Report
3M: Anchored Safety Film Blast Tests

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Executive Summary

Blast testing of anchored film glazing systems, under supervision of TPS, was undertaken at the Spadeadam Test Facility, MoD R5, Spadeadam, Gilsand, Cumbria CA36 7AT, England by Avantica Technologies Limited from the 13th to the 20th September 2007.

Glazing systems tested consisted of combinations of glazing, film type and anchoring mechanisms.

The object of the tests was to assess and compare the bomb blast resistance of a selection of systems to the International Organisation for Standards (ISO/FDIS 16933), US General Services Administration (GSA-TS01-2003) and ASTM F 1642-04[1] (Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings). In particular, the hazard ratings and confidence levels for the ISO EXV 25, ISO EXV 33, ISO EXV 45 and GSA C standards. Each sample was tested using a single bomb blast. Note: to achieve full compliance with GSA-TS01-2003, each sample would need to be tested 3 times.

The glazing systems were mounted three in each test structure, with two test structures per test. 6 tests were undertaken with 33 window systems tested in total. Each test structure contained an internal pressure transducer and, for the majority of the tests, a high speed video camera.

3 pressure transducers were mounted on an external gauge block to measure the reflected pressure from the blast and calculate the blast loads on the test samples. 3 Free field transducers were mounted in aerodynamic casings and used to measure the free field pressure used to assess the explosive strength of the blast.

The table on the following page summarises the windows tested and the results of the tests.

The systems tested provide a good sample for comparing different anchoring methods and film types and assessing the bomb blast protection capabilities. This information could be used to decide on which systems would undergo further tests to provide consistency in the results and confidence in the protection afforded by the anchored safety film.

[1] Note: The Witness Panel used in the tests differs from the one specified by ASTM F 1642-04, clause 8.7.5.

3M: Anchored Safety Film Blast Tests

Test	Location	Target Description	Blast Loading		%Difference to Test Standard		Rating Awarded	
			Pressure (PSI)	Impulse (PSI.mS)	Pressure	Impulse	GSA	ISO
Test 1 ISO EXV25	1A	Mono SH8CLARL DOW 995	14.1	68.6	21.6%	24.5%	5	High Hazard
	1B	IG Ultra600 +3M Caulk	14.1	70.8	21.6%	28.5%	2	Minimal Hazard
	1C	IG SH8CLARL DOW 995	14.1	68.6	21.6%	24.5%	5	Low Hazard
	2A	Mono SH14CLARL 3M Profile	14.1	68.6	21.6%	24.5%	5	Low Hazard
	2B	Mono SH14CLARL 3M Caulk	14.1	70.8	21.6%	28.5%	5	Low Hazard
	2C	IG SH7CLARL 3M Caulk	14.1	68.6	21.6%	24.5%	4	Low Hazard
Test 2 ISO EXV25	1A	IG SH14CLARL DOW 995	12.3	66.3	6.0%	20.3%	3b	Low Hazard
	1B	IG SH14CLARL DOW 995	12.3	68.5	6.0%	24.3%	3b	Low Hazard
	1C	IG SH8CLARL 3M Caulk	12.3	66.3	6.0%	20.3%	2	Minimal Hazard
	2A	none	12.3	66.3	6.0%	20.3%	n/a	n/a
	2B	none	12.3	68.5	6.0%	24.3%	n/a	n/a
	2C	none	12.3	66.3	6.0%	20.3%	n/a	n/a
Test 3 ISO EXV33	1A	Mono SH7CLARL 3M Caulk	8.4	44.3	15.1%	22.0%	5	Low Hazard
	1B	Mono Ultra Prestige PRS50 3M Caulk	8.4	46.5	15.1%	28.1%	3b	Very Low Hazard
	1C	Mono SH14CLARL Profile	8.4	44.3	15.1%	22.0%	3b	Very Low Hazard
	2A	IG Ultra Prestige PRS50 DOW 995	8.4	44.3	15.1%	22.0%	2	Minimal Hazard
	2B	Mono Ultra600 3M Caulk	8.4	46.5	15.1%	28.1%	3b	Low Hazard
	2C	Mono SH8CLARL 3M Caulk	8.4	44.3	15.1%	22.0%	2	Minimal Hazard
Test 4 ISO EXV33	1A	Mono SH7CLARL 3M Caulk	8	42.1	9.6%	16.0%	5	Low Hazard
	1B	Mono Ultra Prestige PRS50 3M Caulk	8	44.1	9.6%	21.5%	5	Low Hazard
	1C	Mono SH8CLARL 3M Caulk	8	42.1	9.6%	16.0%	3b	Low Hazard
	2A	Mono Ultra600 DOW 995	8	42.1	9.6%	16.0%	3b	Very Low Hazard
	2B	Mono Ultra Prestige PRS50 Profile	8	44.1	9.6%	21.5%	3b	Low Hazard
	2C	Mono Ultra Prestige PRS50 DOW 995	8	42.1	9.6%	16.0%	5	Low Hazard
Test 5 ISO EXV33	1A	Mono SH8CLARL Profile	7.7	41.2	5.5%	13.5%	3b	Low Hazard
	1B	Mono Ultra Prestige PRS50 DOW 995	7.7	43.5	5.5%	19.8%	3b	Low Hazard
	1C	IG Ultra Prestige PRS50 DOW 995	7.7	41.2	5.5%	13.5%	2	Minimal Hazard
	2A	Mono SH8 CLARL 3M Caulk	7.7	41.2	5.5%	13.5%	3b	Low Hazard
	2B	Mono SH7 CLARL 3M Caulk	7.7	43.5	5.5%	19.8%	5	High Hazard
	2C	IG Ultra Prestige PRS50 DOW 995	7.7	41.2	5.5%	13.5%	2	No Hazard
Test 6 GSA C	1A	IG Ultra600 Daylite	4.2	29.0	5.0%	3.6%	3b	Low Hazard
	1B	Mono SCLARL400 3M Caulk	4.2	29.4	5.0%	5.0%	2	Minimal Hazard
	1C	IG Ultra600 Daylite	4.2	29.0	5.0%	3.6%	3b	Low Hazard
	2A	Mono SCLARL400 3M Caulk (2 side)	4.2	29.0	5.0%	3.6%	3b	Low Hazard
	2B	Mono SH7CLARL 3M Caulk	4.2	29.4	5.0%	5.0%	3b	Low Hazard
	2C	IG Ultra600 Daylite	4.2	29.0	5.0%	3.6%	3b	Low Hazard

Contents

1 Introduction

1.1 GENERAL

Blast testing of anchored film glazing systems, under supervision of TPS, was undertaken at the Spadeadam Test Facility, MoD R5, Spadeadam, Gilsand, Cumbria, England by Avantica Technologies Limited from the 13th to the 20th September 2007.

Glazing systems tested consisted of combinations of glazing, film type and anchoring mechanisms.

The object of the tests was to assess and compare the bomb blast resistance of a selection of systems to the International Organisation for Standards (ISO/FDIS 16933), US General Services Administration (GSA-TS01-2003) and ASTM F 1642-04[2] (Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings). In particular, the hazard ratings and confidence levels for the ISO EXV 25, ISO EXV 33, ISO EXV 45 and GSA C standards. Each sample was tested using a single bomb blast. Note: to achieve full compliance with GSA-TS01-2003, each sample would need to be tested 3 times.

[2] Note: The Witness Panel used in the tests differs from the one specified by ASTM F 1642-04, clause 8.7.5.

2 Description of damage and injury categories

2.1 BLAST PHENOMENA

Blast effects of an explosion are in the form of a shock wave composed of a high-intensity shock front, which expands outwards from the surface of the explosion into the surrounding air. As the shock front expands into increasingly larger volumes, the peak incident pressure at the front decreases and the duration of the pressure increases.

2.2 EXTERNAL EXPLOSIONS

The magnitude and distribution of the blast loads on a structure arising from the previously described blast pressures are a function of the following factors:

- Explosive properties, explosive type, energy output and quantity of explosives.
- The location of the explosion relative to the structure. This is termed the “stand-off range (SOR)” or “set back” in US parlance.
- The magnitude and reinforcement of the pressure at the shock front by its interaction with the ground and the structure.

2.3 BOMB BLAST EFFECTS ON GLAZING

The majority of injuries sustained following a terrorist bomb blast are from projected glass fragments. The extent of the injury to persons within the building from the debris and fragment impact will depend on their velocity, mass and shape as well as the location on the body that the impacts occur.

Injury to persons from debris/fragment impact is usually divided into two categories, the first involves penetration and wounding by small objects, and the other involves non-penetrating injury, or blunt trauma caused by a victim striking or being struck by a non-piercing object. Objects causing projectile induced blunt trauma are characterised by their low velocity, lack of cutting and piercing features and large size.

2.4 HUMAN TOLERANCE TO AN EXPLOSION

2.4.1 Tolerance to blast pressures

Human tolerance to the blast output of an explosion is relatively high. The orientation of the person and the shape of the pressure front are significant factors in determining the injuries sustained. Tests have indicated that human tolerance to short duration blast loads is significantly higher than for longer duration blast loads. The air containing

tissues of the lungs are the critical organs in blast pressure injuries. The release of air bubbles from alveoli of the lungs into the vascular system accounts for most deaths.

The magnitude of the pressure to which a person is subjected will depend on the orientation of the body relative to the blast wave, and the proximity of reflecting surfaces such as walls and floors.

Eardrum rupture, although not generally lethal, occurs at lower pressure levels than lung damage injuries. Human tolerance to this type of injury varies with the magnitude of the shock pressure as well as duration. Temporary hearing loss will occur at pressure levels lower than the threshold of eardrum rupture.

3 Explosives Used in Test

3.1 GENERAL

The explosive for each test comprised of Nitro Methane housed in a spherical plastic container. Initiation was by an L2A1 electric detonator embedded in a small quantity of PE4 (plastic explosive) booster charge placed within the centre of the plastic container. The total quantity of explosives was equivalent to 100kg of TNT.

The explosive was located 1 m above the floor level stacked upon light foam blocks.

Figure 1: Typical test charge arrangement

4 Stand-Off Range

4.1 GENERAL

Calculations were undertaken by TPS in order to determine the stand-off range required to produce the correct Mean Peak Pressure and Positive Phase Impulse for each test standard.

A Computational Fluid Dynamics (CFD) program was used to calculate the stand-off range required to produce the blast load requirements stipulated in each of the GSA and ISO standard tests.

The use of CFD, as opposed to Conwep (a program that relies on empirical data from blast trials to calculate blast loads, given the charge weight and range, on an infinite facade), is necessary due to the effects of blast wave clearing around the cubicle, hence reducing the blast load on the test target. To counter this effect, the charge is moved closer than the range suggested by Conwep. It should also be noted that the range suggested by the ISO standard is for a cubicle with a 3 m wide by 3 m high front face. The cubicle used in the following tests has a front face with greater surface area (9.8m wide by 3.2 m high) and therefore will receive greater blast loads. This suggests that the cubicle should be moved further back than the range suggested by the ISO standard but less than the range suggested by Conwep.

5 Glazing Systems

5.1 GENERAL

A range of glazing systems was tested with different combinations of film, anchoring systems and glazing types. The following glazing systems were tested:

Glazing	Film	Anchoring Method	Standards Tested
Mono	SCARL400	3M caulk	GSA C (x2)
Mono	SH7CLARL	3M caulk	ISO EXV33 (x3), GSA C (x1)
Mono	SH8CLARL	3M caulk	ISO EXV33 (x3)
Mono	SH8CLARL	3M Profile	ISO EXV33 (x1)
Mono	SH8CLARL	Dow 995 caulk	ISO EXV25 (x1)
Mono	SH14CLARL	3M caulk	ISO EXV25 (x1)
Mono	SH14CLARL	3M Profile	ISO EXV25 (x1), ISO EXV33 (x1)
Mono	ULTRA600	3M caulk	ISO EXV25 (x1)
Mono	ULTRA600	Dow 995 caulk	ISO EXV33 (x1)
Mono	Ultra Prestige PRS50	3M caulk	ISO EXV33 (x2)
Mono	Ultra Prestige PRS50	3M Profile	ISO EXV33 (x1)
Mono	Ultra Prestige PRS50	Dow 995 caulk	ISO EXV33 (x2)
IG	SH7CLARL	3M caulk	ISO EXV25 (x1)
IG	SH8CLARL	3M caulk	ISO EXV25 (x1)
IG	SH8CLARL	Dow 995 caulk	ISO EXV25 (x1)
IG	SH14CLARL	Dow 995 caulk	ISO EXV25 (x2)
IG	ULTRA600	3M caulk	ISO EXV25 (x1)
IG	ULTRA600	Daylite	GSA C (x3)
IG	UPR400	Dow 995 caulk	ISO EXV33 (x3)

Figure 2: Table of glazing systems tested

5.2 FRAME

Each glazing unit was mounted into an aluminium frame with a standard 15 mm rebate and fitted with rubber inner and outer gaskets.

5.2.1 Fixings

The aluminium frame was fixed to the test structure with bolts at 300 mm centres on the outer face and screws at 300 mm centres on the inner face. (see figure 3).

