# Brammer Standard Company, Inc.

## Certificate of Analysis

## BS 291HE

Certified Reference Material for Chill Cast Iron

### Certified Values[3]

| | Certified Value[1] | Estimate of Uncertainty[2] | | Certified Value[1] | Estimate of Uncertainty[2] |
|---|---|---|---|---|---|
| **Al** | **0.035** | 0.002 | **Mo** | **0.030** | 0.003 |
| **B** | **0.0144** | 0.0009 | **N** | **0.0064** | 0.0006 |
| **C** | **3.35** | 0.05 | **Ni** | **0.101** | 0.009 |
| **Ca** | **0.0010** | 0.0004 | **P** | **0.024** | 0.002 |
| **Cr** | **0.035** | 0.003 | **S** | **0.008** | 0.002 |
| **Cu** | **0.212** | 0.009 | **Si** | **2.31** | 0.05 |
| **Fe** | **93.19** | 0.08 | **Sn** | **0.057** | 0.002 |
| **H** | **0.0005** | 0.0002 | **Ti** | **0.0223** | 0.0009 |
| **Mg** | **0.041** | 0.001 | **V** | **0.0206** | 0.0009 |
| **Mn** | **0.535** | 0.009 | **Zr** | **0.0019** | 0.0007 |

### Reference Values[3,4]

| | Reference Value[1] | Estimate of Uncertainty[2] | | Reference Value[1] | Estimate of Uncertainty[2] |
|---|---|---|---|---|---|
| **As** | **0.004** | 0.001 | **Sb** | **0.006** | 0.003 |
| **Co** | **0.004** | 0.002 | **Ta** | **<0.05** | |
| **Nb** | **0.002** | 0.001 | **W** | **0.003** | 0.002 |
| **O** | **0.0012** | 0.0008 | **Zn** | **<0.05** | |
| **Pb** | **<0.005** | | | | |

[1] For each element, the certified value listed is the present best estimate of the true value based on the mean of the weighted results of an interlaboratory testing program. See page 4 for more information on its calculation.

[2] For each element, the uncertainty listed is based on a statistical evaluation of the contributions of homogeneity and the interlaboratory testing program. See page 4 for more information on its calculation.

[3] Values are given in weight percent. Values in brackets are reported by difference.

[4] Reference values are not certified and are provided for information only.

Trace element information values for Ba, Be, Ce, Cl, Dy, Er, Ga, Gd, Ge, Hf, La, Li, Nd, Pr, Re, Sm, Te, Th, U, Y, Yb, and Zn are shown on page 5.

The requirements of ISO Guides 30, 31, and 35 were followed for the preparation of this Certified Reference Material and certificate of analysis.

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**BS 291HE** * Code for method Certified values listed as weight percent

