# TEST REPORT

ADVANTICA

ComBlast2005

## CPFilms

## LLumar® SCL SR MPS8 Multi-Ply Security Film Tested In Combination With FrameGard Gullwing Flexible Anchoring System

## Explosion Range Testing

## ComBlast 2005

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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 CPFilms security grade multi-ply LLumar® window film type SCL SR MPS8 tested in combination with FrameGard Gullwing flexible anchoring system as part of the ComBlast 2005 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 trials element of the Comblast tests is managed by a partnership comprising of Advantica Limited [test site provider and shot firing], D. J. Goode & Associates [Design Of Test Structures] and Grendon Design Agency [GDA] [Commercial Trials Management].

The CPFilms explosion range test was undertaken on the 13th December 2005 at the Advantica Technology test site at Spadeadam, Cumbria, England, under the supervision of Paul Cronin senior test manager for the ComBlast trials. A total of three identical test specimens were provided for explosion testing as detailed within this test report.

A short cure time of less than 2 weeks and low temperature conditions of 2°C were used so that this blast mitigation test would be a particularly severe test of the security film and anchoring system combination.

The individual test specimens were prepared by FrameGard Limited under supervision from CPFilms and installed in the test cubicle by Advantica Technology Limited at the Spadeadam test range in Cumbria, United Kingdom.

The 2-ply 230 micron LLumar® security window film used in this test program is manufactured by CPFilms and is marketed under the trade reference SCL SR MPS8.

**Validity Of Test Performance**

Three identical test specimens were subjected to the same detonation in order to provide a recognised level of performance in accordance with the draft ISO standard ISO/DIS 16933. The selection of three test specimens gives confidence in the reproducibility of the test results and is in accordance with best practice in international and national test standards.

The blast pressure and impulse loading within this test also exceeds the requirements for the US GSA 4 psi / 28 psi-msec blast test certification and therefore the test results are also scored in accordance with the US GSA classification as an indication of performance.

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

## *1.1 Details Of Test Specimens L1, C2, R3*

All three test specimens were produced in the same workshop and to the following criteria:

| | |
|---|---|
| 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 window frame |
| Clear glass area: | 1627mm x 1119m. |
| Glass: | 6mm annealed float glass with 10mm edge rebate cover into the frame all round. The glass was mounted into the frame using compression gaskets to replicate the most common form of glazing into modern window frames. |
| Window film brand name: | CPFilms LLumar® SCL SR MPS8 2 ply 230 micron security grade window film applied edge to edge of the glass leaving a 1 mm gap around the perimeter. The film did not extend into the rebate in order to replicate a common 'daylight' film application. |
| Date film applied: | 2nd December 2005 |
| Date edge retention applied: | 3rd December 2005 |
| Date of test: | 13th December 2005 |
| Edge retention system: | FrameGard Gullwing flexible anchoring system was attached to the frame and the internal film surface using proprietary double-sided adhesive tape. |
| Mounting of test specimen: | Total 6 x M10 mild steel bolts into test cubicle. |
| Test observation: | The test specimens were prepared less than two weeks before the blast testing and it should be noted that with applied window film products the adhesion curing time can extend to 4 weeks or more depending on a combination of temperature and humidity. The tests were conducted in winter and the ambient temperature at the test site was 2 degrees Celsius [two degrees above freezing, 2°C]. The test specimens were left on the test site overnight and the low temperature experienced in these tests is onerous on window film because of reduced elasticity in the material response compared with tests conducted at 20 degrees Celsius [2°C]. The short cure time plus low sample and test temperatures provide a particularly severe test of the combination of the LLumar® SCL SR MPS8 security film and FrameGard Gullwing anchoring system; this test is therefore believed to be equivalent to the harshest conditions used for blast mitigation testing of a security film with an anchoring system. |

# 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 nitro-methane based explosive liquid contained within a spherical container set at a height of 800mm above the surface of the concrete test pad. Pre-testing of the nitro-methane based explosive was undertaken by Advantica to determine the net equivalency to TNT.

**P1: Explosive charge and test arena**

The nitro-methane charge size used in these tests was selected as a direct equivalent to 100kg TNT high explosives and the equivalency was proven in extensive UK government sponsored testing. The explosive charge was supported on polystyrene packing to ensure that no fragments would be ejected from the steel plate used as the charge support.

