

# Brammer Standard Company, Inc.

## Certificate of Analysis

### BS T-4B

Certified Reference Material for ASTM B348(4) Grade 4 Pure Titanium - UNS Number R50700

	Certified Value <sup>1</sup>	Estimate of Uncertainty <sup>2</sup>	Certified Values <sup>3</sup>	Certified Value <sup>1</sup>	Estimate of Uncertainty <sup>2</sup>
<b>Al</b>	<b>0.038</b>	0.003	<b>O</b>	<b>0.370</b>	0.007
<b>Cr</b>	<b>0.0095</b>	0.0006	<b>Ti</b>	<b>99.5</b>	0.3
<b>H</b>	<b>0.0020</b>	0.0004	<b>V</b>	<b>0.009</b>	0.001

	Reference Value <sup>1</sup>	Estimate of Uncertainty <sup>2</sup>	Reference Values <sup>3,4</sup>	Reference Value <sup>1</sup>	Estimate of Uncertainty <sup>2</sup>
<b>B</b>	<b>0.0004</b>	0.0002	<b>N</b>	<b>0.006</b>	0.002
<b>C</b>	<b>0.03</b>	0.01	<b>Ni</b>	<b>0.010</b>	0.002
<b>Co</b>	<b>0.009</b>	0.004	<b>S</b>	<b>0.0007</b>	0.0004
<b>Cu</b>	<b>0.005</b>	0.002	<b>Si</b>	<b>0.006</b>	0.003
<b>Fe</b>	<b>0.16</b>	0.02	<b>Sn</b>	<b>0.009</b>	0.002
<b>Mn</b>	<b>0.0007</b>	0.0005	<b>W</b>	<b>&lt;0.05</b>	
<b>Mo</b>	<b>0.002</b>	0.001	<b>Zr</b>	<b>0.0010</b>	0.0005

### Informational Values<sup>3,5</sup>

Nb (0.012)

<sup>1</sup> 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.

<sup>2</sup> 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.

<sup>3</sup> Values are given in weight percent. Values in brackets are reported by difference.

<sup>4</sup> Reference values are not certified and are provided for information only.

<sup>5</sup> Informational values are not certified and are provided for information only.

Trace element information values for As, P, Sb, Ta, and Zn are shown on page 4.

The requirements of ISO Guides 30, 31, and 35 were followed for the preparation of this Certified Reference Material and certificate of analysis.

**BS T-4B**

\* Code for method

Certified values listed as weight percent

Analysis	*	Al	*	Cr	*	H	*	O	*	Ti	*	V
1	14	0.03	4	0.0078	2	0.0013867	2	0.36	10	99.30333	3	0.0074
2	4	0.0338	4	0.0088533	2	0.0016	2	0.363	3	99.31	10	0.0074333
3	5	0.0357667	4	0.0089667	2	0.0016667	2	0.365	4	99.31	4	0.0076
4	4	0.0360667	10	0.009	2	0.0018	2	0.3688	16	99.32	4	0.0078
5	3	0.0363	4	0.0090667	2	0.0020667	2	0.37	4	99.34633	4	0.0080667
6	10	0.037	5	0.0091	2	0.0022333	2	0.37167	16	99.35997	4	0.00854
7	4	0.0374333	11	0.0092	2	0.0024	2	0.37333	14	99.4	4	0.009
8	4	0.0376333	4	0.0092	2	0.0024333	2	0.37633	16	99.5192	5	0.0091
9	4	0.0376667	3	0.0094	2	0.0044333	2	0.383	16	99.68	14	0.0091667
10	4	0.0380667	4	0.0094333					4	99.68057	4	0.0097
11	4	0.039	5	0.0097					16	99.70667	4	0.0097
12	11	0.0394	14	0.01					16	99.72	4	0.0098
13	4	0.0400333	4	0.0102					16	99.76783	5	0.0098667
14	3	0.0406667	4	0.011							10	0.0104
15	10	0.0409									11	0.0106
16	4	0.0431667										
17	10	0.0503333										
Average		0.0382		0.00951		0.002030		0.37013		99.496		0.008945
Std Dev		0.0011		0.00029		0.000087		0.00011		0.029		0.000082
H		0.0019906		0.0010585		0.0005587		0.00626		0.193007		0.0010308
U <sub>1</sub>		0.0023		0.0011		0.00057		0.0063		0.20		0.0010
t-statistic		2.1199053		2.1603687		2.3060041		2.306		2.178813		2.1447867
U <sub>2</sub>		0.0048		0.0024		0.0013		0.014		0.43		0.0022
U <sub>3</sub>		0.0012		0.00063		0.00043		0.0048		0.12		0.00057
Certified		<b>0.038</b>		<b>0.0095</b>		<b>0.0020</b>		<b>0.370</b>		<b>99.5</b>		<b>0.009</b>
Uncertainty		0.003		0.0006		0.0004		0.007		0.3		0.001
Tolerance		0.009		0.0024		0.0013		0.021		0.9		0.003

