Brammer Standard Company, Inc.

Certificate of Analysis

BS 4320

Certified Reference Material for Alloy Steel Grade 4320 - UNS Number G43200

Certified Values[3]

	Certified Value[1]	Estimate of Uncertainty[2]		Certified Value[1]	Estimate of Uncertainty[2]
Al	**0.024**	0.002	**Mo**	**0.228**	0.009
As	**0.0036**	0.0008	**N**	**0.0049**	0.0004
B	**0.0002**	0.0001	**Ni**	**1.73**	0.04
C	**0.191**	0.009	**O**	**0.0013**	0.0005
Ca	**0.0005**	0.0002	**P**	**0.0068**	0.0009
Co	**0.0060**	0.0009	**S**	**0.0026**	0.0006
Cr	**0.518**	0.009	**Si**	**0.259**	0.009
Cu	**0.050**	0.002	**Sn**	**0.0040**	0.0008
Fe	**96.4**	0.3	**Ti**	**0.0009**	0.0004
Mg	**0.0002**	0.0001	**V**	**0.0016**	0.0006
Mn	**0.599**	0.009			

Reference Values[3,4]

	Reference Value[1]	Estimate of Uncertainty[2]		Reference Value[1]	Estimate of Uncertainty[2]
H	**<0.005**		**Ta**	**<0.05**	
Nb	**<0.05**		**W**	**<0.05**	
Pb	**<0.005**		**Zr**	**<0.05**	
Sb	**0.0015**	0.0009			

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

Trace element information values for Ce, Ga, Ge, Na, Re, 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.

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BS 4320 * Code for method Certified values listed as weight percent

Analysis	*	Al	*	As	*	B	*	C	*	Ca	*	Co	*	Cr	*	Cu	*	Fe	*	Mg
1	5	0.0213	12	0.0025667	3	0.000055	3	0.184	12	0.00038	5	0.0056333	4	0.4943333	5	0.0464	4	96.2228	5	0.00010
2	11	0.0227	5	0.0029	4	0.0001	1	0.1852	3	0.0004	12	0.0056667	3	0.498	4	0.04867	4	96.2228	12	0.0001633
3	10	0.02283333	10	0.003	12	0.00013	1	0.186633	4	0.0004	4	0.0057	3	0.507	8	0.049	16	[96.2920667]	3	0.0002
4	5	0.02293333	5	0.00303	5	0.0001667	3	0.187	4	0.00048333	10	0.0058	8	0.51	3	0.049	16	[96.3]	4	0.0002
5	3	0.0232	5	0.0034667	5	0.0001967	3	0.188	11	0.0005	11	0.0059	13	0.5106667	3	0.049	16	[96.3177667]	4	0.0002
6	4	0.0235	4	0.0035	4	0.0002	1	0.188733	3	0.0005	4	0.0059333	3	0.5166667	4	0.04933	16	[96.318]	4	0.0002
7	14	0.02356667	5	0.0035667	3	0.0002	1	0.189	4	0.0005	4	0.0059333	4	0.5176667	4	0.0496	16	[96.34]	4	0.0002
8	3	0.02366667	4	0.0037	4	0.0002	1	0.189333	4	0.0005	4	0.0059333	3	0.518	4	0.0498	4	96.3533333	5	0.0002333
