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PROTECTIVE DESIGN CENTER
TECHNICAL REPORT

STANDOFF DISTANCES FOR JAPANESE CONVENTIONAL CONSTRUCTION

Prepared for
U.S. Army Corps of Engineers
Japan Engineer District

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FOREWORD

The Government of Japan (GOJ) funds construction of certain U.S. Department of Defense (DOD) buildings in Japan. When these DOD buildings are inhabited, the requirements of UFC 4-010-01[1] are mandatory. Meeting the UFC 4-010-01 requirement significantly impacts the standoff distances (separation from the building to parking, roadways, and installation perimeter) required, construction, and fenestration.

While UFC 4-010-01 and PDC-TR 10-02[2] provide information on conventional construction, i.e., construction that would be used in the absence of the UFC 4-010-01 requirements, the construction is more representative of that in the contiguous United States (CONUS). The differences between CONUS conventional construction and conventional construction in Japan can lead to challenges in ensuring that the requirements of UFC 4-010-01 are effectively and efficiently satisfied.

The U.S. Army Corps of Engineers (USACE) Japan Engineer District (JED) requested that USACE Protective Design Center (PDC) provide information specific to typical construction used for DOD building in Japan as it relates to meeting the requirements of UFC 4-010-01. Typical construction of DOD buildings in Japan uses reinforced concrete structural components and laminated glass windows.

This is a new document that supersedes PDC-TR 07-02 in its entirety. As with the original document, and subsequent revisions, this revision provides required minimum standoff distances for construction and windows typically used in Japan, which will achieve the protection requirements from UFC 4-010-01. Revisions have been driven by changes in criteria, changes in typical construction used in Japan, and improvements to analytical tools. Revision 1 to PDC-TR 12-08 includes multiple edits for clarity and accuracy.

For this report, the JED provided a matrix of twelve windows sizes and six glazing layups. The PDC determined the standoff distance required to achieve low and very low, levels of protection (LOP) as defined in UFC 4-010-01 for both explosive weights I and II as defined in UFC 4-010-02[3]. The PDC also determined standoff distances required for a low and very low LOP, for both explosive weights I and II, for a revised matrix of reinforced concrete structural components identified by JED as commonly used in Japan.

The information provided will assist in determining if the protection requirements of UFC 4-010-01 are being provided in an effective and efficient manner. Facilities of different construction and facilities that must provide protection from threats greater than those in UFC 4-010-01 must be specifically analyzed.

Revision 1 includes clarification, minor changes, and minor corrections to the original version. The footnotes in tables 5-10 were updated for consistent wording, the roof slab reinforcement was changed to reflect typical reinforcement in Japan, and rounding errors were corrected in the standoff tables. The June 2013 version should no longer be used.

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[1] Unified Facility Criteria (UFC) 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings,* 9 February 2012, http://dod.wbdg.org/
[2] Protective Design Center Technical Report (PDC-TR) 10-01, *Conventional Construction Standoff Distances of the Low and Very Low Levels of Protection IAW UFC 4-010-01*, https://pdc.usace.army.mil/
[3] Unified Facility Criteria (UFC) 4-010-02, *DoD Minimum Antiterrorism Standoff Distances For Buildings*, , 9 February 2012, http://dod.wbdg.org/

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CONTENTS

TABLES

FIGURES

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SECTION 1 – INTRODUCTION

1-1 Background

The Government of Japan (GOJ) funds construction of certain U.S. Department of Defense (DOD) buildings in Japan. When these DOD buildings are inhabited, the requirements of UFC 4-010-01 are mandatory. Meeting the UFC 4-010-01 requirement significantly impacts the standoff distances (separation from the building to parking, roadways, and installation perimeter) required, construction, and fenestration.

While UFC 4-010-01 and PDC-TR 10-02 provide information on conventional construction, i.e., construction that would be used in the absence of the UFC 4-010-01 requirements, the construction is more representative of that in the contiguous United States (CONUS). The differences between CONUS conventional construction and conventional construction in Japan can lead to challenges in ensuring that the requirements of UFC 4-010-01 are effectively and efficiently satisfied.

The U.S. Army Corps of Engineers (USACE) Japan Engineer District (JED) requested that USACE Protective Design Center (PDC) provide information specific to typical construction used for DOD building in Japan as it relates to meeting the requirements of UFC 4-010-01. Typical construction of DOD buildings in Japan uses reinforced concrete structural components and laminated glass windows.