## 2.2 Blast Pressure And Impulse Loading

The test range of 33 metres was chosen on the basis of previous government testing of daylight applied security film at 33 metres resulting in the filmed glass lite landing inside the test cubicle. The daylight filmed lite landed within 3 metres of the window opening thus establishing the Low Hazard threshold for daylight window film and providing a basis of measuring the performance of the combination of CPFilms LLumar® SCL SR MPS8 film and FrameGard Gullwing anchoring system.

All three test specimens were set in a test cubicle at the same range of 33 metres.

Table 1 summarises the average values using the Conwep [Conventional Weapons Effects Program] analytical program developed by the US Government and in use with the UK Home Office Scientific Development Branch.

**Table 1: Blast Pressure And Impulse Loading – Predicted by ConWep**

| 100kg TNT charge Shot number and range | Reflected Pressure | | Reflected Impulse | |
|---|---|---|---|---|
| | $P_{so}$ kPa | $P_{so}$ psi | kPa-msec | psi-msec |
| Shot No 1 @ 33metres | 53.3 | 7.90 | 396 | 58.6 |

The above table shows the predicted pressure and impulse loading calculated using the United States Conventional Weapons Effects Program [CONWEP] arrived at by inputting the surface area of the test cubicle and wing walls and calculating the average reflected pressure and reflected impulse across the face of the window test specimens. The CONWEP software is known to over predict the impulse values as it does not take account of clearing [pressure wave rapidly rolling over the top of a small target] and therefore blast gauges were mounted on a reflecting gauge block set at 33 metres from the charge within the same test arena to record the following side on and reflected pressures and impulses.

**Table 2: Blast Pressure And Impulse Loading – Measured On Range**

| 100kg TNT charge Shot number and range | Reflected Pressure | | Reflected Impulse | |
|---|---|---|---|---|
| | $P_{so}$ kPa | $P_{so}$ psi | kPa-msec | psi-msec |
| Shot No 1 @ 33metres | Effective peak of 57 kPa | 8.4 | 292 | 43 |

Table 2 includes the values measured over 2 separate gauges set into the face of the reinforced concrete gauge block. In addition, 2 side-on gauges standing in the free field arena measured the side on pressure as the blast wave passed by and the results indicated by the side on readings support the reflected pressure values listed above.

The equivalent US GSA test criteria require only 4 psi reflected pressure and 28 psi-msec reflected impulse. It can therefore be seen that the test specimens were subjected to considerably higher pressure [+110%] and impulse [+56%] compared to the US GSA test criteria and therefore validates the performance measured in this report against this criteria.

**P2: Free field gauges**

**P3: Gauge block**

Photos show free field gauges [P2] for measuring side-on incident pressure and the gauge block [P3] used for measuring reflected pressure on the face of test specimen.

# 3. Classification Of Performance

There is no single international standard for measuring blast performance and often individual countries have adopted their own method of classification. The leading nations in defining explosion protection are the United Kingdom and the USA. The results of these tests are therefore measured against the classifications currently in use within these two markets.

## *3.1 ISO/DIS 16933: Glass in Buildings – Explosion Resistant Security Glazing*

The International Standards Organisation ISO/DIS 16933 standard is currently in draft form and entering the final editing stage having passed the detailed technical appraisal and voting process in 2004.

The ISO/DIS 16933 standard is written for testing different glass types under blast loading. The test method calls for the glass lite to be mounted into a steel support frame with compression gaskets providing 50mm edge cover all round. ISO/DIS 16933 does not cover the entire window frame system or any methods of anchoring film into window frames but is recognised as a valid method of testing glass protection systems which can be added to improve existing windows.

The FrameGard anchoring system is designed to upgrade existing windows to offer enhanced blast protection and we have adopted ISO/DIS 16933 to determine the performance of annealed float glass when fitted with CPFilms LLumar® SCL SR MPS8 multi-ply security film and the FrameGard Gullwing flexible anchoring system.

The ISO standard contains the following classifications for defining explosion resistance of glazing. The explosive charge size equivalent is based on an infinite size façade under blast loading. The number within the classification code refers to the equivalent range for a 100kg TNT test on a smaller test structure, thus EXV33 has been calculated as equal to a 100kg TNT test at 33 metres and also comparable to a 30kg charge at 23 metres standoff on an infinite target.

