Brammer Standard Company, Inc.

Certificate of Analysis

BS 450

Certified Reference Material for Stainless Steel Grade 450 - UNS Number S45000

Certified Values[3]

	Certified Value[1]	Estimate of Uncertainty[2]		Certified Value[1]	Estimate of Uncertainty[2]
As	**0.0033**	0.0005	**Ni**	**6.24**	0.04
C	**0.029**	0.002	**O**	**0.0027**	0.0006
Co	**0.028**	0.003	**P**	**0.016**	0.001
Cr	**14.4**	0.1	**S**	**0.0013**	0.0004
Cu	**1.51**	0.03	**Sb**	**0.0010**	0.0004
Fe	**75.5**	0.1	**Si**	**0.323**	0.007
Mn	**0.596**	0.008	**Sn**	**0.0046**	0.0008
Mo	**0.671**	0.009	**V**	**0.051**	0.003
N	**0.022**	0.002	**W**	**0.016**	0.002
Nb	**0.59**	0.002			

Reference Values[3,4]

	Reference Value[1]	Estimate of Uncertainty[2]		Reference Value[1]	Estimate of Uncertainty[2]
Al	**0.003**	0.001	**Pb**	**<0.005**	
B	**0.0003**	0.0002	**Ti**	**<0.008**	
Ca	**<0.005**		**Zr**	**0.004**	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 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.

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

Trace element information values for Bi, Ga, Ge, Ir, Mg, Os, Re, Y, and Zn are shown on page 3.

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

BS 450 * Code for method Certified values listed as weight percent

Analysis	*	As	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mn	*	Mo	*	N	*	Nb
1	4	0.003	1	0.026375	10	0.0227333	4	14.2033333	4	1.451	10	75.1833333	4	0.5731933	4	0.6465	2	0.019433	4	0.559397
2	5	0.0030	1	0.02656	4	0.0241	10	14.23	4	1.4703	3	75.3033333	10	0.581	4	0.66	2	0.019833	4	0.56075
3	12	0.003067	1	0.026867	4	0.0252667	3	14.3	3	1.486667	16	[75.365]	4	0.5846667	4	0.661347	2	0.02	4	0.571333
4	5	0.003167	1	0.027367	5	0.0254	4	14.3333333	4	1.503133	16	[75.3685]	7	0.59	3	0.662	2	0.020667	4	0.571833
5	4	0.003167	1	0.0283	8	0.0268667	4	14.335	11	1.505	13	75.452	4	0.5906667	11	0.6645	2	0.0211	10	0.578
6	10	0.003333	1	0.0284	3	0.027625	11	14.3475	4	1.507333	16	[75.46]	4	0.59075	3	0.67	2	0.021533	11	0.5805
7	11	0.003375	2	0.028567	4	0.0278333	14	14.3666667	4	1.509667	16	[75.5102634]	4	0.5912	3	0.67	2	0.021767	4	0.587367
8	9	0.0034	3	0.028667	8	0.028	4	14.4036	7	1.514333	16	[75.53]	11	0.593	4	0.6701	2	0.022167	3	0.5885
9	3	0.003525	1	0.029	14	0.0285667	17	14.41	4	1.5198	14	75.5333333	4	0.5933333	14	0.671333	2	0.022167	3	0.59
10	15	0.003793	1	0.029133	4	0.0286333	4	14.4159	10	1.52	4	75.6366667	3	0.598	4	0.672767	2	0.022285	4	0.590133
11	5	0.00394	1	0.029367	4	0.0289667	3	14.44	14	1.52	4	75.85	10	0.598	10	0.674	2	0.022333	14	0.591333
12			1	0.0298	4	0.0301	3	14.4433333	4	1.522967			8	0.6	3	0.675	2	0.022433	10	0.591667
13			11	0.03025	3	0.0306667	13	14.4523333	3	1.5275			3	0.60	4	0.675	2	0.0228	3	0.602
14			3	0.031	3	0.0308	3	14.505	3	1.533667			3	0.60	4	0.675667	2	0.0229	4	0.603
15			1	0.0317	4	0.0309733	17	14.5098	10	1.536333			4	0.6002	10	0.676			3	0.61
16			1	0.031767	3	0.0315333	3	14.5233333	3	1.537			14	0.6023333	3	0.6775			4	0.611667
17			3	0.03215	10	0.032	4	14.543	4	1.538			4	0.6036667	4	0.679			4	0.617667
18					11	0.03245			8	1.54			3	0.6185	8	0.69				
19									3	1.55			3	0.623						
Average		0.00334		0.0295		0.028473		14.397773		1.5104		75.477		0.596395		0.6706		0.02159		0.588538
Std Dev		0.00013		0.0010		0.000075		0.000077		0.0053		0.045		0.000073		0.0041		0.00078		0.000077
H		0.00068		0.0018		0.0017		0.054		0.014		0.16		0.0081106		0.0087		0.0015		0.0081
U_1		0.00069		0.0020		0.0017		0.054		0.015		0.17		0.0081		0.0096		0.0017		0.0081
t-statistic		2.23		2.12		2.11		2.12		2.10		2.23		2.10		2.11		2.16		2.12
U_2		0.0015		0.0043		0.0037		0.11		0.031		0.37		0.017		0.020		0.0037		0.017
U_3		0.00047		0.0010		0.00086		0.028		0.0071		0.11		0.0039		0.0048		0.0010		0.0041
Certified		**0.0033**		**0.029**		**0.028**		**14.4**		**1.51**		**75.5**		**0.596**		**0.671**		**0.022**		**0.59**
Uncertainty		0.0005		0.002		0.003		0.1		0.03		0.1		0.008		0.009		0.002		0.02
Tolerance		0.0015		0.006		0.009		0.3		0.09		0.4		0.024		0.027		0.006		0.06

