

CERTIFICATE OF ANALYSIS

13X PH17700 (batch A)

Certified Reference Material Information

Type: PRECIPITATION-HARDENING STEEL (WROUGHT)

Form and Size: Disc, ~38mm diameter

Manufactured by: Commercial Barstock

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 | 0.0732 | 0.551 | 0.0008 | 0.0181 | 0.496 | 6.98 | 16.88 | 0.340 | 0.146 |
| Uncertainty ² | 0.0012 | 0.010 | 0.0002 | 0.0010 | 0.007 | 0.03 | 0.05 | 0.006 | 0.004 |

| Element | Co | V | Nb | W | Al | Ti | Sn | B | N |
|--------------------------|--------|--------|--------|-------|-------|-------|--------|--------|--------|
| Value ¹ | 0.0464 | 0.0390 | 0.0201 | 0.009 | 1.172 | 0.051 | 0.0055 | 0.0033 | 0.0192 |
| Uncertainty ² | 0.0013 | 0.0011 | 0.0014 | 0.002 | 0.008 | 0.002 | 0.0004 | 0.0004 | 0.0010 |

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 29th August 2012

C Eveleigh



Method of Preparation

This reference material was produced from commercial barstock to UNS S17700. The steel was prepared by electric arc melting & argon-oxygen decarburisation. The bar was hot forged and solution annealed.

Sampling

Samples for chemical analysis were taken from various positions throughout the batch. At least 10% of all discs were selected for non-destructive homogeneity testing.

Homogeneity

The discs were checked for lateral segregation, and for local and batch homogeneity using an optical emission spectrometer.

Using the combined 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 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, discussed above.

The final certified uncertainty for each element has been derived by combining these two factors, using the square-root 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: Steels are generally prepared by finishing, grinding, turning or milling. 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.

The recommended sample size is at least five replicate analyses. 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 | Cu |
|----------------|---------------|--------------|---------------|---------------|--------------|--------------|--------------|--------------|--------------|
| 1 | 0.0706 | 0.531 | 0.0004 | 0.0160 | 0.473 | 6.924 | 16.81 | 0.325 | 0.135 |
| 2 | 0.0707 | 0.536 | 0.0006 | 0.0164 | 0.476 | 6.937 | 16.83 | 0.327 | 0.141 |
| 3 | 0.0711 | 0.536 | 0.0006 | 0.0172 | 0.482 | 6.960 | 16.85 | 0.332 | 0.141 |
| 4 | 0.0724 | 0.544 | 0.0007 | 0.0177 | 0.491 | 6.963 | 16.87 | 0.335 | 0.143 |
| 5 | 0.0730 | 0.552 | 0.0007 | 0.0177 | 0.495 | 6.965 | 16.87 | 0.338 | 0.143 |
| 6 | 0.0731 | 0.557 | 0.0008 | 0.0178 | 0.495 | 6.971 | 16.88 | 0.340 | 0.144 |
| 7 | 0.0732 | 0.560 | 0.0008 | 0.0182 | 0.499 | 7.008 | 16.91 | 0.343 | 0.145 |
| 8 | 0.0732 | 0.560 | 0.0009 | 0.0190 | 0.501 | 7.020 | 16.92 | 0.348 | 0.146 |
| 9 | 0.0736 | 0.564 | 0.0010 | 0.0190 | 0.503 | 7.021 | 16.99 | 0.348 | 0.147 |
| 10 | 0.0750 | 0.569 | 0.0010 | 0.0199 | 0.504 | 7.024 | | 0.348 | 0.148 |
| 11 | 0.0750 | | | 0.0203 | 0.507 | | | 0.349 | 0.154 |
| 12 | 0.0753 | | | | 0.509 | | | 0.349 | 0.154 |
| 13 | 0.0757 | | | | 0.510 | | | | 0.158 |
| Mean | 0.0732 | 0.551 | 0.0008 | 0.0181 | 0.496 | 6.979 | 16.88 | 0.340 | 0.146 |
| Std Dev | 0.0017 | 0.013 | 0.0002 | 0.0014 | 0.012 | 0.036 | 0.05 | 0.009 | 0.006 |
| C (95%) | 0.0010 | 0.010 | 0.0002 | 0.0009 | 0.007 | 0.026 | 0.04 | 0.006 | 0.004 |

