

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 316C

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	0.0054	0.0004		Ni	0.09
C	0.0415	0.0009		O	0.0004
Co	0.172	0.002		P	0.001
Cr	16.42	0.05		S	0.0005
Cu	0.076	0.001		Sb	0.0003
Fe	[68.4]	0.2		Si	0.01
Mn	1.75	0.01		Sn	0.0003
Mo	2.26	0.01		V	0.001
N	0.062	0.002		W	0.0003

	Reference Value ¹	Estimate of Uncertainty ²	Reference Values^{3,4}
B	0.0003	0.0002	

Informational Values^{3,5}

Al (0.004)	Ca (0.0003)	Nb (0.005)	Pb (0.001)	Ta (0.01)
Ti (0.001)	Zr (0.004)			

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 5 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 5 for more information on its calculation.

³ Values are given in weight percent.

⁴ Reference values are not certified and are provided for information only.

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

Trace element information values for Bi, Cl, Ga, Ge, K, Mg, Na, Re, Se, 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.

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* Code for method

Certified values listed as weight percent

Analysis	* As	* C	* Co	* Cr	* Cu	* Fe	* Mn	* Mo
1	3 0.004	1 0.0376	4 0.155	4 16.14	3 0.069533	14 68.06667	10 1.70	3 2.15
2	4 0.004333	1 0.038667	12 0.1575	4 16.21733	5 0.0700	16 68.22667	4 1.707	7 2.201333
3	9 0.0045	3 0.0394	10 0.159	13 16.24933	3 0.072	16 68.2564	3 1.71	10 2.215
4	3 0.00475	1 0.0402	5 0.163	10 16.27333	4 0.073	16 68.2675	10 1.71	4 2.216667
5	12 0.0052	3 0.0404	14 0.166	3 16.31667	3 0.073	4 68.27667	4 1.712	3 2.23
6	5 0.005733	1 0.041133	4 0.166167	4 16.33	5 0.073367	16 68.3	3 1.713333	10 2.24
7	4 0.005733	1 0.041567	3 0.16725	4 16.37333	10 0.074	10 68.33	4 1.716667	3 2.25
8	5 0.006067	1 0.0418	8 0.167667	4 16.37667	4 0.074333	16 68.3375	10 1.72	10 2.25
9	5 0.0061	1 0.041833	3 0.168	3 16.4067	10 0.074333	16 68.48667	7 1.738667	4 2.255
10	15 0.00629	1 0.04195	3 0.1691	10 16.41	14 0.074833	10 68.54	4 1.74	14 2.256667
11	4 0.006667	1 0.0424	4 0.169333	3 16.4125	4 0.074967	3 68.61	3 1.7423	3 2.2575
12		1 0.042833	3 0.17	4 16.41603	10 0.075	16 68.64667	4 1.742333	4 2.258
13		1 0.042867	4 0.171	10 16.425	4 0.075667	10 68.65667	4 1.743333	4 2.259333
14		3 0.044	3 0.172	4 16.44233	4 0.076433		10 1.745	3 2.26
15		3 0.044	10 0.172	3 16.45	3 0.07645		14 1.746667	4 2.261
16		3 0.04425	4 0.172667	3 16.4625	4 0.077667		3 1.7475	4 2.262333
17		1 0.045667	4 0.172933	4 16.46667	10 0.079167		4 1.754067	4 2.27
18		3 0.0477	5 0.181033	4 16.50333	4 0.0794		4 1.757333	3 2.2772
19			4 0.1815	3 16.59097	8 0.079433		4 1.765	3 2.277667
20			4 0.1842	4 16.625	4 0.0796		3 1.767167	4 2.2805
21				14 16.64333	12 0.0825		4 1.781	4 2.2936
22					3 0.0825		3 1.79	4 2.306667
23					3 0.0833		3 1.79325	
24					3 0.087133			
Average	0.00536	0.0415	0.1718	16.420	0.0764	68.371	1.7471	2.262
Std dev	0.00029	0.0013	0.0034	0.032	0.0019	0.045	0.0058	0.014
H	0.000523	0.001313	0.002934	0.096345	0.001824	0.382137	0.014563	0.0178
U ₁	0.00060	0.0018	0.0045	0.10	0.0027	0.38	0.016	0.023
t-statistic	2.23	2.11	2.09	2.09	2.07	2.18	2.07	2.08
U ₂	0.0013	0.0039	0.0094	0.21	0.0055	0.84	0.033	0.047
U ₃	0.00040	0.00091	0.0021	0.046	0.0011	0.23	0.0068	0.010
Certified	0.0054	0.0415	0.172	16.42	0.076	[68.4]	1.75	2.26
Uncertainty	0.0004	0.0009	0.002	0.05	0.001	0.2	0.01	0.01
Tolerance	0.0013	0.0039	0.009	0.21	0.006	0.8	0.03	0.05

