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featuring:



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Protective Glazing Council International



WEBINAR
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Terrorist Attacks
Let Us Not Forget



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Blast Hazard Mitigation

Designing For Blast
UFC 4-010-01
(DOD Standard 10)

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Blast Hazard Mitigation

Designing for Blast Loads

- Blast Windows and Doors
- UFC-DOD Requirements
- Window Performance
- Charge Weights and Pressures
- DOD-UFC 4-010-01 2003 & 2007
- Glass Design
- Frame Design
- Anchors and Fasteners
- Overall Requirements for Design
- GSA, DOD Testing and Certification
- No Short Cuts, LIFE Safety**

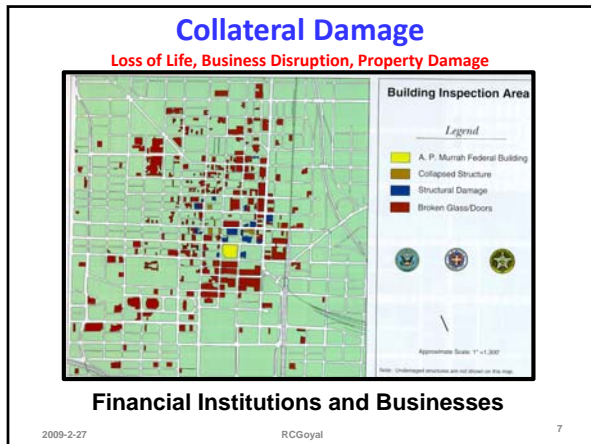
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Damage From Blast Wave

Blast pressure of over 15 PSI can rupture ear drums and collapse the lungs or crush the skull.

Oklahoma federal building bomb blast in 1995 was in the order of 4000 PSI.

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- ### Blast Wave
- Extreme Rapid Release of Energy
- Peak Pressure
 - Occurs instantaneously
 - Dissipates exponentially
 - Positive Phase Duration
 - Time the pressure acts positively on an object
 - Impulse (Cumulative Pressure over Time)
 - Area under pressure-time curve
 - Measure of the total energy acting on an object
 - Negative Phase Duration
 - Rush of air to fill the void behind the blast wave
 - Pulls the product and fragments to the exterior
- Energy is inversely proportional to distance cubed
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- ### Types of Blast Hazards
- Primary Fragments
 - Flying Glass
 - Fly at speeds greater than 200 ft/second (136 mph)
 - Flying Building Debris
 - Secondary Fragment
 - Shrapnel
 - Rocks, Dirt, Etc.
 - Structural Collapse/Damage
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- ### Designing Structures to Resist Explosions and Natural and Intentional Harm
- Terrorist bomb threats
 - Accidental explosions (Refineries)
 - Forced entry
 - Hurricane, Typhoon, Wind, Seismic
 - Air, Water, Structural
 - Thermal, Acoustical
 - RFI, Radio Frequency Interference
 - Ballistics
 - FER, Forced Entry Resistance
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- ### Threat Assessment
- Threats: suitcase, backpack, small car, large truck, semi-truck, etc.
 - The most effective protection is to keep the explosives away from the building
 - Bollards
 - Parking control
 - Traffic control (**Controlled Parameter**)
 - Parking lot locations
 - Physical security/surveillance
- Impact of the threat on the building & people
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Charge Weight and Standoff

- Charge Weight
 - Amount of explosives used (*TNT equivalent*)
- Standoff
 - Distance from *point of detonation*
- How do they relate
 - As charge weight increases, peak pressure increases
 - Pressure decreases *exponentially* with standoff distance
 - As standoff distance increases, peak pressure decreases, and **duration & impulse changes**

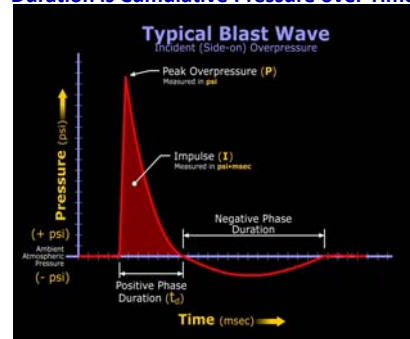
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Pressure/Duration/Impulse

