Brammer Standard Company, Inc.

Certificate of Analysis

BS 500E

Certified Reference Material for Monel K500 plus Silicon

Certified Values[3]

	Certified Value[1]	Estimate of Uncertainty[2]		Certified Value[1]	Estimate of Uncertainty[2]
Al	**2.94**	0.02	**Ti**	**0.607**	0.008
B	**0.0017**	0.0003	**Zr**	**0.0133**	0.0009
C	**0.134**	0.005			
Co	**0.017**	0.002			
Cr	**0.0174**	0.0006			
Cu	**29.9**	0.1			
Fe	**0.722**	0.009			
Mg	**0.0058**	0.0006			
Mn	**0.605**	0.005			
Mo	**0.0044**	0.0008			
Ni	**64.7**	0.2			
O	**0.0005**	0.0002			
P	**0.0022**	0.0006			
S	**0.0006**	0.0002			
Si	**0.148**	0.006			

Informational Values[3,4]

As (0.0008)	Ca (0.0004)	N (0.00025)	Nb (0.002)	Pb (0.0008)
Sn (0.0008)	V (0.001)	W (0.002)	Zn (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 Ga, Hf, and Se 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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BS 500E * Code for method Certified values listed as weight percent

Analysis	*	Al	*	B	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mg
1	4	2.873333	4	0.000533	1	0.125333	3	0.0129	12	0.010667	10	29.52667	3	0.683133	4	0.004003
2	4	2.925	7	0.001103	1	0.1255	12	0.014333	10	0.013667	10	29.64	4	0.708333	3	0.004933
3	10	2.930	4	0.001367	1	0.1259	4	0.0146	10	0.014	10	29.789	3	0.71	5	0.004967
4	4	2.930475	4	0.0015	1	0.129133	4	0.0155	4	0.0170	4	29.8	4	0.710333	5	0.0056
5	14	2.936667	12	0.0016	1	0.129333	4	0.016133	4	0.0172	13	29.81933	4	0.716425	14	0.005633
6	3	2.94	4	0.0016	1	0.13	4	0.016133	5	0.0174	14	29.83333	4	0.716667	4	0.00585
7	3	2.9400	3	0.00176	3	0.1307	4	0.016367	4	0.0175	4	29.84667	4	0.720933	12	0.006033
8	4	2.941333	4	0.002333	1	0.130967	3	0.016633	3	0.017567	3	29.90067	4	0.7260	3	0.006233
9	4	2.95	14	0.0025	1	0.133333	4	0.017	3	0.0176	4	29.94	12	0.726667	4	0.006267
10	4	2.95			3	0.136333	5	0.017433	4	0.017833	6	29.955	4	0.728667	3	0.00654
11	4	3.006667			1	0.136667	5	0.018	10	0.018	4	30.04867	4	0.73	4	0.006667
12	4	3.008667			1	0.141025	10	0.0180	4	0.018233	3	30.05	10	0.73	4	0.006733
13	3	3.0112			1	0.14167	14	0.018733	3	0.0188	4	30.0576	3	0.732333		
14	4	3.025067					4	0.019667	5	0.0190	3	30.33513	4	0.733		
15									4	0.019225	4	30.42333	10	0.746667		
16									14	0.020733			10	0.771		
Average		2.941		0.001702		0.1340		0.01658		0.01742		29.940		0.7216		0.00576
Std dev		0.013		0.000054		0.0027		0.00063		0.00066		0.042		0.0053		0.00020
H		0.023		0.00038		0.0028		0.0009		0.0009		0.17		0.0082		0.00059
U_1		0.026		0.00039		0.0039		0.0011		0.0012		0.17		0.0097		0.00062
t-statistic		2.16		2.31		2.18		2.16		2.13		2.14		2.13		2.20
U_2		0.057		0.00089		0.0085		0.0024		0.0025		0.37		0.021		0.0014
U_3		0.015		0.00030		0.0024		0.0007		0.00061		0.10		0.0052		0.00040
Certified		**2.94**		**0.0017**		**0.134**		**0.017**		**0.0174**		**29.9**		**0.722**		**0.0058**
Uncertainty		**0.02**		**0.0003**		**0.005**		**0.002**		**0.0006**		**0.1**		**0.009**		**0.0006**
Tolerance		0.06		0.0009		0.015		0.006		0.0025		0.4		0.027		0.0016

