.magne-gage.com.

[5] Feritscope, produced by Fischer Technology, Inc., 750 Marshall Road, Windsor, CT 06095; http://www.fischer-technology.com.

[6] Severn Gage, Severn Engineering Co., Old Stage Business Park, 555 Stage Road, Unit A, Auburn, AL 36830; http://www.severnengineering.com.

[7] Elcometer, Elcometer Instruments Ltd., Edge Lane, Manchester, UK M43 6BU; http://www.elcometer.com.

6.1.3 *Zeroing*—Before calibration, zero each primary instrument.

6.1.3.1 When zeroing the instrument, use the "T"-shaped handle to lower the spring-loaded balance arm until the plastic-protection cylinder around the magnet is in contact with a nonmagnetic object. The base plate of the unit is satisfactory.

6.1.3.2 Turn the large-knurled knob on the central shaft counter-clockwise to a dead stop.

6.1.3.3 Rotate the large-knurled knob clockwise until the magnet lifts off the nonmagnetic object and the pivot arm from which the magnet is suspended is parallel to the base plate. Loosen the set screw holding the black dial in position.

6.1.3.4 Set the "0" position on the black dial at the index position and tighten the set screw.

6.1.4 *Determining Black Dial Values for the NIST-SRM Thickness Standards*—Use the NIST-SRM coating thickness standards.

6.1.4.1 Insert, one at a time in random order, the various NIST-SRM coating thickness standards under the plastic protection cylinder. Lower the instrument each time until the cylinder contacts the standard.

6.1.4.2 If the magnet is attracted to the plate when the plastic protection cylinder is placed in contact with the standard, rotate the large-knurled knob clockwise slowly until the magnet breaks contact with the standard. Record the black-dial reading.

6.1.4.3 If the magnet is not attracted to the plate when the plastic cylinder comes in contact with the standard, push the magnet into contact by using the push rod located over the magnet. If the magnet does not adhere to the standard, turn the large-knurled knob counterclockwise a few divisions at a time until the magnet does adhere when it comes in contact with the standard. When the magnet remains in contact with the standard, rotate the large knurled knob clockwise slowly until the magnet breaks contact with the standard. Record the black dial reading.

6.1.4.4 Repeat 6.1.4.3 several times, more than three, with each standard moving the standard under the plastic protection cylinder after each reading. Take the reading in the central area of the standard. Average the readings.

6.1.4.5 Tabulate the black dial readings and the thickness of the coatings on the standards.

6.1.5 *Preparation of Ferrite Percentage Curve*—Calculate the assigned ferrite percentage value for each NIST-SRM coating thickness used in 6.1.4.3 by using Eq. 1, where F is the assigned ferrite content and T is the coating thickness, and the coefficients from Table 1. Round the calculated value to the nearest 0.1 % ferrite.

$$F = B_0 + \frac{B_1}{T} + \frac{B_2}{T_2} + \frac{B_3}{T_3} + \frac{B_4}{T_4} \quad (1)$$

6.1.5.1 Plot on an arithmetic scale the ferrite percentage for each standard and the black dial reading obtained for that standard. This is the calibration curve for the instrument. It is used to designate the ferrite percentage of any sample measured with the instrument.

6.2 *Calibrate primary instruments that use magnetic permeability as criterion as follows*:

NOTE 2—This calibration procedure applies only to the older (pre-1980), analog instruments with the two-point probe. Analog instruments may have iether an analog meter or a digital meter. Newer (post-1980) instruments with digital readouts or single-point probes must be calibrated using the procedure given under Calibration of Secondary Instruments.

6.2.1 If the instrument has more than one measuring range set the instrument to the desired range.

6.2.2 Connect the measuring probe to the instrument.

6.2.3 *Zeroing*—Bring the needle opposite "0" *on the dial* by means of the "zero" knob. Be sure the probe is at least 1 ft [305 mm] away from any magnetic material when this adjustment is made.

6.2.4 *Calibration of "End of Range":*

6.2.4.1 Apply the sensing probe to an NIST-SRM with 2.00-mil [51.0 µm] coating thickness. Using the "end point" control knob, bring the meter needle opposite "29" on the meter. If a digital readout meter is being used, bring the maximum digital reading to "29."

6.2.4.2 If an NIST-SRM with coating thickness other than 2.00-mil [51.0-µm] is used, determine the meter setting to be used from Table 2. It is recommended that coating thickness of 3.25 mil [82.5 µm] or less be used.

6.2.4.3 When measuring ranges are changed, the "zero" setting must be adjusted to "0."

6.2.5 *Determining the Meter Readings for the NIST-SRM Thickness Standards*:

6.2.5.1 Apply the probe to the various NIST-SRM standards several times, more than three. Rotate the probe 90° between reading. Record the readings and average them.

