

CERTIFICATE OF ANALYSIS

11X C6 (batch W)

Certified Reference Material Information

Type: CAST IRON (CHILL CAST)
Form and Size: Disc ~40mm diameter
Produced by: Maybrey Reliance Ltd
Certified and supplied by: MBH Analytical Ltd

Assigned Values

Percentage element by weight

Element	C	Si	S	P	Mn	Ni	Cr	Mo	Cu
Value ¹	3.80	0.810	0.064	0.088	0.967	0.0727	0.396	1.322	0.952
Uncertainty ²	0.03	0.012	0.002	0.003	0.006	0.0014	0.008	0.015	0.008

Element	Al	Ti	V	Co	Nb	W	Sn	As	B
Value ¹	0.021	0.195	0.0456	0.0469	0.010	0.0242	0.0307	0.0544	0.0043
Uncertainty ²	0.002	0.003	0.0014	0.0010	0.001	0.0008	0.0012	0.0009	0.0003

Element	Sb	Pb	Bi	Zn	Se	Te	Cd	Ag	N
Value ¹	0.058	0.007	0.007	0.0045	0.006	0.0133	(0.0003)	0.0042	0.0070
Uncertainty ²	0.003	0.001	0.001	0.0004	0.001	0.0012	-	0.0004	0.0007

Note: values in parentheses are not certified; they are provided for information only

Definitions

- ¹ The certified values are the present best estimates of the true content for each element. Each value is a panel consensus, based on the averaged results of an interlaboratory testing programme, detailed on page 3.
- ² The uncertainties are value judgements, based on the 95% confidence interval derived from the wet analysis results, in combination with a statistical assessment of the homogeneity data, as described on page 2.

Certified by:

MBH ANALYTICAL LIMITED



on 5th November 2019

C Eveleigh

Method of Preparation

This reference material was produced from commercial pig iron, with the minor and trace elements added as pure elements or master alloys. The discs are the product of one melt poured into multiple chill moulds with feeding systems designed to ensure sound discs. Approximately 2mm has been removed from the cast faces of the discs to minimise surface effects.

Sampling

Milled samples for chemical analysis were taken from random positions within the casting sequence. In addition, approximately 8% of all discs were selected for non-destructive homogeneity checking.

Homogeneity

Samples representative of the batch were checked for uniformity using an optical emission spectrometer.

For all accepted material, through-batch variation values were derived for each element as an indicator of any minor compositional variation (as determined for the specific sample size and other limitations of the spectrometer).

Chemical Analysis

Analysis was carried out on millings taken from samples representative of the product. It was performed by a panel of laboratories mostly operating within the terms of EN ISO/IEC 17025, using documented standard reference methods and validated by appropriate reference materials.

The individual values listed overpage are the average of each analyst's results.

Traceability

Much of the analytical work performed to assess this material has been carried out by laboratories with proven competence, as indicated by their accreditation to ISO 17025. It is an implicit requirement for this accreditation that analytical work should be performed with due traceability, via an unbroken chain of comparisons, each with stated uncertainty, to primary standards such as the mole, or to nationally- or internationally-recognised reference materials.

Of the individual results herein, some have traceability (to the mole) via primary analytical methods. Some are traceable to substances of known stoichiometry. Most have traceability via commercial solutions. Furthermore, some results have additional traceability to NIST standards, as part of the analytical calibration or process control.

Estimation of Uncertainties

The uncertainty values are generated from the 95% half-width confidence interval $C_{(95\%)}$, which is derived from the wet analysis results, in accordance with the following equation:

$$C_{(95\%)} = (t \times SD) / \sqrt{n}$$

where n is the number of available values, t is the Student's t value for n-1 degrees of freedom, and SD is the standard deviation of the test results.

As a separate exercise, the degree of compositional variation of the batch for each element has been quantified by a programme of non-destructive application testing, described above. These values have been combined, using the square-root of the summed squares, to derive the final uncertainty values.

Usage

Intended use: With optical emission and X-ray fluorescence spectrometers.

Recommended method of use: Cast irons are generally prepared by grinding. However, users are recommended to follow the calibration and sample preparation procedures specified by the relevant instrument manufacturer. Preparation should be the same for reference materials and the samples for test.

For optical emission spectroscopy, a minimum of five consistent replicate analyses is recommended to provide the necessary sample size. Users are advised to check against possible bias between reference materials and production samples due to differences in metallurgical history and be aware of possible inter-elemental effects.

