**Supplemental Material for**

Determining the cut-off diameter and counting efficiency of optical particle counters with an aerodynamic aerosol classifier and an inkjet aerosol generator

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Table S1. The list of PSL particles used to evaluate the relationship between pulse height and the diameter of PSL particles.

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| --- | --- | --- | --- | --- | --- |
| Grade† | Particle diameter | | Coefficient of variation⁑ | Specific gravity | Index of refraction |
| average | Expanded uncertainty (*k* = 2) |
| mm | mm | - | - | - |
| SC-0080-D | **0.080** | 0.002 | 0.048 | 1.065 | 1.590 |
| SC-100-D | **0.100** | 0.003 | 0.0247 | 1.060 | 1.592 |
| SC-016-S | **0.152** | 0.007 | 0.0246 | 1.069 | 1.592 |
| SC-024-S | **0.202** | 0.005 | 0.0269 | 1.058 | 1.593 |
| SC-025-R | **0.254** | 0.008 | 0.0319 | 1.065 | 1.592 |
| SC-031-S | **0.294** | 0.009 | 0.0153 | 1.054 | 1.595 |
| SC-034-S | **0.352** | 0.011 | 0.0239 | 1.064 | 1.592 |
| SC-042-R | **0.402** | 0.006 | 0.0389 | 1.081 | 1.578 |
| SC-046-S | **0.458** | 0.014 | 0.0235 | 1.059 | 1.594 |
| SC-051-S | **0.506** | 0.012 | 0.0201 | 1.054 | 1.595 |
| SC-061-S | **0.603** | 0.014 | 0.0222 | 1.054 | 1.595 |
| SC-081-S | **0.814** | 0.019 | 0.0281 | 1.065 | 1.591 |
| SC-103-S | **1.005** | 0.021 | 0.0231 | 1.053 | 1.597 |
| SC-200-S | **2.005** | 0.042 | 0.0275 | 1.051 | 1.591 |
| SS-032-P | **3.210** | 0.072 | 0.0092 | 1.052 | 1.585 |
| SS-053-P | **5.124** | 0.115 | 0.0122 | 1.050 | 1.586 |
| SS-074-P | **7.088** | 0.088 | 0.008 | 1.048 | 1.590 |
| SS-103-P | **10.04** | 0.147 | 0.0081 | 1.046 | 1.587 |

† These grades are not commercially available any more since the manufacture discontinued these products at the end of March 2019.

⁑ Equivalent to the relative standard deviation of particle size distribution.

This supplementary material (SM) explains how the counting efficiency of the reference CPC, , was evaluated in this study. Since the particle diameter range where the KC-01E OPC was tested is broader than the size range where the KC-22B OPC was tested, the was assumed to be a constant when the KC-22B OPC was tested while the constant is merged with a size dependent function at larger sizes when KC-01E OPC was tested. This SM explains the evaluation of for testing with the KC-22B and KC-01E, separately.

KC-22B OPC

In this study, a condensation particle counter (CPC, Model 3790, TSI Inc.) was used as a reference instrument to evaluate the counting efficiency of OPCs. The was assumed to be constant when the KC-22B OPC was tested since the size of test particles belonged to the plateau region of versus particle size (ISO 2015). For the evaluation of the KC-22B OPC the size of test particles was varied from 60 to 500 nm in terms of mobility diameter. For the evaluation of , PSL particles with a certified diameter at 100 nm was used as test particles, and a Faraday cup aerosol electrometer (FCAE, Sakurai and Ehara (2011)) was used as the reference instrument. The was evaluated by taking the ratio of particle number concentration measured by the CPC, , to that of the FCAE, . Since the CPC software assumes the nominal flowrate to calculate the values of , the reported values were corrected for the error in the sampling flowrate. The actual sampling flowrate of the CPC and its expanded uncertainty U(*k* = 2) were 0.9581 and 0.0042 L/min, respectively. After the correction, the value of and its U(*k* = 2) were 0.951 and 0.011, respectively, and the average value of was 9.5 × 103 cm-3 during the measurement.

The value of during the calibration of the OPC was less than 20 cm-3 which is 2.7 magnitudes lower than the during the calibration of . It is assumed that the true value of during the OPC calibration is higher than 0.951 since the probability of error due to coincidence in particle detection increases with the concentration. The true value of during the OPC calibration and its uncertainty was estimated. The lower bound of the true value, , was estimated by 0.951 – 0.011 = 0.940. The upper bound of the true value, , was set to 100% or unity. It was assumed that the probability of the true value is uniformly distributed within these bounds. The estimate of the true value over the plateau region, was calculated from the average of and .

|  |  |
| --- | --- |
|  | (S1) |

The standard uncertainty of , was estimated by (ISO 2010)

|  |  |
| --- | --- |
|  | (S2) |
|  | (S3) |

Which gives the 95% confidence intervals of as 0.935 and 1.005. The uncertainty of the counting efficiency of the OPC, ,was estimated by

|  |  |
| --- | --- |
|  | (S4) |

where is the reported value which is the average among the measured . The first term on the righthand side is the random component of the uncertainty in . *n* is the number of measurements to calculate the average and standard deviation, .

KC-01E OPC

As it was explained in Section 2, the counting efficiency of the CPC including the transport efficiency through a 88 cm long conductive tube was evaluated by using the IAG as a reference instrument. The counting efficiency evaluated by the IAG decreased as the size increased. The results are included in Figure S1. The value was 0.983±0.020 at 663 nm and decreased to 0.755±0.038 at 3700 nm. The value at 663 nm is within the 95% confidence interval of the FCAE-based measurements: 0.935 1.005; therefore, it is most likely that the plateau region of the CPC counting efficiency includes this size. As it was discussed in Section 3.3 of the manuscript, the IAG-based method cannot properly simulate the mixing state and transport losses of aerosol particles under the count-matching method. As a compromise, the counting efficiency of the CPC during the evaluation of the KC-01E OPC, , was estimated by the product of the value of the plateau region ( = 0.971) and the values evaluated by the IAG method, .

|  |  |
| --- | --- |
|  | (S5) |

The value of was set to 0.983 at sizes below 633 nm, and a second order polynomial equation was fitted to the measured versus optical diameter at larger sizes. The polynomial equation was used to obtain the value of at the optical diameters of AAC-classified DOP particles. Figure S1 shows as a function of the optical diameter. The value over the plateau region is 0.953 which is within the 95% confidence interval of the FCAE-based measurements. In conclusion, although the CPC counting efficiencies for analyzing the counting efficiencies of the KC-22B and KC-01E OPCs were not identical, these values are statistically equivalent. The uncertainty of at a given optical diameter is estimated by

|  |  |
| --- | --- |
|  | (S6) |

where the standard uncertainty of , , is constant at sizes below 633 nm, and the values at larger sizes were estimated by the uncertainty of the least square fitting.



**Figure S1.** The counting efficiency of CPCs which also includes the transport efficiency through a 88 cm conductive tubing. Square symbols are the values evaluated by the IAG method, . Triangle symbols are the values used to correct the counting efficiencies of KC-01E OPC. The error bars represent 95% confidence intervals.

**References used in the Supplemental Material**

ISO (2015). ISO 27891:2015 Aerosol particle number concentration — Calibration of condensation particle counters, First Edition. ed. International Organization for Standardization, Switzerland.

ISO (2010). ISO/IEC GUIDE 98-3:2008 [JCGM/WG1/100] Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995), First Edition. ed. International Organization for Standardization, Switzerland.

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