**BS T-4B**

\* Code for method

Reference values listed as weight percent

Analysis	*	B	*	C	*	Co	*	Cu	*	Fe	*	Mn	*	Mo	*	N	*	Ni	*	S
1	11	0.0003	1	0.0166667	10	0.0034667	5	0.00287	14	0.145333	5	0.00015	5	0.0013	2	0.0036	3	0.0074	3	0.0002
2	5	0.0003833	1	0.0167333	4	0.0046	14	0.00343	4	0.145333	3	0.0002	3	0.0013333	2	0.004733	3	0.0077	1	0.000357
3	4	0.0006	3	0.0175	11	0.0052	11	0.0045	10	0.147	5	0.0004967	5	0.0014333	2	0.005	4	0.0082	1	0.000423
4			1	0.02	14	0.0053667	4	0.00453	3	0.147	4	0.0010	10	0.0019333	2	0.005167	4	0.0086	1	0.000525
5			1	0.0210833	4	0.0241667	4	0.00587	4	0.148667	14	0.0010667	5	0.0019567	2	0.005433	5	0.008733	11	0.0006
6			1	0.024			4	0.00597	3	0.158333	11	0.0014	11	0.0027	2	0.006267	11	0.0088	1	0.000733
7			1	0.0250667			5	0.00643	4	0.160333			4	0.0027667	2	0.00675	4	0.009133	1	0.0011
8			1	0.0279			3	0.0069	11	0.165			14	0.0028333	2	0.007023	10	0.009633	1	0.002
9			1	0.03825					10	0.166667			4	0.0030333	2	0.007067	4	0.009637		
10			1	0.0482					4	0.169867			4	0.0031667	2	0.007767	5	0.009867		
11			1	0.0536667					4	0.170733			4	0.0034	2	0.007803	4	0.0099		
12									5	0.174			3	0.0034			10	0.010		
13									4	0.183067			10	0.0035667			10	0.010167		
14									4	0.185							4	0.0109		
15									4	0.187667							4	0.011533		
16									4	0.191733							4	0.013		
Average		0.00043		0.028097		0.009		0.00506		0.165358		0.0007		0.002525		0.00611		0.009575		0.0007
Std Dev		0.00083		0.000095		0.084		0.00011		0.000079		0.0016		0.000088		0.00028		0.000079		0.0015
H		0.000314		0.0017235		0.0010335		0.00081		0.004102		0.0003736		0.0006091		0.000876		0.001062		0.000374
U <sub>1</sub>		0.00089		0.0017		0.084		0.00082		0.0041		0.0017		0.00062		0.00092		0.0011		0.0015
t-statistic		4.3026527		2.2281389		2.7764451		2.36462		2.13145		2.5705818		2.1788128		2.228139		2.13145		2.364624
U <sub>2</sub>		0.0038		0.0038		0.23		0.0019		0.0087		0.0043		0.0013		0.0021		0.0023		0.0036
U <sub>3</sub>		0.0022		0.0012		0.10		0.00068		0.0022		0.0018		0.00037		0.00062		0.00057		0.0013
Reference		<b>0.0004</b>		<b>0.03</b>		<b>0.009</b>		<b>0.005</b>		<b>0.16</b>		<b>0.0007</b>		<b>0.002</b>		<b>0.006</b>		<b>0.010</b>		<b>0.0007</b>
Uncertainty		0.0002		0.01		0.004		0.002		0.02		0.0005		0.001		0.002		0.002		0.0004
Tolerance		0.0003		0.02		0.008		0.004		0.06		0.0006		0.001		0.005		0.006		0.0006

**BS T-4B** \* Code for method Reference values listed as weight percent

Analysis	*	Si	*	Sn	*	W	*	Zr
1	10	0.0029333	5	0.0071667	3	0.000031	5	0.00054
2	4	0.0046	5	0.0072333	5	0.0001533	5	0.00067
3	4	0.0047667	4	0.0076667	4	0.0003667	4	0.0010
4	4	0.0051333	5	0.00803	5	0.0012733	3	0.0014
5	3	0.0055333	10	0.0089	11	0.0126	10	0.00157
6	14	0.0056667	10	0.0094667				
7	4	0.0063	4	0.0096333				
8	4	0.0067633	4	0.0096333				
9	10	0.007	3	0.01				
10	5	0.0073333	4	0.0100667				
11	3	0.0078	4	0.0104				
12	4	0.0089333	4	0.0105				
13			11	0.011				
<b>Average</b>		0.006064		0.009207		0.003		0.0010
<b>Std Dev</b>		0.000091		0.000088		0.019		0.0035
<b>H</b>		0.0008728		0.0010438		0.0006526		0.00043
<b>U<sub>1</sub></b>		0.00088		0.0010		0.019		0.0035
<b>t-statistic</b>		2.2009852		2.1788128		2.7764451		2.77645
<b>U<sub>2</sub></b>		0.0019		0.0023		0.053		0.0098
<b>U<sub>3</sub></b>		0.00056		0.00063		0.024		0.0044
		<b>0.006</b>		<b>0.009</b>		<b>&lt;0.05</b>		<b>0.0010</b>
<b>Uncertainty</b>		0.003		0.002				0.0005
<b>Tolerance</b>		0.005		0.006				0.0009