1-2 Purpose and Scope

This is a new document that supersedes PDC-TR 07-02 in its entirety. As with the original document, and subsequent revisions, this report provides required standoff distances for construction and windows typically used in Japan, which will achieve the protection requirements from UFC 4-010-01. Revisions have been driven by changes in criteria, changes in typical construction used in Japan, and improvements to analytical tools.

For this revision, the JED provided a matrix of twelve windows sizes and six glazing layups. The PDC determined the standoff distance required to achieve low and very low levels of protection (LOP) as defined in UFC 4-010-01 for both explosive weights I and II as defined in UFC 4-010-02. The PDC also determined standoff distances required for a low and very low LOP, for both explosive weights I and II, for a revised matrix of reinforced concrete structural components identified by JED as commonly used in Japan.

Section 2 of this document provides information on the required standoff distances for structural components. Section 3 provides information on the required standoff distances for fenestration. The information provided will assist in determining if the protection requirements of UFC 4-010-01 are being provided in an effective and efficient manner.

This report does not address any requirements related to conventional loads (e.g., seismic, wind, live, dead). The adequacy of structural components and windows to resist these loads is the responsibility of the Engineer of Record for the design.

1-3 Applicability

The information in this report is for use with facilities required to meet only the UFC 4-010-01 requirements and whose windows and construction fall within the limits of those detailed in this report. Facilities of different construction and facilities that must provide protection from threats greater than those in UFC 4-010-01 must be specifically analyzed. This report is a tool for engineers and architects with experience and knowledge of antiterrorism standards and blast effects. It should not be used without complete understanding of its results and limitations.

1-4 References

The following references are cited in this report by designation only.

- ASTM Standard E1300, *Standard Practice for Determining Load Resistance of Glass in Buildings,* 2012, http://www.astm.org/
- ASTM Standard F1642, *Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings,* 2004, http://www.astm.org/
- ASTM Standard F2247, *Standard Test Method for Metal Doors Used in Blast Resistant Applications,* 2011, http://www.astm.org/
- ASTM Standard F2248, *Standard Practice for Specifying an Equivalent 3-Second Duration Design Loading for Blast Resistant Glazing Fabricated with Laminated Glass,* 2009, http://www.astm.org/
- Protective Design Center Technical Report (PDC-TR) 10-01, *Conventional Construction Standoff Distances of the Low and Very Low Levels of Protection IAW UFC 4-010-01*, https://pdc.usace.army.mil/
- Protective Design Center Technical Report (PDC-TR) 06-08, Rev. 1, *Single Degree of Freedom Structural Response Limits for Antiterrorism Design*, https://pdc.usace.army.mil/
- Protective Design Center Technical Report (PDC-TR) 07-02, *Standoff Distances for Standard Japan Facilities Improvement Program Construction (Structures and Windows)*, https://pdc.usace.army.mil/
- Protective Design Center Technical Report (PDC-TR) 06-01, *Methodology Manual for the Single-Degree-of-Freedom Blast Effects Design Spreadsheets (SBEDS)*, https://pdc.usace.army.mil/
- Protective Design Center Technical Report (PDC-TR) 12-01, *Methodology Manual for the SBEDS-W Window Analysis Spreadsheet*, https://pdc.usace.army.mil/
- *Single-Degree-of-Freedom Blast Effects Design Spreadsheets (SBEDS) version 4.2*, USACE Protective Design Center https://pdc.usace.army.mil/
- *Single-Degree-of-Freedom Blast Effects Design Spreadsheets – Windows (SBEDS-W) version 1.0*, USACE Protective Design Center https://pdc.usace.army.mil/
- Unified Facility Criteria (UFC) 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings,* 9 February 2012, http://dod.wbdg.org/
- Unified Facility Criteria (UFC) 4-010-02, *DoD Minimum Antiterrorism Standoff Distances For Buildings,* 9 February 2012, https://pdc.usace.army.mil/
- Unified Facility Criteria (UFC) 4-020-01, *DoD Security Engineering Facilities Planning Manual,* http://dod.wbdg.org/
- Unified Facilities Guide Specifications (UFGS) 08 51 13, *Aluminum Windows,* http://dod.wbdg.org/

1-5 Relationship to Other Requirements

This document is intended to supersede only PDC-TR 07-02 and is not intended to supersede, nor lessen, any other requirements. In the case of conflicts between this PDC-TR and other applicable criteria, use the more stringent requirement.

