

# CERTIFICATE OF ANALYSIS

**11X C4 (batch S)**

## 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
Value <sup>1</sup>	1.954	2.98	0.096	0.1014	0.565	3.21	1.382	0.177
Uncertainty <sup>2</sup>	0.017	0.02	0.005	0.0016	0.005	0.02	0.017	0.004

Element	Cu	Al	Ti	V	Co	Nb	W	Sn
Value <sup>1</sup>	0.095	0.006	0.080	0.0165	0.0210	0.0233	0.099	0.0140
Uncertainty <sup>2</sup>	0.002	0.001	0.002	0.0010	0.0014	0.0013	0.002	0.0008

Element	As	Sb	Pb	Bi	Zn	Se	B	N
Value <sup>1</sup>	0.0235	0.0055	0.034	0.0070	0.0037	0.009	0.0351	0.0126
Uncertainty <sup>2</sup>	0.0015	0.0007	0.002	0.0012	0.0010	0.001	0.0007	0.0011

## Definitions

- <sup>1</sup> 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.
- <sup>2</sup> The uncertainty values are generated from 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 9<sup>th</sup> January 2019

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## **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
1	1.916	2.956	0.0877	0.0980	0.5537	3.150	1.345	0.1700
2	1.929	2.958	0.0909	0.0988	0.5555	3.179	1.349	0.1712
3	1.934	2.966	0.0912	0.0999	0.5560	3.189	1.352	0.1713
4	1.941	2.968	0.0917	0.1002	0.5570	3.200	1.357	0.1720
5	1.942	2.970	0.0947	0.1008	0.5600	3.207	1.376	0.1730
6	1.952	2.978	0.0949	0.1020	0.5600	3.208	1.377	0.1740
7	1.966	2.985	0.0959	0.1025	0.5616	3.210	1.390	0.1746
8	1.977	2.996	0.0960	0.1030	0.5635	3.221	1.392	0.1778
9	1.980	2.999	0.0977	0.1040	0.5684	3.222	1.400	0.1800
10	1.980	3.000	0.0977	0.1045	0.5697	3.230	1.402	0.1813
11	1.981		0.0985		0.5710	3.239	1.413	0.1820
12			0.1001		0.5740	3.246	1.425	0.1830
13			0.1026		0.5750			0.1850
14			0.1030		0.5795			
<b>Mean</b>	<b>1.954</b>	<b>2.978</b>	<b>0.0959</b>	<b>0.1014</b>	<b>0.5646</b>	<b>3.208</b>	<b>1.382</b>	<b>0.1766</b>
<b>Std Dev</b>	0.024	0.017	0.0045	0.0022	0.0083	0.027	0.027	0.0052
<b>C (95%)</b>	0.016	0.012	0.0026	0.0016	0.0048	0.017	0.017	0.0031

Sample	Cu	Al	Ti	V	Co	Nb	W	Sn
1	0.0907	0.0044	0.0756	0.0141	0.0187	0.0201	0.0934	0.0120
2	0.0918	0.0046	0.0773	0.0142	0.0195	0.0207	0.0967	0.0120
3	0.0920	0.0050	0.0777	0.0146	0.0196	0.0207	0.0970	0.0125
4	0.0937	0.0057	0.0781	0.0150	0.0201	0.0215	0.0977	0.0132
5	0.0946	0.0061	0.0793	0.0154	0.0210	0.0220	0.0980	0.0137
6	0.0949	0.0065	0.0798	0.0164	0.0210	0.0230	0.0983	0.0141
7	0.0956	0.0066	0.0816	0.0166	0.0211	0.0237	0.0992	0.0147
8	0.0957	0.0072	0.0820	0.0167	0.0216	0.0241	0.0992	0.0147
9	0.0959	0.0081	0.0820	0.0167	0.0216	0.0244	0.0995	0.0149
10	0.0959	0.0090	0.0830	0.0167	0.0219	0.0253	0.1033	0.0149
11	0.0974		0.0831	0.0180	0.0230	0.0255	0.1038	0.0154
12	0.0991			0.0181	0.0231	0.0259		0.0158
13	0.1000			0.0190		0.0262		
14				0.0192				
<b>Mean</b>	<b>0.0952</b>	<b>0.0063</b>	<b>0.0798</b>	<b>0.0165</b>	<b>0.0210</b>	<b>0.0233</b>	<b>0.0987</b>	<b>0.0140</b>
<b>Std Dev</b>	0.0027	0.0015	0.0026	0.0017	0.0014	0.0021	0.0029	0.0013
<b>C (95%)</b>	0.0016	0.0011	0.0017	0.0010	0.0009	0.0013	0.0020	0.0008

