

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 3941

Certified Reference Material for AISI Carbon Steel Grade 1040 - UNS Number G10400

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values³	Certified Value ¹	Estimate of Uncertainty ²
Al	0.0019	0.0003	S	0.023	0.001
As	0.0036	0.0007	Sb	0.0005	0.0002
C	0.407	0.004	Si	0.257	0.006
Ca	0.0011	0.0002	Sn	0.0019	0.0006
Co	0.0042	0.0003	Ti	0.0017	0.0005
Cr	0.069	0.001	V	0.0025	0.0005
Cu	0.053	0.001			
Mn	0.802	0.006			
Mo	0.0061	0.0004			
N	0.0069	0.0004			
Nb	0.033	0.003			
Ni	0.018	0.001			
O	0.0055	0.0004			
P	0.016	0.001			
Pb	0.0010	0.0002			

Informational Values^{3,4}

B (0.0001) Fe [98.3] Mg (0.0002) Ta (0.0004) W (0.0004)
Zr (0.0003)

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, Ce, Cl, Ga, Ge, K, Na, 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.

BS 3941

* Code for method Certified values listed as weight percent

Analysis	*	Al	*	As	*	C	*	Ca	*	Co	*	Cr	*	Cu	*	Mn
1	17	0.0012	12	0.0020	3	0.396	4	0.000817	12	0.0036	12	0.0620	14	0.0501	17	0.792
2	4	0.001253	5	0.002033	1	0.402333	4	0.000867	4	0.003833	4	0.066633	12	0.0510	4	0.793
3	5	0.0014	4	0.002867	1	0.40247	12	0.00089	5	0.003833	4	0.066833	4	0.051667	4	0.793667
4	4	0.001533	10	0.0029	2	0.402667	4	0.001012	4	0.003867	4	0.067	4	0.052567	14	0.799333
5	4	0.001533	17	0.00295	1	0.403	5	0.001067	14	0.003967	10	0.068	17	0.05295	3	0.80
6	5	0.0016	12	0.0030	1	0.403667	14	0.001133	5	0.003967	4	0.0681	3	0.053	8	0.800333
7	5	0.001633	4	0.0033	1	0.404	4	0.0012	5	0.004	4	0.068267	4	0.0532	3	0.802
8	4	0.002	9	0.003367	1	0.405667	17	0.0012	3	0.0040	5	0.068533	4	0.053233	4	0.802
9	4	0.0022	9	0.0034	1	0.406	4	0.001267	4	0.004167	4	0.068633	8	0.0538	5	0.803333
10	14	0.002233	4	0.003567	1	0.407	4	0.0013	4	0.0043	5	0.068667	3	0.054	4	0.803667
11	5	0.002783	4	0.003667	1	0.408	12	0.0013	10	0.0044	3	0.069	10	0.054	4	0.804
12	3	0.003	3	0.004	1	0.4085	3	0.00133	12	0.0045	17	0.0699	4	0.054	4	0.805233
13			4	0.0040	1	0.408667	4	0.0014	4	0.0046	3	0.070	4	0.0541	4	0.805333
14			5	0.004167	3	0.41	12	0.0015	4	0.0047	4	0.0703	5	0.054233	4	0.813
15			15	0.004373	1	0.410			17	0.004915	14	0.0707	4	0.0552	10	0.82
16			5	0.0045	1	0.414733					5	0.080033	5	0.0560	4	0.82
17			12	0.0048	4	0.429							5	0.056033		
Average		0.001864		0.00364		0.4069		0.001122		0.004177		0.0692		0.0534		0.8017
Std dev		0.000091		0.00020		0.0060		0.000066		0.000082		0.0019		0.0015		0.0063
H		0.00039		0.00050		0.0055		0.00034		0.00052		0.0019		0.0016		0.009
U ₁		0.00041		0.00054		0.0082		0.00034		0.00053		0.0027		0.0022		0.011
t-statistic		2.20		2.12		2.12		2.16		2.14		2.13		2.12		2.13
U ₂		0.00089		0.0011		0.017		0.00074		0.0011		0.0058		0.0047		0.023
U ₃		0.00026		0.00028		0.0042		0.00020		0.00029		0.0014		0.0011		0.0058
Certified		0.0019		0.0036		0.407		0.0011		0.0042		0.069		0.053		0.802
Uncertainty		0.0003		0.0007		0.004		0.0002		0.0003		0.001		0.001		0.006
Tolerance		0.0009		0.0021		0.017		0.0007		0.0011		0.006		0.005		0.023

