ANSI/AWS A4.2-91
An American National Standard

Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal

American Welding Society

Keywords — instrument calibration, delta ferrite, stainless steel weld metal, austenitic stainless weld metal, duplex stainless weld metal

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Approved by
American National Standards Institute
February 14, 1991

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Supersedes ANSI/AWS A4.2-86

Prepared by
AWS Committee on Filler Metal
and The Welding Research Council Subcommittee
on Welding Stainless Steels

Under the Direction of
AWS Technical Activities Committee

Abstract

Calibration procedures are specified for a number of commercial instruments that can then provide reproducible measurements of the ferrite content of austenitic stainless steel weld metals. Certain of these instruments can be further calibrated for measurements of the ferrite content of duplex austenitic-ferritic stainless steel weld metals. Calibration with primary standards (non-magnetic coating thickness standards from the U. S. National Institute of Standards and Technology) is the preferred method for appropriate instruments. Alternatively, these and other instruments can be calibrated with weld metal secondary standards.

Reproducibility of measurement after calibration is specified. Problems associated with accurate determination of ferrite are described.

American Welding Society
550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135

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International Standard Book Number: 0-87171-361-6

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Foreword

(This Foreword is not a part of ANSI/AWS A4.2-91, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal*, but is included for information purposes only.)

This document is a revision of the *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal*, first published in 1974 and revised in 1986. This revision was by the Subcommittee on Welding Stainless Steel of the Welding Research Council and by the AWS Filler Metal Committee. The current revision expands the range of calibration and measurement to include, for the first time, duplex austenitic-ferritic stainless steel weld metals.

A certain minimum ferrite content in most austenitic stainless steel weld metals is useful in assuring freedom from microfissures and hot cracks. Upper limits on ferrite content in austenitic stainless steel weld metals can be imposed to limit corrosion in certain media or to limit embrittlement due to transformation of ferrite to sigma phase during heat treatment or elevated temperature service. Upper limits on ferrite content in duplex austenitic-ferritic stainless steel weld metals can be imposed to help assure ductility, toughness, and corrosion resistance in the as-welded condition.

Reproducible quantitative ferrite measurements in stainless steel weld metals are therefore of interest to filler metal producers, fabricators of weldments, weldment end users, regulatory authorities, and insurance companies.

Comments and suggestions for improvement are welcome. They should be sent in writing to Secretary, Filler Metal Committee, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135.

Table of Contents

List of Tables

List of Figures

Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal

1. Scope

1.1 This standard prescribes procedures for the calibration and maintenance of calibration of instruments for measuring, by magnetic attraction or permeability, the delta ferrite content of an austenitic or duplex austenitic-ferritic stainless steel weld metal in terms of its Ferrite Number (FN).

1.2 A thorough review of the Appendix is recommended before any instrument is calibrated or used. The Appendix presents background information which is essential to understanding the many problems and pitfalls in determining and specifying the ferrite content of weld metals.

1.3 Calibration can be accomplished with the use of the National Institute of Standards and Technology (NIST, formerly National Bureau of Standards) primary standards or weld metal secondary standards. At the present time, only three instruments [Magne-Gage (including a torsion balance using essentially a Magne-Gage Number 3 magnet, hereinafter referred to as a *Magne-Gage type instrument*), Feritscope (also sometimes identified as *Ferritescope*), and Inspector Gage] can be calibrated by the use of NIST primary standards, and the range of possible calibration depends upon the particular instrument (see Tables 1, 2, and 3). This is not an endorsement of any particular instrument. (See 3.1.)

2. Definitions[1]

2.1 Delta Ferrite. The ferrite which remains at room temperature from that which was formed from the molten state upon freezing. Much of the original ferrite that formed upon freezing transforms to austenite during cooling.

2.2 Draw Filing. A weld pad surface preparation technique suitable for subsequent ferrite measurements only up to about 20 FN. (See 8.2.) A sharp clean 14-inch mill bastard file which has not been contaminated by ferromagnetic materials, held parallel to the base metal and perpendicular to the long axis of the weld metal sample, is stroked smoothly with a firm downward pressure, forward and backward along the weld length. No cross filing is done. The finished surface is flat with at least a 1/8-in. (3.2 mm) width where all weld ripples are removed.

2.3 Ferrite Number (FN). An arbitrary, standardized value designating the ferrite content of austenitic and duplex austenitic-ferritic stainless steel weld metal (see Appendix A2).

2.4 Primary Standards. Specimens with accurate thickness of non-magnetic material on carbon steel base plate containing 0.25 percent carbon maximum. Each primary standard is assigned an FN of an equivalent magnetic weld metal, this assigned value being specific to a particular make (and model, if applicable) of measuring instrument (i.e., Magne-Gage, Feritscope, or Inspector Gage). (See Appendix A3.1.)

The primary standards upon which the standard procedures are based are the NIST's sets of coating thickness standards, consisting of a very uniform layer of electroplated copper covered with a chromium flash over a carbon steel base. (See Appendix A4.1.)

2.5 Weld Metal Secondary Standards. Small weld metal pads certified for FN in a manner traceable to these standard procedures. (See Appendix A4.2.)

1. For AWS terms and definitions, refer to the latest edition of ANSI/AWS A3.0, *Standard Terms and Definitions*. Please note that some of the terms and definitions used in this publication are not included in AWS A3.0. They are either new terms defined after the latest revision of A3.0 or they are used specific to this publication.

Table 1
Ferrite Numbers (FN) for Primary Standards
Calibration of Instruments Using a Magne-Gage No. 3 Magnet or Equivalent
(Magne-Gage-Type Instruments)

mils	mm	FN	mils	mm	FN	mils	mm	FN	mils	mm	FN
1.20	0.0305	89.5	3.5	0.0889	46.8	15.0	0.381	15.6	41.0	1.041	5.8
1.25	0.0318	87.5	3.6	0.0914	45.9	15.5	0.394	15.2	42.0	1.067	5.7
1.30	0.0330	85.7	3.7	0.0940	45.1	16.0	0.406	14.8	43.0	1.092	5.5
1.35	0.0343	83.9	3.8	0.0965	44.3	16.5	0.419	14.4	44.0	1.118	5.4
1.40	0.0356	82.3	3.9	0.0991	43.5	17.0	0.432	14.0	45.0	1.143	5.2
1.45	0.0368	80.6	4.0	0.1016	42.7	17.5	0.445	13.7	46.0	1.168	5.1
1.50	0.0381	79.1	4.1	0.1041	42.0	18.0	0.457	13.3	47.0	1.194	5.0
1.55	0.0394	77.6	4.2	0.1067	41.3	18.5	0.470	13.0	48.0	1.219	4.8
1.60	0.0406	76.2	4.3	0.1092	40.7	19.0	0.483	12.7	49.0	1.245	4.7
1.65	0.0419	74.9	4.4	0.1118	40.0	19.5	0.495	12.4	50.0	1.270	4.6
1.70	0.0432	73.6	4.5	0.1143	39.4	20.0	0.508	12.1	51.0	1.295	4.5
1.75	0.0445	72.4	4.6	0.1168	38.8	20.5	0.521	11.8	52.0	1.321	4.4
1.80	0.0457	71.2	4.7	0.1194	38.2	21.0	0.533	11.6	53.0	1.346	4.3
1.85	0.0470	70.0	4.8	0.1219	37.7	21.5	0.546	11.3	54.0	1.372	4.2
1.90	0.0483	68.9	4.9	0.1245	37.1	22.0	0.559	11.1	55.0	1.397	4.1
1.95	0.0495	67.8	5.0	0.127	36.6	22.5	0.572	10.8	56.0	1.422	4.0
2.00	0.0508	66.8	5.2	0.132	35.6	23.0	0.584	10.6	57.0	1.448	3.9
2.05	0.0521	65.8	5.4	0.137	34.7	23.5	0.597	10.4	58.0	1.473	3.8
2.10	0.0533	64.8	5.6	0.142	33.8	24.0	0.610	10.2	59.0	1.499	3.75
2.15	0.0546	63.9	5.8	0.147	32.9	24.5	0.622	10.0	60.0	1.524	3.67
2.20	0.0559	63.0	6.0	0.152	32.1	25.0	0.635	9.8	61.0	1.549	3.59
2.25	0.0572	62.2	6.2	0.157	31.4	25.5	0.648	9.6	62.0	1.575	3.52
2.30	0.0584	61.3	6.4	0.163	30.7	26.0	0.660	9.4	63.0	1.600	3.44
2.35	0.0597	60.5	6.6	0.168	30.0	26.5	0.673	9.2	64.0	1.626	3.37
2.40	0.0610	59.7	6.8	0.173	29.3	27.0	0.686	9.1	65.0	1.651	3.30
2.45	0.0622	58.9	7.0	0.178	28.7	27.5	0.699	8.9	66.0	1.676	3.24
2.50	0.0635	58.2	7.5	0.191	27.3	28.0	0.711	8.7	67.0	1.702	3.17
2.55	0.0648	57.5	8.0	0.203	26.0	28.5	0.724	8.6	68.0	1.727	3.11
2.60	0.0660	56.8	8.5	0.216	24.8	29.0	0.737	8.4	69.0	1.753	3.05
2.65	0.0673	56.1	9.0	0.229	23.7	29.5	0.749	8.3	70.0	1.778	2.99
2.70	0.0686	55.4	9.5	0.241	22.7	30.0	0.762	8.1	71.0	1.803	2.93
2.75	0.0699	54.8	10.0	0.254	21.8	31.0	0.787	7.9	72.0	1.829	2.88
2.80	0.0711	54.1	10.5	0.267	21.0	32.0	0.813	7.6	73.0	1.854	2.82
2.85	0.0724	53.5	11.0	0.279	20.2	33.0	0.838	7.4	74.0	1.880	2.77
2.90	0.0737	52.9	11.5	0.292	19.5	34.0	0.864	7.1	75.0	1.905	2.72
2.95	0.0749	52.3	12.0	0.305	18.8	35.0	0.889	6.9	76.0	1.930	2.67
3.00	0.0762	51.8	12.5	0.318	18.2	36.0	0.914	6.7	77.0	1.956	2.62
3.1	0.0787	50.7	13.0	0.330	17.6	37.0	0.940	6.5	78.0	1.981	2.57
3.2	0.0813	49.6	13.5	0.343	17.1	38.0	0.965	6.3	79.0	2.007	2.53
3.3	0.0838	48.6	14.0	0.356	16.6	39.0	0.991	6.2	80.0	2.032	2.48
3.4	0.0864	47.7	14.5	0.368	16.1	40.0	1.016	6.0			

