

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 4942A

Certified Reference Material for ASTM Steel Grade A193 - UNS Number K14072

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values³	Certified Value ¹	Estimate of Uncertainty ²
Al	0.011	0.001		Si	0.006
As	0.0031	0.0003		Sn	0.0006
C	0.393	0.004		Ti	0.0004
Ca	0.0012	0.0004		V	0.007
Co	0.0077	0.0006			
Cr	0.976	0.006			
Cu	0.067	0.003			
Fe	96.8	0.3			
Mg	0.0004	0.0002			
Mn	0.64	0.01			
Mo	0.538	0.005			
N	0.0072	0.0004			
Ni	0.058	0.003			
O	0.0020	0.0003			
S	0.0013	0.0003			

Informational Values^{3,4}

B (0.0001)	Nb (0.0015)	P (0.007)	Pb (0.0007)	Sb (0.001)
W (0.0009)	Zr (0.001)			

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, Cd, Cl, Ga, Ge, K, Na, Re, Sc, 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	5	0.008333	3	0.002	1	0.383333	3	0.00118	5	0.006067	14	0.959	10	0.052133	13	96.46333
2	12	0.0084	5	0.0025	1	0.38343	14	0.0012	5	0.006133	3	0.959333	12	0.0560	16	[96.59]
3	4	0.008767	9	0.002667	1	0.386333	4	0.0012	4	0.006367	4	0.960667	3	0.0616	16	[96.67383]
4	3	0.0096	4	0.002867	1	0.388333	4	0.001233	12	0.0065	10	0.962	5	0.062333	16	[96.67667]
5	3	0.0099	5	0.002867	1	0.388333	3	0.00131	4	0.0068	10	0.965	4	0.062533	16	[96.69]
6	4	0.010007	10	0.0032	1	0.389	4	0.001603	5	0.007133	3	0.967	14	0.064333	16	[96.72]
7	5	0.0103	5	0.003333	1	0.39	4	0.001633	8	0.00715	3	0.97	4	0.065333	16	[96.73333]
8	14	0.010333	4	0.0034	3	0.39	12	0.0023	4	0.007213	4	0.970667	4	0.0654	3	96.74333
9	4	0.010333	15	0.00344	1	0.3915	5	0.0028	10	0.0073	4	0.9707	5	0.066267	10	96.75
10	5	0.0112	12	0.0035	1	0.391667	4	0.007567	4	0.974667	3	0.9665	5	0.0665	4	96.76
11	4	0.012267	5	0.0038	3	0.393	3	0.0076	3	0.975	3	0.975	3	0.067467	14	96.8
12	4	0.013333	5	0.003933	1	0.396333	5	0.0081	10	0.976667	4	0.976667	4	0.067933	10	96.81333
13	4	0.0206	3	0.0042	1	0.397333	14	0.008433	4	0.978	10	0.978	10	0.068	4	97.73333
14					1	0.398571	3	0.0090	4	0.978133	3	0.978133	3	0.068		
15					3	0.403	3	0.0092	4	1.003333	5	1.003333	5	0.068467		
16									4	1.006667	4	1.006667	4	0.0685		
17											8	0.070333	8	0.070333		
18											4	0.070333	4	0.070333		
19											10	0.074	10	0.074		
Average		0.01103		0.00309		0.3930		0.001208		0.00772		0.9758		0.0669		96.772
Std dev		0.00044		0.00021		0.0042		0.000061		0.00026		0.0055		0.0016		0.028
H		0.00073		0.00044		0.0052		0.00033		0.00063		0.010		0.0018		0.53
U ₁		0.00086		0.00049		0.0067		0.00033		0.00068		0.011		0.0024		0.54
t-statistic		2.18		2.18		2.14		2.31		2.14		2.13		2.10		2.18
U ₂		0.0019		0.0011		0.014		0.00077		0.0015		0.024		0.0051		1.17
U ₃		0.00050		0.00030		0.0037		0.00026		0.00038		0.0060		0.0012		0.32
Certified		0.011		0.0031		0.393		0.0012		0.0077		0.976		0.067		96.8
Uncertainty		0.001		0.0003		0.004		0.0004		0.0006		0.006		0.003		0.3
Tolerance		0.002		0.0011		0.014		0.0012		0.0018		0.024		0.009		1.2

