Brammer Standard Company, Inc.

Certificate of Analysis

BS 286CF

Certified Reference Material for Nodular Cast Iron

Certified Values[3]

	Certified Value[1]	Estimate of Uncertainty[2]		Certified Value[1]	Estimate of Uncertainty[2]
Al	**0.012**	0.002	**Mn**	**0.714**	0.007
B	**0.0086**	0.0009	**Mo**	**0.258**	0.007
C	**3.27**	0.04	**Ni**	**1.43**	0.03
Ca	**0.0012**	0.0004	**P**	**0.20**	0.01
Co	**0.027**	0.002	**Si**	**2.00**	0.03
Cr	**0.349**	0.006	**Ti**	**0.052**	0.002
Cu	**0.363**	0.007	**V**	**0.150**	0.005
Fe	**91.1**	0.2	**W**	**0.0025**	0.0005
Mg	**0.049**	0.001			

Informational Values[3,4]

As (0.002)	Ce (0.03)	La (0.005)	N (0.005)	Nb (0.005)
O (0.003)	Pb (0.0007)	S (0.012)	Sb (0.003)	Sn (0.01)
Te (0.02)	Zn (0.001)	Zr (0.003)		

[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 Ba, Bi, Cl, Dy, Ga, Gd, Ge, Hf, Na, Nd, Pr, Re, Se, Sm, Sr, Th, U, and Y 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 286CF * Code for method Certified values listed as weight percent

Analysis	*	Al	*	B	*	C	*	Ca	*	Co	*	Cr	*	Cu	*	Fe	*	Mg	*	Mn
1	5	0.0096	3	0.0077	1	3.213333	14	0.0008	12	0.02167	4	0.324333	3	0.345	13	90.4827	3	0.0485	8	0.70
2	5	0.009773	3	0.0077	3	3.22	4	0.0008	4	0.0227	11	0.343	4	0.355	10	90.93	3	0.0485	4	0.703
3	4	0.010367	3	0.0077	1	3.24	4	0.001017	3	0.02427	3	0.344	4	0.35733333	16	90.97	3	0.0486	4	0.704
4	11	0.0115	11	0.0079	10	3.25	4	0.001033	4	0.02542	10	0.345	4	0.35966667	16	90.9933	3	0.0486	4	0.704
5	3	0.0118	4	0.0080	1	3.256733	11	0.0012	4	0.0263	4	0.345	4	0.35996667	3	91.0033	3	0.0487	4	0.708667
6	3	0.012	14	0.0081	1	3.258333	3	0.0013	11	0.0265	4	0.346333	11	0.360	4	91.02	3	0.0488	4	0.71
7	4	0.0124	4	0.0083	1	3.261	4	0.001447	4	0.0266	4	0.34747	4	0.36008333	16	91.04	3	0.0488	4	0.711667
8	4	0.01258	7	0.008667	1	3.27			10	0.027	4	0.347733	4	0.36066667	16	91.04	3	0.0488	3	0.713
9	14	0.0129	4	0.008913	1	3.27			8	0.027	4	0.348	4	0.361	16	91.0498	3	0.0488	3	0.713
10	4	0.012953	5	0.009133	1	3.28			4	0.02703	3	0.348	8	0.362	14	91.2	3	0.0489	11	0.718
11	4	0.012967	4	0.0092	11	3.28			14	0.02737	3	0.348333	8	0.36333333	16	91.21	3	0.0489	14	0.719
12	4	0.013833	4	0.010133	1	3.2875			4	0.02776	3	0.35	10	0.365	16	91.2733	3	0.0490	4	0.719267
13	3	0.0141	4	0.010673	3	3.29			5	0.02787	4	0.350233	10	0.36666667	10	91.3333	3	0.0490	4	0.719867
14	3	0.0144			1	3.293333			3	0.028	8	0.351	4	0.3673	4	91.6	3	0.0490	3	0.72
15	4	0.014667			1	3.306			3	0.0282	14	0.352667	3	0.369			3	0.0490	10	0.72
16					1	3.3072			3	0.0288	4	0.354	3	0.37			3	0.0490	4	0.720867
17					1	3.323333			4	0.02957	4	0.354833	4	0.37116667			3	0.0490	10	0.721667
18											4	0.363733	4	0.37436667			3	0.0491	4	0.7248
19											10	0.366333					3	0.0491		
20																	3	0.0491		
21																	3	0.0491		
22																	3	0.0491		
23																	3	0.0492		
24																	3	0.0492		
25																	3	0.0492		
26																	3	0.0492		
27																	3	0.0492		
28																	3	0.0493		
29																	3	0.0493		
30																	3	0.0494		
Average		0.01213		0.00859		3.2698		0.001162		0.02702		0.3494		0.3625		91.101		0.04898		0.713933
Std Dev		0.00043		0.00030		0.0049		0.000060		0.00088		0.0040		0.0045		0.030		0.00089		0.000075
H		0.0012		0.0010		0.021		0.00045		0.0017		0.0061		0.0062		0.18		0.00224		0.0090
U_1		0.0013		0.0011		0.022		0.00045		0.0019		0.0073		0.0077		0.18		0.0024		0.0090
t-statistic		2.14		2.18		2.12		2.45		2.12		2.10		2.11		2.16		2.05		2.11
U_2		0.0027		0.0023		0.047		0.0011		0.0040		0.015		0.016		0.40		0.0049		0.019
U_3		0.00069		0.00064		0.011		0.00042		0.0010		0.0035		0.0038		0.11		0.00090		0.0045
Certified		**0.012**		**0.0086**		**3.27**		**0.0012**		**0.027**		**0.349**		**0.363**		**91.1**		**0.049**		**0.714**
Uncertainty		0.002		0.0009		0.04		0.0004		0.002		0.006		0.007		0.2		0.001		0.007
Tolerance		0.006		0.0027		0.12		0.0011		0.006		0.018		0.021		0.6		0.003		0.021

