Brammer Standard Company, Inc.

Certificate of Analysis

BS 33F

Certified Reference Material for S-1 Mod Tool Steel

Certified Values[3]

	Certified Value[1]	Estimate of Uncertainty[2]		Certified Value[1]	Estimate of Uncertainty[2]
Al	**0.019**	0.001	**N**	**0.0124**	0.0008
C	**0.569**	0.007	**Ni**	**0.211**	0.006
Co	**0.017**	0.002	**O**	**0.0024**	0.0006
Cr	**1.31**	0.03	**P**	**0.0134**	0.0007
Cu	**0.039**	0.001	**S**	**0.0009**	0.0003
Fe	**94.0**	0.1	**Si**	**0.76**	0.02
Mn	**0.295**	0.009	**V**	**0.25**	0.01
Mo	**0.202**	0.004	**W**	**2.28**	0.03

Informational Values[3,4]

As (0.003)	B (0.0007)	Nb (0.002)	Pb (0.0004)	Sb (0.01)
	Sn (0.004)	Ti (0.002)	Zr (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.

[4] Values in parentheses are not certified and are provided for information only.

Trace element information values for Ag, Ca, Ce, Cl, Ga, Ge, Mg, Pt, Re, Ta, 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.

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BS 33F * Code for method Certified values listed as weight percent

Analysis	*	Al	*	C	*	Co	*	Cr	*	Cu	*	Fe	*	Mn	*	Mo	*	N	*	Ni
1	4	0.016267	1	0.56	4	0.0122	10	1.263	4	0.0358333	10	93.89667	10	0.286	3	0.19667	2	0.01053333	18	0.201
2	4	0.016333	1	0.562333	14	0.01573333	3	1.27575	4	0.0378667	16	[93.95]	3	0.29	10	0.19767	2	0.01126667	4	0.20267
3	5	0.017033	1	0.563333	5	0.01576667	3	1.276	18	0.038	16	[93.97]	18	0.29	3	0.198	2	0.012	8	0.204
4	3	0.017625	3	0.5637	4	0.01586667	3	1.2779	3	0.038	3	93.98333	4	0.2900667	14	0.198	2	0.0123	10	0.2045
5	14	0.018867	1	0.564933	12	0.0160	3	1.28	3	0.038	16	[93.9885]	4	0.2902	3	0.199	3	0.01234	4	0.20567
6	3	0.0193	1	0.566	3	0.016	4	1.282	8	0.0384	16	[93.9926]	3	0.291	4	0.19913	2	0.01243333	3	0.20688
7	11	0.0194	3	0.568	3	0.017	4	1.2966667	4	0.0386667	16	[94]	3	0.291375	10	0.20	2	0.01243333	10	0.20933
8	4	0.0199	1	0.568667	10	0.017	4	1.3066667	10	0.03887	14	94.0	4	0.2916667	3	0.20	2	0.01248	3	0.21
9	3	0.0199	3	0.5695	8	0.01716667	3	1.31	3	0.039	4	94.00333	4	0.2928667	18	0.20	2	0.0127	4	0.21
10	4	0.019967	1	0.57	4	0.0172	4	1.3113333	14	0.0390667	13	94.123	14	0.2933333	4	0.20	2	0.0129	10	0.21
11	3	0.020	1	0.57	4	0.01733333	4	1.314	4	0.0391			10	0.2933333	11	0.2	2	0.01316667	4	0.2101
12	3	0.020	3	0.57	4	0.0174	14	1.32	11	0.0394			3	0.294	4	0.20073	2	0.0137	4	0.2102
13	3	0.0200	1	0.571767	3	0.0182	4	1.32	3	0.039875			3	0.2942	4	0.201			14	0.21233
14	4	0.0201	11	0.572	4	0.01886667	18	1.32	10	0.0399			3	0.2953333	4	0.2022			3	0.213
15	4	0.020433	1	0.576	3	0.0190	4	1.3201333	4	0.04			4	0.2956667	3	0.2031			3	0.21333
16	10	0.0251	3	0.578	3	0.020875	11	1.34	3	0.0400			4	0.3036667	4	0.20333			11	0.214
17			1	0.5807			10	1.35072	3	0.0402667			11	0.304	7	0.20367			4	0.215
18							10	1.3533333	4	0.0404333			10	0.305978	4	0.206			4	0.21613
19							3	1.36	10	0.041			8	0.3063333	3	0.20875			3	0.218
20													4	0.31	10	0.20978			3	0.2200
Average		0.019389		0.569114		0.01667		1.3120		0.0388		93.977		0.295451		0.2022		0.01237		0.2114
Std Dev		0.000079		0.000077		0.00065		0.0051		0.0011		0.036		0.000071		0.0031		0.00044		0.0031
H		0.0015		0.0079		0.0014		0.013		0.0020		0.19		0.0055531		0.0046		0.0012		0.0047
U_1		0.0015		0.0079		0.0015		0.014		0.0023		0.19		0.0056		0.0055		0.0013		0.0056
t-statistic		2.13		2.12		2.13		2.10		2.10		2.26		2.09		2.09		2.20		2.09
U_2		0.0031		0.017		0.0032		0.029		0.0048		0.43		0.012		0.012		0.0028		0.012
U_3		0.00078		0.0041		0.00080		0.0066		0.0011		0.14		0.0026		0.0026		0.00081		0.0026
Certified		**0.019**		**0.569**		**0.017**		**1.31**		**0.039**		**94.0**		**0.295**		**0.202**		**0.0124**		**0.211**
Uncertainty		0.001		0.007		0.002		0.03		0.001		0.1		0.009		0.004		0.0008		0.006
Tolerance		0.003		0.021		0.006		0.09		0.005		0.4		0.027		0.012		0.0028		0.018