| Analysis | * | Al | * | B | * | C | * | Ca | * | Cr | * | Cu | * | Fe | * | H | * | Mg | * | Mn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 0.034 | 12 | 0.0100 | 1 | 3.15 | 4 | 0.0003 | 4 | 0.0306667 | 5 | 0.188 | 4 | 93.03666667 | 2 | 0.0001667 | 3 | 0.041 | 4 | 0.46533333 |
| 2 | 3 | 0.034 | 4 | 0.013667 | 1 | 3.2366667 | 12 | 0.000633 | 3 | 0.031375 | 10 | 0.199 | 3 | 93.11 | 2 | 0.000180 | 3 | 0.041 | 4 | 0.506175 |
| 3 | 3 | 0.034 | 3 | 0.013667 | 3 | 3.2925 | 14 | 0.0007 | 14 | 0.0317667 | 4 | 0.2040667 | 16 | [93.14] | 2 | 0.0002875 | 3 | 0.041 | 4 | 0.524 |
| 4 | 3 | 0.035 | 4 | 0.013733 | 3 | 3.3 | 4 | 0.000717 | 4 | 0.0320 | 3 | 0.209 | 16 | [93.14] | 2 | 0.000422 | 3 | 0.041 | 3 | 0.527 |
| 5 | 3 | 0.035 | 3 | 0.01375 | 11 | 3.3133333 | 3 | 0.0009 | 3 | 0.032 | 4 | 0.2093333 | 16 | [93.16] | 2 | 0.0004333 | 3 | 0.041 | 4 | 0.528 |
| 6 | 3 | 0.035 | 4 | 0.013967 | 3 | 3.3166667 | 3 | 0.0009 | 4 | 0.0323333 | 4 | 0.2096667 | 16 | [93.16] | 2 | 0.0004367 | 3 | 0.041 | 4 | 0.52836667 |
| 7 | 3 | 0.035 | 3 | 0.014 | 4 | 3.32 | 2 | 0.001 | 3 | 0.0331667 | 10 | 0.210 | 16 | [93.1606334] | 2 | 0.00048 | 3 | 0.041 | 3 | 0.529 |
| 8 | 3 | 0.035 | 4 | 0.014043 | 11 | 3.33 | 4 | 0.001 | 4 | 0.0334 | 4 | 0.21 | 3 | 93.17 | 2 | 0.0004833 | 3 | 0.041 | 11 | 0.52966667 |
| 9 | 3 | 0.035 | 14 | 0.0141 | 3 | 3.33 | 4 | 0.001 | 3 | 0.0336667 | 3 | 0.21 | 16 | [93.17] | 2 | 0.0005 | 3 | 0.041 | 4 | 0.53 |
| 10 | 3 | 0.035 | 4 | 0.014133 | 11 | 3.34 | 11 | 0.001033 | 10 | 0.034 | 14 | 0.2100 | 16 | [93.17] | 2 | 0.0005333 | 3 | 0.041 | 10 | 0.53 |
| 11 | 3 | 0.035 | 11 | 0.0144 | 2 | 3.34 | 4 | 0.0011 | 3 | 0.034 | 10 | 0.21 | 16 | [93.18] | 2 | 0.00054 | 3 | 0.041 | 4 | 0.53 |
| 12 | 3 | 0.035 | 11 | 0.0145 | 3 | 3.3454667 | 11 | 0.0011 | 11 | 0.0348 | 4 | 0.2102333 | 16 | [93.18667] | 2 | 0.0008167 | 3 | 0.041 | 2 | 0.53 |
| 13 | 3 | 0.035 | 4 | 0.0146 | 3 | 3.35 | 11 | 0.0011 | 11 | 0.0349 | 11 | 0.2106667 | 16 | [93.18667] | | | 3 | 0.041 | 4 | 0.5309 |
| 14 | 3 | 0.035 | 4 | 0.0146 | 11 | 3.35 | 4 | 0.0011 | 11 | 0.035 | 4 | 0.2107333 | 16 | [93.2] | | | 3 | 0.041 | 4 | 0.531 |
| 15 | 3 | 0.035 | 11 | 0.0146 | 11 | 3.35 | 11 | 0.0011 | 11 | 0.035 | 11 | 0.211 | 16 | [93.2094334] | | | 3 | 0.041 | 3 | 0.532 |
| 16 | 3 | 0.035 | 3 | 0.0146 | 1 | 3.3515333 | 11 | 0.0011 | 4 | 0.0353 | 3 | 0.211 | 16 | [93.21] | | | 3 | 0.041 | 3 | 0.53233333 |
| 17 | 3 | 0.036 | 11 | 0.0146 | 1 | 3.3526667 | 11 | 0.0011 | 3 | 0.0353 | 11 | 0.211 | 4 | 93.21173333 | | | 3 | 0.041 | 11 | 0.534 |
| 18 | 3 | 0.039 | 11 | 0.0146 | 11 | 3.36 | 3 | 0.001467 | 10 | 0.0354 | 11 | 0.211 | 16 | [93.2181667] | | | 3 | 0.041 | 4 | 0.534 |
| 19 | 3 | 0.036 | 3 | 0.014667 | 1 | 3.36 | 4 | 0.001475 | 11 | 0.0354 | 11 | 0.211 | 10 | 93.27666667 | | | 3 | 0.041 | 3 | 0.53466667 |
