TEST REPORT

ADVANTICA

ComBlast

Madico Inc

ISO 16933: Glass in Buildings – Explosion Resistant Security Glazing.

Test and Classification in Arena Air Blast Loading

Madico Safety Shield 800 Safety Film With Wet-Glaze Attachment System

Classification EXV33

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ComBlast 2009

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GDA & DGA

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

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1. Introduction

This test report records the results of explosion range tests conducted on Madico Inc security grade multi-ply window film tested as part of the ComBlast 2009 Explosion Range Trials.

The ComBlast trials were established to allow commercial companies to undertake explosion testing of their products alongside the formal Home Office annual range trails.

The commercial element of the ComBlast test program is managed by a partnership comprising of GL Technology [test site provider and shot firing], D. J. Goode & Associates [Design Of Test Structures] and Grendon Design Agency [GDA] [Commercial Trials Management].

The Madico explosion range tests were conducted between the 22nd – 28th September 2009 at the GL Technology (formerly Advantica) test site at Spadeadam, Cumbria, England, under the supervision of Simon Trundle test manager for the ComBlast trials.

The individual test specimens were prepared by Xtral Limited under supervision from Madico Inc and installed in the test cubicle by GL Technology at the Spadeadam test range in Cumbria, United Kingdom.

Validity of Test

Three identical test specimens were subjected to the same detonation in order to provide a recognised level of performance in accordance with ISO standard ISO/DIS 16933.

These test results relate only to the materials and the configurations tested and no alterations to the material manufacture, composition or assembly method can be accepted unless further testing is undertaken.

1.1 Details of Test Specimens

Test specimens number 4, 5 and 6 were installed in the face of the test structure measuring 9.2 metres wide and 3.2 metres high.

All three test specimens were produced to the following specification:

Test specimen window frame:	1727mm x 1219mm [68 inches x 48 inches] extruded aluminium framed windows of 2.25mm wall thickness.
Style:	Fixed lite non-opening shop-front window frame
Clear glass area:	1627mm x 1119m.
Glass:	6mm annealed float glass on the exterior lite, 12mm air space and 6mm annealed glass on the internal lite. Insulated units mounted into frame with 10mm edge rebate cover using compression gaskets.
Window film brand name:	Madico Safety Shield 800 200 micron multi-ply security grade window film applied to the inside surface of the glass extending to the edge of the vision area of the glass.
Date of test:	23rd September 2009
Edge retention system:	Wet glaze anchoring system attached the window film to the aluminium window frame on all four sides. Details of the wet glaze attachment system are provided in Annex B.
Mounting of test specimen:	Total 10 x M10 mild steel bolts secured the test specimen into the individual openings in the test cubicle.

Commercial In Confidence

Details of the Wet Glaze film anchoring system were declared by Madico Inc and record drawings and specification details are retained on file. Details of a typical wet-glaze application are contained within Annex B.

2. 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.

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. This 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 drawing the glass out of the test structure.

2.1 Details Of The Explosive Charges

Tests were conducted using a 100kg TNT equivalent liquid explosive details of which are available to approved parties. The explosives were contained within a cylindrical container set at a height of 800mm above the surface of the concrete test pad. Pre-testing of the explosive was undertaken by GL Technology on behalf of the United Kingdom government to determine the net equivalency to TNT.

The explosive charge was supported on polystyrene packing to ensure that no fragments would be ejected from the steel plate used as a shield between the charge and the concrete pad.

2.2 Blast Classification: ISO 16933

The three test specimens were tested in accordance with classification EXV33 of ISO 16933: standard at a range of 33 metres from the explosive charge. The following tables are extracted from ISO 16933 and provide information on the classification method [Table 1] and pressure and impulse values [Table 2].