Duration is Cumulative Pressure over Time



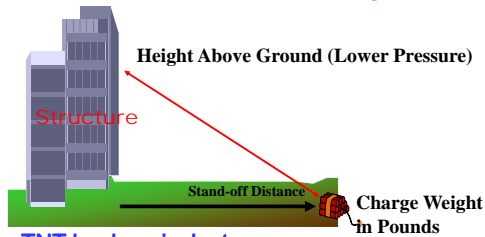
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Identifying a Threat Level

Mid to High Rise Buildings



- TNT load equivalent
- Create Larger Standoff distance
- Height of glazing

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DESIGNING STRUCTURES TO RESIST EXPLOSIONS



US Embassy, Moscow, Russia

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Blast Resistant Glazing Standards & Specifications

- Industry Standards
 - ASTM F1642-04
 - AAMA 510-06
 - ISO16933 & ISO16934
- Government Standards
 - General Services Administration (GSA)
 - DOD-UFC 4-010-01 & 2
 - ASTM E1300 and ASTM F 2248
- Other Industry Standards

Protective Glazing For Blast Loads

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ISO 16933 & 16934

- Explosion Resistant Security Glazing



- Test and Classification for Arena Testing ISO16933
- Test and Classification for Shock Tube Testing ISO16934

Laminated architectural glass (LAG) provides time to for assessment and action.

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ASTM F1642 & AAMA 510

- **ASTM F1642-04 - Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings.**
- **AAMA 510-06 – Guide Specifications and certification for blast hazard mitigation of fenestration systems based on standard test sizes.**

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Energy & Sustainability

- Building code requirements for U value and solar heat gain affect security glazing
- **High performance coatings utilized**
- Insulating glass units with Warm Edge spacer provide better thermal performance
- **Glazing provides day lighting and views**

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UFC 4-010-01	Standoff Distance 33 Feet		Standoff Distance 82 Feet	
	Rating (PSI)	Impulse (PSI-MSEC)	Rating (PSI)	Duration (PSI-MSEC)
10	10.1	24.3	2.6	9.2
20	15.7	33.9	3.5	14.8
55	33.6	81.7	5.8	29.7
100	56.6	124.7	7.9	44.9
200	109.5	206.8	11.9	72.7
500	275	408.6	22.3	138.7

Data generated by ATBLAST By ARA

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Proposed Changes to ASTM F2248

High Pressure – Low Impulse

- ¼" Lami w/0.060" PVB
- Minimal Hazard
- **P = 8.9 psi**
- **I = 42 psi-msec**
- ¼" screws at four jamb corners – screws bending - tearing in frame wall at connections pushing limits of ASTM F2248



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Proposed Changes to ASTM F2248

Low Pressure-High Impulse

- ¼" Lami w/0.060" PVB
- High Hazard – Blowout, frame hit wall, folded in ½, glazing retained, no tears in PVB.
- **P = 7.7 psi**
- **I = 71 psi-msec**
- HazL rupture threshold
- ¼" screws at four jamb corners – failed in bending / shear



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ASTM F 1642-04

- Procedures for the evaluation of hazards of glazing or glazing systems compared to specific air blast loading
- Provides a rating system to evaluate the hazards of the window for a specified blast loading
- Testing Requirements
 - Testing Facilities
 - Testing Layout
 - Reporting Processes
 - Blast Level Scaling



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ASTM F 1642 Test Method Hazard Classifications

1	No break	Glazing does not fracture and no damage to the framing system
2	No hazard	Glazing fractures but is fully retained in the frame
3	Minimum hazard	The glazing fractures and is not fully retained in the frame
3a	Very Low Hazard	The glazing fractures and is not fully retained in the frame
3b	Low Hazard	The glazing fractures and is mostly retained in the frame
4	High Hazard	Glazing fails catastrophically

