Certified Test Report BR604 Blast Resistant Glazing System

SHOCK TUBE TESTING OF WINDOWS FOR BLAST RESISTANCE CERTIFICATION

BakerRisk Project No. 01-00750-002-00

Prepared for: United States Aluminum Corp.

> Prepared by: Michael J. Lowak

September 8, 2004



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Table of Contents

1.0	TEST INFORMATION
2.0	SPECIMEN DESCRIPTION
3.0	DISCUSSION OF RESULTS

List of Tables

Table 1.	Summary	of Test Results	3
14010 1.	5 annia j		-

List of Figures

Figure 1. BR604 T	est Specimen	.2
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Appendices

Appendix 1 Test Approach and Setup	4
Appendix 2 Detailed Test Data	10
Appendix 3 Window Specimen Details	26
Appendix 4 GSA Document	40

1.0 TEST INFORMATION

Test Sponsor:	United States Aluminum 720 Cel-River Road	Corp.	
	Rock Hill, South Carolin	a, 2973()
Manufacturer:	United States Aluminum	Corp.	
	720 Cel-River Road		
	Rock Hill, South Carolin	a, 2973()
Testing Agency:	Baker Engineering and R 3330 Oakwell Court, Suit San Antonio, TX 78218	tisk Cor e 100	nsultants, Inc. (BakerRisk)
Window Model:	BR604 Blast Resistant Gl	azing S	ystem
Test Load:	Peak Blast Pressure	=	4.3 psi
	Positive Phase Impulse	=	32 psi-msec
Test Standard:	ASTM F 1642 – 03 "Stan Systems Subject to Airblas	dard Te t Loadi	est Method for Glazing and Glazing ngs"

Baker Engineering & Risk Consultants, Inc. (BakerRisk) certifies that all information contained in this document is accurate to the best of our knowledge, and that every attempt was made during these tests to meet the requirements of the referenced test method.

Michael J. Lowak, Senior Consultant

2.0 SPECIMEN DESCRIPTION

The Series BR604 Blast Resistant System units submitted for testing had overall dimensions of 96 inches in width and 96 inches in height. The units represented an 8-foot wide window wall including four panes of glass as shown in Figure 1. Each lite was a 1 5/16-inch thick IGU consisting of a ¹/₄-inch thick glass exterior lite, a ¹/₂-inch air space, and a ¹/₂-inch thick laminated annealed glass interior lite. The laminated lite included a 0.030-inch thick Butacite interlayer. Panes A and C included annealed glass exterior lites, but panes B and D included tempered glass exterior lites. The glass extended into the frame 0.562-inch on all sides, and a 1/4-inch wide by 7/16-inch deep Dow 995 silicone bead was provided on the interior face of the IGU.

The detailed drawings of the framing system are included in Appendix 3. The center vertical mullion was reinforced with a steel insert to improve the flexural strength of the member. Details of the insert are provided in Detail 8. All connections of horizontal members to vertical members were made using the screw races that are part of the aluminum extruded shapes. The perimeter frame members were attached to a steel test buck using 3/8-inch diameter, Grade 5 bolts at the spacings shown in the detail drawings. The vertical mullion insert was attached directly to the test buck with two ½-inch diameter Grade 5 bolts at each end.



Figure 1. BR604 Test Specimen

3.0 DISCUSSION OF RESULTS

Three Series BR604 Blast Resistant System specimens were tested to certify the level of blast resistance for a test load having a peak applied pressure in excess of 4 psi and an applied impulse in excess of 30 psi-msec. All tests resulted in ASTM "Minimal Hazard" or better window responses. In Test UA5, the only breakage of glass observed was to the large glass pane. The external monolithic lite shattered and fell to the floor on the non-protected side of the specimen. The layer of glass on the non-protected side of the laminated glass also cracked, but the layer of glass on the protected side of the window did not crack. No debris was generated in the test at all. In Test UA6, all layers of glass in the large pane shattered, with some dusting debris generated, but no impacts or perforations were observed in the witness panel. In Test UA7, no fracture of the glass was observed. In all tests, the framing members were observed to be undamaged, and measurements indicated that permanent mid-span deformations were less than 1/16-inch, or within straightness tolerances. The worst level of debris hazard observed in Test UA6 is allowable under the ASTM "Minimal Hazard" rating and GSA Performance Condition 2.

