

BRAMMER STANDARD COMPANY, INC.

Certificate of Analysis

BS 9905A

Certified Reference Material for Steel Alloy number F-91 (ASTM 182) - UNS Number K90901

	Certified Value ¹	Estimate of Uncertainty ²	Certified Values³	Certified Value ¹	Estimate of Uncertainty ²	
Al	0.0186	0.0008		Si	0.34	0.01
As	0.0065	0.0005		Sn	0.0060	0.0008
C	0.113	0.004		Ti	0.0023	0.0006
Co	0.0136	0.0005		V	0.216	0.006
Cr	8.75	0.09		W	0.0024	0.0007
Cu	0.091	0.004				
Fe	88.9	0.3				
Mn	0.465	0.007				
Mo	0.95	0.01				
N	0.034	0.002				
Nb	0.074	0.004				
Ni	0.152	0.004				
O	0.0024	0.0005				
P	0.0133	0.0007				
S	0.0040	0.0006				

Informational Values^{3,4}

B (0.0005)	Ca (0.002)	Mg (0.0004)	Pb (0.002)	Sb (0.003)
Ta (0.01)	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 Ga, Ge, Re, 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 9905A

* Code for method Certified values listed as weight percent

Analysis	*	Al	*	As	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mn
1	5	0.016467	4	0.0059	1	0.1082	4	0.011433	4	8.4500	10	0.065	16	[88.70863]	4	0.45
2	4	0.017433	4	0.0059	1	0.109667	3	0.012233	4	8.48	5	0.077667	13	88.73	10	0.454
3	4	0.0181	4	0.005967	1	0.109867	4	0.012667	10	8.527	4	0.083633	16	[88.74667]	3	0.456
4	14	0.018267	4	0.006433	3	0.11	12	0.0131	4	8.553333	4	0.085667	16	[88.75]	4	0.456467
5	4	0.018667	5	0.006567	1	0.1103	4	0.013233	10	8.636667	4	0.086667	3	88.80	3	0.457467
6	3	0.0188	5	0.0067	1	0.1115	5	0.013333	4	8.646667	14	0.087567	14	88.8	4	0.459433
7	4	0.018933	15	0.006797	1	0.1122	4	0.013567	4	8.654667	3	0.0881	10	88.87667	14	0.460667
8	3	0.019	5	0.006833	1	0.112967	4	0.013567	3	8.683333	10	0.089	16	[88.89667]	4	0.463
9	5	0.0190	12	0.006867	1	0.115667	5	0.013667	14	8.713333	4	0.089333	4	88.94	10	0.466
10	5	0.0190	9	0.006967	1	0.117	10	0.0137	17	8.7152	5	0.090867	4	89.36667	3	0.469
11	12	0.01925	3	0.0076	1	0.118867	8	0.0139	13	8.725	3	0.092			4	0.4690
12	4	0.019867	5	0.007867	1	0.119	3	0.014	4	8.736333	5	0.092167			4	0.469
13	4	0.019967			3	0.119283	5	0.014067	13	8.76	10	0.0936			3	0.47
14					3	0.12	5	0.014467	10	8.77	4	0.093667			4	0.471
15					1	0.121333	14	0.0150	13	8.7725	4	0.095667			4	0.471
16							3	0.0152	3	8.78	4	0.0966			8	0.472667
17							4	0.0153	4	8.79	4	0.097267			4	0.473033
18							5	0.016733	3	8.81980	8	0.097733			10	0.474
19									3	8.90	3	0.0986			4	0.478
20											12	0.0990				
21											3	0.100778				
22											4	0.102667				
Average		0.01861		0.00646		0.1126		0.01362		8.747		0.0909		88.895		0.4648
Std dev		0.00080		0.00031		0.0024		0.00054		0.039		0.0020		0.041		0.0040
H		0.0010		0.00066		0.0026		0.0009		0.053		0.0023		0.41		0.0062
U ₁		0.0013		0.00073		0.0036		0.0011		0.066		0.0030		0.41		0.0073
t-statistic		2.18		2.20		2.14		2.11		2.10		2.08		2.26		2.10
U ₂		0.0029		0.0016		0.0076		0.0022		0.14		0.0063		0.94		0.015
U ₃		0.00079		0.00046		0.0020		0.00052		0.032		0.0014		0.30		0.0035
Certified		0.0186		0.0065		0.113		0.0136		8.75		0.091		88.9		0.465
Uncertainty		0.0008		0.0005		0.004		0.0005		0.09		0.004		0.3		0.007
Tolerance		0.0029		0.0016		0.012		0.0022		0.27		0.016		0.9		0.021

