Brammer Standard Company, Inc.

Certificate of Analysis

BS 4340B

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

	Certified Value[1]	Estimate of Uncertainty[2]	**Certified Values[3]**		Certified Value[1]	Estimate of Uncertainty[2]
Al	**0.022**	0.002		**N**	**0.0060**	0.0009
As	**0.009**	0.001		**Ni**	**1.85**	0.03
C	**0.42**	0.02		**O**	**0.0009**	0.0003
Co	**0.014**	0.002		**P**	**0.0078**	0.0009
Cr	**0.81**	0.03		**S**	**0.016**	0.002
Cu	**0.170**	0.006		**Sb**	**0.0017**	0.0003
Fe	**95.5**	0.1		**Si**	**0.283**	0.009
Mg	**0.0002**	0.0001		**Sn**	**0.008**	0.001
Mn	**0.658**	0.009		**Ti**	**0.0019**	0.0006
Mo	**0.235**	0.009		**V**	**0.0033**	0.0008

	Reference Value[1]	Estimate of Uncertainty[2]	**Reference Values[3,4]**		Reference Value[1]	Estimate of Uncertainty[2]
B	**<0.005**			**Pb**	**<0.005**	
Ca	**<0.005**			**W**	**0.0028**	0.0009
H	**<0.005**			**Zr**	**0.0006**	0.0004
Nb	**0.0021**	0.0009				

[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 3 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 3 for more information on its calculation.

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

[4] Reference values are not certified and are provided for information only.

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

The requirements of ISO Guides 30, 31, and 35 were followed for the preparation of this Certified Reference Material and certificate of analysis.

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

Analysis	*	Al	*	As	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mg	*	Mn	*	Mo
1	5	0.02066667	4	0.0056667	1	0.40	4	0.009	4	0.786333333	3	0.1646667	4	95.39	12	0.000096	4	0.6406667	12	0.1866667
2	10	0.02076667	9	0.0071	1	0.404	4	0.0100333	4	0.794633333	3	0.165	16	[95.4]	5	0.00017	8	0.6453333	4	0.226
3	3	0.021	12	0.0073667	1	0.409	5	0.0125333	10	0.80	4	0.1673333	16	[95.4]	3	0.0002	4	0.6512667	4	0.2299667
4	5	0.02146667	3	0.0077	1	0.4091667	12	0.0126667	3	0.800	3	0.168	16	[95.406334]	4	0.0002	3	0.653	10	0.23
5	3	0.0216	10	0.0085	1	0.4096667	3	0.013	4	0.800333333	4	0.1681333	3	95.44	4	0.0002	3	0.653	4	0.2300667
6	11	0.0217	4	0.0088333	11	0.41	4	0.0134333	4	0.803333333	4	0.1696667	10	95.4466667	4	0.0002	4	0.6543333	3	0.2313333
7	3	0.022	4	0.0088367	1	0.41	4	0.0138333	4	0.8041	4	0.1700	16	[95.47]	4	0.00044	4	0.6546667	4	0.2315
8	3	0.02216667	4	0.0089	1	0.4101333	4	0.0140	14	0.806	10	0.17	16	[95.4758]			4	0.6549	4	0.2317667
9	14	0.0223	3	0.009	3	0.411	4	0.0144333	4	0.809	4	0.1700	16	[95.489867]			3	0.655	4	0.232
10	4	0.02253333	3	0.009	1	0.4137	3	0.0146	3	0.809	10	0.17	16	[95.49]			14	0.6583333	4	0.233
11	4	0.02276667	5	0.0092667	1	0.414	4	0.0146667	4	0.8100	3	0.17	4	95.4907667			10	0.6600	4	0.2343333
12	4	0.0228	4	0.0093333	1	0.416	5	0.0147333	10	0.81	4	0.1700333	14	95.4966667			4	0.66	3	0.235
13	3	0.023	5	0.0093767	1	0.4173333	14	0.0148667	13	0.81	10	0.1703333	16	[95.5049]			3	0.66	3	0.235
14	4	0.0230	4	0.0094	3	0.42	4	0.0149	3	0.81	8	0.1703333	13	95.523			10	0.66	10	0.236
15	4	0.02303333	5	0.0099333	1	0.4203333	3	0.015	10	0.810666667	4	0.1703333					4	0.6601333	11	0.236
16	4	0.02343333	3	0.010	3	0.423	5	0.0150667	11	0.812	14	0.1706667					4	0.6602667	14	0.2366667
17	4	0.02433333	5	0.0104667	1	0.425	11	0.0151	3	0.82	4	0.171					4	0.6613333	4	0.2371667
18	4	0.025	11	0.0118	1	0.443	4	0.0157	4	0.82	3	0.172					3	0.6616667	7	0.2386667
19					1	0.4653333	10	0.016	3	0.820333333	4	0.172					10	0.663	3	0.24
20					12	0.4900			4	0.820666667	5	0.172					11	0.664	7	0.24
21									4	0.821467	11	0.174					4	0.671	10	0.24
22									4	0.823667	4	0.175033					4	0.672	4	0.242667
23											4	0.179					4	0.672	3	0.245
																			4	0.251
																			5	0.275667
Average		0.02232		0.008916		0.421033		0.013872		0.8099		0.1700		95.450		0.0002000		0.6577		0.2352
Std Dev		0.00074		0.000075		0.000071		0.000073		0.0038		0.0027		0.031		0.0000020		0.0034		0.0028
H		0.0015		0.0010		0.0067		0.0012		0.010		0.0042		0.19		0.00024		0.0086		0.0049
U_1		0.0017		0.0010		0.0067		0.0013		0.010		0.0049		0.19		0.00024		0.0092		0.0056
t-statistic		2.11		2.11		2.09		2.10		2.08		2.07		2.16		2.45		2.07		2.06
U_2		0.0036		0.0022		0.014		0.0026		0.021		0.010		0.41		0.00059		0.019		0.012
U_3		0.00085		0.00051		0.0031		0.00060		0.0046		0.0021		0.11		0.00022		0.0040		0.0023
Certified		**0.022**		**0.009**		**0.42**		**0.014**		**0.81**		**0.170**		**95.5**		**0.0002**		**0.658**		**0.235**
Uncertainty		0.002		0.001		0.02		0.002		0.03		0.006		0.1		0.0001		0.009		0.009
Tolerance		0.006		0.003		0.06		0.006		0.09		0.018		0.4		0.0001		0.027		0.027