A summary of the test results is provided in Table 1. The test setup and equipment are described in Appendix 1. Detailed test information, pressure-time histories for the applied load, and a limited photographic record for each test are included in Appendix 2. Each test was documented using still photography, video, and high-speed video. All photographs, video footage, and highspeed video footage taken of the tests are included on an accompanying compact disc along with an electronic version of this report.

Test No.	Specimen Description	Pressure (psi)	Impulse (psi-msec)	Duration (msec)	Response
UA5	Series BR604 (96" x 96")	4.3	32	19	GSA - Condition 2 ASTM - No Hazard
UA6	Series BR604 (96" x 96")	4.4	33	19	GSA - Condition 2 ASTM - Minimal Hazard
UA7	Series BR604 (96" x 96")	4.4	32	19	GSA - Condition 1 ASTM - No Break

Table 1. Summary of Test Results

APPENDIX 1 TEST APPROACH AND SETUP

Test Approach

The test program followed the general procedures and window performance criteria from the ASTM F 1642-03 *Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings*. Also referenced is the General Services Administration (GSA) *Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings*. The two documents are very similar, but have slightly different methods of reporting window performance. The ASTM document provides descriptions of various Hazard Ratings, and the GSA document provides descriptions of various Hazard Ratings, and the terminology is different, the two systems are very comparable. A tabularized comparison of the two performance rating schemes is provided in Appendix 1 - Table 1. A copy of the ASTM document can be obtained from ASTM. The GSA document is available for public distribution and a copy of the document is provided in Appendix 4.

The referenced test standards require the testing of three like specimens to certify performance of a glazing or glazing system. This program was conducted as a combined certification and research program. The window system was tested to various blast loads to determine the best suited blast loading to use in the certification tests, and then additional repeat tests were conducted to satisfy the repeatability requirement of the referenced test standards.

ASTM Hazard	ASTM Description	Similar GSA Performance	GSA Description
Rating		Condition	
No Break	no visible damage to the glazing system.	1	visible damage to glazing or frame.
No Hazard	The glazing is observed to fracture but is fully retained in the facility test frame or glazing system frame, and the rear surface (the surface opposite the airblast loaded side of the specimen) is intact.	2	Glazing cracks but is retained by the frame. Dusting or very small fragments near sill or on floor acceptable.
Minimal	length of tears in the glazing plus the total length of pullout from the edge of the frame is less than 20%		Clazing gracks Fragments
Hazard	of the glazing sight perimeter. Also there are less than 3 pinhole perforations and no fragment indents anywhere in a vertical witness panel located 3 m (120 in.) from the interior face of the specimen,	3A	enter space and land on floor no further than 3.3 ft. from the window.
	and there are fragments with a sum total united dimension of 25 cm (10 in.) or less on the floor between 1 m (40 in) and 3 m (120 in) from the		
	interior face of the specimen. Glazing dust and slivers are not accounted for in the rating.		
Very Low Hazard Low Hazard	The glazing is observed to fracture and is located within 1 m (40 in.) of the original location. Also, there are three or less pinhole perforations and no fragment indents anywhere in a vertical witness panel located 3 m (120 in.) from the interior face of the specimen and there are fragments with a sum total united dimension of 25 cm (10 in.) or less on the floor between 1 m (40 in.) and 3 m (120 in.) from the interior face of the specimen. Glazing dust and slivers are not accounted for in the rating. The glazing is observed to fracture, but glazing fragments generally fall between 1 m (40 in.) of the interior face of the specimen and 0.5 m (20 in.) or	3B	Glazing cracks. Fragments enter space and land on floor no further than 10 ft. from the window.
	less above the floor of a vertical witness panel located 3 m (120 in.) from the interior face of the specimen. Also, there are ten or fewer perforations in the area of a vertical witness panel located 3 m (120 in.) from the interior face of the specimen and higher than 0.5 m (20 in.) and none of the perforations penetrate through the first layer of the witness panel.	4	Glazing cracks. Fragments enter space and land on floor and impact a vertical witness panel at a distance of no more than 10 ft. from the window at a height no greater than 2 ft. above the floor.
High Hazard	Glazing is observed to fracture and there are more than ten perforations in the area of a vertical witness panel located 3 m (120 in.) from the interior face of the specimen and higher than 0.5 m (20 in.) above the floor or there are one or more perforations in the same witness panel area with a fragment penetration into the second layer of the witness panel	5	Glazing cracks and window sys-tem fails catastrophically. Frag-ments enter space impacting a vertical witness panel at a dis-tance of no more than 10ft. from the window at a height greater than 2 ft. above the floor