1-6 Conventional Explosive Effects Considered

Detonation of a conventional explosive device results in a release of energy that occurs so rapidly that there is a local accumulation of energy at the site of the explosion. The accumulated energy dissipates violently through blast waves, propulsion of fragments, and thermal radiation. Depending on the configuration and location of the device, the released energy may cause a pressure wave in air (airblast), groundshock, fragmentation, cratering, thermal radiation, or any combination of these effects.

For terrorist conventional explosive devices considered in UFC 4-010-01, airblast is the primary effect considered in design of structures. The required standoff distances presented in this report are based on airblast requirements.

1-7 Determining Applicable Level of Protection and Explosive Weight

All buildings meeting the definition in UFC 4-010-01 for ‘inhabited building’ require at a minimum a very low LOP. Buildings meeting the definition in UFC 4-010-01 for ‘billeting’, ‘high occupancy family housing’, or ‘primary gathering buildings’ require a low LOP. Descriptions of the expected damage associated with these LOP are found in Table 2-1 and Table 2-2 of UFC 4-010-01.

The applicable explosive weight to use is dependent on whether the installation has a controlled perimeter as defined in UFC 4-010-01. Explosive weight I, as defined in UFC 4-010-02, is associated with charges detonated at a controlled perimeter. Explosive weight II, as defined in UFC 4-010-02, is associated with charges detonated in parking areas and roadways if the installation has a controlled perimeter. If an installation lacks a controlled perimeter, detonation of explosive weight I should be considered in parking areas, the limits of unobstructed space, and roadways.

1-8 Changes in Revision 1

Revision 1 includes clarification, minor changes, and minor corrections to the original version. The footnotes in tables 5-10 were updated for consistent wording, the roof slab reinforcement was changed to reflect typical reinforcement in Japan, and rounding errors were corrected in the standoff tables. The June 2013 version should no longer be used.

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SECTION 2 – STRUCTURAL COMPONENTS

2-1 General

The PDC examined the typical structural components identified by JED to determine minimum required standoff distance for structural components. Standoff distances for low and very low LOP, for both explosive weights I and II, are determined as discussed below.

2-2 Components Examined

The components shown in Table 1 were identified by JED as typical construction for DOD facilities in Japan.

As specified by JED, for all components:

- 21 MPa was used for static compressive strength of concrete.
- 295 MPa was used for reinforcing static yield strength.
- 440 MPa was used for reinforcing static ultimate strength.

Table 1 – Structural Components Considered (All Reinforced Concrete)

Component	Sections (mm)	Spans (m)	Reinforcing	Support Condition
Column	600 x 600 700 x 700 800 x 800	3.5 - 6[1]	18 - D22	Fixed - Simple
Girder	350 x 950 400 x 1400	8 - 12	8 to 13 - D22/25	Fixed - Fixed
Roof Beam	350 x 650 450 x 900	4.5 - 6.5	6 to 10 - D19/22	Fixed - Fixed
Wall[1]	150 mm	3.4 - 10	D10, 150 mm each way in middle of wall	One and two way, all fixed
Roof Slab	130 mm	3 - 3.5	D10, 200 mm each way at top and bottom of slab	Fixed - Fixed

1 - Clear height of the column
2 - Walls are assumed to be nonload-bearing (support less than 2,919 N/m of vertical load, not including the weight of wall) as defined by the 2012 International Building Code.

2-3 Methodology

To determine the required minimum standoff distance, information contained in previous versions of PDC-TR 07-02 and PDC-TR 10-01 were first investigated. The required standoff distance for many of the components identified in Table 1 could be found in these two documents. SBEDS v4.2 recommended increase factors for average strength and dynamic effects were applied to the static strengths identified by JED.

For components not contained in these documents, SBEDS v4.2 and PDC-TR 06-08 were used to determine the required standoff distances to achieve the required LOP. The response due to blast loads was determined using SBEDS and the response limits from PDC-TR 06-08 were used to determine the expected LOP.

2-4 Results and Conclusions

Table 2 contains the required minimum standoff distances for low LOP and very low LOP, for both explosive weights I and II, for reinforced concrete structural components common for DOD facilities in Japan (see Table 1). The values presented in Table 2 are based on review of previous versions of PDC-TR 07-02, PDC-TR 10-01, and SBEDS analysis of components not found in these two documents.

The distances given in Table 2 assume fully reflected blast loading i.e., a line of sight exists from the charge to the component. Should a line of sight not exist, analysis may show lesser standoff required because side-on pressures will usually dominate the response instead of reflected pressures. However, in no case use standoffs less than the minimum standoffs specified in UFC 4-010-01.

