

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 4340A

Certified Reference Material for Low Alloy Steel Grade 4340 - UNS Number G43400

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values³	Certified Value ¹	Estimate of Uncertainty ²	
Al	0.031	0.001		Sn	0.0081	0.0004
As	0.0059	0.0004		V	0.0024	0.0004
C	0.423	0.004		W	0.0005	0.0002
Co	0.0111	0.0005		Zr	0.0016	0.0005
Cr	0.879	0.006				
Cu	0.128	0.004				
Fe	95.4	0.3				
Mg	0.0004	0.0002				
Mn	0.766	0.005				
Mo	0.259	0.006				
N	0.0102	0.0005				
Ni	1.80	0.02				
O	0.0007	0.0002				
P	0.0062	0.0004				
Si	0.253	0.006				

Informational Values^{3,4}

B (0.0002)	Ca (0.0002)	Nb (0.002)	Pb (0.0003)	S (0.0008)
Sb (0.0018)	Ti (0.0011)			

¹ For each element, the certified value listed is the present best estimate of the true value based on the mean of the weighted results of an interlaboratory testing program. See page 4 for more information on its calculation.

² For each element, the uncertainty listed is based on a statistical evaluation of the contributions of homogeneity and the interlaboratory testing program. See page 4 for more information on its calculation.

³ Values are given in weight percent. Values in brackets are reported by difference.

⁴ Values in parentheses are not certified and are provided for information only.

Trace element information values for Bi, Cl, Ga, Ge, K, Na, Re, and Zn are shown on page 4.

The requirements of ISO Guides 31, 34, and 35 were followed for the preparation of this Certified Reference Material and certificate of analysis. This is a Certified Reference Material as defined by ISO Guide 30.

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* Code for method Certified values listed as weight percent

Analysis	*	Al	*	As	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mg
1	12	0.0265	5	0.0047	1	0.416943	5	0.009733	4	0.8675	12	0.1100	13	95.122	3	0.000243
2	5	0.027967	5	0.005033	1	0.418667	14	0.0099	4	0.873333	4	0.12	16	[95.3436]	3	0.00026
3	14	0.029333	3	0.00505	1	0.419667	12	0.0100	3	0.874	3	0.120333	10	95.36	4	0.00040
4	3	0.0294	3	0.005675	1	0.4197	3	0.0106	4	0.875333	10	0.122	16	[95.36667]	12	0.0004
5	4	0.030267	4	0.005833	3	0.42125	4	0.010833	4	0.875633	4	0.124	14	95.4	5	0.000467
6	4	0.030333	10	0.0061	3	0.42175	4	0.0113	14	0.876667	4	0.124333	3	95.40667	5	0.000473
7	3	0.030525	12	0.0063	1	0.422	4	0.0113	3	0.87775	4	0.125	16	[95.41667]	4	0.000613
8	4	0.030667	4	0.0063	1	0.422333	8	0.011467	10	0.878	3	0.126	10	95.41667		
9	4	0.031733	15	0.006397	1	0.422667	10	0.0116	3	0.879	14	0.126667	16	[95.42]		
10	4	0.031967	5	0.007267	1	0.423333	4	0.011733	10	0.881	4	0.128	16	[95.43333]		
11	3	0.032275	5	0.0076	1	0.423333	5	0.011833	4	0.882	4	0.128167	4	95.44		
12	5	0.0325			1	0.424967	5	0.011967	4	0.883333	4	0.128967	16	[95.45]		
13	4	0.035267			1	0.428333	3	0.012	4	0.8868	8	0.129				
14					3	0.43	3	0.013	4	0.889333	3	0.13				
15									3	0.89	10	0.130				
16									10	0.913333	3	0.131				
17											10	0.133333				
18											5	0.1344				
19											5	0.1350				
Average		0.0306		0.00594		0.4228		0.01105		0.8789		0.1279		95.410		0.000427
Std dev		0.0011		0.00028		0.0041		0.00060		0.0053		0.0027		0.033		0.000037
H		0.0012		0.00057		0.0055		0.00073		0.009		0.0026		0.53		0.00025
U ₁		0.0016		0.00063		0.0068		0.00095		0.011		0.0037		0.53		0.00025
t-statistic		2.18		2.23		2.16		2.16		2.13		2.10		2.20		2.45
U ₂		0.0035		0.0014		0.015		0.0021		0.022		0.0079		1.16		0.00062
U ₃		0.0010		0.00043		0.0039		0.00055		0.0056		0.0018		0.34		0.00023
Certified		0.031		0.0059		0.423		0.0111		0.879		0.128		95.4		0.0004
Uncertainty		0.001		0.0004		0.004		0.0005		0.006		0.004		0.3		0.0002
Tolerance		0.004		0.0014		0.015		0.0021		0.022		0.012		1.2		0.0004