Analysis	*	Mn	*	Mo	*	Ni	*	O	*	P	*	S	*	Si	*	Ti
1	10	0.580	5	0.0034	4	64.30	2	0.00022	12	0.001027	1	0.000225	5	0.1336	10	0.536667
2	4	0.58	14	0.003567	4	64.43333	2	0.000273	5	0.0012	1	0.00025	10	0.136	4	0.59
3	10	0.581	5	0.003633	3	64.44147	4	0.00035	3	0.0014	1	0.0004	3	0.1414	4	0.591333
4	3	0.5952	4	0.00365	16	[64.49263]	2	0.0004	4	0.0018	1	0.00045	3	0.142967	3	0.596267
5	3	0.599033	12	0.003933	4	64.55	2	0.000423	5	0.001867	1	0.000467	4	0.144167	7	0.600
6	4	0.600667	5	0.0041	10	64.586	2	0.000633	4	0.002133	1	0.0006	4	0.144333	4	0.601667
7	3	0.602	4	0.004467	13	64.558667	2	0.000733	7	0.00231	12	0.00077	4	0.145333	12	0.603333
8	4	0.603667	5	0.004607	10	64.69333	2	0.000833	10	0.0028	1	0.001067	4	0.146667	4	0.603667
9	4	0.6043	3	0.004633	16	[64.7]			3	0.002833	3	0.0011	12	0.146667	4	0.607
10	4	0.607	3	0.0049	14	64.73333			4	0.003233	3	0.001133	10	0.146667	3	0.608167
11	4	0.608	4	0.0060	16	[64.75333]			5	0.003667			4	0.1491	10	0.610
12	10	0.613333	4	0.006467	4	64.82667							4	0.151	4	0.610267
13	4	0.613667			16	[64.86333]							4	0.156667	3	0.611
14	4	0.653333			3	64.89073							3	0.157	4	0.615
15					10	65.05							4	0.16	14	0.622
16															4	0.623333
17															4	0.6378
18															10	0.653
Average		0.6049		0.004446		64.663		0.000473		0.002206		0.00065		0.1482		0.606694
Std dev		0.0047		0.000091		0.054		0.000053		0.000095		0.00010		0.0030		0.000075
H		0.0072		0.00053		0.35		0.00027		0.00042		0.00029		0.0029		0.00723
U_1		0.0086		0.00054		0.35		0.00027		0.00043		0.00031		0.0042		0.0072
t-statistic		2.16		2.20		2.14		2.36		2.23		2.26		2.14		2.11
U_2		0.019		0.0012		0.76		0.00065		0.0010		0.00070		0.0089		0.015
U_3		0.0050		0.00034		0.20		0.00023		0.00029		0.00022		0.0023		0.0036
Certified		**0.605**		**0.0044**		**64.7**		**0.0005**		**0.0022**		**0.0006**		**0.148**		**0.607**
Uncertainty		**0.005**		**0.0008**		**0.2**		**0.0002**		**0.0006**		**0.0002**		**0.006**		**0.008**
Tolerance		0.019		0.0024		0.8		0.0004		0.0018		0.0005		0.018		0.024

BS 500E * Code for method Certified values listed as weight percent

Analysis	*	Zr
1	12	0.008233
2	4	0.008833
3	4	0.011667
4	5	0.0130
5	5	0.013233
6	4	0.0138
7	4	0.013833
8	3	0.0139
9	10	0.0141
10	14	0.0141
11	4	0.0144
12	4	0.015433
13	4	0.016
Average		0.01329
Std dev		0.00054
H		0.00084
U_1		0.0010
t-statistic		2.18
U_2		0.0022
U_3		0.00060
Certified		**0.0133**
Uncertainty		**0.0009**
Tolerance		0.0027