| 20 | 3 | 0.036 | 4 | 0.014667 | 1 | 3.375857 | 4 | 0.001567 | 11 | 0.0354 | 3 | 0.211 | 13 | 93.314 | | | 3 | 0.041 | 10 | 0.535 |
| 21 | 3 | 0.037 | 4 | 0.0147 | 1 | 3.36775 | | | 4 | 0.0356 | 3 | 0.211667 | 16 | [93.35333] | | | 3 | 0.041 | 11 | 0.535 |
| 22 | 3 | 0.037 | 3 | 0.0147 | 1 | 3.376 | | | 4 | 0.0356 | 4 | 0.212 | 16 | [93.46667] | | | 3 | 0.041 | 11 | 0.536 |
| 23 | 3 | 0.037 | 3 | 0.0147 | 4 | 3.38 | | | 3 | 0.035733 | 11 | 0.212 | | | | | 3 | 0.041 | 11 | 0.536 |
| 24 | 3 | 0.037 | 11 | 0.0147 | 3 | 3.38 | | | 3 | 0.036 | 4 | 0.213 | | | | | 3 | 0.041 | 11 | 0.536 |
| 25 | | | 4 | 0.01495 | 1 | 3.38 | | | 5 | 0.036067 | 3 | 0.213 | | | | | | | 4 | 0.536333 |
| 26 | | | 7 | 0.0161 | 1 | 3.391667 | | | 4 | 0.036533 | 4 | 0.213 | | | | | | | 4 | 0.536633 |
| 27 | | | 4 | 0.016467 | 1 | 3.4 | | | 4 | 0.0366 | 4 | 0.214933 | | | | | | | 3 | 0.540 |
| 28 | | | 5 | 0.016767 | 1 | 3.401167 | | | 3 | 0.037 | 4 | 0.215333 | | | | | | | 3 | 0.54 |
| 29 | | | | | 1 | 3.47667 | | | 4 | 0.037 | 4 | 0.2158 | | | | | | | 3 | 0.543 |
| 30 | | | | | 1 | 3.586 | | | 4 | 0.037667 | 4 | 0.217667 | | | | | | | 10 | 0.547 |
| 31 | | | | | | | | | 4 | 0.0379 | 3 | 0.21775 | | | | | | | 4 | 0.556667 |
| 32 | | | | | | | | | 4 | 0.0397 | 3 | 0.22 | | | | | | | 4 | 0.579333 |
| 33 | | | | | | | | | | | 4 | 0.221667 | | | | | | | 4 | 0.594 |
| 34 | | | | | | | | | | | 8 | 0.227 | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| Average | | 0.04 | | 0.014428 | | 3.3524 | | 0.000957 | | 0.034884 | | 0.2124 | | 93.190 | | 0.0004788 | | 0.04 | | 0.5354 |
| Std Dev | | 0.16 | | 0.000060 | | 0.0063 | | 0.000028 | | 0.000056 | | 0.0020 | | 0.023 | | 0.0000069 | | 0.18 | | 0.0027 |
| H | | 0.0020 | | 0.0013 | | 0.022 | | 0.00042 | | 0.0019 | | 0.0047 | | 0.18 | | 0.00033 | | 0.0020 | | 0.0076 |
| $U_1$ | | 0.16 | | 0.0013 | | 0.023 | | 0.00042 | | 0.0019 | | 0.0051 | | 0.19 | | 0.00033 | | 0.18 | | 0.0081 |
| t-statistic | | 2.07 | | 2.05 | | 2.05 | | 2.09 | | 2.04 | | 2.03 | | 2.08 | | 2.20 | | 2.07 | | 2.04 |
| $U_2$ | | 0.34 | | 0.0026 | | 0.046 | | 0.00088 | | 0.0039 | | 0.010 | | 0.39 | | 0.00072 | | 0.38 | | 0.017 |
| $U_3$ | | 0.068 | | 0.00049 | | 0.0085 | | 0.00020 | | 0.00069 | | 0.0018 | | 0.082 | | 0.00021 | | 0.077 | | 0.0029 |
| **Certified** | | **0.035** | | **0.0144** | | **3.35** | | **0.0010** | | **0.035** | | **0.212** | | **93.19** | | **0.0005** | | **0.041** | | **0.535** |
| Uncertainty | | 0.002 | | 0.0009 | | 0.05 | | 0.0004 | | 0.003 | | 0.009 | | 0.08 | | 0.0002 | | 0.001 | | 0.009 |
| Tolerance | | 0.006 | | 0.0027 | | 0.15 | | 0.0009 | | 0.009 | | 0.027 | | 0.24 | | 0.0004 | | 0.003 | | 0.027 |

