

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS FeV 45

Certified Reference Material for Ferrovandium

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values ³	Certified Value ¹	Estimate of Uncertainty ²	
Al	0.017	0.001		Mo	0.0079	0.0005
C	0.241	0.006		N	0.26	0.01
Ca	0.010	0.001		Ni	4.32	0.03
Cr	5.82	0.04		S	0.334	0.006
Cu	0.40	0.02		Si	4.90	0.06
Fe	33.7	0.3		Ti	0.021	0.001
Mg	0.014	0.001		V	45.1	0.2
Mn	4.12	0.08				

	Reference Value	Estimate of Uncertainty	Reference Values ^{3,4}	Reference Value	Estimate of Uncertainty
P	0.13	0.02			

Informational Values^{3,5}

As (0.013)

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 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 B, Co, O, and Sn 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 FeV 45

* Code for method

Certified values listed as weight percent

Analysis	*	Al	*	C	*	Ca	*	Cr	*	Cu	*	Fe	*	Mg	*	Mn
1	17	0.0118	1	0.226	4	0.008	4	5.71	4	0.35	4	33.0	4	0.0115	4	4.05
2	4	0.0128	1	0.235667	4	0.009	17	5.78	4	0.3585	4	33.34	4	0.014	4	4.07
3	4	0.016	1	0.236	4	0.01	4	5.78	4	0.383	4	33.44	4	0.015	4	4.07
4	4	0.0160	4	0.24	4	0.010	4	5.78	4	0.384	4	33.49	4	0.015	4	4.07
5	4	0.0168	4	0.24	4	0.010	4	5.8	4	0.385	4	33.54	4	0.015	18	4.07
6	4	0.01685	4	0.24	4	0.010	4	5.80	4	0.390	18	33.55	17	0.016	18	4.08
7	4	0.017	4	0.24	4	0.0155	4	5.80	17	0.398	18	33.61			17	4.09
8	17	0.0170	1	0.2409			4	5.80	4	0.40	18	33.62			4	4.09
9	17	0.0172	1	0.242			4	5.815	4	0.40	4	33.65			18	4.09
10	4	0.0176	1	0.243			4	5.82	4	0.40	4	33.67			4	4.10
11	4	0.0176	1	0.246			4	5.83	7	0.402	18	33.69			4	4.10
12	4	0.018167	1	0.247			4	5.84	4	0.405	4	33.76			4	4.10
13	4	0.0219	1	0.2485			18	5.84	4	0.415433	4	33.9			7	4.11
14	4	0.0219	1	0.253333			18	5.85	4	0.425	4	33.9			18	4.12
15	17	0.0219					18	5.86	4	0.427	4	33.9015			4	4.156
16							4	5.878	4	0.429	4	34.0			4	4.1605
17							4	5.924	4	0.45	4	34.0			4	4.18
18							4	5.93			4	34.0			4	4.19
19											4	34.0			4	4.193
20											13	34.035			4	4.235
21											4	34.1			4	4.239
Average		0.01737		0.2413		0.01036		5.8244		0.4001		33.70353		0.01442		4.1219
Std dev		0.00047		0.0027		0.00039		0.0015		0.0028		0.00053		0.00061		0.0017
H		0.0009		0.003806		0.000714		0.039489		0.005284		0.189527		0.000826		0.029679
U ₁		0.0010		0.0047		0.00081		0.040		0.0060		0.19		0.0010		0.030
t-statistic		2.14		2.16		2.45		2.11		2.12		2.09		2.57		2.09
U ₂		0.0022		0.010		0.0020		0.083		0.013		0.40		0.0026		0.062
U ₃		0.00056		0.0027		0.00075		0.020		0.0031		0.086		0.0011		0.014
Certified		0.017		0.241		0.010		5.82		0.40		33.7		0.014		4.12
Uncertainty		0.001		0.006		0.001		0.04		0.02		0.3		0.001		0.08
Tolerance		0.003		0.010		0.002		0.08		0.04		0.6		0.003		0.16

