

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 1020

Certified Reference Material for Carbon Steel Grade 1020 - UNS Number G10200

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values³	Certified Value ¹	Estimate of Uncertainty ²
Al	0.0006	0.0002		Mo	0.001
As	0.0074	0.0005		N	0.0005
C	0.210	0.003		Ni	0.001
Ca	0.0022	0.0003		O	0.0004
Co	0.0070	0.0004		P	0.0004
Cr	0.109	0.002		S	0.0007
Cu	0.184	0.002		Si	0.003
Fe	[98.5]	0.5		Sn	0.0005
Mn	0.568	0.006		V	0.0009

	Reference Value ¹	Estimate of Uncertainty ²	Reference Values^{3,4}	Reference Value ¹	Estimate of Uncertainty ²
Nb	0.0003	0.0002		Sb	0.0007

Informational Values^{3,5}

B (0.0001)	Mg (0.0001)	Pb (0.0002)	Ti (0.0005)	W (0.0004)
Zr (0.0005)				

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.

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

⁵ Values in parentheses are not certified and are provided for information only.

Trace element information values for Ag, 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.

BS 1020

* Code for method Certified values listed as weight percent

Analysis	*	Al	*	As	*	C	*	Ca	*	Co	*	Cr	*	Cu	*	Fe
1	4	0.0003	3	0.0065	1	0.205233	4	0.0019	5	0.0055	3	0.100333	4	0.167	16	98.45333
2	5	0.0005	12	0.007	1	0.2055	5	0.0020	4	0.0057	10	0.102	10	0.176	16	98.46333
3	5	0.000547	10	0.0070	1	0.2115	4	0.002033	5	0.006033	4	0.104733	3	0.177	10	98.47333
4	5	0.00055	5	0.0072	1	0.211667	12	0.0025	4	0.006233	3	0.105	3	0.178	16	98.476
5	12	0.00068	4	0.007267	1	0.212333	3	0.00256	3	0.0066	10	0.106333	4	0.179567	3	98.48333
6	5	0.000917	4	0.007333	1	0.213	4	0.0029	4	0.006733	4	0.1064	4	0.18	16	98.49
7	4	0.000967	4	0.00737	1	0.213667	4	0.002933	10	0.0068	4	0.1065	12	0.180	4	98.49
8	4	0.001	5	0.0074	1	0.2144	4	0.002997	4	0.007	4	0.107333	4	0.1800	16	98.5
9	4	0.00165	5	0.007667	1	0.2166			8	0.00702	4	0.107333	10	0.180333	10	98.56667
10	3	0.0019	5	0.0080	1	0.216667			5	0.007033	4	0.108667	3	0.181333		
11			4	0.0082	1	0.217			4	0.007133	3	0.11	8	0.182333		
12					3	0.217			3	0.0072	5	0.1116	4	0.183		
13					3	0.222			4	0.007213	5	0.112133	5	0.183267		
14									12	0.0074	4	0.1125	4	0.184333		
15											4	0.113333	4	0.184667		
16													5	0.1856		
17													10	0.186667		
18													4	0.19175		
Average		0.000581		0.00745		0.2102		0.00215		0.00699		0.1089		0.1843		98.48
Std dev		0.000057		0.00034		0.0041		0.00011		0.00027		0.0024		0.0033		0.38
H		0.00025		0.00059		0.0033		0.00037		0.00057		0.0022		0.0031		0.52
U ₁		0.00026		0.00068		0.0053		0.00038		0.00063		0.0033		0.0045		0.64
t-statistic		2.26		2.23		2.18		2.36		2.16		2.14		2.11		2.31
U ₂		0.00058		0.0015		0.012		0.00091		0.0014		0.0070		0.010		1.48
U ₃		0.00018		0.00045		0.0032		0.00032		0.00036		0.0018		0.0023		0.49
Certified		0.0006		0.0074		0.210		0.0022		0.0070		0.109		0.184		[98.5]
Uncertainty		0.0002		0.0005		0.003		0.0003		0.0004		0.002		0.002		0.5
Tolerance		0.0006		0.0015		0.012		0.0009		0.0014		0.007		0.010		1.5

