



# Certificate of Calibration

## TWO GLASS SAMPLES REFLECTANCE AND TRANSMITTANCE

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**FOR:** SIA GroGlass  
Katlakalna iela 4B  
Riga  
LV-1073  
Latvia

**DESCRIPTION:** One sample named ARTGLASS 99<sup>TM</sup> is a regular glass sample with UV-blocking coating on one side. One sample named ARTGLASS AR99<sup>TM</sup> is a glass sample with anti-reflective coating on both sides and UV-blocking coating on one side. The samples, both supplied by the customer for measurement, are approximately 100 mm x 100 mm in size.

**IDENTIFICATION:** The sample ARTGLASS 99<sup>TM</sup> was given the NPL Identifier AM17 and the sample ARTGLASS AR99<sup>TM</sup> was given the NPL Identifier AN17. Each sample had its NPL Identifier scribed on the rear face near one corner. Also the side with the UV-blocking coating had been identified with the letters UV scribed on the front face near one corner.

**DATES OF  
CALIBRATION:** 07 – 22 August 2017

**UNCERTAINTIES:** The reported expanded uncertainties are based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a coverage probability of approximately 95 %.

**Reference:** 2017070053

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**Date of issue:** 6 September 2017

**Signed:**

**(Authorised Signatory)**

**Checked by:** SP N/A

**Name:** R Winkler

**on behalf of NPLML**

## MEASUREMENTS AND RESULTS

### TRANSMITTANCE

A Perkin-Elmer Lambda 900 spectrophotometer fitted with a 150 mm integrating sphere accessory was used to make measurements of the total transmittance of the samples. Measurements were made at 5 nm intervals across the range 280 nm to 780 nm. An area of approximately 13 mm x 7 mm in the centre of the samples was measured. The samples were mounted in front of the integrating sphere entrance port.

For the reference scans, the sampling beam was allowed to pass unobstructed into the integrating sphere.

### REFLECTANCE

A Perkin-Elmer Lambda 900 spectrophotometer fitted with a 150 mm integrating sphere accessory was used to make measurements in the specular included ( $8^\circ$ :di) geometry. An area of 18 mm x 5 mm in the centre of each sample was measured. The samples were measured at 5 nm intervals over the spectral range 300 nm to 780 nm.

Measurements were made by substitution with respect to an NPL first-surface mirror standard. The standard had previously been calibrated on a Varian Cary 5E spectrophotometer fitted with a VW Specular Reflectance accessory used to measure absolute specular reflectance. The accuracy of this instrument is checked periodically using transfer standards traceable to the NPL Reference Spectrophotometer.

For measurement of both spectral reflectance and transmittance, spectral scans were made in the order: dark, reference, sample, reference, dark. The mean of the two reference scans together with the appropriate dark correction was used in the calculation of the spectral reflectance and spectral transmittance values. The sample to reference ratios were then multiplied by the appropriate reference data in order to obtain the absolute spectral reflectance or spectral transmittance values. Two sets of measurements of each quantity were made on separate occasions on each sample, one with the identifier upright and the other with the identifier inverted. Reflectance measurements were made on the surface with the UV-blocking coating.

A deuterium lamp was used as the source from 280 nm to 315 nm and a tungsten lamp was used from 320 nm to 780 nm. The detector was a photomultiplier and the bandwidth was set at 2 nm across the full range of measurement.

The spectral reflectance values and spectral transmittance values are given for sample AM17 in Table 1, and for sample AN17 in Table 2 below.

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The Light Reflectance ( $\rho_v$ ) and Light Transmittance ( $\tau_v$ ) for Standard Illuminant D65 and UV Transmittance ( $\tau_{UV}$ ) have been calculated as defined in BS EN 410:2011. The results for each sample are given in Table 3.

All results quoted are for a temperature of  $23\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ .

### UNCERTAINTIES

The absolute uncertainties in the spectral reflectance values are:

| Sample | Absolute Uncertainty in Spectral Reflectance |              |              |              |
|--------|----------------------------------------------|--------------|--------------|--------------|
|        | 300 – 375 nm                                 | 380 – 400 nm | 405 – 460 nm | 465 - 780 nm |
| AM17   | $\pm 0.75\%$                                 | $\pm 0.15\%$ | $\pm 0.75\%$ | $\pm 0.20\%$ |
| AN17   | $\pm 0.80\%$                                 | $\pm 0.30\%$ | $\pm 0.15\%$ | $\pm 0.25\%$ |

The absolute uncertainties in the spectral transmittance values are:

| Sample | Absolute Uncertainty in Spectral Transmittance |              |              |              |
|--------|------------------------------------------------|--------------|--------------|--------------|
|        | 280 – 375 nm                                   | 380 – 395 nm | 400 – 420 nm | 425 - 780 nm |
| AM17   | $\pm 0.10\%$                                   | $\pm 0.25\%$ | $\pm 0.40\%$ | $\pm 0.50\%$ |
| AN17   | $\pm 0.10\%$                                   | $\pm 0.35\%$ | $\pm 0.45\%$ | $\pm 0.50\%$ |

Values of spectral reflectance or transmittance plus or minus the associated uncertainty can be ignored where they lie outside the range 0.00 % to 100.00 %

The uncertainties in the Light Reflectance, Light Transmittance and UV Transmittance values were calculated from the uncertainties in the relevant spectral values and are given alongside the results in Table 3.

Values of Light Reflectance, Light Transmittance and UV Transmittance plus or minus the associated uncertainty can be ignored where they lie outside the range 0.0000 to 1.0000.

The uncertainty in the wavelength scale is  $\pm 0.15\text{ nm}$ .

All percentages are with respect to the 100 % level and not the reflectance or transmittance value.

[1] *NPL scales for radiance factor and total diffuse reflectance*, C. J. Chunnillall, A. J. Deadman, L. Crane, E. Usadi, *Metrologia* 40, S192-S195 (2003)

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Table 1

ARTGLASS 99™ AM17

Absolute values

| Wavelength<br>nm | Reflectance<br>%<br>8°:di | Transmittance<br>% | Wavelength<br>nm | Reflectance<br>%<br>8°:di | Transmittance<br>% |
|------------------|---------------------------|--------------------|------------------|---------------------------|--------------------|
| 280              |                           | 0.18               | 450              | 8.60                      | 90.02              |
| 285              |                           | 0.15               | 455              | 8.73                      | 90.19              |
| 290              |                           | 0.12               | 460              | 8.70                      | 90.24              |
| 295              |                           | 0.10               | 465              | 8.53                      | 90.34              |
|                  |                           |                    | 470              | 8.45                      | 90.53              |
| 300              | 4.74                      | 0.10               | 475              | 8.51                      | 90.64              |
| 305              | 4.71                      | 0.11               | 480              | 8.59                      | 90.56              |
| 310              | 4.69                      | 0.13               | 485              | 8.58                      | 90.46              |
| 315              | 4.65                      | 0.16               | 490              | 8.49                      | 90.50              |
| 320              | 4.64                      | 0.17               | 495              | 8.43                      | 90.54              |
| 325              | 4.65                      | 0.17               | 500              | 8.44                      | 90.61              |
| 330              | 4.69                      | 0.17               | 505              | 8.47                      | 90.55              |
| 335              | 4.70                      | 0.15               | 510              | 8.47                      | 90.35              |
| 340              | 4.73                      | 0.13               | 515              | 8.40                      | 90.12              |
| 345              | 4.80                      | 0.13               | 520              | 8.30                      | 89.94              |
| 350              | 4.88                      | 0.12               | 525              | 8.24                      | 89.87              |
| 355              | 4.97                      | 0.12               | 530              | 8.25                      | 89.86              |
| 360              | 5.05                      | 0.15               | 535              | 8.28                      | 89.81              |
| 365              | 5.10                      | 0.23               | 540              | 8.31                      | 89.63              |
| 370              | 5.16                      | 0.45               | 545              | 8.28                      | 89.26              |
| 375              | 5.18                      | 1.07               | 550              | 8.23                      | 88.73              |
| 380              | 5.16                      | 2.81               | 555              | 8.16                      | 88.06              |
| 385              | 5.18                      | 7.06               | 560              | 8.13                      | 87.44              |
| 390              | 5.25                      | 15.52              | 565              | 8.13                      | 87.14              |
| 395              | 5.37                      | 28.62              | 570              | 8.16                      | 87.33              |
| 400              | 6.05                      | 44.38              | 575              | 8.20                      | 87.97              |
| 405              | 6.75                      | 59.18              | 580              | 8.21                      | 88.74              |
| 410              | 7.24                      | 70.72              | 585              | 8.19                      | 89.41              |
| 415              | 8.01                      | 78.39              | 590              | 8.15                      | 89.91              |
| 420              | 8.38                      | 82.89              | 595              | 8.11                      | 90.16              |
| 425              | 8.34                      | 85.79              | 600              | 8.09                      | 90.24              |
| 430              | 8.52                      | 87.70              | 605              | 8.08                      | 90.18              |
| 435              | 8.76                      | 88.64              | 610              | 8.08                      | 90.08              |
| 440              | 8.70                      | 89.08              | 615              | 8.09                      | 90.07              |
| 445              | 8.55                      | 89.60              | 620              | 8.10                      | 90.05              |