Analysis	*	Mo	*	N	*	Nb	*	Ni	*	O	*	P	*	Pb	*	S
1	4	0.00553	2	0.006633	12	0.0223	12	0.0150	1	0.004967	5	0.0120	4	0.000733	12	0.0175
2	5	0.005967	2	0.0067	4	0.0248	4	0.0158	2	0.0051	5	0.014667	4	0.000767	1	0.020289
3	4	0.006	2	0.0067	12	0.0260	4	0.016	2	0.005167	5	0.015033	12	0.00082	1	0.0214
4	3	0.006	2	0.006763	3	0.029	3	0.016	2	0.0052	4	0.015167	4	0.000867	1	0.0214
5	4	0.006033	2	0.0068	14	0.030233	8	0.016667	2	0.005333	4	0.0154	12	0.00090	1	0.021433
6	4	0.0061	2	0.006867	10	0.0305	5	0.016933	2	0.005533	4	0.016	17	0.00099	3	0.022
7	5	0.006133	2	0.0069	4	0.0309	4	0.016967	2	0.005603	4	0.016	9	0.0010	10	0.022
8	4	0.006167	12	0.0069	4	0.0317	4	0.0170	2	0.00569	12	0.0160	3	0.0010	4	0.0226
9	14	0.006233	2	0.006933	5	0.032233	5	0.017	2	0.005927	3	0.0160	12	0.001	1	0.022667
10	3	0.0064	2	0.006946	12	0.0325	10	0.0170	2	0.006033	4	0.0164	4	0.001067	1	0.0228
11	5	0.0064	2	0.0071	3	0.033	4	0.0172	2	0.0076	4	0.0168	5	0.0011	1	0.023
12	17	0.00649	1	0.0071	4	0.034	5	0.0177			10	0.017	5	0.0012	1	0.023
13	10	0.0066	2	0.00723	4	0.034567	17	0.01945			4	0.0172	9	0.0012	2	0.023
14	4	0.006667			4	0.034933	4	0.0195			3	0.018	5	0.001203	1	0.024
15	4	0.006867			4	0.035267	14	0.019867			14	0.020033	5	0.001233	3	0.024
16					5	0.038333	3	0.02					4	0.0013	1	0.0243
17					5	0.038667	4	0.026567					10	0.0016	1	0.0246
18															1	0.024667
19															1	0.025433
Average		0.00613		0.00693		0.0331		0.01793		0.00554		0.01604		0.000962		0.02256
Std dev		0.00024		0.00034		0.0012		0.00068		0.00028		0.00069		0.000082		0.00096
H		0.00060		0.00063		0.0013		0.0010		0.00058		0.0009		0.00032		0.0011
U ₁		0.00065		0.00072		0.0018		0.0012		0.00064		0.0011		0.00033		0.0014
t-statistic		2.14		2.18		2.12		2.12		2.23		2.14		2.12		2.10
U ₂		0.0014		0.0016		0.0038		0.0025		0.0014		0.0025		0.00071		0.0030
U ₃		0.00036		0.00044		0.00090		0.00060		0.00043		0.00060		0.00017		0.00070
Certified		0.0061		0.0069		0.033		0.018		0.0055		0.016		0.0010		0.023
Uncertainty		0.0004		0.0004		0.003		0.001		0.0004		0.001		0.0002		0.001
Tolerance		0.0014		0.0016		0.009		0.003		0.0014		0.003		0.0007		0.003

