

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 48B

Certified Reference Material for ASTM A182 Grade F9 Cr-Mo Steel Alloy - UNS Number K90941

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values³	Certified Value ¹	Estimate of Uncertainty ²	
Al	0.0157	0.0007		Sn	0.0049	0.0004
As	0.0048	0.0006		Ti	0.0031	0.0003
C	0.110	0.002		V	0.033	0.003
Co	0.0165	0.0009		W	0.026	0.001
Cr	8.78	0.03				
Cu	0.070	0.003				
Fe	88.7	0.3				
Mn	0.365	0.007				
Mo	0.949	0.009				
N	0.0088	0.0005				
Ni	0.165	0.005				
O	0.0022	0.0003				
P	0.0228	0.0008				
S	0.0068	0.0003				
Si	0.75	0.01				

Informational Values^{3,4}

B (0.0002)	Ca (0.003)	Mg (0.0002)	Nb (0.001)	Pb (0.0002)
Sb (0.001)	Zn (0.0003)	Zr (0.002)		

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 Cl, Ga, Ge, K, Na, and Re 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.

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* Code for method Certified values listed as weight percent

Analysis	*	Al	*	As	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mn
1	5	0.0133	4	0.003433	1	0.101	12	0.0140	10	8.59	12	0.0595	4	88.3	4	0.34
2	12	0.0135	5	0.0037	1	0.104667	4	0.014767	4	8.61	5	0.063233	16	[88.58667]	4	0.354333
3	3	0.015	4	0.003867	1	0.105667	8	0.014967	14	8.666667	3	0.065	16	[88.63]	7	0.355333
4	4	0.015067	12	0.0041	1	0.105933	4	0.0156	4	8.676667	10	0.067	13	88.644	4	0.358667
5	3	0.0153	3	0.0042	1	0.10625	4	0.015767	4	8.726667	4	0.0676	3	88.65	3	0.362
6	4	0.0155	5	0.004267	1	0.108333	5	0.015767	13	8.741	4	0.067833	16	[88.68]	10	0.362
7	3	0.0156	9	0.004333	1	0.11	4	0.016	4	8.779833	3	0.0684	16	[88.72773]	4	0.364267
8	14	0.0156	15	0.00489	3	0.11	3	0.0164	4	8.787333	10	0.069	14	88.73	14	0.366
9	5	0.015667	5	0.005133	1	0.111	5	0.016567	3	8.79	14	0.0713	16	[88.75]	4	0.3681
10	4	0.016067	5	0.0052	1	0.111333	10	0.017	4	8.803	4	0.072	10	88.89667	3	0.37
11	5	0.019233	3	0.0056	1	0.112167	14	0.017367	3	8.81	4	0.072367	4	89.0	3	0.37
12	4	0.019967			3	0.116	4	0.0175	4	8.876667	4	0.072367			4	0.376667
13					1	0.1165	3	0.0185	10	8.88	5	0.0739			4	0.386667
14					3	0.119	5	0.0197	3	8.90	3	0.0742			12	0.3900
15											8	0.074233			10	0.396667
16											5	0.074367			5	0.411067
Average		0.01574		0.00475		0.1103		0.01652		8.7808		0.0702		88.721		0.3650
Std dev		0.00062		0.00021		0.0025		0.00067		0.0046		0.0017		0.041		0.0043
H		0.0008		0.00051		0.0023		0.0009		0.056		0.0018		0.50		0.0049
U ₁		0.0010		0.00055		0.0034		0.0011		0.056		0.0025		0.51		0.0065
t-statistic		2.20		2.23		2.16		2.16		2.16		2.13		2.23		2.13
U ₂		0.0023		0.0012		0.0074		0.0024		0.12		0.0053		1.13		0.014
U ₃		0.00067		0.00037		0.0020		0.00063		0.032		0.0013		0.34		0.0035
Certified		0.0157		0.0048		0.110		0.0165		8.78		0.070		88.7		0.365
Uncertainty		0.0007		0.0006		0.002		0.0009		0.03		0.003		0.3		0.007
Tolerance		0.0023		0.0012		0.007		0.0024		0.12		0.005		1.1		0.014

