

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 500D

Certified Reference Material for Monel K500 - UNS Number N05500¹

	Certified Value ²	Estimate of Uncertainty ³	Certified Values ⁴	Certified Value ²	Estimate of Uncertainty ³
Al	2.98	0.01	O	0.0008	0.0002
As	0.0015	0.0001	P	0.0086	0.0003
B	0.00022	0.00003	Pb	0.00028	0.00003
C	0.154	0.002	S	0.00099	0.00007
Ca	0.0030	0.0002	Sb	0.00006	0.00002
Co	0.0347	0.0007	Si	0.0700	0.0009
Cr	0.212	0.002	Ta	0.00019	0.00006
Cu	29.66	0.06	Ti	0.446	0.003
Fe	0.723	0.005	V	0.0020	0.0001
Mg	0.0110	0.0003	W	0.0021	0.0002
Mn	0.677	0.004	Zr	0.030	0.001
Mo	0.0243	0.0004			
N	0.00015	0.00006			
Nb	0.0073	0.0003			
Ni	65.0	0.2			

Informational Values^{4,5}

Sn (0.0004)

¹ This certificate is a revision. For more information on the nature and extent of the revision, see the revision statement on page 7.

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.

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

Trace element information values for Ag, Au, Ba, Be, Bi, Br, Cd, Ce, Cl, Cs, Dy, Er, Eu, F, Ga, Gd, Ge, Hf, Hg, Ho, I, In, Ir, K, La, Li, Lu, Na, Nd, Os, Pd, Pr, Pt, Rb, Re, Rh, Ru, Sc, Se, Sm, Sr, Tb, Te, Th, Tl, Tm, U, Y, Yb, and Zn are shown on page 5.

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 500D

* Code for method Certified values listed as weight percent

Analysis	*	Al	*	As	*	B	*	C	*	Ca	*	Co	*	Cr	*	Cu
1	4	2.94	9	0.0007	5	0.000005	1	0.146	5	0.0012	10	0.0308	4	0.197	4	29.40
2	10	2.96	12	0.0009	7	0.000035	1	0.146	4	0.0024	4	0.0315	5	0.198	4	29.43
3	13	2.96	15	0.0012	5	0.000095	1	0.148	12	0.0025	3	0.0323	4	0.206	4	29.46
4	4	2.96	5	0.0012	4	0.00010	1	0.149	4	0.0025	3	0.0330	4	0.210	4	29.54
5	4	2.97	5	0.0015	8	0.00010	1	0.150	4	0.0033	4	0.0346	10	0.210	4	29.55
6	10	2.97	5	0.0016	5	0.00011	1	0.150	4	0.0037	4	0.0348	10	0.210	4	29.58
7	4	2.98	5	0.0019	4	0.00020	1	0.151	4	0.0046	4	0.0348	4	0.212	3	29.61
8	4	2.98	5	0.0024	3	0.00020	1	0.154	4	0.0051	8	0.0350	3	0.217	3	29.70
9	4	2.98	4	0.0025	4	0.00050	1	0.155			3	0.0358	4	0.217	4	29.71
10	3	2.99			5	0.00060	1	0.164			5	0.0364	10	0.217	10	29.71
11	4	2.99			4	0.00060	1	0.166			4	0.0380	3	0.218	13	29.76
12	3	2.99					1	0.169			8	0.0391	4	0.220	10	29.79
13	10	3.00													4	29.79
14															4	29.80
15															4	29.84
Average		2.975		0.00154		0.000216		0.1538		0.00305		0.03465		0.2120		29.658
Std dev		0.015		0.00015		0.000043		0.0018		0.00024		0.00082		0.0025		0.062
H		0.017		0.00007		0.000016		0.0019		0.00011		0.0007		0.0024		0.09
U ₁		0.023		0.00016		0.000046		0.0027		0.00026		0.0010		0.0035		0.11
t-statistic		2.18		2.31		2.23		2.20		2.36		2.20		2.20		2.14
U ₂		0.049		0.00037		0.00010		0.0059		0.00062		0.0023		0.0077		0.23
U ₃		0.014		0.00012		0.000031		0.0017		0.00022		0.00067		0.0022		0.060
Certified		2.98		0.0015		0.00022		0.154		0.0030		0.0347		0.212		29.66
Uncertainty		0.01		0.0001		0.00003		0.002		0.0002		0.0007		0.002		0.06
Tolerance		0.05		0.0004		0.00010		0.006		0.0006		0.0023		0.002		0.23