Table 1 — Hazard rating criteria for arena tests

Hazard rating	Hazard rating description	Definition
A	No Break	The glazing is observed not to fracture and there is no visible damage to the glazing system
B	No Hazard	The glazing is observed to fracture but the inner, rear face leaf is fully retained in the facility test frame or glazing system frame with no breach and no material is lost from the interior surface. Outer leaves from the attack face may be sacrificed and may fall or be projected out.
C	Minimal Hazard	The glazing is observed to fracture. Outer leaves from the attack face may be sacrificed and may fall or be projected out. The inner, rear face leaf shall be substantially retained having the total length of tears plus the total length of pullout from the edge of the frame less than 50 percent of the glazing sight perimeter. Also, there are no more than 3 rateable perforations or indents anywhere in the witness panel and any fragments on the floor between 1 m and 3 m from the interior face of the specimen have a sum total united dimension of 250 mm or less. Glazing dust and slivers are not accounted for in the hazard rating. If by design intent there is more than 50 % pullout but the glazing remains firmly anchored by purpose designed fittings a rating of C (Minimal Hazard) may be awarded provided the other fragment limitations are complied with. The survival condition and anchoring provisions shall be described in the test report
D	Very Low Hazard	The glazing is observed to fracture and significant parts are located no further than 1m behind the original location of the rear face. Parts may be projected any distance from the attack face towards the blast source. Also, there are no more than 3 rateable perforations or indents anywhere in the witness panel and any fragments on the floor between 1 m and 3 m from the interior face of the specimen have a sum total united dimension of 250 mm or less. Glazing dust and slivers are not accounted for in the rating
E	Low Hazard	The glazing is observed to fracture but glazing fragments or the whole of the glazing fall beyond 1 m and up to 3 m behind the interior face of the specimen and not more than 0,5 m above the floor at the vertical witness panel. Also, there are 10 or fewer rateable perforations in the area of the vertical witness panel higher than 0,5 m above the floor and none of the perforations penetrate more than 12 mm.
F	High Hazard	Glazing is observed to fracture and there are more than 10 rateable perforations in the area of the vertical witness panel higher than 0,5 m above the floor or there are one or more perforations in the same witness panel area with fragment penetration more than 12 mm.