Table 2 - Required Minimum Standoff Distances for Structural Components*

Explosive Weight	Required Minimum Standoff Distance (m)	
	Low LOP	Very Low LOP
I	8	6
II	4	4

* - distance given assume fully reflected loading (i.e., a line of sight exists from the charge to the component.)

Before applying the standoff distance in Table 2, verify that the structural components are similar to those in Table 1 and that the required minimum standoff for windows (see SECTION 3) is not greater than those in Table 2.

Facilities of different construction or facilities that must provide protection from threats greater than those in UFC 4-010-01 must be specifically analyzed.

SECTION 3 – DOORS AND FENESTRATION

3-1 General

In this section, the alternate design strategy for exterior doors, or the interior doors in a vestibule or foyer type arrangement, is discussed along with the required minimum standoff distances for a matrix of window sizes and glazing layups.

3-2 Doors

See section B-3.3 of UFC 4-010-01 for the standards that apply to door design and selection.

3-3 Windows

3-3.1 General

The JED specified six glazing layups (see Table 3) and twelve window geometries (see Table 4) commonly used for DOD facilities in Japan. The windows have aluminum frames and mullions with a minimum yield strength of 110 MPa. For each of the geometries, the required minimum standoff distance for each of the glazing systems was investigated. As with the structural components, the required minimum standoff distances assume a fully reflected blast loading. The rough opening is the opening in the wall that the window system will be framed into.

The operable glazing systems provided by JED are rated for a Design Pressure (DP) of 3.6 kPa for windows 6 to 12.

Table 3 – Glazing Layups Considered

Layup Number	Layup[1]	Required Minimum Standoff	Silicone Tensile Strength[5] (MPa)
1	Single pane, 6-mm (0.76) laminate[2]	See Table 5	1.0
2	Single pane, 6-mm (1.52) laminate[2]	See Table 6	1.7
3	IGU[3], 3-mm monolithic + air gap[4] + 6-mm (0.76) laminate	See Table 7	1.7
4	IGU[3], 3-mm monolithic + air gap[4] + 6-mm (1.52) laminate	See Table 8	1.7
5	IGU[3], 6-mm monolithic + air gap[4] + 6-mm (0.76) laminate	See Table 9	1.7
6	IGU[3], 6-mm monolithic + air gap[4] + 6-mm (1.52) laminate	See Table 10	1.7

1 - Number in parentheses is the PVB inner layer thickness in mm for laminated pane.

2 - Glazing is anchored to the frame w/ structural silicon beads on all four edges, both faces.

3 - Insulated glazing unit (IGU) with a laminated pane on interior side of unit and anchored to frame with structural silicon bead on all four edges, interior face only.

4 - 6 and 12-mm air gaps were analyzed.

5 - Structural silicone bead minimum width is 9.5-mm and the minimum thickness is 5-mm

Table 4 – Window Geometry

Window Number	Rough Opening[2]		Number of Sashes	Sash Width[1] (m)	Height of Sill Above Floor (m)	Minimum Mullion Moment of Inertia (mm^4)	Frame Design Pressure (kPa)	Structural Test Pressure (kPa)	Static Reaction Load (kPa)
	Height (m)	Width (m)							
1	0.6	0.3	1	0.3	1.4	-[3]	-[3]	-[3]	-[3]
2	0.6	0.45	1	0.45	1.4	-[3]	-[3]	-[3]	-[3]
3	0.6	0.6	1	0.6	1.4	-[3]	-[3]	-[3]	-[3]
4	0.9	0.6	1	0.6	1.1	-[3]	-[3]	-[3]	-[3]
5	0.9	0.9	1	0.9	1.1	-[3]	-[3]	-[3]	-[3]
6	0.9	1.2	2	0.6	1.1	23700	3.6	5.4	10.8
7	1.2	1.2	2	0.6	0.8	70300	3.6	5.4	10.8
8	1.2	1.5	2	0.75	0.8	87900	3.6	5.4	10.8
9	1.2	1.8	2	0.9	0.8	106000	3.6	5.4	10.8
10	1.5	1.8	2	0.9	0.5	234000	3.6	5.4	10.8
11	2.1	1.8	2	0.9	0	738000	3.6	5.4	10.8
12	2.1	2.1	2	1.05	0	861000	3.6	5.4	10.8

1 - Sash height equal to rough opening height.
2 - Rough opening dimensions coordinated with the JED
3 - Not applicable for single sash windows

3-3.2 Methodology

UFC 4-010-01 allows both static and dynamic analysis of windows systems (i.e., glazing, framing members, and anchorage). To determine the minimum standoffs required for the low LOP and very low LOP, a dynamic approach using the SBEDS-W software is used for the glazing. The default material properties from SBEDS-W, as described in the software documentation, were used.