Analysis	*	Mo	*	N	*	Nb	*	Ni	*	O	*	P	*	S	*	Si
1	4	0.922667	2	0.031275	5	0.066033	3	0.141	2	0.00187	5	0.0108	3	0.003	12	0.2870
2	4	0.926667	2	0.031833	4	0.0677	3	0.145133	2	0.001875	5	0.0112	1	0.0033	4	0.294667
3	4	0.9381	2	0.0325	5	0.069433	14	0.147	2	0.002083	10	0.011733	1	0.003367	5	0.317333
4	4	0.94	2	0.032833	10	0.07	4	0.1481	2	0.00231	7	0.0123	10	0.0037	10	0.324333
5	10	0.946667	2	0.033433	10	0.072467	4	0.1486	2	0.0025	3	0.0128	4	0.003967	3	0.33
6	4	0.947467	2	0.033907	4	0.0729	5	0.149667	2	0.002733	3	0.012933	1	0.004167	5	0.333333
7	10	0.948	2	0.0345	5	0.0730	3	0.15	2	0.003133	4	0.0135	1	0.0042	3	0.334
8	14	0.948667	2	0.034933	4	0.074533	4	0.15	2	0.003383	4	0.013533	1	0.004367	14	0.339333
9	3	0.95	2	0.036667	3	0.074856	10	0.151333	2	0.004267	4	0.0136	12	0.004467	6	0.343667
10	4	0.950533	2	0.037833	12	0.0760	4	0.151667	2	0.0043	5	0.013667	1	0.0046	6	0.344667
11	4	0.961000			4	0.0774	8	0.151667	4	0.013833	1	0.013833	1	0.004733	3	0.346
12	3	0.961			14	0.077867	12	0.153333		3	0.014	1	0.004743	4	0.348667	
13	7	0.962			4	0.0783	4	0.154		10	0.014	1	0.004833	4	0.349667	
14	3	0.964333			4	0.078967	3	0.154333		14	0.0141	1	0.0050	10	0.35	
15	3	0.97			10	0.080	4	0.155333		7	0.014167			4	0.350067	
16	4	0.976667			4	0.080067	4	0.156667		4	0.0144			4	0.351333	
17	10	0.98					4	0.1590		4	0.014667	12		4	0.356667	
18	4	0.980333					10	0.162						4	0.364333	
19							5	0.1624						3	0.372233	
20														4	0.373667	
Average		0.9512		0.0336		0.0738		0.1518		0.002423		0.01331		0.00404		0.3430
Std dev		0.0055		0.0012		0.0018		0.0035		0.000080		0.00062		0.00015		0.0040
H		0.010		0.0014		0.0021		0.0031		0.00046		0.0009		0.00055		0.0051
U ₁		0.011		0.0018		0.0028		0.0047		0.00047		0.0011		0.00057		0.0065
t-statistic		2.11		2.26		2.13		2.10		2.26		2.12		2.16		2.09
U ₂		0.024		0.0042		0.0059		0.010		0.0011		0.0023		0.0012		0.014
U ₃		0.0057		0.0013		0.0015		0.0023		0.00034		0.00056		0.00033		0.0030
Certified		0.95		0.034		0.074		0.152		0.0024		0.0133		0.0040		0.34
Uncertainty		0.01		0.002		0.004		0.004		0.0005		0.0007		0.0006		0.01
Tolerance		0.03		0.006		0.016		0.012		0.0015		0.0025		0.0018		0.03

BS 9905A * Code for method Certified values listed as weight percent

Analysis	*	Sn	*	Ti	*	V	*	W
1	4	0.002233	4	0.001067	4	0.205333	3	0.0012
2	5	0.005267	10	0.0020	10	0.207	4	0.001767
3	5	0.005667	5	0.0022	3	0.207844	10	0.0018
4	4	0.005733	5	0.0023	4	0.21	5	0.00262
5	5	0.0059	5	0.002467	3	0.21	4	0.002733
6	4	0.0060	5	0.00260	3	0.214	5	0.003033
7	5	0.006233	12	0.002633	4	0.216	5	0.0031
8	5	0.006413	3	0.0028	4	0.216	5	0.0031
9	3	0.0067	5	0.0028	4	0.216467	5	0.0032
10	4	0.007067	4	0.002933	4	0.217	12	0.003467
11	9	0.007133	14	0.003067	5	0.217333		
12	4	0.008867	4	0.003167	14	0.221333		
13	3	0.010883	4	0.004367	4	0.222		
14					3	0.222333		
15					10	0.222333		
16					12	0.2250		
17					7	0.225667		
Average		0.00600		0.002321		0.2161		0.00239
Std dev		0.00018		0.000069		0.0033		0.00026
H		0.00064		0.00046		0.0038		0.00046
U ₁		0.00067		0.00046		0.0050		0.00053
t-statistic		2.18		2.18		2.12		2.26
U ₂		0.0015		0.0010		0.011		0.0012
U ₃		0.00040		0.00028		0.0026		0.00038
Certified		0.0060		0.0023		0.216		0.0024
Uncertainty		0.0008		0.0006		0.006		0.0007
Tolerance		0.0024		0.0018		0.018		0.0021

