TEST REPORT

Solamatrix Inc.

GLASS-GARD GGL800 Multi-ply Window Film and 'Wetglaze' Anchoring System on Single 6mm (1/4") Annealed Glass.

Class 3B

US General Services Administration Explosion Resistant Standard

Test report prepared by: S. Trundle GDA

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An Advantica Ltd.,
Grendon Design Agency Ltd.
and David Goode & Associates
group project.

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1.0 Introduction

This test report records the results of explosion testing conducted on Solamatrix Inc., security window film products during the United Kingdom ComBlast Explosion Range Trials in May 2009.

The ComBlast trials were established to allow commercial companies to undertake explosion testing of their products alongside the United Kingdom Home Office annual range trials. The commercial element of the ComBlast trials are managed by a partnership comprising of Advantica - GL Technology [test site provider and shot firing], D. J. Goode & Associates [test structure design] and Grendon Design Agency [Trials Manager].

The 2009 ComBlast explosion range tests were carried out during week commencing 18th May 2009 at the Spadeadam test site in Cumbria, England, under the supervision of Simon Trundle, Managing Director of Grendon Design Agency.

Details of the technical and manufacturing process relating to each of the individual test specimens have been fully declared by Solamatrix Inc to GDA and were confirmed on the test site prior to the explosion test. Details of the construction of the test specimen are limited within this report to maintain commercial confidentiality, however, full manufacturing and construction details are held on record at Grendon Design Agency.

Photo 1: View of test set up showing steel test cubicle with three test specimens separated by internal walls. To reduce the effect of clearing of the blast wave, additional concrete walls were built at both sides of the container and the height of the container was extended by a steel plate above the window specimens. The overall dimensions of the test structure was 9.710m (31.85 ft.) wide x 3.3m (10.82 ft.) high.

1.1 Test Specimens GLASS-GARD GGL800 (8mil) Multi-Ply Window Film With Wetglaze Anchoring System on 6mm (1/4”) Annealed Glass

Description:	Solamatrix Inc., product reference GGL 800 multi-ply 200 micron (8mil) security grade window film.
Window Frame Size:	1676mm x 1219mm (66 inches x 48 inches) overall size.
Glazing:	Single glazed window containing 6mm (1/4 inch) annealed float glass.
Attachment system:	Wetglaze system comprising of 18mm (3/4 inch) bead of D993 structural silicone connecting the daylight window film to the aluminium window frame on four sides.
Explosive:	Liquid explosive equivalent mass to 100 kg (220lb) TNT
Range:	33 m (108ft).

Photo 2: Close up of the 18mm (¾ x ¾ inch) ‘Wetglaze’ silicone bead used to connect the GGL800 film to the aluminium window frame. The window frames were secured to the test structure by 10 nr M12 steel bolts.

This mounting arrangement was used to ensure the window frame remained securely mounted in the test structure and the full load was transferred to the filmed glass and the wetglaze anchoring system.

2.0 High Explosive Testing

The following text describes in general terms the forces applied to a test specimen in an explosion.

Detonation of a high order explosive produces a shock in air, which takes the form of a rapidly expanding pressure wave in the surrounding atmosphere. The blast wave expands outwards until it meets an object in its path i.e. the test cubicle containing the test specimens.

The expanding blast pressure wave is arrested in its travel and in this instance 'reflects' against the front surface of the test cubicle. This expanding pressure wave is referred to as the positive phase or reflected pressure load.

A negative phase effect is experienced immediately following the rapid overpressure load generated by the expanding pressure wave. The negative phase [suction] is created when the detonation of the high explosive and rapid outward movement of the blast wave creates a vacuum at the seat of the explosion, which is rapidly filled by the surrounding atmosphere being drawn back into the evacuated space.

The rapid return of air to fill the void created at the centre of the blast causes a reverse flow in the surrounding atmosphere, which causes drag or suction on the face of the test specimen.

The negative phase can sometimes coincide with the elastic response of the test specimen and thereby further increase the rebound effect.

2.1 Details Of The Explosive Charge

The open range tests were conducted using a liquid explosive contained within a cylindrical container.

Pre-testing of the liquid state explosive was undertaken by Advantica to determine the net equivalency to TNT. The charge size used in these tests was selected as a direct equivalent to 100kg (220lb) TNT High Explosives. The explosive charge was supported on polystyrene packing to ensure that no fragments would be ejected from the charge support. The explosive charge was set at 1,000 mm (39.37 inches) above the test pad surface to the centre of the charge.

The liquid explosive is not identified within this report as it is classified under United Kingdom rules. Details of the composition of the explosive charge can be made available to approved persons or agencies on a need to know basis.

