Blast Loading For Glazing

- What is Required by code?
- What to Look for in Specs & Plans?
- What will soon be required?
- What has worked & not worked?
Glass Thickness = 0.394 in – No film
nominal P = 5 psi
Glass Injuries - Oklahoma City (4000psi)
What is Required? – Unified Facilities Criteria (UFC)

**UFC 4-010-01 Intent** - The intent of these standards is to minimize the possibility of mass casualties in buildings owned, leased, controlled by DOD.

**Applicability** – New and Existing Buildings

1-6.2 **Existing Buildings.** These standards will apply to existing facilities starting with the Fiscal Year 2004 program when triggered as specified below, regardless of funding source. Projects funded prior to that fiscal year should comply with these standards where possible. For existing leased buildings see paragraph 1-6.4.

1-6.2.3 **Glazing Replacement.** Because of the significance of glazing hazards in a blast environment, implementation of the glazing provisions of these standards is mandatory for existing inhabited buildings within any planned window or door glazing replacement project, regardless of whether that project meets the 50% cost trigger above. Such replacements may require window frame modification or replacement.
What is Required? – Unified Facilities Criteria (UFC)

- **Are the Antiterrorism Standards a Moving Target?**
  - YES

- **Blast Criteria Sources in Specifications**
  - **Low & Very Low Levels of Protection**
    - UFC 4-010-01 – (2003 version)
    - UFC 4-010-01 – (Including change 1, 22 January 2007)
    - UFC 4-010-01 – (NEW CHANGE THIS YEAR)
    - UFC 4-010-02 – Minimum Standoff Distances for Buildings
  - **Medium & High Levels of Protection**
    - DoD Security Engineering Facilities Design Manual (FOUO)
### What is Required? – Levels of Protection

Table 2.1 Levels of Protection – New and Existing Buildings

<table>
<thead>
<tr>
<th>Level of Protection</th>
<th>Potential Building Damage / Performance</th>
<th>Potential Door and Glazing Hazards</th>
<th>Potential Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below AT standards¹</td>
<td>Severe damage. Progressive collapse likely. Space in and around damaged area will be unusable.</td>
<td>Doors and windows will fail catastrophically and result in lethal hazards. (High hazard rating)</td>
<td>Majority of personnel in collapse region suffer fatalities. Potential fatalities in areas outside of collapsed area likely.</td>
</tr>
<tr>
<td>Very Low</td>
<td>Heavy damage - Onset of structural collapse, but progressive collapse is unlikely. Space in and around damaged area will be unusable.</td>
<td>Glazing will fracture, come out of the frame, and is likely to be propelled into the building, with the potential to cause serious injuries. (Low hazard rating) Doors may be propelled into rooms, presenting serious hazards.</td>
<td>Majority of personnel in damaged area suffer serious injuries with a potential for fatalities. Personnel in areas outside damaged area will experience minor to moderate injuries.</td>
</tr>
<tr>
<td>Low</td>
<td>Moderate damage – Building damage will not be economically repairable. Progressive collapse will not occur. Space in and around damaged area will be unusable.</td>
<td>Glazing will fracture, potentially come out of the frame, but at a reduced velocity, does not present a significant injury hazard. (Very low hazard rating) Doors may fail, but they will rebound out of their frames, presenting minimal hazards.</td>
<td>Majority of personnel in damaged area suffer minor to moderate injuries with the potential for a few serious injuries, but fatalities are unlikely. Personnel in areas outside damaged areas will potentially experience a minor to moderate injuries.</td>
</tr>
<tr>
<td>Medium</td>
<td>Minor damage – Building damage will be economically repairable. Space in and around damaged area can be used and will be fully functional after cleanup and repair.</td>
<td>Glazing will fracture, remain in the frame and results in a minimal hazard consisting of glass dust and splinters. (Minimal hazard rating) Doors will stay in frames, but will not be reusable.</td>
<td>Personnel in damaged area potentially suffer minor to moderate injuries, but fatalities are unlikely. Personnel in areas outside damaged areas will potentially experience superficial injuries.</td>
</tr>
<tr>
<td>High</td>
<td>Minimal damage. No permanent deformations. The facility will be immediately operable.</td>
<td>Glazing will not break. (No hazard rating) Doors will be reusable.</td>
<td>Only superficial injuries are likely.</td>
</tr>
</tbody>
</table>

**Notes:**
1. This is not a level of protection, and should never be a design goal. It only defines a realm of more severe structural response, and may provide useful information in some cases.
2. For damage / performance descriptions for primary, secondary, and non-structural members, refer to UFC 4-020-02: DoD Security Engineering Facilities Design Manual.
3. Glazing hazard levels are from ASTM F 1542.