9	4	0.0238	10	0.0037333	4	0.0002667	3	0.19	4	0.00051667	3	0.006	10	0.5183333	4	0.0499	16	[96.36]	5	0.00035
10	4	0.02386667	3	0.0038	3	0.0003	1	0.19	4	0.00051667	3	0.006	10	0.52	10	0.05	16	[96.368834]		
11	3	0.024	9	0.0038333			1	0.19	10	0.00056667	3	0.006	4	0.52	10	0.05	16	[96.375334]		
12	3	0.024	4	0.0039667			1	0.1913			4	0.0060	4	0.52	4	0.05017	3	96.3933333		
13	4	0.0240	4	0.0039667			1	0.1913			4	0.0061033	3	0.52	10	0.05043	10	96.3966667		
14	4	0.02413333	3	0.004			1	0.1926			14	0.0062333	13	0.5200	4	0.05057	14	96.4		
15	4	0.02416667	4	0.0043667			1	0.192667			4	0.0064	10	0.52	11	0.051	16	[96.47]		
16	4	0.02416667					1	0.193333			4	0.0065	3	0.52	4	0.05103	4	96.6633333		
17	4	0.02466667					1	0.193333			4	0.0069	4	0.5205333	4	0.05107				
18	3	0.025					2	0.194			3	0.0069333	4	0.5205333	4	0.05107				
19	3	0.0259					11	0.197					4	0.5208	4	0.0512				
20							1	0.199667					4	0.5215333	14	0.0513				
21							1	0.20					14	0.521667	3	0.05167				
22													4	0.523	3	0.052				
23													11	0.523	3	0.0529				
24													4	0.523467	3	0.053				
25													4	0.528267						
26													4	0.537667						
Average		0.02355		0.00362		0.000172		0.1906		0.0005149		0.00604		0.5181		0.0505		96.3690		0.000210
Std Dev		0.00073		0.00012		0.000020		0.0027		0.0000077		0.00019		0.0086		0.0012		0.0030		0.000019
H		0.0016		0.00070		0.00023		0.0044		0.00033		0.00087		0.0075		0.0023		0.19		0.00025
U_1		0.0017		0.00071		0.00023		0.0052		0.00033		0.00089		0.0082		0.0026		0.19		0.00025
t-statistic		2.10		2.14		2.26		2.09		2.23		2.11		2.06		2.07		2.13		2.31
U_2		0.0037		0.0015		0.00052		0.011		0.00075		0.0019		0.017		0.0053		0.40		0.00057
U_3		0.00084		0.00040		0.00017		0.0024		0.00022		0.00044		0.0033		0.0011		0.10		0.00019
Certified		**0.024**		**0.0036**		**0.0002**		**0.191**		**0.0005**		**0.0060**		**0.518**		**0.050**		**96.4**		**0.0002**
Uncertainty		0.002		0.0008		0.0001		0.009		0.0002		0.0009		0.009		0.002		0.3		0.0001
Tolerance		0.006		0.0024		0.0001		0.027		0.0004		0.0027		0.027		0.006		0.9		0.0001

