

October 20, 2008

# Glasstec

Dusseldorf, Germany

Protective Glazing For Blast Loads

## Protective Glazing For Blast Loads and other disasters

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**TECHNOFORM**

**R.C. (RAJ) GOYAL**  
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## Thank You - TECHNOFORM



**Technologies of tomorrow**

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## Hazards From Glazing Failure Architectural Window F-AW 130



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## Discussion Items

- Protective Glazing for Blast Loads
- PGC Introduction
- Charge Weight, Pressure, Impulse
- ISC Protection Criteria
- Test Standards and Specifications
- Protection from Hurricanes and Other Disasters
- GSA, DOD-UFC Testing and Certification
- Design Variations for Low and High Loads
- No Short Cuts, LIFE Safety

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## Protective Glazing to Resist Explosions & Natural and Intentional Harm

- Terrorist bomb threats
- Accidental explosions (Refineries)
- Forced Entry Resistance (FER)
- Hurricanes, Typhoon, Wind, Seismic
- Air, Water, Structural
- Thermal/ Acoustical
- RFI, Radio Frequency Interference
- Ballistics
- BIO Terrorism

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## Helping Protect Personnel and Property



[www.protectiveglazing.org](http://www.protectiveglazing.org)

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## PGCI HISTORY

- Incorporated in 1997 in Washington, D.C.
- Formed to address the growing need for protective glazing systems by the General Services Administration and other government agencies, as well as in general construction in the United States

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## PGCI MISSION STATEMENT

Engage PGC International's active, diverse membership:

- To promote implementation of standards and performance criteria by government and industry
- To identify and promote programs to encourage the use of protective glazing technologies
- To promote the growth of the protective glazing market
- To encourage and promote the development of emerging protective glazing technologies and techniques

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## PGCI MEMBERS

Members from diversified industry groups

- Glass Fabricators
- Suppliers of materials and accessories
- Window Film manufacturers
- Curtain Wall and Window manufacturers
- Sealant suppliers
- Consultants and Architects
- Contractors and Engineers
- Test Laboratories
- Fenestration Industry Organizations
- Trade Associations

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## PGCI MEMBER SERVICES

- Two yearly meetings
  - Spring Meeting
    - Focus on membership & association development
  - Annual Symposium
    - Two-day event with a series of speakers relevant to newest trends in protective glazing industry
    - Exhibit area
    - Held in Washington, D.C. area to attract local government and building code officials, architects and specifiers
- Informational papers & videos
  - Provided by PGC Intl members and available on website
- E-News

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## PGCI Resources: Website [www.protectiveglazing.org](http://www.protectiveglazing.org)



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## Why Protective Glazing?

- Bomb Blast Events are common
- Glass part of terrorist's arsenal
- Flying glass shards major contributor to injuries
- Blast wave damage upon penetrating the building
- Inter-layers in Laminated Glass have been tested for common and extreme blast levels

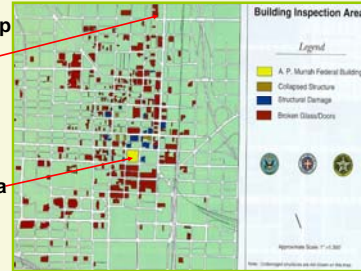
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## Why Protective Glazing?

Glass Shards up to 18 blocks away

Blast event area



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## SAFETY vs. SECURITY

**Safety** = refers to freedom from the risk OR occurrence of injury/loss from natural causes

**Security** = refers to freedom from the risk OR occurrence of injury/loss from the intentional actions of mankind

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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**

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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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## ASTM E1300 & ASTM F2248

- **ASTM E1300-04 - Standard Practice for Determining Load Resistance of Glass in Buildings**
- **ASTM F2248-03 – Standard Practice for Specifying an Equivalent 3-Second Duration Design Loading for Blast Resistant Glazing Fabricated with Laminated Glass**

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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 F1915 & ASTM F1233

- ASTM F1915- Standard test methods for glazing for detention facilities. Grades are based on time and blunt and sharp impacts.
- ASTM F1233- Standard Test Method for Security Glazing Materials and Systems, specific number and order of blunt impacts, sharp impacts, thermal attack, and chemical attack to the glass.
- (HPW-TP-0500) - HP White Transparent Materials used for forced entry.

