

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 199B

Certified Reference Material for Nickel Alloy (Waspaloy) - UNS Number N07001

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values ³	Certified Value ¹	Estimate of Uncertainty ²
Al	1.370	0.008	S	0.0005	0.0002
B	0.0053	0.0004	Si	0.034	0.005
C	0.041	0.001	Sn	0.0006	0.0002
Co	12.41	0.05	Ti	3.00	0.05
Cr	19.46	0.08	V	0.071	0.002
Cu	0.015	0.001	W	0.048	0.001
Fe	1.17	0.01	Zr	0.045	0.001
Mg	0.0032	0.0004			
Mn	0.0240	0.0008			
Mo	3.87	0.02			
N	0.0038	0.0004			
Nb	0.069	0.001			
Ni	58.4	0.2			
O	0.0006	0.0002			
P	0.0031	0.0003			

Informational Values^{3,4}

Ta (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 3-4 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 3-4 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 As, Bi, Ca, Cl, Ga, Hf, K, Na, Pb, Re, Sb, U, 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 199B

* Code for method Certified values listed as weight percent

Analysis	*	Al	*	B	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mg
1	10	1.3116667	12	0.0048	1	0.038967	14	12.12	4	19.15	14	0.0118	4	1.13	5	0.002333
2	4	1.326667	3	0.005	1	0.03954	4	12.275	3	19.31667	5	0.014133	4	1.140667	14	0.002433
3	10	1.341967	4	0.00505	3	0.040	4	12.31	13	19.33933	4	0.0142	4	1.144333	4	0.0026
4	4	1.3425	4	0.005067	1	0.040467	4	12.325	4	19.39333	5	0.0145	10	1.156667	5	0.002667
5	14	1.346667	7	0.00519	1	0.0406	3	12.33	3	19.40	3	0.014667	10	1.158367	12	0.0032
6	3	1.36	3	0.0052	1	0.040833	3	12.38	10	19.43	3	0.015	10	1.16	4	0.00329
7	3	1.36	14	0.005333	1	0.040987	10	12.38333	10	19.44667	12	0.0150	10	1.162	3	0.00341
8	4	1.363333	5	0.005467	1	0.041933	10	12.39	4	19.46348	4	0.01625	3	1.17	4	0.0037
9	10	1.366667	4	0.005467	1	0.042117	4	12.39333	4	19.48	10	0.0164	3	1.2	5	0.004133
10	4	1.367367	3	0.00556	1	0.043133	3	12.40	4	19.50867	3	0.0165	14	1.203333		
11	4	1.370333	5	0.0058	1	0.043467	4	12.4065	4	19.5153	10	0.016567	4	1.215333		
12	10	1.372			3	0.0437	10	12.4082	10	19.54553	8	0.0167	4	1.2311		
13	4	1.3901					4	12.46333	3	19.55	4	0.0176				
14	4	1.395333					4	12.47843	10	19.58667	4	0.0178				
15	3	1.433333					10	12.53			4	0.0180				
Average		1.3700		0.00528		0.0412		12.408		19.457		0.01533		1.1727		0.00320
Std dev		0.0060		0.00020		0.0015		0.049		0.074		0.00064		0.0069		0.00018
H		0.012		0.00053		0.0013		0.07597		0.11		0.0008		0.011		0.00045
U ₁		0.014		0.00057		0.0020		0.090		0.14		0.0010		0.013		0.00048
t-statistic		2.14		2.23		2.20		2.14		2.16		2.14		2.20		2.31
U ₂		0.029		0.0013		0.0044		0.19		0.30		0.0022		0.029		0.0011
U ₃		0.0076		0.00038		0.0013		0.050		0.079		0.00058		0.0083		0.00037
Certified		1.370		0.0053		0.041		12.41		19.46		0.015		1.17		0.0032
Uncertainty		0.008		0.0004		0.001		0.05		0.08		0.001		0.01		0.0004
Tolerance		0.029		0.0013		0.004		0.19		0.30		0.002		0.03		0.0011