Photo 3: View of explosive charge contained within a plastic sphere set on polystyrene packing with a typical test structure in the background.

2.2 Blast Pressure Loading

Pressure sensors were installed on the front face of the test structure between the window specimens. Additional free field blast pressure measurements were captured to confirm pressure levels.

The liquid based explosive used in these tests typically produces a higher peak pressure and impulse loading than standard TNT.

The reflected pressures were recorded on time-pressure plots a sample of which is included within Annex A of this report. The test structure measured 9.71 m wide x 3.3 metres high (31.85 ft x 10.82 ft).

The test cubicle was extended at the top and sides to reduce the effect of early clearing of the blast wave. Clearing is where the blast wave envelopes the test structure and releases around edges. If insufficient surface area is present around the test specimen the blast wave will leave the surface of the test specimen early in the event and result in a reduction of the reflected impulse loading.

The size of the test specimens combined with the explosive charge and standoff distance to the test structure means that the test specimens can be certified in accordance with the following explosion resistant standards:

1. US GSA Standard Test Method for Glazing and Window Systems Subject To Dynamic Overpressure Loading.
    a. The GSA classification requires 4psi peak pressure and 28psi-millisecond peak reflected impulse loading. The peak values achieved in this test substantially exceed the GSA requirement.

Examination of the captured blast data plots indicates that the peak reflected pressure on the face of the test specimens was 604 mBar (60.4 kPa) (8.83 psi). As explained in Annex A, the peak reflected pressure was adjusted downwards to 480 mBar (48 kPa) (7.01psi) to remove the initial low energy ‘noise spike’. The average impulse loading on the surface of the test specimens was measured at 238 kPa-millisecond (34 psi-millisecond) after adjusting the peak pressure value as outlined above.

Previous testing conducted at the same range and with similar charge and target dimensions provided a check on the pressure and impulse values which were found to be within the expected variance of +-2%.

2.3 Details Of The Test Arena

The individual test specimens were mounted in steel test structures which were orientated to face square on to the centre of the explosive charge

Photo 4: Test set up showing windows installed in the face of the steel test structure. The front face of the test structure measured 9.71 metres wide (31.85 ft) and 3.3 metres high (10.82 ft).

Three identical test specimens were tested to achieve verification of the performance over a minimum of 3 test specimens.

Photo 5: View of test specimen mounting detail into the steel test structure. Each of the three specimens were fixed into the steel structure using 10 no M12 HS bolts

Blast gauges were mounted between the windows on the face of the test cubicle.

3 Hazard Criteria And Classification Of Results

In order to facilitate wider circulation of this test report we have classified the results in accordance with the following criteria:

- US General Services Administration classification system for glazing subjected to airblast loading.

3.1 US GSA Hazard Criteria And Explosion Resistance Classification

The United States General Services Administration uses the following method for classifying performance of glazing under blast loading.

Table 1 and Figure 2 are extracted from the United States General Services Administration [GSA] Standard Test Method for Glazing and Window Systems Subject to Dynamic Overpressure Loading.

Table 1. Extract From GSA Criteria for Test Specimen Performance Conditions

Performance Condition	Protection Level	Hazard Level	Description of Window Glazing Response
1	**Safe**	**None**	Glazing does not break. No visible damage to glazing or frame.
2	**Very High**	**None**	Glazing cracks but is retained by the frame. Dusting or very small fragments near sill on floor acceptable.
3a	**High**	**Very Low**	Glazing cracks. Fragments enter space and land on floor no further than 3.3ft. from the window.
3b	**High**	**Low**	Glazing cracks. Fragments enter space and land on floor no further than 10 ft. from the window.
4	**Medium**	**Medium**	Glazing cracks. Fragments enter space and land on floor and impact a vertical witness panel at a distance of no more than 10 ft. from the window at a height no greater than 2 ft. above the floor.
5	**Low**	**High**	Glazing cracks and window system fails catastrophically. Fragments enter space impacting a vertical witness panel at a distance of no more than 10 ft. from the window at a height greater than 2 ft. above the floor.

Note: In the USA, Category C facilities require protection from a blast load peak pressure of 4psi and an impulse of 28psi-millisecond. A performance condition (Damage Level) 4 is permitted for Category C facilities. A graphical depiction of the performance conditions contained in the criteria is shown in Figure 2. A description of the performance conditions and hazard levels are outlined in Table 1 above.