BS 286CF * Code for method Certified values listed as weight percent

Analysis	*	Mo	*	Ni	*	P	*	Si	*	Ti	*	V	*	W
1	3	0.25	3	1.39	10	0.186667	4	1.941667	4	0.04646	4	0.138003	4	0.00206667
2	4	0.25	4	1.396	4	0.187933	3	1.95	3	0.05	4	0.139333	4	0.00206667
3	10	0.251	10	1.40	7	0.188	4	1.975133	3	0.0504	4	0.145	12	0.00216667
4	3	0.251667	4	1.404667	14	0.191	6	1.993333	4	0.0507	3	0.146	4	0.0023
5	10	0.252	10	1.41	4	0.196333	4	1.997	10	0.051	3	0.146667	3	0.0023
6	3	0.254	14	1.416667	4	0.197583	6	1.998333	4	0.05104	14	0.148667	14	0.00233333
7	4	0.254333	4	1.419667	4	0.199667	3	2.00	10	0.05133	4	0.149933	11	0.0024
8	4	0.256	3	1.42	17	0.200	10	2.00	4	0.05133	4	0.15	5	0.00343667
9	11	0.257	4	1.4200	3	0.200667	4	2.001933	4	0.05193	10	0.151	5	0.0038
10	14	0.259333	3	1.43	3	0.201	4	2.01	14	0.05207	4	0.151667		
11	4	0.259933	8	1.43	11	0.206	17	2.01	11	0.0526	11	0.152		
12	4	0.261333	3	1.434	4	0.2075	6	2.012333	5	0.05313	5	0.153333		
13	8	0.263	4	1.438967	10	0.208	14	2.016667	4	0.0534	3	0.155		
14	4	0.263367	11	1.44	3	0.208	4	2.016667	3	0.05347	3	0.155		
15	4	0.264933	4	1.4431	4	0.20929	11	2.02	3	0.0536	4	0.155343		
16	3	0.267	4	1.450	4	0.2099	4	2.020267	7	0.05363	4	0.156133		
17	4	0.2673	4	1.453333	3	0.21	3	2.03	4	0.0537	4	0.1577		
18			4	1.454383	4	0.210127			4	0.05513				
19			4	1.4775										
Average		0.257776		1.4310		0.1992		1.9976		0.0521		0.150046		0.00254
Std Dev		0.000077		0.0055		0.0035		0.0056		0.0014		0.000077		0.00011
H		0.0052		0.013		0.0045		0.016		0.00231		0.0039		0.00061
U_1		0.0052		0.014		0.0057		0.017		0.0027		0.0039		0.00062
t-statistic		2.12		2.10		2.11		2.12		2.11		2.12		2.31
U_2		0.011		0.030		0.012		0.036		0.0057		0.0083		0.0014
U_3		0.0027		0.0069		0.0028		0.0087		0.0014		0.0020		0.00048
Certified		**0.258**		**1.43**		**0.20**		**2.00**		**0.052**		**0.150**		**0.0025**
Uncertainty		0.007		0.03		0.01		0.03		0.002		0.005		0.0005
Tolerance		0.021		0.09		0.03		0.09		0.006		0.015		0.0014