Analytical Data

Percentage element by weight

Sample	C	Si	S	P	Mn	Ni	Cr	Mo	Cu
1	3.752	0.7830	0.0588	0.0819	0.9548	0.0684	0.3800	1.289	0.9405
2	3.762	0.7850	0.0594	0.0835	0.9550	0.0698	0.3817	1.292	0.9410
3	3.771	0.8002	0.0620	0.0851	0.9572	0.0702	0.3824	1.305	0.9430
4	3.776	0.8061	0.0621	0.0853	0.9580	0.0705	0.3845	1.308	0.9457
5	3.790	0.8067	0.0621	0.0855	0.9608	0.0714	0.3870	1.316	0.9460
6	3.798	0.8170	0.0635	0.0860	0.9618	0.0718	0.3905	1.320	0.9480
7	3.798	0.8180	0.0642	0.0869	0.9630	0.0719	0.3930	1.324	0.9515
8	3.800	0.8200	0.0652	0.0887	0.9640	0.0722	0.3975	1.327	0.9520
9	3.819	0.8214	0.0655	0.0892	0.9695	0.0727	0.4000	1.329	0.9521
10	3.820	0.8270	0.0656	0.0901	0.9733	0.0729	0.4000	1.337	0.9544
11	3.821	0.8289	0.0659	0.0907	0.9750	0.0748	0.4070	1.340	0.9575
12	3.846		0.0661	0.0911	0.9777	0.0751	0.4096	1.343	0.9682
13	3.866		0.0664	0.0918	0.9780	0.0755	0.4110	1.350	0.9707
14			0.0667	0.0926	0.9788	0.0764	0.4148		
15			0.0677		0.9850	0.0765			
Mean	3.801	0.8103	0.0641	0.0877	0.9674	0.0727	0.3956	1.322	0.9516
Std Dev	0.033	0.0157	0.0027	0.0033	0.0099	0.0025	0.0118	0.019	0.0095
C (95%)	0.020	0.0105	0.0015	0.0019	0.0055	0.0014	0.0068	0.012	0.0057

Sample	Al	Ti	V	Co	Nb	W	Sn	As	B
1	0.0172	0.1887	0.0422	0.0441	0.0075	0.0215	0.0283	0.0524	0.0038
2	0.0185	0.1900	0.0428	0.0445	0.0079	0.0220	0.0290	0.0525	0.0039
3	0.0190	0.1910	0.0434	0.0447	0.0093	0.0224	0.0291	0.0528	0.0039
4	0.0196	0.1912	0.0440	0.0458	0.0104	0.0235	0.0293	0.0535	0.0040
5	0.0197	0.1913	0.0442	0.0462	0.0105	0.0239	0.0298	0.0535	0.0040
6	0.0199	0.1940	0.0448	0.0462	0.0105	0.0240	0.0305	0.0538	0.0041
7	0.0213	0.1945	0.0449	0.0463	0.0107	0.0240	0.0311	0.0539	0.0042
8	0.0220	0.1950	0.0449	0.0466	0.0109	0.0242	0.0312	0.0550	0.0042
9	0.0228	0.1955	0.0456	0.0467	0.0113	0.0243	0.0312	0.0554	0.0045
10	0.0229	0.1969	0.0465	0.0468	0.0115	0.0244	0.0312	0.0554	0.0045
11	0.0233	0.1970	0.0475	0.0476	0.0122	0.0253	0.0317	0.0559	0.0049
12		0.1979	0.0489	0.0489		0.0254	0.0320	0.0560	0.0050
13		0.2004	0.0492	0.0494		0.0261	0.0320	0.0568	0.0053
14		0.2010	0.0494	0.0494		0.0262	0.0335		
15				0.0503		0.0265			
Mean	0.0206	0.1946	0.0456	0.0469	0.0102	0.0242	0.0307	0.0544	0.0043
Std Dev	0.0020	0.0038	0.0024	0.0019	0.0015	0.0015	0.0014	0.0015	0.0005
C (95%)	0.0014	0.0022	0.0014	0.0010	0.0010	0.0008	0.0008	0.0009	0.0003

Sample	Sb	Pb	Bi	Zn	Se	Te	Cd	Ag	N
1	0.0545	0.0052	0.0060	0.0039	0.0040	0.0110	0.00026	0.0034	0.0057
2	0.0557	0.0059	0.0060	0.0040	0.0042	0.0112	0.00026	0.0037	0.0057
3	0.0576	0.0062	0.0061	0.0040	0.0054	0.0122	0.00030	0.0040	0.0064
4	0.0578	0.0063	0.0067	0.0042	0.0057	0.0129	0.00030	0.0042	0.0070
5	0.0588	0.0064	0.0072	0.0043	0.0058	0.0136	0.00030	0.0043	0.0071
6	0.0589	0.0070	0.0082	0.0046	0.0065	0.0141	0.00038	0.0043	0.0074
7	0.0589	0.0073	0.0089	0.0048	0.0067	0.0145	0.00050	0.0045	0.0076
8	0.0598	0.0077		0.0048	0.0072	0.0149	<0.0005	0.0048	0.0077
9	0.0603	0.0085		0.0053	0.0073	0.0154	<0.0005	0.0049	0.0086
10	0.0624	0.0086		0.0054	0.0074		<0.001		
11		0.0092							
Mean	0.0584	0.0071	0.0070	0.0045	0.0060	0.0133	(0.00032)	0.0042	0.0070
Std Dev	0.0022	0.0013	0.0012	0.0005	0.0012	0.0016	-	0.0005	0.0010
C (95%)	0.0016	0.0009	0.0011	0.0004	0.0009	0.0012	-	0.0004	0.0007