Analysis	*	N	*	Ni	*	O	*	P	*	S	*	Sb	*	Si	*	Sn	*	Ti	*	V
1	2	0.005	10	1.83	2	0.0006	12	0.0056333	12	0.012333333	12	0.0013	5	0.270	4	0.00633333	12	0.0011333	12	0.0020
2	2	0.00516667	4	1.8364	2	0.0006	4	0.0065	1	0.014	10	0.0015	6	0.27	12	0.00676667	3	0.0013	4	0.0027
3	2	0.00533333	4	1.8433333	2	0.00067	5	0.0067667	1	0.0140	5	0.0015	3	0.275	11	0.0069	4	0.0013667	14	0.0029
4	2	0.005625	4	1.8458	2	0.0007733	3	0.007	1	0.014366667	5	0.0015233	11	0.277	4	0.00696667	5	0.0015667	3	0.003
5	2	0.00572	14	1.8466667	2	0.0009	4	0.0070633	1	0.014966667	5	0.0015333	3	0.277	4	0.0070	14	0.0016	10	0.003
6	2	0.00579333	4	1.8485	2	0.0009	4	0.0075333	1	0.015	11	0.0017	4	0.28	9	0.0072	11	0.0018	4	0.003
7	2	0.0059	11	1.85	2	0.0010	3	0.0076	10	0.015	3	0.0017	3	0.2800	4	0.00736667	5	0.0019	5	0.0030667
8	2	0.00603333	3	1.85	2	0.0011	4	0.0078267	1	0.015226667	5	0.0017667	3	0.28	4	0.0076	4	0.0019333	5	0.00319
9	2	0.00617	3	1.85	2	0.001175	4	0.0079	1	0.015633333	9	0.0018	10	0.28	3	0.0079	4	0.0020	11	0.0032
10	2	0.0062	7	1.85	2	0.0024667	10	0.0079333	1	0.0157	4	0.0020	4	0.28016667	3	0.008	4	0.0020	3	0.0032
11	2	0.0062	4	1.8500	2	0.0026867	7	0.0079333	1	0.0158	4	0.0020333	14	0.28033333	3	0.008	4	0.0020367	4	0.0037667
12	2	0.00635333	4	1.850	2	0.003	4	0.008	4	0.0158	4	0.0020667	7	0.28056667	4	0.0081	3	0.0021	4	0.0038
13	2	0.006525	4	1.8503333			10	0.0080	3	0.016			4	0.2814	10	0.0082	5	0.00217	4	0.0039
14	2	0.0074	4	1.8511667			3	0.008	3	0.0162			3	0.28466667	5	0.0083	4	0.0022	4	0.0039333
15			8	1.8513333			4	0.0080667	11	0.0162			4	0.28593333	5	0.00841333	4	0.0026	4	0.0039667
16			7	1.8536667			3	0.0082	1	0.016333333			4	0.28633333	5	0.00853333	3	0.003	4	0.0040
17			10	1.8566667			11	0.0083	1	0.0168			10	0.28733333	4	0.0086			3	0.004
18			3	1.86			4	0.0083	1	0.017			4	0.288	4	0.00886333				
19			3	1.867			3	0.0089667	1	0.01707			7	0.29133333	3	0.0089				
20			10	1.87			4	0.0092333	1	0.0175			4	0.29433333	10	0.009				
21			4	1.87					3	0.018			4	0.294333	3	0.009				
22			4	1.876667									4	0.297	5	0.009533				
23			4	1.879																
24			3	1.88																
Average		0.00595		1.854856		0.000940		0.00782		0.015663		0.001702		0.2827		0.007976		0.001919		0.003331
Std Dev		0.00020		0.000065		0.000059		0.00030		0.000069		0.000091		0.0031		0.000067		0.000079		0.000077
H		0.00087		0.015		0.00042		0.0010		0.0013		0.00052		0.0054		0.00098		0.0005465		0.00068
U_1		0.00089		0.015		0.00042		0.0010		0.0013		0.00053		0.0063		0.00098		0.00055		0.00069
t-statistic		2.16		2.07		2.20		2.09		2.09		2.20		2.08		2.08		2.13		2.12
U_2		0.0019		0.032		0.00093		0.0021		0.0028		0.0012		0.013		0.0020		0.0012		0.0015
U_3		0.00051		0.0065		0.00027		0.00048		0.00060		0.00034		0.0028		0.00044		0.00029		0.00035
Certified		**0.0060**		**1.85**		**0.0009**		**0.0078**		**0.016**		**0.0017**		**0.283**		**0.008**		**0.0019**		**0.0033**
Uncertainty		0.0009		0.03		0.0003		0.0009		0.002		0.0003		0.009		0.001		0.0006		0.0008
Tolerance		0.0027		0.09		0.0008		0.0027		0.006		0.0009		0.027		0.003		0.0018		0.0024

