

Brammer Standard Company, Inc.

Certificate of Analysis

BS 51F

Certified Reference Material for Low Alloy Steel Grade 4620 - UNS Number G46200

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values^{2,3,4}	Certified Value ¹	Estimate of Uncertainty ²
Al	0.022	0.002	N	0.0061	0.0007
C	0.188	0.004	Ni	1.68	0.03
Co	0.0086	0.0008	P	0.016	0.001
Cr	0.156	0.004	S	0.017	0.001
Cu	0.231	0.004	Si	0.24	0.01
Fe	[96.7]	0.2	Sn	0.008	0.001
Mn	0.519	0.006	Ti	0.0012	0.0005
Mo	0.224	0.005	V	0.0030	0.0006

	Reference Value ¹	Estimate of Uncertainty ²	Reference Values^{2,3,4,5}	Reference Value ¹	Estimate of Uncertainty ²
As	0.005	0.003	W	0.0024	0.0010
Ca	0.0005	0.0002			

Informational Values^{4,6}

B (0.0002)	Mg (0.0001)	Nb (0.0007)	O (0.002)	Pb (0.0008)
Sb (0.003)	Ta (0.005)	Zr (0.0009)		

¹ This certificate is a revision. For more information on the nature and extent of the revision, see the revision statement on page 5.

² 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.

³ 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.

⁴ Values are given in weight percent. Values in brackets are reported by difference.

⁵ Reference values not certified and are provided for information only.

⁶ Values in parentheses are not certified and are provided for information only.

Trace element information values for Te 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.

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* Code for method

Certified values listed as weight percent

Analysis	*	Al	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mn	*	Mo	*	N	*	Ni
1	17	0.017	1	0.1866667	12	0.0075	17	0.150	3	0.227	16	[96.61]	4	0.514	3	0.216	2	0.0058	17	1.639
2	12	0.0190	3	0.187	11	0.0078	3	0.154	3	0.228	16	[96.64]	4	0.514	3	0.219	2	0.0060	4	1.65
3	3	0.02	11	0.187	3	0.008	3	0.156	3	0.228	16	[96.65]	3	0.515	4	0.221	2	0.0060	3	1.66
4	4	0.020	11	0.187	17	0.0085	11	0.156	17	0.228	16	[96.65]	3	0.516	4	0.222	2	0.006	12	1.6700
5	3	0.0215	1	0.188	11	0.0086	3	0.157	11	0.229	16	[96.67]	4	0.516	11	0.223	2	0.0061	11	1.68
6	4	0.0220	1	0.188	3	0.0088	11	0.157	11	0.23	16	[96.69]	3	0.519	11	0.223	12	0.0068	3	1.68
7	11	0.02224	3	0.189	12	0.009	3	0.158	12	0.23			11	0.52	17	0.223			3	1.68
8	3	0.0228	3	0.189	3	0.0091	4	0.158	4	0.230			17	0.521	17	0.223			11	1.69
9	3	0.023	1	0.1893333	4	0.0095	4	0.158	4	0.233			17	0.521	17	0.226			4	1.71
10	11	0.0232	3	0.192	3	0.01			17	0.239			3	0.521	3	0.229			3	1.72
11	12	0.0270							3	0.239			11	0.522	3	0.233				
12															12	0.2350				
Average		0.02152		0.1880		0.00864		0.1556		0.2307		96.652		0.5191		0.2238		0.00612		1.67790
Std Dev		0.00086		0.0037		0.00038		0.0032		0.0035		0.039		0.0048		0.0033		0.00013		0.00010
H		0.0015		0.0044		0.0010		0.0040		0.0049		0.19		0.0075		0.0048		0.00088		0.015
U₁		0.0017		0.0057		0.0011		0.0051		0.0060		0.19		0.0089		0.0059		0.00089		0.015
t-statistic		2.23		2.26		2.26		2.31		2.23		2.57		2.23		2.20		2.57		2.26
U₂		0.0039		0.013		0.0025		0.012		0.013		0.50		0.020		0.013		0.0023		0.033
U₃		0.0012		0.0041		0.00078		0.0039		0.0040		0.20		0.0060		0.0037		0.00093		0.010
Certified		0.022		0.188		0.0086		0.156		0.231		[96.7]		0.519		0.224		0.0061		1.68
Uncertainty		0.002		0.004		0.0008		0.004		0.004		0.2		0.006		0.005		0.0007		0.03
Tolerance		0.006		0.013		0.0025		0.012		0.013		0.5		0.020		0.015		0.0021		0.09

