Brammer Standard Company, Inc.

Certificate of Analysis
BS 321D

Certified Reference Material for Stainless Steel Grade 321 - UNS Number S32100

Certified Values[3]

	Certified Value[1]	Estimate of Uncertainty[2]		Certified Value[1]	Estimate of Uncertainty[2]
Al	0.103	0.004	Mo	0.274	0.005
As	0.0040	0.0006	N	0.0083	0.0006
B	0.0012	0.0002	Ni	9.09	0.09
C	0.060	0.001	O	0.0009	0.0003
Co	0.096	0.004	P	0.024	0.002
Cr	17.42	0.04	S	0.022	0.002
Cu	0.358	0.007	Si	0.27	0.01
Fe	69.8	0.1	Sn	0.0091	0.0009
Mg	0.0007	0.0003	Ti	0.55	0.02
Mn	1.76	0.02	V	0.054	0.002

Informational Values[3,4]

Ca (0.0003)	Nb (0.009)	Pb (0.0003)	Sb (0.001)	W (0.03)
Zr (0.001)				

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[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 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 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 Au, Bi, Ga, Ge, Ir, Os, Pd, Pt, Re, Rh, Ru, Se, Sr, Ta, and Zn are shown on page 4.

The requirements of ISO Guides 30, 31, and 35 were followed for the preparation of this Certified Reference Material and certificate of analysis.

BS 321D   * Code for method   Certified values listed as weight percent

Analysis	*	Al	*	As	*	B	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mg	*	Mn
1	4	0.08866667	4	0.0034	4	0.0007	1	0.057	3	0.0844	10	17.34000	18	0.324	16	[69.5033]	5	0.00036	12	1.721
2	4	0.096	9	0.0034333	12	0.00076333	1	0.058	4	0.0902	4	17.36933	5	0.3313333	4	69.55	12	0.00046	4	1.723
3	4	0.0987	3	0.0035	11	0.0009	1	0.058333	5	0.0916333	10	17.37467	10	0.340	4	69.666667	3	0.00047	7	1.7426667
4	3	0.1	5	0.0039	5	0.00116667	1	0.0584	11	0.0923	4	17.38467	4	0.35	3	69.67	4	0.0006	10	1.75
5	4	0.1005	4	0.0042333	4	0.00116667	1	0.0585	10	0.0923	3	17.38800	10	0.3533333	4	69.733333	5	0.0007667	3	1.75
6	4	0.1021	5	0.0043433	5	0.00117	1	0.058933	4	0.0924667	13	17.39000	4	0.354	13	69.735333	8	0.0008	4	1.7533
7	4	0.10230667	5	0.0043533	14	0.00123333	1	0.0592	10	0.0925	10	17.39200	4	0.355	16	[69.8]	12	0.00084	4	1.754
8	4	0.10276667	12	0.0045033	3	0.00131	1	0.059233	4	0.0927	3	17.40000	3	0.3593	11	69.8	4	0.0008433	3	1.7543
9	5	0.103	5	0.0047333	4	0.00136667	1	0.0597	4	0.0939333	4	17.40800	10	0.3596	16	[69.9]	4	0.0009	4	1.755
10	3	0.104			7	0.00143333	1	0.06	3	0.094	4	17.41000	4	0.3596667	16	[69.9]			4	1.758
11	3	0.104			3	0.00143333	3	0.060	4	0.0943333	11	17.42000	4	0.3601	10	69.933			3	1.76
12	4	0.104			4	0.00153333	1	0.060033	4	0.0944333	10	17.43000	10	0.361	14	69.933333			4	1.76
13	10	0.105			4	0.00158667	11	0.0602	4	0.0947	14	17.43333	3	0.363	16	[69.99]			4	1.7631667
14	10	0.10526667			3	0.00183	1	0.060867	4	0.0947333	4	17.43333	11	0.363	10	70.076667			10	1.768
15	12	0.10533333					1	0.061333	3	0.0953	3	17.44000	14	0.363	18	71.285333			10	1.768
16	18	0.10533333					1	0.0615	14	0.0955333	17	17.44457	10	0.3636667					10	1.7708333
17	11	0.106					3	0.0618	10	0.0979333	4	17.45000	4	0.3645333					10	1.7762
18	4	0.107					1	0.062	3	0.10	10	17.46067	3	0.365					3	1.78
19	4	0.10733333					3	0.0641	8	0.1004667	3	17.47000	4	0.3654333					11	1.78
20	14	0.111							10	0.1009667	13	17.47933	4	0.3696667					4	1.7966667
21	10	0.1132							4	0.103333	4	17.49667	4	0.372					4	1.78
22	3	0.114							12	0.1200	4	17.50700	4	0.373333					4	1.785367
23	10	0.117											8	0.376					4	1.789333
24																			4	1.796667
Average		0.1030		0.00409		0.001228		0.0601		0.095826		17.423708		0.3584		69.844		0.000711		1.763146
Std Dev		0.0019		0.00016		0.000025		0.0015		0.000067		0.000067		0.0031		0.047		0.000045		0.000065
H		0.00293		0.000667		0.000423		0.002229		0.002823		0.0667537		0.00574		0.183072		0.000349		0.0147056
U₁		0.0035		0.00069		0.00042		0.0027		0.0028		0.067		0.0065		0.19		0.00035		0.015
t-statistic		2.07		2.31		2.16		2.10		2.08		2.08		2.07		2.14		2.31		2.07
U₂		0.0073		0.0016		0.00091		0.0056		0.0059		0.14		0.013		0.41		0.00081		0.030
U₃		0.0015		0.00053		0.00024		0.0013		0.0013		0.030		0.0028		0.10		0.00027		0.0062
Certified		0.103		0.0040		0.0012		0.060		0.096		17.42		0.358		69.8		0.0007		1.76
Uncertainty		0.004		0.0006		0.0002		0.001		0.004		0.04		0.007		0.1		0.0003		0.02
Tolerance		0.012		0.0018		0.0009		0.006		0.012		0.14		0.021		0.4		0.0007		0.06

