ABS Consulting
RISK CONSULTING DIVISION

PENTAGON PROTECTION USA

Shock Tube Testing for Window Systems

March 2009
San Antonio, Texas

ABS Consulting Project Number 2127174

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Introduction

ABSG Consulting, Inc. (ABS Consulting) has conducted testing of window systems upgrades for Pentagon Protection USA (Pentagon Protection). The tests were conducted in accordance with testing protocol in ASTM F1642-04[1] and US General Services Administration (GSA)[2]. The windows consisted of single pane commercial windows retrofitted with four sided anchored film. The film anchorage system consisted of Pentagon Protection's Elite Glass Security Seal attachment with 3M ST1200 tape. The objective of the testing was to certify the performance of windows upgraded with Pentagon Protection's Glass Security Seal, when subjected to blast loads resulting from attack scenarios defined by the Unified Facilities Criteria (UFC)[3] and GSA. Testing was conducted at the ABS Consulting facilities in San Antonio, Texas, USA March 17-18, 2009.

Test Approach

Blast loads were applied using a "shock tube" as shown in Figure 1. This device uses a sudden burst of compressed air to create a blast pulse, which travels down the tube and is applied to the test specimen which is secured to the end of the tube. An enclosure (test cubicle) is attached to the end of the tube. The blast load creates a specified positive blast pressure and impulse on the test specimens. Negative phase blast loads may occur but the system is not designed to produce a negative pulse typical of a high explosive load. Testing commenced with blast loads designed to meet the various threat – standoff combinations as described in the UFC. The same blast pressure was applied to each specimen.

[1] ASTM Standard, F 1642-04, "Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings," ASTM Book of ASTM Standards, Vol. 04.07, March 2004.
[2] US General Services Administration (GSA), GSA-TS01-2003, "Standard Test Method for Glazing and Glazing Systems Subject to Dynamic Overpressure Loadings," GSA, January, 2003.
[3] Department of Defense (DoD), Unified Facilities Criteria (UFC) UFC4-010-01, "DoD Minimum Antiterrorism Standards for Buildings," DoD, October 2003.

Figure 1. ABS Consulting Shock Tube Apparatus

Test Specimens

Pentagon Protection provided the window systems fully assembled with a four sided anchored film system pre-installed. ABS Consulting personnel measured framing, glazing and film dimensions and confirmed glass type for each window assembly. The window glazing for each of the tests consisted of annealed monolithic glass in a single ¼-inch pane. 3M Ultra 6-mil fragment retaining film was bonded to the interior face of the windows. The film was anchored to the frame using a proprietary product developed by Pentagon Protection USA called Elite "Glass Security Seal" (GSS). This anchoring system consists of three attachment legs as detailed in Figure 2. One was inserted in place of the interior dry glazing gasket. The remaining two were bonded to the frame and film using 3M ST1200 tape.

Window frame assemblies were rigidly supported along the head and sill of the window frame. Steel angles and plates were used to support the framing to prevent lateral displacement. This configuration simulates a fully anchored window system installed in the field. Figure 3 shows a typical Pentagon Protection test window mounted in the ABS shock tube. A close-up view of the shock tube mounting restraint is shown in Figure 4.

