Brammer Standard Company, Inc.

Certificate of Analysis

BS 316E

Certified Reference Material for Stainless Steel Grade 316 - UNS Number S31600

Certified Values[3]

	Certified Value[1]	Estimate of Uncertainty[2]		Certified Value[1]	Estimate of Uncertainty[2]
Al	**0.0027**	0.0004	**S**	**0.0214**	0.0007
As	**0.0045**	0.0004	**Si**	**0.268**	0.004
B	**0.0036**	0.0003	**Sn**	**0.0082**	0.0005
C	**0.0183**	0.0007	**V**	**0.074**	0.001
Co	**0.287**	0.003	**W**	**0.067**	0.003
Cr	**16.70**	0.06			
Cu	**0.408**	0.004			
Fe	**68.1**	0.3			
Mn	**1.413**	0.008			
Mo	**2.06**	0.01			
N	**0.042**	0.001			
Nb	**0.0282**	0.0009			
Ni	**10.43**	0.05			
O	**0.0039**	0.0004			
P	**0.0295**	0.0008			

Informational Values[3,4]

Ca (0.0006) Mg (0.0004) Pb (0.0002) Sb (0.002) Ti (0.002)
Zr (0.002)

[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, Cl, Ga, Ge, K, Na, Pt, Re, Ta, 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.

Brammer Standard Company, Inc., 14603 Benfer Road, Houston, TX 77069-2895
Telephone: (281) 440-9396 Fax: (281) 440-4432 Website: www.brammerstandard.com

BS 316E * Code for method Certified values listed as weight percent

Analysis	*	Al	*	As	*	B	*	C	*	Co	*	Cr	*	Cu	*	Fe
1	12	0.00090	4	0.0011	12	0.0022	1	0.01706	5	0.275433	13	16.48333	12	0.3700	10	67.72667
2	4	0.0024	9	0.003833	3	0.003	1	0.017475	4	0.278333	4	16.5	3	0.386333	13	67.76875
3	14	0.002667	12	0.0040	5	0.0032	1	0.017677	10	0.28	10	16.64	10	0.386333	4	67.775
4	3	0.0027	3	0.0041	5	0.003233	3	0.0179	14	0.280667	4	16.6989	10	0.387633	16	[67.90]
5	4	0.002717	5	0.0042	4	0.0033	1	0.018367	3	0.281667	14	16.70333	8	0.394667	10	67.90667
6	4	0.002933	4	0.004533	4	0.003467	1	0.018567	3	0.283	4	16.72333	3	0.401	16	[68.0509]
7	4	0.003533	15	0.004723	7	0.00352	1	0.0190	4	0.283667	4	16.7256	14	0.404	14	68.08667
8			5	0.005033	5	0.003663	1	0.019133	4	0.2842	10	16.7338	5	0.404067	16	[68.10667]
9			5	0.005233	3	0.00373	1	0.019667	4	0.2848	3	16.76	4	0.408667	4	68.13
10			5	0.007167	7	0.00376	1	0.019733	4	0.285333	4	16.77	4	0.409667	16	[68.19]
11					14	0.0039	3	0.020	10	0.288	4	16.77633	3	0.41	3	68.21667
12					3	0.0039	1	0.020267	3	0.29	3	16.82	4	0.411667		
13					4	0.0040			10	0.296067	3	16.84667	10	0.412		
14									4	0.298	10	16.89667	4	0.412133		
15									8	0.302667	10	17.48	4	0.41475		
16													4	0.416533		
17													10	0.418		
18													5	0.439933		
Average		0.00272		0.00448		0.00356		0.01833		0.2875		16.7011		0.4083		68.058
Std dev		0.00013		0.00024		0.00010		0.00073		0.0044		0.0036		0.0047		0.059
H		0.00042		0.00050		0.00046		0.0009		0.0041		0.100		0.0052		0.39
U_1		0.00044		0.00056		0.00047		0.0012		0.0061		0.10		0.0070		0.39
t-statistic		2.45		2.26		2.18		2.20		2.14		2.14		2.11		2.23
U_2		0.0011		0.0013		0.0010		0.0025		0.013		0.21		0.015		0.87
U_3		0.00041		0.00040		0.00029		0.00074		0.0034		0.055		0.0035		0.26
Certified		**0.0027**		**0.0045**		**0.0036**		**0.0183**		**0.287**		**16.70**		**0.408**		**68.1**
Uncertainty		**0.0004**		**0.0004**		**0.0003**		**0.0007**		**0.003**		**0.06**		**0.004**		**0.3**
Tolerance		0.0011		0.0013		0.0010		0.0025		0.013		0.21		0.015		0.9

