

CERTIFICATE OF ANALYSIS

11X C9 (batch D)

Certified Reference Material Information

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

Assigned Values

Percentage element by weight

Element	C	Si	S	P	Mn	Ni	Cr	Mo
Value ¹	3.24	1.462	0.0260	0.069	1.886	2.79	1.206	0.155
Uncertainty ²	0.02	0.016	0.0010	0.003	0.013	0.02	0.010	0.003

Element	Cu	Co	Sn	Al	Ti	V	Nb
Value ¹	0.581	0.1301	0.040	0.051	(0.062)	0.359	0.0766
Uncertainty ²	0.015	0.0016	0.002	0.002	-	0.005	0.0016

Element	W	As	Pb	Sb	Te	Zn	B
Value ¹	0.304	0.068	0.0052	0.149	0.011	0.009	0.0049
Uncertainty ²	0.005	0.003	0.0005	0.002	0.001	0.001	0.0003

Note: values given 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 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 21st April 2016

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Method of Preparation

This reference material was produced from commercial-purity metals, with the minor and trace elements added as pure elements, binaries and 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, 10% of all discs were selected for homogeneity checking.

Homogeneity

Samples representative of the batch were checked for uniformity using an optical emission spectrometer. Multiple measurements were taken from each surface under test.

Using the meaned data from each surface, standard deviation values were derived for each element as an indicator of any non-homogeneity (as determined for the specific sample size taken by 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 - 2005, 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 a national authority. It is part of the 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 primary reference materials.

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.

Separate standard deviation values were also derived for each element, from the homogeneity testing described above. These values were combined with the 95% half-width confidence intervals ($C_{(95\%)}$) obtained from the wet analysis programme, 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-element effects.

Analytical Data

Percentage element by weight

Sample	C	Si	S	P	Mn	Ni	Cr	Mo
1	3.201	1.439	0.0251	0.0649	1.865	2.760	1.183	0.1498
2	3.210	1.449	0.0253	0.0659	1.867	2.776	1.189	0.1500
3	3.215	1.454	0.0255	0.0661	1.876	2.779	1.195	0.1511
4	3.223	1.455	0.0255	0.0681	1.876	2.780	1.196	0.1514
5	3.224	1.456	0.0255	0.0684	1.879	2.782	1.201	0.1530
6	3.242	1.467	0.0258	0.0685	1.881	2.785	1.207	0.1534
7	3.244	1.479	0.0261	0.0698	1.887	2.789	1.210	0.1540
8	3.245	1.480	0.0261	0.0709	1.889	2.801	1.211	0.1540
9	3.250	1.482	0.0262	0.0720	1.897	2.811	1.211	0.1549
10	3.254		0.0265	0.0726	1.900	2.812	1.212	0.1550
11	3.257		0.0265	0.0729	1.901	2.813	1.228	0.1560
12	3.280		0.0265		1.902	2.813	1.230	0.1590
13	3.280		0.0269		1.903			0.1602
14								0.1614
Mean	3.240	1.462	0.0260	0.0691	1.886	2.792	1.206	0.1545
Std Dev	0.025	0.015	0.0006	0.0028	0.013	0.018	0.014	0.0036
C (95%)	0.015	0.012	0.0004	0.0019	0.008	0.011	0.009	0.0021

Sample	Cu	Co	Sn	Al	Ti	V	Nb
1	0.555	0.1262	0.0369	0.0476	0.0597	0.345	0.0746
2	0.558	0.1263	0.0375	0.0496	0.0599	0.350	0.0751
3	0.563	0.1282	0.0385	0.0499	0.0602	0.351	0.0752
4	0.568	0.1290	0.0391	0.0499	0.0618	0.351	0.0754
5	0.568	0.1291	0.0401	0.0500	0.0619	0.352	0.0754
6	0.578	0.1295	0.0407	0.0507	0.0628	0.355	0.0761
7	0.578	0.1300	0.0408	0.0510	0.0630	0.360	0.0762
8	0.584	0.1301	0.0411	0.0524	0.0635	0.364	0.0762
9	0.593	0.1304	0.0417	0.0527	0.0637	0.364	0.0778
10	0.596	0.1306	0.0424	0.0531	0.0642	0.364	0.0799
11	0.601	0.1310	0.0428	0.0533		0.365	0.0804
12	0.603	0.1320		0.0533		0.371	
13	0.606	0.1322				0.374	
14		0.1330					
15		0.1340					
Mean	0.581	0.1301	0.0401	0.0511	0.0621	0.359	0.0766
Std Dev	0.018	0.0022	0.0019	0.0018	0.0017	0.009	0.0020
C (95%)	0.011	0.0012	0.0013	0.0011	0.0012	0.005	0.0013

