

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 316D

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

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values³	Certified Value ¹	Estimate of Uncertainty ²
As	0.0048	0.0004		Si	0.004
B	0.0038	0.0003		Sn	0.0005
C	0.0185	0.0008		V	0.002
Co	0.294	0.005		W	0.002
Cr	16.76	0.06			
Cu	0.409	0.004			
Fe	68.1	0.3			
Mn	1.400	0.008			
Mo	2.05	0.01			
N	0.042	0.001			
Nb	0.0277	0.0009			
Ni	10.38	0.03			
O	0.0039	0.0004			
P	0.0294	0.0008			
S	0.0189	0.0007			

Informational Values^{3,4}

Al (0.002)	Ca (0.0008)	Mg (0.0004)	Pb (0.0003)	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.

BS 316D

* Code for method Certified values listed as weight percent

Analysis	*	As	*	B	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mn
1	3	0.00385	12	0.0020	1	0.01696	4	0.284333	4	16.45	10	0.387667	13	67.807	10	1.356667
2	9	0.003867	3	0.003	1	0.017627	4	0.287033	10	16.66	3	0.388	4	67.85	4	1.37
3	4	0.0044	4	0.003533	1	0.01796	14	0.287333	4	16.74333	8	0.392	10	67.94	3	1.385
4	5	0.0044	4	0.003567	1	0.018067	4	0.288333	3	16.75	10	0.398533	16	[67.95]	10	1.388867
5	15	0.004897	14	0.003633	1	0.0185	3	0.289	4	16.76333	10	0.402	10	67.95667	4	1.398333
6	12	0.0049	7	0.003697	3	0.0186	4	0.290233	10	16.77487	3	0.4035	14	68.02667	10	1.40
7	5	0.004967	5	0.0037	1	0.0187	10	0.294	4	16.7798	4	0.40975	16	[68.06643]	3	1.403333
8	5	0.005533	5	0.003733	1	0.0187	10	0.296	4	16.78087	3	0.41	4	68.19333	4	1.405667
9	5	0.006467	5	0.00387	1	0.018967	3	0.29625	4	16.781	4	0.410333	16	[68.2175]	4	1.406667
10			3	0.004025	1	0.019833	4	0.297333	3	16.785	4	0.410633	16	[68.24867]	4	1.4073
11			4	0.004033	1	0.019967	5	0.298833	14	16.79333	4	0.411	3	68.26667	4	1.4133333
12			3	0.0042	3	0.020	4	0.29975	3	16.82667	4	0.411			10	1.423
13							3	0.30	4	16.83	5	0.4123			4	1.4233333
14							8	0.302667	10	16.89	14	0.413333			3	1.430
15							10	0.304467			4	0.416733			14	1.43
16							5	0.339933			10	0.417			8	1.439667
17											12	0.4200				
Average		0.00480		0.00376		0.01854		0.2943		16.7618		0.4086		68.122		1.4001
Std dev		0.00028		0.00011		0.00077		0.0044		0.0026		0.0047		0.059		0.0077
H		0.00052		0.00047		0.0009		0.0042		0.100		0.0052		0.39		0.013
U ₁		0.00058		0.00049		0.0012		0.0061		0.10		0.0070		0.39		0.015
t-statistic		2.31		2.20		2.20		2.13		2.16		2.12		2.23		2.13
U ₂		0.0013		0.0011		0.0026		0.013		0.22		0.015		0.87		0.031
U ₃		0.00045		0.00031		0.00076		0.0032		0.058		0.0036		0.26		0.0078
Certified		0.0048		0.0038		0.0185		0.294		16.76		0.409		68.1		1.400
Uncertainty		0.0004		0.0003		0.0008		0.005		0.06		0.004		0.3		0.008
Tolerance		0.0013		0.0011		0.0026		0.013		0.22		0.015		0.9		0.031