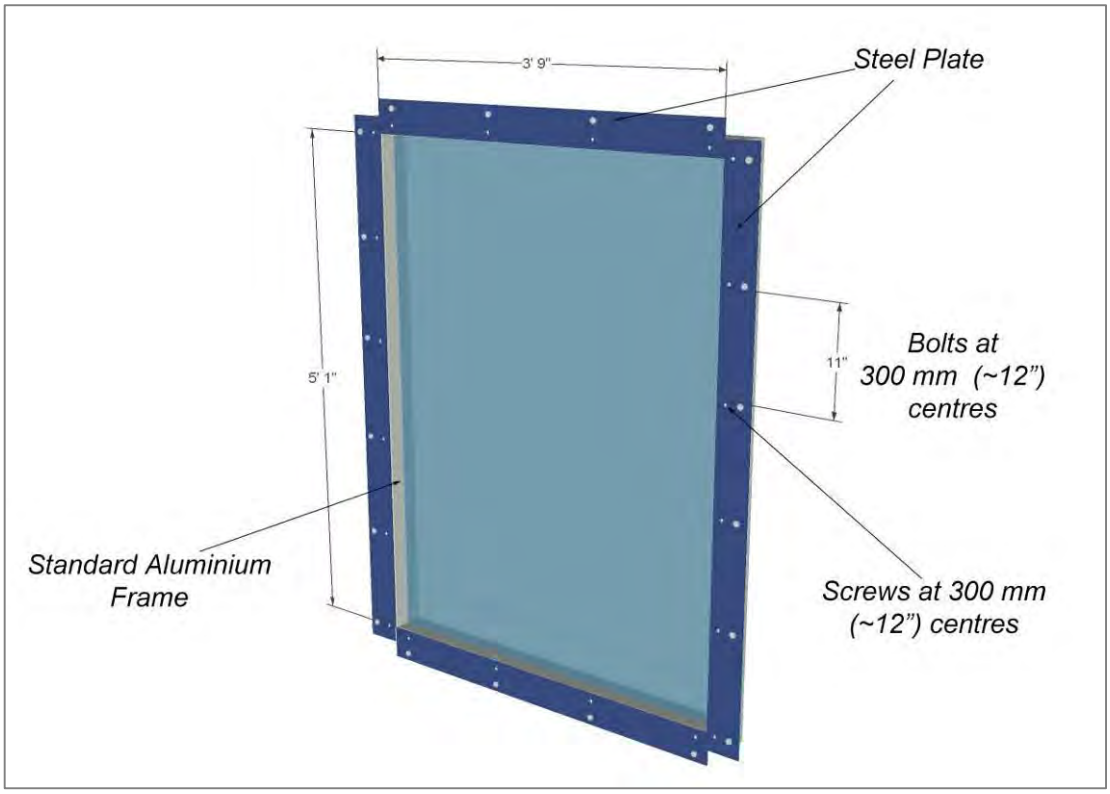


Figure 3: Fixings used in 3M blast tests

5.3 ANCHORING SYSTEMS

The following anchoring Systems were tested:

- DOW 995 caulk
- 3M caulk
- 3M Adhesive Profile
- Daylite Film (No anchor)

5.3.1 Caulk

When used, 12.7 mm (½“) of structural silicone (caulk) was applied on the inside face of the glazing. The caulk type could be easily identified by the colour; DOW 995 was black and 3M caulk was white.

5.3.2 Retrofitted Adhesive Profile

A rubber adhesive profile applied to the inside face of the glazing. ½” adhesive was applied to the frame and 5/8” was applied to the film.

5.3.3 Daylite

Daylite attachment of film to glazing system indicates that no anchoring mechanism is used, i.e. no direct securing of the film to the window frame. The film is applied only the visible window area outside of the rebate.

6 Test Procedures, Equipment and Instrumentation

6.1 LAYOUT

Figures 4 to 6 show the layout of the test site for each of the tests. Two test structures were used in each test, with three glazing systems mounted in each.

It should be noted that in shot 6 the concrete block adjacent the test structures were rotated backwards to reduce the area of the front face and hence the impulse seen by the test samples.

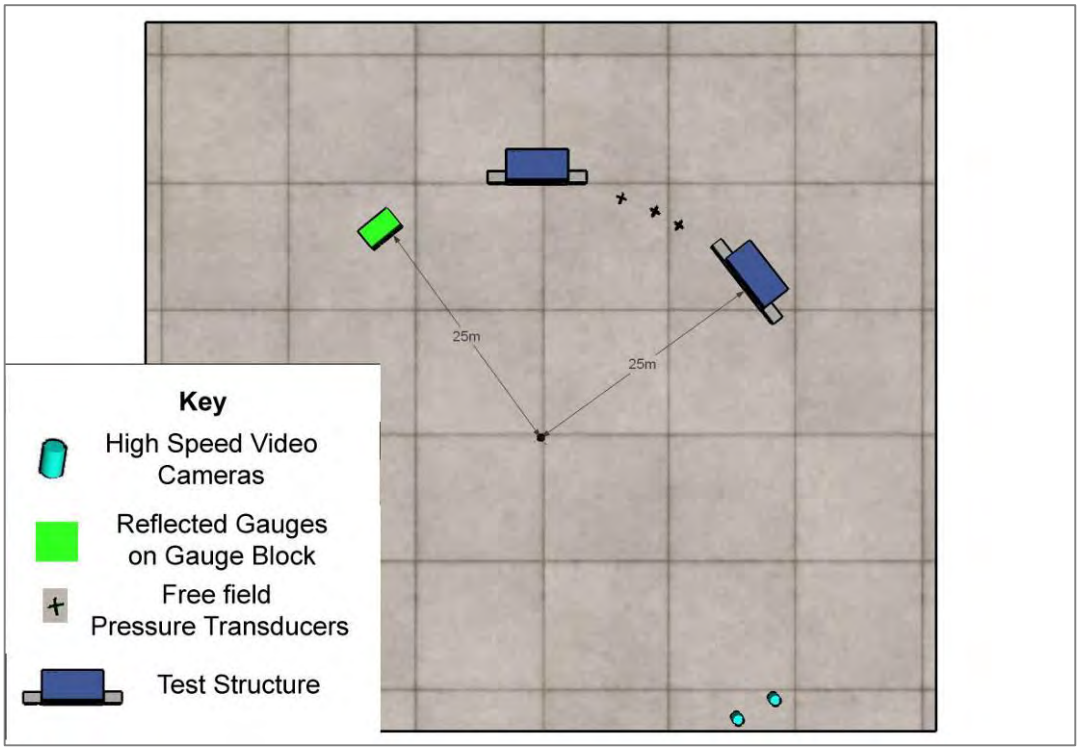


Figure 4: Layout for shots 1 and 2

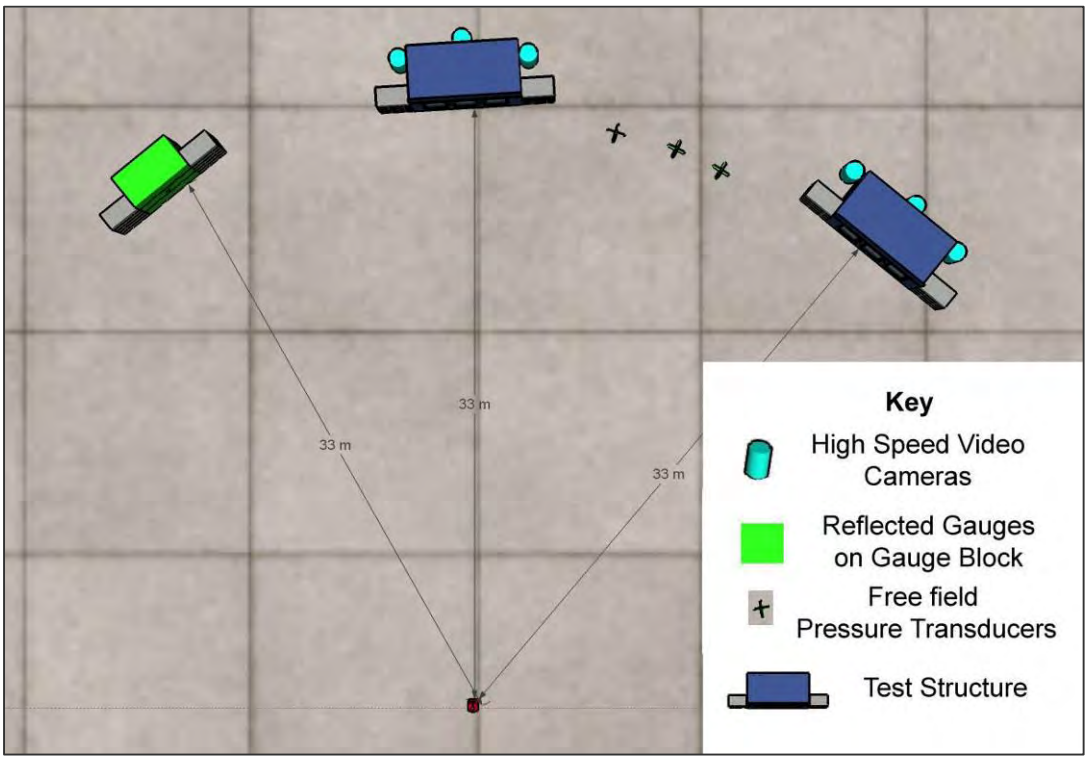


Figure 5: Layout for shots 3, 4 and 5

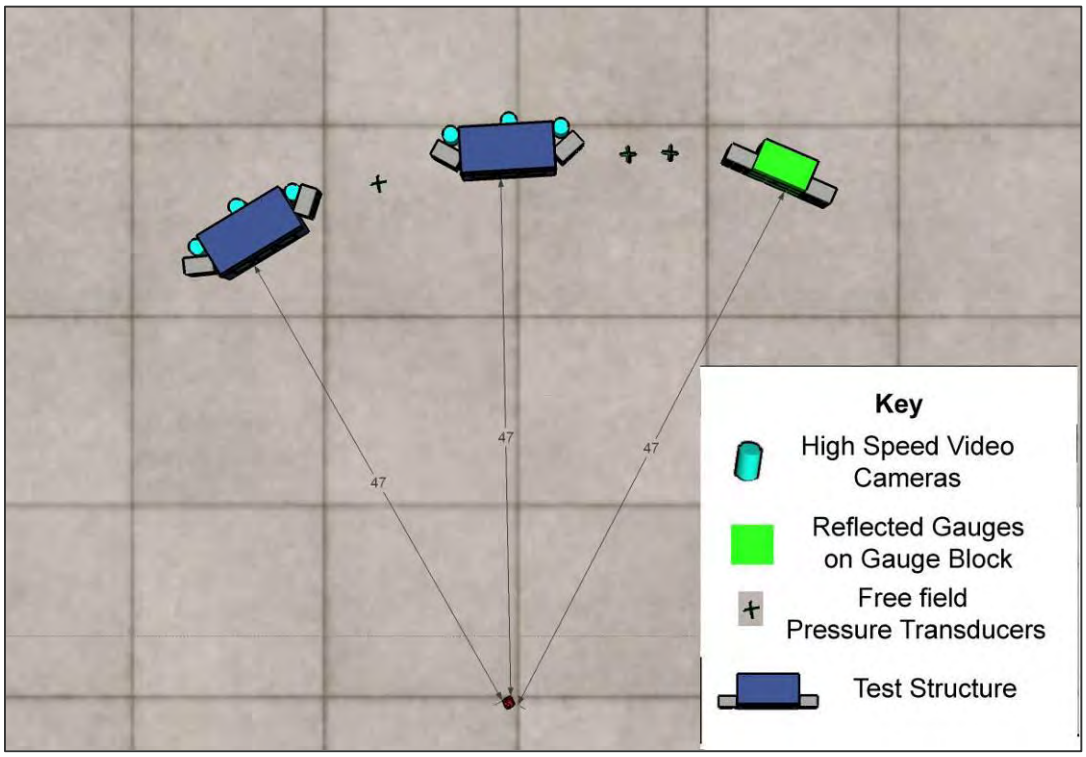


Figure 6: Layout for shot 6

6.2 TEST STRUCTURE

The test structure consisted of a standard ISO container with three openings cut out of one of the longer sides into which the windows were mounted. The walls of the structure were internally braced with steel sections in order to ensure the test structure remained unreactive during the test load. Wooden board partitions were used to isolate each test specimen and stop cross contamination of test results for glazing fragments and internal overpressure readings.

Concrete blocks were stacked on either side of the structure and a steel plate bolted to the top of the front face to reduce the clearing effect of the blast load around the structure and hence equalise the loads seen by each test glazing system.