BS 4340B * Code for method Reference values listed as weight percent

Analysis	*	B	*	Ca	*	H	*	Nb	*	Pb	*	W	*	Zr
1	3	0.000037	11	0.000026	2	0.000030	4	0.0008333	12	0.0000083	12	0.0018667	12	0.000022
2	11	0.000055	12	0.000052	2	0.000057	12	0.00088	5	0.000023	3	0.0019	11	0.0002
3	4	0.00006	4	0.0002	2	0.0001	5	0.0013667	11	0.000027	3	0.002	4	0.0006
4	4	0.00010	4	0.0002	2	0.00011	5	0.0015333	5	0.000133333	5	0.0024333	4	0.0006
5	12	0.00012	3	0.0003	2	0.00012	5	0.0015667	3	0.0002	5	0.0024767	3	0.0007
6	3	0.0002	4	0.0003	2	0.0001233	3	0.002	4	0.0004	4	0.0025133	4	0.0007
7	7	0.00035333			2	0.0001667	14	0.0022	4	0.00065	5	0.0025333		
8	5	0.00041			2	0.0002667	3	0.0022	14	0.0007	4	0.0027		
9					2	0.0006333	11	0.0029			4	0.0028		
10							10	0.003			4	0.0028333		
11							3	0.003			4	0.0030		
12							4	0.0033			4	0.0030333		
13											4	0.0031733		
14											4	0.0039		
15											11	0.0041		
Average		0.0000601		0.0002000		0.0001001		0.002065		0.0003606		0.00282		0.0006000
Std Dev		0.0000014		0.0000015		0.0000015		0.000091		0.0000033		0.00010		0.0000079
H		0.00017		0.00024		0.00019		0.00056		0.00030		0.00064		0.00064
U_1		0.00017		0.00024		0.00019		0.00057		0.00030		0.00064		0.00064
t-statistic		2.36		2.57		2.31		2.20		2.36		2.14		2.57058184
U_2		0.00039		0.00062		0.00045		0.0013		0.00070		0.0014		0.0016
U_3		0.00014		0.00025		0.00015		0.00036		0.00025		0.00036		0.00067
Reference		**<0.005**		**<0.005**		**<0.005**		**0.0021**		**<0.005**		**0.0028**		**0.0006**
Uncertainty								0.0009				0.0009		0.0004
Tolerance								0.0020				0.0027		0.0005

For each element, in accordance with the requirements of ISO 17034 and Guide 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:

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

*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 Uncertainty is a measure of the quality of the **Certified** value.*

The Tolerance is a measure of the expected performance of an analysis. This involves further expanding the sample uncertainty to include instrument and operator uncertainty, for those without access to such calculations.