Analysis	*	O	*	P	*	S	*	Si	*	V	*	W
1	2	0.0016	4	0.011567	1	0.00013333	10	0.70401	4	0.2353333	10	2.22652
2	2	0.0019	3	0.012367	12	0.00016333	3	0.7326667	10	0.2356667	4	2.251333
3	2	0.002	3	0.0125	1	0.00059667	3	0.7399	3	0.2386667	10	2.252
4	2	0.002067	3	0.013	1	0.0007	6	0.7476667	3	0.242	4	2.2592
5	2	0.0022	3	0.013	1	0.00080	4	0.7543333	3	0.24375	3	2.2593
6	2	0.0024	3	0.0131	1	0.00083333	10	0.76	10	0.244	4	2.2638
7	2	0.002467	10	0.0132	10	0.0011	3	0.762	14	0.2493333	14	2.273333
8	2	0.00259	10	0.013333	1	0.00126667	4	0.7626667	3	0.2500	3	2.276667
9	2	0.003	11	0.0134	1	0.0019	3	0.76525	4	0.2502333	11	2.28
10	2	0.004356	5	0.013533	3	0.002	17	0.7693	3	0.251	4	2.281667
11			4	0.013767			6	0.7696667	11	0.251	3	2.29
12			4	0.013867			18	0.77	4	0.253	3	2.29
13			17	0.014			3	0.77	4	0.254	4	2.293333
14			4	0.0141			3	0.771	4	0.2569333	10	2.316667
15			14	0.0141			4	0.7715333	4	0.26	4	2.335
16			3	0.014125			9	0.773	3	0.26		
17			4	0.0146			6	0.775	4	0.2603333		
18							4	0.78				
19							11	0.794				
20							10	0.812				
Average		0.002376		0.01345		0.00095		0.764200		0.2494		2.276588
Std Dev		0.000098		0.00060		0.00010		0.000071		0.0035		0.000082
H		0.00059		0.0012		0.00042		0.0093		0.0051		0.017
U_1		0.00060		0.0014		0.00043		0.0093		0.0062		0.017
t-statistic		2.26		2.12		2.26		2.09		2.12		2.14
U_2		0.0014		0.0029		0.0010		0.019		0.013		0.037
U_3		0.00043		0.00071		0.00031		0.0044		0.0032		0.010
Certified		**0.0024**		**0.0134**		**0.0009**		**0.76**		**0.25**		**2.28**
Uncertainty		0.0006		0.0007		0.0003		0.02		0.01		0.03
Tolerance		0.0018		0.0029		0.0008		0.06		0.03		0.09