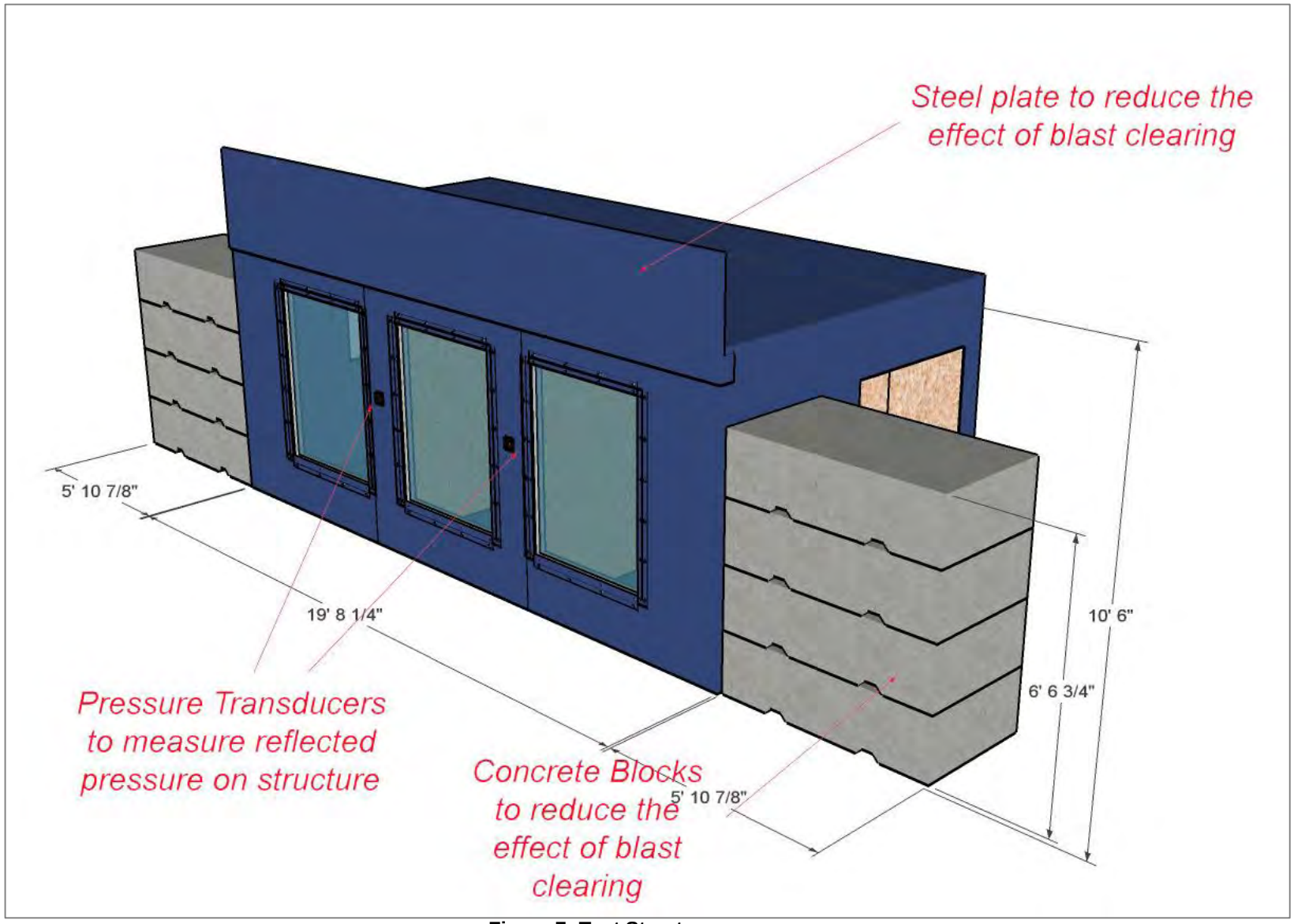


Figure 7: Test Structure

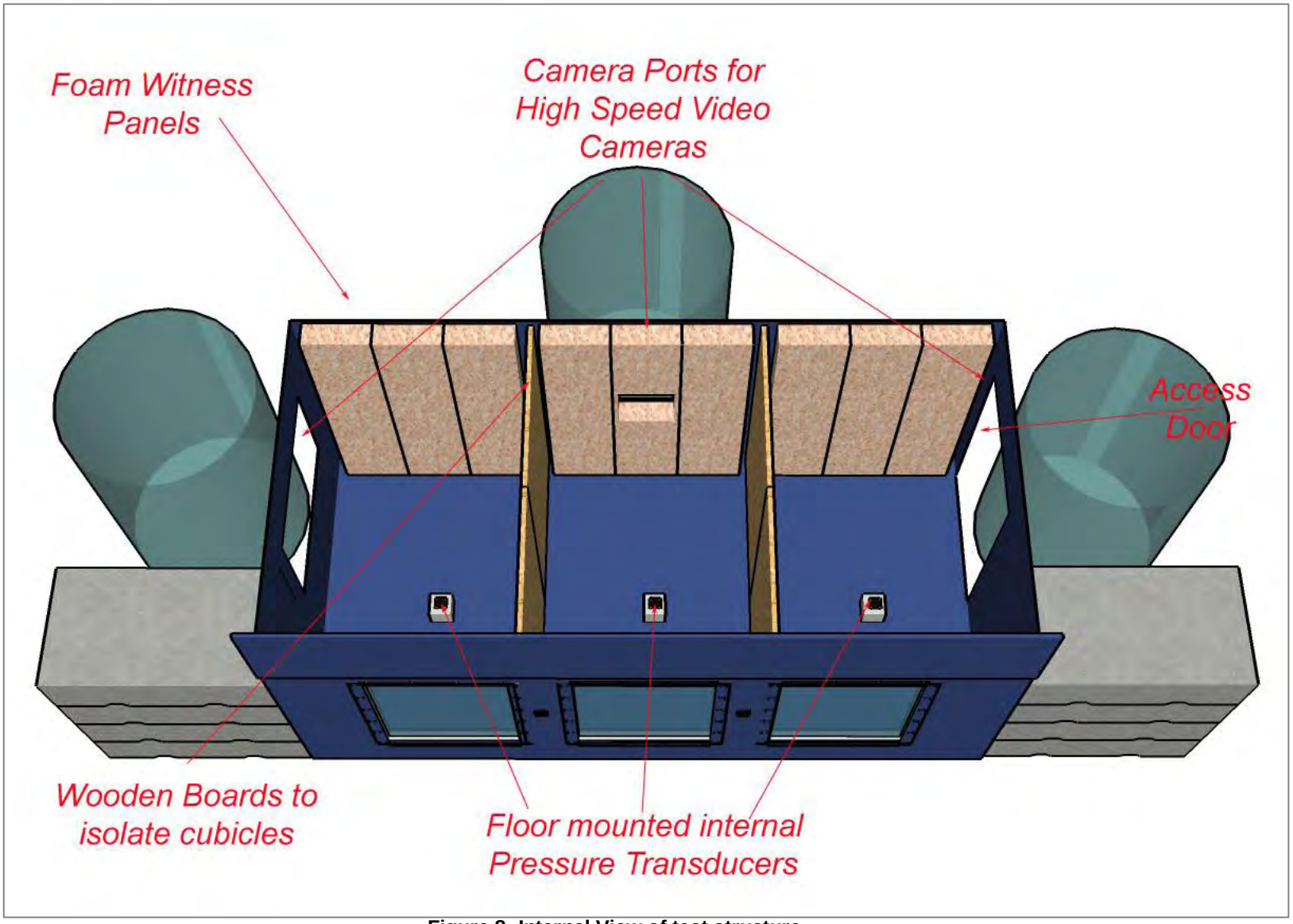


Figure 8: Internal View of test structure

6.3 INSTRUMENTATION

6.3.1 Pressure Transducers

PcB type M102 Pressure transducers with built in amplifiers were used to measure the following information:

1. Three Free Field overpressure measurements were taken using pressure transducers mounted in aerodynamic housings located at the same range as the test structures. (see figure 9 below)
2. Three Reflected overpressure measurements were recorded using transducers mounted on the front face of a concrete block located at the same stand off range as the test structures (See figure 10 Below).
3. Six Internal overpressure measurements were taken (one for each glazing system) using floor mounted pressure transducers located in the floor of each test cubicle.
4. Reflected overpressure measurements on the test structure were taken using pressure gauges mounted to the front face of the structure either side of the central window bay.

The locations of transducers stated in 3 and 4 can been seen in figure 8 on page 18. The location of transducers in 1 and 2 varies with each test and can be seen in the test layouts in figures 4 to 6.

Figure 9: Free Field pressure transducer in aerodynamic housing

Figure 10: Reflected Pressure Transducers on gauge block

6.4 PHOTOGRAPHY

6.4.1 High Speed Video

For the first two tests, high speed video cameras were located opposite the test structures in order to get two external views; one for each test structure. In all tests following test 2, high speed cameras were mounted adjacent to each test structure in order to record internal views of each test system.

6.4.2 Photographs

Still photographs were taken before and after each test to record the state of the tested windows, films and anchors.

7 Pass/Fail Criteria

7.1 GENERAL

The Following tests were conducted during the course of the trials:

- ISO EXV25
- ISO EXV33
- ISO EXV45
- GSA C

The required peak reflected pressure and positive reflective impulse for these tests are shown in the table below. Imperial units are shown in brackets.

Test	Peak Pressure kPa (PSI)	Positive Phase Impulse kPa.mSecs (PSI.mSec)
ISO EXV25	80 (11.6)	380 (55.1)
ISO EXV33	50 (7.3)	250 (36.3)
ISO EXV45	30 (4.4)	180 (26.1)
GSA C	27.6 (4.0)	193 (28.0)

Figure 11: Table of standards and associated pressure and impulse values

For each test the hazard rating for the glazing system was assessed using the criteria detailed in the relevant test standards. This required study of damage to the window frame, film, anchoring system and glazing. The criteria also require the assessment of fragments produced by the failure of the glazing and how far these travel into the test cubicle. Details of the test criteria for both standards can be found in the appended documents.

7.2 HAZARD LEVELS

Each of the test standards classifies the performance of the glazing system with ratings related to hazard levels created under testing.

7.2.1 ISO Standard Hazard Levels

The ISO standard defines three main hazard levels which are described in the following sections.

7.2.1.1 Superficial Hazard

This is defined as the level of hazard where glass debris would fall at low velocity within a 1m zone of the window. Unless immediately adjacent to the window, only superficial cuts would be expected to persons in areas behind the glazing.

7.2.1.2 Low Hazard

This is defined as the level of hazard where glass debris would be projected into a room for a distance of not more than 3m (~3'3") and not exceeding 0.5m (~1'8") above the floor at this distance. Injuries would be limited to low body cuts, and fatalities would not be expected, although persons close to the window could be seriously injured.

7.2.1.3 High Hazard

This is defined as the level of hazard where glass debris would be projected further into the room than 3m (~3'3"), and above 0.5m (~1'8") high at 3m (~3'3") into the room. Serious injuries including cuts to the upper body and face, and fatalities could occur.

These glazing classifications are shown in Figure 12 below.

7.2.2 GSA Standard Hazard Levels

In the United States, General Services Administration (GSA) performance standards for glazing subject to dynamic overpressure loading (i.e. bomb blast) have been established.

These can be compared against the ISO standard levels and Figure 13 on the following page details the comparisons.

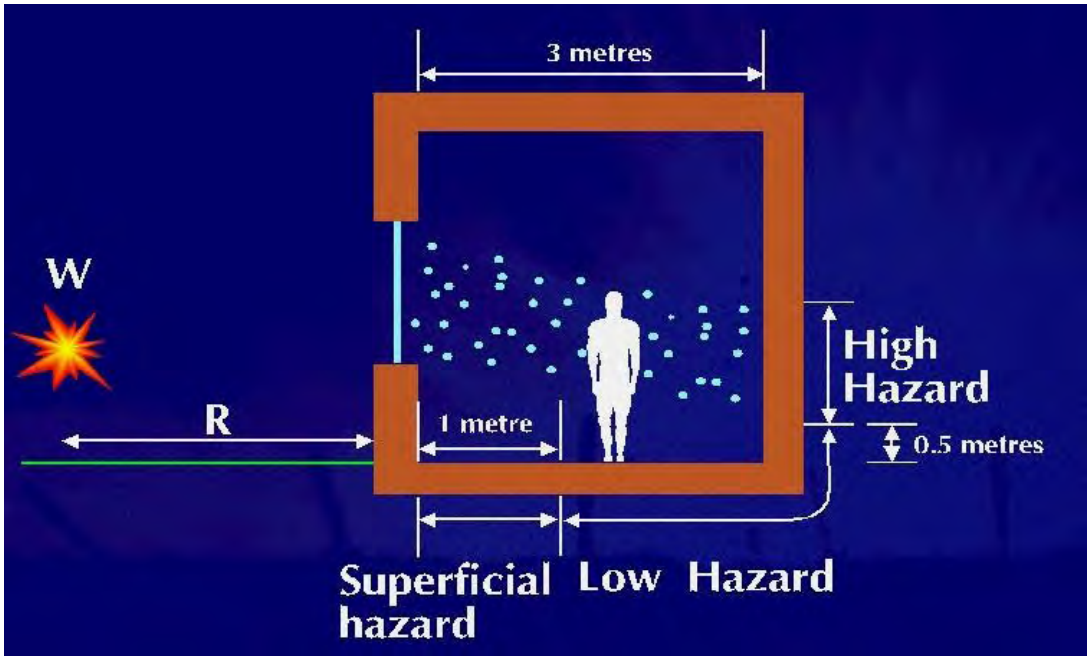


Figure 12: ISO glazing hazard levels

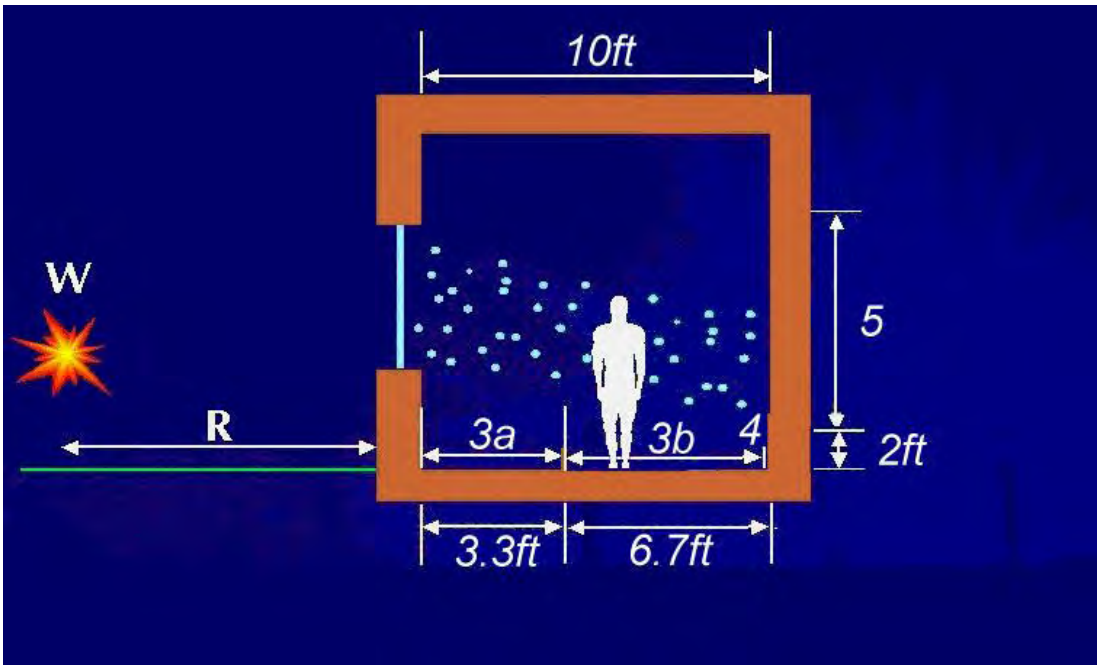


Figure 13: GSA glazing Hazard Levels

Hazard Rating	Hazard Rating Description	Description of Window Glazing Response
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 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 this 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 1 m 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 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 more than 12 mm.