Analysis	*	Ni	*	O	*	P	*	S	*	Sb	*	Si	*	Sn	*	V	*	W
1	4	6.171667	2	0.0015	5	0.0135333	1	0.0009825	5	0.000237	3	0.315	11	0.002025	12	0.0360	5	0.012067
2	4	6.173333	2	0.00215	12	0.0136667	1	0.001	12	0.00056	4	0.31633333	3	0.0032	5	0.047933	4	0.0127
3	14	6.20	2	0.00224	11	0.014275	1	0.00103333	5	0.000677	5	0.31733333	9	0.0035333	3	0.049333	5	0.0127
4	8	6.20	2	0.002267	7	0.0147	1	0.00103333	5	0.0007	10	0.319	4	0.0040333	4	0.050133	4	0.015367
5	4	6.200933	2	0.0023	4	0.0148	11	0.00105	9	0.0009	14	0.31933333	4	0.0040667	4	0.0502	5	0.015633
6	4	6.2032	2	0.002363	4	0.0153333	1	0.00106667	9	0.001167	3	0.32	12	0.0043	10	0.050933	4	0.015833
7	4	6.2045	2	0.002667	4	0.0159333	1	0.00113333	11	0.0015	4	0.3202	5	0.0045	10	0.051	3	0.016
8	3	6.2175	2	0.002667	4	0.0159333	3	0.00116667			10	0.321	4	0.0047333	4	0.0511	4	0.0164
9	4	6.236	2	0.002783	3	0.016	12	0.00126667			3	0.3215	5	0.0049333	3	0.051233	11	0.017825
10	4	6.239667	2	0.003133	4	0.0160333	1	0.00136667			3	0.322	5	0.0049333	14	0.0519	14	0.018
11	6	6.243333	2	0.003767	10	0.0163	1	0.00137			4	0.32335	5	0.0051033	3	0.052	4	0.018067
12	3	6.27	2	0.003793	3	0.0163333	1	0.00153333			4	0.32356667	4	0.0053633	3	0.0521	3	0.018175
13	17	6.27	2	0.0040	3	0.0166	1	0.00156667			4	0.326	3	0.0066333	4	0.052167	10	0.0182
14	11	6.27			3	0.0167667	1	0.0017			4	0.32633333	3	0.007125	4	0.053467	3	0.019667
15	4	6.271267			4	0.0175333	1	0.00186667			11	0.3265			4	0.054133		
16	3	6.28			10	0.0183333	1	0.0019			17	0.33			11	0.054525		
17	3	6.28			4	0.0192					17	0.33623333			3	0.0547		
18	3	6.28									3	0.34			4	0.05593		
19	10	6.282																
20	6	6.293333																
Average		6.239337		0.00271		0.015957		0.001315		0.000987		0.3231		0.004606		0.051044		0.016188
Std Dev		0.000071		0.00010		0.000077		0.000079		0.000062		0.0037		0.000085		0.000075		0.000085
H		0.032		0.00063		0.0013		0.00047		0.00042		0.0058		0.00078		0.0023		0.0013
U_1		0.032		0.00063		0.0013		0.00048		0.00043		0.0069		0.00078		0.0023		0.0013
t-statistic		2.09		2.18		2.12		2.13		2.45		2.11		2.16		2.11		2.16
U_2		0.066		0.0014		0.0028		0.0010		0.0010		0.015		0.0017		0.0048		0.0029
U_3		0.015		0.00038		0.00069		0.00026		0.00040		0.0034		0.00045		0.0011		0.00077
Certified		**6.24**		**0.0027**		**0.016**		**0.0013**		**0.0010**		**0.323**		**0.0046**		**0.051**		**0.016**
Uncertainty		0.04		0.0006		0.001		0.0004		0.0004		0.007		0.0008		0.003		0.002
Tolerance		0.12		0.0018		0.003		0.0012		0.0009		0.021		0.0024		0.009		0.006