6.2.5.2 Tabulate the average meter readings and the thickness of the measured standards.

6.2.6 *Preparation of Ferrite Percentage Curve*:

6.2.6.1 Calculate the assigned ferrite percentage for each NIST-SRM measured in 6.2.5.1 by using Eq. 1, where F is the assigned ferritic content and T is the coating thickness, and the coefficients from Table 1. Round the calculated value to the nearest 0.1 % ferrite.

6.2.6.2 Plot on an arithmetic scale the ferrite percentage for each standard and the meter or digital readings obtained for that standard. This is the calibration curve for the instrument.

TABLE 1 Coefficients for Calculating Assigned Ferrite Values

Instrument	Units	B_0	B_1	B_2	B_3	B_4
Magne-Gage	Mils	–0.6727	164.8	–334.3	516.2	–352.6
	mm	–0.6727	6 486	–518 100	31 500 000	–847 100 000
Feritscope (Note 2)	Mils	–2.042	296.5	–1656	5 440	–6 945
	mm	–2.042	11 670	–2 566 000	332 000 000	–16 680 000 000

TABLE 2 "End Point" Settings to be used with Coating Thickness Other than 2.00 mils [51.0 µm]

Coating Thickness, mils [µm]	"End Point"
1.66 [42.2]	30
2.04 [51.8]	28.5
2.1 [53.3]	28
2.2 [55.9]	27.7
2.3 [58.4]	27.5
2.4 [61.0]	27
2.5 [63.5]	26.5
2.6 [66.0]	26.3
2.7 [68.6]	26
2.8 [71.1]	25.7
2.9 [73.7]	25.5
3.0 [76.2]	25.2
3.1 [78.8]	25
3.22 [81.8]	24.5

7. Checking Calibration

7.1 Whenever any instrument is to be used after a period of nonuse, the zero point and the black dial or meter readings of one or more coating thickness standards must be determined to see if the instrument is in calibration.

8. Calibration of Secondary Instruments

8.1 *Correlating Ferrite Percentage of Secondary Standards with Primary Instruments*:

8.1.1 Determine the proper readings (black dial or meter) with a calibrated instrument for each secondary standard[8].

[8] The secondary standards may be produced by a foundry that produces cast stainless steel or purchased from an organization such as NIST (Standard Reference Materials 8480 and 8481 are available from the NIST Standard Reference Materials Program at 100 Bureau Drive, Stop 2322, Gaithersburg, MD 20899–2322; http://ts.nist.gov/ts/htdocs/230/232/232.htm).

8.1.1.1 Measure each secondary standard with a primary instrument and note the black dial or meter reading. Tabulate the results.

8.1.1.2 Determine the reading from the secondary instrument for each secondary standard. Make several readings on each standard.

8.1.1.3 Plot the black dial or meter readings and the readings from the secondary instrument. This curve can be used to obtain the ferrite percentage of the material measured with the secondary instrument from the primary calibration curve.

8.2 *Secondary Instruments that have Set Point Readings*:

8.2.1 Measure each secondary standard with various inserts in the secondary instrument set.

8.2.1.1 Note the lowest ferrite percentage of the secondary standard set that will pull the measuring magnet of the instrument away from the insert.

8.2.1.2 Note the highest ferrite percentage of the secondary standard set that will not pull the measuring magnet of the instrument from the insert.

8.2.1.3 For each insert, tabulate the values obtained in 8.2.1.1 and 8.2.1.2. Each insert will be designated as "greater than _____ ferrite percentage less than _____ ferrite percentage."

9. Checking of Calibration of Secondary Instruments

9.1 Before using a secondary instrument to measure the ferrite content of a casting, it should be checked with one or more of the secondary standards.

9.1.1 Periodically, the set of secondary standards shall be checked with the primary instrument by determining the proper readings. Compare these values with those obtained in 8.1.1.

10. Keywords

10.1 calibration; ferrite; stainless steel castings

SUMMARY OF CHANGES

Subcommittee A01.18 has identified the location of selected changes to this standard since the last issue (A 799/A 799M – 92(2002)) that may impact the use of this standard.

(1) Eliminated references to specific NIST coating thickness standards in several places, including the deletion of Table 1.
(2) Revised the discussion of the definition of *ferrite percentage*.
(3) Revised 4.4.
(4) Added Notes 1 and 2.
(5) Removed Fig. 1, and replaced it with Eq. 1 and a new Table 1.
(6) Revised 6.1.5 and 6.2.6.1.