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## UL 752 and NIJ 0108

- UL 752 - Standard for Bullet Resisting Products, Components tested and listed separately (792), No spall permitted, Eight rating levels.
- NIJ 0108-01- Ballistic Resistant Protective Materials, Rating levels specified, including ammunition, grade, velocity, and number of shots. National Institute of Justice

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## UL 972 - Vandal-Resistant Glazing

Standard for safety for burglary resistance glazing material

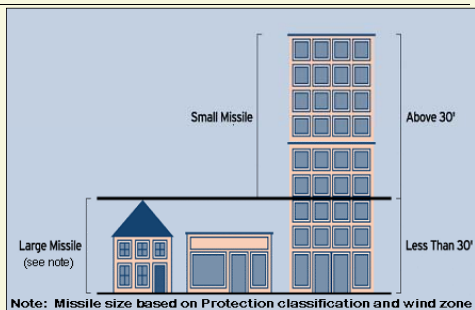


Laminated architectural glass (LAG) provides time to for assessment and action.

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## HURRICANE GLAZING ZONES



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## Hurricane Impact Testing

- Large Missile



- Small Missile



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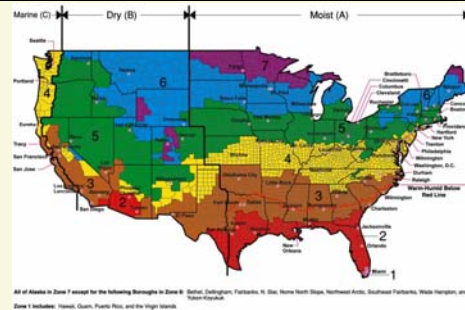
## Energy & Sustainability

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

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## USGBC Climate Zone Map



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## Arena Test (No Witness Chambers)



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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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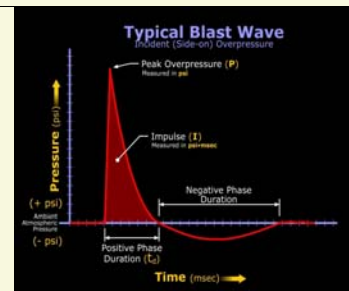
## Blast Wave Extreme Rapid Release of Energy

- **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
- **Blast Energy is inversely proportional to distance cubed**

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## Pressure/Duration/Impulse Duration is Cumulative Pressure over Time



Absorb Blast Energy In The Same Manner

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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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## Threat Assessment Types of threats

- **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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## Basis of Protection

- **Laminated Glass is**
- **.....The Key to Protection**
- **By minimizing hazardous flying debris, ...80-90% of injuries can be prevented.**

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## GSA/ISC- Adopted 2001 Interagency Security Committee

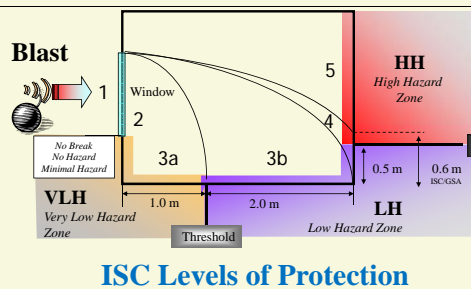
Condition	Description	Glazing Response
1	Glass not cracked, fully survived and/or fully retained by frame and no glass fragments either inside or outside structure.	None
2	Glass may be cracked but is retained in frame.	No significant fragments. Dusting or very small fragments near sill or on floor acceptable
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 product performed

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## BLAST PROTECTION / HAZARD RATING



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## POST BLAST ANALYSIS

- **Blast Information, P//D**
- **Examination of Debris in witness panel**
- **Glass Shards/ Shatter Review**
- **Glass Retention / Opening Review**
- **Location of Shards**
- **Damage to Witness Panel**
- **Glass Dust Review**
- **Frame Analysis**
- **Hardware analysis**

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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 change*

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## Distance to Charge weight

Stand-Off (Feet)	Weight Of Charge TNT (lbs)	Rating (PSI)	Duration (msec)
10	10	196.76	0.98
	50	964.80	0.68
	100	1777.31	0.63
	200	3065.04	0.64
	500	5732.23	0.73
	700	7062.86	0.78
	1000	8735.23	0.86

