

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 4340

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	0.028	0.001		Si	0.279	0.006
As	0.0043	0.0003		Sn	0.0063	0.0003
C	0.418	0.004		Ti	0.0014	0.0002
Ca	0.0005	0.0002		V	0.0033	0.0004
Co	0.0068	0.0006		W	0.0012	0.0004
Cr	0.807	0.005		Zr	0.0005	0.0002
Cu	0.149	0.002				
Fe	95.5	0.3				
Mn	0.695	0.005				
Mo	0.231	0.004				
N	0.0080	0.0005				
Ni	1.79	0.02				
O	0.0012	0.0002				
P	0.0119	0.0005				
S	0.0187	0.0007				

Informational Values^{3,4}

B (0.0002)

Mg (0.0002)

Nb (0.001)

Pb (0.0002)

Sb (0.0013)

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	*	Ca	*	Co	*	Cr	*	Cu	*	Fe
1	12	0.0246	5	0.0033	3	0.41	4	0.0004	4	0.005433	4	0.7846	12	0.1200	13	95.248
2	5	0.026633	5	0.003767	3	0.41	3	0.00046	3	0.0055	3	0.789333	4	0.14	16	[95.44]
3	14	0.027633	10	0.0039	1	0.413567	4	0.000467	5	0.005567	4	0.796667	3	0.140667	10	95.47
4	3	0.027667	4	0.004033	1	0.413833	4	0.000533	12	0.0060	3	0.797	10	0.142333	16	[95.4979]
5	4	0.028	3	0.0041	1	0.414333	3	0.00062	4	0.006187	14	0.797667	4	0.144333	14	95.5
6	3	0.028	3	0.0042	3	0.416	12	0.00062	8	0.00625	3	0.798	4	0.145667	4	95.53667
7	4	0.028067	4	0.004267	1	0.4162	4	0.00062	4	0.006387	4	0.802333	3	0.147	16	[95.54]
8	4	0.028067	9	0.004333	1	0.416667			14	0.006833	10	0.802333	4	0.1472	16	[95.54667]
9	3	0.0283	15	0.004343	1	0.418			4	0.006933	10	0.804	3	0.148	10	95.54667
10	4	0.0287	12	0.0047	1	0.418			5	0.0071	4	0.8041	14	0.148333	16	[95.55]
11	4	0.029133	5	0.004833	1	0.42			3	0.0074	3	0.81	4	0.148867	16	[95.56]
12	5	0.030367	5	0.0057	1	0.4242			10	0.0077	4	0.810667	4	0.149333	3	95.56333
13	4	0.033433			1	0.428333			5	0.008133	4	0.812333	3	0.15		
14					1	0.429667			3	0.009	4	0.8124	8	0.150667		
15											4	0.813333	4	0.151333		
16											10	0.85	10	0.152		
17													10	0.156667		
18													5	0.159433		
19													5	0.174267		
Average		0.0282		0.00434		0.4181		0.000508		0.00679		0.8068		0.1487		95.534
Std dev		0.0010		0.00022		0.0041		0.000046		0.00024		0.0049		0.0029		0.031
H		0.0011		0.00050		0.0054		0.00026		0.00060		0.0086		0.0028		0.53
U ₁		0.0015		0.00055		0.0068		0.00027		0.00065		0.0099		0.0041		0.53
t-statistic		2.18		2.20		2.16		2.45		2.16		2.13		2.10		2.20
U ₂		0.0033		0.0012		0.015		0.00065		0.0014		0.021		0.0085		1.16
U ₃		0.00090		0.00035		0.0039		0.00025		0.00037		0.0053		0.0020		0.34
Certified		0.028		0.0043		0.418		0.0005		0.0068		0.807		0.149		95.5
Uncertainty		0.001		0.0003		0.004		0.0002		0.0006		0.005		0.002		0.3
Tolerance		0.003		0.0012		0.015		0.0005		0.0018		0.021		0.009		1.2