**BS 291HE** * Code for method Certified values listed as weight percent

| Analysis | * | Mo | * | N | * | Ni | * | P | * | S | * | Si | * | Sn | * | Ti | * | V | * | Zr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 0.0256667 | 2 | 0.005723 | 4 | 0.0861 | 12 | 0.0170 | 1 | 0.0044333 | 10 | 2.23 | 4 | 0.050133333 | 5 | 0.0201333 | 12 | 0.01433333 | 12 | 0.00029667 |
| 2 | 12 | 0.0263333 | 2 | 0.005733 | 12 | 0.0863333 | 10 | 0.0199 | 12 | 0.0055667 | 3 | 2.258 | 12 | 0.051 | 4 | 0.021 | 5 | 0.01713333 | 5 | 0.0004 |
| 3 | 4 | 0.0276667 | 2 | 0.005967 | 7 | 0.093 | 4 | 0.0201 | 1 | 0.0063 | 3 | 2.27 | 3 | 0.0544 | 10 | 0.021 | 3 | 0.0191 | 5 | 0.00045 |
| 4 | 3 | 0.027675 | 2 | 0.0061 | 4 | 0.0953333 | 5 | 0.0216 | 1 | 0.0064167 | 6 | 2.2793333 | 3 | 0.0547 | 4 | 0.02155 | 3 | 0.01955 | 3 | 0.0015 |
| 5 | 14 | 0.0282333 | 2 | 0.006157 | 10 | 0.096 | 7 | 0.022567 | 1 | 0.007 | 6 | 2.29 | 3 | 0.054833333 | 11 | 0.0218 | 3 | 0.0199 | 4 | 0.00166667 |
| 6 | 4 | 0.0283333 | 2 | 0.0063 | 14 | 0.0962 | 4 | 0.023175 | 1 | 0.0072 | 3 | 2.3 | 3 | 0.055 | 3 | 0.0219 | 3 | 0.0199 | 4 | 0.0017 |
| 7 | 10 | 0.029 | 2 | 0.006333 | 10 | 0.0973333 | 3 | 0.0233 | 1 | 0.0073467 | 4 | 2.3039 | 4 | 0.0551 | 3 | 0.022 | 3 | 0.02 | 3 | 0.0017 |
| 8 | 2 | 0.029 | 2 | 0.0065 | 3 | 0.0973333 | 11 | 0.0238 | 1 | 0.0075 | 3 | 2.3066667 | 4 | 0.0552 | 3 | 0.022 | 4 | 0.02 | 3 | 0.001775 |
| 9 | 5 | 0.0290667 | 2 | 0.006575 | 4 | 0.0994333 | 3 | 0.0238 | 3 | 0.0076 | 4 | 2.3084333 | 4 | 0.0554 | 5 | 0.022 | 4 | 0.02025 | 4 | 0.0018 |
| 10 | 4 | 0.029075 | 2 | 0.0068 | 4 | 0.0999333 | 4 | 0.023867 | 1 | 0.0076 | 6 | 2.3098333 | 11 | 0.0557 | 4 | 0.0221 | 3 | 0.02033333 | 10 | 0.0018 |
| 11 | 11 | 0.0293 | 2 | 0.007033 | 10 | 0.10 | 11 | 0.0239 | 1 | 0.0076667 | 4 | 2.3099667 | 4 | 0.055966667 | 11 | 0.0221 | 14 | 0.0205 | 3 | 0.00193333 |
| 12 | 3 | 0.0293333 | 2 | 0.007333 | 4 | 0.1001333 | 13 | 0.024 | 3 | 0.0077 | 11 | 2.31 | 4 | 0.056075 | 3 | 0.0221 | 3 | 0.0205 | 4 | 0.002 |
| 13 | 11 | 0.0293333 | | | 4 | 0.1002 | 4 | 0.024 | 1 | 0.0079 | 11 | 2.31 | 11 | 0.0563 | 11 | 0.0221 | 5 | 0.02053333 | 4 | 0.00206667 |
| 14 | 4 | 0.0295333 | | | 3 | 0.101 | 11 | 0.0241 | 2 | 0.008 | 11 | 2.31 | 4 | 0.056666667 | 4 | 0.0221 | 14 | 0.02066667 | 3 | 0.0022 |
| 15 | 11 | 0.0297 | | | 11 | 0.101 | 3 | 0.0241 | 1 | 0.008 | 11 | 2.31 | 4 | 0.056733333 | 3 | 0.0221667 | 11 | 0.0207 | 11 | 0.0023 |
| 16 | 4 | 0.0297667 | | | 11 | 0.101 | 11 | 0.0241 | 3 | 0.0082 | 11 | 2.31 | 3 | 0.0568 | 11 | 0.0222 | 11 | 0.0207 | 11 | 0.0023 |
| 17 | 7 | 0.0297667 | | | 3 | 0.1013333 | 11 | 0.0242 | 4 | 0.0082 | 7 | 2.3104667 | 11 | 0.0569 | 4 | 0.0222 | 11 | 0.0208 | 11 | 0.0023 |
| 18 | 11 | 0.0298 | | | 11 | 0.1013333 | 4 | 0.0243 | 1 | 0.0085333 | 14 | 2.3133333 | 4 | 0.0571 | 11 | 0.0223 | 11 | 0.0209 | 11 | 0.0023 |
| 19 | 11 | 0.0298 | | | 4 | 0.1013333 | 4 | 0.0243 | 1 | 0.0089667 | 3 | 2.3166667 | 3 | 0.057333333 | 4 | 0.0224333 | 3 | 0.0209 | 11 | 0.0023 |
| 20 | 11 | 0.0299 | | | 4 | 0.102 | 4 | 0.0244 | 10 | 0.009 | 4 | 2.3175 | 4 | 0.0574 | 4 | 0.022533 | 3 | 0.02091 | 4 | 0.0024 |
