

# CERTIFICATE OF ANALYSIS

## IMZ 316L PWD

### CERTIFIED REFERENCE MATERIAL STAINLESS STEEL POWDER FOR ADDITIVE MANUFACTURING

Analysis listed as percent by weight [% m/m]

|    | Certified value | Expanded uncertainty |    | Certified value | Expanded uncertainty |
|----|-----------------|----------------------|----|-----------------|----------------------|
| C  | 0.021           | ± 0.003              | S  | 0.0067          | ± 0.0004             |
| Co | 0.031           | ± 0.002              | Si | 0.37            | ± 0.03               |
| Cr | 17.57           | ± 0.19               | W  | 0.006           | ± 0.002              |
| Cu | 0.049           | ± 0.003              | V  | 0.033           | ± 0.002              |
| Mn | 1.51            | ± 0.05               | O  | 0.0536          | ± 0.0074             |
| Mo | 2.84            | ± 0.08               | Al | (0.013)         |                      |
| N  | 0.071           | ± 0.007              | Nb | (0.004)         |                      |
| Ni | 13.96           | ± 0.37               | H  | (0.0004)        |                      |
| P  | 0.012           | ± 0.002              | Ti | (0.008)         |                      |

Values in brackets are informative

| Analysis             | Al**   | * | C            | * | Co           | * | Cr           | * | Cu           | * | H**      | * | Mn          | * | Mo          | * |
|----------------------|--------|---|--------------|---|--------------|---|--------------|---|--------------|---|----------|---|-------------|---|-------------|---|
| 1                    | 0.006  | 1 | 0.02092      | 3 | 0.0299       | 1 | 17.4401      | 1 | 0.04436      | 1 | 0.000277 | 4 | 1.4717      | 1 | 2.76400     | 1 |
| 2                    | 0.0072 | 1 | 0.021        | 3 | 0.0305       | 1 | 17.4801      | 6 | 0.04755      | 1 | 0.0005   | 4 | 1.490       | 1 | 2.81344     | 1 |
| 3                    | <0.020 | 1 | 0.020163     | 3 | 0.03072      | 1 | 17.513       | 1 | 0.0480       | 2 |          |   | 1.49766     | 1 | 2.8186      | 1 |
| 4                    | 0.025  |   | 0.019295     | 3 | 0.03083      | 1 | 17.530       | 6 | 0.0489       | 1 |          |   | 1.5159      | 1 | 2.8481      | 1 |
| 5                    |        |   | 0.0205       | 3 | 0.030875     | 1 | 17.5458      | 1 | 0.049        | 1 |          |   | 1.51817     | 1 | 2.86850     | 1 |
| 6                    |        |   | 0.0235       | 3 | 0.031288     | 1 | 17.57        | 1 | 0.050008     | 1 |          |   | 1.52        | 2 | 2.87        | 1 |
| 7                    |        |   |              |   | 0.0334       | 1 | 17.645       | 1 | 0.0501       | 1 |          |   | 1.52268     | 1 | 2.903242    | 1 |
| 8                    |        |   |              |   |              |   | 17.70        | 6 | 0.05015      | 1 |          |   | 1.5243      | 1 |             |   |
| 9                    |        |   |              |   |              |   | 17.78        | 1 |              |   |          |   |             |   |             |   |
| Average              | 0.013  |   | 0.021        |   | 0.031        |   | 17.57        |   | 0.049        |   | 0.0004   |   | 1.51        |   | 2.84        |   |
| Standard deviation   | 0.011  |   | 0.0007       |   | 0.0005       |   | 0.091        |   | 0.0013       |   | 0.0002   |   | 0.0094      |   | 0.041       |   |
| u characterization   | -      |   | 0.00036      |   | 0.00024      |   | 0.037        |   | 0.00058      |   | -        |   | 0.0042      |   | 0.019       |   |
| u homogeneity        | -      |   | 0.0011       |   | 0.00032      |   | 0.075        |   | 0.00054      |   | -        |   | 0.017       |   | 0.031       |   |
| Certified value      | -      |   | <b>0.021</b> |   | <b>0.031</b> |   | <b>17.57</b> |   | <b>0.049</b> |   | -        |   | <b>1.51</b> |   | <b>2.84</b> |   |
| Expanded uncertainty | -      |   | 0.003        |   | 0.002        |   | 0.19         |   | 0.003        |   | -        |   | 0.05        |   | 0.08        |   |