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Table 1

ARTGLASS 99™ AM17

Absolute values

| Wavelength<br>nm | Reflectance<br>%<br>8°:di | Transmittance<br>% | Wavelength<br>nm | Reflectance<br>%<br>8°:di | Transmittance<br>% |
|------------------|---------------------------|--------------------|------------------|---------------------------|--------------------|
| 625              | 8.09                      | 90.03              | 700              | 7.83                      | 88.82              |
| 630              | 8.06                      | 89.98              | 705              | 7.87                      | 89.27              |
| 635              | 8.03                      | 89.92              | 710              | 7.87                      | 89.46              |
| 640              | 8.00                      | 89.90              | 715              | 7.89                      | 89.49              |
| 645              | 7.98                      | 89.83              | 720              | 7.89                      | 89.49              |
| 650              | 7.97                      | 89.76              | 725              | 7.88                      | 89.42              |
| 655              | 7.95                      | 89.63              | 730              | 7.88                      | 89.42              |
| 660              | 7.93                      | 89.34              | 735              | 7.87                      | 89.31              |
| 665              | 7.90                      | 88.84              | 740              | 7.86                      | 89.26              |
| 670              | 7.85                      | 88.17              | 745              | 7.85                      | 89.16              |
| 675              | 7.80                      | 87.58              | 750              | 7.83                      | 89.10              |
| 680              | 7.76                      | 87.26              | 755              | 7.81                      | 89.03              |
| 685              | 7.75                      | 87.23              | 760              | 7.80                      | 89.00              |
| 690              | 7.76                      | 87.60              | 765              | 7.79                      | 88.90              |
| 695              | 7.79                      | 88.24              | 770              | 7.76                      | 88.82              |
|                  |                           |                    | 775              | 7.75                      | 88.79              |
|                  |                           |                    | 780              | 7.74                      | 88.70              |

