NATIONAL PHYSICAL LABORATORY
Teddington Middlesex UK TW11 0LW Telephone +44 20 8977 3222

Certificate of Calibration

TWO GLASS SAMPLES
REFLECTANCE AND TRANSMITTANCE

FOR:	SIA GroGlass Katlakalna iela 4B Riga LV-1073 Latvia
DESCRIPTION:	One sample of Anti-Reflective Glass by GroGlass (on monolithic low-iron glass substrate). One sample of Artglass AR Protect by GroGlass (on pre-laminated low-iron glass substrate). The samples, both supplied by the customer for measurement, are approximately 75 mm x 75 mm in size.
IDENTIFICATION:	The sample of Anti-Reflective Glass by GroGlass was given the NPL Identifier AW15 and the sample of Artglass AR Protect by GroGlass was given the NPL Identifier AY15. Each sample had its NPL Identifier scribed on the rear face near one corner.
DATES OF CALIBRATION:	12 – 22 May 2015
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: 2015030538/R **Page 1 of 8**

Date of issue: 8 July 2015 **Signed:** . **(Authorised Signatory)**

Checked by: RM JS **Name: D Gibbs** **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 300 nm to 800 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°: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 800 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 on the rear upright and the other with the identifier inverted.

A deuterium lamp was used as the source from 300 nm to 315 nm and a tungsten lamp was used from 320 nm to 800 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 AW15 in Table 1, and for sample AY15 in Table 2 below.

The Light Reflectance (ρ_v) and Light Transmittance (τ_v) for Standard Illuminant D65 and UV Transmittance (τ_{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 °C ± 1 °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 - 800 nm
AW15	± 1.25 %	± 0.45 %	± 0.15 %	± 0.25 %
AY15	± 1.15 %	± 0.25 %	± 0.10 %	± 0.25 %

The absolute uncertainties in the spectral transmittance values are:

Sample	Absolute Uncertainty in Spectral Transmittance			
	300 – 340 nm	345 – 375 nm	380 – 595 nm	600 - 800 nm
AW15	± 0.15 %	± 0.30 %	± 0.30 %	± 0.40 %
AY15	± 0.15 %	± 0.15 %	± 0.30 %	± 0.40 %

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 4.

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 ± 0.15 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. Chunnilall, A. J. Deadman, L. Crane, E. Usadi, Metrologia 40, S192-S195 (2003)*

Table 1 ANTI-REFLECTIVE GLASS AW15 Absolute values

Wavelength nm	Reflectance % 8°:di	Transmittance %	Wavelength nm	Reflectance % 8°:di	Transmittance %
300	29.63	0.00	450	0.62	98.27
305	28.76	0.00	455	0.43	98.59
310	27.61	0.01	460	0.30	98.82
315	25.93	0.03	465	0.21	99.00
320	23.38	0.14	470	0.15	99.14
325	19.86	0.48	475	0.13	99.20
330	15.87	1.43	480	0.14	99.25
335	13.16	3.64	485	0.16	99.25
340	14.06	7.47	490	0.21	99.22
345	19.08	12.69	495	0.27	99.23
350	25.94	18.80	500	0.33	99.20
355	31.74	25.51	505	0.40	99.16
360	34.96	32.83	510	0.47	99.09
365	35.53	40.52	515	0.54	98.96
370	33.92	48.44	520	0.61	98.70
375	30.78	55.88	525	0.67	98.80
380	26.68	63.10	530	0.72	98.83
385	22.43	69.77	535	0.77	98.79
390	18.37	75.57	540	0.81	98.77
395	14.70	80.46	545	0.84	98.74
400	11.55	84.45	550	0.85	98.75
405	8.97	87.64	555	0.85	98.75
410	6.89	90.20	560	0.84	98.76
415	5.25	92.24	565	0.81	98.78
420	3.98	93.85	570	0.78	98.80
425	3.00	95.08	575	0.75	98.83
430	2.24	96.05	580	0.70	98.85
435	1.66	96.81	585	0.64	98.88
440	1.21	97.41	590	0.59	98.94
445	0.87	97.90	595	0.53	98.98