Participating Laboratories

Element Ltd
Sheffield Analytical Services
Metals Technology (Testing) Ltd
Anchorcert Analytical
Universal Scientific Laboratory Pty Ltd
Genitest, Inc
Shanghai Jinyi Test Tech Co
Luo Yang Copper
Raghavendra SpectroMet Laboratory
TCR Engineering Services Ltd
Instytut Metalurgii Zelaza
Tec-Eurolab
TUV Nord Czech
INCDMNR-IMNR
Mineral & Metallurgical Laboratories
AMG Superalloys UK Ltd
LGC Standards
Analyticka Laborator Lithea sro

Middlesbrough, England
Sheffield, England
Sheffield, England
Birmingham, England
Milperra, NSW, Australia
Montreal, Canada
Shanghai, China
Luo Yng, He Nan, China
Bangalore, India
Mumbai, India
Gliwice, Poland
Campogalliano, Italy
Brno, Czech Republic
Pantelimon, Romania
Bangalore, India
Rotherham, England
Manchester, NH, USA
Brno, Czech Republic

UKAS accreditation 0239
UKAS accreditation 0012
UKAS accreditation 0963
UKAS accreditation 0667
NATA accreditation 0492
PJ accreditation L17-153
CNAS accreditation 0041
CNAL accreditation 0173
NABL accreditation 0371
NABL accreditation 0367
PCA accreditation AB554
ACCREDIA accreditation 52
CAI accreditation L1060

Note: to achieve the above accreditation (UKAS, etc), test houses must demonstrate conformity to the general requirements of EN ISO/IEC 17025.

Analytical Methods Used

ELEMENT	RESULT No. & METHOD			
	ICP-AES	FAAS		OTHER
Carbon	-	-	all	combustion (infra-red detection)
Silicon	1, 3, 4, 9-11	-	5, 8	gravimetric (perchloric acid)
			2, 6, 7	photometric (molybdenum blue)
Sulfur	3-5	-	1, 2, 6-15	combustion (infra-red detection)
Phosphorus	1-9, 13	-	11, 12, 14	photometric (molybdenum blue)
			10	volumetric (alkalimetric)
Manganese	1-3, 5, 8-10, 12-15	6, 7	4, 11	volumetric (arsenite)
Nickel	1-4, 6, 7, 10-15	5, 8	9	photometric (dimethyl glyoxime)
Chromium	2-4, 6, 8, 10-14	1, 5, 9	7	volumetric (ferrous ammonium sulfate)
Molybdenum	3-5, 7-12	1, 13	2, 6	photometric (thiocyanate)
Copper	1, 3, 4, 7, 9-13	2, 5, 8	6	photometric (BCO)
Aluminium	2, 4-6, 8, 9, 11	1, 3, 7	10	photometric (chrome azurol S)
Titanium	1, 2, 4, 5, 7-13	3, 6	14	photometric (diantipyryl methane)
Vanadium	1-3, 6, 8, 9, 11, 13, 14	4, 5, 10	7, 12	volumetric (ferrous ammonium sulfate)
Cobalt	1, 6-10, 12-15	4, 5, 11	2	photometric (5-Cl-PADAP)
			3	gravimetric
Niobium	1-7, 10, 11	8	9	photometric (chlorosulfophenol)
Tungsten	1-4, 6-9, 11, 12, 14, 15	5, 10	13	photometric (thiocyanate)
Tin	1-3, 5-7, 10-12, 14	4, 9, 13	8	gravimetric (oxide)
Arsenic	1-3, 5-8, 10-13	4, 9		
Boron	1-13	-		
Antimony	1, 3-5, 7, 9, 10	2, 8	6	volumetric (permanganate)
Lead	1, 2, 4-7, 9, 11	3, 8, 10		
Bismuth	1-7	-		
Zinc	1, 3, 5, 6, 8-10	2, 4, 7		
Selenium	1-6, 8-10	7		
Tellurium	1-7, 9	8		
Cadmium	1, 3-10	2		
Silver	1, 3, 4, 7-9	2, 5, 6		
Nitrogen	-	-	1-5, 7-9	inert gas fusion (thermal conductivity)
			6	photometric (Nessler reagent)

Notes

This Certified Reference Material has been produced and certified, wherever possible, in accordance with the requirements of ISO 17034 and the associated Guides, taking into account the requirements of the ISO Guide to the Expression of Uncertainty in Measurement (GUM).

The unidirectional solidification effects associated with this method of chill casting have led to the formation of inhomogeneous segregates in the rear portion of the disc. The above certification is therefore only applicable from the front face of the disc to a depth of 12mm. Material to the rear of the disc, to a depth of ~3 mm, is not certified.

This material will remain stable indefinitely, provided adequate precautions are taken to protect it from cross-contamination, extremes of temperature and atmospheric moisture. All production records will be retained for a period of 20 years from the date of this certificate. Technical support for this certification will therefore expire in November 2039, although we reserve the right to make changes as issue revisions, in the intervening period.

The manufacture, analysis and certification of this product were supervised by C Eveleigh, PhD, Technical Director, MBH Analytical Ltd.

The material to which this certificate of analysis refers is supplied subject to our general conditions of sale.