3. Calibration Methods

3.1 Primary Standards. Since each type of ferrite measuring instrument responds differently to the primary standards, it is not possible to specify a generic calibration procedure; rather, it is necessary to tailor a calibration procedure to a particular instrument. As of the previous revision of this standard, three types of instruments had been subjected to extensive testing, and detailed procedures and appropriate tables and values were contained in that standard to provide for their calibration to primary standards. These instruments are the Magne-Gage-type instruments, Feritscope, and Inspector Gage. At the time of publication of ANSI/AWS A4.2-86, however, the probe of the Feritscope was changed so that the Feritscope calibration table does not apply to newer instruments. This situation continues. Since that time, the range of calibration by primary

Table 2
Ferrite Numbers (FN) for Primary Standards for Feritscope (Ferritescope) Model FE8-KF Calibration (See 5.1.1)

Thickness			Thickness			Thickness		
mils	mm	FN	mils	mm	FN	mils	mm	FN
7.0	0.178	25.8	22.5	0.572	9.1	46.0	1.168	4.4
7.5	0.191	24.3	23.0	0.584	8.9	47.0	1.194	4.3
8.0	0.203	23.0	23.5	0.597	8.7	48.0	1.219	4.2
8.5	0.216	21.8	24.0	0.610	8.6	49.0	1.245	4.1
9.0	0.229	20.7	24.5	0.622	8.4	50.0	1.270	4.0
9.5	0.241	19.7	25.0	0.635	8.3	51.0	1.295	3.9
10.0	0.254	18.8	25.5	0.648	8.1	52.0	1.321	3.8
10.5	0.267	18.0	26.0	0.660	8.0	53.0	1.346	3.7
11.0	0.279	17.2	26.5	0.673	7.8	54.0	1.372	3.6
11.5	0.292	16.6	27.0	0.686	7.7	55.0	1.397	3.5
12.0	0.305	15.9	27.5	0.699	7.6	56.0	1.422	3.4
12.5	0.318	15.4	28.0	0.711	7.4	57.0	1.448	3.3
13.0	0.330	14.8	28.5	0.724	7.3	58.0	1.473	3.2
13.5	0.343	14.4	29.0	0.737	7.2	59.0	1.499	3.15
14.0	0.356	13.9	29.5	0.749	7.1	60.0	1.524	3.1
14.5	0.368	13.5	30.0	0.762	6.9	61.0	1.549	2.98
15.0	0.381	13.1	31.0	0.787	6.7	62.0	1.575	2.9
15.5	0.394	12.7	32.0	0.813	6.5	63.0	1.600	2.83
16.0	0.406	12.3	33.0	0.838	6.3	64.0	1.626	2.75
16.5	0.419	12.0	34.0	0.864	6.1	65.0	1.651	2.7
17.0	0.432	11.7	35.0	0.889	6.0	66.0	1.676	2.6
17.5	0.445	11.4	36.0	0.914	5.8	67.0	1.702	2.55
18.0	0.457	11.1	37.0	0.940	5.6	68.0	1.727	2.5
18.5	0.470	10.8	38.0	0.965	5.4	69.0	1.753	2.42
19.0	0.483	10.6	39.0	0.991	5.3	70.0	1.778	2.35
19.5	0.495	10.3	40.0	1.016	5.15	72.0	1.829	2.23
20.0	0.508	10.1	41.0	1.041	5.0	74.0	1.880	2.15
20.5	0.521	9.9	42.0	1.067	4.9	76.0	1.930	2.0
21.0	0.533	9.7	43.0	1.092	4.75	78.0	1.981	1.9
21.5	0.546	9.5	44.0	1.118	4.6	80.0	2.032	1.8
22.0	0.559	9.3	45.0	1.143	4.5			

standards of Magne-Gage-type instruments has been expanded to include FNs appropriate to duplex austenitic-ferritic stainless steel weld metals.

3.2 Secondary Standards

3.2.1 Calibration by means of primary standards is the preferred method of maintaining calibration of appropriate instruments. But the need for frequent in-process checks is recognized along with the fact that primary standards are not necessarily "durable" for frequent use outside of a laboratory environment. Therefore, it is recommended that a set of secondary standards be used for frequent in-process checks. (See Appendix A4.2.)

3.2.2 When secondary standards are used, the average reading on each standard shall be within the maximum allowable deviation from the calibration curve as specified in Table 4. If a maximum allowable deviation is exceeded, the instrument cannot be considered calibrated. Calibration with primary standards or instrument repair is then necessary.

3.2.3 Instruments for which there is not a detailed calibration procedure in this standard utilizing primary standards can only be calibrated using secondary standards. Refer to Section 7 for proper calibration instructions.

3.3 For all calibration methods and instruments, the range of calibration is defined by the interval of FNs between and including the lowest FN standard and the highest FN standard used in developing the calibration according to the corresponding procedure.

Table 3
Ferrite Numbers (FN) for Primary Standards for Inspector Gage Calibration*

Thickness			Thickness			Thickness		
mils	mm	FN	mils	mm	FN	mils	mm	FN
7.0	0.178		22.5	0.572	16.9	46.0	1.168	8.3
7.5	0.191		23.0	0.584	16.6	47.0	1.194	8.1
8.0	0.203		23.5	0.597	16.2	48.0	1.219	7.9
8.5	0.216		24.0	0.610	15.9	49.0	1.245	7.7
9.0	0.229		24.5	0.622	15.6	50.0	1.270	7.5
9.5	0.241		25.0	0.635	15.4	51.0	1.295	7.4
10.0	0.254		25.5	0.648	15.1	52.0	1.321	7.2
10.5	0.267	>30	26.0	0.660	14.8	53.0	1.346	7.0
11.0	0.279	29.9	26.5	0.673	14.5	54.0	1.372	6.9
11.5	0.292	29.0	27.0	0.686	14.3	55.0	1.397	6.7
12.0	0.305	28.1	27.5	0.699	14.1	56.0	1.422	6.6
12.5	0.318	27.3	28.0	0.711	13.8	57.0	1.448	6.4
13.0	0.330	26.5	28.5	0.724	13.6	58.0	1.473	6.3
13.5	0.343	25.8	29.0	0.737	13.4	59.0	1.499	6.1
14.0	0.356	25.1	29.5	0.749	13.1	60.0	1.524	6.0
14.5	0.368	24.4	30.0	0.762	12.9	61.0	1.549	5.9
15.0	0.381	23.8	31.0	0.787	12.5	62.0	1.575	5.75
15.5	0.394	23.2	32.0	0.813	12.2	63.0	1.600	5.6
16.0	0.406	22.6	33.0	0.838	11.8	64.0	1.626	5.5
16.5	0.419	22.0	34.0	0.864	11.4	65.0	1.651	5.4
17.0	0.432	21.5	35.0	0.889	11.1	66.0	1.676	5.3
17.5	0.445	21.0	36.0	0.914	10.8	67.0	1.702	5.1
18.0	0.457	20.5	37.0	0.940	10.5	68.0	1.727	5.0
18.5	0.470	20.0	38.0	0.965	10.2	69.0	1.753	4.9
19.0	0.483	19.6	39.0	0.991	9.9	70.0	1.778	4.8
19.5	0.495	19.2	40.0	1.016	9.7	72.0	1.829	4.6
20.0	0.508	18.7	41.0	1.041	9.4	74.0	1.880	4.4
20.5	0.521	18.4	42.0	1.067	9.2	76.0	1.930	4.2
21.0	0.533	18.0	43.0	1.092	9.0	78.0	1.981	4.0
21.5	0.546	17.6	44.0	1.118	8.7	80.0	2.032	3.85
22.0	0.559	17.2	45.0	1.143	8.5			

*This table shall be used only for calibrating Inspector Gage Model Number 111 with 6F or 7F scale for measuring the delta ferrite content of as-welded austenitic stainless steel weld metals.