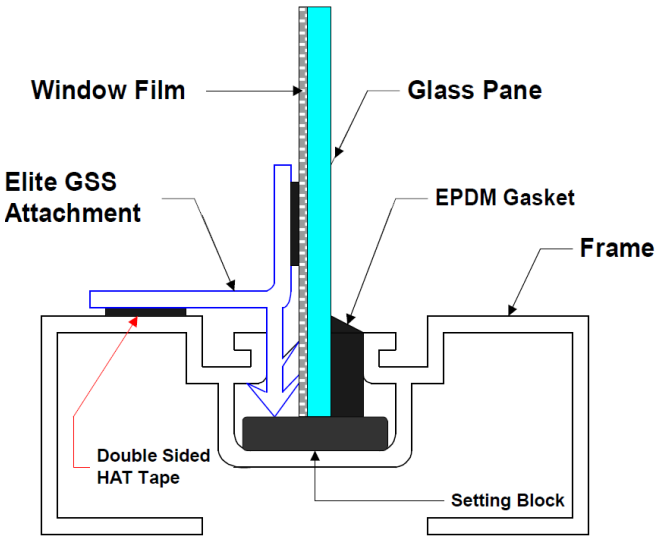

Figure 2. GSS Film Anchoring Detail

Figure 3. Window Mounted in Test Fixture

Figure 4. Close-up View of Mounting Restraint

Test Fixtures

The test enclosure, nominally 10 feet deep, 10 feet wide and 10 feet tall, was placed flush with the end of the tube. A bulkhead plate on the end of the tube prevented blast pressures from wrapping around the structure and reaching the back side of the window. This represents a typical window installation on an exterior wall. A witness panel was provided on the back wall to detect the impact of glass shards. Composition of the witness panel was in accordance with ASTM-1642.

Five dynamic pressure sensors (gauges 1-5) measuring applied pressure were mounted on the shock tube bulkhead facing the oncoming blast wave, immediately adjacent to the test specimen (see Figure 5). A single pressure sensor (gauge 6) was also mounted inside the test cubicle to measure pressure changes. Dynamic pressure sensors were selected based on rise time and frequency response and calibrated for a 0-10 psi peak pressure range. Pressure waveforms were recorded by a Yokagawa digital data acquisition system sampling at a minimum of 1000 kHz.

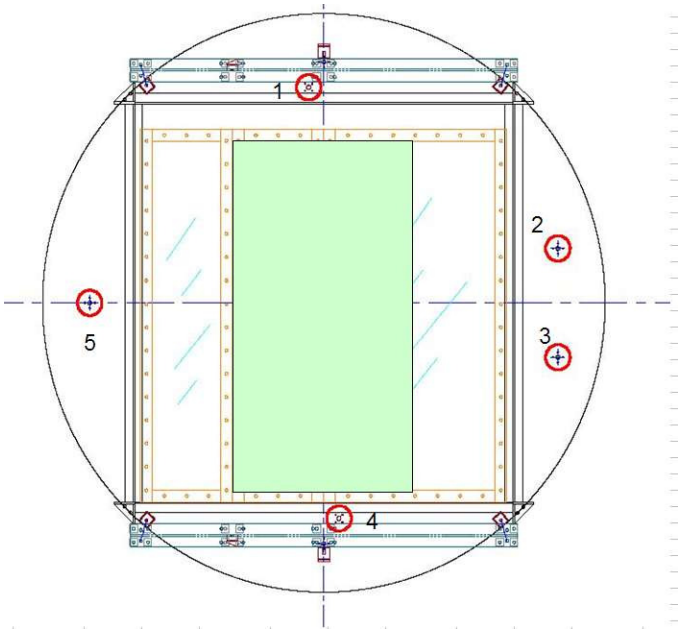

Figure 5. Pressure Gauge Locations

Test Procedure

Testing was conducted in accordance with ASTM F1642-04 and the GSA "Standard Test Method for Windows and Glazing Systems Subject to Dynamic Overpressure Loadings" dated January 1, 2003. The objective of the testing is to determine the performance of the windows as defined in Table 2.1 and 2.2 in the UFC. Blast loads varied by test and were selected to encompass specified charge weights and standoffs as defined by the UFC and GSA. Actual applied loads are included in the appendices. Window performance conditions were assigned in accordance with the performance criteria in ASTM 1642 and the GSA test protocol.

Ambient and glass temperatures were recorded at 30 minutes and 5 minutes prior to each test. Photographs were taken of test specimens and the test setup prior to and following each test to document window performance. Appendix B contains photographs taken of the test specimen throughout the testing. Normal speed (30 pps) and high speed video (1000 pps) were also recorded for each test. The normal speed video is submitted with this report.

Following each test, glass fragments were collected and the unified dimensions of fragments projected into the test cubicle were determined for classification per the ASTM 1642 protocol. Fragments striking and embedding in the witness panel were collected and documented. Frame deformations were recorded and performance of framing was documented. Hazard Ratings and Performance Conditions for each test item were assigned and recorded in accordance with ASTM 1642-04 and the GSA criteria as shown in Figure 6 and Figure 7, respectively.