Stand-Off (Feet)	Weight Of Charge TNT (lbs)	Rating (PSI)	Duration (msec)
50	10	5.16	6.02
	50	12.63	7.51
	100	20.28	7.62
	200	34.92	7.26
	500	79.49	6.18
	700	110.15	5.71
	1000	157.99	5.21

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## Arena Test - Charge Weight and Distance



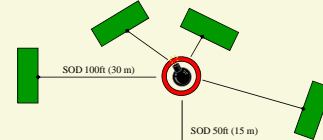
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## TESTING METHODOLOGIES

### Arena Testing

- Several products tested simultaneously
- True blast event with *negative pressure*
- Expensive , Must include Witness Rooms 10X10X10
- Weather Restrictions may apply
- Little Chance for research and development



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**FPED5-Quantico, Va. April 21,2005**  
**50 Lbs. TNT @ 55Ft. ( P=10.6PSI,**  
**Impulse=42.8 PSIMSEC**



**No Witness Chamber Used Here**

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**Innovative Indoor New Shock Tube**  
**ATI, York, PA.**



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**Innovative New Shock Tube  
ATI, York, PA**



Window Installation Module Separated For Easy Install

Window Installation Module Placed in Shock Tube



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**Shock Tube Testing**

- ❖ Requires 4 Test Samples
- ❖ GSA test size 48" X 66"
- ❖ Three samples must comply
- ❖ Pressure/Impulse/Duration recorded
- ❖ Debris location recorded
- ❖ Lowest performance is certified

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**Fenestration Performance & certification  
HP Fenestration & Energy ratings are a must**

- ❖ Air, Water, Structural, **AAMA**
- ❖ Thermal, U , SHGC, VT, **NFRC**
- ❖ Acoustical, **AAMA**
- ❖ Impact, Large Missile, Dade County Florida
- ❖ LEED Requirements, **USGBC**
- ❖ Minimum Window Classification, **AAMA**
- ❖ Egress, **Applicable Code**
- ❖ Safety and Security, **Applicable Code**
- ❖ Ventilation, Historical, **Project Requirements**

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**CLASSIFICATION / PERFORMANCE**

**GSA Levels**

- Level C Building 4 psi /28 PSI-MSEC
- Level D Building 10 psi/88 PSI-MSEC

**Other Government**

- DOD-UFC 4-010-01, Weight I or II and Distance (Weight I or Weight II Classified)
- DOD-UFC 4-010-02 , Classified
- DOS: Classified (Need to know basis)
- DOJ: 6psi/40- PSI-MSEC and higher
- DOS and DOJ require Ballistics and FER

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**Casement Window  
6PSI/40PSI-MSEC- Passed**



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**Glazing Damages Without Fragments**

▪ **Glass**



▪ **Frame Damage**



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**Curtain-wall test**  
 Courtesy of Harmon Contract glazing



Laminated Glass At Exterior Can Prevent Flying Glass

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**Fixed Window at 10 PSI**  
 F-AW 130 – Failed  
 All tests, Courtesy Of Graham Architectural



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**Disastrous Glass Failure @10psi**  
 Progressive Design Process

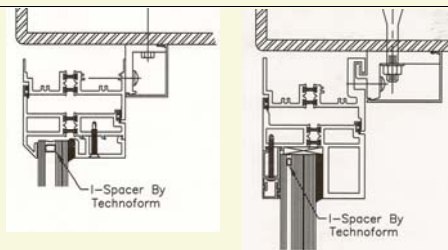


135 Lbs of Glass

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**6 PSI-42KPa Vs. 32 PSI/224KPa**  
 Courtesy of Graham Architectural



Technoform Technologies I-Spacer and I-Strut  
 Energy rated glass with protection from Blast, Hurricanes

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**UFC 4-010-01 Jan 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")
- Frame design per UFC Criteria
- Connection calculations per UFC criteria
- Word "minimum" standoff deleted
- Residential, 13 units or more must provide protection

11/19/2008

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**Load Summary**

- Glazing load = 103-psf
- Window frame load = 206-psf with L/160 limit
- Window connection load = 206-psf
- Supporting element load = 8 x 103 = 824-psf

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## Systems Approach- Not Just Glass

- 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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## Method of Compliance, UFC/GSA/Others