Table 4
Maximum Allowable Deviation, Calibration Point to Calibration Curve, for Instruments Being Calibrated with Weld Metal Secondary Standards

Ferrite Number Range	Maximum Allowable Deviation
0 to 5 FN	± 0.30
over 5 to 10 FN	± 0.30
over 10 to 15 FN	± 0.40
over 15 to 25 FN	± 0.50
over 25 to 50 FN	± 5% of assigned FN
over 50 to 90 FN	± 8% of assigned FN

4. Calibration of Magne-Gage-Type[2] Instruments

4.1 Calibration by Means of Primary Standards. All Magne-Gage-type instruments can be calibrated by the following procedure. Torsion balances other than a Magne-Gage may not require use of counterweights, so that statements regarding ranges of calibration may not apply. However, the requirements for the number of standards for calibration over a specific FN range shall

2. Trademark of Magne-Gage Sales & Service. (See Appendix A6.1.)

apply to all Magne-Gage-type instruments. (See Appendix A6.1.)

4.1.1 The FNs shall be assigned from Table 1 to each of the available primary standards (coating thickness standards) as defined in 2.3. For thicknesses between those given in the table, the FNs shall be interpolated as closely as possible. Alternatively, FN may be calculated directly from one of the two following formulas:

For thickness (T) in mils:

$$\ln(FN) = 4.5891 - 0.50495\ln(T) - 0.08918[\ln(T)]^2 + 0.01917[\ln(T)]^3 - 0.00371[\ln(T)]^4$$

For thickness (T) in mm:

$$\ln(FN) = 1.8059 - 1.11886\ln(T) - 0.17740[\ln(T)]^2 - 0.03502[\ln(T)]^3 - 0.00367[\ln(T)]^4$$

See Section 9 for information on the precision of the measurements.

4.1.2 Magne-Gage-type instruments are sensitive to premature magnet detachment from a standard or from a sample due to very small vibrations. The Magne-Gage minimizes, but does not eliminate, this effect, as compared to other torsion balances. Repetitive measurements at a given point will yield a range of FN values due to this effect, and the range increases with increasing FN. With a Magne-Gage, above 20 FN, it is necessary to make several measurements at any given point of a standard or sample, and to accept only the highest FN as the correct value for that point. With other Magne-Gage-type instruments (torsion balances) this practice is necessary for all levels of FN.

4.1.3 A Magne-Gage can be used for measurements over a range of about 30 FN with a single calibration. The exact range to be used at any given time is determined by the choice of a counterweight (if any) added to the balance beam of the instrument at a hole provided for this purpose. The hole is located about 1.5 inches (38 mm) from the fulcrum opposite from the point of suspension of the magnet (see Figure A1). Care should be taken that the counterweight, if used, is free to swing without touching any other part of the instrument when the magnet is in contact with specimen or standards. Without a counterweight, a Magne-Gage will cover from 0 to about 30 FN. With a counterweight of about 7.5 grams, a Magne-Gage will cover from about 30 to 60 FN; with a counterweight of about 15 g, the measurement range will be about 60 to 90 FN. Exact ranges will depend upon the precise weight of the counterweight and upon the strength of the magnet in use. A separate calibration is required for each counterweight, and recalibration is required whenever the magnet is changed.

4.1.4 Without a counterweight, eight or more primary standards shall be used, with nominal thicknesses that provide corresponding Ferrite Numbers well distributed over the range of 0 to 28 FN. With the No. 3 magnet in place, the zero point (the white dial reading at which the magnet lifts free from a completely nonmagnetic material) shall be determined. If a counterweight is used, five or more primary standards, similarly well distributed, shall be used, but no zero point can be determined. In either case, the white dial reading for each of the available primary standards covering the FN range of interest shall then be determined. (See Appendix A4.1).

4.1.5 The white dial readings shall be plotted on Cartesian coordinate paper versus the FNs as illustrated in Figure 1. If no counterweight is used, the zero point reading (white dial reading when the magnet just barely lifts from a nonmagnetic material) on the dial of the gage can be included as 0 FN.

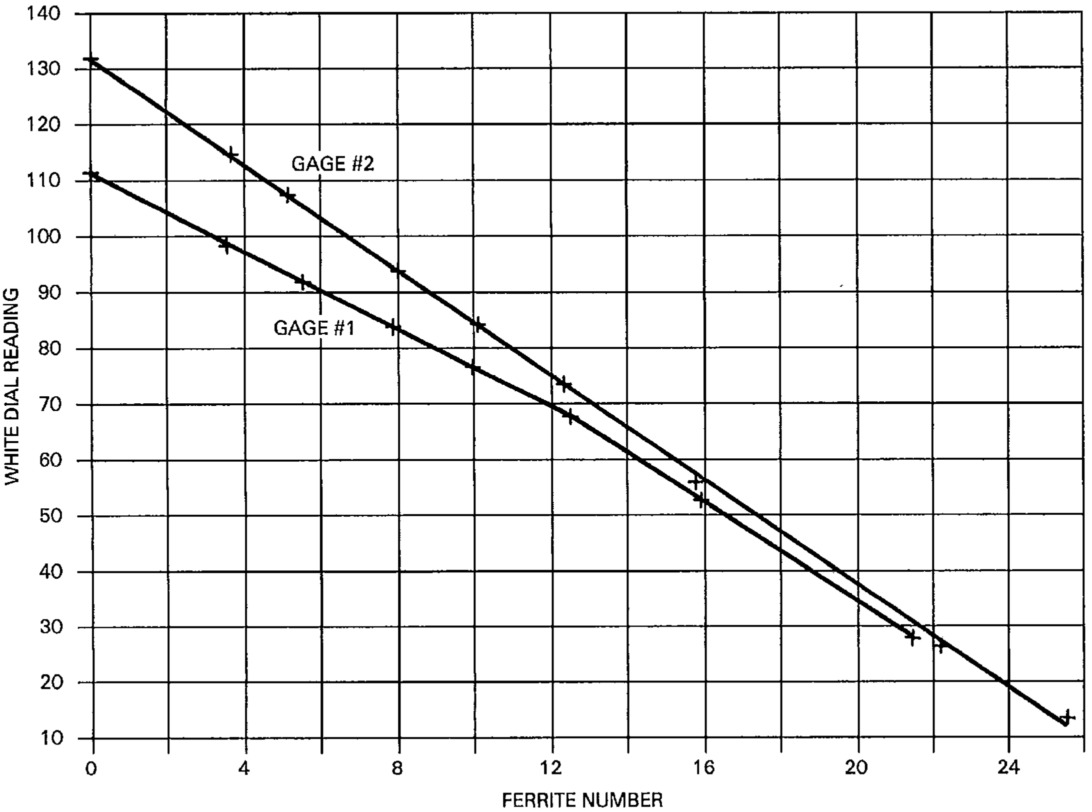
4.1.6 A "best fit" straight line shall be drawn through the points plotted in accordance with 4.1.5. Alternatively, a linear regression equation shall be fit to the data collected as described in 4.1.4. Magne-Gages tested to date have produced a straight line up to at least 10 FN. Most yield a straight line through all points, but some have shown a slight bend. An example of each is shown in Figure 1. For acceptable calibration, all points must fall within the maximum allowable deviations shown in Table 5. If any of the calibration points fall outside of the allowed variations, the data shall be restudied, or the manufacturer of the instrument shall be consulted, or both.

4.1.7 Two common sources of discrepant readings during calibration (as well as during measurement) are mechanical vibrations and dirt (usually magnetic particles) clinging to the magnet. Either factor tends to produce premature detachment of the magnet from the sample, with a correspondingly low FN determination (high white dial reading). A vibration-free environment is essential to accurate FN determination, especially above 15 FN. Wiping of the magnet end with a clean,

Table 5
Tolerance on the Position of Calibration Points Using Primary Standards

Ferrite Number Range	Maximum Allowable Deviation
0 to 5	± 0.40
over 5 to 10	± 0.50
over 10 to 15	± 0.70
over 15 to 20	± 0.90
over 20 to 30	± 1.00
over 30 to 90	± 5% of assigned FN

Note: The maximum variations in the position of the calibration points from the curve (example is shown in Fig. 1) occur when the primary thickness standards are at the maximum five percent variation from the certified thicknesses.



