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 Values[3]

	Certified Value[1]	Estimate of Uncertainty[2]		Certified Value[1]	Estimate of Uncertainty[2]
Al	**0.038**	0.003	**O**	**0.37**	0.02
Cr	**0.0095**	0.0006	**S**	**0.0005**	0.0003
H	**0.0020**	0.0006	**Ti**	**99.5**	0.3
N	**0.006**	0.001	**V**	**0.009**	0.001

Reference Values[3,4]

	Reference Value[1]	Estimate of Uncertainty[2]		Reference Value[1]	Estimate of Uncertainty[2]
B	**0.0004**	0.0002	**Mo**	**0.002**	0.001
C	**0.03**	0.02	**Ni**	**0.010**	0.002
Co	**0.009**	0.004	**Si**	**0.006**	0.003
Cu	**0.005**	0.002	**Sn**	**0.009**	0.002
Fe	**0.16**	0.02	**W**	**<0.05**	
Mn	**0.0007**	0.0005	**Zr**	**0.0010**	0.0005

Informational Values[3,5]

Nb (0.012)

[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 3 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 3 for more information on its calculation.

[3] Values are given in weight percent. Values in brackets are reported by difference.

[4] Reference values are not certified and are provided for information only.

[5] 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 and Standards 33401 and 33405 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	*	N	*	O	*	S	*	Ti	*	V
1	14	0.03	4	0.0078	2	0.0011267	2	0.0036	2	0.36	3	0.0002	10	99.303333	3	0.0074
2	4	0.0338	4	0.0088533	2	0.0013867	2	0.004733	2	0.363	1	0.0003567	3	99.31	10	0.007433
3	5	0.0357667	4	0.0089667	2	0.0014667	2	0.005	2	0.365	1	0.0004233	4	99.31	4	0.0076
4	4	0.0360667	10	0.009	2	0.0016	2	0.005167	2	0.3688	1	0.000525	16	99.32	4	0.0078
5	3	0.0363	4	0.0090667	2	0.0016667	2	0.005433	2	0.37	11	0.0006	4	99.346333	4	0.008067
6	10	0.037	5	0.0091	2	0.0016667	2	0.0055	2	0.371667	1	0.0007333	16	99.359967	4	0.00854
7	4	0.0374333	11	0.0092	2	0.0017333	2	0.0058	2	0.373333	1	0.0011	14	99.4	4	0.009
8	4	0.0376333	4	0.0092	2	0.0018	2	0.006267	2	0.374			16	99.5192	5	0.0091
9	4	0.0376667	3	0.0094	2	0.0020667	2	0.0065	2	0.376333			16	99.68	14	0.009167
10	4	0.0380667	4	0.0094333	2	0.0022333	2	0.006633	2	0.376667			4	99.680567	4	0.0097
11	4	0.039	5	0.0097	2	0.0024	2	0.00675	2	0.380333			16	99.706667	4	0.0097
12	11	0.0394	14	0.01	2	0.0024333	2	0.007023	2	0.383			16	99.72	4	0.0098
13	4	0.0400333	4	0.0102	2	0.00443	2	0.007067	2	0.383			16	99.767833	5	0.009867
14	3	0.0406667	4	0.011			2	0.007767	2	0.389667					10	0.0104
15	10	0.0409					2	0.007803							11	0.0106
16	4	0.0431667														
17	10	0.0503333														
Average		0.0382		0.00951		0.001971		0.00610		0.3732		0.000466		99.496		0.008945
Std Dev		0.0011		0.00029		0.000076		0.00027		0.0052		0.000040		0.029		0.000082
H		0.0019906		0.0010585		0.00055		0.00087		0.0063		0.00032		0.1930067		0.001031
U_1		0.0023		0.0011		0.00056		0.00092		0.0081		0.00033		0.20		0.0010
t-statistic		2.1199053		2.1603687		2.18		2.14		2.16		2.45		2.1788128		2.144787
U_2		0.0048		0.0024		0.0012		0.0020		0.018		0.00080		0.43		0.0022
U_3		0.0012		0.00063		0.00034		0.00051		0.0047		0.00030		0.12		0.00057
Certified		**0.038**		**0.0095**		**0.0020**		**0.006**		**0.37**		**0.0005**		**99.5**		**0.009**
Uncertainty		0.003		0.0006		0.0006		0.001		0.02		0.0003		0.3		0.001
Tolerance		0.009		0.0024		0.0018		0.003		0.06		0.0004		0.9		0.003