Analysis	*	Mn	*	Mo	*	N	*	Ni	*	O	*	P	*	S	*	Si	*	Sn	*	Ti
1	8	0.58	4	0.217	2	0.00445	10	1.69	2	0.001	4	0.0059133	1	0.0013	10	0.24233	12	0.0031	12	0.0003567
2	3	0.582	10	0.22	2	0.00449	4	1.692667	2	0.001	3	0.006	11	0.0018	10	0.25	5	0.0031	5	0.0006
3	10	0.59	8	0.22	2	0.0046	3	1.696667	2	0.001	5	0.0060333	1	0.002	5	0.250	5	0.00336667	5	0.0006
4	10	0.59	4	0.2226	2	0.0046333	4	1.699	2	0.00105667	4	0.0063	1	0.0020	3	0.25	5	0.00342667	4	0.0007333
5	4	0.594	4	0.223	2	0.0046633	4	1.709333	2	0.00115	4	0.0065667	3	0.002	3	0.252	4	0.0036	14	0.0008
6	4	0.596	3	0.224	2	0.0048	10	1.71	2	0.00119667	4	0.0066633	1	0.0021333	4	0.25733	5	0.00363333	11	0.0009
7	3	0.596	11	0.224	2	0.0048	8	1.72	2	0.00126667	10	0.0067	12	0.0021333	3	0.258	4	0.00393333	4	0.0009
8	3	0.59666667	4	0.2243667	2	0.0048	3	1.723333	2	0.0014	3	0.0067333	1	0.0024667	5	0.25933	4	0.00393333	3	0.0010
9	4	0.597	4	0.2253333	2	0.00485	4	1.728667	2	0.0015	3	0.007	10	0.0025	9	0.25967	3	0.00396667	4	0.0010333
10	4	0.59933333	3	0.2263333	2	0.0048667	4	1.729933	2	0.00155	4	0.0070	1	0.0025133	4	0.260	3	0.004	4	0.0010333
11	14	0.59966667	10	0.227	2	0.0049333	14	1.73	2	0.00193333	7	0.0070	1	0.0027	11	0.26	3	0.0041	4	0.0010667
12	4	0.59966667	4	0.229	2	0.0049333	3	1.73	2	0.00203667	3	0.007	3	0.0028	3	0.26	10	0.0042	3	0.0011
13	4	0.60033333	3	0.23	2	0.005	3	1.73			7	0.0070	1	0.0029	3	0.26	4	0.00426667	3	0.0011
14	3	0.60133333	3	0.23	2	0.0053	3	1.73			3	0.0071	1	0.0029667	4	0.2600	9	0.0043	3	0.0012
15	4	0.6014	10	0.23	2	0.0054333	4	1.736133			11	0.0071	1	0.0029667	6	0.26	4	0.0044		
16	4	0.60186667	3	0.23			4	1.736667			4	0.0071667	1	0.0031	13	0.26073	3	0.005		
17	4	0.60186667	7	0.23			10	1.74			4	0.0071667	3	0.0031667	6	0.26073	3	0.005		
18	10	0.60366667	4	0.2301			7	1.74			4	0.0073333	4	0.0033	3	0.261				
19	4	0.60466667	4	0.231			4	1.74			3	0.0076	1	0.00334	4	0.261				
20	4	0.605	14	0.2313333			4	1.742133			4	0.0077333	1	0.0034	4	0.26493				
21	4	0.605233	4	0.231467			4	1.74213			10	0.007967	4	0.003533	4	0.26567				
22	11	0.606	4	0.231467			4	1.744067							4	0.266				
23	3	0.61	4	0.231467			3	1.745							4	0.27547				
24	3	0.61	4	0.232333			11	1.75												
25			3	0.233			4	1.756												
Average		0.5990		0.2282		0.00490		1.7299		0.00134		0.00678		0.002587		0.2595		0.00396		0.00089
Std Dev		0.0036		0.0026		0.00013		0.0047		0.00036		0.00023		0.000075		0.0030		0.00056		0.00024
H		0.0081		0.0048		0.00080		0.015		0.00045		0.00092		0.00062		0.0052		0.00072		0.00043
U_1		0.0089		0.0055		0.00081		0.015		0.00045		0.00094		0.00062		0.0060		0.00073		0.00043
t-statistic		2.07		2.06		2.14		2.06		2.20		2.09		2.09		2.07		2.12		2.16
U_2		0.018		0.011		0.0017		0.032		0.0010		0.0020		0.0013		0.012		0.0015		0.00092
U_3		0.0038		0.0023		0.00045		0.0064		0.00029		0.00043		0.00028		0.0026		0.00038		0.00025
Certified		**0.599**		**0.228**		**0.0049**		**1.73**		**0.0013**		**0.0068**		**0.0026**		**0.259**		**0.0040**		**0.0009**
Uncertainty		0.009		0.009		0.0004		0.04		0.0005		0.0009		0.0006		0.009		0.0008		0.0004
Tolerance		0.027		0.027		0.0017		0.12		0.0014		0.0027		0.0018		0.027		0.0024		0.0008