Analysis	*	Fe	*	Mg	*	Mn	*	Mo	*	N	*	Nb	*	Ni	*	O
1	10	0.700	4	0.0080	4	0.651	5	0.0207	2	0.00005	5	0.0055	3	64.2	2	0.0003
2	4	0.704	3	0.0090	8	0.655	12	0.0210	2	0.00010	4	0.0060	10	64.8	2	0.0004
3	4	0.707	12	0.0090	4	0.665	4	0.0210	2	0.00015	5	0.0060	10	64.9	2	0.0008
4	3	0.714	8	0.0100	3	0.666	4	0.0222	2	0.00019	3	0.0067	10	65.0	2	0.0012
5	4	0.715	4	0.0107	10	0.675	4	0.0228	2	0.00020	3	0.0070	4	65.3		
6	8	0.720	4	0.0110	4	0.678	4	0.0230			4	0.0071	4	65.7		
7	4	0.720	4	0.0115	4	0.680	3	0.0240			12	0.0077				
8	4	0.724	4	0.0118	10	0.681	4	0.0240			5	0.0085				
9	5	0.726	3	0.0119	4	0.683	5	0.0246			4	0.0088				
10	10	0.732	4	0.0119	4	0.686	5	0.0255			5	0.0089				
11	10	0.733	5	0.0121	4	0.689	10	0.0257			5	0.0095				
12	3	0.734	3	0.0121	10	0.690	4	0.0259								
13	5	0.742	4	0.0125	5	0.698	4	0.0262								
14	3	0.749	4	0.0127	3	0.699	3	0.0266								
15							3	0.0300								
Average		0.7233		0.01100		0.6767		0.02430		0.000146		0.00727		64.99		0.00075
Std dev		0.0054		0.00036		0.0048		0.00058		0.000046		0.00031		0.15		0.00014
H		0.0060		0.00028		0.0057		0.00050		0.000012		0.00021		0.16		0.00004
U ₁		0.0081		0.00046		0.0074		0.00077		0.000047		0.00037		0.22		0.00014
t-statistic		2.16		2.16		2.16		2.14		2.78		2.23		2.57		3.18
U ₂		0.017		0.0010		0.016		0.0016		0.00013		0.00083		0.56		0.00045
U ₃		0.0047		0.00027		0.0043		0.00042		0.000059		0.00025		0.23		0.00022
Certified		0.723		0.0110		0.677		0.0243		0.00015		0.0073		65.0		0.0008
Uncertainty		0.005		0.0003		0.004		0.0004		0.00006		0.0003		0.2		0.0002
Tolerance		0.017		0.0010		0.016		0.0016		0.00013		0.0008		0.6		0.0004

BS 500D

* Code for method Certified values listed as weight percent

Analysis	*	P	*	Pb	*	S	*	Sb	*	Si	*	Ta	*	Ti	*	V
1	4	0.0075	8	0.00015	1	0.00010	5	0.000005	12	0.0600	5	0.000005	4	0.435	4	0.00067
2	7	0.0076	5	0.00020	1	0.00010	5	0.000040	3	0.0600	5	0.000010	4	0.439	4	0.00095
3	4	0.0078	3	0.00020	1	0.00030	5	0.000050	4	0.0600	5	0.00016	3	0.442	5	0.00110
4	3	0.0082	9	0.00020	1	0.00045	9	0.000050	4	0.0651	5	0.00021	10	0.442	5	0.00140
5	3	0.0085	3	0.00025	1	0.00080	5	0.000065	10	0.0670	5	0.00025	4	0.443	12	0.00200
6	4	0.0085	5	0.00027	1	0.00100	12	0.000075	4	0.0699	4	0.00050	10	0.444	4	0.00220
7	4	0.0086	12	0.00027	1	0.00100	5	0.000080	4	0.0700			4	0.445	10	0.00257
8	5	0.0088	5	0.00030	1	0.00110	15	0.000090	4	0.0710			8	0.445	4	0.00270
9	4	0.0089	5	0.00032	1	0.00130	5	0.00011	3	0.0718			3	0.447	4	0.00280
10	4	0.0089	5	0.00032	1	0.00145			4	0.0718			5	0.449	8	0.00300
11	4	0.0090	4	0.00034	1	0.00170			4	0.0740			12	0.450	4	0.00300
12	10	0.0090	5	0.00036	1	0.00194			4	0.0741			7	0.450	4	0.00300
13	4	0.0090	5	0.00038	3	0.00205			4	0.0788			4	0.458	3	0.00350
14			3	0.00040	1	0.00236			5	0.0825						
15									3	0.0853						
Average		0.00860		0.000278		0.00099		0.000055		0.0700		0.000186		0.4461		0.00204
Std dev		0.00036		0.000042		0.00010		0.000027		0.0012		0.000059		0.0032		0.00014
H		0.00024		0.000019		0.00005		0.000006		0.0011		0.000014		0.0042		0.00008
U ₁		0.00043		0.000047		0.00011		0.000027		0.0016		0.000060		0.0053		0.00016
t-statistic		2.18		2.16		2.16		2.31		2.14		2.57		2.18		2.18
U ₂		0.00093		0.00010		0.00024		0.000063		0.0035		0.00016		0.012		0.00035
U ₃		0.00026		0.000027		0.000065		0.000021		0.00089		0.000063		0.0032		0.00010
Certified		0.0086		0.00028		0.00099		0.00006		0.0700		0.00019		0.446		0.0020
Uncertainty		0.0003		0.00003		0.00007		0.00002		0.0009		0.00006		0.003		0.0001
Tolerance		0.0009		0.00010		0.00024		0.00006		0.0035		0.00016		0.012		0.0004

