Brammer Standard Company, Inc.

Certificate of Analysis
BS 1144A

Certified Reference Material for Grade 1144 - UNS Number G11440

	Certified Value[1]	Estimate of Uncertainty[2]	**Certified Values[3]**		Certified Value[1]	Estimate of Uncertainty[2]
Al	**0.0020**	0.0004		**Sn**	**0.0079**	0.0005
As	**0.0052**	0.0004		**V**	**0.0015**	0.0003
C	**0.468**	0.008				
Co	**0.0064**	0.0004				
Cr	**0.076**	0.002				
Cu	**0.147**	0.007				
Fe	**97.3**	0.3				
Mn	**1.43**	0.02				
Mo	**0.0154**	0.0008				
N	**0.0095**	0.0006				
Ni	**0.063**	0.005				
O	**0.0019**	0.0003				
P	**0.0108**	0.0009				
S	**0.271**	0.008				
Si	**0.214**	0.007				

Informational Values[3,4]

B	(0.0003)	Ca	(0.0005)	Mg	(0.0004)	Nb	(0.002)	Pb	(0.0006)
Sb	(0.002)	Ti	(0.0008)	W	(0.0009)	Zr	(0.0006)		

[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 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 1144A   * Code for method   Certified values listed as weight percent

Analysis	*	Al	*	As	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mn
1	4	0.001233	12	0.0049	1	0.450833	5	0.004933	12	0.068667	5	0.126667	13	97.12867	4	1.398667
2	3	0.0014	4	0.005033	1	0.459333	12	0.0056	3	0.071067	4	0.137	3	97.1975	4	1.399
3	4	0.002233	4	0.005067	1	0.460133	4	0.006	7	0.073133	10	0.138333	10	97.21667	10	1.405
4	14	0.002267	4	0.005133	3	0.4625	5	0.006333	3	0.074	4	0.14	14	97.23333	4	1.406667
5	4	0.0023	5	0.005167	1	0.464667	4	0.006383	10	0.074433	4	0.14	3	97.24	14	1.41
6	5	0.0025	5	0.00519	2	0.464667	4	0.006433	4	0.074867	3	0.143	16	[97.26107]	10	1.41
7			3	0.0053	1	0.464667	5	0.006433	4	0.075333	4	0.143667	4	97.26667	4	1.4119
8			9	0.005333	3	0.4660	4	0.006467	3	0.0754	5	0.1457	16	[97.27667]	4	1.416667
9			10	0.0055	1	0.470667	4	0.006567	5	0.075833	3	0.146	16	[97.30667]	4	1.417667
10			5	0.005567	1	0.4754	10	0.0066	4	0.075933	10	0.147	10	97.31	3	1.430
11					1	0.475667	8	0.006833	10	0.076	4	0.147067	16	[97.36]	4	1.4354
12					1	0.486	14	0.007233	4	0.076133	4	0.147667			8	1.435667
13							3	0.007275	14	0.076933	3	0.148			4	1.443333
14									10	0.077333	4	0.150267			10	1.476667
15									4	0.077467	14	0.151333			3	1.50
16									4	0.077467	8	0.153			3	1.5125
17											12	0.156667				
Average		0.00199		0.00524		0.4680		0.006392		0.0758		0.1466		97.294		1.4277
Std dev		0.00013		0.00029		0.0045		0.000088		0.0020		0.0033		0.019		0.0065
H		0.00039		0.00055		0.0060		0.00060		0.0020		0.0029		0.51		0.013
U_1		0.00041		0.00062		0.0075		0.00060		0.0028		0.0044		0.51		0.015
t-statistic		2.57		2.26		2.20		2.18		2.13		2.12		2.23		2.13
U_2		0.0011		0.0014		0.016		0.0013		0.0060		0.0093		1.14		0.031
U_3		0.00043		0.00044		0.0048		0.00036		0.0015		0.0023		0.34		0.0080
Certified		**0.0020**		**0.0052**		**0.468**		**0.0064**		**0.076**		**0.147**		**97.3**		**1.43**
Uncertainty		**0.0004**		**0.0004**		**0.008**		**0.0004**		**0.002**		**0.007**		**0.3**		**0.02**
Tolerance		0.0011		0.0014		0.024		0.0013		0.008		0.021		1.1		0.06