Appendix 1 - Table 1. ASTM Hazard Ratings and GSA Performance Conditions

Test Apparatus

The dynamic tests of the windows were conducted in BakerRisk's large shock tube. BakerRisk's shock tube is a test apparatus that consists of two major sections, a driver section and an expansion section. Blast pressures are generated when a rupture diaphragm placed between the two sections fails due to pressure in the driver section. A shock wave then travels down the expansion section and loads the test specimen at the end of the expansion section. In this particular test series, the driver was baffled to reduce the effects of reloading by reflections that exist in the shock tube. A photograph of the shock tube is shown in Appendix 1 - Figure 1.

The shock tube has an 8-foot square target area. The test specimens were 66.5 inches wide and 92.5 inches tall and were mounted such that the specimen was centered in the target area of the shock tube. An 8-foot wide by 10-foot deep room was placed behind the window specimens with a witness panel mounted to the back wall of the room. A photograph illustrating the typical mounting of a window specimen is shown in Appendix 1 - Figure 2. The witness room behind the window was used to allow determination of the ASTM Hazard Ratings and GSA Performance Conditions for each test. Appendix 1 - Figure 3 graphically depicts the ASTM Hazard Rating System. Appendix 1 - Figure 4 graphically depicts the GSA Performance Condition rating system.



Appendix 1 - Figure 1. Photograph of BakerRisk Large Shock Tube

BakerRisk Project No. 01-00750-002-00 September 8, 2004



Appendix 1 - Figure 2. Mounted Specimen in Shock Tube



Appendix 1 - Figure 3. Illustration of ASTM Hazard Rating System



Side view schematic of criteria

Appendix 1 - Figure 4. Illustration of GSA Performance Conditions

Active Instrumentation

The applied test load was measured in the test using three dynamic pressure transducers. The transducers were located on the sidewalls and floor of the shock tube very near the target face in order to record the applied pressure data. Baseline tests have been performed with a rigid plate mounted over the shock tube target area and an additional pressure transducer mounted at the center of the plate. These baseline tests were performed to determine the shock tube configuration required to deliver specific loads for various threats and to serve as proof that the side and floor-mounted transducers record loads similar to that recorded by the center mounted transducer. The typical variation between transducer readings is approximately 5%. Another dynamic pressure transducer was fielded in the sidewall of the witness room, five feet behind the window specimen, to measure any blast pressure entering the protected space.

The data from the pressure transducers were recorded using a LeCroy - 6810, 16-channel 12-bit waveform digitizer that is capable of sampling rates up to 5 Mhz; however, a 1 Mhz sample rate was used for these tests. The voltage signals from the transducers were conditioned using a PCB-483B07 multipurpose 12-channel amplifying power unit. Recorded data was saved to computer disk for data plotting and interpretation. High-speed video, normal video, and digital still photography were also used to document the tests. Video and photographic data accompanies this report on CD. Several views were recorded using high-speed video cameras at different times during the tests. In all cases, an overall view of the window was recorded with normal and high-speed video. Other high-speed video views included a close-up view of the intermediate horizontal members to document movement of the member or of the member connections.