Analysis	*	Mn	*	Mo	*	N	*	Ni	*	O	*	P	*	Si	*	Sn
1	3	0.74675	10	0.236667	2	0.009533	8	1.750333	2	0.000633	7	0.00564	4	0.236667	12	0.0070
2	10	0.753333	5	0.2446	2	0.009943	10	1.767	2	0.000633	12	0.0058	3	0.24	4	0.007333
3	4	0.75675	3	0.252	2	0.01008	3	1.77	2	0.000657	5	0.005967	12	0.2465	5	0.007733
4	4	0.760667	10	0.257	2	0.0102	4	1.778333	2	0.000671	3	0.006	4	0.247067	3	0.007925
5	4	0.7656	4	0.257767	2	0.0104	10	1.78	2	0.00075	4	0.006103	4	0.248	5	0.0080
6	4	0.769333	4	0.259	2	0.0104	3	1.78	2	0.000933	4	0.006167	4	0.249333	9	0.0082
7	4	0.769667	3	0.25925	2	0.010433	4	1.783867	2	0.000933	3	0.006175	4	0.2498	5	0.008233
8	3	0.77	3	0.26	2	0.0106	3	1.785	2	0.000963	14	0.0062	10	0.250	3	0.008375
9	3	0.770	4	0.26	2	0.0107	4	1.786667	2	0.0011	4	0.006233	6	0.251	5	0.00853
10	3	0.770667	14	0.260667	2	0.010867	4	1.793333	2	0.001336	4	0.006333	3	0.256	4	0.008533
11	14	0.771	3	0.26325	2	0.011	14	1.793333			4	0.0069	10	0.256333	4	0.0086
12	8	0.772	4	0.263633	4	1.794667					5	0.0070	14	0.256667	10	0.008767
13	4	0.773333	7	0.264	3	1.803333					10	0.0070	3	0.25725	5	0.009167
14	4	0.773667	4	0.2648	4	1.816667							3	0.257333	10	0.0097
15	4	0.774667	10	0.265	4	1.842567							4	0.257667	3	0.010
16	10	0.780667	4	0.267333			10	1.86					4	0.260667		
17	10	0.784	4	0.269									10	0.266667		
18			12	0.2700									5	0.274667		
19			5	0.270667												
Average		0.7658		0.2593		0.01023		1.7973		0.000709		0.00619		0.2533		0.00814
Std dev		0.0049		0.0034		0.00040		0.0065		0.000068		0.00038		0.0037		0.00031
H		0.0082		0.0040		0.00071		0.015		0.00028		0.00058		0.0039		0.00065
U ₁		0.0096		0.0052		0.00082		0.017		0.00029		0.00069		0.0054		0.00072
t-statistic		2.12		2.10		2.23		2.13		2.26		2.18		2.11		2.14
U ₂		0.020		0.011		0.0018		0.036		0.00066		0.0015		0.011		0.0015
U ₃		0.0049		0.0025		0.00055		0.0090		0.00021		0.00042		0.0027		0.00040
Certified		0.766		0.259		0.0102		1.80		0.0007		0.0062		0.253		0.0081
Uncertainty		0.005		0.006		0.0005		0.02		0.0002		0.0004		0.006		0.0004
Tolerance		0.020		0.018		0.0018		0.06		0.0007		0.0015		0.018		0.0015