| 21 | 10 | 0.03 | | | 4 | 0.102 | 4 | 0.024433 | 11 | 0.009 | 4 | 2.32 | 9 | 0.0574 | 3 | 0.022575 | 4 | 0.0210 | 11 | 0.0024 |
| 22 | 4 | 0.030067 | | | 4 | 0.102 | 4 | 0.0245 | 11 | 0.009 | 3 | 2.32 | 11 | 0.057867 | 7 | 0.0226 | 10 | 0.021 | 4 | 0.0024 |
| 23 | 4 | 0.0302 | | | 11 | 0.102 | 11 | 0.024733 | 11 | 0.0091 | 4 | 2.32 | 11 | 0.0581 | 4 | 0.022633 | 11 | 0.021 | 4 | 0.0035 |
| 24 | 4 | 0.0302 | | | 11 | 0.102 | 4 | 0.024933 | 11 | 0.0091 | 11 | 2.3233333 | 4 | 0.058467 | 3 | 0.022667 | 4 | 0.0211 | | |
| 25 | 4 | 0.0305 | | | 11 | 0.102 | 4 | 0.024933 | 11 | 0.0092 | 6 | 2.325 | 4 | 0.0585 | 3 | 0.022667 | 4 | 0.0211 | | |
| 26 | 3 | 0.0309 | | | 8 | 0.102333 | 7 | 0.025033 | 3 | 0.0095 | 6 | 2.325725 | 5 | 0.058667 | 14 | 0.022667 | 4 | 0.021167 | | |
| 27 | 3 | 0.031 | | | 4 | 0.1025 | 3 | 0.025567 | 1 | 0.009533 | 4 | 2.33 | 3 | 0.060 | 4 | 0.022733 | 11 | 0.0213 | | |
| 28 | 4 | 0.0312 | | | 4 | 0.1026 | 3 | 0.025775 | 11 | 0.009833 | 4 | 2.33 | 3 | 0.060575 | 3 | 0.023 | 4 | 0.021333 | | |
| 29 | 4 | 0.0313 | | | 3 | 0.103 | 4 | 0.026133 | 3 | 0.010 | 4 | 2.332 | 10 | 0.063567 | 4 | 0.0230 | 4 | 0.021567 | | |
| 30 | 4 | 0.0314 | | | 3 | 0.103 | 3 | 0.026667 | 3 | 0.0101 | 4 | 2.358 | 4 | 0.063867 | 4 | 0.023367 | 4 | 0.022033 | | |
| 31 | 3 | 0.0315 | | | 3 | 0.104 | 10 | 0.027 | 4 | 0.011025 | | | | | 10 | 0.023667 | 3 | 0.022633 | | |
| 32 | 3 | 0.0317 | | | 3 | 0.10425 | 3 | 0.027 | 1 | 0.0136 | | | | | | | 10 | 0.025433 | | |
| 33 | 3 | 0.032 | | | 4 | 0.106667 | 4 | 0.028333 | | | | | | | | | | | | |
| 34 | 4 | 0.0348 | | | 5 | 0.107333 | 3 | 0.0309 | | | | | | | | | | | | |
| 35 | | | | | 4 | 0.108667 | | | | | | | | | | | | | | |
| 36 | | | | | 3 | 0.11 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| Average | | 0.02975 | | 0.00641 | | 0.1014 | | 0.02431 | | 0.008379 | | 2.3093 | | 0.0568 | | 0.02225 | | 0.02059 | | 0.001891 |
| Std Dev | | 0.00073 | | 0.00020 | | 0.0016 | | 0.00053 | | 0.000056 | | 0.0037 | | 0.0011 | | 0.00050 | | 0.00047 | | 0.000066 |
| H | | 0.0018 | | 0.00089 | | 0.0032 | | 0.0016 | | 0.0010 | | 0.017 | | 0.0024 | | 0.0015 | | 0.0015 | | 0.00054 |
| $U_1$ | | 0.0019 | | 0.00092 | | 0.0036 | | 0.0017 | | 0.0010 | | 0.018 | | 0.0027 | | 0.0016 | | 0.0016 | | 0.00055 |
| t-statistic | | 2.03 | | 2.20 | | 2.03 | | 2.03 | | 2.04 | | 2.05 | | 2.05 | | 2.04 | | 2.04 | | 2.07 |
| $U_2$ | | 0.0039 | | 0.0020 | | 0.0072 | | 0.0035 | | 0.0020 | | 0.037 | | 0.0054 | | 0.0033 | | 0.0032 | | 0.0011 |
| $U_3$ | | 0.00067 | | 0.00058 | | 0.0012 | | 0.00059 | | 0.00036 | | 0.0067 | | 0.0010 | | 0.00060 | | 0.00056 | | 0.00024 |
| **Certified** | | **0.030** | | **0.0064** | | **0.101** | | **0.024** | | **0.008** | | **2.31** | | **0.057** | | **0.0223** | | **0.0206** | | **0.0019** |
| Uncertainty | | 0.003 | | 0.0006 | | 0.009 | | 0.002 | | 0.002 | | 0.05 | | 0.002 | | 0.0009 | | 0.0009 | | 0.0007 |
| Tolerance | | 0.009 | | 0.0018 | | 0.027 | | 0.006 | | 0.006 | | 0.15 | | 0.006 | | 0.0027 | | 0.0027 | | 0.0018 |