Analysis	*	Mg	*	Mn	*	Mo	*	N	*	Ni	*	O	*	S	*	Si
1	3	0.00021	4	0.616333	10	0.493333	2	0.0067	5	0.054667	2	0.0015	1	0.001	12	0.2600
2	5	0.000303	10	0.623667	10	0.518333	2	0.00700	14	0.0548	2	0.001533	3	0.0010	14	0.261667
3	5	0.000303	4	0.626133	7	0.520	2	0.00706	4	0.0550	2	0.001633	12	0.0011	3	0.27
4	12	0.00045	3	0.63	3	0.524	2	0.007067	3	0.0551	2	0.001667	1	0.001177	3	0.271
5	5	0.000453	10	0.63	4	0.529667	2	0.00714	3	0.0551	2	0.001733	1	0.0012	10	0.274
6	4	0.0005	10	0.631	5	0.531467	2	0.007233	8	0.056067	2	0.001833	1	0.001233	3	0.275
7	5	0.000567	3	0.631	4	0.534033	2	0.007267	12	0.0570	2	0.001877	1	0.001233	4	0.275333
8	4	0.00067	8	0.632667	4	0.536667	2	0.0073	10	0.057667	2	0.00203	1	0.0014	4	0.276333
9			4	0.633	14	0.539	2	0.007333	3	0.058667	2	0.00206	1	0.0016	6	0.278333
10			4	0.636667	4	0.539333	2	0.007333	4	0.059467	2	0.002067	1	0.0017	5	0.278667
11			14	0.637333	3	0.54	2	0.007693	4	0.059533	2	0.0021	1	0.001767	4	0.279
12			4	0.637667	3	0.542	2	0.008167	4	0.059667	1	0.001833	3	0.001833	3	0.279667
13			4	0.639667	4	0.5433	3	0.060	3	0.060	1	0.002097	4	0.281		
14			3	0.657	10	0.545	10	0.060	10	0.060			4	0.283333		
15			3	0.665	4	0.547333	5	0.060767	5	0.060767			4	0.286067		
16			4	0.6714	4	0.552333	4	0.061167	4	0.061167			10	0.290667		
17			4	0.676667	3	0.558	5	0.0617	5	0.0617			10	0.303333		
18					4	0.566667	4	0.063333	4	0.063333			5	0.318933		
19							10	0.0646	10	0.0646						
Average		0.000421		0.6449		0.5381		0.00725		0.0579		0.00197		0.00127		0.2755
Std dev		0.000035		0.0048		0.0044		0.00025		0.0015		0.00013		0.00010		0.0041
H		0.00025		0.0073		0.0065		0.00062		0.0016		0.00038		0.00033		0.0041
U ₁		0.00025		0.0087		0.0078		0.00066		0.0023		0.00040		0.00035		0.0059
t-statistic		2.36		2.12		2.11		2.20		2.10		2.23		2.18		2.11
U ₂		0.00060		0.019		0.017		0.0015		0.0047		0.00090		0.00076		0.012
U ₃		0.00021		0.0050		0.0039		0.00042		0.0011		0.00027		0.00021		0.0029
Certified		0.0004		0.64		0.538		0.0072		0.058		0.0020		0.0013		0.275
Uncertainty		0.0002		0.01		0.005		0.0004		0.003		0.0003		0.0003		0.006
Tolerance		0.0004		0.03		0.019		0.0015		0.009		0.0009		0.0009		0.018

BS 4942A * Code for method Certified values listed as weight percent

Analysis	*	Sn	*	Ti	*	V
1	4	0.003	5	0.0024	7	0.265
2	12	0.0035	12	0.0025	4	0.269
3	5	0.004133	5	0.002667	14	0.269333
4	5	0.004333	14	0.0027	3	0.27
5	5	0.004433	5	0.002733	4	0.27
6	5	0.004583	4	0.002767	4	0.273667
7	4	0.0046	5	0.002793	3	0.275
8	5	0.004833	3	0.0028	3	0.276
9	3	0.005	5	0.002867	10	0.277
10	4	0.0052	4	0.0032	4	0.2787
11	10	0.0059	10	0.0033	10	0.279333
12	3	0.006	4	0.003433	4	0.2805
13	5	0.006033	3	0.0037	3	0.283
14	9	0.006267	3	0.004	12	0.2850
15					5	0.292133
16					5	0.2955
17					4	0.303333
Average		0.00444		0.00313		0.2799
Std dev		0.00019		0.00014		0.0044
H		0.00051		0.00045		0.0042
U ₁		0.00054		0.00047		0.0061
t-statistic		2.16		2.16		2.12
U ₂		0.0012		0.0010		0.013
U ₃		0.00031		0.00027		0.0031
Certified		0.0044		0.0031		0.280
Uncertainty		0.0006		0.0004		0.007
Tolerance		0.0018		0.0012		0.021