BS 286CF * Code for method Informational values listed as weight percent

Analysis	*	As	*	Ce	*	La	*	N	*	Nb	*	O	*	Pb	*	S	*	Sb	*	Sn
1	5	0.00068	14	0.002333	12	0.002467	2	0.005123	12	0.00039	2	0.001007	9	0.0000674	1	0.006403	5	0.0014	12	0.0103
2	5	0.0012	5	0.00573	12	0.002867	2	0.00518	5	0.0006	2	0.001673	5	0.0001	1	0.008177	5	0.00153	11	0.0104
3	12	0.001233	12	0.033	5	0.004433	2	0.005398	5	0.00072	2	0.002433	9	0.0001	1	0.0093	5	0.0016	4	0.01092
4	5	0.001267	12	0.0444	5	0.005367	2	0.005967	5	0.00084	2	0.003513	5	0.0001	1	0.010178	10	0.0017	4	0.010967
5	15	0.001277	4	0.057333	5	0.005567			10	0.0011	2	0.00393	5	0.00015667	12	0.010233	5	0.00176	4	0.011033
6	5	0.00135	5	0.0582	11	0.0075			11	0.0030			5	0.00017667	1	0.010833	12	0.00187	9	0.0113
7	4	0.001367							3	0.0034			10	0.0002	1	0.011767	4	0.00226	5	0.011967
8	10	0.0030							4	0.00463			4	0.0012	1	0.01189	14	0.00337	3	0.012
9	3	0.0030							4	0.0050			12	0.00143333	3	0.012	3	0.0046	5	0.012667
10	4	0.003567							14	0.00517			11	0.0018	1	0.012333	3	0.0048	10	0.013
11	9	0.003767							3	0.0063			3	0.002	1	0.0133	4	0.00603	10	0.013367
12	4	0.0041							4	0.01119					11	0.0137	11	0.0066	3	0.0135
13	4	0.004187							5	0.0179					10	0.014			5	0.014767
14	4	0.0042													1	0.014			4	0.015
15															3	0.0140			5	0.015367
16															1	0.014427			3	0.016
17															1	0.0145				
18															1	0.015033				
Average		0.0024		0.03		0.005		0.005		0.005		0.003		0.0007		0.012		0.003		0.013
Std Dev		0.0088		0.31		0.035		0.052		0.023		0.015		0.0010		0.066		0.014		0.074
H		0.0006		0.0017		0.0008		0.001		0.001		0.001		0.0004		0.001		0.001		0.001
U_1		0.0088		0.31		0.035		0.052		0.023		0.015		0.0011		0.066		0.014		0.074
t-statistic		2.16		2.57		2.57		3.18		2.18		2.78		2.23		2.11		2.20		2.13
U_2		0.019		0.80		0.090		0.17		0.051		0.043		0.0025		0.14		0.031		0.16
U_3		0.0051		0.33		0.037		0.083		0.014		0.019		0.00074		0.033		0.0088		0.039
Informational		(0.002)		(0.03)		(0.005)		(0.005)		(0.005)		(0.003)		(0.0007)		(0.012)		(0.003)		(0.01)

