

31X 7835.6 C Page 1 of 4 February 2016

HOLLAND HOUSE • QUEENS ROAD • BARNET • EN5 4DJ • ENGLAND • TEL: +44 (0)20 8441 2024 • FAX: +44 (0)20 8449 0810 email: info@mbh.co.uk web: www.mbh.co.uk

# CERTIFICATE OF ANALYSIS

31X 7835.6 (batch C)

### **Certified Reference Material Information**

Type: LEADED BRASS (CHILL CAST)

Form and Size: Disc ~40mm diameter

Manufactured by: Polycast Ltd

Certified and Supplied by: MBH Analytical Ltd

### **Assigned Values**

#### Percentage element by weight

Element	Sn	Pb	Fe	Ni	Al	Cu	Si	S	Te
Value <sup>1</sup>	0.548	1.422	0.0211	0.021	0.573	60.70	0.0214	(0.0016)	(0.0010)
Uncertainty 2	0.006	0.013	8000.0	0.002	0.005	0.03	0.0010	-	-

Element	Со	As	Р	Bi	Se	Cd	Ag	В	Zn
Value 1	0.0048	0.0152	0.0253	0.0043	0.0010	0.0017	0.0044	0.0045	36.60
Uncertainty <sup>2</sup>	0.0004	0.0003	0.0008	0.0004	0.0002	0.0001	0.0005	0.0002	0.09

Note: values given in parentheses are not certified - they are provided for information only.

### **Definitions**

- 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.
- 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.

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Certified	hw.
Certified	Dy.

on 29th February 2016

MBH ANALYTICAL LIMITED \_\_\_\_\_

C Eveleigh





#### **Method of Preparation**

This reference material was produced from commercial-purity metals, and master alloys. The discs are the product of one melt poured into a sequence of multiple chill moulds with feeding systems designed to ensure sound discs. At least 2mm has been removed from the chill-cast faces of the discs to minimise surface effects.

#### **Sampling**

Samples for chemical analysis were taken from various positions throughout the casting process. At least 15% of all discs were selected for non-destructive homogeneity testing.

### **Homogeneity**

The discs were checked for sample and batch uniformity using an optical emission spectrometer.

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.

#### **Estimation of Uncertainties**

Each element certified has been analysed by several laboratories, and 95% half-width confidence intervals ( $C_{(95\%)}$ ) for the resultant mean values have been derived by the method shown on page 3.

As a separate exercise, the degree of non-homogeneity of the batch for each element has been quantified by a programme of non-destructive application testing, described above.

The final certified uncertainty for each element has been derived by combining these two factors, using the squareroot of the summed squares.

### **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. In addition, some of the results derived as part of this testing programme have traceability to NIST standards, as part of the analytical calibration or process control.

#### **Usage**

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

Recommended method of use:

Copper alloys are generally prepared by machining on a mill or a lathe. 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.