BS 3941 * Code for method Certified values listed as weight percent

Analysis	*	Sb	*	Si	*	Sn	*	Ti	*	V
1	12	0.00022	4	0.248	17	0.00102	12	0.0010	4	0.002
2	9	0.00046	4	0.249	4	0.001033	5	0.001033	4	0.002233
3	5	0.000483	14	0.25	12	0.0012	5	0.001067	5	0.002333
4	5	0.000487	4	0.252	12	0.0012	4	0.0012	5	0.0024
5	5	0.0005	4	0.253333	4	0.0016	3	0.0012	5	0.002467
6	5	0.00050	3	0.254	5	0.0016	4	0.001467	4	0.0026
7	12	0.0005	17	0.2555	5	0.0017	4	0.0015	12	0.0027
8	4	0.000533	4	0.256167	4	0.001733	4	0.0016	12	0.0028
9	14	0.000667	4	0.259	5	0.001753	5	0.001827	4	0.002933
10	4	0.0008	3	0.26	9	0.0018	14	0.001933	17	0.00295
11	12	0.00088	5	0.260667	5	0.001833	4	0.002567	4	0.002967
12	4	0.0010	6	0.263	10	0.002	5	0.002933	10	0.0030
13			10	0.264	4	0.002333	3	0.003	14	0.003267
14			4	0.27	9	0.002367				
15			4	0.2713	12	0.0026				
16					4	0.003				
17					3	0.0030				
Average		0.000518		0.2574		0.001869		0.001717		0.00253
Std dev		0.000035		0.0066		0.000077		0.000088		0.00013
H		0.00028		0.0041		0.00039		0.00038		0.00044
U ₁		0.00028		0.0078		0.00040		0.00039		0.00045
t-statistic		2.20		2.14		2.12		2.18		2.18
U ₂		0.00061		0.017		0.00085		0.00086		0.0010
U ₃		0.00018		0.0043		0.00021		0.00024		0.00027
Certified		0.0005		0.257		0.0019		0.0017		0.0025
Uncertainty		0.0002		0.006		0.0006		0.0005		0.0005
Tolerance		0.0005		0.018		0.0018		0.0015		0.0015

BS 3941 * Code for method Informational values listed as weight percent

Analysis	*	B	*	Fe	*	Mg	*	Ta	*	W	*	Zr
1	12	0.000050	16	[98.27333]	12	0.000088	12	0.00006	12	0.00025	12	0.00023
2	12	0.000052	16	[98.3]	12	0.00010	12	0.00026	12	0.00028	12	0.00023
3	12	0.00011			3	0.00011	3	0.001	4	0.0003	5	0.000233
4	4	0.00016			12	0.00017			12	0.00036	12	0.00026
5	5	0.000197			17	0.00018			5	0.000467	5	0.000437
6					4	0.00020			5	0.000493	4	0.000487
7					4	0.0002						
8					5	0.0003						
9					5	0.00044						
10					4	0.00052						
Average		0.000114		98.287		0.00023		0.00044		0.00036		0.00031
Std dev		0.000034		0.067		0.00012		0.00088		0.00041		0.00031
H		0.00021		0.53		0.00023		0.00027		0.00025		0.00025
U ₁		0.00021		0.54		0.00026		0.00092		0.00048		0.00039
t-statistic		2.78		12.71		2.26		4.30		2.57		2.57
U ₂		0.00058		6.80		0.00059		0.0039		0.0012		0.0010
U ₃		0.00026		4.81		0.00019		0.0023		0.00050		0.00041
(Informational)		(0.0001)		[98.3]		(0.0002)		(0.0004)		(0.0004)		(0.0003)

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. U₁ is the combined uncertainty from homogeneity and labs. U₂ is U₁ multiplied by the coverage factor (95 % t-statistic). U₃ is U₂ 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 U₃ 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.