NOTE: A different set of coating thickness standards was used for each instrument, although the sets included the same standard numbers

DATA FOR THE CURVES

NBS COATING THICKNESS STANDARD	GAGE #1 CALIBRATION				GAGE #2 CALIBRATION			
	mils	mm	FN	WHITE DIAL	mils	mm	FN	WHITE DIAL
1312					8.2	.208	25.5	13.2
1313	10.2	.259	21.5	28.0	9.8	.249	22.2	27.0
1314	14.7	.373	15.9	53.0	15.0	.381	15.6	57.0
1315	19.2	.488	12.6	68.0	19.7	.500	12.3	74.0
1316	24.5	.622	10.0	76.0	24.3	.617	10.1	84.1
1317	31.2	.792	7.8	84.0	30.5	.775	8.0	93.5
1318	43.0	1.092	5.5	92.0	45.5	1.156	5.2	107.3
1319	63.0	1.600	3.4	99.0	60.5	1.537	3.6	114.8
Zero Point			0.0	111.5			0.0	132.0

Figure 1—Examples of Calibration Curves for Two Magne-Gage Instruments, Each with a No. 3 Magnet for Measuring the Delta Ferrite Content of Weld Metals

lint-free cloth is suggested when dirt is encountered. In case of doubt, examination of the magnet end under a microscope is appropriate.

4.1.8 The graph plotted as in 4.1.6, or a regression equation fit to it, may now be used to determine the FNs of stainless steel weld metals from the white dial readings of the instrument obtained on those weld metals with the same No. 3 magnet and counterweight (if used).

4.2 Calibration by Means of Weld Metal Secondary Standards

4.2.1 Calibration by primary standards is the recommended method, as previously mentioned, but calibration utilizing secondary standards is acceptable.[3] Five or

3. Weld metal secondary standards have been commercially sold by The Welding Institute, Abington Hall, Abington, Cambridge, CB1 5AL, United Kingdom.

more such standards are required for calibration curves for 0 to 15 FN; eight or more are required for calibration curves for 0 to 30 FN; and five or more are required for any range of 30 FN above 15 FN. In all cases, the Ferrite Numbers of the standards shall be well distributed over the range of interest. (See also Appendix A4.2).

4.2.2 It should be recognized that weld metal secondary standards are unlikely to provide readings from point to point that are as uniform as those from primary standards. Care must therefore be exercised to take readings on secondary standards in precisely those locations used in assigning the original FNs to the standards. In case of doubt, the producer of the secondary standards should be consulted.

4.2.3 Other than the departures noted in 4.2.1 and 4.2.2, the remainder of the calibration procedure with secondary standards shall be the same as that used with primary standards as given in 4.1.2 through 4.1.8.

5. Calibration of Feritscopes ("Ferritescopes")

5.1 Calibration by Means of Primary Standards

5.1.1 This instrument is calibrated to the FN scale by the manufacturer, but calibration should be verified by the user. The only Feritscope[4] (Ferritescope) which can be calibrated with primary standards according to Table 2 is the pre-1980 Model FE8-KF with analog readout and dual-contact ("normalized") probe. No tables for calibration with primary standards are available for post-1980 instruments (those with digital readouts or single-pole probes). Other Feritscopes may be calibrated by weld metal secondary standards as described in Section 7.

4. Trademark of Fischer Technology. (See Appendix A6.2.)

5.1.2 The manufacturer's instructions with regard to the use of the instrument and the adjustments of the scale shall be followed.

5.1.3 The FNs shall be assigned from Table 2 to each of the available primary thickness standards as defined in 2.3. For thicknesses between those given in the table, the FNs shall be interpolated as closely as possible. Eight or more thickness standards shall be used, with nominal thickness corresponding to Ferrite Numbers well distributed in the range 0 to 25 FN (see Appendix A4.1). The instrument reading for each of the available primary standards shall then be determined.

5.1.4 The instrument readings shall be plotted on Cartesian coordinate paper versus the FN assigned from Table 2 for each primary standard. A "best fit" line shall be drawn through the data. Alternatively, a regression equation shall be fit to the data collected as described in 5.1.3.

5.1.5 For approved calibration, all readings shall fall within the maximum allowable deviations from the "best fit" line shown in Table 6. If any of the calibration readings fall outside of these allowed variations, the data shall be restudied, or the manufacturer of the instrument shall be consulted, or both.

5.1.6 The graph plotted as in 5.1.4, or a regression equation fit to it, may now be used to determine the FNs of stainless steel weld metals from the instrument reading.

5.2 Calibration by Means of Weld Metal Secondary Standards

5.2.1 As previously mentioned, calibration to primary standards is the preferred method for suitable instruments, but calibration to weld metal secondary standards is acceptable. Calibration to weld metal secondary standards is necessary for other Feritscopes.

Table 6
Maximum Allowable Deviation of the Periodic Ferrite Number (FN) Check for Feritscopes (Ferritescopes)

	Maximum Allowable Deviation of the Periodic Ferrite Number Check		
Ferrite Number Range	From the Ferrite Number Value Assigned to the Primary Standard in Table 2	From the Ferrite Number Value Assigned to the Secondary Standard by the Seller	From the Ferrite Number Value First Assigned to the Secondary Standard by the User
0 to 5	± 0.40	± 0.40	± 0.20
over 5 to 10	± 0.40	± 0.40	± 0.20
over 10 to 15	± 0.70	± 0.70	± 0.20
over 15	± 1.0	± 1.0	± 0.30

5.2.2 Refer to 7.2 for instructions to calibrate the Feritscope to weld metal secondary standards.

6. Calibration of Inspector Gages[5]

6.1 Calibration By Means of Primary Standards

6.1.1 This instrument is the Inspector Gage Model Number 111 with either a 6F ("% ferrite") or a 7F (FN) scale. The latter is preferable because it has smaller divisions. (see also Appendix A6.3).

6.1.2 The manufacturer's instructions with regard to the use of the instrument and adjustments of the scale shall be followed.

6.1.3 The FNs shall be assigned from Table 3 to each of the available primary thickness standards as defined in 2.3. For thicknesses between those given in the table, the FNs shall be interpolated as closely as possible. Eight or more thickness standards shall be used, with nominal thicknesses corresponding to Ferrite Numbers well distributed in the range 0 to 30 FN (see Appendix A4.1). The instrument reading for each of the available primary standards shall then be determined.

6.1.4 The instrument readings shall be plotted on Cartesian coordinate paper versus the FN assigned from Table 3 for each primary standard. A "best fit" line shall be drawn through the data. Alternatively, a regression equation shall be fit to the data collected as described in 6.1.3.

6.1.5 For approved calibration, all readings shall fall within the maximum allowable deviations from the "best fit" line shown in Table 7. If any of the calibration readings fall outside of these allowed variations, the data shall be restudied, or the manufacturer of the instrument shall be consulted, or both.

5. Trademark of Elcometer Instruments Ltd. (See Appendix A6.3.)

6.1.6 The graph plotted as in 6.1.4, or a regression equation fit to it, may now be used to determine the FNs of stainless steel weld metals from the instrument reading.

6.2 Calibration by Means of Weld Metal Secondary Standards

6.2.1 As previously mentioned, calibration to primary standards is the preferred method, but calibration to weld metal secondary standards is acceptable.

6.2.2 Refer to 7.2 for instructions to calibrate the Inspector Gage to weld metal secondary standards.

7. Calibration of Other Instruments

7.1 Calibration by Means of Primary Standards. As of this revision of this standard (see 3.1) only Magne-Gage type instruments, Feritscopes with normalized probes, and Inspector Gages can be calibrated to this standard by means of primary standards. All other instruments must be calibrated by means of weld metal secondary standards (see also Appendix A6.4).

7.2 Calibration by Means of Weld Metal Secondary Standards

7.2.1 Other instruments can be calibrated by weld metal secondary standards to produce a satisfactory correlation between the instrument readout and weld metal FN. While it may be desirable that the instrument readout be precisely the calibrated value of FN, this is not essential, so long as a unique correlation between readout and FN can be determined. Such instruments may be used if they have been calibrated using secondary weld metal standards to which FNs were assigned by an instrument with primary standard calibration.

7.2.2 Five or more such secondary standards are required for calibration curves covering 0 to 15 FN; eight or more such secondary standards are required for

Table 7
Maximum Allowable Deviation of the Periodic Ferrite Number (FN) Check for Inspector Gages

	Maximum Allowable Deviation of the Periodic Ferrite Number Check		
Ferrite Number Range	From the Ferrite Number Value Assigned to the Primary Standard in Table 3	From the Ferrite Number Value Assigned to the Secondary Standard by the Seller	From the Ferrite Number Value First Assigned to the Secondary Standard by the User
0 to 5	± 0.40	± 0.40	± 0.20
over 5 to 10	± 0.40	± 0.40	± 0.20
over 10 to 15	± 0.70	± 0.70	± 0.20
over 15	± 1.0	± 1.0	± 0.30

calibration from 0 to 28 FN; and five or more such secondary standards are required for calibration of any 30 FN interval above 15 FN. In all cases, the Ferrite Numbers of the secondary standards shall be well distributed over the range of interest.