**BS T-4B** \* Code for method Informational values listed as weight percent

Analysis	*	Nb
1	5	0.0002567
2	4	0.0020
3	3	0.017
4	4	0.0177
5	4	0.0181333
6	11	0.0198
<b>Average</b>		0.01159
<b>Std Dev</b>		0.00057
<b>H</b>		0.0011543
<b>U<sub>1</sub></b>		0.0013
<b>t-statistic</b>		2.5705818
<b>U<sub>2</sub></b>		0.0033
<b>U<sub>3</sub></b>		0.0014
<b>Certified</b>		(0.012)

For each element, in accordance with the requirements of ISO 17034 and Guide 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 T-4B

\* Code for analytical method

Trace analysis listed as mg/kg (ppm)

Analysis	*	As	*	P	*	Sb	*	Ta	*	Zn										
1	5	11.2	5	7	5	4.0	5	0.9	5	23.2										
2	5	12.0	5	7	5	4.0	5	1.0	5	24.0										
3	5	12.3	5	7	5	4.3	5	1.0	5	24.3										

#### 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

Lab Name	Location	Registrar	Accreditation
Brammer Standard Company, Inc.	Houston, TX	A2LA	17025, 17034
NSL Analytical	Cleveland, OH	ANAB	17025
Dirats Laboratories	Westfield, MA	ANAB	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
Element Materials Technology	Glendale Heights, IL	A2LA	17025
Luvak Inc.	Boylston, MA	PRI	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI	17025
Shiva Analyticals Private Limited	Hoskote, Bangalore	NABL	17025
TUV Rheinland Pvt Ltd	Bangalore, India	NABL	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
APL, Inc	Milwaukee, WI	A2LA	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	17025

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

**Analysis:** Chemical analyses were made on solid pieces and chips prepared by or 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: AR 114C, 582, 585, 586, 589, 592, 631, 637, 641, 642, 647, 648, 649, 650, 651, 711B, 869, 892, 920K, 1216B; BAS 356; BS T-2, T-4, T-4A, T-5A, T-23, T-24, T-24A, T-26, T-80, T-81; DSZU CA017, CA018, CA019; IARM Ti64P18, Ti662-18, 174A, 174B, 174C, 271B, 303B, 312B; LECO 501-201, 502-888, 502-891, 502-947, 503-511; NCS 23901; SRM 173, 173A, 173B, 173C, 174, 176, 647, 649.

**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: BS T-2, T-2A, T-4A, T-26, T-80, T-81; IARM 303B.

**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 T-4B is valid indefinitely. The certification is nullified if this CRM is damaged, contaminated, or otherwise modified.

**Storage:** This CRM must be stored in a cool, dry, non-corrosive environment.

**Source:** The bar stock for this CRM was produced by TSI Titanium; Derby, PA.

**Form:** This CRM is machined in the form of a disc, approximately 38mm in diameter and 19mm 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.

Caution: CRM contains significant insoluble soft metal inclusions. Surface smearing may occur. Spark atomic emission spectrometers may require extended preburns to compensate.

**Certificate Number:** The unique identification number for this certificate of analysis is T-4B-112922. You may obtain information on revisions of certificates from the internet at [www.brammerstandard.com](http://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.**  
14603 Benfer Road  
Houston, Texas 77069-2895 USA

**Phone: (281) 440-9396**  
**Fax: (281) 440-4432**

**Web: [www.brammerstandard.com](http://www.brammerstandard.com)**  
**Email: [contact@brammerstandard.com](mailto:contact@brammerstandard.com)**

**Brammer Standard Company, Inc., is accredited by the American Association For Laboratory Accreditation (A2LA) to ISO Standard 17034 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 by National Quality Assurance (NQA), U.S.A.**

**The scopes of accreditation are listed on the website: [www.brammerstandard.com](http://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 17025:2017 General requirements for the competence of testing and calibration laboratories

ISO Standard 9001:2015 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 Standard 17034:2016 General requirements for the competence of reference material producers

ISO Guide 35:2017 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](http://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 November 29, 2022.

Beau R. Brammer

President