Analysis	*	Mo	*	N	*	Ni	*	O	*	P	*	S	*	Si	*	Sn
1	5	0.012333	2	0.00903	5	0.050333	2	0.0014	5	0.0067	2	0.246667	6	0.194333	12	0.006333
2	12	0.013333	2	0.009033	10	0.054	2	0.00154	5	0.007967	10	0.253333	5	0.1961	3	0.007
3	4	0.014433	2	0.009533	12	0.055333	2	0.001747	10	0.0097	1	0.254667	10	0.202667	3	0.0073
4	4	0.014633	2	0.009537	8	0.055667	2	0.0018	14	0.009967	1	0.259267	14	0.207	9	0.0075
5	7	0.014967	2	0.009567	4	0.058667	2	0.001867	7	0.009977	1	0.265067	10	0.209	4	0.007533
6	4	0.015	2	0.0096	4	0.059367	2	0.002067	4	0.010533	1	0.267	4	0.210333	5	0.007933
7	5	0.015033	2	0.0096	4	0.059667	2	0.0021	4	0.010767	3	0.2675	4	0.211667	5	0.0082
8	4	0.015133	2	0.009697	4	0.0607	2	0.002517	4	0.0108	1	0.267667	4	0.212333	5	0.008277
9	4	0.0156	2	0.009793	5	0.0613	2	0.0026	4	0.0109	1	0.270667	4	0.212667	4	0.008533
10	14	0.015767			3	0.062			5	0.011167	1	0.270933	4	0.216233	5	0.008633
11	10	0.016			10	0.063			3	0.0115	3	0.276	3	0.2165	4	0.008667
12	3	0.016125			3	0.063167			4	0.011667	1	0.291333	12	0.216667		
13	4	0.016133			3	0.063225			10	0.011733	1	0.300333	4	0.220		
14	10	0.0189			10	0.064533			12	0.012333	12	0.310	3	0.22		
15	3	0.019767			4	0.0686			3	0.012467			10	0.223333		
16					14	0.069233							3	0.225		
17					4	0.072367										
Average		0.01542		0.00949		0.0631		0.00192		0.01076		0.2714		0.2136		0.00794
Std dev		0.00077		0.00040		0.0018		0.00014		0.00062		0.0044		0.0041		0.00034
H		0.0009		0.00070		0.0018		0.00038		0.00074		0.0042		0.0036		0.00065
U_1		0.0012		0.00081		0.0025		0.00041		0.00097		0.0060		0.0054		0.00074
t-statistic		2.14		2.31		2.12		2.31		2.14		2.16		2.13		2.23
U_2		0.0025		0.0019		0.0053		0.00094		0.0021		0.013		0.012		0.0016
U_3		0.00064		0.00062		0.0013		0.00031		0.00054		0.0035		0.0029		0.00049
Certified		**0.0154**		**0.0095**		**0.063**		**0.0019**		**0.0108**		**0.271**		**0.214**		**0.0079**
Uncertainty		**0.0008**		**0.0006**		**0.005**		**0.0003**		**0.0009**		**0.008**		**0.007**		**0.0005**
Tolerance		0.0030		0.0019		0.015		0.0009		0.0027		0.024		0.021		0.0016

BS 1144A   * Code for method   Certified values listed as weight percent

Analysis	*	V
1	12	0.0011
2	5	0.001133
3	5	0.00120
4	5	0.0012
5	4	0.001267
6	4	0.001733
7	4	0.0018
8	14	0.001867
9	3	0.001925
Average		0.00147
Std dev		0.00011
H		0.00035
U_1		0.00037
t-statistic		2.31
U_2		0.00085
U_3		0.00028
Certified		**0.0015**
Uncertainty		**0.0003**
Tolerance		0.0008