Analysis *	* Code for analytical method		Trace analysis listed as mg/kg (ppm)													
	Bi	Ce	Cl	Ga	Ge	K	Na	Zn								
1	12 0.075	12 0.07	12 0.42	12 3.4	5 3	12 0.50	12 0.50	12 3.2								
2	12 0.10	5 0.12		5 5.8	5 4			5 3.2								
3		5 0.12		5 6	5 5			5 3.3								
4		5 0.13		5 6	5 27			5 4.0								
5		12 0.23		5 6	5 27			5 5								
6		12 0.40		5 6.1	5 27			5 5								
7				5 6.1	12 34			5 10								
8								12 10								
9								12 10.0								

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 | 17 Atomic Absorption Spectrometry |
| 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
Analytical Associates	Farmington Hills, MI	A2LA	
Dirats Laboratories	Westfield, MA	ACCLASS	17025
Crucible Specialty Metals	Syracuse, NY		
LECO Corporation	St. Joseph, MI	A2LA	17025
Northern Analytical Laboratory, Inc.	Londonderry, NH	PRI/Nadcap	17025
Shiva Technologies, Inc.	Cicero, NY		
VHG Labs	Manchester, NH	A2LA	17025, Guide 34
NSL Analytical	Cleveland, OH	ACCLASS	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI/Nadcap	17025
Luvak Inc.	Boylston, MA	PRI/Nadcap	17025
Evans Analytical Group	Liverpool, NY	A2LA	17025
Exova	Glendale Heights, IL	A2LA	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	AB 554
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Northern Analytical Laboratory, Inc.	Londonderry, NH	PRI/Nadcap	17025

A2LA = American Association for Laboratory Accreditation
ACCLASS = 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: 11XC4, 11XC8, 12X357; LECO 501-320, 501-501, 501-503, 501-504, 501-505, 501-644, 501-675, 501-677, 501-991, 501-993, 502-348, 502-416, 502-870, 502-874; AR 644, 654, 657, 659, 673, 675, 875, 891, 1652, 1653; BAM 039-1, 044-1; BAS 54, 342, 345, 346, 405/1, 434, 455/1, 456/1, 457/1, 458/1, 464/1; BS CSN 2-2, H3C, LAS-1, 11A, 12, 13, 14A, 50D, 56H, 61G, 66L, 75G, 200-2, 200-4, 718B, 2931A; CKD 162A, 165D, 170H; ECRM 084-1, 85, 085-1, 86, 87, 088-1, 096-1, 097-1, 184-1, 186-1, 191-1; IARM 28G, 57B, 62E, 210C; IMZ 1.22, 1.74/3, 63/1, 74, 112, 114, 119, 187, 202; IPT 43, 208; JSS 169-4, 1706-, 171-4; SRM C1173, 30F, 55D, 101E, 160B, 291, 293, 361, 362, 363, 364, 365, 898, 1249, 1256, 1261A, 1262A, 1263A, 1264, 1264A, 1265A, 1761, 1762, 1763, 1764, 1765, 1766, 1767, 3109A, 3128, 3131A.

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 — BAM 044-1; BAS 405/1, 455/1, 456/1, 457/1, 458/1; BS LAS-1, 11A, 12, 13, 14A, 50D; CKD 165D, 170H; ECRM 085-1, 088-1, 096-1, 097-1, 184-1, 186-1, 191-1; IMZ 1.22, 1.74/3; IPT 43; JSS 169-4, 170-6, 171-4; SRM C1173, 125B, 361, 362, 363, 364, 365, 1256, 1261A, 1262A, 1263A, 1264A, 1265A, 1270, 1761, 1762, 1763, 1764, 1765, 1766, 1767.

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 3941 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 Inland Steel Corporation, East Chicago, Indiana.

Form: This CRM is machined in the form of a disc, approximately 41 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.

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 REV3941-082316. 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. Phone: (281) 440-9396 Web: www.brammerstandard.com
14603 Benfer Road
Houston, Texas 77069-2895 USA Fax: (281) 440-4432 Email: contact@brammerstandard.com

Revision: This certified reference material was originally certified as a reference material on May 31, 1995. Additional interlaboratory testing was performed. O, Sb, Sn, and Ti have been changed from informational to certified. Revised values for all elements except Cu, Mg, P, Pb, and S, are presented. Informational values for B, Fe, Ta, W, and Zr are provided. All trace data are presented in mg/kg (ppm). A number of trace elements have been added.

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 31:2015 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 August 23, 2016.

Beau R. Brammer