Analysis	*	Mn	*	Mo	*	N	*	Ni	*	O	*	P	*	S	*	Si
1	10	0.551	10	0.016367	2	0.010	5	0.054967	2	0.003975	3	0.005067	1	0.023667	4	0.234
2	4	0.551667	3	0.016433	2	0.0100	5	0.0565667	2	0.004133	10	0.005133	1	0.024133	5	0.236667
3	4	0.557333	4	0.017433	2	0.0104	10	0.0557	2	0.00440	7	0.00527	1	0.024633	4	0.237333
4	4	0.558667	4	0.017433	2	0.0108	4	0.057333	2	0.004433	4	0.005367	1	0.024725	10	0.243333
5	4	0.56275	5	0.017667	2	0.010825	3	0.0595	2	0.004523	5	0.005567	10	0.025	4	0.244667
6	3	0.564	4	0.017767	2	0.010993	12	0.0595	2	0.00455	4	0.005997	1	0.025	4	0.246667
7	3	0.569	5	0.017833	2	0.011133	5	0.059867	2	0.00472	4	0.006667	1	0.025	6	0.248
8	8	0.570	10	0.018	2	0.0118	10	0.060	2	0.005133	4	0.0069	3	0.0253	3	0.248
9	10	0.572	4	0.0180	2	0.011825	8	0.060233	2	0.005167	4	0.007133	1	0.025433	3	0.249333
10	4	0.5761	7	0.0185	2	0.011833	4	0.060533	2	0.0053	4	0.007333	3	0.026	3	0.25
11	4	0.58	12	0.0185	2	0.01194	4	0.0608			12	0.0074	1	0.02605	10	0.25
12	3	0.581	3	0.0185	2	0.012	3	0.061			10	0.0074	1	0.026333	5	0.253033
13	4	0.58175	3	0.019			4	0.061133			3	0.008	1	0.0277	4	0.257233
14							4	0.061667			3	0.0081	1	0.0281	4	0.258633
15															10	0.265333
16															4	0.266667
17															12	0.2900
Average		0.5684		0.0180		0.01093		0.0594		0.00459		0.00585		0.02493		0.2503
Std dev		0.0085		0.0014		0.00032		0.0014		0.00018		0.00031		0.00059		0.0044
H		0.0064		0.0009		0.00069		0.0016		0.00048		0.00053		0.0010		0.0037
U ₁		0.011		0.0016		0.00076		0.0021		0.00052		0.00061		0.0012		0.0057
t-statistic		2.18		2.18		2.20		2.16		2.26		2.16		2.16		2.12
U ₂		0.023		0.0036		0.0017		0.0045		0.0012		0.0013		0.0025		0.012
U ₃		0.0064		0.00099		0.00048		0.0012		0.00037		0.00035		0.00068		0.0030
Certified		0.568		0.018		0.0109		0.059		0.0046		0.0058		0.0249		0.250
Uncertainty		0.006		0.001		0.0005		0.001		0.0004		0.0004		0.0007		0.003
Tolerance		0.023		0.004		0.0017		0.005		0.0012		0.0013		0.0025		0.012

BS 1020 * Code for method Certified values listed as weight percent

Analysis	*	Sn	*	V
1	4	0.008267	4	0.0331
2	5	0.008933	10	0.0340
3	5	0.009033	4	0.034567
4	3	0.0092	3	0.0349
5	5	0.0093333	3	0.035
6	4	0.0093333	3	0.035433
7	4	0.0096333	4	0.035667
8	3	0.0097	10	0.036
9	10	0.0097	4	0.0361
10	5	0.009833	5	0.036767
11	5	0.0104	4	0.036933
12			4	0.036967
13			7	0.0375
14			5	0.038633
Average		0.00899		0.03630
Std dev		0.00028		0.00096
H		0.00063		0.0012
U ₁		0.00069		0.0016
t-statistic		2.23		2.16
U ₂		0.0015		0.0043
U ₃		0.00047		0.00090
Certified		0.0090		0.0363
Uncertainty		0.0005		0.0009
Tolerance		0.0015		0.0034

BS 1020 * Code for method Reference values listed as weight percent

Analysis	*	Nb	*	Sb
1	5	0.0002	5	0.001467
2	5	0.000217	4	0.001633
3	5	0.00030	5	0.001833
4	4	0.000367	12	0.0020
5	12	0.00045		
6	5	0.000553		
7	4	0.0008		
8	10	0.0011		
Average		0.000343		0.00185
Std dev		0.000035		0.00025
H		0.00022		0.00035
U ₁		0.00022		0.00043
t-statistic		2.36		3.18
U ₂		0.00053		0.0014
U ₃		0.00019		0.00068
Reference		0.0003		0.0018
Uncertainty		0.0002		0.0007
Tolerance		0.0003		0.0014