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

1         0.5419         1.394         0.0191         0.0193         0.5684         60.68         0.0201         0.0010         0.0005           2         0.5420         1.398         0.0191         0.0194         0.5684         60.68         0.0201         0.0010         0.0005           3         0.5440         1.401         0.0197         0.0199         0.5703         60.71         0.0207         0.0012         0.0010           5         0.5465         1.411         0.0201         0.0201         0.5710         60.71         0.0217         0.0012           6         0.5470         1.418         0.0204         0.0203         0.5710         60.71         0.0214         0.0017         0.0012           7         0.5470         1.418         0.0204         0.0203         0.5730         60.73         0.0215         0.0019         0.0012           8         0.5471         1.420         0.0210         0.0208         0.5730         0.071         0.0218         0.0021           10         0.5483         1.424         0.0216         0.0210         0.5771         0.0218         0.0021           11         0.5490         1.434         0.0217         0.0214 <th>Sample</th> <th>Sn</th> <th>Pb</th> <th>Fe</th> <th>Ni</th> <th>Al</th> <th>Cu</th> <th>Si</th> <th>S</th> <th>Te</th>	Sample	Sn	Pb	Fe	Ni	Al	Cu	Si	S	Te
3 0.5440 1.401 0.0197 0.0199 0.5703 60.71 0.0207 0.0010 0.0008 4 0.5445 1.408 0.0198 0.0200 0.5703 60.71 0.0207 0.0012 0.0010 5 0.5465 1.411 0.0201 0.0201 0.5710 60.71 0.0210 0.0013 0.0011 6 0.5470 1.415 0.0203 0.0202 0.5710 60.71 0.0214 0.0015 0.0012 7 0.5470 1.418 0.0204 0.0203 0.5720 60.73 0.0215 0.0017 0.0012 8 0.5470 1.419 0.0208 0.0204 0.5730 0.0215 0.0017 0.0012 9 0.5471 1.429 0.0210 0.0208 0.5733 0.0215 0.0019 0.0017 10 0.5483 1.423 0.0213 0.0210 0.5740 0.0218 0.0021 11 0.5490 1.424 0.0216 0.0210 0.5771 0.0218 0.0022 11 0.5500 1.434 0.0217 0.0214 0.5775 0.0228 0.0231 13 0.5506 1.435 0.0220 0.0214 0.5800 0.0231 14 0.5520 1.438 0.0234 0.0224 15 0.5550 1.438 0.0234 0.0224 16 0.5557 1.4415 0.0224 0.0224 17 1.451  Mean 0.5481 1.422 0.0211 0.0208 0.5734 60.70 0.0214 (0.0016) (0.0010)  Std Dev 0.0043 0.017 0.0015 0.0010 0.0043 0.03 0.0005  C(95%) 0.0023 0.008 0.0008 0.0005 0.0025 0.003 0.0005 0.0040 36.57 2 0.0042 0.0147 0.0236 0.0039 0.0008 0.0016 0.0035 0.0040 36.57 2 0.0042 0.0147 0.0236 0.0039 0.0008 0.0016 0.0035 0.0040 36.57 2 0.0042 0.0147 0.0236 0.0039 0.0008 0.0016 0.0035 0.0041 36.57 3 0.0044 0.0149 0.0246 0.0040 0.0008 0.0016 0.0035 0.0041 36.57 3 0.0044 0.0149 0.0248 0.0041 0.0008 0.0016 0.0038 0.0041 36.57 3 0.0044 0.0152 0.0254 0.0041 0.0008 0.0016 0.0039 0.0041 36.57 3 0.0044 0.0152 0.0254 0.0041 0.0009 0.0016 0.0039 0.0041 36.57 3 0.0047 0.0152 0.0254 0.0041 0.0009 0.0016 0.0031 0.0041 36.56 6 0.0047 0.0152 0.0254 0.0041 0.0009 0.0016 0.0041 0.0044 36.66 7 0.0047 0.0152 0.0254 0.0045 0.0011 0.0017 0.0042 0.0046 11 0.0044 36.66 6 0.0047 0.0152 0.0254 0.0045 0.0011 0.0017 0.0045 0.0049 12 0.0046 11 0.0008 0.0016 0.0031 0.0041 0.0044 36.66 6 0.0047 0.0152 0.0254 0.0045 0.0011 0.0017 0.0042 0.0046 11 0.0008 0.0016 0.0031 0.0041 0.0044 36.66 6 0.0047 0.0152 0.0254 0.0044 0.0010 0.0017 0.0042 0.0048 11 0.0008 0.0016 0.0031 0.0041 0.0044 36.66 6 0.0047 0.0152 0.0254 0.0046 0.0011 0.0017 0.0042 0.0048 11 0.0008 0.0066 0.0068 0.0068 0.0068 0.0068 0.0068 0.0068 0.0068 0.0068 0.0068 0.0068 0.0068 0										
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11		0.5471	1.420	0.0210	0.0208	0.5733		0.0218	0.0021	
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14       0.5520       1.437       0.0231       0.0216       0.5823         15       0.5550       1.438       0.0234       0.0224       0.0229         17       1.451       0.0242       0.0229       0.0229         Mean       0.5481       1.422       0.0211       0.0208       0.5734       60.70       0.0214       (0.0016)       (0.0010)         Std Dev       0.0043       0.017       0.0015       0.0010       0.0043       0.03       0.0009       -       -         C(95%)       0.0023       0.008       0.0008       0.0005       0.0025       0.03       0.0005       -       -         Sample       Co       As       P       Bi       Se       Cd       Ag       B       Zn         1       0.0042       0.0142       0.0234       0.0038       0.0006       0.0015       0.0035       0.0040       36.57         2       0.0042       0.0147       0.0236       0.0039       0.0016       0.0035       0.0041       36.57         3       0.0044       0.0149       0.0248       0.0041       0.0008       0.0016       0.0038       0.0043       36.58         4       0.0045									0.0023	
15								0.0231		