APPENDIX 2 DETAILED TEST DATA

BakerRisk Project No. 01-00750-002-00 September 8, 2004

Test UA5

United States Aluminum Window Testing

Gauge Number Serial Type Full Scale Voltage (volts) Offset Voltage (volts) Conditioner Gain Peak Pressure Maximum Impulse Dura 1 102M196 18619 100.1 4 -1 1 4.3 32.0 19 2 102M196 18620 94.31 4 -1 1 4.1 32.6 17 3 102M196 21227 99.82 4 -1 1 0.1 0.9 15 5 353B18 60248 10.53 10 -2 0.5 1.56 19.6 7 Average Airblast Data 4.3 32.4 19 9 11	Test Name Driver Leng RWE	UA5 jth 24"	60	Test Date Driver Press	6/24/2004 sure	18	psi	Tempera Ambient Witness R At Glass S	ature Informa oom Interior urface	tion (°F) 82 85 87
1 102M196 18619 100.1 4 -1 1 4.3 32.0 19 2 102M196 18620 94.31 4 -1 1 4.1 32.6 17 3 102M196 21227 99.82 4 -1 1 4.4 32.5 20 4 102M196 21225 103 4 -1 1 0.1 0.9 15 5 353B18 60248 10.53 10 -2 0.5 1.56 19.6 6 14 10.1 0.9 15 7 10.6 <th>Gauge Number</th> <th>Gauge Type</th> <th>Serial Number</th> <th>Sensitivity</th> <th>Full Scale Voltage (volts)</th> <th>Negative Offset Voltage (volts)</th> <th>Conditioner Gain</th> <th>Peak Pressure</th> <th>Maximum Impulse</th> <th>Duration</th>	Gauge Number	Gauge Type	Serial Number	Sensitivity	Full Scale Voltage (volts)	Negative Offset Voltage (volts)	Conditioner Gain	Peak Pressure	Maximum Impulse	Duration
2 102M196 18620 94.31 4 -1 1 4.1 32.6 17 3 102M196 21227 99.82 4 -1 1 4.4 32.5 20 4 102M196 21225 103 4 -1 1 0.1 0.9 15 5 353B18 60248 10.53 10 -2 0.5 1.56 19.6 6 7 <td>1</td> <td>102M196</td> <td>18619</td> <td>100.1</td> <td>4</td> <td>-1</td> <td>1</td> <td>4.3</td> <td>32.0</td> <td>19.5</td>	1	102M196	18619	100.1	4	-1	1	4.3	32.0	19.5
3 102M196 21227 99.82 4 -1 1 4.4 32.5 20 4 102M196 21225 103 4 -1 1 0.1 0.9 15 5 353B18 60248 10.53 10 -2 0.5 1.56 19.6 6 19.6 7 19.6 8	2	102M196	18620	94.31	4	-1	1	4.1	32.6	17.4
4 102M196 21225 103 4 -1 1 0.1 0.9 15 5 353B18 60248 10.53 10 -2 0.5 1.56 19.6 6 19.6 7 <td>3</td> <td>102M196</td> <td>21227</td> <td>99.82</td> <td>4</td> <td>-1</td> <td>1</td> <td>4.4</td> <td>32.5</td> <td>20.1</td>	3	102M196	21227	99.82	4	-1	1	4.4	32.5	20.1
5 353B18 60248 10.53 10 -2 0.5 1.56 19.6 6 7 1	4	102M196	21225	103	4	-1	1	0.1	0.9	15.7
6 Image: Airblast Data 4.3 32.4 19 9 Image: Airblast Data 4.3 32.4 19 9 Image: Airblast Data 4.3 32.4 19 10 Image: Airblast Data 4.3 32.4 19 11 Image: Airblast Data 4.3 32.4 19 12 Image: Airblast Data Image: Airblast	5	353B18	60248	10.53	10	-2	0.5	1.56		19.6
7 Average Airblast Data 4.3 32.4 19 9 Average Airblast Data 4.3 32.4 19 9 Image: Airblast Data 4.3 32.4 19 10 Image: Airblast Data Image: Airblast Data 4.3 32.4 19 10 Image: Airblast Data Image: Airblast Data </td <td>6</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	6									
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9 Image: Constraint of the specime and the exterior layer of glass of the laminated lite was cracked. No glass dusting or any other debris was observed on the protected side of the window. No apparent damage framing members was observed. Less than 1/16-inch deflection was measured for the vertical mullion. Video Time Offset 0 msec 10 Image: Video Time Offset 0 msec Image: Video Time Offset 0 msec 11 Image: Video Time Offset 0 msec Image: Video Time Offset Image: Video Time Offs	8					Averag	e Airblast Data	4.3	32.4	19.0
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15 Window Description Window Description United States Aluminum Series BR604 Blast Resistant Glazing System in an 8-foot by 8-foot window wall configuration w door as shown in drawings labeled USA-2774, Sheets 1 through 15, dated 1/14/04. Response Description Only the large glass pane was fractured by the applied load. The exterior lited fracture and the fragments fell on the non-protected side of the specimen, and the exterior layer of glass of the laminated lite was cracked. The interior lite was uncracked. No glass dusting or any other debris was observed on the protected side of the window. No apparent damag framing members was observed. Less than 1/16-inch deflection was measured for the vertical mullion.	14									
16 Window Description United States Aluminum Series BR604 Blast Resistant Glazing System in an 8-foot by 8-foot window wall configuration w door as shown in drawings labeled USA-2774, Sheets 1 through 15, dated 1/14/04. Response Description Only the large glass pane was fractured by the applied load. The exterior lited fracture and the fragments fell on the non-protected side of the specimen, and the exterior layer of glass of the laminated lite was cracked. The interior lite was uncracked. No glass dusting or any other debris was observed on the protected side of the window. No apparent damag framing members was observed. Less than 1/16-inch deflection was measured for the vertical mullion.	15									
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Pressure in Protected Space, Gauge 4