| Analysis             | N            | * | Nb**     | * | Ni           | * | O             | * | P            | * | S             | * | Si          | * | Ti**    | * |
|----------------------|--------------|---|----------|---|--------------|---|---------------|---|--------------|---|---------------|---|-------------|---|---------|---|
| 1                    | 0.061        | 4 | 0.001623 | 1 | 13.64        | 1 | 0.0478        | 4 | 0.010125     | 1 | 0.0056        | 3 | 0.34        | 1 | 0.00098 | 1 |
| 2                    | 0.061625     | 4 | 0.00137  | 1 | 13.7901      | 1 | 0.0478        | 4 | 0.0102       | 1 | 0.0065        | 3 | 0.3429      | 1 | 0.00142 | 1 |
| 3                    | 0.072851     | 4 | 0.0051   | 1 | 13.885       | 1 | 0.052674      | 4 | 0.01138      | 1 | 0.00653       | 3 | 0.35        | 5 | 0.0017  | 1 |
| 4                    | 0.0741       | 4 | 0.006    | 1 | 13.91        | 1 | 0.0588        | 4 | 0.01183      | 1 | 0.006613      | 3 | 0.3608      | 1 | 0.0024  | 1 |
| 5                    | 0.076        | 4 |          |   | 14.0151      | 5 | 0.059975      | 4 | 0.013025     | 1 | 0.006685      | 3 | 0.363       | 1 |         | 1 |
| 6                    |              |   |          |   | 14.06838     | 5 |               |   | 0.013121     | 1 | 0.0067        | 3 | 0.38709     | 1 |         |   |
| 7                    |              |   |          |   | 14.09        | 7 |               |   | 0.014        | 6 | 0.00704       | 3 | 0.3975      | 1 |         |   |
| 8                    |              |   |          |   | 14.298       | 5 |               |   | 0.015        | 1 | 0.00713       | 3 | 0.425       | 1 |         |   |
| Average              | 0.071        |   | 0.004    |   | 13.96        |   | 0.0536        |   | 0.012        |   | 0.0067        |   | 0.37        |   | 0.008   |   |
| Standard deviation   | 0.0048       |   | 0.0024   |   | 0.17         |   | 0.0056        |   | 0.0018       |   | 0.0002        |   | 0.026       |   | 0.014   |   |
| u characterization   | 0.0027       |   | -        |   | 0.075        |   | 0.0031        |   | 0.00080      |   | 0.00009       |   | 0.011       |   | -       |   |
| u homogeneity        | 0.0015       |   | -        |   | 0.11         |   | 0.0017        |   | 0.00020      |   | 0.00015       |   | 0.0081      |   | -       |   |
| Certified value      | <b>0.071</b> |   | -        |   | <b>13.96</b> |   | <b>0.0536</b> |   | <b>0.012</b> |   | <b>0.0067</b> |   | <b>0.37</b> |   | -       |   |
| Expanded uncertainty | 0.007        |   | -        |   | 0.37         |   | 0.0074        |   | 0.002        |   | 0.0004        |   | 0.03        |   | -       |   |

| Analysis             | V            | * | W            | * |
|----------------------|--------------|---|--------------|---|
| 1                    | 0.03332      | 1 | 0.004073     | 1 |
| 2                    | 0.030275     | 1 | 0.00524      | 1 |
| 3                    | 0.031079     | 1 | 0.0056       | 1 |
| 4                    | 0.032542     | 1 | 0.00565      | 1 |
| 5                    | 0.0327       | 1 | 0.006807     | 1 |
| 6                    | 0.037        | 1 | 0.00669      | 1 |
| 7                    |              |   | 0.007        | 1 |
| Average              | 0.033        |   | 0.006        |   |
| Standard deviation   | 0.0017       |   | 0.0011       |   |
| u characterization   | 0.00087      |   | 0.00052      |   |
| u homogeneity        | 0.00038      |   | 0.00089      |   |
| Certified value      | <b>0.033</b> |   | <b>0.006</b> |   |
| Expanded uncertainty | 0.002        |   | 0.002        |   |