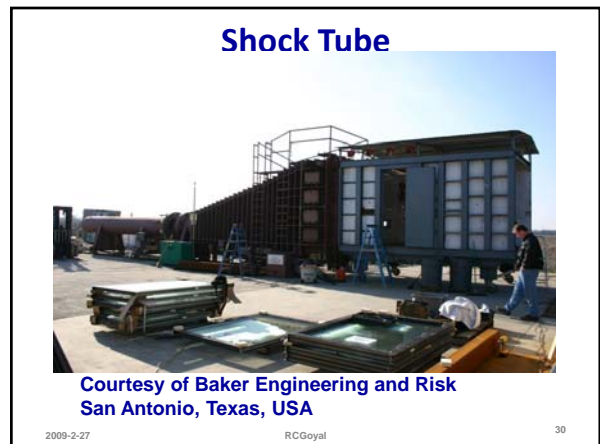
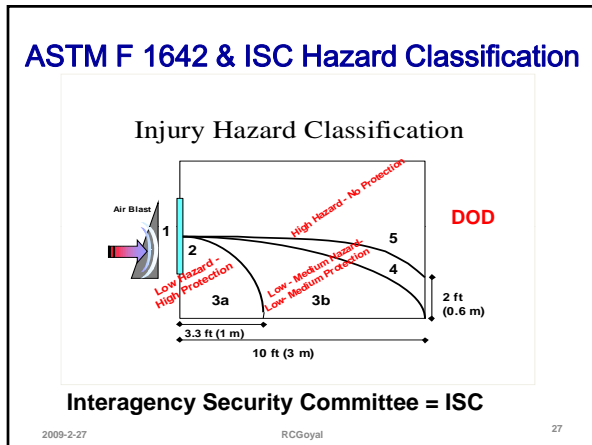
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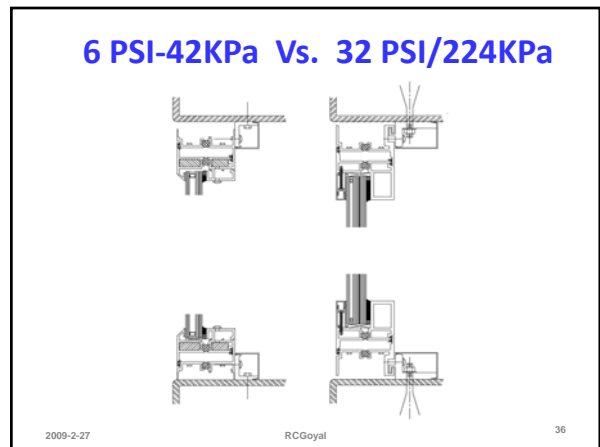
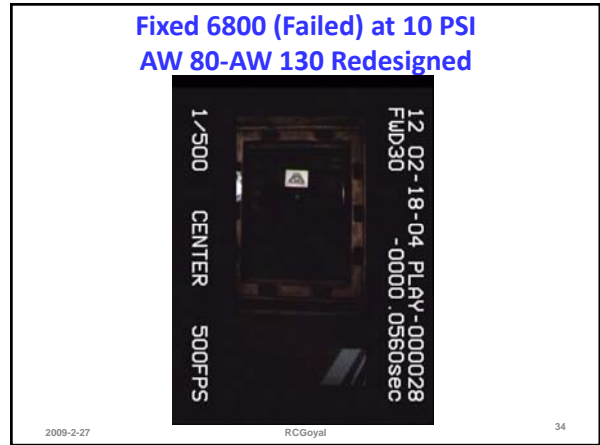
GSA/ISC- Interagency Security Committee

