Attachment 7.11.1

Universal Laser Systems Inc.			
Document Title:	Transmissivity of Laminated Annealed Safety Glass to CO_2 Lasers		
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Section 1 Purpose of Test

The purpose of this test was to determine the suitability of laminated annealed safety glass as a viewing port material for laser systems. This test was done in two phases. The first phase was the determination of the level of laser power transmitted through the object under test at power levels under that required to permanently damage the material. The second phase was the determination of the level of laser power with which the object was permanently damaged under the influence of laser radiation (for safety glass only).

Test Conducted by: Vladimir Cherezov
Test Conducted at: Universal Laser Systems

Section 2 Details of Test

Test samples (object 1) Annealed Laminated Safety Glass sheet, thickness 2.5 mm laminating layer .75 mm,
(object 2) Acrylic sheet, thickness 5.8 mm

Tests were conducted according to optical diagram depicted in Diagram 1.

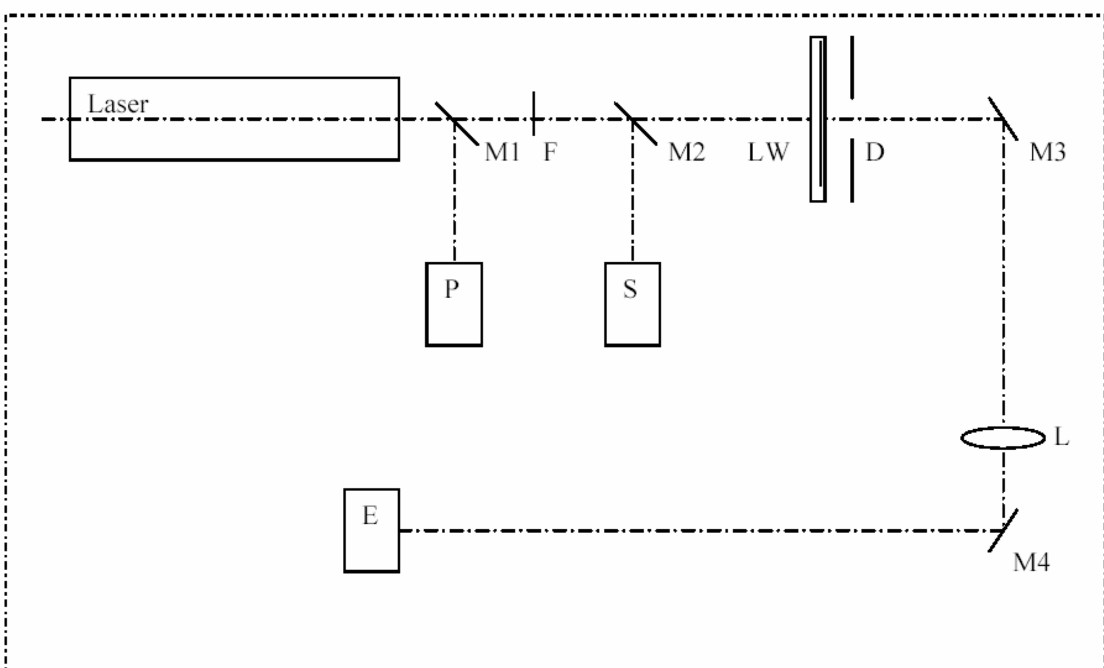

Diagram 1

Attachment 7.11.1

Laser	Universal Laser Systems UL-150 150 watt laser*
M1	flat mirror (coefficient of transmission 25%);
F	flat mirror (coefficient of transmission 35%)
M2	flat mirror (coefficient of transmission 25%)
M3	flat mirror (reflection coefficient 95%);
M4	flat mirror (reflection coefficient 95%);
LW	object under test- (Acrylic and Safety glass);
D	diaphragm 7 and 3.5 mm;
L	lens with a focal length of 1m;
P	power meter LaserStar 150A, Ophir Optronics Ltd
S	CO2 Laser Spectrum Analyzer, Macken Instruments Inc.
E	“radiometer” Universal Laser Radiometer R-752 with Pyroelectric Probe P444 and Power Head PH-30, Terahertz Technologies Inc.**

* The tested laser had emissions, corresponding to lines P12, P14, P16, P22, P22, P24, P26, P28, R12, R14, R16, R18, R20, R22 ($00^{0}0$-$10^{0}0$) and P16, P18, P20, P22, P24, P26 ($00^{0}0$ – $02^{0}0$) for a molecule of carbon dioxide. The number of lines of emission changed in the time.

** Background noise level measured was 0.2-0.3 mW using the power scale or 0.056-0.072 µJ using the energy scale and averaging 100 pulses or 63.19 - 72.25 µJ using the energy scale and summing over 1000 pulses.

<u>Section 3 Results of Test</u>

During the first phase of the test the level of laser power transmitted through the object under test was measured. Using the “radiometer” with the scale set to 10 mW max, there was no measurable laser radiation transmitted through the object under test during the test period. Power and energy measurements for the safety glass where recorded here for reference but all measurements are within the noise threshold of the measuring device.

Laser Power (W)	34	63	94	125	156	188
Laser Power on laminated glass (W)	2.72	5.04	7.52	10*	12.5*	15.04*
Radiometer reading (mW)	<.3	<0.3	<0.3	<0.3	<0.3	<0.3
Radiometer reading (µJ)**	.056	.065	.072	.071	.071	.070
Radiometer reading (µJ)***	91.41	87.23	83.15	76.66	72.25	70.51

* Permanent damage to the object under test occurred at these power levels over time. Below these power levels the object under test was not damaged over time.
** Using the averaging over 100 pulses method
*** Using the summing over 1000 pulses method

During the second phase of the test the level of laser power required to compromised the material under test was determined for object 2 only. The level of laser power was smoothly varied from minimum value to the maximum in 1 W increments pausing at each value for 60 seconds. It was determined, that at 8 ± 1 W on the material the material was compromised. The method of failure is the formation of a small hole in the first layer of glass at a diameter of about 2.5 mm at which the inner laminate layer starts to burn and discolor followed by the formation of a smaller pinhole in the second layer of glass at which point laser radiation can be measured through the object under test.

Section 4 Conclusions

The annealed laminated safety glass provides similar protection to acrylic when used as a viewing port material for a laser processing system. While both materials provide adequate protection from scattered radiation indefinitely, both materials will fail under a direct hit by an unfocused beam of over 8 watts. In failure mode both acrylic and safety glass provide an adequate visual indication of a compromise of the surface to warn the user that the material has been compromised and needs to be replaced.