Sample	W	As	Pb	Sb	Te	Zn	B
1	0.2950	0.0649	0.0048	0.1461	0.0097	0.0079	0.0045
2	0.2980	0.0658	0.0049	0.1470	0.0104	0.0081	0.0047
3	0.2997	0.0661	0.0049	0.1476	0.0105	0.0089	0.0047
4	0.3001	0.0669	0.0050	0.1479	0.0110	0.0091	0.0048
5	0.3040	0.0680	0.0051	0.1484	0.0114	0.0094	0.0048
6	0.3060	0.0688	0.0052	0.1500	0.0115	0.0096	0.0051
7	0.3061	0.0693	0.0052	0.1500	0.0119	0.0097	0.0052
8	0.3085	0.0694	0.0052	0.1517		0.0105	0.0052
9	0.3100	0.0700	0.0053	0.1519		0.0108	
10	0.3100	0.0710	0.0054	0.1532			
11	0.3110	0.0716	0.0056				
12			0.0057				
Mean	0.3044	0.0683	0.0052	0.1494	0.0109	0.0093	0.0049
Std Dev	0.0055	0.0022	0.0003	0.0024	0.0008	0.0010	0.0003
C (95%)	0.0037	0.0015	0.0002	0.0017	0.0007	0.0008	0.0003

Participating Laboratories

Exova Ltd
Sheffield Assay Office
Metals Technology (Testing) Ltd
Universal Scientific Laboratory Pty Ltd
Laboratory Testing, Inc
Shanghai Jinyi Test Technology Co
Shandong Metallurgical & Science Research
Raghavendra Spectromet Laboratory
Bureau Veritas CPS Pvt
TCR Engineering Services Ltd
Tec-Eurolab
Instytut Metalurgii Zelaza
Mineral & Metallurgical Laboratories
Coleshill Laboratories Ltd
AMG Superalloys UK Ltd
Analyticka Laborator Lithea, sro

Middlesbrough, England
Sheffield, England
Sheffield, England
Milperra, NSW, Australia
Hatfield, PA, USA
Shanghai, China
Jinan, Shandong, China
Bangalore, India
Chennai, India
Mumbai, India
Campogalliano, Italy
Gliwice, Poland
Bangalore, India
Birmingham, England
Rotherham, England
Brno, Czech Republic

UKAS accreditation 0239
UKAS accreditation 0012
UKAS accreditation 0963
NATA accreditation 0492
A2LA accreditation 0117
CNAL accreditation 0783
CNAS accreditation 1461
NABL accreditation 0371
NABL accreditation 0025
NABL accreditation 0367
ACCREDIA accreditation 52
PCA accreditation AB554

Note: to achieve the above accreditation (UKAS, NATA, 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, 5, 7, 9	-	3, 4, 8	photometric (molybdenum blue)
Sulfur	5	-	1, 6 1, 3, 4, 6-13	gravimetric (perchloric acid) combustion (infra-red detection)
Phosphorus	1, 3-5, 8, 9	-	2 6, 11	volumetric (iodate) photometric (molybdenum blue)
Manganese	1-6, 11, 12	10	2, 7, 10 9, 13	volumetric (alkalimetric) volumetric (arsenite, FAS)
Nickel	3, 6, 8, 10-12	2, 4	7, 8 5, 7	photometric (periodate) photometric (dimethyl glyoxime)
Chromium	1, 2, 5, 8, 10, 11	7, 12	1, 9 3, 6, 9	gravimetric (dimethyl glyoxime) volumetric (ferrous ammonium sulfate)
Molybdenum	1-3, 6, 8, 9, 11-14	4, 7	4 5, 10	photometric (diphenyl carbazide) photometric (thiocyanate)
Copper	1, 2, 4, 6, 8, 10, 12, 13	5, 9, 11	3, 7	photometric (BCO)
Cobalt	1-5, 8-10, 13, 15	6, 7, 11	12 14	photometric (2 β -naphтол) gravimetric (oxide)
Tin	1, 4, 6-9, 11	2, 3, 5	10	gravimetric (perchloric acid)
Aluminium	3, 5-8, 12	1, 2, 10	4, 11 9	photometric (chrome azurol s) volumetric (EDTA)
Titanium	1, 2, 4-6, 8	7, 10	3, 9	photometric (diantipryl methane, peroxide)
Vanadium	1, 4, 5, 8, 9, 11-13	2, 6, 10	3, 7	volumetric (ferrous ammonium sulfate)
Niobium	1-3, 6-11	-	5 4	photometric (chlorosulfophenol) gravimetric
Tungsten	2-4, 6-10	1	5 11	photometric (thiocyanate) gravimetric
Arsenic	2, 4-11	1, 3		
Lead	1, 2, 4, 5, 7, 8, 10-12	3, 6, 9		
Antimony	1, 3, 5-10	2, 4		
Tellurium	1-7	-		
Zinc	1, 3-5, 7-9	2, 6		
Boron	1-8	-		

Notes

This Certified Reference Material has been produced and certified in accordance with the requirements of ISO Guide 34-2009, ISO Guide 31-2015 and ISO Guide 35-2006, 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. Material to the rear of the disc, to a depth of ~5mm, is not certified.

This material will remain stable 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 April 2036, 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 L Maxim, Technical Director, MBH Analytical Ltd.

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