**Table 3: ISO/DIS 16933: Nominal charge sizes and standoff distances for a large façade for vehicle bomb classifications**

| Classification Code | Charge Size, kg TNT Equivalent | Standoff Distance, m |
|---|---|---|
| EXV45 | 30 | 32 |
| EXV33 | 30 | 23 |
| EXV25 | 40 | 19 |
| EXV19 | 64 | 17 |
| EXV15 | 80 | 14.4 |
| EXV12 | 100 | 12.4 |
| EXV10 | 125 | 11 |

The 33 metre range within classification EXV33 of ISO/DIS 16933 is based on a 3.6m x 3.6m sized test rig with a single window contained in the centre of the reflecting surface. In this current test the test structure size was modified to contain 3 window specimens within a single test structure measuring 6.0m x 3.0m and with side walls extending the overall frontal area to 9.0 metres x 3.0 metres.

In a previous test on un-filmed annealed float glass at 33 metres from 100kg TNT the glass was driven to the rear of the test cubicle striking and impacting into the witness board as indicated in the photograph below.

**P4:** Fragments of untreated glass measuring more than 300mm in length embedded into the rear witness panel.

This photograph is reproduced in this report to provide a benchmark for performance of annealed float glass at 33 metres range from 100kg and thus allow comparison of the CPFilms and FrameGard products under similar test conditions.

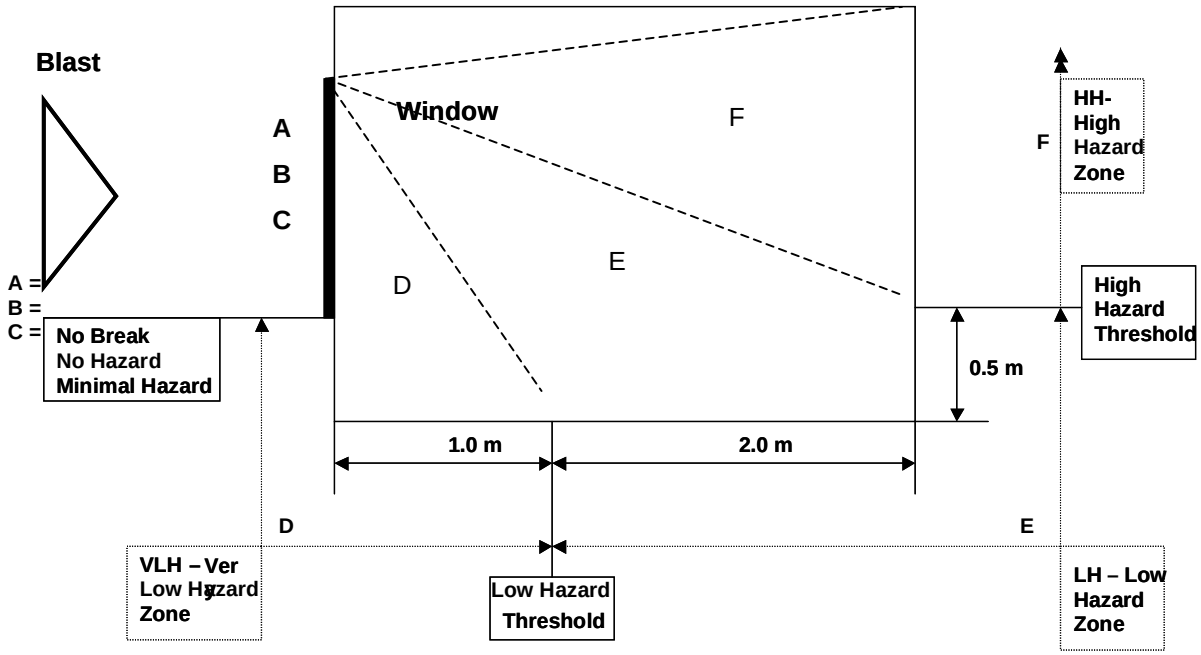
The ISO/DIS 16933 contains the following classification for measuring the performance of window specimens post blast impact.

**Table 4: ISO/DIS 16933 Hazard ratings**

| 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 is fully retained in the facility test frame or glazing system frame with no breach and no material is lost from the interior surface |
| C | | Minimal Hazard | The glazing is observed to fracture and the total length of tears in the glazing plus the total length of pullout from the edge of the frame is less than 20 percent of the glazing sight perimeter. Also, there are no more than 3 perforations or indents anywhere in the vertical 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 20% 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 is located 1m behind the original location. Also, there are no more than 3 perforations or indents anywhere in the vertical 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 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 perforations in the area of the vertical witness panel and higher than 0.5 m above the floor and none of the perforations penetrate more than 12 mm through the thickness of the foil backed insulation board layer of the witness panel as defined in paragraph 3.14 |
| F | | High Hazard | Glazing is observed to fracture and there are more than 10 perforations in the area of the vertical witness panel and 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 through the thickness of the foil backed insulation board layer of the witness panel. |