BS 4340A * Code for method Certified values listed as weight percent

Analysis	*	V	*	W	*	Zr
1	5	0.001933	5	0.000273	3	0.001075
2	10	0.0020	12	0.0004	3	0.0019
3	5	0.002003	5	0.00040	10	0.0021
4	5	0.002033	5	0.00052	3	0.00215
5	4	0.0021	5	0.00057	4	0.0022
6	3	0.00215	4	0.0009	14	0.002433
7	3	0.0022	3	0.003533		
8	12	0.0024				
9	4	0.0026				
10	14	0.003133				
11	3	0.003425				
Average		0.00244		0.000468		0.00163
Std dev		0.00017		0.000039		0.00030
H		0.00041		0.00026		0.00036
U ₁		0.00045		0.00026		0.00047
t-statistic		2.23		2.45		2.57
U ₂		0.0010		0.00063		0.0012
U ₃		0.00030		0.00024		0.00049
Certified		0.0024		0.0005		0.0016
Uncertainty		0.0004		0.0002		0.0005
Tolerance		0.0012		0.0005		0.0012

BS 4340A * Code for method Informational values listed as weight percent

Analysis	*	B	*	Ca	*	Nb	*	Pb	*	S	*	Sb	*	Ti
1	4	0.0001	4	0.000157	5	0.0001	9	0.00004	1	0.00063	5	0.0017	5	0.000687
2	12	0.0001	12	0.00016	12	0.00030	5	0.0000433	12	0.00068	4	0.0018	12	0.00070
3	5	0.000133	3	0.00017	5	0.00047	5	0.00006133	1	0.000767	12	0.0018	5	0.000723
4	4	0.000167	4	0.0002	4	0.000933	12	0.000070	1	0.000767			5	0.000767
5	5	0.00020	3	0.00032	4	0.0014	3	0.0001	10	0.001			4	0.000767
6	3	0.000243	4	0.000367	3	0.0016	5	0.0001633	10	0.0011			4	0.0010
7	7	0.000387			10	0.0027	5	0.0003	1	0.001167			3	0.001275
8					3	0.010875	3	0.0005	1	0.001267			5	0.00136
9							10	0.0012	1	0.0013			14	0.001667
10									1	0.001563			3	0.0017
11									3	0.001625			4	0.0017
12									3	0.0018				
Average		0.000190		0.00023		0.002		0.00028		0.000780		0.002		0.0011
Std dev		0.000095		0.00016		0.011		0.00019		0.000077		0.011		0.0054
H		0.00021		0.00022		0.000		0.00023		0.00029		0.00038		0.00032
U ₁		0.00023		0.00027		0.011		0.00030		0.00030		0.011		0.0054
t-statistic		2.45		2.57		2.36		2.31		2.20		4.30		2.23
U ₂		0.00057		0.00069		0.025		0.00069		0.00066		0.049		0.012
U ₃		0.00022		0.00028		0.0089		0.00023		0.00019		0.028		0.0037
(Informational)		(0.0002)		(0.0002)		(0.002)		(0.0003)		(0.0008)		(0.0018)		(0.0011)

For each element, in accordance with the requirements of ISO Guides 34 and 35, an effort must be made to account for the effects on the certified value of the uncertainty estimate from homogeneity testing (H) and the uncertainties of the contributing laboratories. The average (A) is calculated using a weighted mean where the reciprocal of the square of each laboratory's combined uncertainty (C_L), calculated from its standard deviation (S_L) and its uncertainty estimate (U_L), is used as the weight (W_L) for its mean (M_L). The standard deviation (S) is calculated as the square root of the reciprocal of the sum of the weights. U_1 is the combined uncertainty from homogeneity and labs. U_2 is U_1 multiplied by the coverage factor (95 % t-statistic). U_3 is U_2 divided by the square root of the number of determinations (n). Thus:

$$C_L = \sqrt{S_L^2 + U_L^2} \quad W_L = \frac{1}{C_L^2} \quad A = \frac{\sum_{i=1}^n W_L M_L}{\sum_{i=1}^n W_L} \quad S = \frac{1}{\sqrt{\sum_{i=1}^n W_L}} \quad U_1 = \sqrt{H^2 + S^2} \quad U_2 = t \times U_1 \quad U_3 = \frac{U_2}{\sqrt{n}}$$

All but the final reported values are taken to two significant figures as determined by each quantity's uncertainty estimate. The final reported Uncertainty is U_3 rounded to one significant figure and represents the half width of the 95 % confidence interval for the **Certified** value. The final reported **Certified** value is A rounded to the same decimal place as the Uncertainty. The Tolerance is the half width of the 95 % confidence interval for measurements rounded to the same decimal place as the Uncertainty. The Uncertainty is a measure of the quality of the **Certified** value. The Tolerance is a measure of the expected performance of an analysis.