BS 4320 * Code for method Certified values listed as weight percent

Analysis	*	V
1	11	0.0004
2	12	0.00086667
3	4	0.00106333
4	5	0.0011
5	3	0.0012
6	5	0.0013
7	4	0.00183333
8	4	0.00183333
9	14	0.00206667
10	10	0.0021
11	3	0.00216667
12	4	0.00216667
13	4	0.00216667
14	4	0.00223333
15	3	0.0023
Average		0.00165
Std Dev		0.00061
H		0.00048
U_1		0.00049
t-statistic		2.14
U_2		0.0011
U_3		0.00027
Certified		**0.0016**
Uncertainty		0.0006
Tolerance		0.0015

BS 4320 * Code for method Reference values listed as weight percent

Analysis	*	H	*	Nb	*	Pb	*	Sb	*	Ta	*	W	*	Zr
1	2	0.000058	5	0.0001	5	0.000013	5	0.0005	5	0.000001	5	0.0003	12	0.000078
2	2	0.000087	12	0.0001033	12	0.000015	12	0.000587	5	0.00011	12	0.0003	5	0.0001
3	2	0.000087	5	0.0001633	5	0.000015	5	0.00061	4	0.00353333	5	0.00030	5	0.0001633
4	2	0.000089	2	0.0017667	14	0.0005	5	0.00067	3	0.0039	5	0.0003567	11	0.0003
5	2	0.00009	4	0.0018	3	0.0006667	5	0.000867	4	0.0041	11	0.001	4	0.0009
6	2	0.00012	3	0.0018667	4	0.0008667	11	0.0015	4	0.0041	3	0.0016667	4	0.0009333
7	2	0.00013333	10	0.0019	4	0.0008667	14	0.0016	4	0.00416667	4	0.0019667	4	0.0009333
8	2	0.00016667	11	0.002	3	0.0009	4	0.0022			4	0.0019667	4	0.0010333
9	2	0.00023333	3	0.002	4	0.0010	4	0.0022			4	0.002	3	0.0015
10	2	0.00027667	4	0.0020667			4	0.002333			44	0.0022	4	0.0016
11			4	0.0020667			4	0.002367			3	0.0027		
12			4	0.0023			3	0.0026						
Average		0.0000887		0.000960		0.0000349		0.00150		0.00275		0.001264		0.00075
Std Dev		0.0000045		0.000050		0.0000071		0.00082		0.00011		0.000033		0.00057
H		0.00019		0.00042		0.00014		0.00046		0.00063		0.00047		0.00047
U_1		0.00019		0.00042		0.00014		0.00047		0.00064		0.00047		0.00047
t-statistic		2.26		2.20		2.31		2.20		2.45		2.23		2.26
U_2		0.00042		0.00093		0.00033		0.0010		0.0016		0.0010		0.0011
U_3		0.00013		0.00027		0.00011		0.00030		0.00059		0.00031		0.00033
Reference		**<0.005**		**<0.05**		**<0.005**		**0.0015**		**<0.05**		**<0.05**		**<0.05**
Uncertainty								0.0009						
Tolerance								0.0014						

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:

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

*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 4320 * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis	*	Ce	*	Ga	*	Ge	*	Na	*	Re	*	Zn
1	12	0.01	12	5.9	12	18	12	0.01	12	0.25	12	15
2	12	0.01	12	5.9	12	18	12	0.03	12	0.25	12	16
3	12	0.02	12	6	12	18			12	0.27	12	16

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
Element Materials Technology	Glendale Heights, IL	A2LA	17025
Elemental Analysis, Inc.	Lexington, KY	A2LA	17025
TUV Rheinland Pvt Ltd	Bangalore, India	NABL	17025
Shiva Analyticals Private Limited	Hoskote, Bangalore	NABL	17025
Dirats Laboratories	Westfield,MA	ANAB	17025
Luvak Inc.	Boylston, MA	PRI	17025
Laboratory Testing, Inc.	Hatfield, PA	A2LA	17025
Raghavendra Spectro Metallurgical Laboratory	Karnataka, India	NABL	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	17025
APL, Inc	Milwaukee, WI	A2LA	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: AR 115C, 546,555, 614A, 641, 644, 645, 659, 662, 667, 668, 673, 675, 676, 867, 869, 870, 872, 890, 960, 1653; BAS 331, 406, 409, 458, 460, 464/1; BS E521000, HON T, 30D, 45B, 46A, 46B, 51E, 56H, 61G, 69A, 69B, 73B, 210, 1005, 1016, 1026A, 1031, 1032, 1991, 2931, 3961, 3962, 4130, 4140, 4330MOD, 4340, 4340A, 8620F; CKD 181B, 244C, 249C; DSZU CA031; ECRM 85-1, 86-1, 87-1; IARM 20A, 30C, 30D, 31E, 31G, 31F, 229; IMZ 162; IPT 12A, 17A, 36; JSS GS-1d, 505-3; LECO 501-503, 501-506, 502-712, 502-856, 502-863, 502-916, 502-928, 502-963, 502-990; SPL LA-3B, 307A; SRM 16E, 160B, 361, 362, 363, 364, 1168, 1261A, 1269, 1767.

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 51e, 210, 1031, 1032, 1991, 3961, 3962; JSS 505-; SRM 1261A.

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 4320 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 purchased from Next Generation Metals, Inc.; Boca Raton, Fl.

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 4320-050824. 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:

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Web: www.brammerstandard.com
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 (our current Certificate Number 656.02 expires 01/31/2025)

Brammer Standard Company's Chemical Laboratory is accredited by A2LA to ISO Standard 17025. (Our current Certificate Number 656.01 expires 01/31/2025)

By current Certificate Number 10539 expiring 01/01/2027, 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 May 8, 2024.

Beau R. Brammer

President