---

**UFC 4-010-01**

**DoD Security Eng. Facilities Manual**
What is Required? – Standoff Distances

<table>
<thead>
<tr>
<th>Location</th>
<th>Building Category</th>
<th>Standoff Distance Requirements</th>
<th>Applicable Level of Protection</th>
<th>Conventional Construction Standoff Distance</th>
<th>Minimum Standoff Distanced (1)</th>
<th>Applicable Explosive Weight (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled Perimeter or Parking and Roadways without a Controlled Perimeter</td>
<td>Billeting and High Occupancy Family Housing</td>
<td>Low</td>
<td>45 m (148 ft.)</td>
<td>25 m (82 ft.)</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primary Gathering Building</td>
<td>Low</td>
<td>45 m (148 ft.)</td>
<td>25 m (82 ft.)</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inhabited Building</td>
<td>Very Low</td>
<td>25 m (82 ft.)</td>
<td>10 m (33 ft.)</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>Parking and Roadways within a Controlled Perimeter</td>
<td>Billeting and High Occupancy Family Housing</td>
<td>Low</td>
<td>25 m (82 ft.)</td>
<td>10 m (33 ft.)</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primary Gathering Building</td>
<td>Low</td>
<td>25 m (82 ft.)</td>
<td>10 m (33 ft.)</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inhabited Building</td>
<td>Very Low</td>
<td>10 m (33 ft.)</td>
<td>10 m (33 ft.)</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>Trash Containers</td>
<td>Billeting and High Occupancy Family Housing</td>
<td>Low</td>
<td>25 m (82 ft.)</td>
<td>10 m (33 ft.)</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Primary Gathering Building</td>
<td>Low</td>
<td>25 m (82 ft.)</td>
<td>10 m (33 ft.)</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inhabited Building</td>
<td>Very Low</td>
<td>10 m (33 ft.)</td>
<td>10 m (33 ft.)</td>
<td>II</td>
<td></td>
</tr>
</tbody>
</table>

(1) Even with analysis, standoff distances less than those in this column are not allowed for new buildings, but are allowed for existing buildings if constructed/retrofitted to provide the required level of protection at the reduced standoff distance.

(2) See UFC 4-010-02, for the specific explosive weights (kg/pounds of TNT) associated with designations – I and II. UFC 4-010-02 is for Official Use Only (FOUO).

(3) For existing buildings, see paragraph E-1.1.2.2 for additional options.

(4) For existing family housing, see paragraph E-1.1.2.3 for additional options.
What is Required? – Standoff Distances

What is Standoff Distance?

Figure B-1 Standoff Distances – Controlled Perimeter

Note: Standoff distances are from Conventional Construction Standoff Distance column of Table B-1

- 45 m = 148 ft
- 25 m = 82 ft
- 10 m = 33 ft

Legend:
- Trash Containers
- Inhabited Buildings
- Primary Gathering Buildings or Billeting
- Unobstructed Space
- Low occupancy Building
- Roadways
- Controlled Perimeter
- Parking

© 2008 JEI Structural.
### What is Required? – Glass Thickness

#### Table B-3. Laminated Glass Thickness Selection for Insulating Glass Unit (IGU) Windows

<table>
<thead>
<tr>
<th>Applicable Level of Protection</th>
<th>Applicable Explosive Weight</th>
<th>Nominal Laminated Glass Thickness w/ PVB Interlayer Requirements&lt;sup&gt;(1)&lt;/sup&gt;</th>
<th>Between Conventional Construction and Minimum Standoff Distances&lt;sup&gt;(2)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>I</td>
<td>Glass Thickness&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>Minimum Interlayer Thickness&lt;sup&gt;(4)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>6mm (1/4&quot;)</td>
<td>0.75mm (0.030&quot;)</td>
</tr>
<tr>
<td>Very Low</td>
<td>I</td>
<td>F224845/E130&lt;sup&gt;(5)&lt;/sup&gt;</td>
<td>0.75mm (0.030&quot;)</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>6mm (1/4&quot;)</td>
<td>0.75mm (0.030&quot;)</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> Nominal thickness will be achieved by laminating two thinner glass panes of the same thickness to achieve the nominal thickness.