16 17         0.5574 1.455         1.445 1.451         0.0242 0.0229         0.0229           Mean         0.5481         1.422         0.0211 0.0208         0.5734 0.07         0.0214 (0.0016) (0.0010)         (0.0016) (0.0010)           Std Dev         0.0043         0.017 0.0015 0.0010 0.0043         0.03 0.0009 0.0005         -         -           C(95%)         0.0023 0.008 0.008 0.0008 0.0005 0.0025 0.003         0.0005 0.0005 0.0005         0.0035 0.0005 0.0040         -           1 0.0042 0.0142 0.0142 0.0234 0.0038 0.0006 0.0015 0.0035 0.0041 0.0035 0.0041 0.0036 0.0016 0.0035 0.0041 0.0035 0.0041 0.0036 0.0016 0.0035 0.0041 0.0036 0.0016 0.0035 0.0041 0.0045 0.0041 0.0049 0.0040 0.0008 0.0016 0.0035 0.0041 0.0043 0.058         4 0.0045 0.0151 0.0248 0.0041 0.0008 0.0016 0.0038 0.0043 0.0043 0.662 0.0040 0.0040 0.0008 0.0016 0.0038 0.0043 0.0043 0.0045 0.0041 0.0045 0.0044 0.0044 0.0044 0.0009 0.0016 0.0041 0.0043 0.0044 0.0044 0.0046 0.0041 0.0044 0.0048 0.0044 0.0048 0.0044 0.0048 0.0044 0.0048 0.0044 0.0048 0.0044 0.0048 0.0044 0.0048 0.0044 0.0048 0.0044 0.0018 0.0047 0.0049 0.0051 0.0051 0.0052 0.0154 0.0268 0.0048 0.0048 0.0014 0.0018 0.0047 0.0049 0.0051 0.0051 0.0052 0.0156 0.0278 0.0044 0.0046 0.0014 0.0018 0.0047 0.0049 0.0051 0.0051 0.0052 0.0156 0.0278 0.0048 0.0049 0.0051 0.0052 0.0052 0.0156 0.0278 0.0049 0.0051 0.0052 0.0052 0.0156 0.0278 0.0049 0.0051 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0052 0.0						0.3623				
Mean         0.5481         1.422         0.0211         0.0208         0.5734         60.70         0.0214         (0.0016)         (0.0010)           Std Dev         0.0043         0.017         0.0015         0.0010         0.0043         0.03         0.0009         -         -         -           C(95%)         0.0023         0.008         0.0008         0.0005         0.0025         0.03         0.0005         -         -         -           Sample         Co         As         P         Bi         Se         Cd         Ag         B         Zn           1         0.0042         0.0142         0.0234         0.0038         0.0006         0.0015         0.0035         0.0040         36.57           2         0.0042         0.0147         0.0236         0.0039         0.0008         0.0016         0.0035         0.0041         36.57           3         0.0044         0.0149         0.0246         0.0040         0.0008         0.0016         0.0035         0.0041         36.57           3         0.0045         0.0150         0.0248         0.0041         0.0008         0.0016         0.0038         0.0043         36.62 <td< th=""><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></td<>										
Std Dev         0.0043         0.017         0.0015         0.0010         0.0043         0.03         0.0009         -         -           C(95%)         0.0023         0.008         0.0008         0.0005         0.0025         0.03         0.0005         -         -           Sample         Co         As         P         Bi         Se         Cd         Ag         B         Zn           1         0.0042         0.0142         0.0234         0.0038         0.0006         0.0015         0.0035         0.0040         36.57           2         0.0042         0.0147         0.0236         0.0039         0.0008         0.0016         0.0035         0.0041         36.57           3         0.0044         0.0149         0.0246         0.0040         0.0008         0.0016         0.0038         0.0043         36.58           4         0.0045         0.0150         0.0248         0.0041         0.0008         0.016         0.0039         0.0043         36.62           5         0.0045         0.0151         0.0248         0.0041         0.0008         0.016         0.0041         0.0043         36.62           6         0.0047         0.		0.00.		0.02.2	0.0220					
C <sub>(95%)</sub> 0.0023         0.008         0.0008         0.0005         0.0025         0.03         0.0005         -         -           Sample         Co         As         P         Bi         Se         Cd         Ag         B         Zn           1         0.0042         0.0142         0.0234         0.0038         0.0006         0.0015         0.0035         0.0040         36.57           2         0.0042         0.0147         0.0236         0.0039         0.0008         0.0016         0.0035         0.0041         36.57           3         0.0044         0.0149         0.0246         0.0040         0.0008         0.0016         0.0038         0.0043         36.58           4         0.0045         0.0150         0.0248         0.0041         0.0008         0.0016         0.0038         0.0043         36.58           4         0.0045         0.0151         0.0248         0.0041         0.0009         0.0016         0.0039         0.0043         36.62           5         0.0047         0.0152         0.0251         0.0041         0.0009         0.0016         0.0041         0.0043         36.62           6         0.0047	Mean	0.5481	1.422	0.0211	0.0208	0.5734	60.70	0.0214	(0.0016)	(0.0010)
Sample   Co   As   P   Bi   Se   Cd   Ag   B   Zn	Std Dev	0.0043	0.017	0.0015	0.0010	0.0043	0.03	0.0009	-	-
1         0.0042         0.0142         0.0234         0.0038         0.0006         0.0015         0.0035         0.0040         36.57           2         0.0042         0.0147         0.0236         0.0039         0.0008         0.0016         0.0035         0.0041         36.57           3         0.0044         0.0149         0.0246         0.0040         0.0008         0.0016         0.0038         0.0043         36.58           4         0.0045         0.0150         0.0248         0.0041         0.0008         0.0016         0.0039         0.0043         36.58           5         0.0045         0.0151         0.0248         0.0041         0.0009         0.0016         0.0039         0.0043         36.62           6         0.0047         0.0152         0.0251         0.0041         0.0009         0.0016         0.0041         0.0043         36.62           6         0.0047         0.0152         0.0254         0.0042         0.0010         0.0017         0.0042         0.0046           8         0.0047         0.0152         0.0254         0.0044         0.0010         0.0017         0.0045         0.0047           9         0.0048         0.	C <sub>(95%)</sub>	0.0023	0.008	0.0008	0.0005	0.0025	0.03	0.0005	-	-