7.2.3 Instrument readings shall be determined for each of the available secondary standards and, if possible, for a zero point. When taking readings on secondary standards, the same precaution noted in 4.2.2 should be taken.

7.2.4 Instrument readings shall be plotted against assigned secondary standard FN values on Cartesian coordinate paper, and the zero point can be included if applicable.

7.2.5 A "best fit" smooth line shall be drawn through the points plotted in 7.2.4. For acceptable calibration, no data point may vary from the curve any more than the allowable deviations shown in Table 4. If any point falls outside of the appropriate allowed deviation, the data shall be restudied, or the manufacturer of the instrument shall be consulted, or both.

7.2.6 The graph plotted as in 7.2.4, or a regression equation fit to it, may now be used to determine the FNs of stainless steel weld metals over the calibration range.

7.2.7 It is the responsibility of the user to ensure that the instrument is properly calibrated—i.e., such that the results obtained with weld metal secondary standards in the FN range(s) of use are within the expected range of variations shown in Table 4.

8. Use of Calibrated Instruments

8.1 Maintaining Calibration. Instruments must be checked periodically on a regular basis against primary or secondary standards to ensure and verify the maintenance of the original calibration. Records of such checks shall be maintained. It is the responsibility of the user to check at a frequency which is adequate to maintain calibration. For frequently used instruments, a weekly calibration check is recommended. For seldomly used instruments, a calibration check before each use is recommended. Two standards, one near each extreme of the calibration range being checked, shall be used for each of the ranges shown in Tables 4 and 6 through 8, as appropriate, for which the instrument is used. When the instrument no longer produces values within the maximum deviation specified in the relevant table, it shall be removed from service and the manufacturer shall be consulted. (see Appendix A3.2).

8.2 Variations in Measurements. Based upon round robin tests within the Welding Research Council Subcommittee on Welding Stainless Steels, the FNs determined by these instruments are expected to fall within the limits shown in Table 9, 10, or 11 as compared to the overall average FN values of stainless steel weld metals checked on other instruments of the same type calibrated to this standard. When measurements are made with a variety of calibrated instrument types, somewhat larger variation in measurements than those indicated in Table 9, 10, or 11 might be expected, but the magnitude of the variation has not been determined. Weld ripples and other surface perturbations must be removed because surface finish affects measurement accuracy. Up to about 20 FN, the practice known as "draw filing" produces acceptable accuracy (see 2.2). For accurate and reproducible ferrite measurements, above 20 FN, a Magne-Gage No. 3 magnet or equivalent requires a flat surface at least 1/8-in. (3.2 mm) in diameter finished no coarser than with a 600 grit abrasive [about 8 microinches (0.2 microns) RMS]. Rougher surfaces or convex sur-

Table 8
Maximum Allowable Deviation of the Periodic Ferrite Number (FN) Check for Magne-Gage-Type Instruments

	Maximum Allowable Deviation of the Periodic Ferrite Number Check		
Ferrite Number Range	From the Ferrite Number Value Assigned to the Primary Standard in Table 1	From the Ferrite Number Value Assigned to the Secondary Standard by the Seller	From the Ferrite Number Value First Assigned to the Secondary Standard by the User
0 to 5	± 0.50	± 0.50	± 0.20
over 5 to 10	± 0.50	± 0.50	± 0.20
over 10 to 15	± 0.60	± 0.60	± 0.30
over 15 to 25	± 0.80	± 0.80	± 0.40
over 25 to 90	± 5% of assigned FN value	± 5% of assigned FN value	± 3% of assigned FN value

Table 9
Expected Range of Variation in Measurements with Calibrated Magne-Gage-Type Instruments*

Ferrite Number Range	67% of the Instruments	95% of the Instruments
0 to 10	± 0.30 FN	± 0.60 FN
over 10 to 18	± 0.35 FN	± 0.70 FN
over 18 to 25	± 0.45 FN	± 0.90 FN
over 25 to 90	± 5% of mean FN value	± 10% of mean FN value

*Based upon WRC round robin tests.

Table 10
Expected Range of Variation in Measurements with Calibrated Feritscopes (Ferritescopes)*

Ferrite Number Range	67% of the Instruments	95% of the Instruments
0 to 10	± 0.20 FN	± 0.40 FN
over 10 to 18	± 0.40 FN	± 0.80 FN
over 18 to 25	± 0.50 FN	± 1.0 FN
over 25 to 80	± 5% of mean FN value	± 10% of mean FN value

*Based upon WRC round robin tests.

faces will result in artificially low FN values and shall be avoided. Other instruments may respond differently to rough, convex, or narrow surfaces and should be examined fully before use. At all ferrite levels, surface preparation must be accomplished without contamination by ferromagnetic materials.

Table 11
Expected Range of Variation in Measurements with Calibrated Inspector Gages*

Ferrite Number Range	67% of the Instruments	95% of the Instruments
0 to 10	± 0.20 FN	± 0.40 FN
over 10 to 18	± 0.40 FN	± 0.80 FN
over 18 to 30	± 0.50 FN	± 1.0 FN

*Based upon WRC round robin tests.

9. Significant Figures in Reporting Measurement Results

9.1 Calibration Data. For purposes of developing calibration data or demonstrating compliance of an instrument with calibration requirements, the number of significant figures shown in the relevant Table herein shall be used.

9.2 Measurement Data. For purposes of reporting measurement data on weld metal test samples or demonstrating compliance with the requirements of a specification other than this specification, the precision implied by the number of significant figures in the Tables herein is generally inappropriate. For ferrite measurements of 25 FN or higher, rounding off to the nearest whole number conveys appropriate precision. For ferrite measurement of 5 to 25 FN, rounding off to the nearest 0.5 FN conveys appropriate precision. For ferrite measurements less than 5 FN, rounding off to the nearest 0.1 FN conveys appropriate precision.

Appendix

(This Appendix is not a part of ANSI/AWS A4.2-91, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal*, but is included for information purposes only.)

A1. Acknowledgment

These standard procedures are based upon the studies and recommendations made by the Subcommittee on Welding Stainless Steel of the High Alloys Committee of the Welding Research Council (WRC).[6] The document on which most of this standard is based is the *Calibration Procedure for Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal*, published by the WRC on July 1, 1972.

Expansion of the measurement system beyond 28 FN is based upon *Extension of the WRC Ferrite Number System*, D. J. Kotecki, *Welding Journal*, November, 1982 and International Institute of Welding Documents II-C-730-84, II-C-821-88, II-C-835-88 and II-C-836-88.

A2. Ways of Expressing Ferrite Content

A2.1 The methods of determining ferrite content in stainless steel weld metals have evolved over an extended time period. The interested reader is referred to WRC Bulletin 318 (September, 1986). Only a few of the pertinent conclusions of that Bulletin are summarized briefly in the following paragraphs.

A2.2 Measured Percent Ferrite. The percent ferrite in austenitic stainless steel weld metals in the past has too often been regarded as a firm fixed value. Extensive round robins have been run on sets of weld metal specimens, containing up to a nominal 25 percent ferrite, in the U.S. under the sponsorship of the WRC and on similar sets in Europe by the International Institute of Welding (IIW). These round robins showed that most laboratories used somewhat different calibration curves as well as a variety of instruments. At nominal levels of up to 10 percent ferrite, which is often the most useful and pertinent range, the values obtained by participating laboratories ranged from 0.6 to 1.6 times the nominal value. The instrument calibration procedure defined in this standard is designed to overcome this problem.

A similar problem existed with metallographic determinations due to the extreme fineness of the ferrite in weld metals, variations in the etching media and the degree of etch, and to the Quantitative Television Microscope (QTM) settings, if a QTM was used. Similar problems, though perhaps to a lesser degree, have been encountered with magnetic saturation, x-ray diffraction, Mossbauer studies, and with other methods of determining the ferrite content of weld metals. Thus a "percent ferrite" figure in past literature is very dependent upon the source, and should be defined in relation to the instrument, the laboratory using it, and the calibration source, or to the diagram if derived from a constitution diagram. In the opinion of the WRC Subcommittee, it has been impossible, to date, to determine accurately the true absolute ferrite content of stainless steel weld metals.

A2.3 Ferrite Number. Because on a given specimen, laboratory A might rate the percent ferrite at as low as 3 percent, laboratory B at 5 percent, and laboratory C at as high as 8 percent, the WRC Subcommittee decided to use the new term *Ferrite Number* (FN) to define the ferrite quantity as measured by instruments calibrated with its recommended procedure. Thus, FN is an arbitrary, standardized value related to the ferrite content of an equivalently magnetic weld metal. It is not necessarily the true absolute ferrite percentage of the weld. FNs below 10 do represent an excellent average of the "percent ferrite" as determined by U.S. and world methods of measuring delta ferrite, based upon the previously discussed round robins conducted by the WRC Subcommittee and the IIW Subcommission II-C. FNs above 10 clearly exceed the true volume percent. Magnetic saturation measurements on castings of known percent ferrite have shown that the magnetic response of a given percent ferrite depends upon its composition. So

6. Welding Research Council, 345 East 47th St., New York, NY 10017.

any relation between percent ferrite and FN will be influenced somewhat by composition of the ferrite. For common duplex austenic-ferritic weld metals, it is not unreasonable to estimate that the percent ferrite is on the order of 0.7 times the FN as measured herein, but this should not be considered as exact.