| Sample | Co | V | Nb | W | Al | Ti | Sn | B | N |
|----------------|---------------|---------------|---------------|---------------|--------------|---------------|---------------|---------------|---------------|
| 1 | 0.0440 | 0.0375 | 0.0180 | 0.0048 | 1.155 | 0.0467 | 0.0048 | 0.0022 | 0.0173 |
| 2 | 0.0444 | 0.0376 | 0.0180 | 0.0060 | 1.158 | 0.0476 | 0.0049 | 0.0023 | 0.0174 |
| 3 | 0.0451 | 0.0377 | 0.0182 | 0.0065 | 1.158 | 0.0484 | 0.0050 | 0.0023 | 0.0180 |
| 4 | 0.0454 | 0.0383 | 0.0188 | 0.0075 | 1.160 | 0.0489 | 0.0050 | 0.0029 | 0.0181 |
| 5 | 0.0454 | 0.0390 | 0.0191 | 0.0081 | 1.163 | 0.0496 | 0.0051 | 0.0031 | 0.0189 |
| 6 | 0.0455 | 0.0391 | 0.0200 | 0.0084 | 1.170 | 0.0499 | 0.0054 | 0.0032 | 0.0195 |
| 7 | 0.0463 | 0.0395 | 0.0219 | 0.0099 | 1.171 | 0.0512 | 0.0058 | 0.0032 | 0.0196 |
| 8 | 0.0468 | 0.0401 | 0.0219 | 0.0099 | 1.173 | 0.0518 | 0.0058 | 0.0033 | 0.0200 |
| 9 | 0.0468 | 0.0401 | 0.0222 | 0.0100 | 1.174 | 0.0522 | 0.0062 | 0.0034 | 0.0203 |
| 10 | 0.0469 | 0.0410 | 0.0230 | 0.0111 | 1.181 | 0.0530 | 0.0063 | 0.0038 | 0.0210 |
| 11 | 0.0475 | | | 0.0122 | 1.181 | 0.0531 | 0.0064 | 0.0041 | 0.0215 |
| 12 | 0.0490 | | | | 1.195 | 0.0538 | | 0.0042 | |
| 13 | 0.0498 | | | | 1.195 | 0.0539 | | 0.0043 | |
| Mean | 0.0464 | 0.0390 | 0.0201 | 0.0086 | 1.172 | 0.0508 | 0.0055 | 0.0033 | 0.0192 |
| Std Dev | 0.0017 | 0.0012 | 0.0020 | 0.0023 | 0.013 | 0.0024 | 0.0006 | 0.0007 | 0.0014 |
| C (95%) | 0.0010 | 0.0009 | 0.0014 | 0.0015 | 0.008 | 0.0015 | 0.0004 | 0.0004 | 0.0010 |

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 Materials Testing | Middlesbrough, England | UKAS accreditation 0239 |
| Metals Technology (Testing) Ltd | Sheffield, England | UKAS accreditation 0963 |
| Sheffield Assay Office | Sheffield, England | UKAS accreditation 0012 |
| Universal Scientific Laboratory | Milperra, NSW, Australia | NATA accreditation 0492 |
| Laboratory Testing, Inc | Hatfield, PA, USA | A2LA accreditation 0117 |
| Genitest, Inc | Montreal, Canada | PRI accreditation 123077 |
| Institute of Iron and Steel Technology | Shanghai, China | CNAL accreditation 0783 |
| Luo Yang Copper Co | Luo Yang, He Nan, China | CNAL accreditation 0173 |
| Sargam Metals Pvt Ltd | Chennai, India | NABL accreditation 0025 |
| TCR Engineering Services Ltd | Mumbai, India | NABL accreditation 0367 |
| Raghavendra Spectrometallurgical Lab. | Bangalore, India | NABL accreditation 0371 |
| De Bruyn Spectroscopic Solutions Ltd | Johannesburg, South Africa | |
| Coleshill Laboratories Ltd | Birmingham, England | |
| London & Scandinavian Met. Co Ltd | Rotherham, England | |

Note: to achieve the above-noted accreditation (eg 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 |
| Carbon | - | - | all | combustion (IR or volumetric detection) |
| Silicon | 3, 4, 6, 9 | - | 1, 5, 7, 8 | gravimetric (perchloric acid) |
| | | | 2, 10 | photometric (molybdenum blue) |
| Sulfur | 6, 8 | - | 1-5, 7, 9, 10 | combustion (IR or volumetric detection) |
| Phosphorus | 2-8 | - | 1, 9 | volumetric (alkalimetric) |
| | | | 10, 11 | photometric (molybdenum blue) |
| Manganese | 1, 2, 4-6, 8-10 | 3, 7, 12 | 11 | volumetric (arsenite) |
| | | | 13 | photometric (periodate) |
| Nickel | 2, 4, 9, 10 | 6 | 1, 3, 5, 8 | gravimetric (dimethyl glyoxime) |
| | | | 7 | volumetric (dimethyl glyoxime/EDTA) |
| Chromium | 3-7 | - | 1, 2, 8, 9 | volumetric (ferrous ammonium sulfate) |
| Molybdenum | 1-3, 5, 7, 9-12 | 8 | 4 | ICP-MS |
| | | | 6 | photometric (thiocyanate) |
| Copper | 3-5, 7-11, 13 | 1, 2, 12 | 6 | photometric (BCO) |
| Cobalt | 1-5, 7-9, 12, 13 | 6, 10, 11 | | |
| Vanadium | 1-3, 5-10 | - | 4 | ICP-MS |
| Niobium | 1, 2, 4, 6-10 | - | 3 | ICP-MS |
| | | | 5 | photometric (chlorosulfophenol) |
| Tungsten | 1-5, 7-11 | - | 6 | ICP-MS |
| Aluminium | 1-4, 6, 7, 9, 11-13 | 5, 8, 10 | | |
| Titanium | 1, 2, 4-6, 8, 10-12 | 3, 9 | 7 | ICP-MS |
| | | | 13 | photometric (diantipyryl methane) |
| Tin | 2, 3, 6-11 | 4, 5 | 1 | ICP-MS |
| Boron | 1-7, 9-13 | - | 8 | ICP-MS |
| Nitrogen | - | - | 2 | photometric (Nessler reagent) |
| | | | 1, 10 | volumetric (hydrochloric acid) |
| | | | 3-9, 11 | inert gas fusion (thermal conductivity) |

Notes

This Certified Reference Material has been produced and certified in accordance with the requirements of ISO Guide 34-2009, ISO Guide 31-2000 and ISO Guide 35-2006, taking into account the requirements of the ISO Guide to the Expression of Uncertainty in Measurement (GUM).

This certification is applicable to the whole of the disc. However, in accordance with normal practice for OES, it is appropriate to avoid usage of the central portion of approx 6mm diameter.

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 August 2032, 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.