Figure 14: ISO Standard Hazard Levels

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 in frame. Dusting or very small fragments near sill or floor acceptable.
3a	High	Very Low	Glazing cracks. Fragments enter space and land on floor no further than 3.3 ft 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 of 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.

Figure 15: GSA Standard Hazard Levels

It is worth noting that the ISO standard has a tolerance of glazing fragments between the levels D and E. The total unified length (the sum of the x, y and z dimensions) of all fragments found at a distance greater than 1 m (~3'3") into the test cubicle must be less than 250 mm (~10") for a classification level of D. Also between levels E and F there must be a total of greater than 10 impacts above 0.5 meters on the witness pack for a classification level of F. In Comparison the GSA standard has very little tolerance to fragments with any fragments located in the regions dictating the performance level. This sometimes leads to the GSA giving a rating that is more hazardous than the ISO for the same test data.

8 Test Results

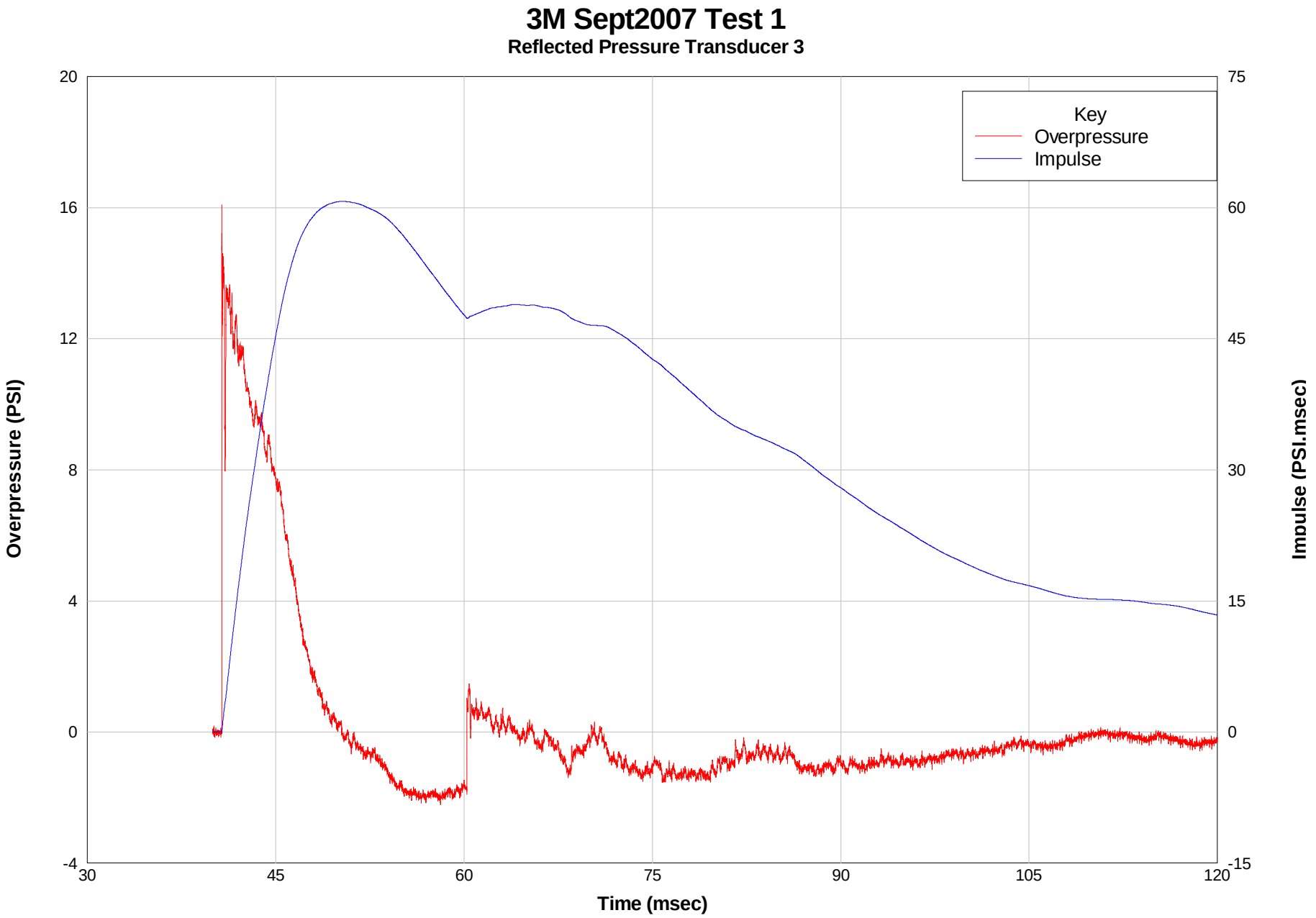
8.1 SUMMARY OF RESULTS

Figure 14 on the following page shows the results from each test for the glazing systems tested. This includes the ISO and GSA ratings awarded and the Peak overage pressure and positive phase impulse measured by the blast gauges and how they compare to the required test standard values.

Test	Location	Target Description	Blast Loading		%Difference to Test Standard		Rating Awarded	
			Pressure (PSI)	Impulse (PSI.mS)	Pressure	Impulse	GSA	ISO
Test 1 ISO EXV25	1A	Mono SH8CLARL DOW 995	14.1	68.6	21.6%	24.5%	5	High Hazard
	1B	IG Ultra600 +3M Caulk	14.1	70.8	21.6%	28.5%	2	Minimal Hazard
	1C	IG SH8CLARL DOW 995	14.1	68.6	21.6%	24.5%	5	Low Hazard
	2A	Mono SH14CLARL 3M Profile	14.1	68.6	21.6%	24.5%	5	Low Hazard
	2B	Mono SH14CLARL 3M Caulk	14.1	70.8	21.6%	28.5%	5	Low Hazard
	2C	IG SH7CLARL 3M Caulk	14.1	68.6	21.6%	24.5%	4	Low Hazard
Test 2 ISO EXV25	1A	IG SH14CLARL DOW 995	12.3	66.3	6.0%	20.3%	3b	Low Hazard
	1B	IG SH14CLARL DOW 995	12.3	68.5	6.0%	24.3%	3b	Low Hazard
	1C	IG SH8CLARL 3M Caulk	12.3	66.3	6.0%	20.3%	2	Minimal Hazard
	2A	none	12.3	66.3	6.0%	20.3%	n/a	n/a
	2B	none	12.3	68.5	6.0%	24.3%	n/a	n/a
	2C	none	12.3	66.3	6.0%	20.3%	n/a	n/a
Test 3 ISO EXV33	1A	Mono SH7CLARL 3M Caulk	8.4	44.3	15.1%	22.0%	5	Low Hazard
	1B	Mono Ultra Prestige PRS50 3M Caulk	8.4	46.5	15.1%	28.1%	3b	Very Low Hazard
	1C	Mono SH14CLARL Profile	8.4	44.3	15.1%	22.0%	3b	Very Low Hazard
	2A	IG Ultra Prestige PRS50 DOW 995	8.4	44.3	15.1%	22.0%	2	Minimal Hazard
	2B	Mono Ultra600 3M Caulk	8.4	46.5	15.1%	28.1%	3b	Low Hazard
	2C	Mono SH8CLARL 3M Caulk	8.4	44.3	15.1%	22.0%	2	Minimal Hazard
Test 4 ISO EXV33	1A	Mono SH7CLARL 3M Caulk	8	42.1	9.6%	16.0%	5	Low Hazard
	1B	Mono Ultra Prestige PRS50 3M Caulk	8	44.1	9.6%	21.5%	5	Low Hazard
	1C	Mono SH8CLARL 3M Caulk	8	42.1	9.6%	16.0%	3b	Low Hazard
	2A	Mono Ultra600 DOW 995	8	42.1	9.6%	16.0%	3b	Very Low Hazard
	2B	Mono Ultra Prestige PRS50 Profile	8	44.1	9.6%	21.5%	3b	Low Hazard
	2C	Mono Ultra Prestige PRS50 DOW 995	8	42.1	9.6%	16.0%	5	Low Hazard
Test 5 ISO EXV33	1A	Mono SH8CLARL Profile	7.7	41.2	5.5%	13.5%	3b	Low Hazard
	1B	Mono Ultra Prestige PRS50 DOW 995	7.7	43.5	5.5%	19.8%	3b	Low Hazard
	1C	IG Ultra Prestige PRS50 DOW 995	7.7	41.2	5.5%	13.5%	2	Minimal Hazard
	2A	Mono SH8 CLARL 3M Caulk	7.7	41.2	5.5%	13.5%	3b	Low Hazard
	2B	Mono SH7 CLARL 3M Caulk	7.7	43.5	5.5%	19.8%	5	High Hazard
	2C	IG Ultra Prestige PRS50 DOW 995	7.7	41.2	5.5%	13.5%	2	No Hazard
Test 6 GSA C	1A	IG Ultra600 Daylite	4.2	29.0	5.0%	3.6%	3b	Low Hazard
	1B	Mono SCLARL400 3M Caulk	4.2	29.4	5.0%	5.0%	2	Minimal Hazard
	1C	IG Ultra600 Daylite	4.2	29.0	5.0%	3.6%	3b	Low Hazard
	2A	Mono SCLARL400 3M Caulk (2 sided)	4.2	29.0	5.0%	3.6%	3b	Low Hazard
	2B	Mono SH7CLARL 3M Caulk	4.2	29.4	5.0%	5.0%	3b	Low Hazard
	2C	IG Ultra600 Daylite	4.2	29.0	5.0%	3.6%	3b	Low Hazard

Figure 16: Summary of Test Results

8.2 TEST 1 – ISO EXV25



8.2.1 Window 1 (Location 1A)

8.2.1.1 Specimen Description

Mono SH8 CLARL DOW 995

A 6 mm annealed glass, single leaf system in a standard aluminium frame with 8 mil thick 3M SH8CLARL, an anti-shatter and abrasion resistant film, applied to the inside face and anchored with ½“ of DOW 995 caulk.

8.2.1.2 Damage Description

The window shattered and was thrown inwards by the blast load. The film remained intact and was found adjacent the witness panel at the back of the test cubicle. The silicone tore along all four edges.

8.2.1.3 Window Glazing Response

The majority of the glazing was thrown into the test cubicle and significant sized fragments spread consistently throughout. Approximately 15 impacts were recorded above 0.5 m on the witness pack with a further 10 below 0.5 m.

8.2.1.4 Conclusion

Due to the large number of high hazard fragments impacting on the witness pack this system has been given an ISO EXV rating of F (High Hazard).

Rating ISO EXV (F)

8.2.2 Window 2 (Location 1B)

8.2.2.1 Specimen Description

IG ULTRA600 3M Caulk

A double glazed system consisting of two 6 mm annealed glass leaves with an air gap of 12.7 mm in a standard aluminium frame. 3M ULTRA600, a 6 mil thick high performance safety film, was applied to the inside face and anchored with 12.7 mm (½") of 3M caulk.

8.2.2.2 Damage Description

The glazing shattered but the majority of the glass remained attached to the film. No tears were recorded in the film, which remained securely attached in the frame.

8.2.2.3 Window Glazing Response

The glazing fractured with the outer leaf shattering and being thrown outward towards the charge. The majority of the inner leaf remained attached to the film and the rest was thrown out of the test cubicle towards the charge location. Very few fragments were found within the test cubicle and no impacts were recorded on the witness panel.

8.2.2.4 Conclusion

Since the inner leaf of the glazing system shattered, however the majority of glass remained firmly in place and no significant fragments were found in the test cubicle or impacted on the witness panel. Thus, an ISO EXV rating of C (Minimal Hazard) was awarded.