The results of the test classification are expressed in the following graphic

**Figure 1: ISO/DIS 16933 standard hazard zones.**




**Cross- Section through Witness Area**

Table 5: United States General Services Agency Method Of Classification

The following table summarises the performance criteria adopted by the US General Services Administration.

| Performance Condition | Description | Glass Fragments | | Hazard Level | Protection Level |
|---|---|---|---|---|---|
| | | Exterior to structure | Interior to structure | | |
| 1 | Glass not cracked, fully survived and/or fully retained by frame and no glass fragments either inside or outside structure. | None | None | NA | Very High |
| 2 | Glass may be cracked but is retained by the frame. | Yes | No significant fragments. Dusting or very small fragments near sill or on floor acceptable. | Very Low | Very High |
| 3a | Glass failed and not fully retained in frame. | Yes | Yes - land on floor no more than 40 inches from window | Low | High |
| 3b | Glass failed and not fully retained in frame. | Yes | Yes - land on floor no more than 10 ft from window. | Low | High |
| 4 | Glass failed and not fully retained in frame. | Yes | Yes - Land on floor more than 10 ft from window and impact a vertical surface located not more than 10 ft behind the window no higher than 2 ft above floor level. | Medium | Medium |
| 5 | Glass fails catastrophically. | Yes | Yes - land on floor more than 10 ft from window and impact a vertical surface not more than 10 ft behind window above a height of 2 ft. | High | Low |

Note: In the USA, Category C facilities require protection from window fragments up to a blast load with a peak pressure of 4 psi and an impulse of 28 psi-ms. A performance condition (Damage Level) 4 is permitted for Category C. A graphical depiction of the performance conditions contained in the criteria is shown in Figure 3.

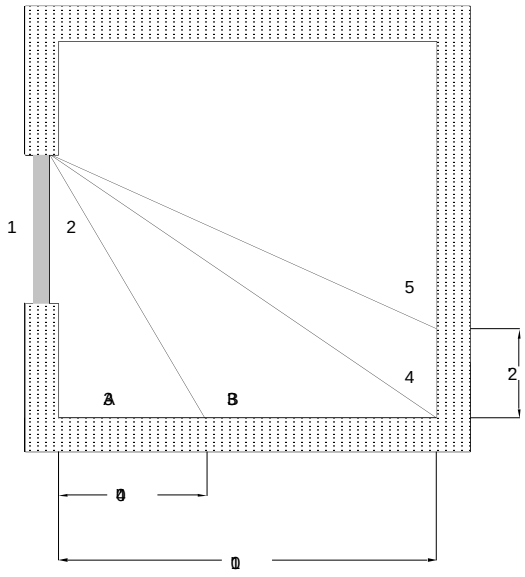



**Figure 3: US GSA Performance Zones**

Note that the High Hazard rating 5 equates to high risk of fatal injury to occupants

## *3.2 Details Of The Test Specimens*

Window test specimens were mounted into a steel test structure with reinforced concrete walls at either side to increase the front face area to 9m x 3.0m overall.

**P5: View of test structure prior to detonation**

The identical test specimens are numbered as follows:

L1 = left hand

C2 = centre

R3 = right hand

### Note on Test Conditions

The test specimens were prepared 10-11 days before the blast testing; the normal adhesion curing time for a 230 micron security film can extend to 4 weeks or more depending on a combination of temperature and humidity. The tests were conducted in winter and the ambient temperature at the test site was 2 degrees Celsius [two degrees above freezing, 2°C]. The test specimens were left on the test site overnight. The low temperature experienced in these tests is onerous on window film because of reduced elasticity in the material response and the reduced adhesion strength of pressure sensitive adhesives, especially when compared with blast mitigation tests conducted at 20 degrees Celsius [20°C]. The short cure time plus low sample and test temperatures provide a particularly severe test of the combination of the LLumar® SCL SR MPS8 security film and FrameGard Gullwing anchoring system; this test is therefore believed to be equivalent to the harshest conditions used for blast mitigation testing of a security film with an anchoring system.