<sup>(2)</sup> Refer to Table B-1 for applicable standoff distances.

<sup>(3)</sup> Glass thickness is the same for interior and exterior panes.

<sup>(4)</sup> Interlayer is within the inboard pane only as a minimum.

<sup>(5)</sup> 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

---

```
\text{Low  I} \\
\text{II} \\
\text{Very Low I} \\
\text{II} \\
\text{Low  I} \\
\text{II} \\
\text{Very Low I} \\
\text{II} \\
\text{Low  I} \\
\text{II} \\
\text{Very Low I} \\
\text{II} \\
\text{Low  I} \\
\text{II} \\
\text{Very Low I} \\
\text{II} \\
\text{Low  I} \\
\text{II} \\
```
Blast - Laminated Glass
1) Typical Specification w/ UFC 4-010-01 (2003 Version)

- **Glazing**
  - inner pane 1/4” laminated w/ .75mm PVB
  - Bite – 3/8” w/structural glazing or 1” non

- **Mullion/Frame Design - Ultimate Strength Design**
  - Design Load = 1.0 psi (144 psf)
  - Deflection Limit = L/60

- **Connection Design - All parts, including glazing stop**
  - Glazing panels < 10.8 SF – Use 10.8 psi (1555 psf)!!
  - Glazing Panels >10.8 SF < 32 SF – Use 4.4 psi (634 psf)!!
What to Look For in Specifications

1) Typical Specification w/ UFC 4-010-01 (2003 Version)

No! Really! it's in there!

F. Blast Resistance:

1. Provide entrances and storefronts with framing members capable of withstanding a uniform static pressure applied to all glazing and exposed frame surfaces equal to the full static capacity of the supported glazing panel as determined in accordance with ASTM E1300, but not less than 1 lbf/sq. in.
   a. Framing member deformations normal to the glazing plane shall not exceed 1/60 of the unsupported length.

2. Provide entrance and storefront connections to surrounding structural elements, hardware and associated connections, and glazing stop connections capable of withstanding a uniform static shear applied along the entire perimeter of each glazing panel equal to 75 lbf/in., but not less than a uniform static pressure applied to all glazing and exposed frame surfaces equal to the following:
   a. Vision area less than or equal to 10.8 sq. ft.: 10.8 lbf/sq. in.
   b. Vision area greater than 10.8 sq. ft. and less than or equal to 32 sq. ft.: 4.4 lbf/sq. in.

3. For the purpose of determining blast resistance, member, connection, and hardware capacities shall be based on the following:

FRLY08410.PKG7
November 14, 2007
2) Typical Specification w/ UFC 4-010-01 (2007 Version) 
(UFC 4-010-01 including change 1, 22 January 2007)

- **Glazing Design**—
  - Determine from Tables B-2 & B-3
  - **Bite** – ASTM F 2248 (Standard Practice for Specifying an Equivalent 3-Second Duration Design Loading for Blast Resistant Glazing Fabricated with Laminated Glass)

- **Mullion/Frame Design** – Allowable Stress Design
  - **Design Load** = Equivalent 3 second design load ASTM F 2248
  - **Info Required** –
    - 1) Level of Protection
    - 2) Explosive Weight
    - 3) Standoff Distance
  - **Deflection Limit** = L/160
What to Look For in Specifications

2) Typical Specification w/ UFC 4-010-01 (2007 Version)
(UFC 4-010-01 including change 1, 22 January 2007)
2) Typical Specification w/ UFC 4-010-01 (2007 Version) 
(UFC 4-010-01 including change 1, 22 January 2007)

- Connection Design - All parts, including glazing stop
  - Allowable Stress Levels
  - Design Load – Refers to ASTM F 2248 (2 x Design Load for Frame)

- But Look Out For Changes in 2008!
What Will Soon Be Required?

3) UFC 4-010-01 (2008 Version?)