Analysis	*	P	*	S	*	Si	*	Sn	*	Ti	*	V									
1	4	0.0153	12	0.014	12	0.2000	11	0.0064	11	0.0011	17	0.002									
2	11	0.0155	1	0.0165333	4	0.224	11	0.0067	12	0.0011	4	0.0024									
3	4	0.016	3	0.0169	17	0.227	4	0.0080	3	0.0011	17	0.0024									
4	3	0.016	3	0.017	3	0.235	17	0.0080	12	0.0012	12	0.0025									
5	3	0.0163	1	0.0172667	3	0.242	4	0.0082	11	0.0013	3	0.0029									
6	17	0.0164	11	0.0173	3	0.244	3	0.0083	3	0.0014	11	0.003									
7	17	0.0164	1	0.0174667	11	0.244	3	0.0087			3	0.003									
8	12	0.0165	12	0.0175	11	0.245	3	0.009			3	0.0031									
9	11	0.0168	11	0.0177	17	0.248	12	0.0093			11	0.0032									
10	3	0.0168	3	0.0178	3	0.249	3	0.01			12	0.0034									
11	3	0.017	1	0.019	4	0.252					4	0.0035									
12			3	0.02							3	0.004									
Average		0.01629		0.01736		0.2393		0.00786		0.00120		0.002950									
Std Dev		0.00057		0.00072		0.0038		0.00037		0.00013		0.000091									
H		0.0013		0.0014		0.0050		0.0010		0.00046		0.00065									
U₁		0.0015		0.0016		0.0062		0.0010		0.00047		0.00065									
t-statistic		2.23		2.20		2.23		2.26		2.57		2.20									
U₂		0.0033		0.0034		0.014		0.0024		0.0012		0.0014									
U₃		0.0010		0.0010		0.0042		0.00074		0.00050		0.00042									
Certified		0.016		0.017		0.24		0.008		0.0012		0.0030									
Uncertainty		0.001		0.001		0.01		0.001		0.0005		0.0006									
Tolerance		0.003		0.003		0.03		0.003		0.0012		0.0018									

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* Code for method

Reference values listed as weight percent

Analysis	*	As	*	Ca	*	W
1	4	0.0023	3	0.00032	3	0.0014
2	17	0.0024	3	0.00036	12	0.0015
3	17	0.0024	17	0.00037	3	0.002
4	12	0.0025	3	0.0004	3	0.002
5	11	0.0028	11	0.0004	11	0.0021
6	3	0.0053	3	0.0004	11	0.0031
7	3	0.0066	11	0.0005	3	0.0031
8	3	0.007	12	0.0005	12	0.0032
9	4	0.0074	12	0.00067	4	0.0034
10	12	0.0076	4	0.0007		
11			4	0.00072		
Average		0.00480		0.000351		0.00242
Std Dev		0.00025		0.000024		0.00011
H		0.00079		0.00029		0.00060
U ₁		0.00083		0.00029		0.00061
t-statistic		2.26		2.23		2.31
U ₂		0.0019		0.00065		0.0014
U ₃		0.00059		0.00020		0.00047
Reference		0.005		0.0005		0.0024
Uncertainty		0.003		0.0002		0.0010
Tolerance		0.004		0.0004		0.0020