BS 500E * Code for method Informational values listed as weight percent

Analysis	*	As	*	Ca	*	N	*	Nb	*	Pb	*	Sn	*	V	*	W
1	5	0.000167	12	0.0000567	2	0.000226	3	0.0005	5	0.00031	4	0.0001	4	0.000233	12	0.00035
2	5	0.00021	4	0.0001	2	0.000267	5	0.00097	12	0.000377	5	0.000197	5	0.00037	4	0.0006
3	12	0.000217	3	0.0001			5	0.0013	5	0.00038	5	0.0002	5	0.000377	5	0.0008
4	4	0.000933	4	0.000575			12	0.001433	5	0.0004	5	0.000203	12	0.000383	4	0.008
5	3	0.0013	4	0.0006			5	0.0016	4	0.000633	3	0.0008	5	0.0004		
6	5	0.0021	4	0.0008667			5	0.0016	3	0.0008	4	0.000933	4	0.0019		
7							4	0.002267	3	0.0013333	4	0.0010	4	0.002533		
8							3	0.003133	14	0.002467	4	0.0022	3	0.0026		
9							4	0.0041			14	0.0032	4	0.002733		
10							14	0.004167								
Average		0.0008		0.00038		0.00025		0.0021		0.0008		0.00080		0.0013		0.002
Std dev		0.0021		0.00047		0.00032		0.0083		0.0019		0.00031		0.0038		0.016
H		0.0003		0.00026		0.00024		0.0004		0.0003		0.00031		0.0004		0.0004
U_1		0.0021		0.00053		0.00039		0.0083		0.0019		0.00044		0.0038		0.016
t-statistic		2.57		2.57		12.71		2.26		2.36		2.31		2.31		3.18
U_2		0.0054		0.0014		0.0050		0.019		0.0045		0.0010		0.0088		0.052
U_3		0.0022		0.00056		0.0035		0.0059		0.0016		0.00034		0.0029		0.026
(Informational)		**(0.0008)**		**(0.0004)**		**(0.00025)**		**(0.002)**		**(0.0008)**		**(0.0008)**		**(0.001)**		**(0.002)**

BS 500E * Code for method Informational values listed as weight percent

Analysis	*	Zn
1	5	0.0006
2	5	0.00062
3	5	0.000697
4	4	0.000837
5	4	0.001267
6	4	0.0027
Average		0.0011
Std dev		0.0037
H		0.0003
U_1		0.0037
t-statistic		2.57
U_2		0.0095
U_3		0.0039
(Informational)		**(0.001)**

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 it's 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 500E * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis	*	Ga	*	Hf	*	Se
1	5	4	5	2	5	7

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

Laboratory	Location	Registrar	Accreditation
Brammer Standard Company, Inc.	Houston, TX	A2LA	17025, Guide 34
Evans Analytical Group	Liverpool, NY	A2LA	17025
Dirats Laboratories	Westfield,MA	ACLASS	17025
NSL Analytical	Cleveland, OH	ACLASS	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
Anderson Laboratories, Inc.	Greendale, WI	A2LA	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	AB 554
Laboratory Testing, Inc.	Hatfield, PA	PRI/Nadcap	17025
Exova	Glendale Heights, Il	A2LA	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Luvak Inc.	Boylston, MA	PRI/Nadcap	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: 13X32101A, 24X07001, 212X4003, 212X4003K, 212X4004; AR 511, 512, 645, 662, 871, 875, 892, 1648, 1652, 1652, 1653; BAS 351, 363/1, 387, 403, 451; BS H2C, 200-1, 200-2, 200-3, 400-2, 400D, 500B, 500C, 750C; DSZU CA01A; IARM 51C, 52A, 52B, 52C, 56C, 63C, 163B, 257A; IMZ 99, 184; JSS GS-6; KMS LCSON-001; LECO 501-320, 501-501, 501-502, 501-550, 501-644, 501-646, 501-675, 501-676, 501-992, 501-993, 502-348, 502-873; NCS NS11028; SRM 15E, 36, 160B, 162A, 363, 866, 882, 1413, 3103A, 3109A, 3168A.

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 351, 363/1; BS 400-2, 400D, 500C; DSZU CA01A; IARM 51C; KMS LCSON-001; LECO 501-676, 502-873; NCS NS11028; SRM 106B, 882.

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 500E 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 Deutsche Nickrl GMBH; Schwerte, Germany.

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.

Certificate Number: The unique identification number for this certificate of analysis is 500E-102816. 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**
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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 30:2015 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 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 October 28, 2016.

Beau R. Brammer