BS 9905A * Code for method Informational values listed as weight percent

Analysis	*	B	*	Ca	*	Mg	*	Pb	*	Sb	*	Ta	*	Zr
1	5	0.000173	14	0.001267	5	0.00018	5	0.00002467	5	0.002633	5	0.000267	5	0.0000567
2	3	0.00018	3	0.0013	5	0.000233	12	0.0000357	5	0.002833	5	0.000427	4	0.0002
3	12	0.000257	4	0.001467	12	0.000255	4	0.0009333			4	0.003133	5	0.0003533
4	5	0.0003	4	0.001547	4	0.000733	3	0.003			4	0.005133	4	0.0007333
5	4	0.000333	12	0.00215			3	0.0057			3	0.038867	4	0.0008333
6	4	0.0004	4	0.002167									3	0.001
7	7	0.00041											4	0.0026333
8	4	0.0005											3	0.0068223
9	3	0.000713												
10	4	0.00095												
11	14	0.000967												
Average		0.00047		0.0016		0.00035		0.002		0.003		0.010		0.0016
Std dev		0.00053		0.0071		0.00048		0.010		0.028		0.096		0.0057
H		0.00029		0.0004		0.00027		0.000		0.000		0.001		0.0004
U ₁		0.00060		0.0072		0.00055		0.010		0.028		0.096		0.0058
t-statistic		2.23		2.57		3.18		2.78		12.71		2.78		2.36
U ₂		0.0013		0.018		0.0017		0.028		0.35		0.27		0.014
U ₃		0.00040		0.0075		0.00087		0.013		0.25		0.12		0.0048
(Informational)		(0.0005)		(0.002)		(0.0004)		(0.002)		(0.003)		(0.01)		(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 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 9905A * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis *	Ga	Ge	Re	Zn
1	5 12	5 8	5 0.68	12 0.31
2	5 13	5 9	5 1.1	12 0.70
3	5 14	5 9	5 1.3	12 1.2
4	5 14	5 15	5 2	5 4
5	5 14	5 25	5 2	5 4
6	5 16	5 29	5 2	5 6

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 | 17 Wet |
| 6 Gravimetric | 12 GD Mass Spectrometry | |

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

Laboratory

Brammer Standard Company, Inc.

Location

Houston, TX

Registrar

A2LA

Accreditation

17025, Guide 34

Brammer Standard Company, Inc., 14603 Benfer Road, Houston, TX 77069-2895

Telephone: (281) 440-9396 Fax: (281) 440-4432 Website: www.brammerstandard.com

Certificate Number 9905A-011917 Page 4/7

NSL Analytical	Cleveland, OH	ANAB	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	AB 554
Anderson Laboratories, Inc.	Greendale, WI	A2LA	17025
Dirats Laboratories	Westfield, MA	ANAB	17025
TUV Rheinland India Pvt Ltd.	Karnataka, India	NABC	17025
Luvak Inc.	Boylston, MA	PRI/Nadcap	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI/Nadcap	17025
Evans Analytical Group	Liverpool, NY	A2LA	17025
Exova	Glendale Heights, IL	A2LA	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025

A2LA = American Association for Laboratory Accreditation

ANAB = 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: 12X722M24, 12XLA5, 13X15023, 13X431000A; BAS 69, 331, 406, 409, 460, 464/1, 473, 4952; BS 30D, 47A, 47B, 48A, 56H, 61G, 153, 316E, 410B, 422; CKD 184A, 187A; ECRM 085-1, 86, 87, 296-1; IARM 36A, 36B, 41C, 42B, 238A, 299A; IMZ 112, 123, 160, 167, 170, 171; JK 31, 37; LECO 501-320, 501-501, 501-502, 501-503, 501-504, 501-644, 501-674, 501-677, 501-993, 502-257, 502-416, 502-449; AR 637, 646, 668, 673, 872, 875, 892, 1647, 1648, 1652, 1653; SRM 15G, 36, 55D, 101C, 101E, 126, 129A, 133A, 133B, 160B, 343A, 361, 362, 363.

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 — BAS 4-94, 473; BS 47A, 47B, 48A, 48B, 410B, 422; ECRM 230-1; IMZ 170; LECO 501-676, 502-869, 502-873; SRM 343A.

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 9905A 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 9905A-011917. 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 30:2015 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, 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

Certified by: _____ on January 19, 2017.

Beau R. Brammer