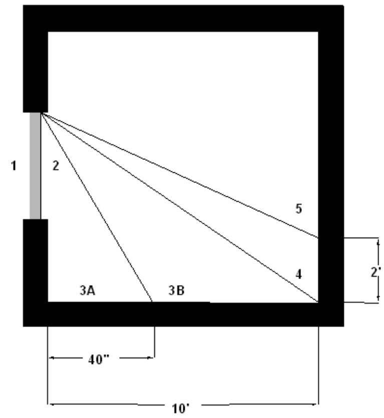


Figure 2. GSA Performance Conditions

4.0 Results And Photographic Record Of Tests

The following photographs are used to confirm the hazard and performance classifications in accordance with the performance criteria outlined in section 3 of this report.

Photo 6:

The three test specimens achieved similar performance in the blast test.

The Solamatrix GGL800 multi-ply window film in conjunction with the 'wetglaze' film anchoring system retained the glass in the opening during the positive phase of the blast. The film tore on rebound after the majority of the glass had been ejected outside of the test cubicle.

Photo 7: View of interior of the central test cubicle with the majority of the glass retained on the window film which tore and split on rebound on two edges.

There were no glass impact marks in the witness panel at the rear wall of the test cubicle or on the floor of the test cubicle.

Glass fragments landed on the floor of the test structure within GSA zones 3A and 3B.

Photo 8: View of floor of the test structure behind left-hand window.

Glass fragments were scattered across the floor of the test structure within the GSA 3B Low Hazard zone.

The total glass fragment mass was measured at 936 grams for the left hand cubicle (see photo), 536 grams for the centre cubicle and 490 grams for the right hand cubicle.

The absence of fragments within the witness panel indicates that the fragments fell to the ground with low velocity and would therefore have posed a low hazard to occupants behind the windows.

Photo P9: View of floor inside right hand cubicle showing 8 mil film lying on the floor. The majority of the glass has been ejected outside of the cubicle in the rebound phase.

In all three test specimens the witness panels were free of impact marks with any glass fragments located on the floor within zones 3A and 3B.

4.1 Classification Of Results:

Solamatrix Inc.'s GLASS-GARD GGL 800 (8mil) (200 micron) multi-ply safety window film when applied to 6mm annealed float glass in combination with a four-sided Wetglaze anchoring system is assessed as having achieved a GSA 3B classification (Low Hazard/High Protection).

Test certified:

Simon Trundle

Commercial Trials Manager

ComBlast 2009 Explosion Range Trials

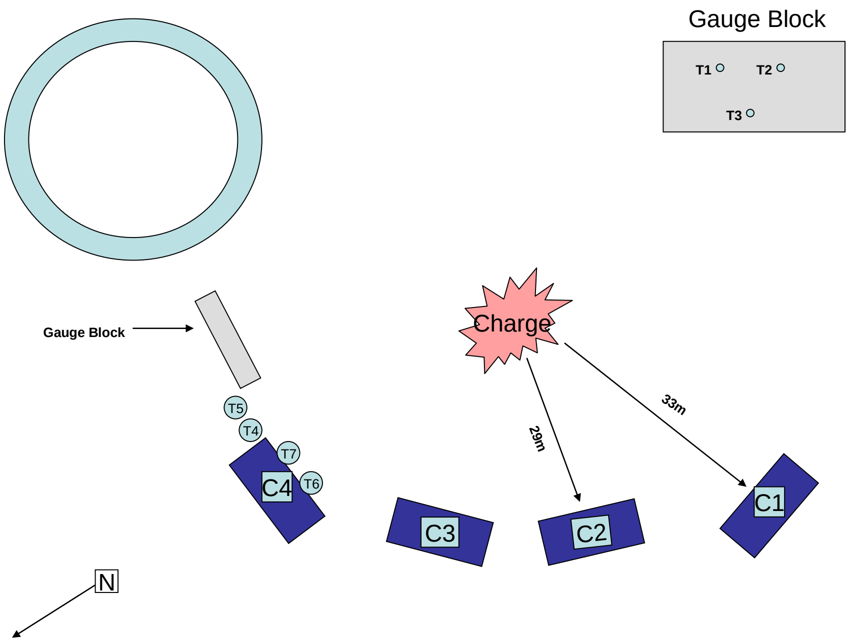
27/06/2009

Annex A

Test Arena Plan And Blast Measurements

Test Arena

The test cubicle referred to within this report is on the right of centre of the test pad and contains pressure gauges t1. t2, t3 within the concrete gauge block and t14, t15 as free-field gauges and t7 and t8 as reflected gauges on the face of the cubicle. The test cubicle was set at a distance of 33 metres (108 ft) from the face of the glass to the centre of the 100kg (220lb) TNT equivalent explosive charge.



