

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS H3C

Certified Reference Material for Hastelloy Type X - UNS Number N06002

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values³	Certified Value ¹	Estimate of Uncertainty ²
Al	0.149	0.003		Si	0.01
B	0.0020	0.0003		Sn	0.0004
C	0.087	0.002		V	0.001
Co	1.37	0.01		W	0.006
Cr	21.50	0.07			
Cu	0.106	0.002			
Fe	19.54	0.08			
Mg	0.0020	0.0003			
Mn	0.492	0.005			
Mo	8.82	0.04			
N	0.0266	0.0009			
Nb	0.095	0.002			
Ni	46.6	0.2			
O	0.0013	0.0003			
P	0.0150	0.0006			

Informational Values^{3,4}

As (0.003)	Ca (0.0003)	S (0.0003)	Sb (0.0003)	Ta (0.0001)
Ti (0.0064)	Zr (0.005)			

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.

⁴ Values in parentheses are not certified and are provided for information only.

Trace element information values for Ag, Bi, Cd, Ce, Cl, Ga, Ge, Hf, In, K, Na, Nd, Pb, Pt, Re, Ru, Sc, Se, Th, 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 H3C

* Code for method Certified values listed as weight percent

Analysis	*	Al	*	B	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mg
1	5	0.134368	5	0.0010	1	0.0845	4	1.34	4	21.39	5	0.0980	4	19.35	3	0.001478
2	4	0.138667	7	0.00172	1	0.0853	10	1.35	4	21.40	4	0.0987	4	19.36667	5	0.001767
3	10	0.14	3	0.0018	1	0.086667	4	1.353667	4	21.480	3	0.10	10	19.37667	12	0.0018
4	3	0.14	5	0.001833	1	0.086767	4	1.36	4	21.48333	10	0.10	4	19.4	5	0.0018
5	5	0.1400	4	0.001833	1	0.08706	4	1.361533	10	21.49	4	0.102	13	19.506	5	0.0019
6	4	0.14	12	0.0020	3	0.0872	4	1.363333	13	21.585	4	0.102014	10	19.53	5	0.0019
7	3	0.14725	5	0.0020	1	0.088	10	1.37	3	21.61	4	0.104333	4	19.55333	4	0.002
8	4	0.150333	4	0.002114	1	0.088525	4	1.379957	4	21.62867	5	0.104467	4	19.61	4	0.002113
9	4	0.153671	4	0.0023	1	0.089133	4	1.383333	13	21.63467	3	0.105333	3	19.64333	5	0.002633
10	4	0.1549	3	0.002718	1	0.090533	4	1.390333	3	21.67	4	0.106667	4	19.65857		
11	10	0.158			1	0.092367	4	1.408333	4	21.68333	8	0.107	4	19.8		
12	4	0.161333							4	21.72383	3	0.1085	4	19.80867		
13	3	0.165667							10	21.75	12	0.1100				
14									3	21.78333	5	0.1110				
15											4	0.1112				
16											10	0.11333				
Average		0.1488		0.00200		0.0869		1.368		21.501		0.1058		19.542		0.00204
Std dev		0.0038		0.00015		0.0023		0.016		0.061		0.0032		0.062		0.00022
H		0.0027		0.00036		0.0020		0.012		0.11		0.0022		0.10		0.00036
U ₁		0.0047		0.00039		0.0030		0.020		0.13		0.0039		0.12		0.00042
t-statistic		2.18		2.26		2.23		2.23		2.16		2.13		2.20		2.31
U ₂		0.010		0.00088		0.0068		0.044		0.28		0.0083		0.27		0.0010
U ₃		0.0028		0.00028		0.0020		0.013		0.075		0.0021		0.077		0.00032
Certified		0.149		0.0020		0.087		1.37		21.50		0.106		19.54		0.0020
Uncertainty		0.003		0.0003		0.002		0.01		0.07		0.002		0.08		0.0003
Tolerance		0.010		0.0009		0.007		0.04		0.28		0.008		0.27		0.0010