Rating: ISO EXV25(C)

8.2.3 Window 3 (Location 1C)

8.2.3.1 Specimen Description

IG SH8CLARL DOW 995

A doubled glazed 6 mm annealed glass system with an air gap of 12.7 mm (½“) in a standard aluminium frame. 3M SH8CLARL, an 8 mil thick anti-shatter and abrasion resistant film, was applied to the inside face and anchored to the frame using ½” of DOW 995 caulk.

8.2.3.2 Damage Description

Both leaves of the system were shattered under the blast load and the inside glazing leaf delaminated from the film. No tears were recorded in the film and the glazing spacer between the two leaves was pulled out of the frame along the left hand edge and 200 mm (8”) along the top from the top left corner. The external gasket was detached along the top and left edge.

8.2.3.3 Window Glazing Response

The majority of the glazing fragments were thrown out of the test cubicle towards the charge location. However, significant fragments were found throughout the test cubicle and 9 impacts were recorded on the witness screen with one of these above 0.5 m (~1’10”).

8.2.3.4 Conclusion

The glazing shattered with fragments landing throughout the cubicle and impacting the witness pack up to 0.5 m (~1’10”) above the ground, hence an ISO EXV rating of E (Low Hazard) has been awarded.

Rating: ISO EXV25(E)

8.2.4 Window 4 (Location 2A)

8.2.4.1 Specimen Description

Mono SH14CLARL 3M Profile

A single leaf, 6mm annealed glass system mounted in a standard aluminium frame. 3M SH14CLARL, a 14 mil thick anti-shatter and abrasion resistant film, was applied to the inside face and anchored to the frame using 3M Profile.

8.2.4.2 Damage Description

The glazing shattered and was thrown into the test cubicle along with the film and landed adjacent to the witness panel. The profile became detached from the frame, but remained attached to the film layer. The external gasket became detached on the top and left hand sides.

8.2.4.3 Window Glazing Response

Significant fragments were found throughout the test cubicle and a large number of impacts were recorded on the witness panel, of which eight were above 0.5 m (1’10”) and nine below.

8.2.4.4 Conclusion

Since significant sized fragments were found throughout the cubicle and many impacts were found on the witness pack, an ISO EXV rating of E (Low Hazard) was awarded.

Rating: ISO EXV25(E)

8.2.5 Window 5 (Location 2B)

8.2.5.1 Specimen Description

Mono SH14CLARL 3M Caulk

A single glazed 6 mm annealed glass system mounted in a standard aluminium frame. 14 mil thick 3M SH14CLARL, an anti shatter and abrasion resistant film, was applied to the internal face and anchored to the frame using ½" 3M Caulk.

8.2.5.2 Damage Description

The glazing shattered and was thrown into the cubicle along with the film. The silicone tore along all four edges, but no tears were recorded in the film. The external gasket became detached along the top edge.

8.2.5.3 Window Glazing Response

The glazing shattered and was thrown inward. Significant fragments were found throughout the cubicle and several impacts were recorded on the witness pack. Of these impacts, five were recorded above 0.5 m and seven below.

8.2.5.4 Conclusion

Due to fragments found impacting the witness panel but less than ten above 0.5 m this system has been awarded an ISO EXV rating of E (Low hazard).

Rating: ISO EXV25(E)

8.2.6 Window 6 (Location 2C)

8.2.6.1 Specimen Description

IG SH7CLARL 3M Caulk

A double glazed 6 mm annealed system with an air gap of 12.7 mm (½“) mounted in a standard aluminium frame. 7 mil thick 3M SH7CLARL, an anti-shatter and abrasion resistant film, was applied to the internal face and anchored to the frame using 3M caulk.

8.2.6.2 Damage Description

Both the internal and external leaves shattered under the blast load and the majority of the fragments were projected out of the test cubicle towards the charge location. The film remained securely held within the frame along with some of the glazing adjacent to the frame, although several tears were present horizontally along the centre of the film layer. The glazing spacer was pulled inward by about 10 mm (~½”) on both the right and left sides of the frame.

8.2.6.3 Window Glazing Response

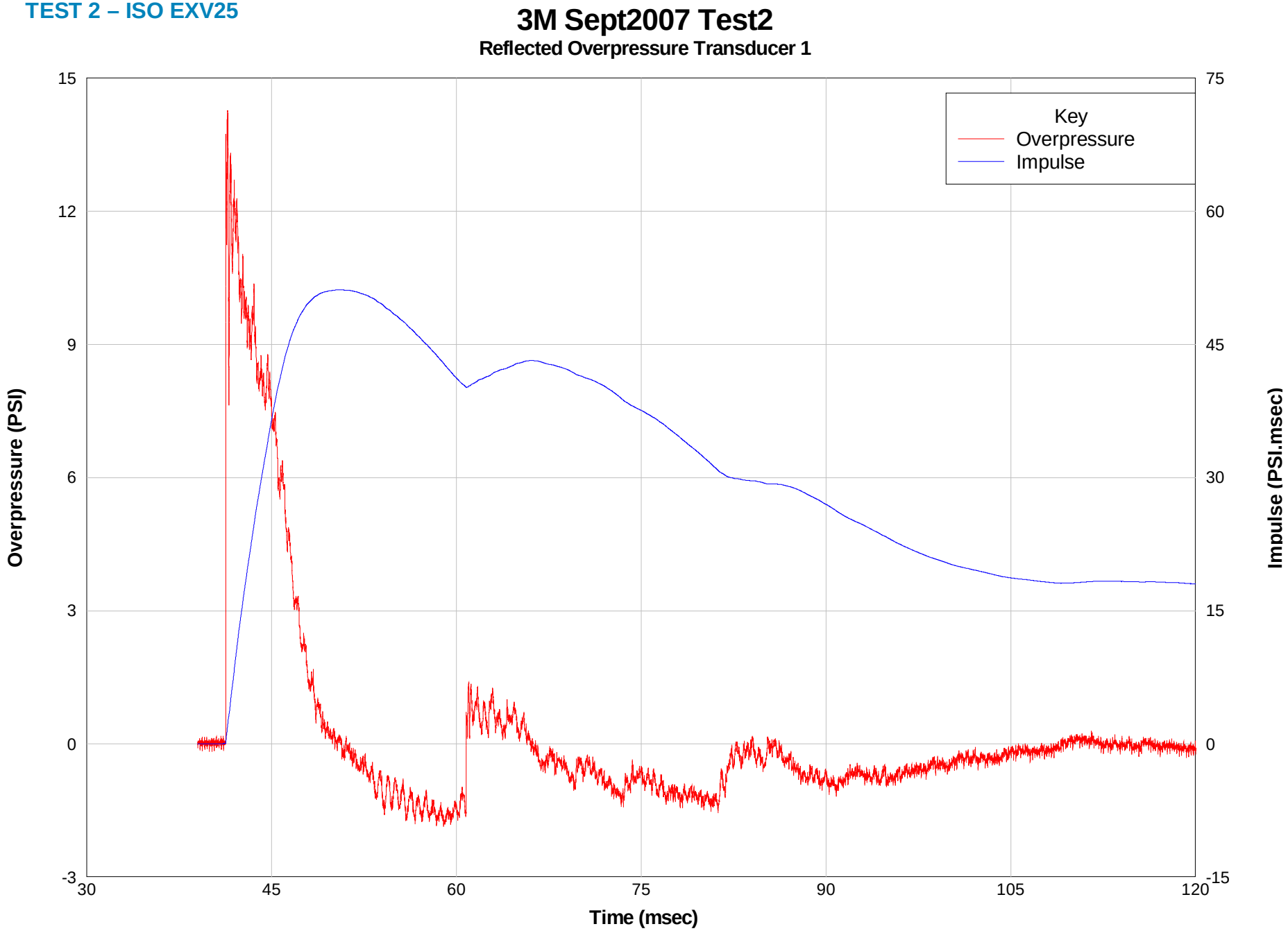
The glazing shattered with the majority being thrown outside of the test cubicle, but some landed inside possible travelling through the opening created by the tear in the film. Significant sized fragments were found even spred throughout the cubicle and three impacts were recorded on the witness pack below 0.5 m (1’10”).

8.2.6.4 Conclusion

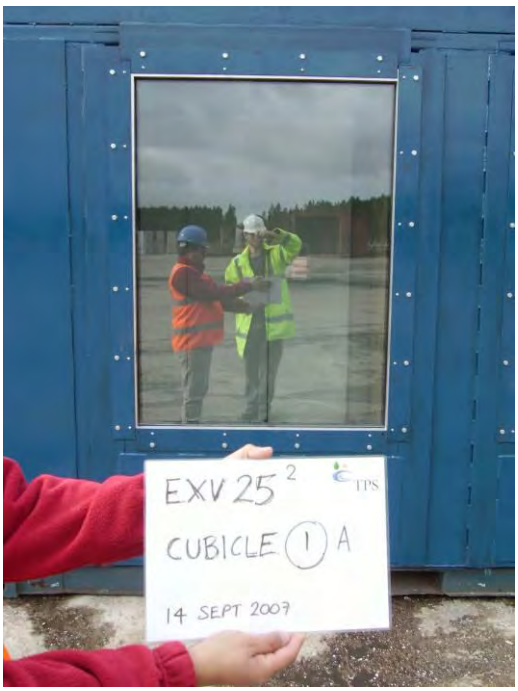
Due to glazing fragments landing inside the test cubicle and impacting the witness pack an ISO EXV rating of E (Low hazard) has been awarded.

Rating: ISO EXV25(E)

8.3 TEST 2 – ISO EXV25



8.3.1 Window 1 (Location 1A)



8.3.1.1 Specimen Description

IG SH14CLARL DOW 995

A double glazed 6 mm annealed glass system with a 12.7 mm (½“) air gap mounted in a standard aluminium frame. 3M SH14CLARL, a 14 mil thick anti shatter and abrasion resistant film, was applied to the internal face and anchored using Dow 995 Caulk.

8.3.1.2 Damage Description

Both leaves of glazing shattered with the outer leaf being thrown outwards while the inner leaf remained attached to the film. The film remained secured by the frame with no rips or tears. The Silicone remained in place except for a couple of tears on the right and left hand edges. The glazing spacer pulled away by about 10 mm (~½“) from both the right and left sides of the frame.

8.3.1.3 Window Glazing Response

The outer leaf fractured and was projected outwards towards the charge location. The majority of the inner leaf was shattered but retained by the film and the rest was also thrown outwards. Six rateable fragments were found greater then 1 m (3’3”) into the cubicle with a total unified length of approximately 260 mm (~10”).

8.3.1.4 Conclusion

Although the inner face remained in place, fragments with unified dimension greater than 250 mm (~10”) were found greater than 1m (3’3”) into the cubicle; hence an ISO EXV rating of E (Low Hazard) was awarded.

Rating: ISO EXV25(E)

8.3.2 Window 2 (Location 1B)

8.3.2.1 Specimen Description

IG SH14CLARL DOW 995

A double glazed 6 mm annealed glass system with a 12.7 mm (½“) air gap mounted in a standard aluminium frame. 3M SH14CLARL, 14 mil thick anti shatter and abrasion resistant film, was applied to the internal face and anchored using Dow 995 caulk.

8.3.2.2 Damage Description

Both leaves of glazing fractured under the blast load, with the majority of fragments being projected out of the test cubicle towards the charge location. The film was undamaged and retained some of the glazing close to the edges on the inner leaf. The glazing spacer pulled 200 mm (8”) away from the frame on the left side for about 50% of the length. The external gasket detached from the left hand side of the frame. The silicone tore along the most of the left hand edge of unit and several small tears were recorded along the top and bottom edges.

8.3.2.3 Window Glazing Response

The majority of the glazing fragments were projected outward but significant amounts were found within the cubicle up to 1m (~3’3”) from the window. Several fragments were found beyond 1m and had a total unified length of approximate 380 mm (~15”). No impacts were recorded on the witness pack.

8.3.2.4 Conclusion

Since the glazing was observed to fracture and significant amounts of fragments were found greater than 1m (~3’3”) into the test cubicle a ISO EXV rating of E (Low Hazard) has been awarded.

Rating: ISO EXV25(E)

8.3.3 Window 3 (Location 1C)

8.3.3.1 Specimen Description

IG SH8CLARL 3M Caulk

A doubled glazed 6 mm annealed glass system with an air gap of 12.7 mm (½“) in a standard aluminium frame. 3M SH8CLARL, 8 mil thick, anti shatter and abrasion resistant film, was applied to the inside face and anchored to the frame using ½” of 3M caulk.

8.3.3.2 Damage Description

Both the inner and outer leaves were observed to fracture under the blast load with the majority of the glazing fragments being projected outwards. No rips or tears were recorded on the film, which remained securely fixed in the frame. The glazing spacer was pulled out of the frame by approximately 10 mm (1/3”) on by the right and left sides.