BS 1020 * Code for method Informational values listed as weight percent

Analysis	* B	* Mg	* Pb	* Ti	* W	* Zr
1	12 0.000073	3 0.00004	5 0.00015	5 0.000273	12 0.00033	12 0.00033
2	5 0.000074	12 0.00014	5 0.000153	4 0.0004	5 0.000527	3 0.0007
3	5 0.0000867	5 0.000287	5 0.00017	12 0.00051		10 0.0008
4	3 0.0001	4 0.000433	5 0.000187	5 0.00061		5 0.000977
5	4 0.0002		3 0.0002	3 0.0008		3 0.0012
6	7 0.000267		5 0.0002			4 0.001633
7			5 0.0002			
8			12 0.00022			
Average	0.000148	0.000131	0.000180	0.000528	0.000365	0.000497
Std dev	0.000012	0.000026	0.000013	0.000086	0.000068	0.000076
H	0.00019	0.00018	0.00019	0.00024	0.00022	0.00024
U ₁	0.00019	0.00018	0.00019	0.00026	0.00023	0.00025
t-statistic	2.57	3.18	2.36	2.78	12.71	2.57
U ₂	0.00048	0.00059	0.00046	0.00072	0.0030	0.00065
U ₃	0.00020	0.00028	0.00016	0.00032	0.0021	0.00026
(Informational)	(0.0001)	(0.0001)	(0.0002)	(0.0005)	(0.0004)	(0.0005)

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 times 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 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 1020 * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis	* Ag	* Bi	* Cl	* Ga	* Ge	* K	* Na	* Re	* Zn
1	5 0.8	12 0.012	12 0.093	5 7.7	5 16	12 0.19	12 0.16	5 0.60	12 8.6
2	12 0.85			5 7.8	5 16		5 100	5 0.63	5 8.9
3	5 0.9			5 7.9	5 17		5 110	5 0.78	5 9.6
4	5 0.9			5 8.2	5 33		5 110		5 9.7
5	5 1.0			5 8.2	5 33				5 11
6	5 1.0			5 8.2	5 33				5 11
7	5 1.1			12 9.7	12 40				5 11

Analytical Method Codes:

- | | | |
|---------------------------|---------------------------|---------------------------|
| 1 Combustion (ASTM E1019) | 7 Photometric | 13 Titrimetric |
| 2 Fusion (ASTM E 1019) | 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

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<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	ACCLASS	17025
NSL Analytical	Cleveland, OH	ACCLASS	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
Evans Analytical Group	Liverpool, NY	A2LA	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI/Nadcap	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Exova	Glendale Heights, IL	A2LA	17025
Northern Analytical Laboratory, Inc.	Londonderry, NH	PRI/Nadcap	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	AB 554

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 E 1806. The laboratories participating in the testing followed the requirements of ISO Standard 17025. Methods of analysis used were a those listed on page 4.

Traceability: The following Certified Reference Materials were used to validate the analytical data listed on page 2-4 — 12x349, 12x356, 12x357, 24x07001, 24x07001B; 501-320, 501-501, 501-503, 501-504, 501-644, 501-646, 501-676, 501-677, 501-991, 501-993, 502-195, 502-257, 502-416, 502-494; AR 657, 869, 875, 878, 883, 884, 1020, 1652; BAS 152/2, 434/2, 435/1, 464/1; BS 30D, 56H, 57B, 57C, 57D, 61G, 202, 1030, 2001; CKD CZ 2006A, 2026A; ECRM 084-1, 85/1, 86/1, 87/1, 284-1, 285-1, 327-1; IARM 1D, 28F, 199A; IMZ 112; KMS HOCS-001; SRM 361, 362, 363, 365, 862, 1246, 1263A, 1608, 3109A, 3113, 3131A.

Homogeneity: This Certified Reference Material (CRM) was tested for homogeneity using ASTM Standard Method E 826 and found acceptable. It was also examined by spark atomic emission spectrometry and found to be compatible with the following Reference Materials — 502-257, 502-416, 501-676; AR 1020; BAS 435/1; BS 57B, 57C, 57D, 202, 2001; CKD CZ 2006A; ECRM 084-1, 284-1, 285-1, 327-2; IARM 1D; KMS HOCS-001.

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 1020 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 Kreher Steel Company, LLC; Alton, IL.

Form: This CRM is machined in the form of a disc, approximately 44 mm in diameter, and 19 mm thick by Brammer Standard Company, Inc.

Use: This CRM is intended for use in spark atomic emission 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 you use for production specimens. Avoid overheating the sample during surface preparation.

Certificate Number: The unique identification number for this certificate of analysis is 1020-071614. You may obtain information on revisions of certificates from the internet at www.brammerstandard.com.

Safety Notice: A Material Safety Data Sheet (MSDS) 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

- E 826 Standard Practice for Testing Homogeneity of a Metal Lot or Batch in Solid Form by Spark Atomic Emission Spectrometry
- E 1019 Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques
- E 1806 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, 1916 Race Street, Philadelphia, PA, 19103.

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 July 16, 2014.

Beau R. Brammer