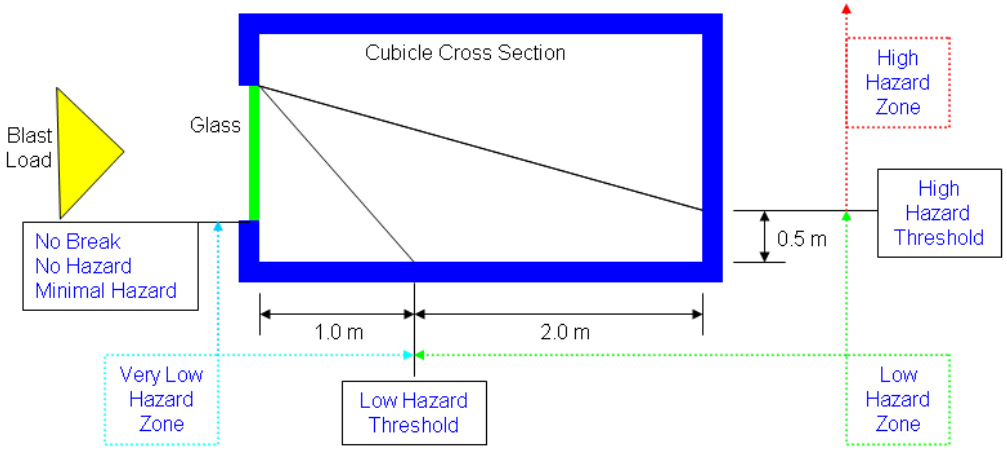

Figure 6. ASTM F1642-04 Performance Criteria

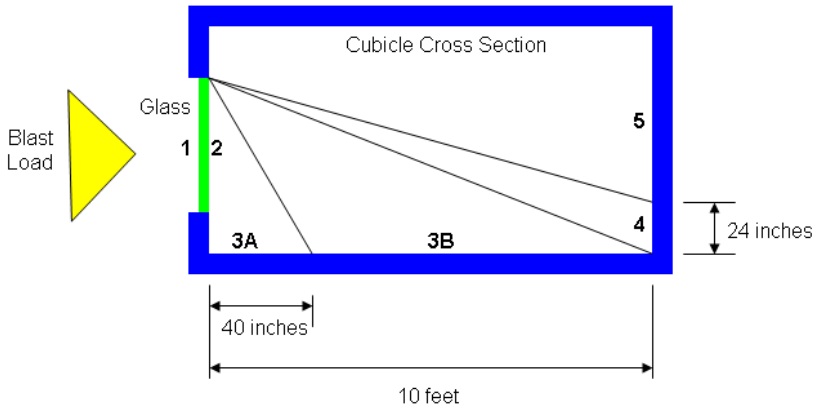

Figure 7. GSA Performance Conditions

Results

Appendix A contains a data sheet for each test specimen. The data sheet includes the following information:

- Detailed description of the unit including the frame, glazing, and attachment into the shock tube.
- Description of the test conditions.
- Detailed description of the performance condition for both ASTM and GSA criteria.
- A pretest and post test photograph.
- A graph of the applied blast history.

Appendix B contains a photographic log for each test. Appendix C summarizes the loads and window responses.

All tests were conducted with the Elite GSS attachment system installed on all 4-sides. Each window was filmed with 3M Ultra 6-mil film. The applied load was the pressure and impulse generated by the UFC Charge Weight II at 82-ft of standoff. The anchoring system retained the glass fragments and resulted in an ASTM certification of "Minimal Hazard".

ASTM certification resulting from shock tube tests performed for this project is listed below. Three samples of the window retrofit system were tested in accordance with the ASTM -1642 test method to permit certification.

Minimal Hazard
Elite GSS with 3M Ultra 6-mil film
(3M ST1200 Tape)

Approved:

Jerry Collinsworth
Lead Engineer
Extreme Loads and Structural Risk
San Antonio, Texas