Condition	Description	Glazing Response
1	Glass not cracked, fully survived and/or fully retained by frame and no glass fragments either inside or outside structure.	None
2	Glass may be cracked but is retained in frame.	No significant fragments. Dusting or very small fragments near sill or on floor acceptable
3a	Glass failed and not fully retained in frame.	Yes - Lands on floor <u>no more</u> than 3.3 feet from window.
3b	Glass failed and not fully retained in frame.	Yes - Lands on floor <u>no more</u> than 10 feet from window.
4	Glass failed and not fully retained in frame.	Yes - Lands on floor more than 10 feet from window and impacts a vertical surface located not more than 10 feet behind window no higher than 2 feet above floor level.
5	Glass fails catastrophically	Yes - Lands on floor <u>more than</u> 10 feet from window and impacts a vertical surface located not more than 10 feet behind window above a height of 2 feet.

Conditions to evaluate the hazards under blast loading to determine how well the window performed

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Basis of Protection

Laminated Glass is
.....The Key to Protection

In minimizing hazardous flying debris,
....80-90% of injuries can be prevented.

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UFC 4-010-01 Standard 10

- At a stand off distance of 82 feet (25 M) mandates a low level of protection per UFC 4-010-01.
- At a standoff distance of 33 feet (10 M) mandates a blast mitigation at higher levels.
- ✓ Ask for Charge Weight and Standoff Distance

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UFC 4-101-01 Standard 10- LOP

DoD Levels of Protection for Explosive Events

Level of Protection	Potential Building Damage	Potential Door and Window Hazards	Potential Injury
Below AT Standards	Severe Damage. Progressive collapse likely. Damaged space unusable.	Doors & windows fail catastrophically resulting in lethal hazards.	Majority of people in collapsed area suffer fatalities. Potential fatalities outside collapsed area.
Very Low (minimum-inhabited buildings)	Heavy Damage. Onset of structural collapse. Damaged space unusable.	Glazing fractures & doors fail, propelled into building with potential for serious injury.	Majority of people in damaged area seriously injured. Possibility of fatalities. People in other areas moderately injured.
Low (minimum-primary gathering)	Moderate Damage. No collapse. Damaged space unrepairable and unusable.	Glazing fractures, may leave frame, but at reduced velocity for lesser injuries. Doors fail and rebound off frames.	Majority of people in damaged area moderately injured. Fatalities unlikely. People in other areas may have minor injuries.

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UFC 4-101-01 Standard 10 (LOP)

Levels of Protection (continued)

Level of Protection	Potential Building Damage	Potential Door and Window Hazards	Potential Injury
Medium	Minor Damage. Damaged space repairable to full functionality.	Glazing fractures, but remains in frame. Doors stay in frame, but will not be reusable.	People in damaged area potentially suffer minor injuries. People in other areas may receive superficial injuries.
High	Minimal Damage. No permanent deformation. Damaged space immediately usable.	Glazing will not fracture. Doors will be reusable.	Only superficial injuries likely.

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Lower the Protection = Higher the Hazard

Level of Protection vs. Hazard Level Other Known Standards

DoD LOP	Hazard Levels			
	UK	GSA	DoS	ASTM F1642 & DoD
VL	Low Hazard	4 & 3b	4	Low Hazard
Low	Minimal Hazard	3a	3	Very Low Hazard
Med	Minimal Hazard	2	2	Minimal Hazard
High	No Break	1	1	No Break & No Hazard

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UFC 4-010-01 Oct.2003 Criteria

- Must be structurally glazed if bite is 3/8" or the product must have a minimum 1" glazing bite.
- B-3.1, (Standard for windows, skylights, and glazed doors) Applies to products up to 32SF.
- B-3.1.2.1, (Frame member design) Equivalent static pressure of 1PSI. Max. Deflection L/60
- Simple 1 PSI (7kpa) static pressure product will not meet this criteria, Must be Static equivalent of Dynamic load
- B-3.1.2.3, (Connection Design) Connections including glazing stop and hardware connections must meet
 - a. 10.8 PSI (75 KPa) for vision area less than 1-square meter(10.8sf)
 - b. 4.4 PSI (30KPa) for vision areas between 10.8 SF (15M) to 32 SF (3SM).