The correlation between levels of protection and the hazard ratings from ASTM F1642-04 normally associated with glazing is given in Figure 1. Laminated windows have a tendency to fail suddenly when they disengage from the frame. As the standoff distance is reduced, a window may go from a medium LOP to a very low LOP without an intermediate standoff that results in a low LOP. For certain geometries and glazing layups, not having a standoff associated with low LOP and very low LOP would not be unexpected. In the tables below, if a low, or very low, LOP was not attainable, the standoff associated with a medium LOP is reported.

To analyze operable windows in SBEDS-W, a boundary condition requirement is that the frame seats in the opening formed by the mullions, so they can be assumed to be at least pinned. Both panes of the double sash operable windows and the frames, mullions and tracks of the windows specified by JED were assumed to be controlled by the low bearing capacity of the mullion. For windows 6-12, a static procedure based on ASTM F2248 was used to determine the applicable standoff. The procedure is described in detail later in this section. Dynamic analyses were conducted on the double sash operable window lites assuming the frame would not fail. The mullions were calculated to have higher required standoff distances than the lites. Therefore, the lites would not control the standoff for the glazing system and the frame standoffs were used.

The design of the window frame members, connection of the frame members to the supporting structural elements (SSE) and the SSE are dependent on both the static equivalent out-of-plane and in-plane window reactions. The out-of-plane reaction is an equivalent static reaction load equal to the maximum window resistance multiplied by the window area and divided by the total supported length along the window perimeter and is determined using SBEDS-W or Equation 5 shown in Appendix A. The maximum resistance for the dynamic analysis is based on the largest of the maximum resistance from the glass response or the post break membrane response based on analysis using SBEDS-W. The maximum resistance for the static analysis was based on a rated Design Pressure (DP) in accordance with UFGS 08 51 13 and the static procedure described below. The in-plane load on the frame for all analyses is based on the maximum tensile strength of the PVB interlayer and varies based on the thickness of the PVB. The in-plane load may be calculated by multiplying the maximum tensile strength of the cured PVB by the PVB thickness. For example, the in-plane load for 0.76 mm PVB with a tensile strength of 24.1 MPa is 18.3 N/mm (18.3 N/mm = 0.76mm*24.1MPa). For 1.52 mm PVB, the in-plane load is 37.6 N/mm.

The design pressures were multiplied by a factor of 1.5 to determine the Structural Test Pressure (STP) in accordance with UFGS 08 51 13 and AAMA/WDMA/CSA 101/I.S.2/A4411. The STP was considered equal to the load resistance (LR) of the window system and ASTM F2248 was used to find the corresponding standoffs. The STP was multiplied by a factor of 2 to determine the out-of-plane reaction, according to ASTM F2248. The minimum moments of inertias of the mullions shown in Table 4 – Window Geometry met the required L/60 deflection criteria. Since the frame is also subject to 150% of the design load and must remain operable, the extra capacity can be used to reduce the standoff of the operable windows. Twice the structural load should be used to design the connection to the supporting structural elements as a safety factor from the conversion from a static pressure to a dynamic pressure. The ASTM procedure provides a MLOP but can be conservatively used for VLLOP and LLOP buildings as well.

When mullions are provided with DPs other than 3.6 kPa for window layups 6 through 12, use the equations shown in Appendix A to determine the corresponding standoff, out-of-plane reactions. Also, verify that the mullion will meet the L/60 deflection criteria when loaded with 2 times the STP.

ASTM F2248 was used to determine the required silicone geometry. This practice sets the width of the structural silicone sealant bead to be at least equal to the larger of approximately 9.5mm or the thickness designation of the glass to which it adheres but not larger than two times the thickness designation of the glass to which it adheres. The minimum thickness of the structural silicone bead shall be 5mm.