BS FeV 45

* Code for method

Certified values listed as weight percent

Analysis	*	Mo	*	N	*	Ni	*	S	*	Si	*	Ti	*	V
1	4	0.0065	2	0.2495	4	4.182	1	0.303	6	4.78	4	0.016	4	43.46
2	4	0.007	2	0.2585	4	4.23	1	0.305	4	4.83	4	0.020	4	44.32
3	18	0.0075	2	0.2596	4	4.27	1	0.320	4	4.83	4	0.0205	4	44.46
4	18	0.0076	4	0.26	4	4.28	1	0.333	4	4.854333	4	0.022	4	44.52
5	18	0.0078	4	0.26	18	4.28	1	0.3362	4	4.88	4	0.022	4	44.795
6	4	0.008	4	0.26	4	4.29	1	0.3365	4	4.90	4	0.022	16	[44.80667]
7	4	0.008	2	0.2675	18	4.29	4	0.34	4	4.90	4	0.022	4	44.9
8	4	0.008	2	0.269333	4	4.30	1	0.34	4	4.90	4	0.022	4	45.0
9	4	0.008			4	4.30	4	0.34	4	4.90	4	0.023	18	45.0
10	18	0.0082			4	4.30	4	0.34	4	4.92	4	0.0230	4	45.024
11	4	0.010467			18	4.30	4	0.34	4	4.926			4	45.04
12					4	4.305	1	0.35	4	4.93			4	45.1
13					18	4.31	1	0.362	4	4.93			4	45.14
14					4	4.32			18	4.93			4	45.19
15					6	4.33			4	4.94			18	45.2
16					4	4.339333			18	4.94			4	45.2
17					17	4.36			18	4.94			4	45.3
18					4	4.421			18	4.94			4	45.3
19					4	4.451							4	45.3
20					4	4.49							18	45.3
21													13	45.305
22													4	45.33
23													18	45.4
24													4	45.43
25													4	45.46
26													4	46.58
Average		0.00792		0.2606		4.3172		0.3343		4.8987		0.02125		45.07116
Std dev		0.00023		0.0037		0.0017		0.0031		0.0017		0.00070		0.00050
H		0.000638		0.003996		0.030822		0.004693		0.034196		0.000989		0.250462
U ₁		0.00068		0.0054		0.031		0.0056		0.034		0.0012		0.25
t-statistic		2.23		2.36		2.09		2.18		2.11		2.26		2.06
U ₂		0.0015		0.013		0.065		0.012		0.072		0.0027		0.52
U ₃		0.00045		0.0045		0.014		0.0034		0.017		0.0087		0.10
Certified		0.0079		0.26		4.32		0.334		4.90		0.021		45.1
Uncertainty		0.0005		0.01		0.03		0.006		0.06		0.001		0.2
Tolerance		0.0015		0.03		0.06		0.012		0.12		0.003		0.5

BS FeV 45 * Code for method Reference values listed as weight percent

Analysis	*	P
1	4	0.113
2	4	0.119
3	7	0.1195
4	4	0.12
5	4	0.12
6	4	0.12
7	4	0.12
8	4	0.1230
9	4	0.1285
10	4	0.148
11	4	0.149
12	4	0.150
13	4	0.152
14	18	0.152
15	18	0.154
16	18	0.155
17	18	0.156
Average		0.1352
Std dev		0.0020
H		0.002667
U ₁		0.0033
t-statistic		2.12
U ₂		0.0071
U ₃		0.0017
Reference		0.13
Uncertainty		0.02
Tolerance		0.07

BS FeV 45 * Code for method Informational values listed as weight percent

Analysis	*	As	*	*	*	*	*	*
1	4	0.013						
2	4	0.013						
3	4	0.013						
4	4	0.014						
Average		0.01325						
Std dev		0.00068						
H		0.000796						
U ₁		0.0010						
t-statistic		3.18						
U ₂		0.0033						
U ₃		0.0017						
(Informational)		(0.013)						

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 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 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 FeV 45		* Code for analytical method		Trace analysis listed as mg/kg (ppm)			
Analysis *	B	* Co	* O	* Sn			
1	4 18	4 399	2 7520	4 58			
2	4 18	4 401	2 7450	4 58			
3	4 19	4 399	2 7390	4 60			

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 Atomic Absorbtion Spectrometry |
| 6 Gravimetric | 12 GD Mass Spectrometry | 18 Wet |

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>
Exova	Glendale Heights, Il	A2LA	17025
Brammer Standard Company, Inc.	Houston, TX		
Andrew S. McCreath & Son, Inc.	Harrisburg, Pa		
Elkem Development Center	Sewickley, Pa		
Ledoux & Company	Teaneck, NJ		
Bear Metallurgical Corporation	Butler, Pa		
Advanced Analytical Service	Praha, Czech Republic		
Dirats Laboratories	Westfield, Ma		
VHG Labs, Inc.	Manchester, NH		
Shieldalloy Metallurgical Corporation	Newfield, NJ		
LECO Corporation	St. Joseph, MI		
Krupp Hoesch Stahl, AG	Germany		

A2LA = American Association for Laboratory Accreditation

Analysis: Chemical analysis 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 a those listed on pages 2-3.

Traceability: The following Certified Reference Materials were used to validate the analytical data listed on page 2-4 — 501-320, 501-501, 501-504, 501-644, 501-993; AR 875; BAS 464/1; ECRM 039/2, 286/1, 455/1, 577/1; IARM 43; IRSID 511-1; JK FeV-2; SRM 4K, 61A, 100B, 129C, 133B, 160B, 342A, 361, 363.

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 45 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, Newfiled, 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 REVFeV45-100115. 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

Expiration: 20 from date of certification, which is October 1, 2035. The material is valid until that date.

Revision: This certified reference material was originally certified as a reference material on May 23, 1996. The documented validity for Brammer Standard Company powder products is 20 years. Additional interlaboratory testing was performed in 2015 to prove stability and has been included on this certificate. Al, Ca, and Mg have been changed from informational to certified. P has changed from certified to reference. Revised values for all elements except Cr and N are presented. Informational values for As are provided. Trace values for B, Co, O and Sn are provided. All trace data are presented in mg/kg (ppm).

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 31-85 Standard Methods for Chemical Analysis of Ferroalloys
- E 365-90 Standard Test Methods for Chemical Analysis of Ferrovandium and Vanadium Alloying Additives

ISO Guide 25:1990 General requirements for the competence of calibration and testing laboratories

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 1, 2015.

Beau R. Brammer