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US-DOD UFC Blast Specifications

- 1 PSI (7KPa) **Static Equivalent** Design did Not Mean 1 PSI (7KPa) Static Design Load
- **The most misunderstood criteria**
 - UFC 4-010-01 Criteria, Oct. 2003
 - (This was corrected in Jan. 2007 edition)



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UFC Myths

- Conventional construction standoff met; **No need for glazing protection**
False (X)
- Project specs do not list protection with conventional standoff distance, **No need for protection**
False (X)
- Bidders need not ask us for clarification when specs do not mention UFC/ATFP requirements
False (X) (Request For Information- RFI)

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UFC 4-010-01 Min. Criteria – Jan. 07

- See Standard 10, Change 1, UFC 4-010-01
- Purpose is to minimize hazards to personnel caused by glazing
- Applies to windows, skylights and glazed doors. Glazed doors moved to standard 12
- Applies to only new and existing inhabited buildings covered by the standard and includes discussion on leased facilities
- Applies even if conventional standoff distances or greater distances for low level of protection are provided

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UFC 4-010-01 Jan 22, 2007

- Applicable to all projects after 2004 (BC Option)
- **No reference to 7Kpa (1 PSI) load**
- Glass pressures per ASTM F2248, 3 second response
- Glass design per ASTM E1300
- Minimum glass size ¼" Laminated (.030" Interlayer)
- Frame design per UFC Criteria
- Connection calculations per UFC criteria
- Word "**minimum standoff**" deleted
- Residential, 13 houses or more must provide protection
- ✓ **Based on Charge weight and Distance**

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Systems Approach

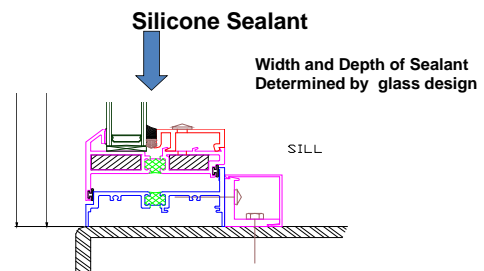
- Window system must be designed to prevent deadly glass shards from flying into the room.
- Glass should remain in the frame.
- Frame must stay attached to the wall.
- Wall must remain intact to hold frame.
- Anchors must be evaluated for each product application.
- Anchors must be evaluated for each wall substrate.
- Designed to Absorb or Resist loads
- Explosive Testing and/or Design Calculations

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Structural Glazing Requirement



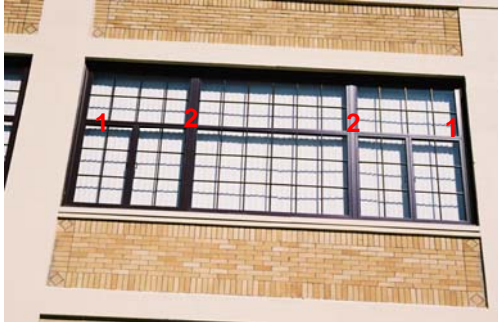
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Analyzing Combination Windows

#1 and #2 must meet the Blast Loads



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High Pressure Products

- The design criteria and test requirements for high pressure windows are much different but the procedures and cautions are same.
- Must determine pressures and impulses from the Charge weight and the Standoff distance.
- GSA... 4 PSI/28 PSI-MSEC
- DOJ... 6 PSI/42 PSI-MSEC OR 10 PSI/89 PSI-MSEC
- DOS... AS NEED BASIS

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Window Response to Blast Load

- Window response provided in terms of hazard to personnel
- UFC uses hazard descriptions as provided by definitions in ASTM F1642
- Other agencies use different criteria
- Well-established procedures exist for designing windows against blast load without fracture (first crack design)
- Current terrorist threats have created desire for reducing hazards from window glazing fragments caused by blast. Design to resist a blast load without glazing fracture is cost prohibitive.