Analysis	*	Mo	*	N	*	Ni	*	O	*	P	*	S	*	Si	*	Sn	*	Ti	*	V
1	4	0.26	2	0.00718	3	8.94	2	0.0006	12	0.0210	3	0.018	4	0.2426667	4	0.0069333	18	0.5053333	4	0.0492667
2	3	0.2614	2	0.0078533	14	8.97	2	0.00064	5	0.0218	12	0.0186667	14	0.2513333	4	0.007	4	0.5316667	10	0.0497
3	4	0.2663	2	0.0078667	10	8.976	2	0.00071	3	0.0222	1	0.0203	3	0.254	12	0.0077	3	0.54	10	0.0512
4	4	0.26666667	2	0.008	3	8.98	2	0.000773	10	0.0223	1	0.0208	10	0.261	9	0.0081667	14	0.5433333	10	0.0522667
5	11	0.268	2	0.0081	10	8.99666667	2	0.00083	14	0.0223333	1	0.0209	10	0.2623333	4	0.0082333	3	0.544	4	0.0524333
6	4	0.2694	2	0.0084333	4	9.02	2	0.000867	4	0.0224	11	0.021	10	0.2651	3	0.0085	4	0.5483333	11	0.0525
7	3	0.270	2	0.0085667	4	9.03333333	2	0.000867	10	0.0228	1	0.0212	3	0.27	10	0.0085333	11	0.549	4	0.0525333
8	10	0.27	2	0.0086	4	9.06033333	2	0.000893	4	0.0229333	3	0.0214	5	0.27	3	0.0086	3	0.5492	4	0.0526333
9	10	0.27196667	2	0.0086433	4	9.06533333	2	0.000925	3	0.023	1	0.0219333	4	0.271	5	0.0087667	3	0.5526667	5	0.0528
10	10	0.272	2	0.0088	3	9.0758	2	0.001	4	0.0232	1	0.022	4	0.2733	5	0.0088133	10	0.554	14	0.0532333
11	10	0.2726	2	0.0091	10	9.08	2	0.0013	4	0.0235	3	0.022	10	0.2739667	5	0.0093	10	0.5553333	5	0.0532667
12	12	0.273	2	0.0091333	13	9.08366667	2	0.0016	4	0.0236333	1	0.0226667	4	0.2745	5	0.0097333	4	0.5554333	3	0.0533
13	4	0.27433333	2	0.0091667	4	9.09666667	2	0.001803	11	0.0239	1	0.0227333	4	0.2761	12	0.0099667	4	0.5581667	4	0.0534
14	4	0.27466667			4	9.10113333	2	0.001867	3	0.024	1	0.0228667	4	0.2763333	3	0.01	10	0.5615333	10	0.0537333
15	3	0.276			10	9.10466667			4	0.0245	10	0.023	6	0.277	4	0.0101667	4	0.5618667	4	0.0538
16	10	0.276			4	9.122			10	0.0249	4	0.023	10	0.2793	10	0.0102333	4	0.5633333	4	0.0539333
17	4	0.27643333			10	9.13366667			4	0.0254667	1	0.0233333	3	0.28	5	0.0104	4	0.566	12	0.0544
18	7	0.27766667			4	9.145			7	0.0257667	1	0.0235	4	0.286	4	0.0109333	4	0.566	3	0.055
19	18	0.278			3	9.14666667			10	0.0262667	1	0.0237667	11	0.286	4	0.011	4	0.567	4	0.0563
20	4	0.27833333			11	9.15			4	0.0272333	1	0.0243	3	0.2901			7	0.572	3	0.0572333
21	3	0.279			4	9.184133			3	0.027433	1	0.024467	17	0.294			4	0.5727	3	0.0607
22	5	0.279333			4	9.233333			4	0.028							10	0.5842	10	0.065
23	4	0.2796			16	9.3											4	0.594	12	0.0690
24	14	0.280333															10	0.6024		
25	4	0.308333																		
Average		0.2741		0.00833		9.086887		0.000949		0.024026		0.021992		0.2736		0.0089		0.5566		0.0537
Std Dev		0.0028		0.00029		0.000066		0.000092		0.000067		0.000069		0.0031		0.0029		0.0032		0.0013
H		0.004944		0.000895		0.042601		0.000386		0.0014343		0.0013768		0.004939		0.000921		0.007376		0.002108
U₁		0.0057		0.00094		0.043		0.00040		0.0014		0.0014		0.0058		0.00096		0.0080		0.0025
t-statistic		2.06		2.18		2.07		2.16		2.080		2.09		2.09		2.10		2.07		2.07
U₂		0.012		0.0021		0.088		0.00086		0.0030		0.0029		0.012		0.0020		0.017		0.0051
U₃		0.0023		0.00057		0.018		0.00023		0.00064		0.00063		0.0027		0.00046		0.0034		0.0011
Certified		0.274		0.0083		9.09		0.0009		0.024		0.022		0.27		0.0091		0.55		0.054
Uncertainty		0.005		0.0006		0.09		0.0003		0.002		0.002		0.01		0.0009		0.02		0.002
Tolerance		0.015		0.0021		0.27		0.0009		0.006		0.006		0.03		0.0027		0.06		0.005