Sample	As	Sb	Pb	Bi	Zn	Se	B	N
1	0.0205	0.0043	0.0319	0.0047	0.0031	0.0074	0.0333	0.0108
2	0.0211	0.0044	0.0320	0.0047	0.0032	0.0077	0.0341	0.0113
3	0.0223	0.0044	0.0321	0.0055	0.0035	0.0083	0.0341	0.0113
4	0.0225	0.0045	0.0327	0.0059	0.0036	0.0095	0.0346	0.0129
5	0.0226	0.0046	0.0328	0.0060	0.0037	0.0099	0.0353	0.0131
6	0.0228	0.0052	0.0333	0.0069	0.0037	0.0102	0.0354	0.0133
7	0.0230	0.0054	0.0334	0.0073	0.0043	0.0102	0.0356	0.0139
8	0.0236	0.0056	0.0341	0.0086	0.0047	0.0106	0.0358	0.0140
9	0.0236	0.0063	0.0348	0.0088	0.0049	0.0115	0.0359	
10	0.0238	0.0063	0.0352	0.0089	0.0055		0.0366	
11	0.0242	0.0066	0.0353	0.0100				
12	0.0259	0.0071	0.0372					
13	0.0266	0.0074	0.0374					
14	0.0270							
<b>Mean</b>	<b>0.0235</b>	<b>0.0055</b>	<b>0.0340</b>	<b>0.0070</b>	<b>0.0037</b>	<b>0.0095</b>	<b>0.0351</b>	<b>0.0126</b>
<b>Std Dev</b>	0.0019	0.0011	0.0019	0.0018	0.0013	0.0014	0.0010	0.0013
<b>C (95%)</b>	0.0011	0.0007	0.0011	0.0012	0.0010	0.0011	0.0007	0.0011

For the derivation of the 95% confidence interval, C<sub>(95%)</sub>, see page 2

## Participating Laboratories

ElementLtd	Middlesbrough, England	UKAS accreditation 0239
Sheffield Assay Office	Sheffield, England	UKAS accreditation 0012
Anchorcert Analytical	Birmingham, England	UKAS accreditation 0667
Metals Technology (Testing) Ltd	Sheffield, England	UKAS accreditation 0963
Universal Scientific Laboratory Pty Ltd	Sydney, Australia	NATA accreditation 492
Shanghai Jinyi Test Tech Co	Shanghai, China	CNAS accreditation L0041
Luo Yang Copper Co	Luo Yang, He Nan, China	CNAL accreditation 0173
Raghavendra SpectroMet Laboratory	Bangalore, India	NABL accreditation T371
Gesra Labs India Pvt	Chennai, India	NABL accreditation 6238
Genitest Inc	Montreal, Canada	PJ accreditation L17-153
Tec-Eurolab	Campogalliano, Italy	ACCREDIA accreditation 52
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA accreditation AB554
TUV Nord Czech	Brno, Czech Republic	CAI accreditation L-1060
Mineral & Metallurgical Laboratories	Bangalore, India	
Analyticka Laborator Lithea sro	Brno, Czech Republic	
INCDMNR-IMNR	Pantelimon, Romania	
AMG Superalloys UK Ltd	Rotherham, England	

Note: to achieve the above accreditation (UKAS, etc), test houses are required to 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	2, 7, 8	-	1, 3, 5, 6, 9 gravimetric (perchloric acid) 4, 10 photometric (molybdenum blue)
Sulfur	2, 7, 14	-	combustion (infra-red detection)
Phosphorus	1-5, 7, 10	-	6 volumetric (alkalimetric)
Manganese	1, 2, 5-11	3, 14	8, 9 photometric (molybdenum blue) 4, 12 volumetric (arsenite)
Nickel	5-8, 10, 12	2	13 photometric (periodate) 1, 9, 11 gravimetric (dimethyl glyoxime) 3, 4 photometric (dimethyl glyoxime)
Chromium	2-5, 8, 9, 11	7, 10, 12	1, 6 volumetric (ferrous ammonium sulfate)
Molybdenum	1-3, 6-10, 12	5	4, 11, 13 photometric (thiocyanate)
Copper	1, 3, 5-7, 10-13	2, 4, 9	8 photometric (BCO)
Aluminium	1-6, 10	9	7 volumetric (EDTA) 8 photometric (chrome azurol S)
Titanium	1-6, 8, 10	7	9, 11 photometric (diantipryl methane)
Vanadium	2, 4, 6-14	3, 5	1 volumetric (ferrous ammonium sulfate)
Cobalt	1-4, 6, 8-11	5, 12	7 photometric (5-Cl-PADAP)
Niobium	1-4, 6, 8, 9, 12, 13	7, 10	5 photometric (chlorosulfophenol) 11 gravimetric
Tungsten	2-6, 8-11	1, 7	
Tin	1-11	12	
Arsenic	1-5, 7-9, 11-14	6, 10	
Antimony	1, 2, 5-9, 12, 13	3, 4, 10, 11	
Lead	1-3, 7-9, 11-13	4, 5, 10	6 gravimetric (sulfate)
Bismuth	1-4, 6, 7, 9, 10	5, 8, 11	
Zinc	1, 2, 4, 5, 7, 10	3, 6, 8, 9	
Selenium	2-8	1, 9	
Boron	1, 3-10	2	
Nitrogen	-	-	1-6, 8 inert gas fusion (thermal conductivity) 7 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 January 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.