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* Code for method

Certified values listed as weight percent

Analysis	*	N	*	Ni	*	O	*	P	*	S	*	Sb	*	Si	*	Sn
1	2	0.059833	4	10.22333	2	0.0046	4	0.0321	12	0.0129	5	0.000987	4	0.391	3	0.00125
2	2	0.059833	4	10.27233	2	0.004733	5	0.0327	3	0.0139	5	0.001197	4	0.400	5	0.004467
3	2	0.0600	4	10.27333	2	0.004867	3	0.0328	1	0.013967	5	0.001367	6	0.400667	5	0.0047
4	2	0.0602	13	10.27833	2	0.0049	10	0.033	1	0.014	5	0.0014	4	0.406667	4	0.004933
5	2	0.0603	10	10.31	2	0.005233	10	0.034	3	0.01425	5	0.001433	12	0.4100	5	0.004933
6	2	0.060667	3	10.32	2	0.005255	3	0.034525	1	0.014267	12	0.0017	4	0.4110	3	0.005
7	2	0.060967	10	10.346	2	0.0053	4	0.0349	1	0.014333	3	0.002	3	0.414	5	0.005037
8	2	0.062833	3	10.35	2	0.005435	3	0.035	1	0.014333	3	0.002	4	0.416667	3	0.00515
9	2	0.063267	3	10.36	2	0.0056	14	0.035167	4	0.014433			10	0.418	12	0.0052
10	2	0.06374	4	10.38333	2	0.00569	3	0.035375	1	0.014467			10	0.418	3	0.005275
11	2	0.06436	14	10.39667	2	0.0061	5	0.0357	1	0.0149			4	0.419333	3	0.006333
12	2	0.064967	4	10.39707	2	0.006133	4	0.0358	3	0.015			3	0.421	5	0.006967
13			3	10.40	2	0.006317	12	0.0360	3	0.015			3	0.42125	9	0.007333
14			4	10.40333			3	0.036	10	0.015			4	0.422333		
15			10	10.42667			4	0.036633	1	0.015133			5	0.422833		
16			4	10.42867			7	0.036767	1	0.015367			3	0.4267		
17			4	10.45333			4	0.0368	1	0.01615			4	0.427467		
18			3	10.50			4	0.038	1	0.0162			3	0.428733		
19			4	10.52			3	0.038533	3	0.0167			14	0.429		
20							3	0.04085					4	0.4308		
21							10	0.042733					3	0.434		
22													10	0.435		
23													4	0.438333		
24													3	0.44		
Average		0.0622		10.296		0.00554		0.0356		0.01463		0.00143		0.4176		0.00517
Std dev		0.0019		0.018		0.00028		0.0013		0.00052		0.00014		0.0046		0.00023
H		0.001629		0.063221		0.00053		0.001214		0.000793		0.000335		0.005193		0.000516
U ₁		0.0025		0.066		0.00060		0.0018		0.00095		0.00036		0.0069		0.00056
t-statistic		2.20		2.10		2.18		2.09		2.10		2.36		2.07		2.18
U ₂		0.0055		0.14		0.0013		0.0037		0.0020		0.00085		0.014		0.0012
U ₃		0.0016		0.032		0.00036		0.00080		0.00046		0.00030		0.0029		0.00034
Certified		0.062		10.31		0.0055		0.035		0.0146		0.0014		0.42		0.0052
Uncertainty		0.002		0.09		0.0004		0.001		0.0005		0.0003		0.01		0.0003
Tolerance		0.006		0.14		0.0013		0.004		0.0020		0.0009		0.01		0.0012

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

Analysis	*	V	*	W
1	7	0.0263	5	0.0023
2	4	0.028	4	0.002367
3	5	0.028467	5	0.002533
4	4	0.029233	5	0.002567
5	12	0.0295	12	0.0028
6	4	0.029667	3	0.00325
7	4	0.030667	4	0.00342
8	3	0.031175	5	0.003467
9	3	0.031275	14	0.0037
10	10	0.031333	3	0.004
11	3	0.0317	10	0.0049
12	4	0.0321	4	0.0051
13	4	0.032233		
14	14	0.032367		
15	4	0.032867		
16	10	0.033		
17	3	0.033		
18	3	0.034		
19	4	0.0341		
20	3	0.0343		
21	5	0.0345		
Average		0.0313		0.00316
Std dev		0.0011		0.00021
H		0.001138		0.000432
U ₁		0.0016		0.00048
t-statistic		2.09		2.20
U ₂		0.0033		0.0011
U ₃		0.00072		0.00030
Certified		0.031		0.0032
Uncertainty		0.001		0.0003
Tolerance		0.003		0.0011