For further information regarding the confidence interval for the certified value see ISO Guide 35:2006 section 6.

BS 4340A		* Code for analytical method		Trace analysis listed as mg/kg (ppm)											
Analysis *	Bi	* CI	* Ga	* Ge	* K	* Na	* Re	* Zn							
1	12 0.023	12 0.27	12 10	5 17	12 0.50	12 0.48	5 0.19	12 3.7							
2			5 12	5 18			5 0.22	5 6.6							
3			5 12	5 18			5 0.22	5 6.8							
4			5 12	12 20			12 0.25	5 6.9							

Analytical Method Codes:

- | | | |
|---------------------------|---------------------------|---------------------------|
| 1 Combustion (ASTM E1019) | 7 Photometric | 13 Titrimetric |
| 2 Fusion (ASTM E1019) | 8 Flame Atomic Absorption | 14 DCP Atomic Emission |
| 3 Spark Atomic Emission | 9 GF Atomic Absorption | 15 HG Atomic Fluorescence |
| 4 ICP Atomic Emission | 10 X-Ray Fluorescence | 16 Difference |
| 5 ICP Mass Spectrometry | 11 GD Atomic Emission | |
| 6 Gravimetric | 12 GD Mass Spectrometry | |

ICP = Inductively Coupled Plasma GF = Graphite Furnace GD = Glow Discharge
 DCP = Direct Current Plasma HG = Hydride Generation

<u>Laboratory</u>	<u>Location</u>	<u>Registrar</u>	<u>Accreditation</u>
Brammer Standard Company, Inc.	Houston, TX	A2LA	17025, Guide 34
LECO Corporation	St. Joseph, MI	A2LA	17025
Dirats Laboratories	Westfield, MA	ACLASS	17025
NSL Analytical	Cleveland, OH	ACLASS	17025
Luvak Inc.	Boylston, MA	PRI/Nadcap	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	AB 554
Laboratory Testing, Inc.	Hatfield, PA	PRI/Nadcap	17025
Exova	Glendale Heights, IL	A2LA	17025
Northern Analytical Laboratory, Inc.	Londonderry, NH	PRI/Nadcap	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025

A2LA = American Association for Laboratory Accreditation
 ACLASS = ANSI-ASQ National Accreditation Board
 CNAS = China National Accreditation Service
 Nadcap = National Aerospace and Defense Contractors Accreditation Program
 PCA = Polish Center For Accreditation
 PRI = Performance Review Institute

Analysis: Chemical analyses were made on solid pieces and chips prepared by an end mill from representative samples for the certified portion of the lot in accordance with ASTM Standard Practice E1806. The laboratories participating in the testing followed the requirements of ISO Standard 17025.

Traceability: The following Certified Reference Materials were used to validate the analytical data: 12X32550, 12X31254, 12X32101; 501-320, 501-348, 501-501, 501-503, 501-504, 501-506, 501-550, 501-644, 501-646, 501-676, 501-677, 501-991, 501-993, 502-197, 502-257, 502-348, 502-868, 502-873; AR 642, 644, 657, 673, 872, 875, 892, 1653, 1656, 4340; BAS 111, 409, 409/1, 434, 434/1, 435, 464/1; BS HON-T, 30D, 56H, 60C, 60D, 210, 300, 1026, 1030, 4130, 4330V, 8620C; ECRM 096-1; IARM 31E, 35H; IMZ 55/1, 58/1, 130, 139; JK 37; NCS NS11028; SRM 19H, 30F, 50C, 55D, 73B, 111B, 160B, 293, 346A, 361, 362, 363, 364, 1168, 1228, 1261, 1261A, 1263A, 1264A, 1413, 1763A, 1765, 1766, 1767; Y 41340B.