Analysis	*	Ca	*	Nb	*	Pb	*	Sb	*	W	*	Zr
1	12	0.0000587	10	0.0036333	12	0.0000323	12	0.0011	4	0.0148667	12	0.00017
2	12	0.00015333	11	0.0048	5	0.0000437			11	0.0165	10	0.0002
3	4	0.00021	4	0.00525	12	0.0000487			10	0.0168	3	0.0008
4	4	0.00037333	5	0.0052667	5	0.0000533			10	0.0186667	4	0.0016
5	3	0.00049	5	0.0053667	5	0.000057			7	0.0192667	3	0.0016
6	11	0.0005	12	0.00548	5	0.0001			4	0.0200667	4	0.0017667
7	14	0.00053333	12	0.0057	4	0.00063333			5	0.0212667	4	0.0024
8			10	0.0081	9	0.0007			4	0.0215667		
9			10	0.0098	3	0.0008			5	0.0218667		
10			10	0.0103	3	0.000989			4	0.022		
11			4	0.0103667					3	0.0221		
12			4	0.0104					10	0.0229667		
13			4	0.0107					4	0.0234667		
14			3	0.011					12	0.0253667		
15			4	0.0111					4	0.0253667		
16			4	0.0112467					12	0.0266667		
17			3	0.0116					3	0.0278		
18			14	0.0117333					10	0.0309333		
19			3	0.0162					4	0.0325		
20									4	0.0327333		
21									4	0.0452333		
22									3	0.047		
23									3	0.0487		
24									14	0.0487		
Average		0.00033		0.009		0.00035		0.0011		0.03		0.0012
Std Dev		0.00032		0.045		0.00029		0.0087		0.13		0.0039
H		0.000273		0.000925		0.000278		0.000406		0.001592		0.000419
U₁		0.00042		0.045		0.00040		0.0087		0.13		0.0040
t-statistic		2.45		2.10		2.26		12.71		2.07		2.45
U₂		0.0010		0.094		0.00091		0.11		0.27		0.0097
U₃		0.00039		0.022		0.00029		0.11		0.055		0.0037
Informational		(0.0003)		(0.009)		(0.0003)		(0.001)		(0.03)		(0.001)

For each element, in accordance with the requirements of ISO 17034 and Guide 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 Uncertainty is a measure of the quality of the **Certified** value.*

The Tolerance is a measure of the expected performance of an analysis. This involves further expanding the sample uncertainty to include instrument and operator uncertainty, for those without access to such calculations.

For further information regarding the confidence interval for the certified value see ISO Guide 35:2006 section 6.