Analysis	*	Mn	*	Mo	*	N	*	Nb	*	Ni	*	O	*	P	*	Si
1	4	0.470667	4	8.695333	2	0.023133	5	0.0250	4	46.2	2	0.000933	10	0.011433	3	0.3375
2	4	0.48	4	8.698	2	0.0248	4	0.089067	6	46.475	2	0.000972	3	0.011733	10	0.341
3	4	0.483	4	8.703333	2	0.025	3	0.0903	13	46.49033	2	0.000975	5	0.0129	4	0.351
4	4	0.483267	4	8.712224	2	0.0251	4	0.092367	10	46.58333	2	0.00106	4	0.013333	3	0.351667
5	10	0.49	4	8.776667	2	0.02534	10	0.092767	10	46.6	4	0.001133	5	0.013733	4	0.353667
6	5	0.49	4	8.817667	4	0.025433	12	0.0930	4	46.7	2	0.0012	7	0.0138	4	0.363333
7	4	0.491057	3	8.8375	2	0.02650	4	0.093467	4	46.71333	2	0.00136	10	0.014	6	0.364333
8	4	0.491667	10	8.84	2	0.026767	4	0.098129	16	46.71667	2	0.0015	5	0.014433	4	0.365929
9	10	0.491667	4	8.863333	2	0.026767	4	0.10	10	46.74			4	0.014467	4	0.369
10	4	0.492333	4	8.8667	2	0.0269	10	0.104667	16	46.78667			4	0.014986	10	0.37
11	12	0.5000	4	8.90	2	0.027067	5	0.106067	16	46.82			3	0.0155	6	0.376667
12	3	0.50	4	8.906667	3	0.106667	4	0.106667	4	46.86333			12	0.0160	5	0.384167
13	8	0.511333	10	8.923333	4	0.115	16	46.99333					4	0.016	4	0.385833
14	4	0.514667					10	0.12					4	0.017833		
15							5	0.1272								
Average		0.4917		8.817		0.02656		0.0955		46.58		0.001291		0.01499		0.3619
Std dev		0.0073		0.034		0.00091		0.0022		0.12		0.000064		0.00055		0.0077
H		0.0057		0.052		0.0010		0.0021		0.24		0.00031		0.00080		0.0047
U ₁		0.0093		0.062		0.0014		0.0030		0.26		0.00032		0.00097		0.0090
t-statistic		2.16		2.18		2.23		2.14		2.18		2.36		2.16		2.18
U ₂		0.020		0.14		0.0031		0.0064		0.57		0.00075		0.0021		0.020
U ₃		0.0053		0.038		0.00093		0.0017		0.16		0.00027		0.00056		0.005
Certified		0.492		8.82		0.0266		0.095		46.6		0.0013		0.0150		0.36
Uncertainty		0.005		0.04		0.0009		0.002		0.2		0.0003		0.0006		0.01
Tolerance		0.020		0.14		0.0031		0.006		0.6		0.0008		0.0021		0.02

BS H3C * Code for method Certified values listed as weight percent

Analysis	*	Sn	*	V	*	W
1	5	0.0017	5	0.0390	10	0.601
2	5	0.0018	3	0.042033	4	0.603333
3	5	0.001833	4	0.044	3	0.607
4	5	0.001867	7	0.0445	3	0.61
5	12	0.0019	10	0.046	4	0.615667
6	5	0.001933	3	0.046	4	0.619667
7	5	0.0021	5	0.046033	10	0.62
8	5	0.002433	10	0.0464	4	0.62
9			4	0.046457	4	0.625333
10			4	0.047	4	0.633657
11			5	0.0496	10	0.636667
12			3	0.04975	4	0.637
13			10	0.05	7	0.641667
14					5	0.642567
15					4	0.646567
Average		0.00190		0.0468		0.6228
Std dev		0.00029		0.0017		0.0085
H		0.00035		0.0014		0.007
U ₁		0.00046		0.0022		0.011
t-statistic		2.36		2.18		2.14
U ₂		0.0011		0.0048		0.023
U ₃		0.00038		0.0013		0.0060
Certified		0.0019		0.047		0.623
Uncertainty		0.0004		0.001		0.006
Tolerance		0.0011		0.005		0.023