1         0.0042         0.0142         0.0234         0.0038         0.0006         0.0015         0.0035         0.0040         36.57           2         0.0042         0.0147         0.0236         0.0039         0.0008         0.0016         0.0035         0.0041         36.57           3         0.0044         0.0149         0.0246         0.0040         0.0008         0.0016         0.0038         0.0043         36.58           4         0.0045         0.0150         0.0248         0.0041         0.0008         0.0016         0.0039         0.0043         36.52           5         0.0045         0.0151         0.0248         0.0041         0.0009         0.0016         0.0039         0.0043         36.62           6         0.0047         0.0152         0.0251         0.0041         0.0009         0.0016         0.0041         0.0043         36.62           6         0.0047         0.0152         0.0254         0.0042         0.0010         0.0017         0.0042         0.0046           7         0.0047         0.0152         0.0254         0.0044         0.0010         0.0017         0.0045         0.0047           8         0.0047         0.										
2         0.0042         0.0147         0.0236         0.0039         0.0008         0.0016         0.0035         0.0041         36.57           3         0.0044         0.0149         0.0246         0.0040         0.0008         0.0016         0.0038         0.0043         36.58           4         0.0045         0.0150         0.0248         0.0041         0.0008         0.0016         0.0039         0.0043         36.58           5         0.0045         0.0151         0.0248         0.0041         0.0009         0.0016         0.0041         0.0043         36.62           6         0.0047         0.0152         0.0251         0.0041         0.0009         0.0016         0.0041         0.0043         36.62           7         0.0047         0.0152         0.0254         0.0042         0.0010         0.0017         0.0042         0.0046           8         0.0047         0.0152         0.0254         0.0044         0.0017         0.0045         0.0047           9         0.0048         0.0153         0.0258         0.0045         0.0011         0.0017         0.0046         0.0048           10         0.0052         0.0153         0.0268										
3       0.0044       0.0149       0.0246       0.0040       0.0008       0.0016       0.0038       0.0043       36.58         4       0.0045       0.0150       0.0248       0.0041       0.0008       0.0016       0.0039       0.0043       36.62         5       0.0045       0.0151       0.0248       0.0041       0.0009       0.0016       0.0041       0.0043       36.62         6       0.0047       0.0152       0.0251       0.0041       0.0009       0.0016       0.0041       0.0043       36.62         7       0.0047       0.0152       0.0254       0.0042       0.0010       0.0017       0.0042       0.0046         8       0.0047       0.0152       0.0254       0.0044       0.0010       0.0017       0.0045       0.0047         9       0.0048       0.0152       0.0255       0.0045       0.0011       0.0017       0.0045       0.0048         10       0.0051       0.0153       0.0264       0.0046       0.0013       0.0017       0.0046       0.0048         11       0.0052       0.0154       0.0268       0.0048       0.0018       0.0049       0.0051         13       0.0252       0.0	Sample	Со	As	Р	Bi	Se	Cd	Ag	В	Zn
4       0.0045       0.0150       0.0248       0.0041       0.0008       0.0016       0.0039       0.0043       36.62         5       0.0045       0.0151       0.0248       0.0041       0.0009       0.0016       0.0041       0.0043       36.62         6       0.0047       0.0152       0.0251       0.0041       0.0009       0.0016       0.0041       0.0044       36.66         7       0.0047       0.0152       0.0254       0.0042       0.0010       0.0017       0.0042       0.0046         8       0.0047       0.0152       0.0254       0.0044       0.0010       0.0017       0.0045       0.0047         9       0.0048       0.0152       0.0255       0.0045       0.0011       0.0017       0.0045       0.0048         10       0.0051       0.0153       0.0258       0.0045       0.0013       0.0017       0.0046       0.0048         11       0.0052       0.0154       0.0268       0.0048       0.0018       0.0049       0.0051         12       0.0052       0.0156       0.0278       0.0019       0.0051       0.0051         15       0.0053       0.0162       0.0051       0.0019       0	1	0.0042	0.0142	0.0234	0.0038	0.0006	0.0015	0.0035	0.0040	36.57