Analysis	*	W	*	Zr	*	*	*	*
1	4	0.0014	4	0.0293				
2	4	0.0015	10	0.0293				
3	12	0.0016	4	0.0300				
4	5	0.0020	5	0.0303				
5	5	0.0022	3	0.0308				
6	5	0.0025	4	0.0314				
7	4	0.0025	4	0.0318				
8	5	0.0029						
9	5	0.0035						
Average		0.00215		0.0305				
Std dev		0.00018		0.0010				
H		0.00009		0.0006				
U ₁		0.00020		0.0012				
t-statistic		2.31		2.45				
U ₂		0.00046		0.0028				
U ₃		0.00015		0.0011				
Certified		0.0021		0.030				
Uncertainty		0.0002		0.001				
Tolerance		0.0005		0.003				

Analysis	*	Sn	*	*	*	*	*	*	*
1	12	0.00035							
2	5	0.00042							
3	5	0.00044							
Average		0.00040							
Std dev		0.00012							
H		0.00003							
U ₁		0.00012							
t-statistic		4.30							
U ₂		0.00051							
U ₃		0.00030							
(Certified)		(0.0004)							
(Uncertainty)		(0.0003)							
(Tolerance)		(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 uncertainty (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:

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

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 500D

* Code for analytical method

Trace analysis listed as mg/kg (ppm)

Analysis	* Ag	* Au	* Ba	* Be	* Bi	* Br	* Cd	* Ce	* Cl	* Cs
1	9 2.5	12 0.5	12 0.05	12 0.025	12 0.15	12 0.0025	12 0.25	12 0.04	12 0.0005	12 0.0025
2	5 3				5 0.18		12 0.25			5 6.4
3	5 3.3				5 0.2		5 0.3			
4	12 4				4 0.2		4 0.4			
5	5 4.45				5 0.21		15 0.5			
6	12 4.6				5 0.5		5 0.6			
7	5 4.9				5 0.5		5 1			
8	5 5.3				9 1		5 2			
9	5 6						4 4			
10							4 5			

Analysis	* Dy	* Er	* Eu	* F	* Ga	* Gd	* Ge	* Hf	* Hg	* Ho
1	12 0.0025	12 0.006	12 0.0025	12 0.025	5 4	12 0.0025	5 0.1	12 2.1	12 0.025	12 0.0025
2					5 4.25		12 0.15			
3					5 5					
4					5 5.1					
5					5 5.6					
6					12 5.9					
7					5 6.1					

Analysis	* I	* In	* Ir	* K	* La	* Li	* Lu	* Na	* Nd	* Os
1	12 0.0025	12 0.05	12 0.025	12 0.05	12 0.02	12 0.0025	12 0.0025	12 0.018	12 0.02	12 0.07
2								12 0.025		

Analysis	* Pd	* Pr	* Pt	* Rb	* Re	* Rh	* Ru	* Sc	* Se	* Sm
1	12 0.82	12 0.006	12 0.05	12 0.005	12 0.025	12 0.025	12 0.025	12 0.0005	9 0.01	12 0.005
2								12 0.05	5 0.05	
3									5 0.05	
4									15 0.05	
5									12 0.25	
6									12 0.5	
7									9 1.5	
8									5 5	