**P6: Mounting Of Samples**

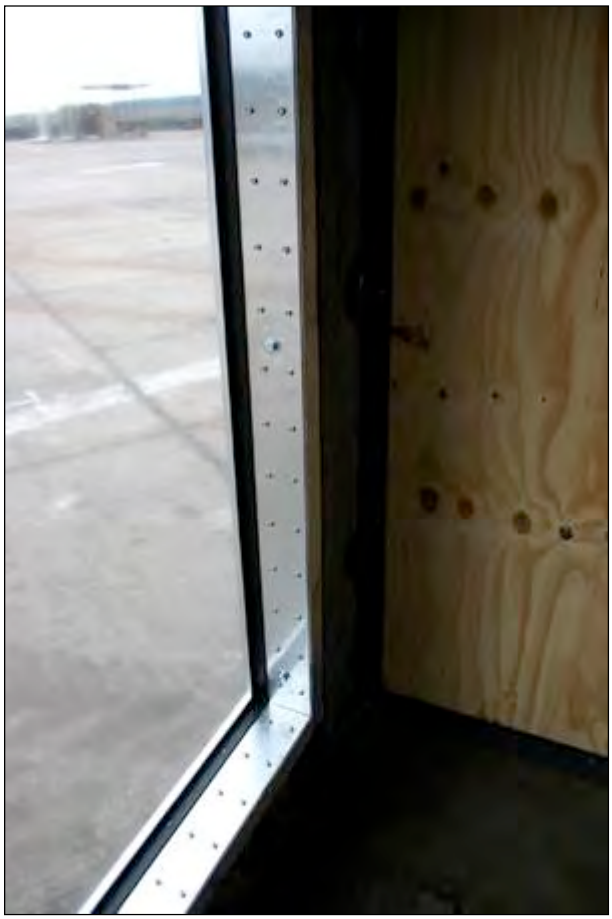


Photo shows detail of typical window test frame. The screws visible in the photo were used to attach a snap-on plate section within the aluminium profile to ensure that the plate did not become detached in the blast and impact upon the results.

A total of 6 number 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 ensures that all of the blast energy is transmitted to the window filmed lite rather than absorbed through deformation of the window frame.

The black section around the perimeter of the glass is the FrameGard Gullwing flexible anchoring system.

### 3.2.1 Security Window Film

The trials were undertaken with CPFilms LLumar® SCL SR MPS8 230 micron thickness - 2 ply security window film manufactured by CPFilms.

### 3.2.2 Disclaimer

The test results recorded within this report apply only to the items tested and any modification of either the window film material or anchoring systems used in these tests will require a separate test for validation of performance.

# 4. Results And Photographic Record Of Tests

## *4.1 Shot No 1: 100kg TNT Equivalent Charge Weight @ 33 Metres*

**P7: View of test cubicle post detonation of 100kg TNT at 31metres stand off.**

The three test specimens suffered loss of glass off the film in the negative rebound energy phase of the blast [also called suction phase] and the glass was deposited to the front of the test cubicle with fragments extending as far as 22 metres from the window opening.

Reviewing the high speed video record of the test showed that the CPFilms LLumar® SCL SR MPS8 security window film in combination with the FrameGard Gullwing flexible anchoring system survived the positive pressure phase of the explosion substantially protecting the interior of the test cubicle before the glass was drawn off the outside face of the film in the negative phase. Small amounts of glass were discovered within the centre and right-hand test cubicles where the film had torn at the perimeter and while passing through several deflection cycles allowing some glass to be cast into the interior of the test cubicle from the torn edge of the film.

### 4.1.1 Results Of Test Specimen L1

View of test specimen L1 post detonation.

**P8: External view of test specimen L1**

The test specimen lost approximately 94% of the glass from the outer surface of the film. The FrameGard Gullwing anchoring system became detached along a section of the left hand reveal measuring 380mm in overall length. The detachment of the anchoring profile allowed a small quantity of glass fragments to land inside the test cubicle. The total of the fragments weighed less than 50 grams.

The test specimen was prepared only 10-11 days before the test, allowing a short time for the LLumar® SCL SR MPS8 security film to cure, in order to provide a severe test of film + anchoring system performance. The cold temperatures on the test pad [2°C] added to the reduced curing period will in our opinion account for the loss of adhesion between the film and the glass and could also have contributed to the minor splitting of the anchoring profile.

**P9: Interior Of Test Cubicle – Left Hand window L1**

Glass fragments were discovered on the found inside the test cubicle totalling less than 50 grams and thought to originate through a small edge tear in the window film. The fragments were all within one metre from the window.