5         0.0045         0.0151         0.0248         0.0041         0.0009         0.0016         0.0041         0.0043         36.62           6         0.0047         0.0152         0.0251         0.0041         0.0009         0.0016         0.0041         0.0044         36.66           7         0.0047         0.0152         0.0254         0.0042         0.0010         0.0017         0.0042         0.0046           8         0.0047         0.0152         0.0254         0.0044         0.0010         0.0017         0.0045         0.0047           9         0.0048         0.0152         0.0255         0.0045         0.0011         0.0017         0.0045         0.0048           10         0.0051         0.0153         0.0258         0.0045         0.0013         0.0017         0.0046         0.0048           11         0.0052         0.0153         0.0264         0.0046         0.0014         0.0018         0.0047         0.0049           12         0.0052         0.0156         0.0278         0.0048         0.0019         0.0050           14         0.0053         0.0162         0.0052         0.0051         0.0052           Mean         0	1 2	0.0042 0.0042	0.0142 0.0147	0.0234 0.0236	0.0038 0.0039	0.0006 0.0008	0.0015 0.0016	0.0035 0.0035	0.0040 0.0041	36.57 36.57
6       0.0047       0.0152       0.0251       0.0041       0.0009       0.0016       0.0041       0.0044       36.66         7       0.0047       0.0152       0.0254       0.0042       0.0010       0.0017       0.0042       0.0046         8       0.0047       0.0152       0.0254       0.0044       0.0010       0.0017       0.0045       0.0047         9       0.0048       0.0152       0.0255       0.0045       0.0011       0.0017       0.0045       0.0048         10       0.0051       0.0153       0.0258       0.0045       0.0013       0.0017       0.0046       0.0048         11       0.0052       0.0153       0.0264       0.0046       0.0014       0.0018       0.0047       0.0049         12       0.0052       0.0154       0.0268       0.0048       0.0018       0.0049       0.0051         13       0.0052       0.0156       0.0278       0.0019       0.0051       0.0051         15       0.0053       0.0162       0.0053       0.0019       0.0051       0.0052         Mean       0.0048       0.0052       0.0043       0.0010       0.0017       0.0044       0.0045       36.60 </th <th>1 2 3</th> <th>0.0042 0.0042 0.0044</th> <th>0.0142 0.0147 0.0149</th> <th>0.0234 0.0236 0.0246</th> <th>0.0038 0.0039 0.0040</th> <th>0.0006 0.0008 0.0008</th> <th>0.0015 0.0016 0.0016</th> <th>0.0035 0.0035 0.0038</th> <th>0.0040 0.0041 0.0043</th> <th>36.57 36.57 36.58</th>	1 2 3	0.0042 0.0042 0.0044	0.0142 0.0147 0.0149	0.0234 0.0236 0.0246	0.0038 0.0039 0.0040	0.0006 0.0008 0.0008	0.0015 0.0016 0.0016	0.0035 0.0035 0.0038	0.0040 0.0041 0.0043	36.57 36.57 36.58
7         0.0047         0.0152         0.0254         0.0042         0.0010         0.0017         0.0042         0.0046           8         0.0047         0.0152         0.0254         0.0044         0.0010         0.0017         0.0045         0.0047           9         0.0048         0.0152         0.0255         0.0045         0.0011         0.0017         0.0045         0.0048           10         0.0051         0.0153         0.0258         0.0045         0.0013         0.0017         0.0046         0.0048           11         0.0052         0.0153         0.0264         0.0046         0.0014         0.0018         0.0047         0.0049           12         0.0052         0.0154         0.0268         0.0048         0.0018         0.0049         0.0051           13         0.0052         0.0156         0.0278         0.0019         0.0050         0.0051           14         0.0053         0.0162         0.0253         0.0043         0.0010         0.0017         0.0044         0.0045         36.60           Mean         0.0048         0.0152         0.0253         0.0043         0.0002         0.0001         0.0044         0.0044         0.0045	1 2 3 4	0.0042 0.0042 0.0044 0.0045	0.0142 0.0147 0.0149 0.0150	0.0234 0.0236 0.0246 0.0248	0.0038 0.0039 0.0040 0.0041	0.0006 0.0008 0.0008 0.0008	0.0015 0.0016 0.0016 0.0016	0.0035 0.0035 0.0038 0.0039	0.0040 0.0041 0.0043 0.0043	36.57 36.57 36.58 36.62
8       0.0047       0.0152       0.0254       0.0044       0.0010       0.0017       0.0045       0.0047         9       0.0048       0.0152       0.0255       0.0045       0.0011       0.0017       0.0045       0.0048         10       0.0051       0.0153       0.0258       0.0045       0.0013       0.0017       0.0046       0.0048         11       0.0052       0.0153       0.0264       0.0046       0.0014       0.0018       0.0047       0.0049         12       0.0052       0.0154       0.0268       0.0048       0.0018       0.0049       0.0051         13       0.0052       0.0156       0.0278       0.0019       0.0050       0.0051         14       0.0053       0.0162       0.0019       0.0051       0.0051       0.0052         16       0.0053       0.0162       0.0053       0.0019       0.0017       0.0044       0.0045       36.60         Std Dev       0.0004       0.0005       0.0012       0.0003       0.0002       0.0001       0.0006       0.0003       0.04	1 2 3 4 5	0.0042 0.0042 0.0044 0.0045 0.0045	0.0142 0.0147 0.0149 0.0150 0.0151	0.0234 0.0236 0.0246 0.0248 0.0248	0.0038 0.0039 0.0040 0.0041 0.0041	0.0006 0.0008 0.0008 0.0008 0.0009	0.0015 0.0016 0.0016 0.0016 0.0016	0.0035 0.0035 0.0038 0.0039 0.0041	0.0040 0.0041 0.0043 0.0043 0.0043	36.57 36.57 36.58 36.62 36.62