Analysis	*	Mn	*	Mo	*	N	*	Ni	*	O	*	P	*	S	*	Si
1	10	0.666667	3	0.220667	2	0.00705	4	1.763333	2	0.001033	5	0.0098	12	0.0152	4	0.27
2	4	0.6818	5	0.2212	2	0.007433	4	1.768667	2	0.001033	7	0.010533	1	0.017057	3	0.27
3	3	0.691333	10	0.223667	2	0.0075	10	1.769	2	0.001033	4	0.010567	1	0.0172	4	0.27175
4	4	0.6918	4	0.224	2	0.00765	4	1.7715	2	0.001107	3	0.011	1	0.01794	10	0.274
5	4	0.692667	7	0.226	2	0.007657	8	1.772	2	0.00111	12	0.0110	3	0.018	4	0.275933
6	4	0.693333	4	0.228	2	0.00785	3	1.78	2	0.00114	4	0.011433	1	0.018	4	0.278
7	8	0.694333	4	0.228733	2	0.007867	3	1.78	2	0.00115	3	0.0116	1	0.0181	6	0.278333
8	4	0.696667	4	0.2298	2	0.0079	10	1.78	2	0.001336	10	0.0118	1	0.0185	3	0.279
9	3	0.7	4	0.2300	2	0.0080	4	1.783333	2	0.00174	4	0.011867	1	0.018633	14	0.279333
10	3	0.70	12	0.23	2	0.008167	3	1.793333	2	0.001933	14	0.011867	10	0.0188	12	0.2800
11	3	0.7	3	0.23	2	0.010867	4	1.794667			4	0.011967	3	0.019	3	0.282
12	10	0.701	3	0.231			14	1.80			4	0.0121	1	0.019333	4	0.285067
13	4	0.705	14	0.231			4	1.803333			4	0.012333	3	0.0199	4	0.287
14	10	0.707	3	0.234			3	1.81			3	0.0124	1	0.020267	3	0.287333
15	4	0.709667	4	0.236			4	1.811633			5	0.013167	1	0.021333	10	0.29
16	14	0.711333	10	0.236667			10	1.85			10	0.0142	1	0.023967	4	0.2915
17	4	0.711433		0.237							3	0.014467		0.023967	10	0.292667
18			10	0.239												
19			5	0.2694												
Average		0.6954		0.2313		0.00803		1.7911		0.001213		0.01193		0.01865		0.2795
Std dev		0.0046		0.0033		0.00027		0.0053		0.000093		0.00053		0.00063		0.0038
H		0.0077		0.0037		0.00064		0.015		0.00033		0.00076		0.0009		0.0042
U ₁		0.0090		0.0049		0.00070		0.016		0.00034		0.00093		0.0011		0.0056
t-statistic		2.12		2.10		2.23		2.13		2.26		2.12		2.13		2.12
U ₂		0.019		0.010		0.0016		0.035		0.00077		0.0020		0.0024		0.012
U ₃		0.0046		0.0024		0.00047		0.0090		0.00024		0.00048		0.00060		0.0029
Certified		0.695		0.231		0.0080		1.79		0.0012		0.0119		0.0187		0.279
Uncertainty		0.005		0.004		0.0005		0.02		0.0002		0.0005		0.0007		0.006
Tolerance		0.019		0.012		0.0016		0.06		0.0008		0.0020		0.0026		0.018