Analysis	*	Mn	*	Mo	*	N	*	Nb	*	Ni	*	O	*	P	*	S
1	8	0.021767	4	3.7525	2	0.002833	5	0.061933	16	[58.19507]	2	0.000167	4	0.0019	1	0.00004
2	3	0.0228	14	3.796667	2	0.002933	3	0.0635	16	[58.2]	2	0.0003	12	0.0020	12	0.00017
3	5	0.023067	4	3.819	2	0.00326	10	0.065933	3	58.26667	2	0.000383	4	0.00220	1	0.000233
4	5	0.023267	10	3.85	2	0.003563	3	0.0673	16	[58.34]	2	0.000433	5	0.002233	1	0.00042
5	4	0.02385	10	3.868033	2	0.003633	4	0.0676	10	58.34333	2	0.000463	14	0.002767	1	0.000433
6	4	0.0243	4	3.869083	2	0.00368	14	0.068767	10	58.38	2	0.00055	4	0.002933	1	0.000603
7	14	0.0246	10	3.876667	2	0.003867	4	0.0689	10	58.46	2	0.000632	3	0.003	1	0.000733
8	4	0.024867	10	3.88	2	0.004033	5	0.0690	13	58.53867	2	0.0008	4	0.0031	1	0.000923
9	4	0.025233	4	3.884667	2	0.004075	7	0.069467	4	58.56	2	0.001033	7	0.00316	1	0.001633
10	4	0.026067	8	3.885667	2	0.004233	4	0.069633	16	[58.57]	2	0.00158	3	0.0032		
11	12	0.0267	4	3.89			4	0.070833	4	58.775			10	0.003233		
12	10	0.0268	3	3.89			10	0.071333					3	0.003467		
13	10	0.027533	4	3.909967			10	0.0717					10	0.0037		
14	3	0.0306	3	3.94			4	0.0722					10	0.004067		
15	10	0.031667	4	3.948			12	0.0790								
16			3	3.96												
Average		0.02402		3.868		0.00378		0.0687		58.387		0.000620		0.00306		0.000500
Std dev		0.00097		0.023		0.00015		0.0020		0.068		0.000069		0.00027		0.000075
H		0.0010		0.028		0.00047		0.0018		0.33		0.00028		0.00044		0.00026
U ₁		0.0014		0.036		0.00050		0.0027		0.34		0.00028		0.00052		0.00027
t-statistic		2.14		2.13		2.26		2.14		2.23		2.26		2.16		2.31
U ₂		0.0030		0.077		0.0011		0.0057		0.75		0.00064		0.0011		0.00063
U ₃		0.00078		0.019		0.00035		0.0015		0.23		0.00020		0.00030		0.00021
Certified		0.0240		3.87		0.0038		0.069		58.4		0.0006		0.0031		0.0005
Uncertainty		0.0008		0.02		0.0004		0.001		0.2		0.0002		0.0003		0.0002
Tolerance		0.0030		0.08		0.0011		0.006		0.8		0.0006		0.0011		0.0005