Analysis	* Sr	* Tb	* Te	* Th	* Tl	* Tm	* U	* Y	* Yb	* Zn
1	12 0.5	12 0.0025	12 0.05	12 0.007	5 0.025	12 0.0025	12 0.025	12 0.085	12 0.008	5 3
2			5 0.05		12 0.025					8 5.5
3			15 0.05		5 0.035					12 5.8
4			9 0.25		5 0.05					5 6
5			5 0.25		5 0.1					5 7.3
6			5 0.5		5 0.5					5 9.5
7			5 ..5		5 0.5					4 13
8					9 1					4 14
9										5 20

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 | |
| 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>
Allegheny Ludlum	Lockport, NY	A2LA	17025
Allvac-Lockport	Lockport, NY	PRI/Nadcap	17025
ATI Allvac	Monroe, NC	PRI/Nadcap	17025
Brammer Standard Company, Inc.	Houston, TX	A2LA	17025, Guide 34
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	AB 554
Dirats Laboratories	Westfield, MA	PRI/Nadcap	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
Inco Test	Huntington, WV	PRI/Nadcap	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI/Nadcap	17025
LECO Corporation	St. Joseph, MI	BSI	9001
Ledoux & Company	Teaneck, NJ	EQA (Ireland)	9001
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Northern Analytical Laboratory, Inc.	Londonderry, NH	PRI/Nadcap	17025
NSL Analytical	Cleveland, OH	PRI/Nadcap	17025
Shiva Technologies	Syracuse, NY	PRI/Nadcap	17025
VHG Labs	Manchester, NH	A2LA	Guide 34

A2LA = American Association for Laboratory Accreditation

BSI = British Standards Institution

CNAS = China National Accreditation Service

EQA = European Quality assurance

Nadcap = National Aerospace and Defense Contractors Accreditation Program

PCA = Polish Center For Accreditation

PRI = Performance Review Institute

Analysis: Chemical analyses were made on chips prepared by a lathe from a representative sample of 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 5.

Traceability: The following Certified Reference Materials were used to validate the analytical data listed on pages 2 through 5: SRM 16F, 867, 882, 897, 898, 899, 1159, 1160, 1186, 1188, 1189, 1190, 1191, 1192, 1193, 1194, 1195, 1198, 1199, 1200, 1201, 160-2, 1207-1, 1208-1, 1208-2, 1230, 1242, 1243, 1244, 1245, 1245A, C1248, 1249, 1250, C1287, C1288, 1775, C2402, 3101A, 3102A, 3103A, 3106, 3107, 3108, 3109A, 312A, 3113, 3114, 3126A, 3128, 3131A, 3132, 3134, 3137, 3139A, 3149, 3150, 3151, 3155, 3156, 3158, 3162A, 3163, 3165, 3168, 3168A, 3169; 501-024, 501-149, 501-501, 501-502, 501-503, 501-504, 501-506, 501-550, 501-673, 501-991, 501-992, 502-257; IMZ 181: NCS HC11520; 24X WASP4 C, ECRM 328-1; IARM 52A, 52B, 190A; AR 511; BAS 335, 337, 345, 346, 346A, 351, 363, 363/1; CSB 2751-1; BS 400, 400B, 400C, 400-2, 400-3, 500C.

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: BS HF 5684, HF 5730, 400, 400B, 400C, 400-2, 400-3, 500C

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 500D 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 INCO Alloys, Huntington, West Virginia.

Form: This CRM is machined in the form of a disc, approximately 38 mm in diameter and 12 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 REV500D-100711. 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.
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 by Brammer Standard Company on June 03, 1991, before extensive homogeneity studies were employed. Based on a comprehensive homogeneity study, including additional information about its contribution to the uncertainty estimates and additional interlaboratory testing, a revision was issued on July 07, 2011. That revision supplied uncertainty estimates for all certified elements, added the elements As, Ca, N, O, Sb, Sn, W, and Zr to the certified list, changed B, Nb, and Ni from informational to certified, refined values for all elements except Al, added an informational value for Ta, and added a number of trace elements. Additional interlaboratory testing was required to resolve the issue of an excessive element total (> 100.2 %). The additional data resulted in the transition of Sn from certified to informational, the transition of Ta from informational to certified, further value refinement, and an acceptable element total (< 100.05 %).

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 October 07, 2011.

Beau R. Brammer