8.3.3.3 Window Glazing Response

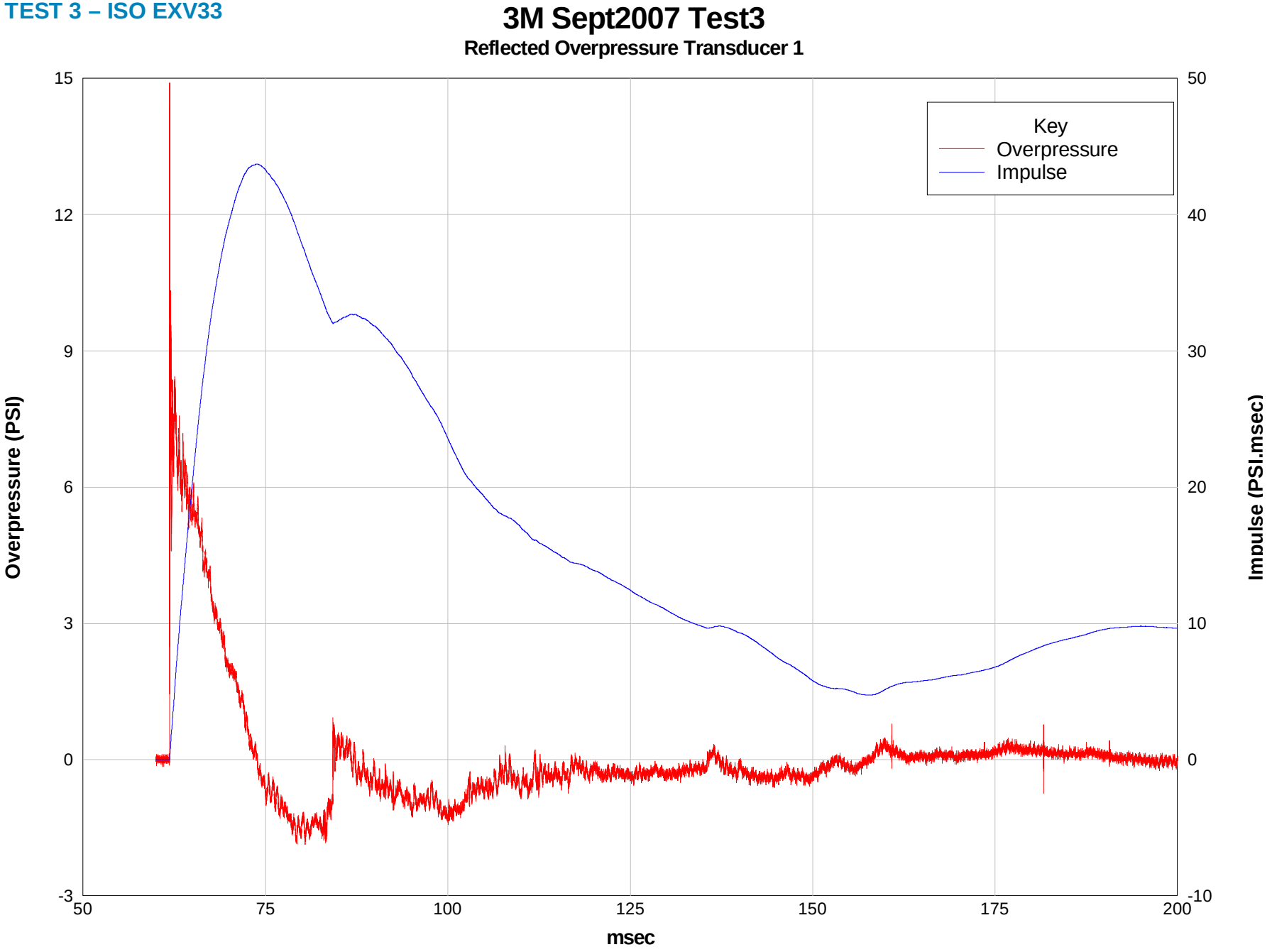
The glazing in both leaves shattered and was thrown outwards. No fragments were recorded within the test cubicle and no impacts were found on the witness pack.

8.3.3.4 Conclusion

Since the film held a large proportion of the inner leaf in the frame and no fragments or impacts were recorded within the test cubicle, an ISO EXV rating of C (Minimal Hazard) was awarded.

Rating: ISO EXV25(C)

8.4 TEST 3 – ISO EXV33



8.4.1 Window 1 (Location 1A)

8.4.1.1 Specimen Description

Mono SH7CLARL 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame with 7 mil thick 3M anti shatter and abrasion resistant film applied to the inside face and anchored to the frame with 12.7 mm (½“) of 3M caulk.

8.4.1.2 Damage Description

The glazing shattered and a large number of fragments entered to cubicle. The film was found to be torn in several places with some pieces broken off and thrown within the cubicle. The external gasket was detached for approximately 500 mm (20”) along the top edge of the frame.

8.4.1.3 Window Glazing Response

A large number of glazing fragments were thrown within the cubicle with a large concentration located on the left hand side. After studying the high speed video, this is observed to be as a result of the film tearing and dropping the fragments towards the left side of the cubicle. A significant number of fragments were found at a distance greater than 1 m (3’3”) into the test cubicle. Two impacts were recorded above 0.5 m (~1’10”) on the witness panel.

8.4.1.4 Conclusion

Due to the fracture of the glazing and large number of fragment found within the cubicle an ISO EXV rating of E (Low Hazard) has been awarded.

Rating: ISO EXV33(E)

8.4.2 Window 2 (Location 1B)

8.4.2.1 Specimen Description

Mono ULTRA PRS-50 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame. 3M ULTRA PRS-50, a 6 mil thick heat rejecting safety film, was applied to the inside face and anchored to the frame using ½" of 3M Caulk.

8.4.2.2 Damage Description

The glazing shattered with the majority of the fragments being thrown out of the test cubicle. The silicone tore along the top edge and approximately 60% of the left hand edge. The film remained intact and no rips or tears were recorded.

8.4.2.3 Window Glazing Response

Several large fragments entered the test cubicle the majority of which were located up to 1 m (~3'3") away from the window. A couple of large fragments landed further than this but the total unified length was significantly lower than 250 mm (~10"). No impacts were recorded on the witness panel.

8.4.2.4 Conclusion

Since a significant number of fragments were found up to 1 m (~3'3") into the test cubicle and those than landed further had a unified dimension of less than 250 mm (~10") an ISO EXV rating of D (Very Low Hazard) was awarded.

Rating: ISO EXV33(D)

8.4.3 Window 3 (Location 1C)

8.4.3.1 Specimen Description

Mono SH14CLARL 3M Profile

A single leaf, 6mm annealed glass system mounted in a standard aluminium frame. 3M SH14CLARL, a 14 mil thick anti-shatter and abrasion resistant film, was applied to the inside face and anchored to the frame using 3M Profile.

8.4.3.2 Damage Description

The glazing shattered but was significantly held by the film. The silicone tore on all edges and the film and shattered glass was thrown outside the cubicle landing 0.5 m (~1'8") away.

8.4.3.3 Window Glazing Response

The majority of the glazing was still bonded to the film although several large glazing fragments were found up to 1 m (~3'3") inside the test cubicle. One glass fragment was found at 1.9 m (~6'3") into the cubicle. No impacts were recorded on the witness panel.

8.4.3.4 Conclusion

The glazing fractured and a significant number of fragments were found up to 1 m (~3'3") into the test cubicle, hence an ISO EXV rating of D (Very low hazard) has been awarded.

Rating: ISO EXV33(D)

8.4.4 Window 4 (Location 2A)

8.4.4.1 Specimen Description

IG ULTRA PRS-50 DOW 995

A doubled glazed 6 mm annealed glass system with an air gap of 12.7 mm (½“) in a standard aluminium frame. 3M ULTRA PRS-50, an 6 mil thick heat rejecting safety film, was applied to the inside face and anchored to the frame using ½” of DOW 995 caulk.

8.4.4.2 Damage Description

Both the internal and external leaves of glazing shattered with the majority of the glazing fragments thrown outside of the test cubicle. The film remained securely held in the frame with no visible rips or tears.

8.4.4.3 Window Glazing Response

The majority of the glazing was thrown outwards, although a significant amount of the inner leaf was still bonded to the film and held in place. No significant sized fragments were found within the test cubicle and no impacts were recorded on the witness panel.

8.4.4.4 Conclusion

The glazing fractured throwing the fragments outwards with no fragments landing inside the test cubicle. The inner leaf was also substantially retained. A ISO EXV rating of C (Minimal Hazard) has been awarded.

Rating: ISO EXV33(C)

8.4.5 Window 5 (Location 2B)

8.4.5.1 Specimen Description

Mono ULTRA600 3M Caulk

A single leaf, 6mm annealed glass system mounted in a standard aluminium frame. 3M ULTRA600, a 6 mil thick high performance safety film, was applied to the inside face and anchored to the frame using ½" 3M caulk.

8.4.5.2 Damage Description

The glazing shattered and the majority was thrown outwards. The silicone tore along the right and left sides for about 75% the length of the frame. No tears were recorded in the film.

8.4.5.3 Window Glazing Response

Although the majority of glazing was thrown outwards, a significant number of fragments were found within the test structure. These were found throughout the structure, although no impacts were recorded on the witness panel.

8.4.5.4 Conclusion

The glazing fractured and a significant amount of fragments was found to have landed throughout the cubicle, hence an ISO EXV rating of E (Low Hazard) has been awarded.

Rating: ISO EXV33(E)

8.4.6 Window 6 (Location 2C)

8.4.6.1 Specimen Description

Mono SH8CLARL 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame with applied, an 8 mil thick anti-shatter and abrasion resistant film applied to the inside face and anchored to the frame with ½" of 3M caulk.

8.4.6.2 Damage Description

The glazing shattered throwing all the glazing out of the test cubicle. The silicone tore along both edges for approximately 50% of the frame length. The external gasket was detached along the top and half of the left edge. The film remained securely in the frame and no rips or tears were observed.

8.4.6.3 Window Glazing Response

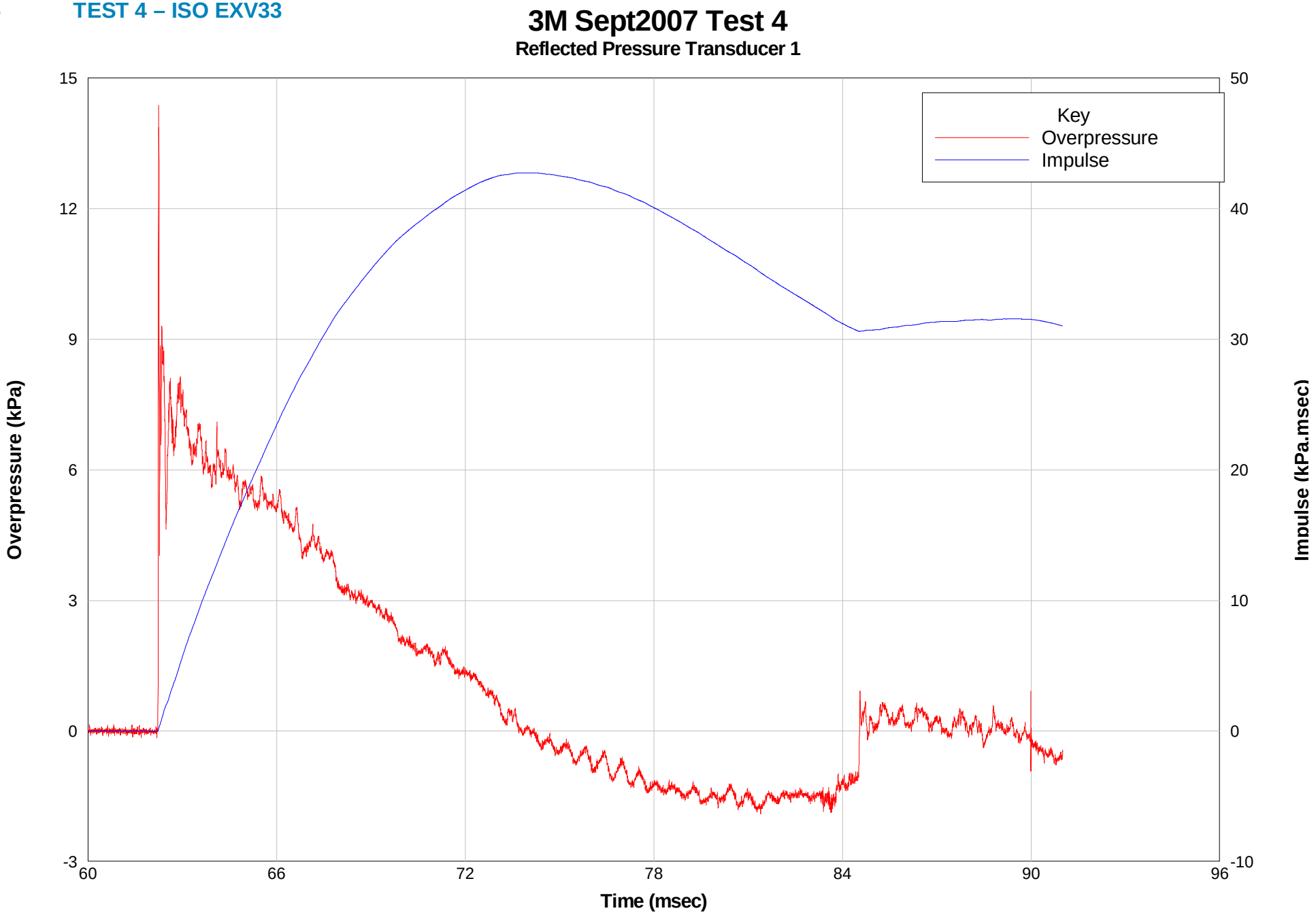
The glazing fractured and delaminated from the film. No significantly sized fragments were found within the test cubicle and no impacts were recorded on the witness panel.