Therefore, the design philosophy is that glazing may fracture but not cause hazards to personnel.

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UFC 4-010-01 Jan. 2007 Design Process

- Determine LOP and Pressures for the Project
- Determine Glass Pressure ASTM F2248
- Determine Glazing design from E 1300
- Determine framing system load
- Determine Anchor loads
- Determine loads to substrate

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UFC 4-010-01 Glazing Requirements – 22 Jan 07 (cont)

Applicable Level of Protection	Applicable Explosive Weight	Nominal Laminated Glass and PVB Interlayer Thickness Requirements ⁽¹⁾			
		At Conventional Construction Standoff Distance ⁽²⁾		Between Conventional Construction and Minimum Standoff Distances ⁽³⁾	
		Nominal Glass Thickness	Minimum Interlayer Thickness	Nominal Glass Thickness	Minimum Interlayer Thickness
Low	I	6 mm (1/4")	0.75 mm (0.030")	F2248/E1300 – 3 mm (1/8") min	1.50 mm (0.060")
	II	F2248 _{II} /E1300 ⁽⁴⁾	1.50 mm (0.060")	F2248/E1300 ⁽⁴⁾	1.50 mm (0.060")
Very Low	I	F2248 _{II} /E1300 ⁽⁴⁾	1.50 mm (0.060")	Refer to DoD Security Engineering Facilities Design Manual	
	II	F2248 _{II} /E1300 ⁽⁴⁾	1.50 mm (0.060")	Not Applicable ⁽⁵⁾	

- (1) Nominal thickness will be achieved by laminating two thinner glass panes of the same thickness to achieve the nominal thickness.
- (2) Refer to Table B-1 for applicable standoff distances.
- (3) Enter ASTM F 2248 with the applicable explosive weight and the actual standoff distance achieved to determine the equivalent 3-second duration design loading.
- (4) Calculate the required laminated glass thickness for this pane by subtracting 3mm (1/8") from the thickness determined by ASTM E 1300.
- (5) For this window, enter ASTM F 2248 with explosive weight I at a standoff distance of 45m (148') to determine the equivalent 3-second duration design loading. The laminated glass thickness selected for this design loading may then be used at the 25m (82') conventional construction standoff distance.
- (6) For this window, enter ASTM F 2248 with explosive weight II at the 10m (33') conventional construction standoff distance to determine the equivalent 3-second duration design loading.
- (7) For standoff distances greater than the conventional construction standoff distance, lower interlayer thicknesses may be allowable based on analysis, but they shall not be less than 1.5 mm (0.060").
- (8) Conventional construction standoff distance = minimum standoff distance.

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UFC 4-010-01 Glazing Requirements – 22 Jan 07 (cont)

Applicable Level of Protection	Applicable Explosive Weight	Nominal Laminated Glass Thickness w/ PVB Interlayer Requirements ⁽¹⁾			
		At Conventional Construction Standoff Distance ⁽²⁾		Between Conventional Construction and Minimum Standoff Distances ⁽³⁾	
		Glass Thickness ⁽⁴⁾	Minimum Interlayer Thickness ⁽⁴⁾	Glass Thickness ⁽⁴⁾	Interlayer Thickness ⁽⁴⁾
Low	I	6mm (1/4")	0.75mm (0.030")	6mm (1/4")	1.50mm (0.060")
	II	F2248 _{II} /E1300 ⁽⁴⁾	0.75mm (0.030")	Refer to DoD Security Engineering Facilities Design Manual	
Very Low	I	F2248 _{II} /E1300 ⁽⁴⁾	0.75mm (0.030")	Refer to DoD Security Engineering Facilities Design Manual	
	II	6mm (1/4")	0.75mm (0.030")	Not Applicable ⁽⁵⁾	

- (1) Nominal thickness will be achieved by laminating two thinner glass panes of the same thickness to achieve the nominal thickness.
- (2) Refer to Table B-1 for applicable standoff distances.
- (3) Glass thickness is the same for interior and exterior panes.
- (4) Interlayer is below the inboard pane only as a minimum.
- (5) For this window, enter ASTM F 2248 with explosive weight I at a standoff distance of 45m (148') to determine the equivalent 3-second duration design loading. The glass thickness selected for both panes of the IGU for this design loading may then be used at the 25m (82') conventional construction standoff distance.
- (6) Conventional construction standoff distance = minimum standoff distance.