BS 321D   * Code for analytical method   Trace analysis listed as mg/kg   (ppm)

Analysis	*	Au	*	Bi	*	Ga	*	Ge	*	Ir	*	Os	*	Pd	*	Pt	*	Re	*	Rh
1	12	0.09	12	0.02	12	22	12	36	12	0.08	12	0.1	12	0.09	12	0.29	12	0.72	12	0.05
2	12	0.09	12	0.02	12	22	12	37	12	0.08	12	0.1	12	0.14	12	0.34	12	0.72	12	0.05
3	12	0.09	12	0.03	12	23	12	37	12	0.09	12	0.11	12	0.15	12	0.39	12	0.75	12	0.06

Analysis	*	Ru	*	Se	*	Sr	*	Ta	*	Zn
1	12	0.11	3	93	12	0.43	3	148	12	4.1
2	12	0.15			12	0.43			12	4.2
3	12	0.17			12	0.43			12	4.2

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	17	Wet
6	Gravimetric	12	GD Mass Spectrometry	18	PIXE

ICP = Inductively Coupled Plasma   GF = Graphite Furnace   GD = Glow Discharge
DCP = Direct Current Plasma   HG = Hydride Generation

Lab Name	Location	Registrar	Accreditation
Brammer Standard Company, Inc.	Houston, TX	A2LA	17025, 17034
LECO Corporation	St. Joseph, MI	A2LA	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI	17025
NSL Analytical	Cleveland, OH	ANAB	17025
Dirats Laboratories	Westfield,MA	ANAB	17025
Anderson Laboratories, Inc.	Greendale, WI	A2LA	17025
Evans Analytical Group	Liverpool, NY	A2LA	17025
TUV Rheinland Pvt Ltd	Bangalore, India	NABL	17025
Luvak Inc.	Boylston, MA	PRI	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Carpenter Technology Corporation	Reading, PA	A2LA	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	17025
Exova	Glendale Heights, IL	A2LA	17025
Exova	Santa Fe Spring, CA	A2LA	17025

A2LA = American Association for Laboratory Accreditation
ANAB = ANSI-ASQ National Accreditation Board
CNAS = China National Accreditation Service
NABL = National Accreditation Board for Testing and Calibration Laboratories
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: 11XC2, 12X353F, 12X356, 13X14211; AR 556, 612B, 614A, 644, 645, 654, 657, 872, 875, 882, 911A, 950, 1648, 1650, 1652, 1653, 1656; BAS 239/3, 331, 434, 435, 459, 459/1, 464/1, 464; BS D-6, HON U, SS3951, 68E, 80F, 85A, 85B, 85D, 0111P, 303, 304, 304A, 304B, 316D, 316E, 321A, 321C, 1018, 1144A, 4130, 4942A, 8620C; IARM 6A, 6D, 6E, 6H, 6I, 289A; IMZ 103A, 116; JK 37; JSS 502-5; LECO 501-320, 501-501, 501-502, 501-504, 501-644, 501-646, 501-674, 501-675, 501-676, 501-993, 502-195, 502-197, 502-702, 502-712, 502-869, 502-894, 502-903; MQ CA01A, CA013; SRM 15G, 19F, 73A, 101A, 101C, 121B, 121D, 132A, 160B, 293, 321D, 361, 362, 363, 364, 1154, 1171, 1413, 1762, 2159.

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 — BAS 465; BS HON U, 85B, 85D, 0111P, 316E; IARM 289A; JSS 502-5; LECO 501-676; MQ CA01a, CA013; SRM 293, 1171.

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 321D is valid indefinitely. The certification is nullified if this CRM is damaged, contaminated, or otherwise modified.

Storage: This CRM must be stored in a cool, dry, non-corrosive environment.

Source: The bar stock for this CRM was produced by Dunkirk Specialty Steel, LLC.; Dunkirk, NY.

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.

> Caution: CRM contains significant insoluble soft metal inclusions. Surface smearing may occur. Spark atomic emission spectrometers may require extended preburns to compensate.

Certificate Number: The unique identification number for this certificate of analysis is 321D-111518. 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) 440-9396Web: 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 Standard 17034 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 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 9001:2015   Quality Management Systems - Requirements

ISO Guide 30:2015   Terms and definitions used in connection with reference materials + 2008 amendment

ISO Guide 31:2015   Reference materials - Contents of certificates and labels

ISO Guide 33:2015   Uses of certified reference materials

ISO Standard 17034:2016 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, 100 Barr Harbor Dr., West Conshohocken, PA 19428.

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 November 15, 2018.

Beau R. Brammer

President