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* Code for method

Informational values listed as weight percent

Analysis	*	B	*	Mg	*	Nb	*	O	*	Pb	*	Sb	*	Ta	*	Zr
1	12	0.00006	3	0.00008	12	0.0005	2	0.0014	12	0.00006	3	0.0003	3	0.002	3	0.0006
2	3	0.0001	12	0.00008	12	0.00051	2	0.001733	12	0.00007	11	0.0005	3	0.0026	11	0.0007
3	12	0.00011	3	0.00009	3	0.0006	2	0.00175	3	0.001	17	0.0011	3	0.003	3	0.0009
4	3	0.00012	3	0.000097	11	0.0008	2	0.0022	4	0.0021	4	0.0011	3	0.0041	3	0.001
5	11	0.0002	4	0.0001	11	0.0012	12	0.0050			11	0.0013	11	0.0096	11	0.0015
6	3	0.0002	12	0.00015							12	0.0023	11	0.0097		
7	11	0.0002	3	0.0002							3	0.005				
8	3	0.0009									12	0.0120				
Average		0.00024		0.000114		0.0007		0.002		0.0008		0.003		0.005		0.0009
Std Dev		0.00014		0.000029		0.0018		0.014		0.0025		0.016		0.040		0.0029
H		0.00026		0.00020		0.0004		0.001		0.0004		0.001		0.001		0.0004
U ₁		0.00029		0.00020		0.0018		0.015		0.0025		0.016		0.040		0.0030
t-statistic		2.36		2.45		2.78		2.78		3.18		2.36		2.57		2.78
U ₂		0.00070		0.00050		0.0051		0.040		0.0080		0.037		0.10		0.0082
U ₃		0.00025		0.00019		0.0023		0.018		0.0040		0.013		0.042		0.0037
Informational		(0.0002)		(0.0001)		(0.0007)		(0.002)		(0.0008)		(0.003)		(0.005)		(0.0009)

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:

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

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 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 51F * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis	*	Te	*	Zn
1	12	12	12	1
2			12	2.5
3			17	6.7
4			4	13

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 AAS |
| 6 Gravimetric | 12 GD Mass Spectrometry | |

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

Lab Name	Location	Registrar	Accreditation
Brammer Standard Company, Inc.	Houston, TX	A2LA	17025, 17034
LECO Corporation	St. Joseph, MI		
Crucible Specialty Metals	Syracuse, NY		
Dirats Laboratories	Westfield, MA		
Shiva Technologies	Syracuse, NY		

A2LA = American Association for Laboratory Accreditation

Analysis: Chemical analyses were made on solid pieces and chips prepared by 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: BAS 457/1, 458/1, 483; BS LAS 1, 11A, 12, 13, 14A, 50D, 51A, 51C, 51E, 51F, 234, 300, 4340; CKD CZ2004A, 165D, 170H, 181A; DSZU CA013; ECRM 186-1, 191-1; JSS 169-4, 170-6, 171-4; SRM C1173, 361, 1161, 1261A, 1262A, 1263A, 1264A, 1265A, 1761, 1762, 1763, 1764, 1765, 1766, 1767; Y 31901.

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 — BAS 457/1, 458/1, 483; BS LAS 1, 11A, 12, 13, 14A, 50D, 51A, 51C, 51E, 51F, 234, 300, 4340; CKD CZ2004A, 165D, 170H, 181A; DSZU CA013; ECRM 186-1, 191-1; JSS 169-4, 170-6, 171-4; SRM C1173, 361, 1161, 1261A, 1262A, 1263A, 1264A, 1265A, 1761, 1762, 1763, 1764, 1765, 1766, 1767; Y 31901.

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 51F 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 Copperweld Steel Company, Warren, OH.

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.

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 REV51F-102920. 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 Web: www.brammerstandard.com

Fax: (281) 440-4432 Email: contact@brammerstandard.com

Revision: This certified reference material was originally certified as a reference material on August 10, 1992. A comprehensive homogeneity study, including additional information about its contribution to the uncertainty estimates, was performed. Revised values for all elements except P, Mg, Mo, and Ni are presented. The remaining values have been revised by concentration, uncertainty, certified, information, or trace.

Brammer Standard Company, Inc., is accredited by the American Association For Laboratory Accreditation (A2LA) to ISO Standard 17034 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 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 9001:2015 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 35:2006 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.ihc.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 October 29, 2020.

Beau R. Brammer
President