- Comply with Pressures and Impulse
- Determine Glass Make up per Product size
- Static Equivalent Analysis, PE Certified/ OR
- Dynamic Analysis, PE Certified/ OR
- ASTM 1642 Test, PE Certified
- Frame Analysis, PE Certified
- Glass holding members Analysis, PE Certified
- Anchor Analysis, PE Certified
- Fasteners, Sizes, Space, Embedment, PE Certified
- Most higher pressure products must have certified test reports

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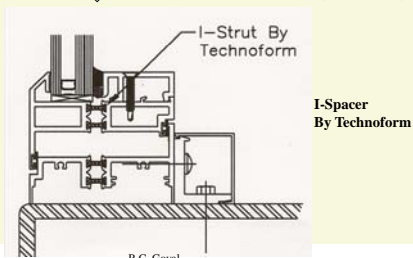
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## Structural Glazing Requirement

### ASTM C1564 Silicone Sealants for Protective Glazing

#### Silicone Sealant

Width and Depth of Sealant Determined by glass design



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## Security Fenestration Rating and Certification

### Two Certification Program Options

- Product Specific Certification
- Project Specific Certification

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## AAMA Product Certification



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## Qualification Criteria

- List of projects completed
- Complete product information
- Copy of a test report per ASTM standard
- AAMA performance information
- Glass performance information
- Product CERTIFICATION letter
- Sub-contractor qualification
- List of jobs completed by the sub-contractor
- Job specific qualifications

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## Shop Drawings and submissions

- Product design and application, Structural sealant
- The substrate configuration
- Glass make up with Structural Bead
- Glass load calculations
- Frame Load calculations
- Anchor load calculations
- Size, spacing, type and embedment of anchors
- Calculations signed by a PE.
- Blast Product CERTIFICATION letter
- Test report from a Blast lab signed by a PE
- AAMA/NFRC Performance test reports

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## Conclusions

- Test methods assess the ability of the security glazing to resist specified impacts
- Glazing is designed for single threat or a combination of threats (Ballistics/Physical Attack/Hurricane/Typhoon/Bullets etc.)
- However, in the real world, anything is possible!

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## Thanks for Attending

- ❖ Thanks to my Sponsors
- ❖ **TECHNOFORM**
- ❖ **PGCI**

## Questions?

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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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## Current Guideline Specifications-1

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. ASCE, Blast Protection of Buildings
10. Physical Design Manual by Department of VA

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## Current Guideline Specifications Continued-2

11. **Balanced Window Design** by Weidinger Associates
12. **Blast Safety of Building Envelope** by Hinman
13. **ISO 16933**, Arena Air-blast Loading
14. **ISO 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, NAVFACINST 11010.45
18. **ASTM F 2247**, Testing of Metal Doors
19. **Protective Glazing Council International**
20. **Blast Resistance Glazing Design**, SDG

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## Current Guideline Specifications Continued-3

21. **ASTM F1233**, Test method for Security glazing
22. **ASTM F1915**, Physical attack resistance
23. **HPW-TP-0500**, Physical attack resistance
24. **UL 752**, Bullet resistance Product
25. **NIJ 0108.01**, Bullet resistance glazing
26. **UL 792**, Bullet resistance glazing
27. **UL 972**, Burglary resistance glazing material
28. **GSA 3D Blast**
29. **Window Glass Design 2004**, SDG
30. **Wind Loads On Structures 2005**, SDG
31. **WINGARD PE, LE** by GSA
32. **DOD UFC 4-010-01 and UFC 4-010-02**
33. **HAZL**

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## Resources and Thanks

- ❖ [www.aamanet.org](http://www.aamanet.org)
- ❖ [www.absconsulting.com](http://www.absconsulting.com)
- ❖ [www.ara.com](http://www.ara.com), Atblast
- ❖ [www.atf.treas.gov](http://www.atf.treas.gov)
- ❖ [www.bakerrisk.com](http://www.bakerrisk.com)
- ❖ [www.defenselink.mil](http://www.defenselink.mil)
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- ❖ [www.bombsecurity.com](http://www.bombsecurity.com)
- ❖ [www.nfrc.org](http://www.nfrc.org)
- ❖ [www.protectiveglazing.org](http://www.protectiveglazing.org) (PGCI)
- ❖ [www.bmag.com](http://www.bmag.com) (Blast Mitigation Action Group)

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