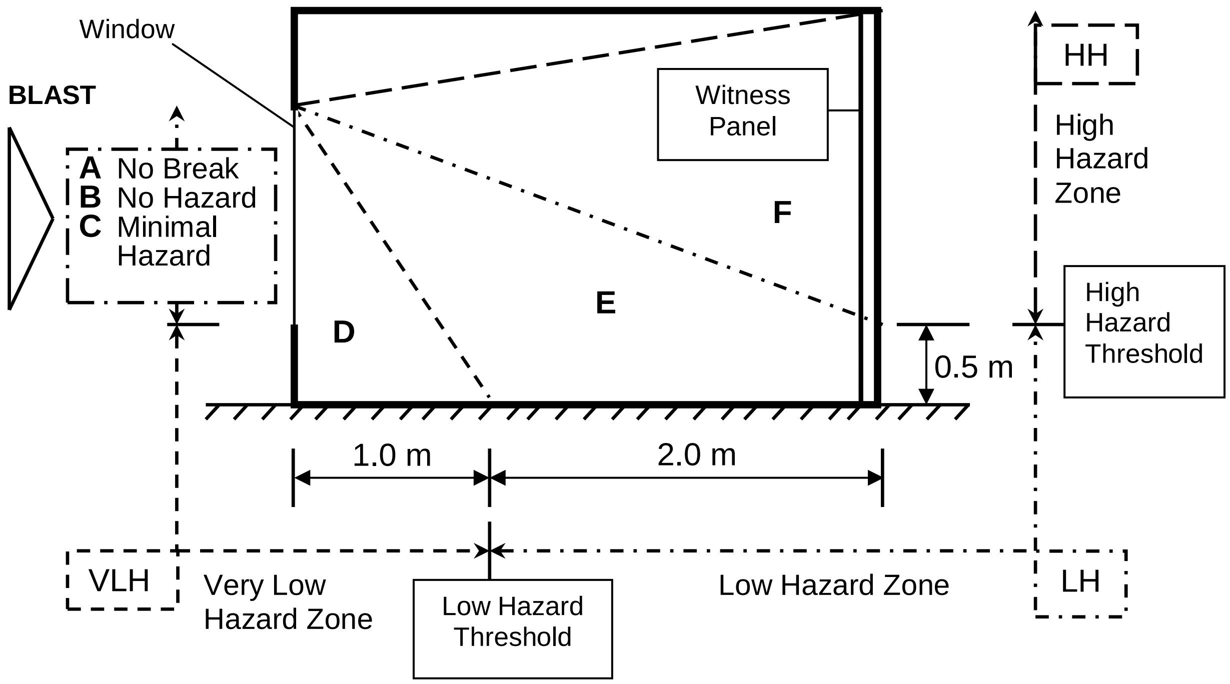


Figure 1 — Cross-section through witness area for arena test

Table 2 — Classification criteria - Vehicle bombs

Classification code[a]	Mean peak air blast pressure kPa	Mean positive phase impulse kPa-ms
EXV45(X)	30	180
EXV33(X)	50	250
EXV25(X)	80	380
EXV19(X)	140	600
EXV15(X)	250	850
EXV12(X)	450	1200
EXV10(X)	800	1600

[a] In the classification code, the first number denotes a nominal standoff distance in meters when a charge of 100 kg TNT equivalent is placed at a point perpendicular to the surface of the test specimen when mounted in a reaction structure (test cubicle) of face size about 3 m x 3 m and X denotes the hazard rating received during the test. For example Classification Code EXV25(C) would apply to a test in which a standard blast having peak air blast pressure of 80 kPa and positive phase impulse of 380 kPa-ms resulted in damage to the glazing resulting in Hazard Rating C

P1: Test Specimens 12, 13 & 14.

View of test specimens mounted in the test structure prior to test.

The identical test specimens are numbered as follows:

No 12 = left hand opening, No 13 = centre opening, No 14 = right hand opening.

P2: Free field gauges

Photo shows typical array of free field gauges set at intervals either side of the test range to confirm the side-on pressure/time reading.

P3: Gauge block

Photo shows the reinforced concrete gauge block used for measuring reflected pressure.

An additional pressure gauge was mounted on the face of the test structure between the test specimens and on the same plane as the external glass in order to measure the pressure on the face of the three identical test specimens.

2.3 Details Of The Test Specimens

P4: Wet Glazed Test Specimen.

Window test specimens were mounted into a steel test structure with reinforced concrete walls at either side to increase the front face area to 9.2m wide x 3.2m high overall.

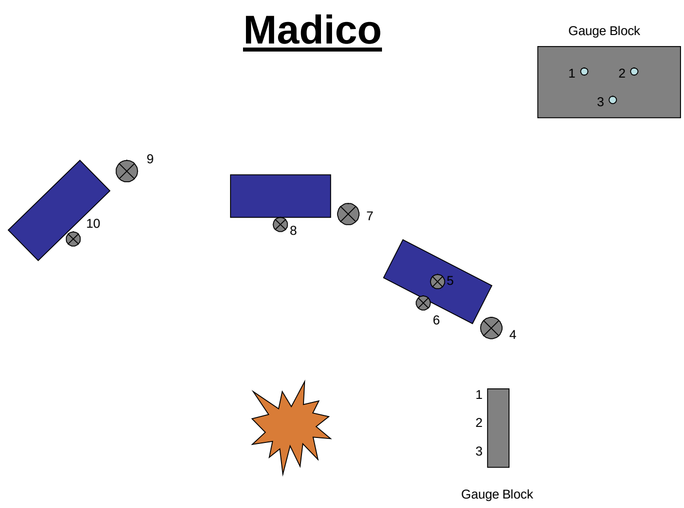
A total of ten M10 high tensile bolts were used to fix the window frame into the test cubicle opening. The rigidity of the fixing method adopted in the trials ensured that all of the blast energy was transmitted to the window filmed lite rather than absorbed through deformation of the window profile.

The plain annealed glass specification used for this test had been previously tested without safety film or attachment system and had reached hazard level F High Hazard at 33 metres from the explosive charge.

The purpose of this test was to demonstrate whether the application of safety film and the wet-glaze anchoring system would improve the performance of the glass unit under blast load EXV33.

P5: Wet Glaze detail.

View of corner detail showing wet glaze bead attaching the window film to the edge of the frame.