Test specimen L1 achieved the following classification:

1. Low Hazard classification in accordance with UK Home Office Scientific Development Board.
2. Classification C Minimal Hazard in accordance with draft ISO/DIS 16933 standard.
3. US GSA classification 2 although it should be noted that this classification was achieved at 8.41 psi pressure loading compared to the 4 psi GSA requirement and similarly 43 psi-msec reflected impulse load compared to 28 psi-msec GSA requirement.

### 4.1.2 Results Of Test Specimen C2

View of test specimen C2 post detonation.

**P10: View of test specimen C2 – centre window slot in test cubicle.**

The test specimen lost approximately 92% of the glass from the outer surface of the film. The film split along the top right hand [880mm] and bottom right hand [989mm] corners.

Examination of the test video showed the tearing of the window film occurred during the negative suction phase which accounts for the relatively low mass of glass landing inside the test cubicle. The FrameGard Gullwing anchoring system remained attached to the window frame.

The test specimen was prepared only 10-11 days before the test, allowing only a short time for the LLumar® SCL SR MPS8 security film to cure, in order to provide a severe test of film + anchoring system performance. The cold temperatures on the test pad [2°C] added to the reduced curing period will in our opinion account for the loss of adhesion between the film and the glass and could also have contributed to the minor splitting of the anchoring profile.

**P11: Interior of centre test cubicle**

The glass scatter was primarily within the 3A Zone i.e. within one metre of the window sill.

The total glass mass discovered inside the test cubicle was as follows:

196 grams in Zone 3A and 52 grams in Zone 3B.

Test specimen C2 achieved the following classification:

1. Low Hazard classification in accordance with UK Home Office Scientific Development Branch.
2. Classification D Very Low Hazard in accordance with ISO/DIS 16933 draft standard.
3. US GSA classification 3B although it should be noted that this classification was achieved at 8.52 psi and 45.13 psi-msec which exceeds the 4 psi and 28 psi-msec requirement of the GSA test.

### 4.1.3 Results Of Test Specimen R3

View of test specimen R3 post detonation.

**P12: External view of test specimen R3 post test.**

The FrameGard Gullwing anchoring system became detached along the left hand edge [in photo] and the window film split diagonally across over a length of 970mm at the position indicated by the arrows.

Examination of the test video showed the tearing of the window film occurred primarily within the negative suction phase with the window film and anchoring thereafter going through several deflection cycles before coming to rest. Glass was ejected into the interior of the test cubicle through the opening made by the splitting of the Gullwing anchoring and the film.

The test specimen was prepared only 10-11 days before the test, allowing only a short time for the LLumar® SCL SR MPS8 security film to cure, in order to provide a severe test of film + anchoring system performance. The cold temperatures on the test pad [2°C] added to the reduced curing period will in our opinion account for the loss of adhesion between the film and the glass and could also have contributed to the minor splitting of the anchoring profile.

**P13: Interior of test cubicle specimen R3.**

The glass scatter was spread throughout zones 3A and 3B. The total glass mass discovered inside the test cubicle was as follows:

98 grams in Zone 3A and 166 grams in Zone 3B with 3 small fragments [< 10g] in the witness panel 230mm above the floor level.

Test specimen R3 achieved the following classification:

1. Low Hazard classification in accordance with UK Home office Scientific Development Branch.
2. Classification D Very Low Hazard in accordance with ISO/DIS 16933 draft standard.
3. US GSA classification 3B although it should be noted that this classification was achieved at 8.52 psi and 45.13 psi-msec which exceeds the 4 psi and 28 psi-msec requirement of the GSA test.

# 5. Summary Of Results

All three test specimens showed a significant increase in performance compared to a daylight application of security film without edge anchoring.

The test results were probably influenced detrimentally by the fact that the window film curing period was 11-12 days compared to a normal full cure period of 28 days or more. In particular, the glass loss from the outer face of the film can be accounted for by the reduced curing time and evidence of the adhesive bond between the film and the glass being moist when inspected post impact.

The test conditions of 2 degrees Celsius [2°C] ambient temperature can also influence the test because polyester film stock loses some elasticity and pressure sensitive adhesive reduces in adhesion strength at lower temperatures.

Reviewing the high speed test video record of the trials showed that the CPFilms LLumar® SCL SR MPS8 film in combination with the FrameGard Gullwing anchoring system survived the positive pressure phase of the explosion protecting the interior of the test cubicle before the glass was ejected from the front face during the negative phase.