Homogeneity: This Certified Reference Material (CRM) was tested for homogeneity using ASTM Standard Method E826 and found acceptable. It was also examined by spark atomic emission spectrometry and found to be compatible with the following Reference Materials — 501-676; AR 4340; BAS 4/88; BS HON-T, 60C, 60D, 210, 4330V; ECRM 096-1; NCS NS11028; SRM 19H, 346A, 1261A; Y 41340B.

Validity statement: ISO Guide 31 states that the certification should contain an expiration date for all materials where instability has been demonstrated or is considered possible, after which the certified value is no longer guaranteed by the certifying body. The certification of BS 4340A is valid indefinitely. The certification is nullified if this CRM is damaged, contaminated, or otherwise modified.

Source: The bar stock for this CRM was produced by Tata Steel UK Limited; Sheffield, UK.

Form: This CRM is machined in the form of a disc, approximately 38 mm in diameter and 19 mm thick by Brammer Standard Company, Inc.

Use: This CRM is intended for use in spark atomic emission, glow discharge, and x-ray spectrometric methods of analysis. Refer to ISO Guide 33 for information about the use of Certified Reference Materials.

Certified Area: The entire depth of the CRM may be used.

Caution: As with any bar material, avoid spark atomic emission spectrometric burns in the center of the CRM (5 mm radius), as some segregation may be present.

Sample Preparation: For best analytical results, use the same method for preparing the analytical surface on all reference materials as used for production specimens. Avoid overheating the sample during surface preparation.

Certificate Number: The unique identification number for this certificate of analysis is 4340A-050516. You may obtain information on revisions of certificates from the internet at www.brammerstandard.com.

Safety Notice: A Safety Data Sheet (SDS) is not required for this material. This material will not release or otherwise result in

Brammer Standard Company, Inc., 14603 Benfer Road, Houston, TX 77069-2895
Telephone: (281) 440-9396 Fax: (281) 440-4432 Website: www.brammerstandard.com
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exposure to a hazardous chemical, under normal conditions of use. Inquiries concerning this Reference Material should be directed to:

Brammer Standard Co., Inc. **Phone: (281) 440-9396** **Web: www.brammerstandard.com**
14603 Benfer Road
Houston, Texas 77069-2895 USA **Fax: (281) 440-4432** **Email: contact@brammerstandard.com**

Brammer Standard Company, Inc., is accredited by the American Association For Laboratory Accreditation (A2LA) to ISO Guide 34 as a Reference Material Producer for the production of Certified Reference Materials and Reference Materials (Certificate Number 656.02)

Brammer Standard Company's Chemical Laboratory is accredited by A2LA to ISO Standard 17025. (Certificate Number 656.01)

By Certificate Number 10539, the Quality System of Brammer Standard Company, Inc., is registered to ISO 9001:2008 by National Quality Assurance (NQA), U.S.A.

The scopes of accreditation are listed on the website: www.brammerstandard.com

References:

Versions used were those available at the time of testing and characterization

- E826 Standard Practice for Testing Homogeneity of a Metal Lot or Batch in Solid Form by Spark Atomic Emission Spectrometry
- E1019 Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques
- E1806 Standard Practice for Sampling Steel and Iron for Determination of Chemical Composition

- ISO Standard 17025:2005 General requirements for the competence of testing and calibration laboratories
- ISO Standard 9001:2008 Quality Management Systems - Requirements
- ISO Guide 30:1992 Terms and definitions used in connection with reference materials + 2008 amendment
- ISO Guide 31:2000 Reference materials - Contents of certificates and labels
- ISO Guide 33:2000 Uses of certified reference materials
- ISO Guide 34:2009 General requirements for the competence of reference material producers
- ISO Guide 35:2006 Reference Materials - General and statistical principles for certification

- ASTM documents available from ASTM, 100 Barr Harbor Dr., West Conshohocken, Pa 19428.*
- ISO Guides and Standards available from Global Engineering - www.global.ihs.com*

Other useful documents available from NIST, U.S. Department of Commerce, Gaithersburg, MD 20899.

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NIST Special Publication 260-100, Handbook for SRM Users

NIST Special Publication 829, Use of NIST Standard Reference Materials for Decisions on Performance of Analytical Chemical Methods and Laboratories

Certified by: _____ on May 5, 2016.

Beau R. Brammer