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

Analysis	*	B	*	C	*	Co	*	Cu	*	Fe	*	Mn	*	Mo	*	Ni	*	Si	*	Sn
1	11	0.0003	11	0.014	10	0.0034667	5	0.002867	14	0.145333	5	0.00015	5	0.0013	3	0.0074	10	0.002933	5	0.007167
2	5	0.0003833	1	0.0166667	4	0.0046	14	0.003433	4	0.145333	3	0.0002	3	0.0013333	3	0.0077	4	0.0046	5	0.007233
3	4	0.0006	1	0.0167333	11	0.0052	11	0.0045	10	0.147	5	0.0004967	5	0.0014333	4	0.0082	4	0.004767	4	0.007667
4			1	0.017	14	0.0053667	4	0.004533	3	0.147	4	0.0010	10	0.0019333	4	0.0086	4	0.005133	5	0.00803
5			1	0.0171667	4	0.0241667	4	0.005867	4	0.148667	14	0.0010667	5	0.0019567	5	0.008733	3	0.005533	10	0.0089
6			1	0.0173667			4	0.005967	3	0.158333	11	0.0014	11	0.0027	11	0.0088	14	0.005667	10	0.009467
7			1	0.0173667			5	0.006433	4	0.160333			4	0.0027667	4	0.009133	4	0.0063	4	0.009633
8			3	0.0175			3	0.0069	11	0.165			14	0.0028333	10	0.009633	4	0.006763	4	0.009633
9			1	0.02					10	0.166667			4	0.0030333	4	0.009637	10	0.007	3	0.01
10			1	0.0210833					4	0.169867			4	0.0031667	5	0.009867	5	0.007333	4	0.010067
11			1	0.024					4	0.170733			4	0.0034	4	0.0099	3	0.0078	4	0.0104
12			1	0.0250667					5	0.174			3	0.0034	10	0.010	4	0.008933	4	0.0105
13			1	0.0279					4	0.183067			10	0.0035667	10	0.010167			11	0.011
14			1	0.03825					4	0.185					4	0.0109				
15			1	0.0482					4	0.187667					4	0.011533				
16			1	0.0536667					4	0.191733					4	0.013				
17			1	0.0613333																
18			4	0.0636667																
Average		0.00043		0.029		0.009		0.00506		0.165358		0.0007		0.002525		0.009575		0.006064		0.009207
Std Dev		0.00083		0.017		0.084		0.00011		0.000079		0.0016		0.000088		0.000079		0.000091		0.000088
H		0.000314		0.0017		0.0010335		0.000809		0.004102		0.0003736		0.0006091		0.001062		0.000873		0.001044
U_1		0.00089		0.0017		0.084		0.00082		0.0041		0.0017		0.00062		0.0011		0.00088		0.0010
t-statistic		4.3026527		2.11		2.7764451		2.364624		2.13145		2.5705818		2.1788128		2.13145		2.200985		2.178813
U_2		0.0038		0.0037		0.23		0.0019		0.0087		0.0043		0.0013		0.0023		0.0019		0.0023
U_3		0.0022		0.0009		0.10		0.00068		0.0022		0.0018		0.00037		0.00057		0.00056		0.00063
Reference		**0.0004**		**0.03**		**0.009**		**0.005**		**0.16**		**0.0007**		**0.002**		**0.010**		**0.006**		**0.009**
Uncertainty		0.0002		0.02		0.004		0.002		0.02		0.0005		0.001		0.002		0.003		0.002
Tolerance		0.0003		0.02		0.008		0.004		0.06		0.0006		0.001		0.006		0.005		0.006

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

Analysis	*	W	*	Zr
1	3	0.000031	5	0.00054
2	5	0.0001533	5	0.0006667
3	4	0.0003667	4	0.0010
4	5	0.0012733	3	0.0014
5	11	0.0126	10	0.0015667
Average		0.003		0.0010
Std Dev		0.019		0.0035
H		0.0006526		0.0004261
U_1		0.019		0.0035
t-statistic		2.7764451		2.7764451
U_2		0.053		0.0098
U_3		0.024		0.0044
Reference		**<0.05**		**0.0010**
Uncertainty				0.0005
Tolerance				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
Average		0.01159
Std Dev		0.00057
H		0.0011543
U_1		0.0013
t-statistic		2.5705818
U_2		0.0033
U_3		0.0014
Informational		(0.012)

For each element, in accordance with the requirements of ISO 17034 and ISO 33405, 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:

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

*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 33405: 2024-05 section 10.

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)
2 Fusion (ASTM E1019)
3 Spark Atomic Emission
4 ICP Atomic Emission
5 ICP Mass Spectrometry
6 Gravimetric
7 Photometric
8 Flame Atomic Absorption
9 GF Atomic Absorption
10 X-Ray Fluorescence
11 GD Atomic Emission
12 GD Mass Spectrometry
13 Titrimetric
14 DCP Atomic Emission
15 HG Atomic Fluorescence
16 Difference

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 Standard 33401 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 Standard 33403 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 REVT-4B-020325. 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**

Revision: This certified reference material was originally certified as a reference material on November 29, 2022. Additional combustion/fusion testing was performed. N and S have been changed from reference to certified. Revised values for elements C, H, and O are also presented.

Brammer Standard Company, Inc., is accredited by the American Association for Laboratory Accreditation (A2LA) to ISO Standard 17034:2016 as a Reference Material Producer for the production of Certified Reference Materials and Reference Materials (our current Certificate Number 656.02 expires 01/31/2027)

Brammer Standard Company's Chemical Laboratory is accredited by A2LA to ISO Standard 17025:2017. (Our current Certificate Number 656.01 expires 01/31/2027)

By current Certificate Number 10539 expiring 01/01/2027, the Quality System of Brammer Standard Company, Inc., is registered to ISO 9001:2015 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 9001:2015 Quality Management Systems - Requirements

ISO Guide 30:2015 Terms and definitions used in connection with reference materials + 2008 amendment

ISO Standard 33401:2024 Reference materials - Contents of certificates, labels, and accompanying documentation

ISO Standard 33403:2024 Reference materials – Requirements and and recommendations for use

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

ISO Standard 33405:2024 Reference materials – Approaches for characterization and assessment of homogeneity and stability

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

NIST Special Publication 829, Use of NIST Standard Reference Materials for Decisions on Performance of Analytical Chemical Methods and Laboratories

Certified by: _____ on February 3, 2025.

Beau R. Brammer

President