BS 1144A   * Code for method   Informational values listed as weight percent

Analysis	*	B	*	Ca	*	Mg	*	Nb	*	Pb	*	Sb	*	Ti	*	W
1	12	0.00012	12	0.0000773	4	0.0002	12	0.0000463	12	0.0000783	5	0.001567	5	0.0002	12	0.000417
2	4	0.000233	4	0.000099	3	0.000223	5	0.0001233	5	0.0001	4	0.001667	5	0.000427	5	0.000433
3	3	0.00025	3	0.0002725	4	0.000397	14	0.0017667	5	0.00014			4	0.000433	5	0.0005
4	4	0.0007	4	0.0003	12	0.000483	4	0.0021667	5	0.0001467			12	0.000453	4	0.000633
5			4	0.0017433	5	0.000687	3	0.002375	10	0.0006667			4	0.0005	5	0.00067
6							4	0.0028667	10	0.0008			5	0.000837	4	0.0013
7									9	0.0009333			4	0.000933	4	0.0015
8									3	0.001075			14	0.0011	3	0.00185
9									4	0.0012667			10	0.0012		
10													3	0.00125		
11													3	0.0013		
Average		0.00033		0.00050		0.00040		0.0016		0.00058		0.002		0.0008		0.0009
Std dev		0.00041		0.00087		0.00055		0.0065		0.00087		0.012		0.0028		0.0022
H		0.00024		0.00026		0.00025		0.0004		0.00027		0.000		0.00029		0.0003
U_1		0.00047		0.00091		0.00061		0.0065		0.00092		0.012		0.0028		0.0022
t-statistic		3.18		2.78		2.78		2.57		2.31		12.71		2.23		2.36
U_2		0.0015		0.0025		0.0017		0.017		0.0021		0.15		0.0063		0.0052
U_3		0.00075		0.0011		0.00075		0.0068		0.00070		0.11		0.0019		0.0019
(Informational)		**(0.0003)**		**(0.0005)**		**(0.0004)**		**(0.002)**		**(0.0006)**		**(0.002)**		**(0.0008)**		**(0.0009)**

Analysis	*	Zr
1	12	0.0000243
2	5	0.0000333
3	4	0.0002667
4	4	0.0007333
5	4	0.0011667
6	3	0.00145
Average		0.0006
Std dev		0.0012
H		0.000272
U_1		0.0012
t-statistic		2.57
U_2		0.0032
U_3		0.0013
(Informational)		**(0.0006)**

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 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 1144A   * Code for analytical method   Trace analysis listed as mg/kg   (ppm)

Analysis	*	Zn			
1	5	23			
2	5	25			
3	5	25			

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
Evans Analytical Group	Liverpool, NY	A2LA	17025
Dirats Laboratories	Westfield,MA	ACLASS	17025
NSL Analytical	Cleveland, OH	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
Exova	Glendale Heights, Il	A2LA	17025
Central Iron and Steel Research Institute	Beijing, China	CNAS	17025
Luvak Inc.	Boylston, MA	PRI/Nadcap	17025

A2LA = American Association for Laboratory Accreditation   PCA = Polish Center For Accreditation
ACLASS = ANSI-ASQ National Accreditation Board   PRI =Performance Review Institute
CNAS = China National Accreditation Service
NABL = National Accreditation Board for Testing and Calibration Laboratories
Nadcap = National Aerospace and Defense Contractors Accreditation Program

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: 12X10180, 12X32550, 13X31254, 13X32101A, 14XMN1, 14XMN3, 212x4001, 212x4003, 212X4004, 212X4005, 215XHB2; LECO 501-320, 501-501, 501-503, 501-504, 501-505, 501-644, 501-646, 501-675, 501-676, 501-677, 501-991, 501-993, 502-102, 502-265, 502-416; AR 614A, 644, 657, 875, 891, 1144, 1652, 1653; BAS 4-94, 152/2, 345, 363, 434, 435, 464/1, 601/1; BS CSN 2-1, HON-T, 52C, 65C, 66A, 181A, 231, 400D, 800, 1144, 3993; ECRM 039-2, 85, 86, 87, 285-1; IARM 52A, 199A; IMZ 1-N4, 1.12/3, 112, 121, 124; NCS NS 20035B; SRM 8F, 55D, 160B, 293, 361, 362, 363, 365, 1413, 3109A, 3128.

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; AR 1144; BAS 4-94, 601/1; BS CSN 2-1, HON-T, 52C, 65C, 66A, 231, 1144, 3993; ECRM 039-2; NCS NS 20035B; SRM 361.

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 1144A 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 Nucor Cold Finish, NE.

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 1144A-081916. 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, 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 August 19, 2016.

Beau R. Brammer