10       0.0051       0.0153       0.0258       0.0045       0.0013       0.0017       0.0046       0.0048         11       0.0052       0.0153       0.0264       0.0046       0.0014       0.0018       0.0047       0.0049         12       0.0052       0.0154       0.0268       0.0048       0.0018       0.0049       0.0051         13       0.0052       0.0156       0.0278       0.0019       0.0050       0.0051         14       0.0053       0.0158       0.0019       0.0051       0.0051         15       0.0053       0.0162       0.0051       0.0052         Mean       0.0048       0.0152       0.0253       0.0043       0.0010       0.0017       0.0044       0.0045       36.60         Std Dev       0.0004       0.0005       0.0012       0.0003       0.0002       0.0001       0.0006       0.0003       0.04	1 2 3 4 5	0.0042 0.0042 0.0044 0.0045 0.0045 0.0047	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152	0.0234 0.0236 0.0246 0.0248 0.0248 0.0251	0.0038 0.0039 0.0040 0.0041 0.0041	0.0006 0.0008 0.0008 0.0008 0.0009 0.0009	0.0015 0.0016 0.0016 0.0016 0.0016 0.0016	0.0035 0.0035 0.0038 0.0039 0.0041 0.0041	0.0040 0.0041 0.0043 0.0043 0.0043 0.0044	36.57 36.57 36.58 36.62 36.62
11       0.0052       0.0153       0.0264       0.0046       0.0014       0.0018       0.0047       0.0049         12       0.0052       0.0154       0.0268       0.0048       0.0018       0.0049       0.0049       0.0051         13       0.0052       0.0156       0.0278       0.0019       0.0050       0.0051         14       0.0053       0.0158       0.0162       0.0051       0.0051         16       0.0052       0.0052       0.0052       0.0052         Mean       0.0048       0.0152       0.0253       0.0043       0.0010       0.0017       0.0044       0.0045       36.60         Std Dev       0.0004       0.0005       0.0012       0.0003       0.0002       0.0001       0.0006       0.0003       0.04	1 2 3 4 5 6 7	0.0042 0.0042 0.0044 0.0045 0.0045 0.0047	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152 0.0152	0.0234 0.0236 0.0246 0.0248 0.0248 0.0251 0.0254	0.0038 0.0039 0.0040 0.0041 0.0041 0.0041	0.0006 0.0008 0.0008 0.0008 0.0009 0.0009	0.0015 0.0016 0.0016 0.0016 0.0016 0.0016 0.0017	0.0035 0.0035 0.0038 0.0039 0.0041 0.0041	0.0040 0.0041 0.0043 0.0043 0.0044 0.0046	36.57 36.57 36.58 36.62 36.62
12       0.0052       0.0154       0.0268       0.0048       0.0018       0.0049       0.0049       0.0051         13       0.0052       0.0156       0.0278       0.0019       0.0050       0.0051         14       0.0053       0.0158       0.0162       0.0051       0.0051         15       0.0053       0.0162       0.0051       0.0052         Mean       0.0048       0.0152       0.0253       0.0043       0.0010       0.0017       0.0044       0.0045       36.60         Std Dev       0.0004       0.0005       0.0012       0.0003       0.0002       0.0001       0.0006       0.0003       0.04	1 2 3 4 5 6 7 8	0.0042 0.0042 0.0044 0.0045 0.0045 0.0047 0.0047 0.0047	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152 0.0152 0.0152 0.0152	0.0234 0.0236 0.0246 0.0248 0.0248 0.0251 0.0254 0.0254	0.0038 0.0039 0.0040 0.0041 0.0041 0.0042 0.0044 0.0045	0.0006 0.0008 0.0008 0.0009 0.0009 0.0010 0.0010 0.0011	0.0015 0.0016 0.0016 0.0016 0.0016 0.0016 0.0017 0.0017	0.0035 0.0035 0.0038 0.0039 0.0041 0.0041 0.0042 0.0045	0.0040 0.0041 0.0043 0.0043 0.0043 0.0044 0.0046 0.0047 0.0048	36.57 36.57 36.58 36.62 36.62
13       0.0052       0.0156       0.0278       0.0019       0.0050         14       0.0053       0.0158       0.0019       0.0051         15       0.0053       0.0162       0.0051       0.0052         Mean       0.0048       0.0152       0.0253       0.0043       0.0010       0.0017       0.0044       0.0045       36.60         Std Dev       0.0004       0.0005       0.0012       0.0003       0.0002       0.0001       0.0006       0.0003       0.04	1 2 3 4 5 6 7 8 9	0.0042 0.0042 0.0044 0.0045 0.0045 0.0047 0.0047 0.0047 0.0048 0.0051	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152 0.0152 0.0152 0.0152 0.0153	0.0234 0.0236 0.0246 0.0248 0.0248 0.0251 0.0254 0.0254 0.0255 0.0258	0.0038 0.0039 0.0040 0.0041 0.0041 0.0042 0.0044 0.0045 0.0045	0.0006 0.0008 0.0008 0.0009 0.0009 0.0010 0.0010 0.0011 0.0013	0.0015 0.0016 0.0016 0.0016 0.0016 0.0016 0.0017 0.0017 0.0017	0.0035 0.0035 0.0038 0.0039 0.0041 0.0041 0.0042 0.0045 0.0045	0.0040 0.0041 0.0043 0.0043 0.0043 0.0044 0.0046 0.0047 0.0048	36.57 36.57 36.58 36.62 36.62
14       0.0053       0.0158       0.0019       0.0051         15       0.0053       0.0162       0.0051         16       0.0052             Mean       0.0048       0.0152       0.0253       0.0043       0.0010       0.0017       0.0044       0.0045       36.60         Std Dev       0.0004       0.0005       0.0012       0.0003       0.0002       0.0001       0.0006       0.0003       0.04	1 2 3 4 5 6 7 8 9 10	0.0042 0.0042 0.0044 0.0045 0.0045 0.0047 0.0047 0.0047 0.0048 0.0051 0.0052	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152 0.0152 0.0152 0.0152 0.0153 0.0153	0.0234 0.0236 0.0246 0.0248 0.0248 0.0251 0.0254 0.0254 0.0255 0.0258 0.0264	0.0038 0.0039 0.0040 0.0041 0.0041 0.0042 0.0042 0.0045 0.0045 0.0046	0.0006 0.0008 0.0008 0.0009 0.0009 0.0010 0.0010 0.0011 0.0013	0.0015 0.0016 0.0016 0.0016 0.0016 0.0016 0.0017 0.0017 0.0017 0.0017	0.0035 0.0035 0.0038 0.0039 0.0041 0.0041 0.0042 0.0045 0.0045 0.0046	0.0040 0.0041 0.0043 0.0043 0.0043 0.0044 0.0046 0.0047 0.0048 0.0048	36.57 36.57 36.58 36.62 36.62