BS 4942A * Code for method Informational values listed as weight percent

Analysis	*	B	*	Nb	*	P	*	Pb	*	Sb	*	W	*	Zr
1	3	0.00007	5	0.000127	5	0.005767	5	0.000167	5	0.0011	3	0.0001	5	0.00002
2	12	0.000085	5	0.000137	12	0.0060	5	0.000193	5	0.001133	5	0.000483	5	0.000103
3	4	0.0001	5	0.0002	10	0.0060	12	0.00020	12	0.0012	12	0.00055	12	0.00018
4	4	0.0001	4	0.000233	5	0.006433	5	0.000217	4	0.0014	5	0.0006	4	0.0002
5	5	0.000100	12	0.00035	3	0.006467	5	0.00031			5	0.000823	3	0.0012
6	5	0.000147	4	0.0006	4	0.0067	5	0.0004			4	0.0009	3	0.0018
7	7	0.000243	5	0.000697	7	0.006843	9	0.000867			5	0.001123	10	0.0021
8			3	0.0012	4	0.007123	3	0.0012			3	0.0017	14	0.002133
9			14	0.0030	3	0.0077	3	0.0015			5	0.0020	3	0.0023
10			10	0.0045	14	0.007933	10	0.0015					5	0.0033
11			3	0.005	3	0.0080								
12					4	0.008033								
13					4	0.008033								
14					4	0.008133								
15					10	0.0082								
16					3	0.0082								
17					4	0.008333								
18					5	0.008967								
Average		0.000121		0.0015		0.007		0.0007		0.0012		0.0009		0.0013
Std dev		0.000033		0.0043		0.037		0.0011		0.0051		0.0021		0.0039
H		0.00020		0.0004		0.001		0.0003		0.0003		0.0003		0.0003
U ₁		0.00020		0.0043		0.037		0.0011		0.0051		0.0021		0.0039
t-statistic		2.45		2.23		2.11		2.26		3.18		2.31		2.26
U ₂		0.00049		0.010		0.078		0.0025		0.016		0.0049		0.0088
U ₃		0.00019		0.0029		0.018		0.00078		0.0082		0.0016		0.0028
(Informational)		(0.0001)		(0.0015)		(0.007)		(0.0007)		(0.001)		(0.0009)		(0.001)

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 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 4942A * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis *	Bi	* Cd	* Cl	* Ga	* Ge	* K	* Na	* Re	* Sc	* Zn
1	12 0.061	5 12	12 0.50	12 8.0	5 9.0	12 0.50	12 0.50	12 0.34	5 1.1	12 45
2		5 12		5 10	5 9.0			5 0.50	5 1.1	5 52
3		5 13		5 10	5 9.3			5 0.65	5 1.5	5 52
4				5 11	12 20			5 0.69		5 52
5				5 11	5 22					5 60
6				5 11	5 23					5 61
7				5 11	5 23					5 62

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
NSL Analytical	Cleveland, OH	ACLASS	17025
Dirats Laboratories	Westfield, MA	ACLASS	17025
Evans Analytical Group	Liverpool, NY	A2LA	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
 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, 502-991, 501-993, 502-197, 502-257, 502-348, 502-868, 502-873; AR 642, 644, 645, 657, 673, 872, 875, 892, 1653, 1656; BAS 4/88, 409, 409/1, 410/2, 434, 434/1, 435, 464/1; BS CCT, HON-T, 30D, 56H, 68E, 300, 1026, 1030, 1962, 4130, 4150M, 8620C; CMSI 2072, 2074, 2075; ECRM 195-1D; IARM 31E, 35H; IMZ 55/1, 130, 139; JK 37; NCS NS20035B; SRM 30F, 55D, 72G, 73B, 111B, 160B, 293, 343A, 361, 362, 363, 364, 1228, 1261, 1263A, 1264A, 1413, 1763A, 1765, 1766, 1767, 3109A, 3136.

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, 501-991; BAS 410/2; BS HON-T, 68E, 4150M; CMSI 2072, 2074, 2075; ECRM 195-1D; NCS NS20035B; SRM 72G, 343A.

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 4942A 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 Rodacciai; Via Leopardi, Italy.

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 4942A-050616. You may obtain information

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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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**

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 6, 2016.

Beau R. Brammer