

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS FeV 42

Certified Reference Material for Ferrovandium¹

	Certified Value ²	Estimate of Uncertainty ³	Certified Values ⁴	Certified Value ²	Estimate of Uncertainty ³
C	0.297	0.008			
Cr	5.18	0.03			
Cu	0.31	0.01			
Fe	39.2	0.4			
Mg	0.059	0.006			
Mn	3.37	0.04			
Mo	0.023	0.004			
N	0.19	0.01			
Ni	3.87	0.09			
P	0.127	0.008			
S	0.31	0.01			
Si	3.77	0.04			
Ti	0.033	0.001			
V	42.2	0.1			

Informational Values^{4,5}

Al (0.05)

As (0.01)

Ca (0.052)

¹ This certificate is a revision. For more information on the nature and extent of the revision, see the revision statement on page 5.

² 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.

³ 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.

⁴ Values are given in weight percent.

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

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

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Analysis	*	C	*	Cr	*	Cu	*	Fe	*	Mg	*	Mn	*	Mo	*	N
1	17	0.272	17	5.09	17	0.26	17	38.73	17	0.043	17	3.2975	4	0.0147	2	0.15
2	1	0.288	4	5.142	17	0.273	17	38.81	4	0.058	17	3.32	4	0.019	2	0.195
3	1	0.289333	17	5.15	17	0.300	17	38.88	4	0.060	4	3.33	4	0.0205	2	0.198033
4	1	0.294	4	5.1525	18	0.303	17	38.93	4	0.065233	7	3.36	17	0.0265	2	0.2029
5	17	0.3	17	5.1875	7	0.306	17	39.2	18	0.069	17	3.39	17	0.027	2	0.2045
6	1	0.300233	4	5.204167	4	0.3094	17	39.21			17	3.391	17	0.0278		
7	1	0.302	17	5.25	4	0.314	17	39.37617			18	3.40				
8	1	0.303	18	5.29	4	0.31975	17	39.495			4	3.408133				
9	17	0.306667			17	0.323	17	39.53			17	3.42				
10	1	0.31			17	0.34	17	39.7			17	3.425				
11					17	0.34	4	39.875								
Average		0.29652		5.18327		0.308014		39.248742		0.05905		3.37416		0.02258		0.19009
Std dev		0.00010		0.00011		0.000095		0.000095		0.00014		0.00010		0.00013		0.00014
H		0.004647		0.034773		0.004758		0.19264		0.001843		0.02494		0.001141		0.003547
U ₁		0.0046		0.035		0.0048		0.19		0.0018		0.025		0.0011		0.0036
t-statistic		2.26		2.36		2.23		2.23		2.78		2.26		2.57		2.78
U ₂		0.011		0.082		0.011		0.43		0.0051		0.056		0.0030		0.0099
U ₃		0.0033		0.029		0.0032		0.13		0.0023		0.018		0.0012		0.0044
Certified		0.297		5.18		0.31		39.2		0.059		3.37		0.023		0.19
Uncertainty		0.008		0.03		0.01		0.4		0.006		0.04		0.004		0.01
Tolerance		0.024		0.08		0.03		0.9		0.018		0.12		0.012		0.03

Analysis	*	Ni	*	P	*	S	*	Si	*	Ti	*	V
1	4	3.659	4	0.102	1	0.3	17	3.609	17	0.028	17	41.44
2	17	3.68	17	0.115	1	0.302	17	3.637	4	0.033433	17	42.025
3	17	3.765	17	0.119	1	0.305533	17	3.73	4	0.0335	17	42.1
4	18	3.84	17	0.12	1	0.3095	17	3.734067	17	0.034	17	42.12
5	4	3.860167	7	0.121	17	0.31	17	3.74	4	0.034	17	42.125
6	6	3.90	4	0.1261	1	0.310333	6	3.77	17	0.0368	4	42.225
7	17	3.90	4	0.15425	1	0.325	17	3.78			17	42.30
8	17	3.97	17	0.15775	17	0.326667	17	3.81			17	42.3
9	17	3.973			17	0.355	4	3.9225			17	42.32363
10	4	3.9825					17	3.9375			17	42.465
11	17	3.9975									17	43.20
Average		3.866106		0.12689		0.31600		3.76701		0.03329		42.238512
Std dev		0.000095		0.00011		0.00011		0.00010		0.00013		0.000095
H		0.027679		0.002803		0.004834		0.027132		0.001376		0.205899
U ₁		0.028		0.0028		0.0048		0.027		0.0014		0.21
t-statistic		2.23		2.36		2.31		2.26		2.57		2.23
U ₂		0.062		0.0066		0.011		0.061		0.0036		0.46
U ₃		0.019		0.0023		0.0037		0.019		0.0015		0.14
Certified		3.87		0.127		0.31		3.77		0.033		42.2
Uncertainty		0.09		0.008		0.01		0.04		0.001		0.1
Tolerance		0.27		0.024		0.03		0.12		0.004		0.5