Analysis	*	Mn	*	Mo	*	N	*	Nb	*	Ni	*	O	*	P	*	S
1	10	1.356667	3	1.993333	2	0.036767	3	0.027	3	10.28333	2	0.003533	12	0.0240	12	0.0165
2	4	1.396667	4	2.023333	2	0.041333	5	0.027033	3	10.31	2	0.003533	4	0.026267	1	0.0197
3	4	1.404667	3	2.05	2	0.041533	4	0.027333	3	10.36	2	0.003533	4	0.027567	1	0.020233
4	10	1.408767	10	2.05	2	0.0423	3	0.0274	10	10.360	2	0.003643	5	0.0279	3	0.021
5	3	1.41	4	2.059	2	0.042533	5	0.027633	4	10.36333	2	0.003907	10	0.028333	1	0.021033
6	10	1.41	3	2.06	2	0.042575	14	0.027667	13	10.39033	2	0.003963	4	0.028833	3	0.0211
7	3	1.413333	10	2.066667	2	0.042633	4	0.0282	4	10.39333	2	0.004033	10	0.0289	10	0.0212
8	4	1.417667	7	2.068	2	0.04276	12	0.0286	4	10.40687	2	0.0041	10	0.028967	1	0.021297
9	4	1.4196	10	2.07	2	0.043033	4	0.028933	10	10.42333	2	0.004233	3	0.029	1	0.021967
10	4	1.419667	4	2.080333	2	0.0431	10	0.0293	10	10.42583	2	0.00552	4	0.029833	1	0.0220
11	4	1.42	4	2.082333			7	0.0294	14	10.43			4	0.030233	1	0.022167
12	14	1.42	10	2.0834			3	0.030	4	10.43483			7	0.0303	1	0.022667
13	10	1.427	14	2.09			4	0.0306	4	10.470			5	0.030333	1	0.022733
14	4	1.431667	4	2.110533			4	0.0317	4	10.475			3	0.0305	1	0.02324
15	3	1.44	4	2.118667					10	10.49667			3	0.030767		
16	8	1.443							4	10.547			14	0.031033		
Average		1.4131		2.0620		0.0422		0.0282		10.4333		0.00388		0.0295		0.02141
Std dev		0.0066		0.0067		0.0015		0.0011		0.0041		0.00015		0.0011		0.00077
H		0.013		0.017		0.0014		0.0011		0.065		0.00048		0.0011		0.0010
U_1		0.014		0.018		0.0020		0.0015		0.065		0.00050		0.0016		0.0012
t-statistic		2.13		2.14		2.26		2.16		2.13		2.26		2.13		2.16
U_2		0.030		0.039		0.0045		0.0033		0.14		0.0011		0.0034		0.0027
U_3		0.0076		0.010		0.0014		0.00088		0.035		0.00036		0.00084		0.00072
Certified		**1.413**		**2.06**		**0.042**		**0.0282**		**10.43**		**0.0039**		**0.0295**		**0.0214**
Uncertainty		**0.008**		**0.01**		**0.001**		**0.0009**		**0.05**		**0.0004**		**0.0008**		**0.0007**
Tolerance		0.030		0.04		0.005		0.0033		0.14		0.0011		0.0034		0.0027