Checked by: RM JS

Table 1 ANTI-REFLECTIVE GLASS AW15 Absolute values

Wavelength nm	Reflectance % 8°:di	Transmittance %	Wavelength nm	Reflectance % 8°:di	Transmittance %
600	0.47	99.04	700	1.62	97.82
605	0.41	99.09	705	1.88	97.54
610	0.35	99.11	710	2.16	97.26
615	0.30	99.18	715	2.45	96.94
620	0.26	99.23	720	2.77	96.65
625	0.22	99.27	725	3.11	96.28
630	0.20	99.27	730	3.47	95.89
635	0.19	99.27	735	3.84	95.53
640	0.18	99.26	740	4.24	95.07
645	0.20	99.22	745	4.63	94.71
650	0.23	99.16	750	5.06	94.26
655	0.28	99.14	755	5.50	93.77
660	0.34	99.06	760	5.94	93.30
665	0.42	98.98	765	6.41	92.84
670	0.53	98.90	770	6.87	92.37
675	0.66	98.79	775	7.35	91.85
680	0.80	98.62	780	7.84	91.37
685	0.97	98.45	785	8.34	90.83
690	1.17	98.29	790	8.83	90.28
695	1.38	98.06	795	9.34	89.75
			800	9.84	89.17

Checked by: RM JS

Table 2 ARTGLASS AR PROTECT AY15 Absolute values

Wavelength nm	Reflectance % 8°:di	Transmittance %	Wavelength nm	Reflectance % 8°:di	Transmittance %
300	30.19	0.01	450	0.64	97.20
305	28.66	0.00	455	0.49	97.48
310	26.69	0.00	460	0.40	97.68
315	24.06	0.00	465	0.34	97.86
320	20.79	0.00	470	0.32	97.95
325	17.60	0.00	475	0.33	98.01
330	15.76	0.01	480	0.36	98.06
335	16.72	0.01	485	0.40	98.07
340	20.25	0.00	490	0.47	98.06
345	24.41	0.00	495	0.54	98.07
350	27.23	0.01	500	0.62	98.02
355	27.89	0.00	505	0.70	97.99
360	26.59	0.00	510	0.78	97.91
365	23.91	0.00	515	0.86	97.85
370	20.48	0.00	520	0.93	97.79
375	16.91	0.00	525	0.99	97.70
380	13.41	0.11	530	1.05	97.64
385	10.40	2.53	535	1.10	97.60
390	8.27	15.35	540	1.13	97.55
395	7.76	40.27	545	1.15	97.52
400	7.85	64.17	550	1.16	97.50
405	7.17	79.02	555	1.15	97.48
410	5.92	86.79	560	1.14	97.46
415	4.64	90.77	565	1.11	97.44
420	3.55	93.03	570	1.07	97.39
425	2.69	94.39	575	1.02	97.35
430	2.02	95.33	580	0.96	97.30
435	1.51	95.96	585	0.90	97.24
440	1.13	96.45	590	0.83	97.22
445	0.84	96.84	595	0.76	97.19

Checked by: RM AJS

Table 2 ARTGLASS AR PROTECT AY15 Absolute values

Wavelength nm	Reflectance % 8°:di	Transmittance %	Wavelength nm	Reflectance % 8°:di	Transmittance %
600	0.70	97.20	700	1.67	94.88
605	0.63	97.19	705	1.91	94.58
610	0.57	97.16	710	2.17	94.24
615	0.51	97.14	715	2.45	93.84
620	0.46	97.12	720	2.75	93.46
625	0.41	97.08	725	3.07	93.01
630	0.38	97.02	730	3.40	92.58
635	0.36	96.92	735	3.75	92.09
640	0.35	96.83	740	4.12	91.57
645	0.36	96.77	745	4.49	91.07
650	0.38	96.67	750	4.89	90.53
655	0.42	96.59	755	5.30	90.07
660	0.48	96.49	760	5.71	89.53
665	0.55	96.36	765	6.14	88.99
670	0.65	96.24	770	6.58	88.46
675	0.76	96.08	775	7.02	87.87
680	0.90	95.91	780	7.48	87.33
685	1.06	95.67	785	7.94	86.77
690	1.24	95.45	790	8.41	86.20
695	1.44	95.15	795	8.87	85.63
			800	9.33	85.02

Checked by: RM MS

Table 3 INTEGRATED VALUES

Sample	Light Reflectance		Light Transmittance		UV Transmittance	
	ρ_v	$\pm \rho_v$	τ_v	$\pm \tau_v$	τ_{UV}	$\pm \tau_{UV}$
AW15	0.0062	0.0010	0.9889	0.0032	0.2541	0.0025
AY15	0.0090	0.0010	0.9747	0.0032	0.0001	0.0016

Checked by: RM JS