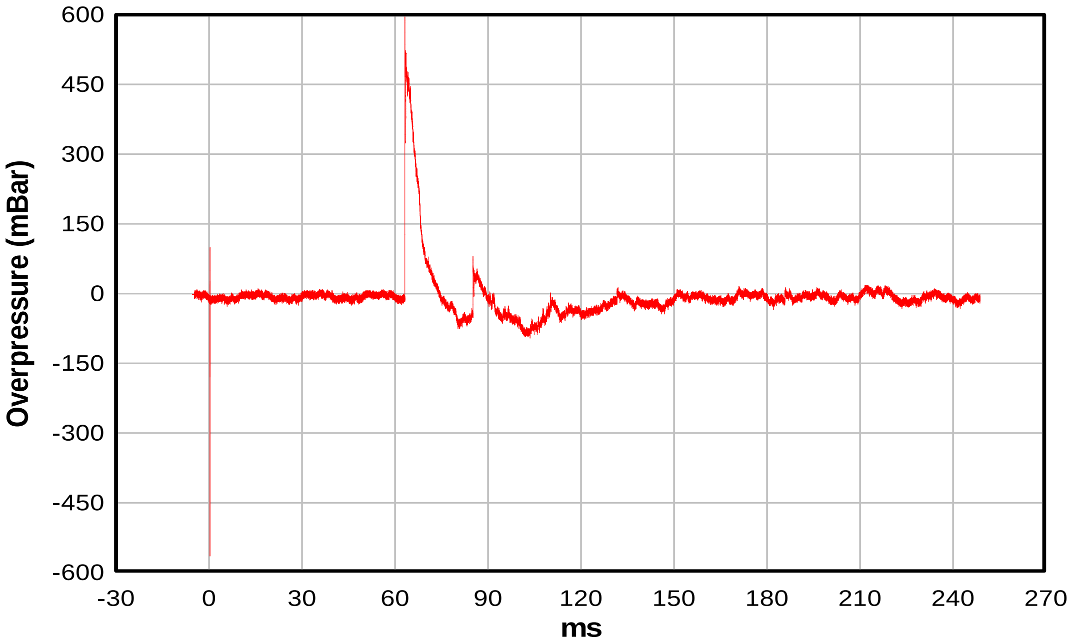
Cubicle layout with test pad references C1 – C4.

C1 = Cubicle A: GGL1200 multi-ply film with wetglaze attachment system at 33m standoff.

C2 = Cubicle C: GGL 800 multi-ply film with wetglaze attachment system at 29m standoff

C3 = Cubicle D: GGL 800 multi-ply film with Gullwing anchoring system at 29 m standoff

C4 = Cubicle B: GGL 800 multi-ply film with wetglaze attachment system at 33m standoff



Plot: Pressure – Time History

The peak pressure was measured as 604 mBar (60.4 kPa) (8.83psi). However this peak value is adjusted to remove the initial noise spike which does not contain any significant energy. The peak pressure value is reduced from a peak of 604 mBar to 480 mBar (48 kPa) (7.01 psi) after eliminating the low energy noise spike in the initial readings. This ensures a conservative approach to calculating the pressure and impulse loading.

The area under the positive pressure/time curve is referred to as the reflected impulse and is measured in kPa-milliseconds. The theoretical reflected impulse is the sum of pressure x time divided by 2 to represent a triangular pressure/time trace. The duration of the blast load for 100kg TNT at 33 metres is 19.90 milliseconds and therefore in theory the reflected triangular impulse load would be 48kPa x 19.9 ÷ 2 = 477.6 kPa-milliseconds. This figure represents a large or infinite reflecting surface whereas the small surface area of the test structure allows the blast wave to clear the edges very quickly. This clearing effect results in reduced impulse loading because the pressure loading does not continue to load the test specimen after the blast wave has cleared the structure. The conservative estimate is that up to 50% of the impulse loading can be lost through clearing of the blast wave. Therefore the theoretical triangular impulse load of 477 kPa-milliseconds is reduced to 238 kPa-milliseconds (34 psi-msec).

The pressure gauges mounted on the face of the test cubicle in the same plane as the windows and between the test specimens, measured an impulse of between 240 – 246 kPa-milliseconds.

The certified test pressure and impulse values are summarised as follows:

Reflected Pressure: 48 kPa (7.01 psi)

Reflected Impulse: 238 kPa-millisecond (34 psi-millisecond)

The US GSA classification requires 4psi reflected pressure and 28 psi-millisecond reflected impulse and therefore the test is considered to have achieved these values and the test specimens can be certified in accordance with GSA requirements and classifications.