A2.4 Ferrite Content Calculated From Constitution Diagrams. The several committees that have investigated and reviewed this subject recommend for most applications the use of measured ferrite as opposed to the use of ferrite calculated from the weld metal analysis. The basic reason for this is that the variables involved in determining the chemical composition, and other variables involved in the diagrams themselves, are very likely to have substantially greater effects than those associated with the direct determination of ferrite content using instruments calibrated in accordance with this standard. Nevertheless, constitution diagrams are very useful tools, even though they are less exact, because they permit anticipation or prediction of ferrite content for a variety of situations. By taking into account dilution effects, such diagrams can also be useful for anticipating or predicting the ferrite content of weld overlays and dissimilar metal joints.

The Schaeffler diagram, developed in the late 1940s, presents its values as percent ferrite, but these are said to be directly equivalent to FNs. The DeLong diagram, January 1973 version, was the first diagram presented in terms of FN. Espy, in 1982, proposed a modification of the Schaeffler Diagram to take into account high nitrogen, high manganese stainless steel weld metals. The more recent diagram of Siewert, McCowan, and Olson, prepared under WRC sponsorship in 1988, is, at the time of this writing, the best estimation tool available for most austenitic and duplex austenitic-ferritic stainless steel weld metals. See *Welding Journal*, December, 1988, pp. 289s–298s, or WRC Bulletin 342, April, 1989. To assist in Ferrite Number estimation, a Personal Computer software package, FERRITEPREDICTOR, is available from the American Welding Society, although, at the time of this writing, only the Schaeffler and DeLong Diagrams are included.

A3. Cautions on the Use of Ferrite Number

A3.1 Instrument Calibration

A3.1.1 Various thicknesses of nonmagnetic material over carbon steel represent a very convenient method of calibrating instruments for the measurement of ferrite in stainless steel weld metals. Useful general information on the subject can be obtained from the latest edition of The American Society for Testing and Materials (ASTM) B499, *Standard Method for Measurement of Coating Thicknesses by Magnetic Method: Nonmagnetic Coatings on Magnetic Base Metals.*[7] The response of the instrument when a nonmagnetic "skin" is between the measuring probe and the plate, versus its response to ferrite in stainless steel weld metal at several levels, can be plotted and the relationship between them established. A change in the magnet size or strength, or in the probe characteristics, changes the relationship. Thus, a calibration curve or table for FN versus nonmagnetic coating thickness for a Magne-Gage-type instrument (Figure A1) will be different for each of the magnets (Nos. 1, 2, 3 and 4) because the strengths of the magnets are different.

A3.1.2 With Magne-Gage-type instruments, only calibration using a No. 3 magnet is considered in this standard. A weaker magnet (No. 1 or No. 2), if used with the calibration points of Table 1, will on weld metal yield falsely high FN values. Conversely, a stronger magnet (No. 4), if used with the calibration points of Table 1, will on weld metal yield falsely low FN values. If the No. 3 magnet of a Magne-Gage is damaged, such as by rough handling or exposure to an ac field which weakens it, it will also yield false readings. Work within the WRC Subcommittee on Welding Stainless Steel, on behalf of the International Institute of Welding, Subcommission II-C, has demonstrated that accurate readings on weld metal are obtained via calibration from Table 1 when the magnet strength is such that it provides a tearing-off force as a function of FN of 5 FN/gram ±0.5 FN/gram. With a torsion balance other than a Magne-Gage, compliance with this requirement is determined directly from the slope of the calibration line. With a Magne-Gage, this can be evaluated simply by suspending a 5 gram iron weight from the No. 3 magnet. When the white dial of the Magne-Gage is turned to just barely lift the weight past the balance point of the instrument, the reading should correspond to 25 FN ±2.5 FN using the calibration line of white dial readings versus FN.

A3.1.3 It is strongly recommended that reference weld metal secondary standards be used along with the calibration curves obtained from primary standards when using a Feritscope to check for compliance with Table 6, when using an Inspector Gage to check for compliance with Table 7, or when using a Magne-Gage type instrument to check for compliance with Table 8. If compliance cannot be obtained as required by the appropriate table, the instrument is in need of recalibration or servicing by the manufacturer, or it is not suitable for calibration with primary standards.

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7. ASTM standards can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

A3.2 Instrument Malfunction. Recalibration or rechecking of each instrument at periodic and sometimes frequent intervals is necessary to ensure that the instrument is operating properly (see 8.1). Permanent magnets may be partially demagnetized by exposure to any significant ac field such as that generated by a strong alternating current in a wire or by a weaker alternating current in a coil. The tips of such permanent magnets, or of the probes which are used to establish a magnetic field in the specimen, may become worn and the response of the system may change for this reason. Bearings may become fouled with dirt and thus fail to operate freely.

A4. Standards for Instrument Calibration

A4.1 Primary Standards. NIST[8] coating thickness standards were developed many years ago to calibrate instruments for the determination of coating thickness. The standards useful for the determination of delta ferrite consist of varying thicknesses of copper electroplated on a carbon steel base and protected with a chromium flash. NIST certifies the thickness of the total coating to within ±5% of the stated thickness, but the majority will be within ±2% or even ±1%. The use of the two sets listed below is recommended for calibration up to 28 FN.

SRM 1363A Nominal Thicknesses—9.6, 16, 20, and 26 mils

SRM 1364A Nominal Thicknesses—32, 39, 59, and 79 mils

These 8 thicknesses correspond nominally to 0.26, 0.39, 0.50, 0.64, 0.80, 1.00, 1.53, and 1.94 mm, respectively.

Sets SRM 1368 (8 to 20 mils), SRM 1369 (25 to 60 mils) and individual standards are no longer available. The 8 mil thickness is now available in set SRM 1362A.

For Ferrite Numbers from about 30 to about 85, the use of the three sets listed below is recommended for calibration:

SRM 1323, Nominal Thicknesses—3.7, 4.4, 5.3, and 6.6 mils (.094, .112, .135, and .167 mm, respectively).

SRM 1322, Nominal Thicknesses—2.1, 2.4, 2.7, and 3.2 mils (.053, .060, .069, and .080 mm, respectively).

SRM 1321, Nominal Thicknesses—1.34, 1.46, 1.65, and 1.85 mils (.034, .037, .042, and .047 mm, respectively).

The sets can be ordered from NIST. Other thickness sets are also available, but do not, of themselves, offer close enough spacing of corresponding Ferrite Numbers for adequate calibration.

A4.2 Secondary Standards

A4.2.1 Weld Metal Secondary Standards. Magnetic instruments may also be calibrated by using weld metal secondary standards prepared from weld metals rated by 2 or more instruments carefully calibrated through the use of these standard procedures. Each such standard should be provided with FN values at specific points on its test surface. These secondary standards can be used for the calibration of a suitable instrument or for maintaining calibration. They can also be used to establish the relationship between other instruments and Magne-Gage-type instruments.

A4.2.2 Other Types of Secondary Standards. The use of cast specimens or powder compacts is risky because the size, shape, and orientation of the magnetic particles may influence the response of the magnetic or other type probes to varying degrees. However, cast specimens or powder compacts calibrated with one instrument traceable to this procedure can be used for calibrating instruments of the same type and manufacture or for day-to-day verification of such instruments.

A5. Effect of Ferrite Size, Shape, and Orientation

It has been established that the ferrite size, shape, and orientation can influence the relative response of the low field strength magnets and probes used with the measuring instruments. For this reason, a measuring instrument may respond differently to a given volume percent ferrite in a stainless steel weld metal as compared to the same volume percent ferrite in a cast stainless steel, or even in a solution heat treated stainless steel weld metal. The ferrite in as-welded weld metal up to about 15 FN is very fine and in the form of lacy, dendritic stringers generally perpendicular to the fusion line, and often extensively interconnected at ferrite contents over 3 or 4 FN. Above about 15 FN in as-welded weld metal, the ferrite and austenite generally form laths which are also very fine. The ferrite in castings is usually much larger and tends to be more spheroidal and much less interconnected except perhaps at very high ferrite contents. The ferrite in wrought steels and in solution heat-treated weld metals tends to be lesser in volume and more spheroidized than in an as-welded weld metal of the same composition because heat treatment tends to

8. Office of Standard Reference Materials, Room B311, Chemistry Building, National Institute of Standards and Technology (formerly National Bureau of Standards), Gaithersburg, MD 20899, Phone 301-975-6776.

transform some ferrite to austenite and spheroidize the balance. Since the volume percent of ferrite in castings is in close agreement when measured by either magnetic response or by metallographic point count, the ferrite content of castings is expressed as a percentage and not by the arbitrary FN, as noted in ASTM Practice A800.