**BS 291HE** * Code for method Reference values listed as weight percent

| Analysis | * | As | * | Co | * | Nb | * | O | * | Pb | * | Sb | * | Ta | * | W | * | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 0.0030333 | 11 | 0.0011 | 12 | 0.0002833 | 2 | 0.000427 | 5 | 0.000020 | 5 | 0.0005567 | 5 | 0.000088 | 12 | 0.0002533 | 12 | 0.000273 |
| 2 | 5 | 0.0032667 | 11 | 0.0013 | 5 | 0.0003933 | 2 | 0.00045 | 12 | 0.000023 | 12 | 0.0005667 | 5 | 0.00027 | 5 | 0.0003267 | 5 | 0.000417 |
| 3 | 4 | 0.00335 | 11 | 0.0023 | 5 | 0.00057 | 2 | 0.0006 | 11 | 0.000061 | 5 | 0.0005733 | 4 | 0.0022 | 5 | 0.0004067 | 10 | 0.001000 |
| 4 | 4 | 0.0035333 | 5 | 0.0025 | 3 | 0.0013 | 2 | 0.000703 | 9 | 0.0001 | 9 | 0.0047667 | 4 | 0.002233 | 4 | 0.0012 | 4 | 0.0013 |
| 5 | 15 | 0.0039433 | 5 | 0.002733 | 3 | 0.0014 | 2 | 0.00078 | 11 | 0.0001 | 11 | 0.0053 | 4 | 0.002375 | 11 | 0.002 | 4 | 0.001667 |
| 6 | 10 | 0.0040333 | 12 | 0.002767 | 2 | 0.0015 | 2 | 0.001 | 4 | 0.0001 | 3 | 0.0054333 | 4 | 0.0025 | 11 | 0.0021 | 4 | 0.0054 |
| 7 | 5 | 0.00409 | 4 | 0.00299 | 4 | 0.0017667 | 2 | 0.00116 | 11 | 0.0001 | 3 | 0.0057 | 3 | 0.0025 | 11 | 0.0028 | 4 | 0.008967 |
| 8 | 4 | 0.0044 | 10 | 0.003 | 16 | 0.0019 | 2 | 0.001433 | 4 | 0.0002 | 4 | 0.0059 | | | 3 | 0.0028 | 4 | 0.011433 |
| 9 | 4 | 0.0045 | 5 | 0.003003 | 3 | 0.0019333 | 2 | 0.001633 | 4 | 0.0003 | 4 | 0.0061 | | | 14 | 0.0031 | | |
| 10 | 4 | 0.0045167 | 11 | 0.0034 | 4 | 0.0020333 | 2 | 0.001733 | 4 | 0.0004 | 11 | 0.0061 | | | 4 | 0.0031 | | |
| 11 | 3 | 0.0046 | 14 | 0.0035 | 4 | 0.0020333 | 2 | 0.001833 | 11 | 0.0004667 | 4 | 0.0062667 | | | 3 | 0.0033 | | |
| 12 | 4 | 0.0048 | 8 | 0.003697 | 4 | 0.00205 | 2 | 0.002067 | 3 | 0.0005 | 4 | 0.0064 | | | 3 | 0.0033 | | |
| 13 | 4 | 0.0048667 | 3 | 0.004 | 4 | 0.0020667 | | | | | 3 | 0.0066 | | | 3 | 0.0034 | | |
| 14 | 4 | 0.005 | 4 | 0.0041 | 4 | 0.0020667 | | | | | 4 | 0.006625 | | | 4 | 0.0037 | | |
| 15 | 4 | 0.005 | 11 | 0.0041 | 14 | 0.0021 | | | | | 4 | 0.0069 | | | 3 | 0.0052 | | |
| 16 | 4 | 0.0050333 | 11 | 0.0043 | 11 | 0.0027 | | | | | 4 | 0.0070333 | | | 11 | 0.0058 | | |
| 17 | 3 | 0.0051 | 4 | 0.004667 | 11 | 0.0027 | | | | | 11 | 0.0091667 | | | 4 | 0.0060333 | | |
| 18 | 9 | 0.0053 | 4 | 0.004967 | 11 | 0.0028 | | | | | 11 | 0.0092 | | | 4 | 0.0060667 | | |
| 19 | 10 | 0.0055 | 3 | 0.0051 | 11 | 0.0029 | | | | | 11 | 0.0095 | | | 4 | 0.0062 | | |
| 20 | 3 | 0.0067 | 4 | 0.005133 | 11 | 0.0031 | | | | | 11 | 0.0103 | | | 4 | 0.0063 | | |
| 21 | | | 4 | 0.0052 | 11 | 0.0031 | | | | | | | | | | | | |
| 22 | | | 4 | 0.005225 | | | | | | | | | | | | | | |
| 23 | | | 4 | 0.005267 | | | | | | | | | | | | | | |
| 24 | | | 4 | 0.0055 | | | | | | | | | | | | | | |
| 25 | | | 3 | 0.005567 | | | | | | | | | | | | | | |
| 26 | | | 3 | 0.005925 | | | | | | | | | | | | | | |
| 27 | | | 4 | 0.006 | | | | | | | | | | | | | | |
| 28 | | | 3 | 0.0061 | | | | | | | | | | | | | | |
| Average | | 0.00447 | | 0.00408 | | 0.001926 | | 0.001152 | | 0.0001912 | | 0.005949 | | 0.0017 | | 0.003369 | | 0.004 |
| Std Dev | | 0.00016 | | 0.00014 | | 0.000069 | | 0.000091 | | 0.0000022 | | 0.000071 | | 0.0072 | | 0.000071 | | 0.023 |
| H | | 0.00077 | | 0.00074 | | 0.00055 | | 0.00045 | | 0.00024 | | 0.00087 | | 0.000521 | | 0.00068 | | 0.000734 |
| $U_1$ | | 0.00078 | | 0.00075 | | 0.00055 | | 0.00046 | | 0.00024 | | 0.00087 | | 0.0072 | | 0.00069 | | 0.023 |
| t-statistic | | 2.09 | | 2.05 | | 2.09 | | 2.20 | | 2.20 | | 2.09 | | 2.45 | | 2.09 | | 2.36 |
| $U_2$ | | 0.0016 | | 0.0015 | | 0.0012 | | 0.0010 | | 0.00053 | | 0.0018 | | 0.018 | | 0.0014 | | 0.054 |
| $U_3$ | | 0.00037 | | 0.00029 | | 0.00025 | | 0.00029 | | 0.00015 | | 0.00041 | | 0.0067 | | 0.00032 | | 0.019 |
| **Reference** | | **0.004** | | **0.004** | | **0.002** | | **0.0012** | | **<0.005** | | **0.006** | | **<0.05** | | **0.003** | | **<0.05** |
| Uncertainty | | 0.001 | | 0.002 | | 0.001 | | 0.0008 | | | | 0.003 | | | | 0.002 | | |
| Tolerance | | 0.003 | | 0.003 | | 0.001 | | 0.0011 | | | | 0.005 | | | | 0.002 | | |

*For each element, in accordance with the requirements of ISO 17034 and Guide 35, an effort must be made to account for the effects on the certified value of the uncertainty estimate from homogeneity testing (H) and the uncertainties of the contributing laboratories. The average (A) is calculated using a weighted mean where the reciprocal of the square of each laboratory's combined uncertainty ($C_L$), calculated from its standard deviation ($S_L$) and its uncertainty estimate ($U_L$), is used as the weight ($W_L$) for its mean ($M_L$). The standard deviation (S) is calculated as the square root of the reciprocal of the sum of the weights. $U_1$ is the combined uncertainty from homogeneity and labs. $U_2$ is $U_1$ multiplied by the coverage factor (95 % t-statistic). $U_3$ is $U_2$ divided by the square root of the number of determinations (n). Thus:*

$$C_L = \sqrt{S_L^2 + U_L^2} \qquad W_L = \frac{1}{C_L^2} \qquad A = \frac{\sum_{i=1}^{n} W_L M_L}{\sum_{i=1}^{n} W_L} \qquad S = \frac{1}{\sqrt{\sum_{i=1}^{n} W_L}} \qquad U_1 = \sqrt{H^2 + S^2} \qquad U_2 = t \times U_1 \qquad U_3 = \frac{U_2}{\sqrt{n}}$$

*All but the final reported values are taken to two significant figures as determined by each quantity's uncertainty estimate. The final reported Uncertainty is $U_3$ rounded to one significant figure and represents the half width of the 95 % confidence interval for the **Certified** value. The final reported **Certified** value is A rounded to the same decimal place as the Uncertainty. The Uncertainty is a measure of the quality of the **Certified** value.*