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Table 2

ARTGLASS AR99™ AN17

Absolute values

| Wavelength<br>nm | Reflectance<br>%<br>8°:di | Transmittance<br>% | Wavelength<br>nm | Reflectance<br>%<br>8°:di | Transmittance<br>% |
|------------------|---------------------------|--------------------|------------------|---------------------------|--------------------|
| 280              |                           | 0.00               | 450              | 0.23                      | 97.81              |
| 285              |                           | 0.00               | 455              | 0.22                      | 98.12              |
| 290              |                           | 0.00               | 460              | 0.23                      | 98.29              |
| 295              |                           | 0.00               | 465              | 0.25                      | 98.38              |
|                  |                           |                    | 470              | 0.30                      | 98.42              |
| 300              | 31.34                     | 0.00               | 475              | 0.37                      | 98.43              |
| 305              | 30.02                     | 0.00               | 480              | 0.44                      | 98.41              |
| 310              | 28.31                     | 0.00               | 485              | 0.52                      | 98.32              |
| 315              | 25.95                     | 0.00               | 490              | 0.59                      | 98.26              |
| 320              | 22.72                     | 0.01               | 495              | 0.66                      | 98.18              |
| 325              | 18.84                     | 0.01               | 500              | 0.73                      | 98.12              |
| 330              | 15.41                     | 0.02               | 505              | 0.80                      | 98.03              |
| 335              | 14.42                     | 0.02               | 510              | 0.85                      | 97.84              |
| 340              | 17.04                     | 0.03               | 515              | 0.90                      | 97.61              |
| 345              | 21.85                     | 0.04               | 520              | 0.93                      | 97.39              |
| 350              | 26.03                     | 0.05               | 525              | 0.95                      | 97.27              |
| 355              | 27.99                     | 0.06               | 530              | 0.96                      | 97.24              |
| 360              | 27.65                     | 0.07               | 535              | 0.97                      | 97.21              |
| 365              | 25.59                     | 0.13               | 540              | 0.97                      | 97.08              |
| 370              | 22.46                     | 0.30               | 545              | 0.96                      | 96.76              |
| 375              | 19.01                     | 0.81               | 550              | 0.96                      | 96.25              |
| 380              | 15.57                     | 2.34               | 555              | 0.97                      | 95.61              |
| 385              | 12.43                     | 6.20               | 560              | 0.97                      | 95.01              |
| 390              | 9.80                      | 14.14              | 565              | 0.94                      | 94.75              |
| 395              | 7.63                      | 26.87              | 570              | 0.88                      | 94.99              |
| 400              | 5.95                      | 42.81              | 575              | 0.80                      | 95.70              |
| 405              | 4.68                      | 58.77              | 580              | 0.69                      | 96.57              |
| 410              | 3.47                      | 71.78              | 585              | 0.59                      | 97.32              |
| 415              | 2.59                      | 81.13              | 590              | 0.51                      | 97.87              |
| 420              | 1.87                      | 87.39              | 595              | 0.46                      | 98.14              |
| 425              | 1.26                      | 91.41              | 600              | 0.43                      | 98.22              |
| 430              | 0.87                      | 94.04              | 605              | 0.41                      | 98.18              |
| 435              | 0.60                      | 95.69              | 610              | 0.41                      | 98.07              |
| 440              | 0.40                      | 96.68              | 615              | 0.42                      | 98.05              |
| 445              | 0.28                      | 97.36              | 620              | 0.45                      | 98.04              |

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Table 2

ARTGLASS AR99™ AN17

Absolute values

| Wavelength<br>nm | Reflectance<br>%<br>8°:di | Transmittance<br>% | Wavelength<br>nm | Reflectance<br>%<br>8°:di | Transmittance<br>% |
|------------------|---------------------------|--------------------|------------------|---------------------------|--------------------|
| 625              | 0.49                      | 98.00              | 700              | 3.63                      | 93.72              |
| 630              | 0.55                      | 97.90              | 705              | 4.03                      | 93.75              |
| 635              | 0.64                      | 97.77              | 710              | 4.44                      | 93.57              |
| 640              | 0.75                      | 97.60              | 715              | 4.84                      | 93.22              |
| 645              | 0.87                      | 97.40              | 720              | 5.27                      | 92.79              |
| 650              | 1.02                      | 97.18              | 725              | 5.72                      | 92.34              |
| 655              | 1.18                      | 96.87              | 730              | 6.17                      | 91.86              |
| 660              | 1.36                      | 96.41              | 735              | 6.64                      | 91.35              |
| 665              | 1.56                      | 95.71              | 740              | 7.11                      | 90.80              |
| 670              | 1.77                      | 94.84              | 745              | 7.60                      | 90.19              |
| 675              | 2.01                      | 94.02              | 750              | 8.09                      | 89.69              |
| 680              | 2.27                      | 93.45              | 755              | 8.60                      | 89.12              |
| 685              | 2.55                      | 93.14              | 760              | 9.08                      | 88.55              |
| 690              | 2.88                      | 93.21              | 765              | 9.60                      | 87.99              |
| 695              | 3.25                      | 93.48              | 770              | 10.10                     | 87.41              |
|                  |                           |                    | 775              | 10.63                     | 86.88              |
|                  |                           |                    | 780              | 11.15                     | 86.27              |

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Table 3

## INTEGRATED VALUES

| Sample | Light Reflectance |              | Light Transmittance |              | UV Transmittance |                 |
|--------|-------------------|--------------|---------------------|--------------|------------------|-----------------|
|        | $\rho_v$          | $\pm \rho_v$ | $\tau_v$            | $\pm \tau_v$ | $\tau_{UV}$      | $\pm \tau_{UV}$ |
| AM17   | 0.0823            | 0.0017       | 0.8930              | 0.0050       | 0.0041           | 0.0011          |
| AN17   | 0.0079            | 0.0009       | 0.9694              | 0.0050       | 0.0027           | 0.0011          |