United States Aluminum Corp. (BR604 Blast Resistant Glazing System) Shock Tube Testing of Windows for Blast Resistance Certification



Pre-test Photographs of Test Specimen



Post-test Photographs of Test Specimen

BakerRisk Project No. 01-00750-002-00 September 8, 2004



Dusting Debris on Floor of Witness Room



Post-test Photograph of Witness Panel

BakerRisk Project No. 01-00750-002-00 September 8, 2004

Test UA6

United States Aluminum Window Testing

Test Name Driver Leng RWE	UA6 th 24"	60	Test Date Driver Press	6/24/2004 sure	18	psi	Tempera Ambient Witness R At Glass S	ature Informat oom Interior urface	tion (°F) 87 90 92
Gauge Number	Gauge Type	Serial Number	Sensitivity	Full Scale Voltage (volts)	Negative Offset Voltage (volts)	Conditioner Gain	Peak Pressure	Maximum Impulse	Duration
1	102M196	18619	100.1	4	-1	1	4.4	32.9	20.1
2	102M196	18620	94.31	4	-1	1	4.3	32.9	17.3
3	102M196	21227	99.82	4	-1	1	4.4	33.1	19.9
4	102M196	21225	103	4	-1	1	0.1	1.0	16.0
5	353B18	60248	10.53	10	-2	0.5	0.95		20.5
6									
7									
8					Averag	e Airblast Data	4.4	33.0	19.1
9									
10				1	Vid	eo Time Offset	0	msec	
11	1								
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	-			Window	Descriptio	n			
United State	s Aluminum	Series BR6	04 Blast Res	sistant Glazir	ng System i	n an 8-foot by 8-	foot window	wall configura	ation with
door as show	wn in drawing	gs labeled l	JSA-2774, Sł	neets 1 throu	ugh 15, date	ed 1/14/04.		-	
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Applied Load, Gauge 3



Pressure in Protected Space, Gauge 4



Accelerometer Data, Gauge 5

United States Aluminum Corp. (BR604 Blast Resistant Glazing System) Shock Tube Testing of Windows for Blast Resistance Certification



Pre-test Photographs of Test Specimen



Post-test Photographs of Test Specimen

BakerRisk Project No. 01-00750-002-00 September 8, 2004



Dusting Debris on Sill of Window



Dusting Debris on Floor of Witness Room

BakerRisk Project No. 01-00750-002-00 September 8, 2004



Post-test Photograph of Witness Panel (Impact in Witness Panel occurred in Test UA3)

Test UA7

United States Aluminum Window Testing

Test Name Driver Lenç	UA7 jth	60	Test Date Driver Press	6/24/2004 sure	18	psi	Tempera Ambient Witness R	ature Information	tion (°F) 91 94	
RWE	24"						At Glass S	urface	96	
Gauge Number	Gauge Type	Serial Number	Sensitivity	Full Scale Voltage (volts)	Negative Offset Voltage (volts)	Conditioner Gain	Peak Pressure	Maximum Impulse	Duration	
1	102M196	18619	100.1	4	-1	1	4.2	31.6	19.9	
2	102M196	18620	94.31	4	-1	1	4.3	31.9	17.0	
3	102M196	21227	99.82	4	-1	1	4.6	32.0	19.7	
4	102M196	21225	103	4	-1	1	0.1	1.3	20.1	
5	353B18	60248	10.53	10	-2	0.5	1.56		19.0	
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7				<u> </u>	<u> </u>	<u> </u>			<u> </u>	
8			'	L	Averag	e Airblast Data	4.4	31.8	18.9	
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10		───	·	├ ────′	├ ────'	 '	┟ ────┤	İ	l	
10		L	'	Window	Descriptic	<u> </u>		L	L	
Linited State		Series BR(604 Blast Res	villuow	na System	n an 8-foot by 8	foot window		ation with	
door as sho	wn in drawin	igs labeled I	USA-2774, Sł	neets 1 throu	ugh 15, date	ed 1/14/04.		wan connigare		
				Response	e Descripti	on				
The test spe	The test specimen was undamaged by the applied load. No glass breakage or permanent frame deformations were									
observed. T	observed. The door rebounded open in the test, but remained completely operational after the test.									