\* - analytical method used, \*\* - informative value

All values are based on recommendations of the ISO 33405:2024 standard:

1. **average** is calculated according to Algorithm A (ISO 33405:2024 clause A.2.3.4),
2. **standard deviation** is calculated according to Algorithm A (ISO 33405:2024 A.2.3.4),
3. **certified value** is the average value rounded to one or two significant digits of expanded uncertainty,
4. **expanded uncertainty** for each certified element was calculated using a coverage factor of  $k=2$  corresponding to an approximate 95% confidence level  $U_{CRM} = k \cdot u_{CRM}$ . The combined standard uncertainty ( $u_{CRM}$ ) associated with each certified value was determined as shown:

$$u_{CRM} = \sqrt{u_{char}^2 + u_{hom}^2 + u_{sts}^2 + u_{lts}^2}$$

where:

- $u_{char}$  uncertainty of characterisation was derived from the results of an interlaboratory comparison performed under repeatability conditions by network of competent laboratories (ISO 33405:2024 clause 9.5) and calculated according to clause B.5.2,
- $u_{hom}$  between-unit uncertainty was calculated based on analysis of variance (ANOVA) using a stratified sampling design. Subsamples were extracted from multiple depth levels of randomly selected units, and standard uncertainties were estimated from between-unit and within-unit variance components, in agreement with ISO 33405:2024 clause 7.11,
- $u_{sts}$  short time stability uncertainty was evaluated under conditions typically encountered during transportation (ISO 33405:2024 clause 8.3.4.1). The study simulated the maximum expected thermal and mechanical stress associated with sample shipment and handling.  $u_{sts}$  was considered negligible,
- $u_{lts}$  long-term stability uncertainty was estimated using a linear regression model, consistent with the ISO 33405:2024 clause 8.7.3. This approach followed a predictive methodology under the assumption of a linear trend in the stability data. For each analyte, a linear regression was fitted to the results obtained during the long-term (41 months) stability study. In all cases the regression slope was not statistically significant (i.e. the absolute value of the Student's t-statistic for the slope did not exceed the critical value at the 95% confidence level). The absence of a meaningful trend allowed for the extrapolation of shelf-life based on the model's prediction interval.

**Certification Process:** Both preparation of this Reference Material and certification process were prepared according to requirements PN-EN 17034 and ISO 33405:2024.

**Chemical Analysis:** Chemical analyses were carried out on metallic powder samples. Single values in the above table are the means obtained by individual laboratories. The following methods were used for analysis:

- 1 – inductive coupled plasma atomic emission spectrometry,
- 2 – flame atomic emission spectrometry,
- 3 – combustion,
- 4 – inert gas fusion,
- 5 – gravimetry,
- 6 – titrimetry,
- 7 – photometry.

**Participating Laboratories:**

- Bundesanstalt für Materialforschung und -prüfung (BAM) (Germany), DAKKs accreditation D-PL-11075-14-00, ISO 17025,
- Dunafer Labor Nonprofit Kft., Dunaújváros (Hungary), NAH accreditation NAH-1-1798/2021, ISO 17025
- Lithea, Ltd. (Czech Republic),
- OnderzoeksCentrum voor de Aanwending van Staal, Zelzate (Belgium),
- Sieć Badawcza Łukasiewicz - Górnośląski Instytut Technologiczny (Poland), PCA accreditation AB 554, ISO 17025,
- Sieć Badawcza Łukasiewicz - Instytut Metali Nieżelaznych (Poland), PCA accreditation AB 274, ISO 17025,
- Laboratory Testing Inc. (USA), NADCAP accreditation 3296228778, ISO 17025,
- Vitkovice Testing Center (Czech Republic), Testing Laboratory Nr 1036, CAI accreditation, ISO 17025.

**Homogeneity:** The homogeneity of this Reference Material was evaluated in accordance with guidelines of ISO 33405:2024. Optical emission spectrometry with plasma excitation method was used.