BS 286CF * Code for method Informational values listed as weight percent

Analysis	*	Te	*	Zn	*	Zr
1	11	0.0025	4	0.000467	5	0.0002
2	5	0.012533	5	0.000533	12	0.000203
3	5	0.016633	12	0.00064	5	0.00039
4	15	0.017067	5	0.0008	5	0.000443
5	5	0.017767	3	0.0012	4	0.0009
6	5	0.023633	11	0.0024	4	0.0017
7	12	0.024667			4	0.00247
8					3	0.0041
9					14	0.0057
10					4	0.005967
11					11	0.0072
Average		0.02		0.0010		0.003
Std Dev		0.15		0.0030		0.011
H		0.0015		0.0004		0.001
U_1		0.15		0.0031		0.011
t-statistic		2.45		2.57		2.23
U_2		0.36		0.0079		0.025
U_3		0.14		0.0032		0.0076
Informational		(0.02)		(0.001)		(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 286CF * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis	*	Ba	*	Bi	*	Cl	*	Dy	*	Ga	*	Gd	*	Ge	*	Hf	*	Na	*	Nd
1	12	0.2	12	0.06	12	0.02	12	0.02	12	16	12	0.1	12	4.2	12	0.03	12	0.01	12	4.5
2	12	0.48	12	0.07	12	0.03	12	0.03	12	17	12	0.15	12	4.2	12	0.03	12	0.01	12	7.2
3	12	0.62	12	0.08	12	0.03	12	0.03	12	17	12	0.16	12	4.4	12	0.03	12	0.02	12	7.5
Analysis	*	Pr	*	Re	*	Se	*	Sm	*	Sr	*	Th	*	U	*	Y				
1	12	1.7	12	0.13	12	0.16	12	0.28	12	0.1	12	1.8	12	0.09	12	0.12				
2	12	2.6	12	0.17	12	0.18	12	0.45	12	0.12	12	2.8	12	0.14	12	0.18				
3	12	2.9	12	0.18	12	0.19	12	0.49	12	0.15	12	3.1	12	0.15	12	0.2				

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
Shijiazhuang Trump Scientific Co., LTD.	Hebei, China	CNAS	17025
Element Materials Technology	Glendale Heights, IL	A2LA	17025
NSL Analytical	Cleveland, OH	ANAB	17025
Eurofins EAG Materials Science, LLC	Liverpool, NY	A2LA	17025
Dirats Laboratories	Westfield,MA	ANAB	17025
Vitkovice Testing Center	Hulvaky, Ostrava	ILAC	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	17025
Luvak Inc.	Boylston, MA	PRI	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
TUV Rheinland Pvt Ltd	Bangalore, India	NABL	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI	17025
Element Materials Technology	Santa Fe Spring, CA	A2LA	17025

A2LA = American Association for Laboratory Accreditation
ANAB = ANSI-ASQ National Accreditation Board
CNAS = China National Accreditation Service
ILAC = International Laboratory Accreditation Cooperation
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 307, 657, 659, 662, 668, 885, 892; BAS 236/3, 405, 406/2, 464/1, 481/1; BS TS-15, LE 204, 30D, 45B, 56H, 61G, 75G, 1016, 1026; CKD 211S, 234, 235, 236, 237, 238, 249; CZ 2019A, 2020A; ECRM 481-1; GBW 01119; IARM 316A; IPT 17A, 75A; LECO 501-024, 501-025, 501-105, 501-504, 501-505, 501-646, 501-676, 501-677, 502-679, 502-712, 502-916, 502-919; NCS HC17201; SPL 1B, 5L, 6E, 6F, 7G, 13A, 14A; SRM 4K, 16D, 16E, 55D, 72D, 160B, 341, 342A, 361, 362, 363, 364, 365, 892, 897, 898, 899; TS N013; YSBC 31901, 41340B.

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 LE 204; GBW 01119; SRM 892; TS N013; YSBC 31901; 41340B.

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 286CF 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 cast stock for this CRM was produced by Shijiazhuang Trump Scientific Co., LTD.; Hebei, China.

Form: This CRM is machined in the form of a disc, approximately 35mm in diameter and 30mm 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 certified area of each disc is the portion extending upward 25mm from the analytical surface.

Note: Shrinkage cavities may appear in the top portion of some discs. These cavities are normal and will not affect the certified portion of the disc.]

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 286CF-091120. 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) 440-9396Web: 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 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 35:2006 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

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

Certified by: _____ on September 11, 2020.

Beau R. Brammer

President