*The Tolerance is a measure of the expected performance of an analysis. This involves further expanding the sample uncertainty to include instrument and operator uncertainty, for those without access to such calculations.*

*For further information regarding the confidence interval for the certified value see ISO Guide 35:2006 section 6.*

**BS 291HE** * Code for analytical method Trace analysis listed as mg/kg (ppm)

| Analysis | * | Ba | * | Be | * | Ce | * | Cl | * | Dy | * | Er | * | Ga | * | Gd | * | Ge | * | Hf |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 0.25 | 12 | 0.005 | 12 | 300 | 12 | 0.01 | 12 | 0.03 | 12 | 0.01 | 12 | 8.7 | 12 | 0.11 | 12 | 5.2 | 12 | 0.05 |
| 2 | 12 | 0.38 | 12 | 0.005 | 12 | 310 | 12 | 0.02 | 12 | 0.03 | | | 12 | 9.5 | 12 | 0.11 | 12 | 5.2 | 12 | 0.05 |
| 3 | 12 | 1.4 | 12 | 0.005 | 12 | 360 | 12 | 0.02 | 12 | 0.04 | | | 12 | 9.6 | 12 | 0.12 | 12 | 5.3 | 12 | 0.09 |
| | | | | | | | | | | | | | | | 5 | 2.2 | | | | |
| Analysis | * | La | * | Li | * | Nd | * | Pr | * | Re | * | Sm | * | Te | * | Th | * | U | * | Y |
| 1 | 12 | 80 | 12 | 0.008 | 12 | 5.4 | 12 | 1.7 | 12 | 0.1 | 12 | 6.4 | 12 | 140 | 12 | 2.5 | 12 | 0.1 | 12 | 2.8 |
| 2 | 12 | 80 | 12 | 0.008 | 12 | 5.6 | 12 | 1.8 | 12 | 0.1 | 12 | 6.6 | 12 | 140 | 12 | 2.42.9 | 12 | 0.11 | 12 | 2.9 |
| 3 | 12 | 95 | 12 | 0.009 | 12 | 6.7 | 12 | 2.1 | 12 | 0.1 | 12 | 7.8 | 12 | 150 | 12 | | 12 | 0.12 | 12 | 3.3 |
| | | | | | | | | | | | | | | | | | | | | |
| Analysis | * | Yb | * | Zn | | | | | | | | | | | | | | | | |
| 1 | 12 | 0.01 | 12 | 2.7 | | | | | | | | | | | | | | | | |
| 2 | 12 | 0.01 | 12 | 2.7 | | | | | | | | | | | | | | | | |
| 3 | | | 12 | 2.8 | | | | | | | | | | | | | | | | |

## Analytical Method Codes:

1 Combustion (ASTM E1019)
2 Fusion (ASTM E1019)
3 Spark Atomic Emission
4 ICP Atomic Emission
5 ICP Mass Spectrometry
6 Gravimetric
7 Photometric
8 Flame Atomic Absorption
9 GF Atomic Absorption
10 X-Ray Fluorescence
11 GD Atomic Emission
12 GD Mass Spectrometry
13 Titrimetric
14 DCP Atomic Emission
15 HG Atomic Fluorescence
16 Difference

ICP = Inductively Coupled Plasma GF = Graphite Furnace GD = Glow Discharge
DCP = Direct Current Plasma HG = Hydride Generation

| Lab Name | Location | Registrar | Accreditation |
|---|---|---|---|
| Brammer Standard Company, Inc. | Houston, TX | A2LA | 17025, 17034 |
| NSL Analytical | Cleveland, OH | ANAB | 17025 |
| Elemental Analysis, Inc. | Lexington, KY | A2LA | 17025 |
| Element Materials Technology | Glendale Heights, IL | A2LA | 17025 |
| Dirats Laboratories | Westfield,MA | ANAB | 17025 |
| Vitkovice Testing Center | Hulvaky, Ostrava | Czech Accreditation Institute | 17025 |
| Shiva Analyticals Private Limited | Hoskote, Bangalore | NABL | 17025 |
| TUV Rheinland Pvt Ltd | Bangalore, India | NABL | 17025 |
| Eurofins EAG Materials Science, LLC | Liverpool, NY | A2LA | 17025 |
| National Analysis Center For Iron And Steel | Beijing, China | CNAS | 17025 |
| Raghavendra Spectro Metallurgical Laboratory | Karnataka, India | NABL | 17025 |
| Lucid Laboratories Pvt Ltd | Telanagana, India | NABL | 17025 |
| Laboratory Testing, Inc. | Hatfiled, PA | A2LA | 17025 |
| Luvak, Inc. | Boylston, MA | PRI | 17025 |
| Analytical Process Laboratories, Inc. | Milwaukee, WI | A2LA | 17025 |
| Instytut Metalurgii Zelaza | Gilwice, Poland | PCA | 17025 |

A2LA = American Association for Laboratory Accreditation
ANAB = ANSI-ASQ National Accreditation Board
CNAS = China National Accreditation Service
NABL = National Accreditation Board for Testing and Calibration Laboratories
PCA = Polish Center for Accreditation
PRI =Performance Review Institute

**Analysis:** Chemical analyses were made on solid pieces and chips prepared by an end mill from representative samples for the certified portion of the lot in accordance with ASTM Standard Practice E1806. The laboratories participating in the testing followed the requirements of ISO Standard 17025.