15 0.0053 0.0162 0.0052  Mean 0.0048 0.0152 0.0253 0.0043 0.0010 0.0017 0.0044 0.0045 36.60  Std Dev 0.0004 0.0005 0.0012 0.0003 0.0002 0.0001 0.0006 0.0003 0.004	1 2 3 4 5 6 7 8 9 10 11	0.0042 0.0042 0.0044 0.0045 0.0045 0.0047 0.0047 0.0047 0.0048 0.0051 0.0052	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152 0.0152 0.0152 0.0152 0.0153 0.0153	0.0234 0.0236 0.0246 0.0248 0.0251 0.0254 0.0254 0.0255 0.0258 0.0264 0.0268	0.0038 0.0039 0.0040 0.0041 0.0041 0.0042 0.0042 0.0045 0.0045 0.0046	0.0006 0.0008 0.0008 0.0009 0.0009 0.0010 0.0010 0.0011 0.0013	0.0015 0.0016 0.0016 0.0016 0.0016 0.0017 0.0017 0.0017 0.0017 0.0018 0.0018	0.0035 0.0035 0.0038 0.0039 0.0041 0.0042 0.0045 0.0045 0.0046 0.0047 0.0049	0.0040 0.0041 0.0043 0.0043 0.0043 0.0044 0.0046 0.0047 0.0048 0.0048	36.57 36.57 36.58 36.62 36.62
Mean       0.0048       0.0152       0.0253       0.0043       0.0010       0.0017       0.0044       0.0045       36.60         Std Dev       0.0004       0.0005       0.0012       0.0003       0.0002       0.0001       0.0006       0.0003       0.04	1 2 3 4 5 6 7 8 9 10 11 12	0.0042 0.0042 0.0044 0.0045 0.0045 0.0047 0.0047 0.0047 0.0051 0.0052 0.0052	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152 0.0152 0.0152 0.0153 0.0153 0.0154 0.0156	0.0234 0.0236 0.0246 0.0248 0.0251 0.0254 0.0254 0.0255 0.0258 0.0264 0.0268	0.0038 0.0039 0.0040 0.0041 0.0041 0.0042 0.0042 0.0045 0.0045 0.0046	0.0006 0.0008 0.0008 0.0009 0.0009 0.0010 0.0010 0.0011 0.0013	0.0015 0.0016 0.0016 0.0016 0.0016 0.0017 0.0017 0.0017 0.0017 0.0018 0.0018 0.0019	0.0035 0.0035 0.0038 0.0039 0.0041 0.0041 0.0042 0.0045 0.0045 0.0046 0.0047 0.0049	0.0040 0.0041 0.0043 0.0043 0.0043 0.0044 0.0046 0.0047 0.0048 0.0048	36.57 36.57 36.58 36.62 36.62
Std Dev         0.0004         0.0005         0.0012         0.0003         0.0002         0.0001         0.0006         0.0003         0.04	1 2 3 4 5 6 7 8 9 10 11 12 13	0.0042 0.0042 0.0044 0.0045 0.0045 0.0047 0.0047 0.0048 0.0051 0.0052 0.0052 0.0052	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152 0.0152 0.0152 0.0153 0.0153 0.0154 0.0156 0.0158	0.0234 0.0236 0.0246 0.0248 0.0251 0.0254 0.0254 0.0255 0.0258 0.0264 0.0268	0.0038 0.0039 0.0040 0.0041 0.0041 0.0042 0.0042 0.0045 0.0045 0.0046	0.0006 0.0008 0.0008 0.0009 0.0009 0.0010 0.0010 0.0011 0.0013	0.0015 0.0016 0.0016 0.0016 0.0016 0.0017 0.0017 0.0017 0.0017 0.0018 0.0018 0.0019	0.0035 0.0035 0.0038 0.0039 0.0041 0.0042 0.0045 0.0045 0.0046 0.0047 0.0049 0.0050 0.0051	0.0040 0.0041 0.0043 0.0043 0.0043 0.0044 0.0046 0.0047 0.0048 0.0048	36.57 36.57 36.58 36.62 36.62
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	0.0042 0.0042 0.0044 0.0045 0.0045 0.0047 0.0047 0.0048 0.0051 0.0052 0.0052 0.0052	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152 0.0152 0.0152 0.0153 0.0153 0.0154 0.0156 0.0158	0.0234 0.0236 0.0246 0.0248 0.0251 0.0254 0.0254 0.0255 0.0258 0.0264 0.0268	0.0038 0.0039 0.0040 0.0041 0.0041 0.0042 0.0042 0.0045 0.0045 0.0046	0.0006 0.0008 0.0008 0.0009 0.0009 0.0010 0.0010 0.0011 0.0013	0.0015 0.0016 0.0016 0.0016 0.0016 0.0017 0.0017 0.0017 0.0017 0.0018 0.0018 0.0019	0.0035 0.0035 0.0038 0.0039 0.0041 0.0042 0.0045 0.0045 0.0046 0.0047 0.0049 0.0050 0.0051	0.0040 0.0041 0.0043 0.0043 0.0043 0.0044 0.0046 0.0047 0.0048 0.0048	36.57 36.57 36.58 36.62 36.62
<b>C</b> <sub>(95%)</sub> 0.0002 0.0003 0.0007 0.0002 0.0002 0.0001 0.0003 0.0002 0.004	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	0.0042 0.0042 0.0044 0.0045 0.0045 0.0047 0.0047 0.0048 0.0051 0.0052 0.0052 0.0052 0.0053	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152 0.0152 0.0152 0.0153 0.0153 0.0154 0.0156 0.0158 0.0162	0.0234 0.0236 0.0246 0.0248 0.0251 0.0254 0.0255 0.0258 0.0264 0.0268 0.0278	0.0038 0.0039 0.0040 0.0041 0.0041 0.0042 0.0044 0.0045 0.0045 0.0046 0.0048	0.0006 0.0008 0.0008 0.0009 0.0009 0.0010 0.0011 0.0013 0.0014	0.0015 0.0016 0.0016 0.0016 0.0016 0.0017 0.0017 0.0017 0.0017 0.0018 0.0018 0.0019	0.0035 0.0035 0.0038 0.0039 0.0041 0.0041 0.0042 0.0045 0.0045 0.0047 0.0049 0.0050 0.0051 0.0051	0.0040 0.0041 0.0043 0.0043 0.0044 0.0046 0.0047 0.0048 0.0048 0.0049 0.0051	36.57 36.57 36.58 36.62 36.62 36.66
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 Mean	0.0042 0.0042 0.0044 0.0045 0.0047 0.0047 0.0047 0.0051 0.0052 0.0052 0.0052 0.0053 0.0053	0.0142 0.0147 0.0149 0.0150 0.0151 0.0152 0.0152 0.0152 0.0153 0.0153 0.0154 0.0156 0.0158 0.0162	0.0234 0.0236 0.0246 0.0248 0.0251 0.0254 0.0255 0.0258 0.0264 0.0268 0.0278	0.0038 0.0039 0.0040 0.0041 0.0041 0.0042 0.0044 0.0045 0.0045 0.0046 0.0048	0.0006 0.0008 0.0008 0.0009 0.0009 0.0010 0.0011 0.0013 0.0014	0.0015 0.0016 0.0016 0.0016 0.0016 0.0017 0.0017 0.0017 0.0017 0.0018 0.0018 0.0019 0.0019	0.0035 0.0035 0.0038 0.0039 0.0041 0.0042 0.0045 0.0045 0.0046 0.0047 0.0049 0.0050 0.0051 0.0051	0.0040 0.0041 0.0043 0.0043 0.0044 0.0046 0.0047 0.0048 0.0048 0.0049 0.0051	36.57 36.58 36.62 36.62 36.66 36.66