A6. Instruments

A6.1 Magne-Gage and Magne-Gage-Type Instruments

A6.1.1 The Magne-Gage[9] (Figure A1) is usable only in the flat position on relatively small specimens. The probe is a long, thin magnet hung on a spiral spring. The spring is wound by means of turning a knob with a corresponding reading on a dial. When the magnet is pulled free of a specimen, the white dial reading used in conjunction with the calibration curve establishes the FN of the specimen.

A6.1.2 Returning the Magne-Gage periodically to the factory for maintenance is desirable. With heavy use, 1 year is a reasonable time; with light use, 2 years.

A6.1.3 A Magne-Gage Number 3 Magnet or equivalent can be used with a variety of torsion balances to obtain the same results as are obtained with a Magne-Gage. A complete example of such a Magne-Gage-type instrument is given in "Extension of the WRC Ferrite Number System" referenced in Section A1. Numerous other configurations could also be conceived. This is outside the scope of this Standard.

A6.2 Feritscope[10] (Ferritescope). This instrument, consisting of a probe connected by a cable to an electronics package (Figure A2), is usable in any position. Several models and a variety of probes are available. Only one model and probe has been shown to be able to be calibrated with primary standards as given in Table 2 (see 5.1.1). All others must be calibrated with weld metal secondary standards. Models are available in either battery powered or ac current versions. At least one model can be calibrated with secondary standards up to 80 FN.

A6.3 Inspector Gage.[11] This instrument (Figure A3), is usable in any position. It is a hand held magnetic instrument with thumb actuated springs tension. The instrument gives direct readings in FN if it is a new model designed to do so. Older models can be rebuilt by the manufacturer to give acceptable readings on weld metal in terms of FN. As of 1989, the ability of Inspector Gages to determine ferrite above 30 FN is unknown.

A6.4 Other Instruments

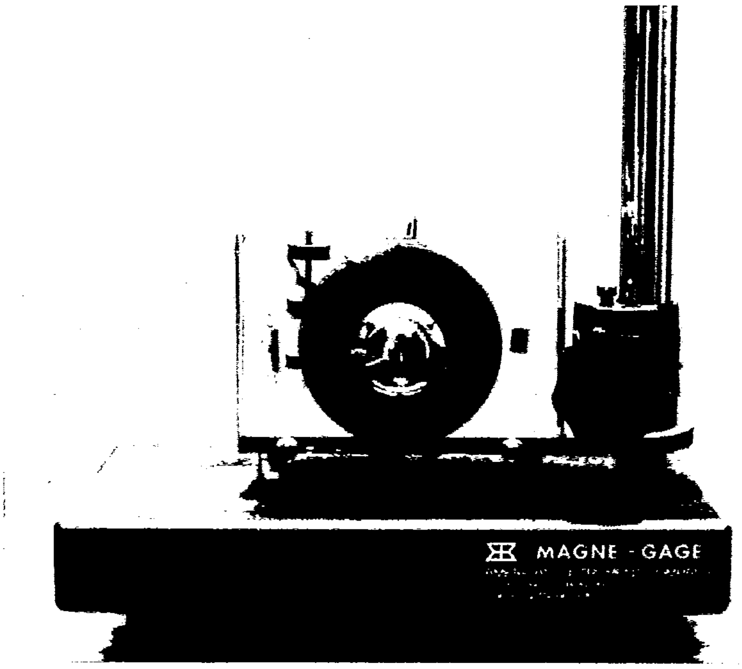
A6.4.1 The following instruments at the time of the writing of this revision are not capable of being calibrated to primary standards. They can, however, be calibrated to weld metal secondary standards and produce acceptable consistent results. Again, it is the responsibility of the user to ensure that instrument calibration is maintained and to have the instrument repaired by the manufacturer if consistent readings on the weld metal secondary standards cannot be obtained. As of 1989, the ability of these instruments to determine ferrite above 30 FN is unknown.

A6.4.1.1 Ferrite Indicator (more commonly called a **Severn Gage**).[12] This instrument (Figure A4) is usable in any position. It is a go-, no-go-type gage which determines whether the ferrite content is above or below each of a number of inserts of various magnetic strengths which come with the instrument. At least one unthreaded test insert must be available for use in conjunction with one of the threaded inserts with specified FN values. The purpose of the unthreaded inserts is to assure that the magnet has not lost strength. Details may be obtained from the manufacturer for conversion of percent ferrite values on earlier model Severn gages to FN. Severn gages calibrated directly in terms of FN are now available. Older model gages can be converted to the FN scale by the manufacturer.

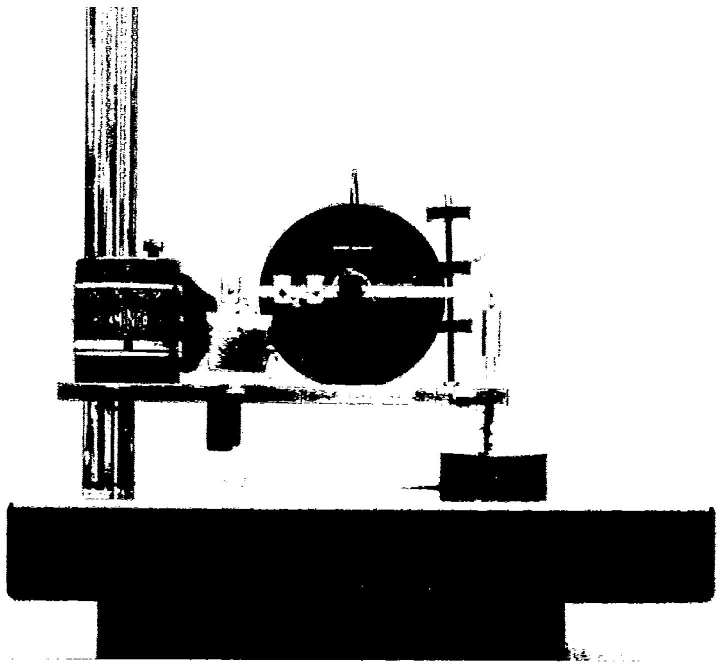
A6.4.1.2 Foerster Ferrite Content Meter.[13] This is a light, portable, battery-operated instrument (Figure A5) usable in any position. It closely resembles the Feritscope in its operation except that it has a single contact point probe which allows ferrite determination in very localized regions. On older models, the meter output indicates ferrite content as a percentage, which can be effectively converted to FN values by the use of suitable weld metal secondary standards to produce a satisfactory calibration curve. Newer models are now available on which the meter reads directly in FN values.

A6.4.2 A number of other magnetic measuring instruments are available for various purposes. Many are regarded as not suitable in their present form because of limitations such as range, problems in calibration, or varying response due to the position of use or to their relation to the north-to-south magnetic field lines of the

9. Manufactured by Magne-Gage Sales & Service, 14376 Dorsey Mill Road, Glenwood, MD 21738.
10. Manufactured by Fischer Technology, 750 Marshall Phelps Road, Windsor, CT 06095.
11. Manufactured by Elcometer Instruments Ltd., 1180 East Big Beaver, Troy, MI 48083.
12. Manufactured by Severn Engineering Co., Inc., 98 Edgewood Street, Annapolis, MD 21401.
13. Marketed by Foerster Instrument Inc., 202 Rosemont Dr., Coraopolis, PA 15108.