BS H3C * Code for method Informational values listed as weight percent

Analysis	*	As	*	Ca	*	S	*	Sb	*	Ta	*	Ti	*	Zr
1	5	0.0023	12	0.00030	12	0.000028	5	0.0002	12	0.000078	5	0.0061	5	0.0025
2	12	0.0030			1	0.000048	12	0.00033			4	0.006333	4	0.004814
3	5	0.0033			1	0.00007	5	0.00040			5	0.006433	5	0.004933
4					1	0.000223					4	0.006497	12	0.0071
5					1	0.000267					3	0.0067		
6					1	0.000367					4	0.0068		
7					1	0.000403					5	0.006867		
8					10	0.0006					4	0.006933		
9					1	0.000733					5	0.007067		
10											5	0.008433		
Average		0.0029		0.000300		0.000300		0.000310		0.0000780		0.00639		0.00482
Std dev		0.0013		0.000057		0.000020		0.000035		0.0000046		0.00020		0.00058
H		0.0004		0.00021		0.00021		0.00021		0.00017		0.00055		0.00049
U ₁		0.0013		0.00022		0.00021		0.00022		0.00017		0.00059		0.00076
t-statistic		4.30		12.71		2.31		4.30		12.71		2.26		3.18
U ₂		0.0057		0.0028		0.0005		0.00094		0.0021		0.0013		0.0024
U ₃		0.0033		0.0028		0.00017		0.00054		0.0021		0.00042		0.0012
(Informational)		(0.003)		(0.0003)		(0.0003)		(0.0003)		(0.0001)		(0.0064)		(0.005)

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. 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 H3C		* Code for analytical method		Trace analysis listed as mg/kg (ppm)																	
Analysis	* Ag	* Bi	* Cd	* Ce	* Cl	* Ga	* Ge	* Hf	* In	* K	* Na	* Nd	* Pb	* Pt	* Re	* Ru	* Sc	* Se	* Th	* U	* Zn
1	12 0.73	12 0.013	5 190	5 0.22	12 0.035	12 22	12 5	5 1.0	12 0.24	12 0.069											
2		5 0.11		5 0.22		5 25	5 12	5 1.0													
3		5 0.13		5 0.22		5 26	5 13	5 1.0													
4		5 0.15				5 26	5 13	12 1.0													
5						5 26	5 14														

Analysis	* Na	* Nd	* Pb	* Pt	* Re	* Ru	* Sc	* Se	* Th	* U
1	12 0.038	5 5	12 2.5	12 0.18	12 4.9	5 2	5 5	5 13	12 0.010	12 0.041
2			5 2.8	5 0.41	5 4.9					5 0.10
3			5 2.8	5 0.41	5 4.9					5 0.10
4			5 2.9	5 0.42	5 5.0					5 0.10
5					5 7					

Analysis	* Zn
1	12 0.75
2	5 14

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
LECO Corporation	St. Joseph, MI	A2LA	17025
Evans Analytical Group	Liverpool, NY	A2LA	17025
Dirats	Westfield, MA	ACLASS	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI/Nadcap	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	AB 554
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Shiva Analyticals	Hoskote, Bangalore	NABL	17025
NSL Analytical	Cleveland, OH	ACLASS	17025
Exova	Glendale Heights, IL	A2LA	17025
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
 NABL = National Accreditation Board for Testing and Calibration Laboratories
 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. Methods of analysis used are those listed on pages 2-4.

Traceability: The following Certified Reference Materials were used to validate the analytical data listed on pages 2-4 — 24X07001, 28X7183; 501-147, 501-501, 501-503, 501-503, 501-566, 501-643, 501-644, 501-645, 501-646, 501-676, 501-952, 501-991, 501-993, 502-102, 502-195, 502-403, 502-411, 502-414, 502-416, 502-494; AR 511, 654, 659, 670, 871, 875, 946, 1653; BAS 180/1, 345, 346, 349, 387; BS E3921, H2B, H2C, H2D, H3, H3B, H4A, H6, H6A, LE204, 625A; CZ 2025A; ECRM 096/1, 284/1, 285/1; IARM 54B, 56C, 62E, 69C; SRM 126C, 349, 862, 865, 866, 867, 1246, 1249, 1263A, 2171, 3131A, 3161A, 3162A.

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, 501-991, 502-416; BS E3921, H2B, H3, H3B, H4A, H6, H6A, HON-T, LE 204; ECRM 096/1, 285/1; SRM 2171.

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 H3C 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 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 you use for production specimens. Avoid overheating the sample during surface preparation.

Certificate Number: The unique identification number for this certificate of analysis is H3C-082514. 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 August 25, 2014.

Beau R. Brammer