23



Pressure in Protected Space, Gauge 4



24

United States Aluminum Corp. (BR604 Blast Resistant Glazing System) Shock Tube Testing of Windows for Blast Resistance Certification

BakerRisk Project No. 01-00750-002-00 September 8, 2004



Pre-test Photographs of Test Specimen



Post-test Photographs of Test Specimen

APPENDIX 3 WINDOW SPECIMEN DETAILS





28























APPENDIX 4 GSA DOCUMENT

US General Services Administration (GSA) Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings¹

This standard is a modified version of ASTM 1642-96. Modifications have been made to reflect the GSA's needs. The tests performed for GSA and by contractors for GSA since 1996 have used this protocol. The tests have been performed in enclosed concrete reaction structures. Test charges have nominally been 500 LB of TNT equivalent.

INTRODUCTION

Historical records show that fragments from glazing that has failed as the result of intentional or accidental explosions present a serious threat of personal injury. Glazing failure also allows blast pressure to enter the interior of buildings thus resulting in additional threat of personal injury and facility damage. These risks increase in direct proportion to the amount of glazing used on the building façade. This test method addresses only glazing and glazing systems. It assumes that the designer has verified that other structural elements have been adequately designed to resist the anticipated airblast pressures.

1. Scope 1.1 This test method sets forth procedures for the evaluation of the resistance of glazing or glazing systems against airblast loadings.

1.2 This test method allows for glazings to be tested with or without framing systems.

1.3 This test method is designed to test all glazings and glazing systems, including those fabricated from glass, plastic, glass-clad plastics, laminated glass, glass/plastic glazing materials, and film-backed glass.

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. See Section 8 for specific hazards statements.

2. Referenced Document

2.1 GSA Security Document:

GSA Security Criteria, Final Working Version, October 8, 1997.

2.2 ISC Security Criteria:

ISC Security Criteria for New Federal Office Buildings and Major Renovation Projects, The Interagency Security Committee, May 28,2001.

2.3 ASTM Standard:

E 997 Test Method for Structural Performance of Glass in Exterior Windows, Curtain Walls, and Doors Under the Influence of Uniform Static Loads by Destructive Methods²

3. Terminology

3.1 Definitions:

3.1.1 ambient temperature - $75 \pm 25^{\circ}$ F.

3.1.2 blast mat-a steel or concrete pad upon which high explosive may be detonated to reduce the incidence of ejecta.

3.1.3 effective positive phase duration (T)-the duration of an idealized triangular positive phase reflected airblast pressure time history, having an instantaneous rise to the measured P, with a linear decay to ambient, such that the impulse of the idealized pressure time history equals I of the measured positive phase of the reflected airblast time history

3.1.3.1 Discussion-The idealized triangular airblast wave is considered to provide a reliable standard measure of the positive phase airblast intensity.

3.1.4 glazing-transparent windows, doors, or other panels. for materials used

3.1.5 glazing system-the assembly comprised of the glazing, its framing system, and anchorage devices.

3.1.6 peak positive pressure (P)-the maximum measured positive phase reflected airblast pressure, pounds per square inch.

3.1.7 positive phase impulse (I)-the integral of the measured positive phase reflected airblast pressure time history, pounds per square inch-milliseconds (more

correctly called the specific positive phase impulse). 3.1.8 reflected airblast pressure—the pressure increase that a surface, oriented other than parallel to the line from the detonation point to the surface, experiences due to the detonation of a high explosive charge.

3.1.8.1 Discussion-The reflected airblast pressure time history, as measured at a point on the surface, consists of two separate phases. The positive phase is characterized by a nearly instantaneous rise to a maximum pressure followed by an exponential decay to ambient pressure. In the negative phase, which follows immediately the positive phase, the pressure decreases below ambient for a period of time before returning to ambient.

3.1.9 simply supported glazings—glazings supported in accordance with Test Method E 997 with the edges of the glass extending to a minimum of 1/8 in. beyond the neoprene supports.

3.1.10 test director-the individual identified by the independent testing laboratory as being responsible to complete the specified tests as required and to document the results in accordance with this test method.