- Mullion/ Frame Design - Mullions
  - Allowable Stress Levels
  - Design Load – 2 x what the glass can take?
    Find Glass Load Capacity ASTM E 1300

- Connection Design - All parts, including glazing stop
  - Allowable Stress Levels
  - Design Load – 4 x what the glass can take?
What to Look for in Specifications?

4) Medium & High Level of Protection – DoD Manual

- Increase in Specified Blast Loads Possible
- Dynamic Analysis Usually Required
- May ask for HAZL or WinGARD (Programs for dynamic analysis)
- May give Peak reflected Pressure & Impulse
- May give maximum ductility
- May ask for connections designed to average peak dynamic loads.
What to Look for in Specifications?
What Works

UFC-4-010-01 Including change 1, 22 January 2007. (Current UFC)

50 psf Frame Loads
100 psf Connections Loads

2’-8” x 7’-3”
What Doesn’t Work

UFC-4-010-01 Including change 1, 22 January 2007. (Current UFC)

50 psf Frame Loads
100 psf Connections Loads

2’-8” x 7’-3”
What Works

UFC-4-010-01 Including change 1, 22 January 2007. (Current UFC)

50 psf Frame Loads
100 psf Connections Loads

2’-8” x 7’-3”
What Doesn’t Work

UFC-4-010-01 Including change 1, 22 January 2007. (Current UFC)

50 psf Frame Loads
100 psf Connections Loads

2’-8” x 7’-3”
What Works

UFC-4-010-01 Including change 1, 22 January 2007. (Current UFC)

50 psf Frame Loads
100 psf Connections Loads

2’-8” x 7’-3”
What Doesn't Work

UFC-4-010-01 (2003 version)
Ultimate Strength

144 psf Frame Loads
633 psf Connections Loads

2’ x 4’
What Doesn’t Work

UFC-4-010-01 (2003 version)
Ultimate Strength

144 psf Frame Loads
633 psf Connections Loads

2’ x 4’
What Doesn’t Work

UFC-4-010-01 (2003 version)
Ultimate Strength

144 psf Frame Loads
633+ psf Connections Loads

4’x5’
What Doesn’t Work

UFC-4-010-01 (2003 version)
Ultimate Strength

144 psf Frame Loads
633+ psf Connections Loads

Door Frame
### What is Performance Level of Glass?

**Specified by GSA**

<table>
<thead>
<tr>
<th>GSA protection levels for glazing response to glass</th>
<th>Description of window glazing response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance condition</strong></td>
<td><strong>Protection level</strong></td>
</tr>
<tr>
<td>1</td>
<td>Safe</td>
</tr>
<tr>
<td>2</td>
<td>Very high</td>
</tr>
<tr>
<td>3a</td>
<td>High</td>
</tr>
<tr>
<td>3b</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Medium</td>
</tr>
<tr>
<td>5</td>
<td>Low</td>
</tr>
</tbody>
</table>
1) Daylight film application - film is applied to vision surface only

2) Mechanical Attached or wet-glazed (glued) film - film is either attached or glued to the window frame

3) Catcher bar, blast curtain or specialty venetian blinds - usually used to catch daylight film

Typical Blast Capacities

<table>
<thead>
<tr>
<th>Thickness, inch</th>
<th>1/4</th>
<th>1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psi</td>
<td>0.5</td>
<td>4.7</td>
</tr>
<tr>
<td>Impulse, psi-ms</td>
<td>22</td>
<td>50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thickness, inch</th>
<th>1/4</th>
<th>1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, psi</td>
<td>2.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Impulse, psi-ms</td>
<td>38</td>
<td>80</td>
</tr>
</tbody>
</table>
## Window Replacement

### Low to Moderate Blast - <5 psi, <50 psi-msec
1) more robust window, thicker glass or insulated
2) Tempered glass stronger than annealed, plus less hazardous shards
3) LAMINATED

### Moderate to High Blast - <10 psi, <100 psi-msec
1) Laminated glass no less than about 1/2 inch thick with deep rebate & wet glazed into frame
2) Robust insulated window with laminated inboard lite, deep rebate, wet glazed

### High Blast - >10 psi, >100 psi-msec
1) Special designed laminated glass, deep rebate, wet glazed
2) Special designed Polycarbonate - typically glass clad but can be used alone

---

Note: the above systems can be used as retrofits behind existing windows to catch or deflect window fragments.
Questions?

- Thank You for Inviting Me!