BS 316C * Code for method Reference values listed as weight percent

Analysis	*	B
1	5	0.000037
2	12	0.000090
3	4	0.0001
4	5	0.0002
5	5	0.0002
6	7	0.000233
7	3	0.000263
8	3	0.00042
9	3	0.000445
10	3	0.000533
11	3	0.0006
Average		0.00028
Std dev		0.00018
H		0.000227
U ₁		0.00029
t-statistic		2.23
U ₂		0.00065
U ₃		0.00020
Reference		0.0003
Uncertainty		0.0002
Tolerance		0.0003

BS 316C

* Code for method Informational values listed as weight percent

Analysis	* Al	* Ca	* Nb	* Pb	* Ta	* Ti	* Zr
1	5 0.000367	3 0.000133	5 0.0004	5 0.00025	12 0.000023	4 0.000325	5 0.0003
2	5 0.000467	3 0.00017	5 0.000417	5 0.00029	5 0.00009	5 0.000337	4 0.0025
3	3 0.0007	3 0.00025	5 0.000633	5 0.0003	4 0.00026	4 0.0004	14 0.002767
4	5 0.000887	4 0.000347	4 0.000933	5 0.000333	4 0.003	5 0.000483	3 0.0037
5	12 0.0012	4 0.000533	4 0.001733	12 0.00036	3 0.00975	5 0.0005	3 0.004
6	5 0.001267		5 0.002233	9 0.00044	3 0.01	12 0.00053	3 0.004
7	4 0.0027		12 0.0027	3 0.0005	3 0.04188	5 0.000533	3 0.006767
8	3 0.0036		4 0.003633	3 0.0012		14 0.001733	3 0.01015
9	14 0.0039		3 0.005	3 0.0012		10 0.0018	
10	3 0.004		3 0.005	3 0.0032		3 0.001975	
11	4 0.004		3 0.0106	3 0.0033		4 0.002	
12	3 0.0046		3 0.013733			4 0.002633	
13	4 0.0053		3 0.017			3 0.0029	
14	4 0.005467					3 0.003	
15	3 0.008467						
16	3 0.00855						
17	4 0.010667						
Average	0.004	0.00029	0.005	0.0010	0.010	0.0014	0.004
Std dev	0.019	0.00027	0.030	0.0025	0.098	0.0075	0.031
H	0.000469	0.000229	0.000509	0.000303	0.000672	0.000333	0.000469
U ₁	0.019	0.00036	0.030	0.0026	0.098	0.0075	0.031
t-statistic	2.12	2.78	2.18	2.23	2.45	2.16	2.36
U ₂	0.040	0.00099	0.065	0.0057	0.24	0.016	0.074
U ₃	0.0096	0.00044	0.018	0.0017	0.091	0.0043	0.026
(Informational)	(0.004)	(0.0003)	(0.005)	(0.001)	(0.01)	(0.001)	(0.004)

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 times 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 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 316C

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

Analysis	* Bi	* Cl	* Ga	* Ge	* K	* Mg	* Na	* Re	* Se	* Zn
1	12 0.054	12 0.013	12 20	12 35	12 0.16	12 0.46	12 0.15	5 0.64	3 30	12 5.5
2			5 29	5 40		5 0.52		12 0.64		
3			5 29	5 40		5 0.60		5 0.65		
4			5 29	5 40		5 0.64		5 0.66		

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

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 E 1806. 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: 501-320, 501-501, 501-502, 501-503, 501-504, 501-644, 501-646, 501-676, 501-991, 501-993, 502-257, 502-328, 502-348, 502-402, 502-416; AR 644, 646, 654, 660, 869, 875; BAS 345, 464/1, 466/2; BS CSN 2-1, HON-T, 84D, 84E, 316B; ECRM 284-2D; IARM 1D, 5E, 6G; IMZ 1.27/3; JK 8F; JSS 652-8; SRM C1151A, C1152A, 36, 55D, 101C, 101D, 101E, 123A, 123C, 125A, 160B, 361, 362, 363, 365, 1155, 1246, 1249, 1263A, 1763, 1763A, 3109A, 3155.

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 — 501-676, 502-257, 502-416; BAS 466/2, 467/1; BS CA316-1, CA316-3, CSN 2-1, HON-T, 84D, 84E, 84J, 316B; ECRM 284-1, 284-2D, 286-1; IARM 1D; IMZ 1.27/3; JK 8F; JSS 652-8; SRM C1151, C1152, C1153, C1154, 73C, 121D, 123C, 160B, 344, 345, 364A, 1155.

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 316C 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 Ferro Alloys Corporation LTD.; Nagpur, India.

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 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 316C-101714. 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. **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

- 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 17, 2014.

Beau R. Brammer