4. Summary of Test Method

4.1 This test method prescribes the required apparatus, procedures, specimens, and other requirements necessary to

¹This test method is under the jurisdiction of ASTM Committee F-12 on This is include the substitution of the strike Committee F-12 and Security Systems and Equipment and is the direct responsibility of Subcommittee F12.10 on Systems, Products, and Services. Current edition approved March 10, 1996. Published July 1996. Originally published as F1642 – 95. Last previous edition F 1642 – 95. ³Annual Book of ASTM Standards, Vol. 04-07.

determine the airblast resistance capacity of a glazing or glazing system.

5. Significance and Use

5.1 This test method provides a structured procedure to establish the airblast resistance capacity and fragmentation characteristics of glazings and glazing systems. Such evaluations will allow comparison of the relative benefits of the glazings and glazing systems on mitigating hazards to building occupants. Knowing the airblast resistance eapacity reduces the risk of personal injury and facility damage.

5.2 The airblast resistance capacity for a glazing or glazing material does not imply that a single specimen will resist the specific airblast for which it is rated with a probability of 1.0. The probability that a single glazing or glazing construction specimen will resist the specific airblast for which it is rated increases proportionally with the number of test specimens that successfully resist the given level of airblast.

6. Performance Criteria

6.1 The performance of the glazing or glazing system shall be rated according to the GSA performance criteria as illustrated in the following figure and table based on the fragment hazard generated by the test specimen. The tested article is given a fragment hazard rating based on the location of fragments in and around the test reaction structure. The GSA scheme was adopted from a similar scheme developed in the United Kingdom for rating the hazard from glazing fragmentation. A witness panel is required no more than 10 ft behind the window to survey fragment impacts.



Side view schematic of criteria

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

7. Apparatus

7.1 Test Facility—The test facility for qualifying a product shall consist of either a shock tube or an open-air arena. Subsequent development tests may use open-air explosives or shock tubes or both. Open-air arenas should be sited on clear and level terrain. The test facility shall be situated, and be of sufficient size, to accommodate the detonation of the required amount of explosives to provide the desired peak positive pressure and positive phase impulse. The test director shall ensure that potential environmental impact issues are determined and resolved prior to testing. The test director shall ensure that testing is conducted at ambient temperature in accordance with Section 3.1.1.

7.2 High Explosive (HE) Charge—A high explosive charge shall be used to generate the desired peak pressure and the positive phase impulse on the test specimen. The charge shall be hemispherical and detonated at ground level. Other charge configurations can be used. The effects of using other charge configurations must be accounted for and documented.

accounted for and documented. 73 Blast Mat-If there is a possibility likelihood of crater ejecta interfering with the test, the high explosive charge shall be placed on a blast mat. The decision to use a blast mat shall be at the discretion of the test director. 7.4 Test Frame—A test frame suitable for supporting glazings or glazing systems shall be used. Glazing tested without a specific framing system shall be support abframe that is attached to the test frame. If a glazing system is tested, the glazing system shall be mounted to the test frame in a manner that closely models the manner in which it will be mounted in the field. The test frame shall be capable of resisting the airblast with deflections that do not exceed L/360 along lines of support for the simple support subframe or the glazing system. The area immediately behind the test specimens shall be enclosed to prevent airblast pressure from wrapping behind the test specimens.

7.5 Simple Support Subframe—A subframe, attachable to the test frame, to support glazing in accordance with Test Method E 997.

7.6 Instrumentation:

7.6.1 Pressure Transducers-A minimum of two airblast pressure transducers shall be used on each test reaction structure to measure the reflected pressure for specimens tested in a face-on configuration and the incident pressure for specimens tested in a side-on orientation. That is, the pressure measured should be the pressure in direction of loading and response of the glazing. minimum of one interior pressure transducer is required in each test structure. If interior partitions are used to isolate interior pressure environments for the test specimens, an interior pressure transducer shall be used in each partitioned volume containing one or more test specimens. The airblast pressure transducers shall be capable of defining the anticipated airblast pressure history within the linear range of the transducer. The transducers shall have a rise/response time and resolution sufficient to capture the complete event.

7.6.2 Data Acquisition System (DAS)—The DAS shall consist of either an analog or digital recording system with a sufficient number of channels to accommodate the pressure transducers and any other electronic measuring devices. The DAS must operate at a sufficiently high frequency to record reliably the peak positive pressure. The DAS shall also incorporate filters to preclude alias frequency effects from the data.

7.6.3 Photographic Equipment—Photographic equipment shall be available to document the test. High Speed Photography (500 to 1000 frames per second), normal speed video, and still photography is recommended. 7.6.4 Temperature Measuring Device (TMD)—A TMD

shall be used to accurately measure glazing surface temperatures.