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

Analysis	*	Sn	*	Ti	*	V	*	W	*	Zr
1	12	0.0047	12	0.0011	5	0.002867	5	0.0011	5	0.000343
2	4	0.005	4	0.001167	5	0.002897	5	0.001187	5	0.0004
3	5	0.0061	5	0.001177	4	0.0029	12	0.0012	5	0.000467
4	5	0.006167	5	0.0012	3	0.0029	5	0.001267	5	0.000533
5	3	0.0062	5	0.001367	5	0.002933	5	0.001533	5	0.000553
6	3	0.0063	5	0.0014	12	0.0031	4	0.001733	12	0.00058
7	10	0.006333	10	0.0014	3	0.0031			3	0.0007
8	4	0.006433	3	0.0016	14	0.0037			3	0.0013
9	5	0.006627	4	0.0018	4	0.003733			10	0.0024
10	5	0.006633	14	0.0019	3	0.0041			4	0.002567
11	4	0.0068	3	0.0021	10	0.0043			3	0.0027
12	9	0.007167	3	0.0023						
13	10	0.0072								
14	5	0.007633								
15	3	0.008								
Average		0.00626		0.00136		0.00334		0.001246		0.000526
Std dev		0.00022		0.00012		0.00021		0.000079		0.000053
H		0.00058		0.00034		0.00046		0.00033		0.00026
U ₁		0.00062		0.00036		0.00050		0.00034		0.00027
t-statistic		2.14		2.20		2.23		2.57		2.23
U ₂		0.0013		0.00079		0.0011		0.00088		0.00060
U ₃		0.00034		0.00023		0.00034		0.00036		0.00018
Certified		0.0063		0.0014		0.0033		0.0012		0.0005
Uncertainty		0.0003		0.0002		0.0004		0.0004		0.0002
Tolerance		0.0013		0.0008		0.0012		0.0009		0.0005

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

Analysis	*	B	*	Mg	*	Nb	*	Pb	*	Sb
1	3	0.00003	5	0.000087	5	0.000193	5	0.0000233	4	0.001167
2	12	0.00016	4	0.0001	5	0.0002	12	0.000030	5	0.0012
3	4	0.0002	3	0.00011	5	0.0002	5	0.0000367	12	0.0016
4	4	0.0002	3	0.00014	12	0.00040	9	0.00004		
5	5	0.00023	5	0.0002	5	0.000837	5	0.0001333		
6	3	0.00024	12	0.00020	4	0.0014	3	0.0002		
7	5	0.0003	4	0.000347	4	0.001467	5	0.0003		
8	7	0.000357			3	0.0017	10	0.0010		
9					3	0.0018				
10					14	0.002333				
11					10	0.0024				
Average		0.00021		0.000169		0.0012		0.00022		0.0013
Std dev		0.00012		0.000073		0.0030		0.00012		0.0069
H		0.00022		0.00021		0.0003		0.00022		0.0003
U ₁		0.00025		0.00022		0.0030		0.00025		0.0069
t-statistic		2.36		2.45		2.23		2.36		4.30
U ₂		0.00058		0.00054		0.0066		0.00060		0.030
U ₃		0.00021		0.00021		0.0020		0.00021		0.017
(Informational)		(0.0002)		(0.0002)		(0.001)		(0.0002)		(0.0013)

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 4340		* Code for analytical method		Trace analysis listed as mg/kg (ppm)											
Analysis	* Bi	* Cl	* Ga	* Ge	* K	* Na	* Re	* Zn							
1	12 0.035	12 0.50	12 6.0	5 20	12 0.50	12 0.35	12 0.12	12 4.2							
2			5 8.7	5 20				5 7.3							
3			5 8.7	5 25				5 7.7							
4			5 8.8	12 45				5 7.8							

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
 BSI = British Standards Institution
 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, 13X31254, 13X32101; 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, 660, 673, 872, 875, 1653, 1656, 4340; BAS 111, 409, 409/1, 434, 434/1, 435, 464/1; BS HON-T, XCCT, 30D, 56H, 60C, 60D, 60E, 210, 300, 1026, 1030, 4130, 4340V, 8620C; ECRM 096-1; IARM 31F, 35H; IMZ 55/1, 58/1, 130, 139; JK 37; NCS NS11028; SRM 19H, 30F, 55D, 73B, 111B, 160B, 346A, 361, 362, 363, 364, 1228, 1261, 1261A, 1263A, 1264A, 1413, 1763A, 1765, 1766, 1767.

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, 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 4340 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 Gerdau; Jackson, Michigan.

Form: This CRM is machined in the form of a disc, approximately 38 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 4340-050516. You may obtain information on

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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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 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.

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