Analysis	*	Mo	*	N	*	Ni	*	O	*	P	*	S	*	Si	*	Sn
1	4	0.918667	2	0.007725	4	0.116667	2	0.0018	3	0.02	12	0.0053	12	0.6820	5	0.0034
2	4	0.92	2	0.008503	12	0.1550	2	0.0020	12	0.020	1	0.00533	4	0.706433	5	0.004233
3	4	0.933333	2	0.00865	8	0.155667	2	0.002052	3	0.0208	3	0.006	4	0.73	5	0.004547
4	4	0.938167	2	0.0087	4	0.156	2	0.002067	4	0.0216	1	0.0063	3	0.73	3	0.0046
5	4	0.941333	2	0.008867	4	0.157133	2	0.0021	4	0.0229	1	0.0064	3	0.735	3	0.0049
6	4	0.942833	2	0.008967	3	0.159	2	0.002267	3	0.023	1	0.006433	3	0.737	5	0.0049
7	3	0.944	2	0.009	3	0.16	2	0.002387	5	0.023333	1	0.006533	4	0.738	12	0.0050
8	3	0.950	2	0.009033	4	0.162	2	0.002425	5	0.023333	1	0.006567	10	0.74	4	0.005233
9	3	0.951	2	0.0092	4	0.162333	2	0.002533	7	0.0234	1	0.006633	10	0.746667	4	0.0053
10	10	0.953	2	0.00931	3	0.163			10	0.0235	1	0.0067	6	0.750667	4	0.005467
11	14	0.960667	2	0.009328	5	0.1662			4	0.023967	3	0.0068	5	0.753667		
12	4	0.969333			4	0.166333			4	0.0244	3	0.007	4	0.755333		
13	10	0.976667			4	0.166667			14	0.026133	1	0.007033	4	0.765667		
14	7	0.989333			10	0.17			4	0.026333	10	0.0075	4	0.766667		
15					14	0.170333					1	0.007667	14	0.769333		
16					5	0.1746					1	0.008523	4	0.769333		
17					10	0.183333							4	0.773333		
Average		0.9486		0.00878		0.1648		0.00216		0.02284		0.00675		0.7546		0.00492
Std dev		0.0053		0.00032		0.0029		0.00021		0.00092		0.00022		0.0055		0.00024
H		0.009		0.00065		0.0029		0.00039		0.0010		0.00059		0.0080		0.00052
U ₁		0.011		0.00073		0.0041		0.00044		0.0014		0.00063		0.0097		0.00057
t-statistic		2.16		2.23		2.12		2.31		2.16		2.13		2.12		2.26
U ₂		0.023		0.0016		0.0087		0.0010		0.0029		0.0013		0.021		0.0013
U ₃		0.0063		0.00049		0.0021		0.00034		0.00079		0.00034		0.0050		0.00041
Certified		0.949		0.0088		0.165		0.0022		0.0228		0.0068		0.75		0.0049
Uncertainty		0.009		0.0005		0.005		0.0003		0.0008		0.0003		0.01		0.0004
Tolerance		0.023		0.0016		0.009		0.0010		0.0029		0.0013		0.02		0.0013

BS 48B * Code for method Certified values listed as weight percent

Analysis	*	Ti	*	V	*	W
1	12	0.0021	5	0.025	5	0.020233
2	5	0.002367	5	0.25333	10	0.0238
3	5	0.002567	7	0.0285	4	0.0247
4	10	0.0028	4	0.0295	3	0.0251
5	5	0.002823	4	0.030667	5	0.0258
6	5	0.0029	4	0.030667	4	0.025967
7	4	0.002993	4	0.031767	12	0.0260
8	4	0.003	4	0.032967	4	0.026467
9	4	0.003267	3	0.033	3	0.0266
10	3	0.0038	3	0.034	14	0.0277
11	3	0.0041	12	0.0345	5	0.0290
12	4	0.0042	14	0.035267		
13	14	0.0043	5	0.035767		
14			3	0.037		
15			5	0.0378		
Average		0.00315		0.0327		0.0262
Std dev		0.00014		0.0012		0.0013
H		0.00044		0.0012		0.0011
U ₁		0.00046		0.0017		0.0017
t-statistic		2.18		2.14		2.23
U ₂		0.0010		0.0036		0.0037
U ₃		0.00028		0.00092		0.0011
Certified		0.0031		0.033		0.026
Uncertainty		0.0003		0.003		0.001
Tolerance		0.0010		0.004		0.004