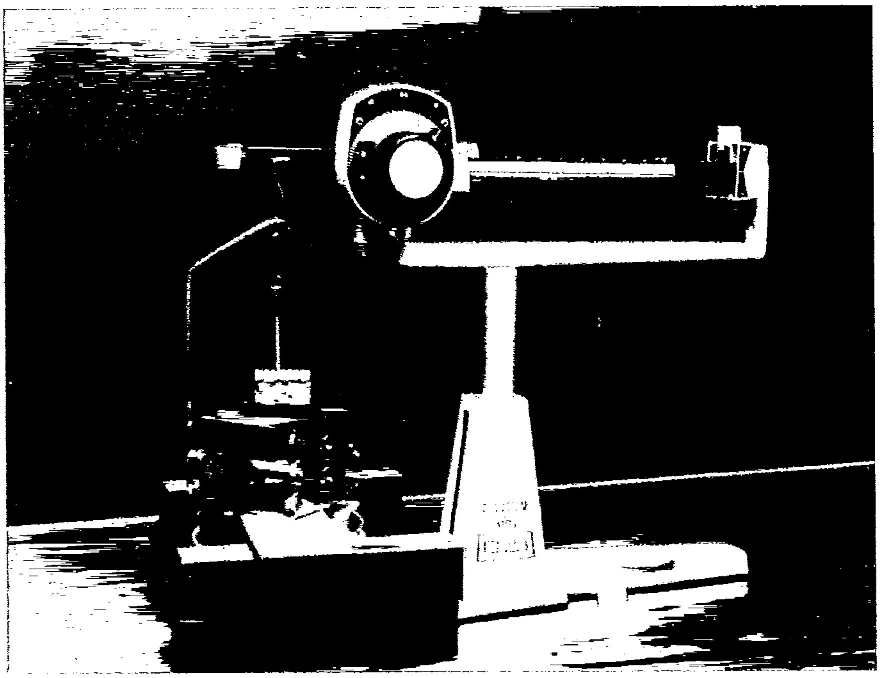
(A) STANDARD MAGNE-GAGE



(B) MAGNE-GAGE FROM REAR, COUNTERWEIGHT ADDED TO LEFT SIDE OF BALANCE BEAM

Figure A1 — Magne-Gage-Type Instruments

AWS A4.2 91 ■ 0784265 0012400 T ■



(C) TORSION BALANCE WITH MAGNE-GAGE NO. 3 MAGNET

Figure A1 (Continued) — Magne-Gage-Type Instruments

Figure A2 — Ferritescope

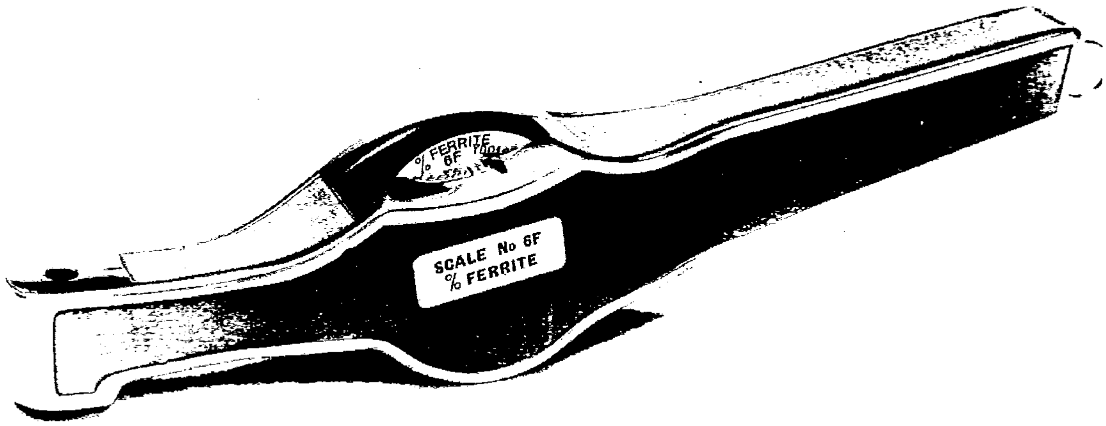


Figure A3 — Inspector Gage

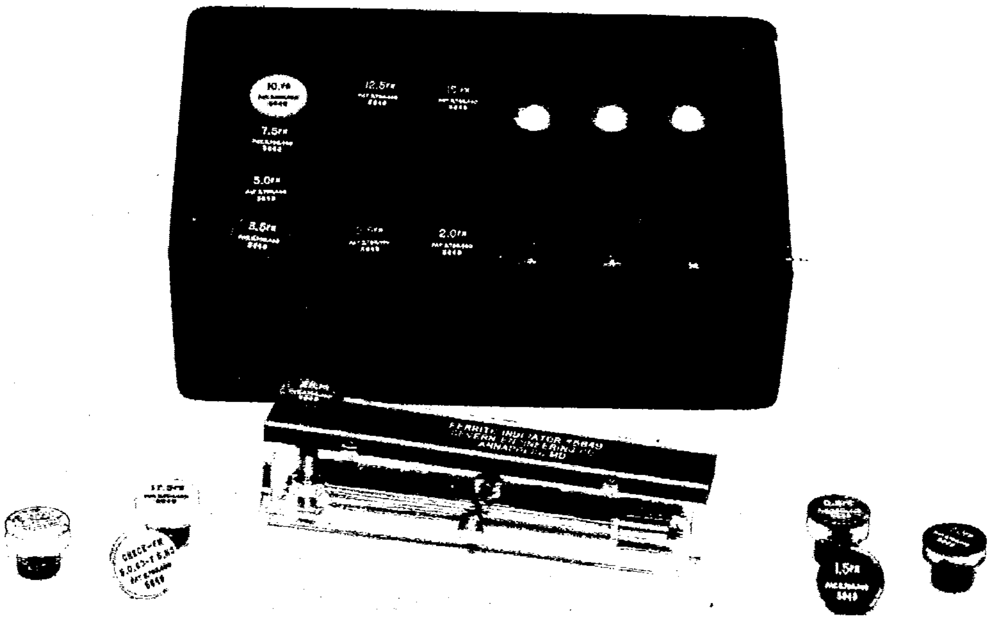


Figure A4 — Ferrite Indicator (Severn Gage)

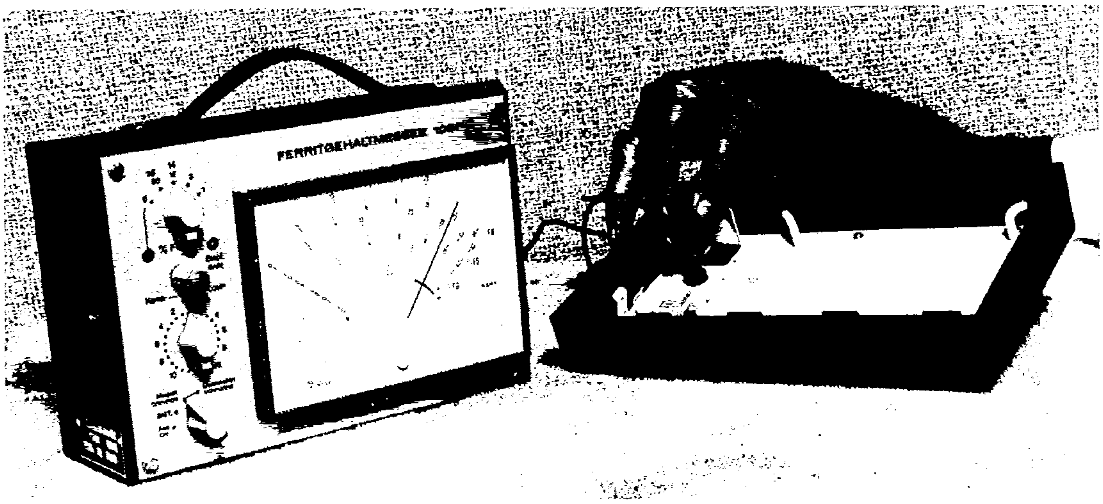


Figure A5 — Foerster Ferrite Content Meter

earth. One that seems promising is the Ferritector Gage.[14] Instruments which are suitable in other respects must still be calibrated to the FN scale in a manner traceable to this standard. This can be accomplished by the use of a set of 5 or more weld metal secondary standards if the calibration is extended up to 15 FN, or 8 or more if it is up to 25 FN. The establishment of an adequate correlation is the responsibility of the user.

A7. Use of Calibrated Instruments

A7.1 Distance for Ferromagnetic Material. The FN values of stainless steel weld deposits on ferromagnetic base metal may be increased by varying degrees on each instrument depending on the distance of the magnet or probe from the base metal, on the ferrite content, and on the permeability of the base metal. Hence, to limit the increase in FN values to 0.2 FN maximum due to the effect of a ferromagnetic carbon steel base metal, the carbon steel base plate should be approximately 0.3 in. (8 mm) or more away from a Magne-Gage magnet or Inspector Gage magnet, 1.0 in. (25 mm) from a Ferrite Indicator (Severn Gage), and 0.2 in. (5 mm) from a Feritscope or Foerster Ferrite Content Meter probe. For other instruments, a safe distance can be obtained by experimentation or by contacting the instrument manufacturer. If it is not possible to obtain the above minimum distances from ferromagnetic material in a production situation, FN measurements can still be meaningful if the effect of the proximity of the ferromagnetic can be taken into account. One way to do this is by comparing FN measured with ferromagnetic material in place to FN measured with ferromagnetic material removed using laboratory samples.

A7.2 Wrought Stainless Steels. It is not intended that the determination of FN be extended to wrought stainless steels. Wrought steels are beyond the scope of this standard.

A7.3 Cast Stainless Steels. The FNs are not used for cast stainless steels. The same measurement scales used for weld metals cannot be used for cast steels (see A5 for an explanation). To calibrate instruments for measuring the ferrite content of cast stainless steels, obtain ASTM A799, *Standard Practice for Calibration Instruments for Estimating Ferrite Content of Cast Stainless Steels.* Equally useful will be ASTM A800, *Standard Practice for Estimating Ferrite Content in Austenitic Alloy Castings.*

14. Manufactured by Elcometer Instruments Ltd., 1180 East Big Beaver, Troy, MI 48083.