**Traceability:** This Reference Material was found traceable to the following CRMs:

2008A ČMI, AR 558LT#716B, B2400, B2420, B2424, B2752, BAM No. 231/1, BAM No 232-1, BCS 463/1, BCS 466/2, BCS 476, BS 254, BS 316 D, BS 316 E, BS 316 F, BS 321D, BS 450, BS 316 C, ČSMU 3-1-19, Euro 042-1, Euro 187-1, Eurostandard 281-1, Euronorm 85-1, Euronorm 86-1, Euronorm 87-1, Euronorm 298-2, IARM 162D, IARM Fe316L, IMZ 1.12/4, IMZ 112A, MBH 125340, MBH 13X18004B, MBH 13X31726A, MBH C13X 125370, Normalprobe no. 177, pure chemicals.

**Production of powder:** This material was manufactured by Electro Optical Systems Finland Oy (Finland) using gas atomisation, lot number S602003, manufactured on 07 October 2020.

**Available form:** Powder.

**Intended use:** This Reference Material is intended for use in inductively coupled plasma atomic emission spectrometry, flame atomic emission spectrometry, combustion with infrared detection, high-temperature extraction with thermal conductivity detection, gravimetry, titrimetry, and photometry.

**Note:** The minimum sample portion recommended for analysis is:

- 0,2 g for Co, Cr, Cu, Mn, Mo, Ni, V,
- 1 g for P, Si, W,
- 0,1 g for O, N,
- 0,5 g for C, S - corresponding to the test portion used in the homogeneity study.

**Validity of certification:** The certification of IMZ 316L PWD is valid indefinitely within the uncertainty specified provided this Reference Material is stored in dry place and in environment free from chemical or other aggressive vapours. Periodic recertification is not required. The certification is nullified if this Reference Material is damaged, contaminated or otherwise modified. Based on a stability study using linear model prediction, the **shelf-time** of this reference material has been established as **70 months** from the date of certificate issue.

**Safety:** This material is a fine metallic powder. Avoid inhalation, ingestion, and contact with skin or eyes. Use only in well-ventilated areas or under local exhaust ventilation. Wear appropriate personal protective equipment, including safety glasses, gloves, and a dust mask or respirator conforming to relevant standards. Keep away from sources of ignition and strong oxidising agents. Handle in accordance with good laboratory practice.

**Storage:** This Reference Material should be stored in dry place and in environment free from chemical or other aggressive vapours.

**Additional information:** The values listed below are taken from the powder manufacturer's Inspection Certificate for the source material from which the certified reference material was prepared. Values are informative.

Particle Size Distribution Analysis

| Test method       | Size characteristics   | Limits  | Result | Test method                       | Size characteristics   | Result |
|-------------------|------------------------|---------|--------|-----------------------------------|------------------------|--------|
| Laser diffraction | $d_{10} [\mu\text{m}]$ | 20 - 32 | 21     | Dynamic image analysis $X_{cmin}$ | $x_{10} [\mu\text{m}]$ | 19     |
|                   | $d_{50} [\mu\text{m}]$ | 32 - 44 | 35     |                                   | $x_{50} [\mu\text{m}]$ | 33     |
|                   | $d_{90} [\mu\text{m}]$ | 48 - 65 | 56     |                                   | $x_{90} [\mu\text{m}]$ | 49     |

Laser diffraction analysis and sample preparation according to ASTM B822 and ISO 13320 with Microtrac S3500 or with Sympatec HelosRodas according to ISO 13320. Dynamic image analysis according to ISO 13322-2 with CAMSIZER XT.

Powder Water Content Analysis

| Property            | Test Method              | Limits   | Result |
|---------------------|--------------------------|----------|--------|
| Water content [ppm] | Coulometric KF titration | Max. 125 | 18     |

Water content determination according to internal procedure using coulometric Karl Fischer titrator C30s with InMotion KF Flex oven autosampler.

Inquiries regarding this Reference Material should be directed to [rm@git.lukasiewicz.gov.pl](mailto:rm@git.lukasiewicz.gov.pl)

Approved by  
Director of the Institute

Prof. Dr. Hab. Eng. Adam Zieliński

Certificate issue date: 3 August 2026