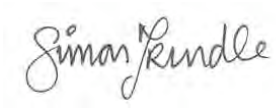
The test specimens achieved the following classifications:

1. Low Hazard classification in accordance with UK Home Office Scientific Development Branch.
2. Classification C Minimal Hazard in accordance with ISO/DIS 16933 draft standard.
3. US GSA classification 3A was achieved by one of the three test specimens and classification 3B by the remaining two specimens although it should be noted that this classification was achieved at 8.52 psi and 45.13 psi-msec which exceeds the 4 psi and 28 psi-msec requirement of the GSA test.

The CPFilms LLumar® SCL SR MPS8 window film in combination with the FrameGard Gullwing anchoring system successfully reduced the hazard from unprotected annealed glass at 33 metres from 100 kg TNT from High Hazard and High Risk of fatal injury to Minimal or Low Hazard and very low risk of injury.

**Report concludes:**

Author:



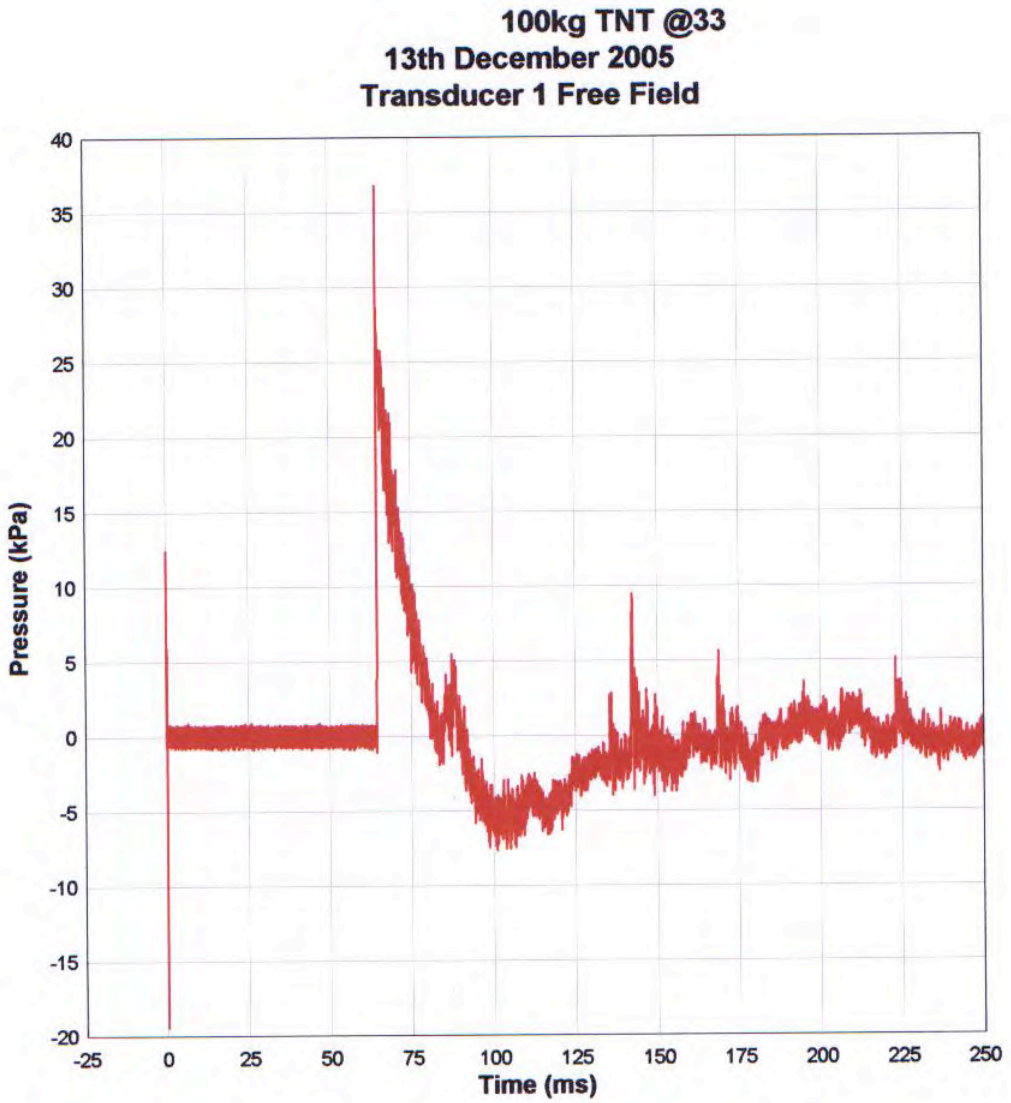
Simon Trundle:

Commercial Trials manager

ComBlast 2005

Date: 20/12/2005

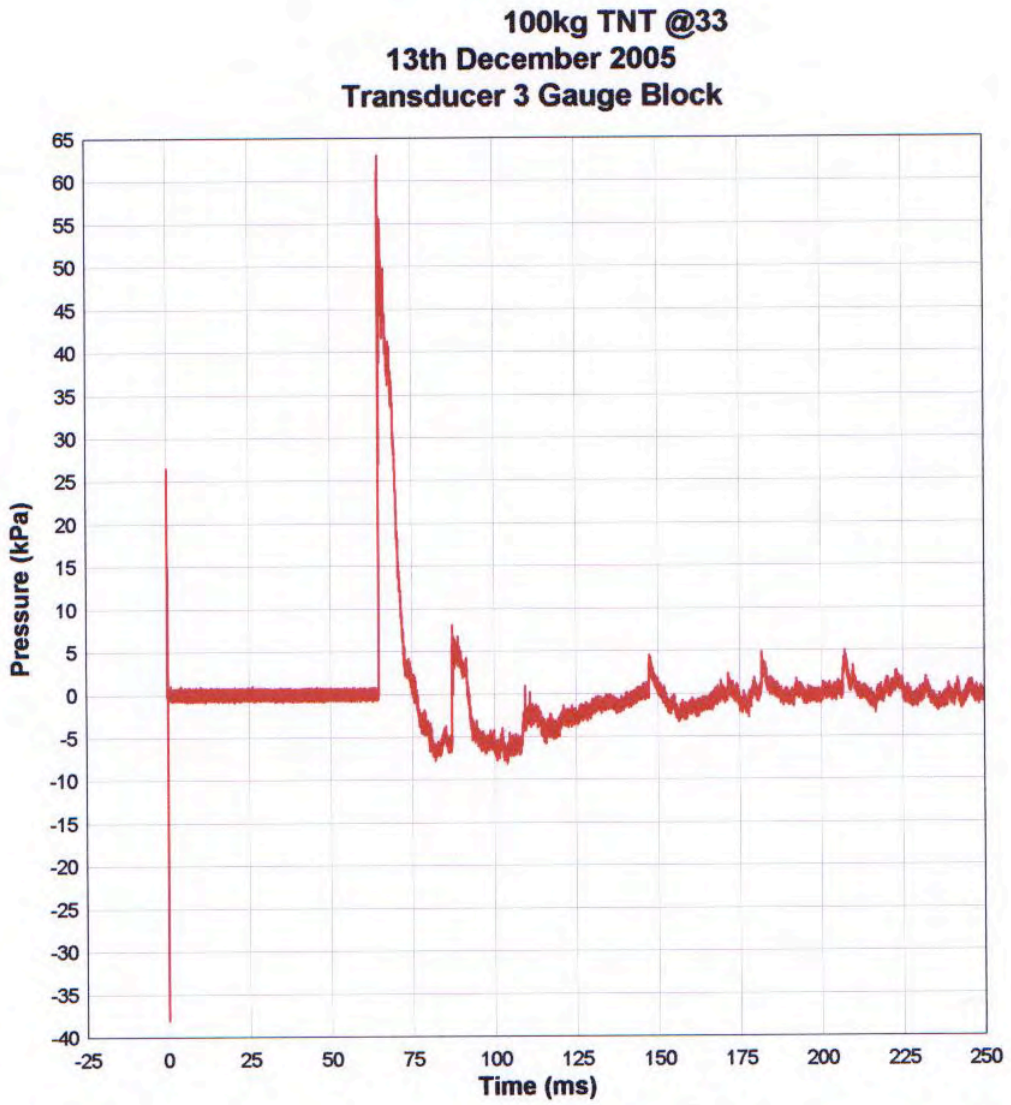
## *Annex A: Blast Plot*




Plot #1: Transducer measurement in free field [side-on] configuration for CPFilms test on 13th December 2005.

The graph indicates a peak side-on pressure of 37kPa; however, interpretation of the graph provides a reading of 26 kPa for side-on pressure after adjusting for 'noise' spike which has minimal energy.

Reflected pressure is predicted as twice the side-on pressure and impulse reading.




Plot #2: Transducer measurement in reflected gauge block set at 33 metres from charge in CPFilms test on 13th December 2005.

The graph indicates a peak pressure of 63 kPa, however, interpretation of the graph provides a true reading of 57 kPa for reflected pressure and 292 kPa-msec for reflected impulse after adjusting for 'noise' spike which has minimal energy.