BS 48B * Code for method Informational values listed as weight percent

Analysis	*	B	*	Ca	*	Mg	*	Nb	*	Pb	*	Sb	*	Zn	*	Zr
1	3	0.00009	4	0.0020	3	0.00009	5	0.0004	12	0.000012	5	0.0009	12	0.000059	3	0.0009
2	5	0.00011	4	0.00225	5	0.00013	4	0.0006	5	0.000015	5	0.0012	5	0.000467	3	0.001
3	12	0.00016	3	0.00244	3	0.00017	5	0.000643	3	0.0002	5	0.0013			12	0.0012
4	3	0.00024	4	0.0025	12	0.00037	4	0.000967	3	0.00053	12	0.0016			5	0.0012
5	3	0.0003	5	0.002833	4	0.0004	12	0.0021			5	0.001633			4	0.0034
6	5	0.000533	14	0.0038			4	0.003533								
7			5	0.0040												
8			3	0.00509												
9			4	0.005267												
Average		0.00024		0.003		0.00023		0.0014		0.00019		0.0013		0.00026		0.0015
Std dev		0.00017		0.020		0.00017		0.0056		0.00012		0.0058		0.00036		0.0075
H		0.00023		0.000		0.00022		0.0003		0.00022		0.0003		0.00023		0.0003
U ₁		0.00028		0.020		0.00028		0.0056		0.00025		0.0058		0.00043		0.0075
t-statistic		2.57		2.31		2.78		2.57		3.18		2.78		12.71		2.78
U ₂		0.00073		0.045		0.00079		0.014		0.00079		0.016		0.0054		0.021
U ₃		0.00030		0.015		0.00035		0.0059		0.00040		0.0072		0.0038		0.0093
(Informational)		(0.0002)		(0.003)		(0.0002)		(0.001)		(0.0002)		(0.001)		(0.0003)		(0.002)

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. 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:

$$C_L = \sqrt{S_L^2 + U_L^2} \quad W_L = \frac{1}{C_L^2} \quad A = \frac{\sum_{i=1}^n W_L M_L}{\sum_{i=1}^n W_L} \quad S = \frac{1}{\sqrt{\sum_{i=1}^n W_L}} \quad U_1 = \sqrt{H^2 + S^2} \quad U_2 = t \times U_1 \quad U_3 = \frac{U_2}{\sqrt{n}}$$

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 48B * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis	* CI	* Ga	* Ge	* K	* Na	* Re
1	12 0.23	12 11	5 3	12 0.21	12 0.16	12 0.62
2		5 18	5 3			5 1.0
3		5 19	5 6			5 1.1
4		5 23	12 20			5 1.1
5			5 24			
6			5 24			
7			5 24			

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

<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
Laboratory Testing, Inc.	Hatfield, PA	PRI/Nadcap	17025
NSL Analytical	Cleveland, OH	ACCLASS	17025
Luvak Inc.	Boylston, MA	PRI/Nadcap	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Evans Analytical Group	Liverpool, New York	A2LA	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	AB 554
Northern Analytical Laboratory, Inc.	Londonderry, NH	PRI/Nadcap	17025
Brammer Standard Company, Inc.	Houston, TX	A2LA	17025, Guide 34

A2LA = American Association for Laboratory Accreditation
ACCLASS = ANSI-ASQ National Accreditation Board
CNAS = China National Accreditation Service
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 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: 12X353, 12X356, 12X52986, 13X14212, 13X31254, 13X41001, 13X41001A, 13X43100; 501-024, 501-320, 501-501, 501-502, 501-503, 501-504, 501-644, 501-646, 501-661, 501-664, 501-675, 501-991, 501-993, 502-195, 502-257, 502-348, 502-416, 502-869; AR 644, 657, 659, 668, 673, 688, 875, 882, 1647, 1652, 1656; BAS 69, 72, 464/1; BS CA304-2, CSN-2D, XDDF, 0232P, 30D, 47, 48, 56H, 90E, 97, 183A, 316C, 316E, 410C, 1030, 3941, 8620, 9902; ECRM 85-1, 86-1, 87-1; IARM 1D, 41C, 42B, 205B; IMZ 1.85, 112, 156, 161, 171, 503; JK 37; IPT 208Fe; SRM C1151A, 50C, 73B, 101E, 133A, 133B, 160B, 361, 362, 363, 862, 1243, 1246, 1249, 1263A, 1264A, 1413, 1763A, 2159, 3107, 3137, 3139A, 3155, 3162A, 3163, 3169.

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, 502-257; BS HON-T, XDDF, 0232P, 47, 48, 90E, 97, 9905; ECRM 096-1; IARM 205B; KMS HCS-001; NCS NS20035B; SRM 30F.

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 48B 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 Metal Ravne, Slovenia.

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 48B-091815. You may obtain information on

Brammer Standard Company, Inc., 14603 Benfer Road, Houston, TX 77069-2895
Telephone: (281) 440-9396 Fax: (281) 440-4432 Website: www.brammerstandard.com
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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, 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 September 18, 2015.

Beau R. Brammer