BS 199B * Code for method Certified values listed as weight percent

Analysis	*	Si	*	Sn	*	Ti	*	V	*	W	*	Zr
1	4	0.020367	5	0.00047	10	2.913333	4	0.062567	3	0.040167	5	0.039733
2	14	0.021933	5	0.0006	7	2.921667	3	0.0641	4	0.0427	5	0.042367
3	4	0.033058	5	0.0006	14	2.976667	3	0.066267	4	0.044433	4	0.0446
4	10	0.034	5	0.000633	4	2.977467	5	0.067467	4	0.046067	3	0.045
5	12	0.0345	5	0.000687	4	2.977767	14	0.067967	14	0.048033	3	0.046
6	10	0.037333	9	0.0007	4	2.985667	10	0.069	4	0.0486	14	0.046367
7	3	0.038333	12	0.00082	4	3.02	4	0.06925	4	0.04898	10	0.0467
8	5	0.0390333	3	0.0011	4	3.022333	10	0.070333	3	0.0493	12	0.0468
9	4	0.039767	4	0.0014	10	3.023	4	0.070533	10	0.0493	4	0.047
10	10	0.041133			3	3.03	4	0.071467	10	0.05	4	0.047033
11	4	0.043667			4	3.03	12	0.0720	12	0.0500	10	0.047933
12	5	0.043767			4	3.039333	5	0.077733	4	0.051767	10	0.0486
13					10	3.04	4	0.0792	10	0.052333	4	0.050033
14					10	3.0438	7	0.0810	10	0.0544	3	0.052433
15					3	3.05						
16					3	3.093333						
Average		0.0335		0.000649		3.0041		0.0712		0.0483		0.0454
Std dev		0.0018		0.000068		0.0063		0.0021		0.0020		0.0017
H		0.00121		0.00028		0.023		0.0018		0.0015		0.0014
U ₁		0.0022		0.00029		0.024		0.0028		0.0025		0.0022
t-statistic		2.20		2.31		2.13		2.16		2.16		2.16
U ₂		0.0048		0.00066		0.050		0.0059		0.0054		0.0047
U ₃		0.0014		0.00022		0.013		0.0016		0.0014		0.0013
Certified		0.034		0.0006		3.00		0.071		0.048		0.045
Uncertainty		0.005		0.0002		0.05		0.002		0.001		0.001
Tolerance		0.006		0.0006		0.06		0.006		0.005		0.005

BS 199B * Code for method Informational values listed as weight percent

Analysis	*	Ta
1	12	0.0010
2	5	0.0015
Average		0.0013
Std dev		0.0081
H		0.0003
U ₁		0.0081
t-statistic		12.71
U ₂		0.10
U ₃		0.073
(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. 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 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 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 199B		* Code for analytical method												Trace analysis listed as mg/kg (ppm)						
Analysis	*	As	*	Bi	*	Ca	*	Cl	*	Ga	*	Hf	*	K	*	Na	*	Pb	*	Re
1	12	3.5	12	0.017	12	0.50	12	0.50	5	14	5	2.6	12	0.10	12	0.16	12	0.060	5	0.35
2									5	14	5	2.6							5	0.36
3									5	14	5	3.0							5	0.36
4									12	17	12	32							12	1.0

Analysis	*	Sb	*	U	*	Zn
1	5	0.73	12	0.037	12	0.30
2	5	0.74				
3	5	0.74				
4	12	1.0				

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
Dirats Laboratories	Westfield, MA	ACLASS	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI/Nadcap	17025
LECO Corporation	St. Joseph, MI	A2LA	17025
Luvak Inc.	Boylston, MA	PRI/Nadcap	17025
NSL Analytical	Cleveland, OH	ACLASS	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Exova	Glendale Heights, IL	A2LA	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	AB 554
Northern Analytical Laboratory, Inc.	Londonderry, NH	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

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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: 11xC4, 11xC5, 11xC8, 13x21800, 13x31245, 13xNSA11, 215xHB2, 24x07001, 28x7183; 501-501, 501-502, 501-503, 501-550, 501-644, 501-646, 501-675, 501-676, 501-952, 501-991, 501-993, 502-102, 502-195, 502-257, 502-348, 502-402, 502-414, 502-416, 502-494, 502-809; AR 644, 661, 875, 891, 961, 1651, 1652, 1653; BAS 4/88, 206, 316A, 346A, 351, 387, 431, 474; BS CA316-2, H3C, SS3951, 198, 199, 625C, 718C; CKD 211; ECRM 085-1, 086-1, 087-1; IARM 54B, 56C, 62A, 62B, 62E, 190A; IMZ 171, 504; IPT 208Fe; NCS NS11028, NS20035B; SRM 55D, 101E, 179, 349, 349A, 865, 866, 1243, 1249, 1413, 2159, 3131A.

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, 502-416; BAS 351; BS 198, 199; IARM 62E; NCS NS11028, NS20035B; SRM 865, 866, 1243.

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 199B 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 Carpenter Technology Corporation; Reading, Pa.

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 199B-070815. 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
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:

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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, 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 08, 2015.

Beau R. Brammer