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UFC 4-010-01 Glazing Criteria – Jan. 07

• Glazing:

- Only laminated glass addressed
- Design per ASTM F2248 and E1300, with modification using tables B-2 and B-3, for very low and low hazard levels
- Modifications necessary since ASTM F2248 procedure is for a minimal hazard rating = medium level of protection
- Use minimum ¼-inch laminated glass pane consisting of 2- panes of 1/8-inch AN and 0.030-inch PVB interlayer
- Chart in ASTM F2248 has limited range therefore refer to DoD Security Engineering Facilities Design Manual when outside the range of the chart

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UFC 4-010-01 Glazing Criteria – Jan. 07

• Glazing Frame Bite:

- Refer to requirements of ASTM F2248
- For structurally glazed windows use bead width equal to 1 but not more than 2 times thickness of glass to which it adheres, but no less than 3/8-inch
 - For single pane glazing apply to both sides
 - For IGU apply to inboard side
- For glazing tape use 2 times but not more than 4 times thickness of glass to which it adheres
- Criteria for dry glazed will be a minimum of 4 times thickness of glass, Still under development

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UFC 4-010-01 Frame Criteria – Jan. 07

• Frames:

- Aluminum or Steel – Per ASTM F2248 - limit deflections to 1/160 of the length of the supported glazing edge at allowable stress for **two times the glazing resistance**
- Applies to all window and skylight components
 - Frames
 - Mullions
 - Sashes
- May require serious modification for reuse of existing frames in existing buildings

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UFC 4-010-01 Connections– Jan. 07

• Connections:

- Applies to all connections within the window and From window to the surrounding structure
- Use **2x the equivalent glazing resistance, Apply as a uniform load over the face of window and frame**
- Design at allowable stress levels for materials being connected
- Account for geometry and connection configuration in calculating shear and tensions loads
- May use connections demonstrated through dynamic testing replicating the project application

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UFC 4-010-01 Supporting Structure

• Supporting Structural Elements:

- Design for flexure using nominal strength of the surrounding structural wall / roof elements
- Design connection of supporting structural elements based on nominal strength ($\phi = 1.0$)
- Do not chase load past supporting structural element connection
- Load based on tributary area of the window
- **Load to be used is 8x the glazing resistance as determined using E1300 in conjunction with F2248**

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UFC 4-010-01 Other Glazing– Jan 07

- **Alternate Glazing** – Refer to other sources. Loads based on ultimate resistance of glazing being used.
- **Alternate Method of Analysis** - Dynamic analysis permitted for any or all parts of window system
- **Testing** – In accordance with ASTM F1642. Loads based on actual standoff but standoff may not be greater than conventional construction standoff distances
- **Window Replacement Projects** – Meet the requirements regardless of meeting other triggers of paragraph 1-6.2

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Load Summary

- Use lay-up provided by analysis. However, it is possible to reduce thickness of outer pane only, but cannot use software.
- Glazing $R_u = 103$ -psf
- Window frame load = 207-psf (same for both load cases) with $L/160$ limit
- Window connection load = 207-psf
- Supporting element load = $8 \times 103 = 824$ -psf

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Shell Point Condos Fort Meyers, Fl. Hurricane & Blast Resistant Series 3400 DH



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Prevention Of Hazard

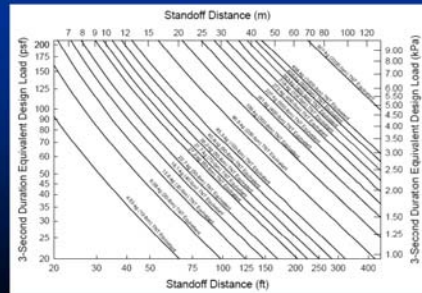


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UFC 4-010-01 Glazing Requirements – 22 Jan 07 ASTM F 2248 Equivalent Load Chart