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

BS 4340B * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis	*	Cl	*	Ga	*	Ge	*	Ir	*	Na	*	Os	*	Re	*	Zn
1	12	0.01	12	8.2	12	11	12	0.01	12	0.01	12	0.01	12	0.28	12	1.4
2			12	8.4	12	11	12	0.01	12	0.01	12	0.01	12	0.29	12	1.4
3			12	8.8	12	12	12	0.01	12	0.02	12	0.01	12	0.29	12	1.5
4															5	2.1
5															5	2.2
6															5	2.5

Analytical Method Codes:

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

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

Lab Name	Location	Registrar	Accreditation
Brammer Standard Company, Inc.	Houston, TX	A2LA	17025, 17034
Anderson Laboratories, Inc.	Greendale, WI	A2LA	17025
NSL Analytical	Cleveland, OH	ANAB	17025
Element Materials Technology	Glendale Heights, IL	A2LA	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
Vitkovice Testing Center	Hulvaky, Ostrava	Czech Accreditation Institute	17025
Shiva Analyticals Private Limited	Hoskote, Bangalore	NABL	17025
Dirats Laboratories	Westfield,MA	ANAB	17025
Eurofins EAG Materials Science, LLC	Liverpool, NY	A2LA	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Luvak Inc.	Boylston, MA	PRI	17025
Laboratory Testing, Inc.	Hatfield, PA	A2LA	17025
Raghavendra Spectro Metallurgical Laboratory	Karnataka, India	NABL	17025
TUV Rheinland Pvt Ltd	Bangalore, India	NABL	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	17025

A2LA = American Association for Laboratory Accreditation
ANAB = ANSI-ASQ National Accreditation Board
CNAS = China National Accreditation Service
NABL = National Accreditation Board for Testing and Calibration Laboratories
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: AR 546, 612B, 641, 644, 657, 662, 668, 673, 870, 873, 884, 892, 947, 960; BAS 409, 410/2, 458, 460, 464/1; BS HON T, XCAS, 60A, 60C, 60D, 60E, 70C, 73C, 210, 234, 300A, 1030A, 4330MOD, 4340, 4340A, 8620E; DSZU CA01a; ECRM 85-1, 86-1, 87-1; IARM 30C, 30D, 31F; IMZ 74, 111, 112, 132, 138, 162; IPS 12A, 13-1, 17A; JSS GS-1D, GS-6b; LECO 501-677, 502-698, 502-863, 502-913, 502-916; NCS NS11078, NS11079; SRM 13F, 132E, 60B, 178, 293, 361, 362, 363, 364, 1261, 1261A.

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: AR 4340; BS 60A, 60C, 60D, 210, 234, 4340; SRM 1261A.

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 4340B is valid indefinitely. The certification is nullified if this CRM is damaged, contaminated, or otherwise modified.

Storage: This CRM must be stored in a cool, dry, non-corrosive environment.

Source: The bar stock for this CRM was produced by Timken Steel, Canton, OH.

Form: This CRM is machined in the form of a disc, approximately 38mm in diameter and 19mm 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.

> Caution: CRM contains significant insoluble soft metal inclusions. Surface smearing may occur. Spark atomic emission spectrometers may require extended preburns to compensate.

Certificate Number: The unique identification number for this certificate of analysis is 4340B-011924. 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 exposure to a hazardous chemical, under normal conditions of use. Inquiries concerning this Reference Material should be directed to:

Brammer Standard Co., Inc.
14603 Benfer Road
Houston, Texas 77069-2895 USA

Phone: (281) 440-9396
Fax: (281) 440-4432

Web: www.brammerstandard.com
Email: contact@brammerstandard.com

The scopes of accreditation and ISO certificates 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 17025:2017 General requirements for the competence of testing and calibration laboratories

ISO Standard 9001:2015 Quality Management Systems - Requirements

ISO Guide 30:2015 Terms and definitions used in connection with reference materials + 2008 amendment

ISO Guide 31:2015 Reference materials - Contents of certificates and labels

ISO Guide 33:2015 Uses of certified reference materials

ISO Standard 17034:2016 General requirements for the competence of reference material producers

ISO Guide 35:2017 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 January 19, 2024.

Beau R. Brammer

President