Analysis	*	Mo	*	N	*	Nb	*	Ni	*	O	*	P	*	S	*	Si
1	3	2.006667	2	0.040437	3	0.025	3	10.22333	2	0.002667	12	0.0260	12	0.0135	12	0.2600
2	10	2.01	2	0.041267	5	0.0258	3	10.3025	2	0.003633	4	0.026267	1	0.017233	10	0.267
3	4	2.013333	2	0.0417	14	0.026333	10	10.33	2	0.003667	4	0.027467	3	0.017775	6	0.268333
4	10	2.036667	2	0.0421	4	0.026667	4	10.34667	2	0.00368	3	0.02865	3	0.018	14	0.271333
5	4	2.042667	2	0.0421	7	0.027	14	10.37333	2	0.00381	4	0.028833	1	0.018267	4	0.272667
6	3	2.05	2	0.04234	10	0.0271	4	10.37667	2	0.003963	4	0.0289	4	0.018533	4	0.273
7	4	2.050667	2	0.042633	4	0.0276	3	10.38	2	0.003967	5	0.028967	10	0.0186	4	0.274
8	3	2.0525	2	0.042633	4	0.027833	4	10.38133	2	0.00409	10	0.0291	1	0.018933	10	0.2753333
9	10	2.06	2	0.0427	3	0.0283	10	10.39	2	0.004433	14	0.029367	1	0.019137	4	0.276
10	4	2.063033	2	0.0427	4	0.029267	4	10.39343			10	0.029467	1	0.0195	4	0.2773
11	4	2.066			4	0.0296	13	10.39767			3	0.030	1	0.019667	10	0.277667
12	7	2.075			3	0.030	4	10.425			5	0.030433	1	0.020167	3	0.282
13	10	2.083467			5	0.030567	10	10.4284			10	0.030533	1	0.0205	5	0.2891
14	14	2.093333			12	0.0373	4	10.43767			4	0.030733	1	0.0209	3	0.290
15	4	2.112667					10	10.45333			3	0.030833			3	0.291
16							4	10.470			7	0.0310				
Average		2.0504		0.0422		0.0277		10.3812		0.00388		0.0294		0.01892		0.2779
Std dev		0.0067		0.0015		0.0011		0.0042		0.00015		0.0011		0.00070		0.0050
H		0.017		0.0014		0.0011		0.065		0.00048		0.0011		0.0009		0.0041
U ₁		0.018		0.0020		0.0015		0.065		0.00050		0.0016		0.0012		0.0064
t-statistic		2.14		2.26		2.16		2.13		2.31		2.13		2.16		2.14
U ₂		0.039		0.0045		0.0033		0.14		0.0012		0.0034		0.0025		0.014
U ₃		0.010		0.0014		0.00088		0.035		0.00038		0.00084		0.00067		0.0036
Certified		2.05		0.042		0.0277		10.38		0.0039		0.0294		0.0189		0.278
Uncertainty		0.01		0.001		0.0009		0.03		0.0004		0.0008		0.0007		0.004
Tolerance		0.04		0.005		0.0033		0.14		0.0012		0.0034		0.0025		0.014

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

Analysis	*	Sn	*	V	*	W
1	3	0.007	4	0.071767	12	0.0600
2	5	0.007167	14	0.071933	10	0.060867
3	5	0.007367	10	0.072167	3	0.0625
4	4	0.007733	4	0.072367	4	0.063267
5	9	0.007733	3	0.07245	4	0.067567
6	3	0.008125	12	0.0735	4	0.06767
7	5	0.008227	5	0.074067	10	0.068
8	5	0.008267	10	0.074867	5	0.069367
9	4	0.009067	3	0.075	10	0.070
10	12	0.0105	4	0.075333	10	0.0726
11	5	0.011467	3	0.0754	7	0.073033
12			10	0.076	3	0.0739
13			4	0.0764	4	0.074167
14			7	0.0767	14	0.0748
15			4	0.077533		
Average		0.00800		0.0738		0.0717
Std dev		0.00035		0.0022		0.0022
H		0.00063		0.0018		0.0018
U ₁		0.00072		0.0029		0.0029
t-statistic		2.23		2.14		2.16
U ₂		0.0016		0.0061		0.0062
U ₃		0.00048		0.0016		0.0017
Certified		0.0080		0.074		0.072
Uncertainty		0.0005		0.002		0.002
Tolerance		0.0016		0.006		0.006

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

Analysis	*	Al	*	Ca	*	Mg	*	Pb	*	Sb	*	Ti	*	Zr
1	5	0.000303	4	0.000647	3	0.000228	12	0.000062	5	0.0013	5	0.000517	5	0.000056
2	5	0.000737	3	0.000745	5	0.00037	9	0.0002133	12	0.0017	5	0.000687	4	0.000767
3	12	0.00082	4	0.0009	12	0.00038	3	0.000775	4	0.0034	5	0.0008	3	0.002875
4	4	0.001607	12	0.0010	4	0.000433					12	0.00085	14	0.0033
5	3	0.001625			4	0.0008					5	0.000883	3	0.005
6	14	0.002067									4	0.0017		
7	4	0.0021									3	0.002475		
8	4	0.002633									3	0.0028		
9	4	0.002833									4	0.0030		
10	3	0.004									14	0.00323		
11											10	0.0033		
12											4	0.003567		
Average		0.0019		0.0008		0.00044		0.00033		0.002		0.002		0.002
Std dev		0.0073		0.0026		0.00069		0.00048		0.016		0.015		0.015
H		0.0004		0.0003		0.00026		0.00024		0.000		0.00038		0.000
U ₁		0.0073		0.0027		0.00073		0.00054		0.016		0.015		0.015
t-statistic		2.26		3.18		2.78		4.30		4.30		2.20		2.78
U ₂		0.016		0.0085		0.0020		0.0023		0.071		0.032		0.043
U ₃		0.0052		0.0042		0.00091		0.0013		0.041		0.0093		0.019
(Informational)		(0.002)		(0.0008)		(0.0004)		(0.0003)		(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 its 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:

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

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.

Analysis *	Bi	* Cl	* Ga	* Ge	* K	* Na	* Pt	* Re	* Ta	* Zn
1	12 0.011	12 0.40	12 26	12 29	12 0.35	12 0.18	12 0.16	12 18	5 1.7	12 0.29
2			5 37	5 32				5 20	5 2.4	
3			5 37	5 33				5 20	5 2.6	
4			5 38	5 34				5 20		

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	ACCLASS	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	ACCLASS	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
ACCLASS = 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 316D 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 316D-071515. 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, 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