Note:  $C_{(95\%)}$  is the 95% half-width confidence interval derived from the 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.

### **Participating Laboratories**

Exova Ltd Sheffield Assay Office Universal Scientific Laboratory Pty Ltd Shanghai Jinyi Test Technology Co Luo Yang Copper Genitest, Inc Bureau Veritas CPS Pvt Ltd Raghavendra Spectromet Laboratory Institute of Non-Ferrous Metals Tec-Eurolab Microlab Mineral & Metallurgical Laboratories Colonial Metals Co AMG Superalloys UK Ltd Coleshill Laboratories Ltd Analyticka Laborator Lithea sro

Middlesbrough, England Sheffield, England Milperra, NSW, Australia Shanghai, China Luo Yang, He Nan, China Montreal, Canada Chennai, India Bangalore, India Gliwice, Poland Campogalliano, Italy Chennai, India Bangalore, India Columbia, PA, USA Rotherham, England Birmingham, England Brno, Czech Republic

UKAS accreditation 0239
UKAS accreditation 0012
NATA accreditation 0492
CNAL accreditation 0783
CNAL accreditation 0173
PRI accreditation 123077
NABL accreditation 0025
NABL accreditation 0371
PCA accreditation AB274
ACCREDIA accreditation 52

Note: to achieve the above accreditation (UKAS, NATA, 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			
Tin	1, 4-8, 10, 11, 14-16	9, 12	2	photometric (phenyl fluorone)			
			13	volumetric (iodate); 3: XRF			
Lead	1-3, 5, 6, 8, 11, 14, 15	7, 9, 13, 17	4, 10, 12	electrogravimetric; 16: XRF			
Iron	1, 2, 4, 5, 7-10, 12, 14	3, 11, 15	6	volumetric (permanganate)			
			13	photometric (orthophenanthroline)			
Nickel	2-4, 6, 7, 9-12, 14, 16	1, 5, 15	8, 13	photometric (dimethyl glyoxime)			
Aluminium	1-5, 7, 9, 10, 12, 14	8, 11	6	volumetric (EDTA)			
			13	photometric (chrome azurol S)			
Copper	6	-	1	volumetric (thiosulfate)			
			2-5, 7	electrogravimetric			
Silicon	3, 4, 6, 7, 11, 12	-	1, 10, 13	photometric (molybdenum blue)			
			2, 5, 8, 9	gravimetric (perchlorate)			
Sulfur	6-8, 10	-	1-5, 9, 11, 12	combustion (infra red detection)			
Tellurium	1, 2, 4-8	3					
Cobalt	1, 2, 6-14	3-5, 15					
Arsenic	1-9, 11, 12, 15	13, 14	10	photometric (turbidity)			
Phosphorus	2, 5, 7, 10-12	-	1, 8, 9, 13	volumetric (alkalimetric)			
			3, 4, 6	photometric (molybdenum yellow)			
Bismuth	1-9	10, 11	12	photometric (iodide)			
Selenium	1, 3-9	10, 11	2	ICP-MS			
Cadmium	3-5, 8-14	1, 2, 6, 7					
Silver	1, 4, 6-10, 12-16	2, 3, 5, 11					
Boron	1-6, 8-12	7					
Zinc	4	-	2, 3, 5, 6	volumetric (EDTA); 1: XRF			

#### **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 to a depth of 12mm. Material to the rear of the disc, to a depth of ~3mm, 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 February 2036, although we reserve the right to make changes as issue revisions, in the intervening period.

This material is also available in the form of chippings.

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.