BS 450 * Code for method Reference values listed as weight percent

Analysis	*	Al	*	B	*	Ca	*	Pb	*	Ti	*	Zr
1	5	0.001967	12	0.000177	12	0.0000177	12	0.0000317	12	0.00013	11	0.00245
2	5	0.002	5	0.0002	11	0.0000636	9	0.0001	5	0.000273	4	0.00276667
3	12	0.002333	7	0.0002	4	0.0001	11	0.0011	5	0.000333	4	0.00382
4	4	0.002787	3	0.0002	3	0.00045	9	0.0018	3	0.001675	10	0.00463333
5	3	0.003133	11	0.0002	14	0.0005	4	0.002	4	0.001713	14	0.00633333
6	4	0.003233	4	0.0005	4	0.0015967	3	0.00285	14	0.0019		
7	4	0.003467	14	0.0006					3	0.002		
8	5	0.00359							4	0.002		
9	4	0.004							11	0.006		
10	3	0.0042										
11	14	0.004333										
12	3	0.00435										
13	11	0.004525										
Average		0.00345		0.000334		0.000616		0.001084		0.00133		0.00400
Std Dev		0.00012		0.000065		0.000058		0.000036		0.00011		0.00014
H		0.00069		0.00029		0.00036		0.00044		0.000474		0.00073
U_1		0.00070		0.00030		0.00036		0.00044		0.00049		0.00075
t-statistic		2.18		2.45		2.57		2.57		2.31		2.78
U_2		0.0015		0.00072		0.00093		0.0011		0.0011		0.0021
U_3		0.00042		0.00027		0.00038		0.00046		0.00037		0.00093
Reference		**0.003**		**0.0003**		**<0.005**		**<0.005**		**<0.008**		**0.004**
Uncertainty		0.001		0.0002								0.002
Tolerance		0.002		0.0002								0.003

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 it's 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 Guide 35:2006 section 6.

BS 450 * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis	*	Bi	*	Ga	*	Ge	*	Ir	*	Mg	*	Os	*	Re	*	Y	*	Zn
1	12	0.01	12	18	12	13	12	0.04	12	0.17	12	0.04	12	0.32	12	0.006	12	14
2	12	0.01	12	20	12	13	12	0.04	12	0.18	12	0.05	12	0.37	12	0.006	12	14
3			12	21	12	14	12	0.05	12	0.18	12	0.05	12	0.37	12	0.007	12	14

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

Lab Name	Location	Registrar	Accreditation
Brammer Standard Company, Inc.	Houston, TX	A2LA	17025, 17034
Eurofins EAG Materials Science, LLC	Liverpool, NY	A2LA	17025
NSL Analytical	Cleveland, OH	ANAB	17025
Luvak Inc.	Boylston, MA	PRI	17025
LECO Corporation	St. Joseph, MI	A2LA	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI	17025
Dirats Laboratories	Westfield,MA	ANAB	17025
Analytical Process Laboratories	Milwaukee, WI	A2LA	17025
Element Materials Technology	Glendale Heights, IL	A2LA	17025
Vitkovice Testing Center	Ostrava, Czech	ILAC	17025
Element Materials Technology	Huntington Beach, CA	A2LA	17025
TUV Rheinland Pvt Ltd	Bangalore, India	NABL	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	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 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: 12XLA90, 13X12536, 13X125370, 13X14934, 13X14935, 23X80030; AR 89, 115C, 414B, 512, 614A, 644, 654, 659, 662, 663, 668, 673, 675, 676, 870, 872, 881, 882, 1650, 1651, 1653; BAS 72, 261, 333, 342, 346A, 386, 406/2, 461, 464/1, 475; BS CA304-3, CU-A, 17-4PHA, 80F, 81G, 82B, 83A, 85D, 95, 95A, 96, 180B, 189A, 302A, 304A, 431, 9811; DSZU CA013; ECRM 085-1, 184-1, 195-1, 196-1, 284-1, 292-1; IARM 4A, 15-5, 15C, 21A, 318B; IMZ 123, 158; IPT 12A, 17A; JK 37; JSS 652-5, 654-5; LECO 501-501, 501-503, 501-644, 501-646, 501-676, 502-414, 502-702, 502-712, 502-855, 502-856, 502-868, 502-903, 502-904, 502-913, 502-928; NCS NS11037. NS11043; SRM C1289, 101G, 160B, 344, 345, 348A, 361, 363, 364, 897, 898, 899, 1155.

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 333, 386, 475; BS Ca304-3, 85D, 95, 95A, 96, 431, 9811; DSZU CA013; ECRM 284-1; IARM 318B; NCS NS11037, NS11043; SRM C1289.

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 450 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 Universal Stainless; Dunkirk, NY.

Form: This CRM is machined in the form of a disc, approximately 45 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.

> 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 450-042121. 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.
14603 Benfer Road
Houston, Texas 77069-2895 USA
Phone: (281) 440-9396 Web: www.brammerstandard.com
Fax: (281) 440-4432 Email: 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

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***

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 April 21, 2021.

Beau R. Brammer

President