8.4.6.4 Conclusion

As no glazing fragments entered the cubicle and the film was still securely in place, an ISO EXV rating of C (Minimal Hazard) was awarded.

Rating: ISO EXV33(C)

8.5 TEST 4 – ISO EXV33



8.5.1 Window 1 (Location 1A)

8.5.1.1 Specimen Description

Mono SH7 CLARL 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame with 7 mil thick anti-shatter and abrasion resistant film applied to the inside face and anchored to the frame with 12.7 mm (½“) of 3M caulk.

8.5.1.2 Damage Description

The glazing shattered and delaminated from the film with the majority of fragments being thrown outwards but a significant amount landing inside the test cubicle up to 1m (~3’3”) from the inside face. The film was torn in several places and the 3M sealant torn along the bottom edge and approximately 650 mm (~2’2”) up one side. The outer gasket became detached along one side an approximately 500 mm (~1’8”) along the bottom edge. The inner gasket remained in place.

8.5.1.3 Window Glazing Response

Many large fragments landed up to 30 m (~100’) outside the test structure. Inside the test cubicle a light dusting of glass was found with several large fragments located up to 1 m (3’3”) from the inside face of the glazing. Four impacts were recorded on the witness pack, all of which were located higher than 0.5 m (~1’8”). One sizeable glass fragment was found to have penetrated to witness pack at a height of 1.8 m (~6’2”).

8.5.1.4 Conclusion

Significant fragments were found at a distance up to 1 m (~3’3”) and several impacts were present on the witness pack; although there were less than 10 recorded above 0.5 m (~1’8”); hence an ISO EXV33 rating of E (Low Hazard) has been awarded.

Rating: ISO EXV33 (E)

8.5.2 Window 2 (Location 1B)

8.5.2.1 Specimen Description

Mono ULTRA PRS-50 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame. 3M ULTRA PRS-50, a 6 mil thick heat rejecting safety film, was applied to the inside face and anchored to the frame using ½" of 3M Caulk.

8.5.2.2 Damage Description

The glazing shattered and delaminated from the film. Significant amounts of glazing fragments were found within the test cubicle, although the majority was thrown outwards. The film was detached from the frame along three edges with no tears or perforations recorded. The silicone remained bonded to the frame, although it is unclear whether the silicone tore or delaminated from the film.

8.5.2.3 Window Glazing Response

The majority of the glazing was thrown outwards towards the charge location. An even spread of large fragments was found on the floor of the test cubicle. The witness pack recorded two impacts; one at 0.4 m (~1'4") and one at 1.3 m (~4'3"). No glazing fragments were found to have penetrated the witness pack.

8.5.2.4 Conclusion

A significant number of fragments were found throughout the test cubicle and less than ten impacts were found on the witness pack, hence an ISO EXV33 rating of E (Low Hazard) has been awarded.

Rating: ISO EXV33 (E)

8.5.3 Window 3 (Location 1C)

8.5.3.1 Specimen Description

Mono SH8CLARL 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame with 8 mil thick 3M anti shatter and abrasion resistant film applied to the inside face and anchored to the frame with ½" of 3M caulk.

8.5.3.2 Damage Description

The glazing, shattering under the blast load, delaminated from the film with the majority thrown outside the test structure towards the charge location. Some of the glass was still held in place adjacent to the frame and some was located behind the film where the silicone had torn. The film remained in place with no tears or perforations. The silicone tore away from the frame for approximately 600 mm (~2') along the left window edge.

8.5.3.3 Window Glazing Response

The majority of the glazing was thrown outwards the charge location and many large fragments were found up to 30 m (~100') from the test structure. Several significant glazing fragments were found between 1 m (~3'3") to 2 m (~6'6") from the inside face of the glass. These were found to have a unified total length of over than 250 mm (10") (approximately 300 mm (~12")). A light dusting of very small glazing fragments was found throughout the cubicle. No impacts were recorded on the witness pack.

8.5.3.4 Conclusion

No impacts were recorded on the witness pack and fragments with a total unified length of greater than 250 mm (~10") were recorded at a distance greater than 1 m (~3'3") from the inside face, hence a ISO EXV33 rating of E (Low Hazard) was awarded.

Rating: ISO EXV33 (E)

8.5.4 Window 4 (Location 2A)

8.5.4.1 Specimen Description

Mono ULTRA600 DOW 995

A single leaf, 6mm annealed glass system mounted in a standard aluminium frame. 3M ULTRA600, a 6 mil thick high performance safety film, was applied to the inside face and anchored to the frame using ½" DOW 995 caulk.

8.5.4.2 Damage Description

The glazing shattered with the majority becoming delaminated and thrown outwards towards the charge location. The film remained undamaged and the silicone torn along the top and sides with the film falling outwards.

8.5.4.3 Window Glazing Response

A light dusting of glass was found through out the cubicle but the majority of glass fragments were thrown out of the test cubicle towards the charge. One significant fragment was found at a distance of 2.1 m (~6'11") but the total unified length was less than 250 mm. Several other small shard-like fragments were found up to 1 m (~3'3") into the test cubicle. No impacts were recorded on the witness pack.

8.5.4.4 Conclusion

The glazing shattered and, although fragments were found at greater than 1 m (~3'3") into the test structure, these had a unified length of less than 250 mm (~10"), hence an ISO EXV rating of D (Very low hazard) was awarded.

Rating: ISO EXV33 (D)

8.5.5 Window 5 (Location 2B)

8.5.5.1 Specimen Description

Mono ULTRA PRS-50 3M Profile

A 6 mm annealed glass, single leaf system in a standard aluminium frame. 3M ULTRA PRS-50, a 6 mil thick heat rejecting safety film, was applied to the inside face and anchored to the frame using 3M Profile.

8.5.5.2 Damage Description

The glazing shattered but was retained by the film. The silicone tore on all edges and the glazing fell outwards. The outer gasket was detached on the top edge and both sides.

8.5.5.3 Window Glazing Response

Glazing dust was found throughout the cubicle. Several large fragments were found up to 1 m (~3'3") into the test cubicle and more were found at a greater distance. The total unified length of the fragments was found to be greater than 250 mm (~10"). No impacts were recorded on the witness panel.

8.5.5.4 Conclusion

The glazing shattered and significant fragments were found throughout the test cubicle, although no impacts were recorded on the witness pack. An ISO EXV33 rating of E (Low Hazard) was awarded.

Rating: ISO EXV33 (E)

8.5.6 Window 6 (Location 2C)

8.5.6.1 Specimen Description

Mono ULTRA PRS-50 DOW 995

A 6 mm annealed glass, single leaf system in a standard aluminium frame. 3M ULTRA PRS-50, a 6 mil thick heat rejecting safety film, was applied to the inside face and anchored to the frame using ½" of DOW 995 caulk.

8.5.6.2 Damage Description

The glazing fractured and the majority of glass fragments delaminated from the film and were thrown outwards. The film tore diagonally from below the top left corner the centre of the window and a semi circular section was missing from the bottom left corner, which had been thrown outwards. The external gasket was detached along the left edge of the frame.

8.5.6.3 Window Glazing Response

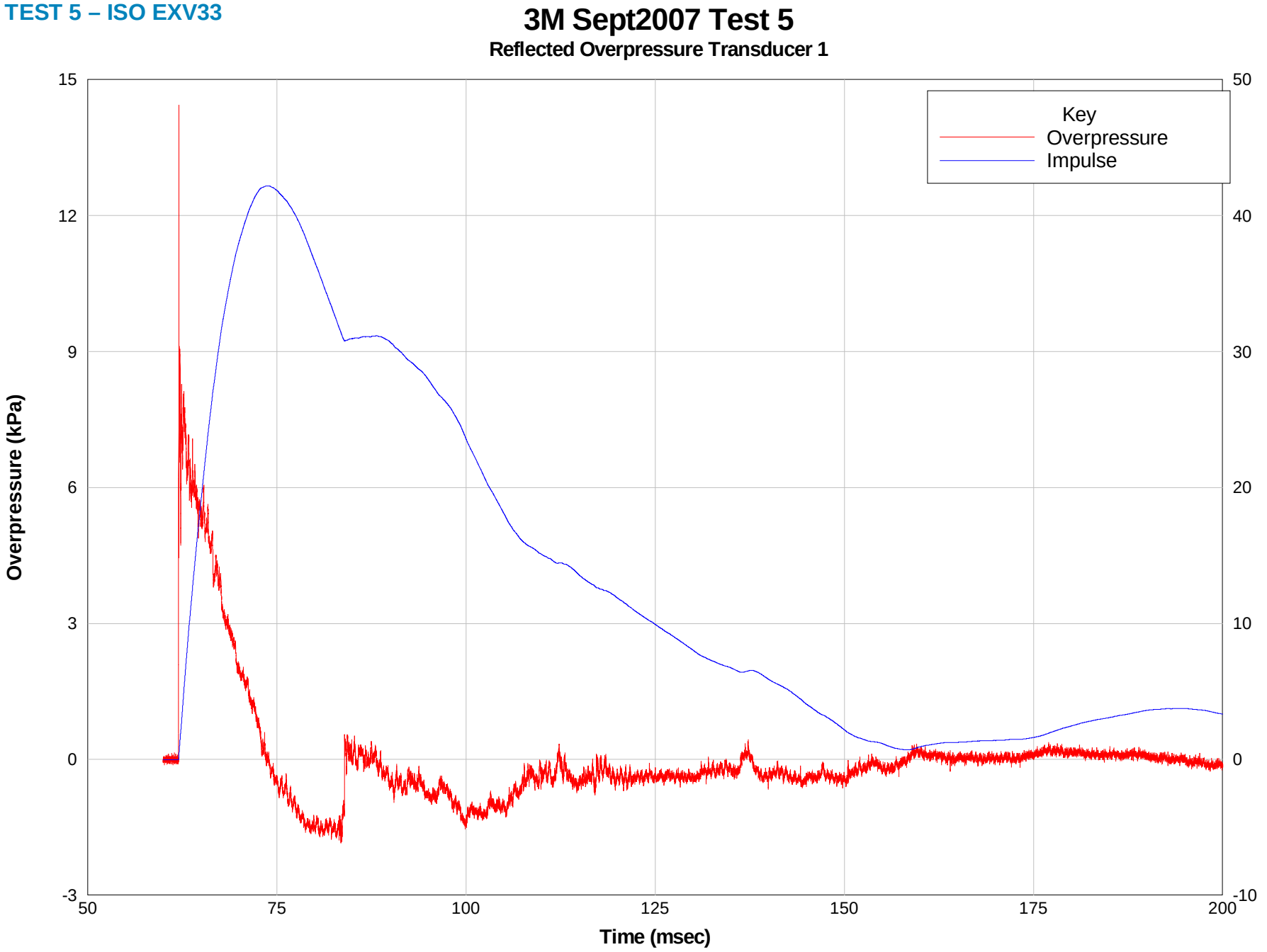
Significant amounts of fragments were recorded within the test cubicle and six impacts were recorded on the witness pack above 0.5 m (~1'8").

8.5.6.4 Conclusion

The glazing fractured with a significant amount of fragments entering the test cubicle and less than ten fragments impacted the witness panel; therefore an ISO EXV rating of E (Low Hazard) was awarded.

Rating: ISO EXV33(E)

8.6 TEST 5 – ISO EXV33



8.6.1 Window 1 (Location 1A)

8.6.1.1 Specimen Description

Mono SH8CLARL 3M Profile

A 6 mm annealed glass, single leaf system in a standard aluminium frame with applied,8 mil thickness, 3M anti shatter and abrasion resistant film applied to the inside face and anchored to the frame with 3M Profile.

8.6.1.2 Damage Description

The glazing shattered and the majority of glazing along with the film was thrown into the test cubicle. The profile delaminated from the frame but remained attached to the film.

8.6.1.3 Window Glazing Response

A large number of fragments were found throughout the test cubicle due to the glazing system breaking and failing inwards. A large amount of the glazing still remained attached to the film which landed at the front of the test cubicle adjacent to the window. No impacts were recorded on the witness panel.

8.6.1.4 Conclusion

Due to large amounts of glass in addition to the film and the remainder of the glazing system landing inside the test cubicle an ISO EXV rating of E (Low Hazard) has been awarded.

Rating: ISO EXV33(E)

8.6.2 Window 2 (Location 1B)

8.6.2.1 Specimen Description

Mono ULTRA PRS-50 DOW 995

A 6 mm annealed glass, single leaf system in a standard aluminium frame. 3M ULTRA PRS-50, a 6 mil thick heat rejecting safty film, was applied to the inside face and anchored to the frame using ½" of DOW 995 caulk.

8.6.2.2 Damage Description

The glazing failed with a significant amount of glazing fragments landing within the test cubicle. The majority of the glass delaminated from the film and was thrown outwards. The film was torn across the top left corner and the silicone tore across the top edge and for approximately 90% of the frame length on the sides. The external gasket was detached along two thirds of the top edge and all of the left hand edge.

8.6.2.3 Window Glazing Response

The glazing shattered and the film failed inwards. A significant amount of fragments were found throughout the test cubicle, but no impacts were recorded on the witness panel.

8.6.2.4 Conclusion

Due to the glazing failing inward and significant fragments located inside the test cubicle, an ISO EXV rating of E (Low Hazard) was awarded.