BS FeV 42 * Code for method Informational values listed as weight percent

Analysis	*	Al	*	As	*	Ca
1	17	0.030	4	0.0106	4	0.040
2	4	0.0457			4	0.044
3	4	0.0546			4	0.044733
4	4	0.0556			17	0.0795
5	17	0.0582				
6	4	0.066				
Average		0.05168		0.01060		0.05206
Std dev		0.00013		0.00032		0.00016
H		0.001719		0.000813		0.001725
U ₁		0.0017		0.00087		0.0017
t-statistic		2.57		12.71		3.18
U ₂		0.0044		0.011		0.0055
U ₃		0.0018		0.011		0.0028
(Certified)		(0.05)		(0.01)		(0.052)

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.

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	17	Wet
6	Gravimetric	12	GD Mass Spectrometry	18	Atomic Absorption Spectrometry

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

Laboratory

Brammer Standard Company, Inc.
Shieldalloy Metallurgical Corporation

Location

Houston, TX
Birmingham, AL

Registrar

Accreditation

Brammer Standard Company, Inc., 14603 Benfer Road, Houston, TX 77069-2895
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Andrew S. McCreath & Son, Inc.	Harrisburg, PA		
LECO	St. Joseph, MI		
Dirats Laboratories	Westfield, MA		
Advanced Analytical Services and Reference Materials	Praha, Czech Republic		
Bear Metallurgical Corporation	Butler, PA		
Elkem Development Center	Sewickley, PA		
US Steel Corporation	Pittsburgh, PA		
VHG Labs	Manchester, NH		
Ledoux	Teaneck, NJ		
W.B. Coleman Testing Laboratories	Riverside, NJ		
Laboratory Testing, Inc.	Hatfield, PA	PRI/Nadcap	17025

Nadcap = National Aerospace and Defense Contractors Accreditation Program

PRI =Performance Review Institute

Analysis: Chemical analyses were made on samples taken from the bulk material. The original participating laboratories normally followed the requirements of ISO Guide 25. The laboratories participating in the stability testing followed the requirements of ISO Standard 17025. Methods of analysis used were those listed on pages 2-3.

Traceability: The following Certified Reference Materials were used to validate the analytical data listed on pages 2-3 - AR 654; BS CSN 2-2; CKD 278; ECRM 039-2, 455-1, 577-1; LECO 502-265; SRM 3109A, 3112A, 3114, 3131A, 3132, 3134, 3139A, 3162A.

Homogeneity: This Certified Reference Material (CRM) was tested for homogeneity using ASTM Standard Method E 826 and found acceptable.

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 FeV 42 is valid for 20 years from the date of this certificate. The certification is nullified if this CRM is damaged, contaminated, or otherwise modified.

Source: This material was produced by the Shieldalloy Metallurgical Corporation, Newfield, New Jersey. The material was made in an electric furnace, cast, and crushed to minus 8 mesh.

Form: This CRM is available only in the form of minus 100 mesh powder in 100 gram containers.

Use: This CRM is intended for use in x-ray spectrometric and solution methods of analysis. Refer to ISO Guide 33 for information about the use of Certified Reference Materials.

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.

Certificate Number: The unique identification number for this certificate of analysis is REVFeV42-092116. 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:

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Houston, Texas 77069-2895 USA

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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

Expiration: 20 years from date of certification, which is September 21, 2036. The material is valid until that date.

Revision: This certified reference material was originally certified as a reference material on May 23, 1992. The documented validity for Brammer Standard Company powder products is 20 years. Additional interlaboratory testing was performed in 2016 to prove stability and has been included on this certificate. Mg has been changed from informational to certified. Revised values for all elements except Mn, S, Cu, and Ti are presented. Informational values for As are provided.

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 30:2015 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 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.

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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 September 21, 2016.

Beau R. Brammer