BS 316E * Code for method Certified values listed as weight percent

Analysis	*	Si	*	Sn	*	V	*	W
1	10	0.253	3	0.007	10	0.069667	5	0.050167
2	6	0.261333	5	0.007433	5	0.0703	10	0.058033
3	4	0.262333	3	0.0076	12	0.0710	3	0.060167
4	4	0.262667	5	0.0078	10	0.071433	4	0.060233
5	10	0.264333	4	0.007867	3	0.0719	5	0.0641
6	4	0.264867	9	0.007867	14	0.0723	4	0.0648
7	5	0.265233	5	0.008077	4	0.072333	4	0.0651
8	3	0.266	5	0.0083	4	0.072533	10	0.068
9	10	0.266267	4	0.009067	10	0.0730	10	0.0697
10	14	0.269	12	0.0105	3	0.074	7	0.070467
11	4	0.270333	5	0.0114	10	0.074367	14	0.0718
12	3	0.272			3	0.0749	4	0.072
13	4	0.274333			4	0.075033	3	0.0723
14	5	0.2778			4	0.075567		
15	3	0.280			4	0.077133		
16					7	0.078467		
17					5	0.0906		
Average		0.2683		0.00819		0.0738		0.0667
Std dev		0.0050		0.00038		0.0021		0.0020
H		0.0040		0.00063		0.0018		0.0017
U_1		0.0063		0.00074		0.0028		0.0027
t-statistic		2.14		2.23		2.12		2.18
U_2		0.014		0.0017		0.0059		0.0058
U_3		0.0035		0.00050		0.0014		0.0016
Certified		**0.268**		**0.0082**		**0.074**		**0.067**
Uncertainty		**0.004**		**0.0005**		**0.001**		**0.003**
Tolerance		0.014		0.0017		0.006		0.006

BS 316E * Code for method Informational values listed as weight percent

Analysis	*	Ca	*	Mg	*	Pb	*	Sb	*	Ti	*	Zr	*	*
1	12	0.00056	5	0.00028	12	0.0000036	5	0.0014	5	0.000453	5	0.000061		
2	4	0.000563	12	0.00032	9	0.00034333	12	0.0015	5	0.000613	4	0.000767		
3	3	0.00067	3	0.00039			4	0.003467	12	0.00062	3	0.0029		
4	4	0.0007	4	0.000393					5	0.000687	14	0.0035		
5			4	0.0007					4	0.0008	3	0.005		
6									4	0.001667				
7									3	0.0027				
8									10	0.0030				
9									3	0.0030				
10									14	0.0030				
11									4	0.0030				
12									4	0.004367				
Average		0.0006		0.00042		0.00017		0.002		0.002		0.002		
Std dev		0.0015		0.00061		0.00014		0.016		0.015		0.016		
H		0.0003		0.00025		0.00022		0.000		0.00038		0.000		
U_1		0.0016		0.00066		0.00025		0.016		0.015		0.016		
t-statistic		3.18		2.78		12.71		4.30		2.20		2.78		
U_2		0.0050		0.0018		0.0032		0.070		0.032		0.044		
U_3		0.0025		0.00081		0.0023		0.041		0.0093		0.020		
(Informational)		**(0.0006)**		**(0.0004)**		**(0.0002)**		**(0.002)**		**(0.002)**		**(0.002)**		

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 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 316E * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis	*	Bi	*	Cl	*	Ga	*	Ge	*	K	*	Na	*	Pt	*	Re	*	Ta	*	Zn
1	12	0.010	12	0.10	12	27	5	23	12	0.18	12	0.14	12	0.11	12	15	5	1.0	12	0.21
2					5	32	5	23							5	22	5	1.4		
3					5	33	5	24							5	22	5	1.7		
4					5	33	12	24							5	23				

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
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 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; 501-320, 501-501, 501-502, 501-503, 501-504, 501-550, 501-644, 501-646, 501-675, 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, 646, 654, 657, 661, 869, 875, 878, 891, 961, 1651, 1652, 1653; BAS 206, 345, 431, 464/1, 466/2, 474; BS CA316-2, SS3951, 84E, 84H, 316A, 316C, 9623P, 9631P; CKD 211; ECRM 085-1, 086-1, 087-1; IARM 2E, 5E, 5F, 62A; IMZ 171, 504; IPT 208Fe; SRM 55D, 101A, 101C, 101D, 101E, 123A, 160B, 179, 341, 361, 362, 363, 365, 1243, 1246, 1249, 1263A, 1264A, 1413, 1763A, 3128, 3131A, 3162A.

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, 502-257, 502-416; BAS 466/2; BS CA316-2, HON-T, 84E, 84H, 316C, 9631P, 9632P; ECRM 284-2; IARM 1D, 5E; IMZ 171; SRM 101G.

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 316E 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 North American Stainless; Houston, Texas.

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 316E-071515. 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:

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 15, 2015.

Beau R. Brammer