7.6.5 Witness Panels—Witness panels shall consist of a foam board with a thin aluminum sheet or paper to record fragment impacts. The witness panel shall be mounted no more than 10 feet from the pretest window location.

8. Hazards

8.1 Storage, handling, and detonation of high explosive material should be conducted in accordance with applicable state and federal statutes by experienced professionals.

9. Specimens

9.1 The test sponsor shall provide the test specimens. The number of specimens provided shall consist of the number of specimens to be tested. Extra samples should be prepared in case of breakage due to transportation and/or installation.

9.2 The test director shall ensure that the test specimens are handled and stored in compliance with manufacturer's instructions.

9.3 Each specimen shall be marked with the manufacturer's model and serial numbers and the date of manufacture.

9.4 Each specimen shall be marked clearly to indicate its proper orientation to the explosive charge to preclude improper installation in the test frame.

improper installation in the test frame. 9.5 To ensure proper support of glazing system test specimens, the test director shall obtain engineering information on anchoring details from the manufacturer.

10. Preparation of Apparatus and Specimens 10.1 Instrumentation:

10.1.1 At least two pressure transducers shall be installed on the test structure. The pressure transducers shall be flush with the outer surface of the test structure. The transducers should be located on the horizontal centerline of the test specimens at a distance from the edge of the test specimens not to exceed one half the shortest dimension of the specimen. Alternate locations may also be used.

10.1.2 The pressure transducers shall then be connected to the DAS and tested to verify proper operation.

10.2 Test Frames:

10.2.1 The test specimens shall be installed in the test frame. The face of the test frame with the test specimens installed shall be approximately a plane surface. No openings shall exist in this surface through which airblast pressure can infiltrate behind the test specimens. The area immediately behind the test specimens shall be enclosed to prevent airblast pressure from wrapping behind the test specimens.

10.3 Specimens:

10.3.1 The test director shall assign a number, and mark accordingly, each test specimen.

10.3.2 Thickness measurements of the glazing material should be made at each corner, 1 in. in from the edges, and recorded. Measurements of the lengths of the edges of the specimens shall be made and recorded.

10.4 Photography:

10.4.1 Prior to the test, a photographic record that adequately portrays the test specimens, the test frame, and the test configuration shall be made. This photographic record shall consist of still photographs and may include motion pictures or video.

10.4.2 If a photographic record of the response of the test specimens during the test is desired, high speed motion picture cameras or high speed video cameras, or both, shall be set up.

10.5 Witness Panels:

10.5.1 Witness panels shall be put in place to record spalling fragmentation from the test specimen.

11. Report

11.1 Upon completion of a test of glazing specimen(s), the test director shall report the results of the test. Report the following mandatory information:

11.1.1 Description of test glazing or glazing system specimens, including pertinent dimensions, construction, and glazing materials.

4

11.1.2 Complete description of framing.

11.1.3 Number of specimens tested. 11.1.4 Ambient temperature should be measured immediately prior to clearing the test range before the test.

11.1.5 Temperature of the glazing should be measured immediately prior to clearing the test range before the test.

11.1.6 Peak positive pressure should be measured from each reflected airblast pressure transducer on the reaction

structure supporting the test specimens. 11.1.7 Positive phase duration should be measured from each reflected airblast pressure transducer on the reaction structure supporting the test specimens.

 11.1.8 Positive phase impulse, I.

 11.1.9 The recorded airblast pressure history from each

pressure transducer.

11.1.10 Condition of the test specimens immediately following the test.

11.1.11 Damage to the witness panels. 11.1.12 Status of the specimens (that is, the performance condition according with 6.1.)

11.2 The test report shall contain the photographic record of the test setup in accordance with 10.4. In addition, the test report shall contain detailed photographs of each test specimen following the test. Each specimen shall be labeled in the post-test photographs to allow for clear identification.

11.3 If any motion picture records are made of the performance of the test specimens, such motion picture

records shall become part of the test report. 11.4 The original copy of the test report shall be furnished to the sponsor of the test. The test director shall keep a copy of the test report on file.

12. Precision and Bias

12.1 No statement is made concerning either the precision or bias of this test method since the result merely states the actual performance of a glazing or glazing system subjected to an airblast loading.

13. Keywords

13.1 airblast rating; effective positive phase duration; glazing; glazing systems; high explosive; peak positive pressure; positive phase impulse; airblast pressure.