Rating: ISO EXV33(E)

8.6.3 Window 3 (Location 1C)

8.6.3.1 Specimen Description

IG ULTRA PRS-50 DOW 995

A doubled glazed 6 mm annealed glass system with an air gap of 12.7 mm (½“) in a standard aluminium frame. 3M UPR400, a 6 mil thick heat rejecting safety film, was applied to the inside face and anchored to the frame using ½” of DOW 995 caulk.

8.6.3.2 Damage Description

The glazing shattered but the majority was retained by the film. The remaining fragments were projected outwards towards the charge location. The film remained fully secured and the silicone was recorded to have no damage.

8.6.3.3 Window Glazing Response

All the glazing was projected outward and no fragments were observed inside the cubicle or impacting on the witness panel.

8.6.3.4 Conclusion

Due to the glazing and film remaining secured within the frame and no fragments entering the test cubicle an ISO EXV rating of C (Minimal Hazard) was awarded.

Rating: ISO EXV33(C)

8.6.4 Window 4 (Location 2A)

8.6.4.1 Specimen Description

Mono SH8CLARL 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame with 8 mil thick anti-shatter and abrasion resistant film applied to the inside face and anchored to the frame with ½" of 3M Caulk.

8.6.4.2 Damage Description

The glazing shattered, delaminated from the film and the majority was projected outwards. The film tore in the bottom left corner and the silicone tore for 25% along the right hand edge of the frame. The external gasket was detached along the top edge and the bottom edge of the frame became dislodged.

8.6.4.3 Window Glazing Response

Although the majority of glazing was projected outwards a significant number of fragments were found throughout the test cubicle. No impacts were recorded on the witness panel.

8.6.4.4 Conclusion

Due to significant numbers of fragments entering the test cubicle and ISO EXV rating of E (Low Hazard) was awarded.

Rating: ISO EXV33(E)

8.6.5 Window 5 (Location 2B)

8.6.5.1 Specimen Description

Mono SH7CLARL 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame with a 7 mil thick 3M anti-shatter and abrasion resistant film applied to the inside face and anchored to the frame with ½" of 3M caulk.

8.6.5.2 Damage Description

The glazing fractured inwards with the film tearing in many places across the centre of the window. As a result large amounts of glazing fragments were projected inwards. The external gasket was detached on all sides, although the caulk remained intact.

8.6.5.3 Window Glazing Response

Due to the large amount of glazing projected inwards, significant amounts of fragments were recorded throughout the cubicle and 14 strikes were recorded above 0.5 m (~1'8") on the witness panel. An additional 3 strikes were recorded below.

8.6.5.4 Conclusion

Since a large number of fragments entered the test cubicle and impacted the witness panel on the rear wall an ISO EXV rating of F (High Hazard) was attained.

Rating: ISO EXV33(F)

8.6.6 Window 6 (Location 2C)

8.6.6.1 Specimen Description

IG ULTRA PRS-50 DOW 995

A doubled glazed 6 mm annealed glass system with an air gap of 12.7 mm (½“) in a standard aluminium frame. 3M UPR400, a 6 mil thick heat rejecting safety film, was applied to the inside face and anchored to the frame using ½” of DOW 995 caulk.

8.6.6.2 Damage Description

Both the inner and outer glazing leaves were shattered under the blast load, with fragments thrown outwards. Any remaining glazing was held securely in the frame. No damage was observed to the film, silicone or frame.

8.6.6.3 Window Glazing Response

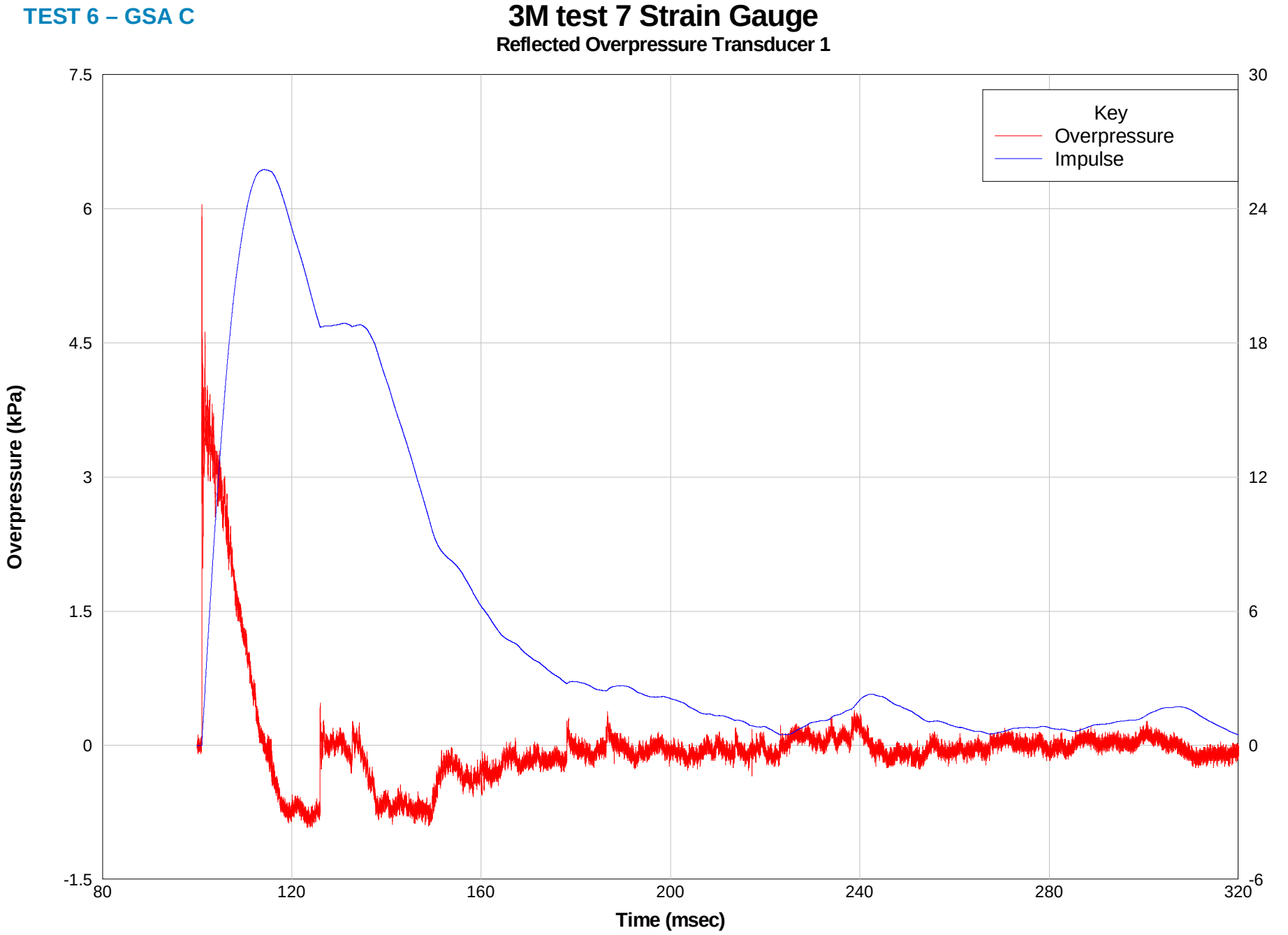
All fragments were either projected outwards or stopped by the film; therefore none were recorded within the cubicle or impacted the witness panel.

8.6.6.4 Conclusion

The film remained secured within the frame and no fragments entered the test structure. Hence an ISO EXV rating of B (No Hazard) was awarded.

Rating: ISO EXV33(C)

8.7 TEST 6 – GSA C



8.7.1 Window 1 (Location 1A)

8.7.1.1 Specimen Description

IG ULTRA600 Daylite

A doubled glazed 6 mm annealed glass system with an air gap of 12.7 mm (½“) in a standard aluminium frame. 3M ULTRA600, a 6 mil thick high performance safety and security film, was applied to the inside face with no anchoring system used.

8.7.1.2 Damage Description

The glazing shattered and pulled out of the frame landing immediately in front of the test structure with a large majority of the glass held by the film. The glazing spacer snapped on the left hand side of the frame. The external gasket was detached along the top, bottom and right hand edge.

8.7.1.3 Window Glazing Response

The film retained the majority of the glass, but several significantly sized fragments entered the test cubicle and landed throughout the floor area. No impacts were recorded on the witness panel.

8.7.1.4 Conclusion

The glazing pulled out of the frame but retained the majority of the glass with some significant fragments entering the depth of the cubicle. Hence a GSA rating of 3b (Low Hazard) was awarded.

Rating: GSA C 3b

8.7.2 Window 2 (Location 1B)

8.7.2.1 Specimen Description

Mono SCLARL400 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame with applied 3M SCARL400, a 4 mil thick safety and security film, applied to the inside face and anchored to the frame with ½" of 3M caulk.

8.7.2.2 Damage Description

The glazing shattered under the blast load, delaminated from the film and was projected outwards. No rips or tears were recorded in the film and the caulk was intact, except for delaminating from the film for approximate 200 mm (~8") along the bottom edge.

8.7.2.3 Window Glazing Response

No fragments entered the test cubicle and no impacts were recorded on the witness panel.

8.7.2.4 Conclusion

The film was fully retained within the frame and no fragments entered the test cubicle. A GSA rating of 2:None (No hazard) was recorded.

Rating: GSA C 2

8.7.3 Window 3 (Location 1C)

8.7.3.1 Specimen Description

IG ULTRA600 Daylite

A doubled glazed 6 mm annealed glass system with an air gap of 12.7 mm (½“) in a standard aluminium frame. 3M ULTRA600, a 6 mil thick high performance safety and security film, was applied to the inside face with no anchoring system used.

8.7.3.2 Damage Description

Both leaves of glazing fractured with a significant amount being thrown outwards. A large amount of glazing entered the cubicle. The silicone tore along the bottom edge. No rips or tears were recorded in the film, which was securely held within the frame.

8.7.3.3 Window Glazing Response

A large amount of the glazing fragments were found in a pile adjacent to the window where the silicone had torn alone the bottom edge. A significant amount of fragments were also found throughout the cubicle. No impacts were recorded on the witness panel.

8.7.3.4 Conclusion

As large of amounts of fragments entered the whole depth of the cubicle a GSA rating of 3b was awarded (Low Hazard)

Rating: GSA C 3b

8.7.4 Window 4 (Location 2A)

8.7.4.1 Specimen Description

Mono SCLARL400 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame with applied 3M SCARL400, a 4 mil thick safety and security film, applied to the inside face and anchored to the frame with ½" of 3M caulk. Silicone was applied to the left and right sides of the frame only.

It should be noted that additional instrumentation was mounted on this window, including a laser deflection gauge on a steel section approximately 1 m (~3'3") behind. The inside face was also layered with foil to allow for better deflection measurements.

8.7.4.2 Damage Description

The glazing fractured under the blast load with a large amount of fragments entering the test cubicle. The silicone along the right hand side tore and the film was blown inwards. No rips or tears were recorded in the film.

8.7.4.3 Window Glazing Response

The glazing shattered with a large amount landing throughout the cubicle. No impacts were recorded on the witness panel.

8.7.4.4 Conclusion

A large amount of glazing fragments landed throughout the test cubicle and therefore a GSA rating of 3b (Low Hazard) was awarded.

Rating: GSA C 3b

8.7.5 Window 5 (Location 2B)

8.7.5.1 Specimen Description

Mono SH7CLARL 3M Caulk

A 6 mm annealed glass, single leaf system in a standard aluminium frame with applied 7 mil thick 3M anti-shatter and abrasion resistant film applied to the inside face and anchored to the frame with ½" of 3M caulk. It should be noted that additional instrumentation was mounted on this window, including 2 strain gauges mounted to the inside face.

8.7.5.2 Damage Description

The glazing shattered and delaminated from the film with the majority of glazing fragments being thrown outwards. The film tore in several places passing through the centre where the strain gauges were located. The caulk remained undamaged although the external gasket became detached along the top and both sides of the frame.

8.7.5.3 Window Glazing Response

A large number of fragments entered the test cubicle through the tears in the film and landed throughout the depth of the cubicle. One impact was recorded on the witness panel below 2 ft.

8.7.5.4 Conclusion

Due to a large number of fragments entering and landing throughout the test cubicle a GSA rating of 4 (Medium Hazard) was awarded.

Rating: GSA C 4

8.7.6 Window 6 (Location 2C)

8.7.6.1 Specimen Description

IG ULTRA600 Daylite

A doubled glazed 6 mm annealed glass system with an air gap of 12.7 mm (½“) in a standard aluminium frame. 3M ULTRA600, an 6 mil thick high performance safety and security film, was applied to the inside face and no anchoring system was used to secure the film to the frame.

8.7.6.2 Damage Description

The outer leaf shattered under the blast load and was projected outwards. The inner leaf was substantially cracked but not de-bonded from the film and held in place in the frame. No tears were visible in the film. The glazing spacer was substantially pulled out of the frame on three sides with the right side of the frame held in place by the corners only. The external gasket was detached along the top, bottom and right edges.

8.7.6.3 Window Glazing Response

A significant number of fragments landed within the cubicle. 15 were located up to 1m (~3’3”) and 5 beyond. No impacts were recorded on the witness panel.

8.7.6.4 Conclusion

Significant fragments were located up to 1 m into the cubicle with several landing further in; hence a GSA rating of 3b (Low Hazard) was awarded.

Rating: GSA C 3b