BS 33F * Code for method Informational values listed as weight percent

Analysis	*	As	*	B	*	Nb	*	Pb	*	Sb	*	Sn	*	Ti	*	Zr
1	5	0.001267	12	0.000145	10	0.00066	12	0.000011	12	0.00	12	0.0024	12	0.0007167	12	0.0000353
2	11	0.0016	4	0.0002	12	0.00143333	5	0.000014	5	0.00	5	0.002567	14	0.0011	3	0.0010
3	12	0.001633	7	0.000337	5	0.0018	5	0.00002	5	0.00	5	0.00275	5	0.0012633	3	0.002
4	5	0.002107	3	0.00035	5	0.00233667	3	0.0003	3	0.01	4	0.002767	5	0.0015333	3	0.002
5	5	0.0022	3	0.0004	3	0.003	10	0.0007	14	0.01	10	0.0033	10	0.00157	10	0.0024
6	10	0.0027	3	0.00050	3	0.0030	3	0.0013	3	0.02	3	0.0039	3	0.0017	3	0.005375
7	4	0.003233	3	0.000638	3	0.003			4	0.04	5	0.0041	3	0.00170		
8	9	0.0033	3	0.0007	4	0.00313333					11	0.0047	4	0.0017667		
9	3	0.0035	11	0.0012	3	0.004125					3	0.005	3	0.0022		
10	4	0.003733	14	0.002933							3	0.005	3	0.0025		
11											4	0.005067				
12											14	0.005167				
13											10	0.00558				
Average		0.003		0.0007		0.002		0.00039		0.011		0.004		0.002		0.002
Std Dev		0.011		0.0013		0.011		0.00049		0.092		0.019		0.011		0.011
H		0.001		0.0004		0.001		0.00030		0.001		0.001		0.0005554		0.001
U_1		0.011		0.0014		0.011		0.00057		0.092		0.019		0.011		0.011
t-statistic		2.26		2.26		2.31		2.57		2.45		2.18		2.26		2.57
U_2		0.025		0.0031		0.026		0.0015		0.23		0.042		0.024		0.028
U_3		0.0079		0.00099		0.0088		0.00060		0.085		0.012		0.0076		0.011
Informational		(0.003)		(0.0007)		(0.002)		(0.0004)		(0.01)		(0.004)		(0.002)		(0.002)

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 33F * Code for analytical method Trace analysis listed as mg/kg (ppm)

Analysis	*	Ag	*	Ca	*	Cl	*	Ga	*	Ge	*	Mg	*	Pt	*	Re	*	Ta	*	Ta
1	12	100	12	0.34	12	0.01	12	20	12	9.5	12	2.8	12	0.24	12	0.69	12	16	12	16
2	12	110	12	0.36	12	0.02	12	21	12	9.8	12	3.2	12	0.24	12	0.72	12	17	12	17
3	12	120	12	0.45	12	0.02	12	22	12	9.8	12	3.4	12	0.37	12	0.89	12	21	12	21
4			3	5.0							3	5.3								

Analysis	*	Zn
1	12	0.83
2	12	0.85
3	12	0.87
4	3	20

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	18	AAS

ICP = Inductively Coupled Plasma GF = Graphite Furnace GD = Glow Discharge
DCP = Direct Current Plasma HG = Hydride Generation AAS = Atomic Absorption Spectrometry

Lab Name	Location	Registrar	Accreditation
Brammer Standard Company, Inc.	Houston, TX	A2LA	17025, 17034
Element Materials Technology	Glendale Heights, IL	A2LA	17025
Dirats Laboratories	Westfield,MA	ANAB	17025
Laboratory Testing, Inc.	Hatfield, PA	PRI	17025
Eurofins EAG Materials Science, LLC	Liverpool, NY	A2LA	17025
TUV Rheinland Pvt Ltd	Bangalore, India	NABL	17025
Vitkovice	Ostrava	ILAC	17025
Enviform	Stare Mesto, Trinec	ILAC	17025
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA	17025
National Analysis Center For Iron And Steel	Beijing, China	CNAS	17025
Luvak Inc.	Boylston, MA	PRI	17025
Chicago Spectro	Chicago, IL	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 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: 11XC4, 12X15255, 12X15260, 12X15266, 12X353, 12X356, 12X43400; AR 644, 654, 668, 673, 882, 886, 889, 892, 946, 1648, 1651, 1652, 1653; BAS 410/2, 423, 451, 464/1, 483; BS LF2B, TH-12, 33A, 33C, 33D, 33E, 45B, 54H, 8620C; CKD 167A, 169A, 183A, 186A, 187A, 189A, 235, 236; DSZU CA013; ECRM 096-1, 179-2D, 184-1, 479-1; IARM 46A, 46B; VS UC3, UG5, UG8, UG9; IMZ 114A; IPT 43, 45, 75A; JSS 168-7; LECO 501-024, 501-644, 501-645, 501-676, 502-198, 502-255, 502-416, 502-712, 502-869, 502-894, 502-916, 502-628; NCS NS11037; SRM 7G, 8F, 16D, 16E, 36, 82, 134A, 153A, 160B, 361, 362, 363, 364, 391, 1263, 1269, 1762.

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 410-2, 483; BS TH-12, 33A, 33C, 33D, 33E; CKD 187A; DSZU CA013; ECRM 179-2, 184-1; VS UG 9; LECO 502-869; NCS NS11037

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 33F 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 Next Generation Metals; Boca Raton, Florida.

Form: This CRM is machined in the form of a disc, approximately 38 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 33F-041320. 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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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 17025:2005 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 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 April 13, 2020.

Beau R. Brammer

President