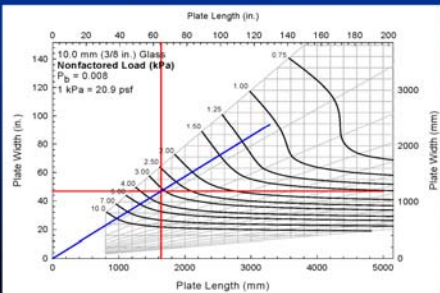


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UFC 4-010-01 Glazing Requirements – 22 Jan 07 ASTM E 1300 (Typical Nonfactored Load Chart)



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AMERICAN ARCHITECTURAL

AAMA 510-06
Voluntary Guide
Specification for
Blast Hazard Mitigation
for Fenestration Systems



Putting it altogether
WWW.AAMANET.ORG



MANUFACTURERS ASSOCIATION

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Blast Fenestration System Certification

- *“As the Responsible Party of blast hazard mitigation fenestration system, we certify that the system, including the frame(s) hardware, glazing and anchoring system(s), complies with the project drawings and specifications”.*

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Security Fenestration Rating and Certification

Two Certification Program Options

- Product Specific Certification
- Project Specific Certification

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Bidding

- Window Size Issues
- Glazing & Frame Issues
- Combination Windows
- Stacks and Mullions
- Calculations for Glass Sizes
- Blast Test Certification
- Anchors and Fasteners
- Substrate Concerns

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Current Guideline Specifications

1. ASTM F 1642, Standard Test Method for Glazing and Glazing Systems Subject to Air-blast Loadings
2. GSA-TS01-2003, Standard Test Method for Glazing and Window Systems Subject to Dynamic Overpressure Loadings
3. UFC 4-010-01, Minimum Antiterrorism Standards for Buildings
4. ASTM E 1300, Standard Practice for Determining Load Resistance of Glass in Buildings
5. ASTM F 2248, Practice for Specifying an Equivalent 3-Second Duration for Blast Resistant Glazing with Laminated Glass
6. AAMA 510-06, Voluntary Guide Specification for Blast Hazard Mitigation for Fenestration Systems
7. FEMA 426 and 452
8. PBS-P 100-2005
9. SEI/ASCE, Blast Protection of Buildings
10. Physical Design Manual by Department of VA

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Current Guideline Specifications Continued

11. Balanced Window Design by Weidlinger Associates
12. Blast Safety of Building Envelope by Hinman
13. SO/FDIS 16933, Arena Air-blast Loading
14. ISO/FDIS 16934, Shock Tube Loading
15. UFGS, United Facilities Guide Specification
16. USACE/PDC, Protective Design Center
17. Structures to Resist Accidental Explosions, ARMY-TM5-1300, NAVY-NAVFAC P-397, AIR FORCE-AFR 88-22
18. ASTM F 2247, Testing of Metal Doors

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Resources and Thanks

- ❖ www.aamanet.org
- ❖ www.absconsulting.com
- ❖ www.ara.com
- ❖ www.atf.treas.gov
- ❖ www.bakerrisk.com
- ❖ www.defenselink.mil
- ❖ www.gsa.gov
- ❖ www.protectiveglazing.org
- ❖ www.umr.edu
- ❖ www.usace.army.mil
- ❖ www.bombsecurity.com
- ❖ www.nfrc.org
- ❖ BMAG, Blast Mitigation Action Group
- ❖ ATBlast by ARA

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“If I had 60 minutes to solve a problem, I’d spend 55 minutes defining it, and 5 minutes solving it.”

Albert Einstein

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GOOD BETTER GRAHAM

Blast Hazard Mitigation

Designing for Blast (UFC Criteria)

Questions ?

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