Gauges 4, 7 & 9 are free field type to measure incident readings

Gauges 6, 8 & 10 and 1,2 & 3 measure reflected pressure.

View of test arena showing layout of test structures and blast gauges [not to scale].

3. Results And Photographic Record Of Tests

3.1 Shot No 4: ISO 16933 EXV 33: 100kg TNT @ 33 Metres

P6: View of test cubicle post detonation of 100kg TNT at 33 metres stand-off.

All three test specimens performed the same under the blast load test. The wet-glaze attachment system retained the bond between the Madico Safety Shield 800 safety film and the edge of the frame with the external 6mm annealed float glass lite shattering and landing outside of the cubicle.

P7: View of interior of test structure.

No glass fragments were located inside the test structure and the wet-glaze attachment system in combination with Madico Safety Shield 800 safety film fully protected the interior space.

All three test specimens achieved a hazard classification B (No Hazard) in accordance with Table 1 of ISO 16933.

4. Summary of Results

The three test specimens achieved performance EXV33(B) (No Hazard) when subjected to the detonation of 100kg TNT at 33 metres standoff in accordance with ISO 16933. EXV33.

GSA equivalent to protection level 2.

Classification EXV33 required a reflected pressure value of 50 kPa (7.30psi) and reflected impulse of 250 kPa-msec (36.54 psi-msec).

Annex A includes blast plot traces which confirm the pressure and impulse values were achieved in the test.

Report concludes:

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ComBlast 2009

Date: 28/11/2009

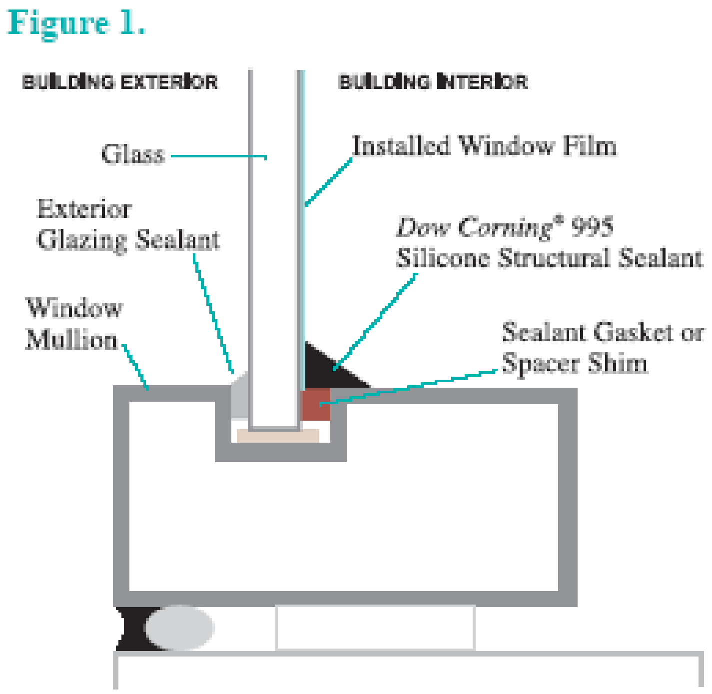
Annex A: Blast Plot

Above plot records the reflected pressure reading from the blast gauge affixed to the face of the test structure between the test specimens. The gauge recorded a peak reflected pressure reading of 54kPa. When adjusted to remove the initial low energy noise spike the reflected pressure was seen to peak at 53 kPa (7.74psi) compared to the required 50kPa (7.3psi) in ISO 16933. The measured reflected impulse loading was 288 kPa-msec (42.1psi-msec) compared to the required 250 kPa-msec (36.5psi-msec).

The captured pressure and impulse values confirmed test was conducted in accordance with ISO 16933 EXV33.

Annex B: Wet Glaze System

Figure 2. Application utilizing a triangular bead of *Dow Corning*® 995 Silicone Structural Adhesive



The Dow Corning 995 silicone bead was applied to the SS800 safety film and to the aluminium frame at height/depth of 12mm (1/2 inch) and trowel finished to a triangular bead. The original glazing tape was retained. The wet-glaze system was applied to all four sides of the vision area of the glass.