**Traceability:** The following Certified Reference Materials were used to validate the analytical data: 11X0331.1G, 11XC3AD, 11XC4A, 1XC5Y, 11XC7P, 11XC8U, 11XC8V; AR 215A, 307, 309, 310, 555, 614A, 644, 645, 668, 673, 780, 868, 892, 1650, 1652, 1657; BAS 236, 464/1, 535, 668-9, 673; BS XX-11B, CC-2, CI4, HON T, 7A, 8, 291, 291EB, 291F, 291FH, 291G, 291GH, 291GI; CKD 236, 244C; CZ 02033 1G, 02033 8A, 2016A; DSZU CA031; ECRM 480-1; IPT 16-4; JSS GS-1D, GS-6B; LECO 501-024, 501-504, 501-919, 502-899, 502-903, 502-928, 502-935, 502-947, 502-963, 762-747; NCS NS 11079; SPL 1B, 3A, 14A, 31A, 36A; SRM 5L, 6F, 82B, 122H, 122I, 160B, 342A, 361, 363, 365, 892, 1140, 1141A, 1754, 3107.

**Homogeneity:** This Certified Reference Material (CRM) was tested for homogeneity using ASTM Standard Method E826 and found acceptable. It was also examined by spark atomic emission spectrometry and found to be compatible with the following Reference Materials: BS CI4, 7A, 8, 291, 291EB, 291GI; SPL 17 31A, 17 36A; SRM 1140, 1141A.

**Validity statement:** ISO Guide 31 states that the certification should contain an expiration date for all materials where instability has been demonstrated or is considered possible, after which the certified value is no longer guaranteed by the certifying body. The certification of BS 291HE is valid indefinitely. The certification is nullified if this CRM is damaged, contaminated, or otherwise modified.

**Storage:** This CRM must be stored in a cool, dry, non-corrosive environment.

**Source:** The cast stock for this CRM was produced by SPL-LABMAT s.r.o.; Bohumin, Czechia.

**Form:** This CRM is machined in the form of a disc, approximately 35mm in diameter and 30mm thick by Brammer Standard Company, Inc.

**Use:** This CRM is intended for use in spark atomic emission, glow discharge, and x-ray spectrometric methods of analysis. Refer to ISO Guide 33 for information about the use of Certified Reference Materials.

**Certified Area:** The certified area of each disc is the portion extending upward several mm inward from each surface.

Note: Shrinkage cavities may appear in the top portion of some discs. These cavities are normal and will not affect the certified portion of the disc.

**Sample Preparation:** For best analytical results, use the same method for preparing the analytical surface on all reference materials as used for production specimens. Avoid overheating the sample during surface preparation.

Caution: CRM contains significant insoluble soft metal inclusions. Surface smearing may occur. Spark atomic emission spectrometers may require extended preburns to compensate.

**Certificate Number:** The unique identification number for this certificate of analysis is 291HE-043024. You may obtain information on revisions of certificates from the internet at **www.brammerstandard.com**.

**Safety Notice:** A Safety Data Sheet (SDS) is not required for this material. This material will not release or otherwise result in exposure to a hazardous chemical, under normal conditions of use. Inquiries concerning this Reference Material should be directed to:

**Brammer Standard Co., Inc.**
**14603 Benfer Road**
**Houston, Texas 77069-2895 USA**

**Phone: (281) 440-9396**
**Fax: (281) 440-4432**

**Web: www.brammerstandard.com**
**Email: contact@brammerstandard.com**

**Brammer Standard Company, Inc., is accredited by the American Association for Laboratory Accreditation (A2LA) to ISO Standard 17034 as a Reference Material Producer for the production of Certified Reference Materials and Reference Materials (our current Certificate Number 656.02 expires 01/31/2025)**

**Brammer Standard Company's Chemical Laboratory is accredited by A2LA to ISO Standard 17025. (Our current Certificate Number 656.01 expires 01/31/2025)**

**By current Certificate Number 10539 expiring 01/01/2027, the Quality System of Brammer Standard Company, Inc., is registered to ISO 9001 by National Quality Assurance (NQA), U.S.A.**

**The scopes of accreditation are listed on the website: www.brammerstandard.com**

## References:

Versions used were those available at the time of testing and characterization

E826 Standard Practice for Testing Homogeneity of a Metal Lot or Batch in Solid Form by Spark Atomic Emission Spectrometry

E1019 Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques

E1806 Standard Practice for Sampling Steel and Iron for Determination of Chemical Composition

ISO Standard 17025:2017 General requirements for the competence of testing and calibration laboratories

ISO Standard 9001:2015 Quality Management Systems - Requirements

ISO Guide 30:2015 Terms and definitions used in connection with reference materials + 2008 amendment

ISO Guide 31:2015 Reference materials - Contents of certificates and labels

ISO Guide 33:2015 Uses of certified reference materials

ISO Standard 17034:2016 General requirements for the competence of reference material producers

ISO Guide 35:2017 Reference Materials - General and statistical principles for certification

*ASTM documents available from ASTM, 100 Barr Harbor Dr., West Conshohocken, PA 19428.*

*ISO Guides and Standards available from Global Engineering - **www.global.ihs.com***

*Other useful documents available from NIST, U.S. Department of Commerce, Gaithersburg, MD 20899.*

NIST Special Publication 260-100, Handbook for SRM Users

NIST Special Publication 829, Use of NIST Standard Reference Materials for Decisions on Performance of Analytical Chemical Methods and Laboratories

Certified by: _____ on April 30, 2024.

Beau R. Brammer

President