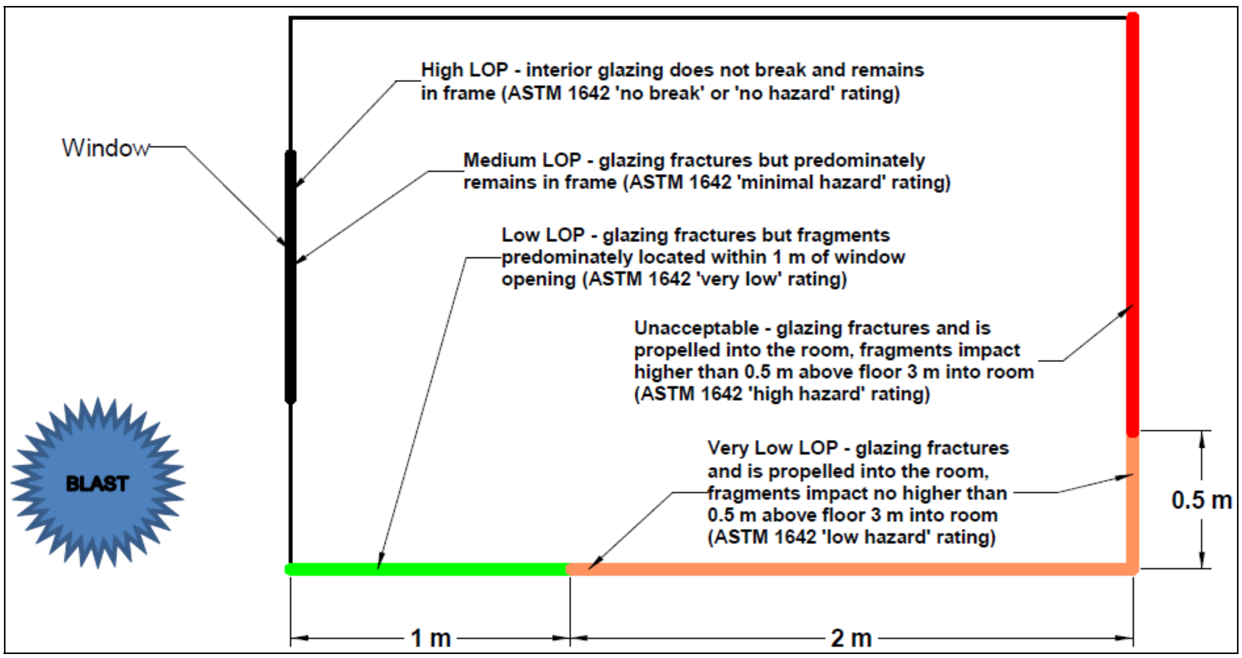

Figure 1 – Glazing LOP - Hazard Level Correlation

3-3.3 Results

The minimum required standoff distances and out-of-plane reactions are contained in Table 5 through Table 10. Each table is for one of the six glazing layups shown in Table 3 and addresses all twelve of the window geometries shown in Table 4. Windows of different glazing layups and/or geometry will need to be specifically analyzed. For glazing layups 1, 3, and 5, the in-plane reaction is 18 N/mm. For glazing layups 2, 4, and 6, the in-plane reaction is 36 N/mm.

Table 5 – Single Pane Glazing Layup 1[1]

Window Number[2]	Level of Protection	Reflected Pressure			
		Explosive Weight I		Explosive Weight II	
		Required Standoff (m)	Out-of-Plane Reaction (N/mm)	Required Standoff (m)	Out-of-Plane Reaction (N/mm)
1	Low	32	6.4	17	6.5
	Very Low	30	6.4	15	6.7
2	Low	31	8.1	16	8.2
	Very Low	30	8.2	15	8.1
3	Low	26	13.1	13	12.9
	Very Low	25	13.1	13	13.0
4	Low	38	7.1	18	7.2
	Very Low	34	7.3	16	7.3
5	Low	30	13.0	14	13.1
	Very Low	28	13.0	13	9.1
6	Low	38	7.1	18	7.2
	Very Low	34	7.3	16	7.3
7	Low	42	6.3	20	6.1
	Very Low	36	6.3	17	6.3
8	Low	41	7.0	19	6.9
	Very Low	36	7.0	17	7.0
9	Low	39	8.2	18	8.0
	Very Low	35	8.2	16	8.2
10	Low	44	6.8	20	6.6
	Very Low	37	6.8	17	6.8
11	Low	46	6.3	20	6.3
	Very Low	33	6.3	15	6.3
12	Low	47	6.3	20	6.6
	Very Low	36	6.3	15	6.7

1 - See Table 3 for glazing layup description.
2 - See Table 4 for window geometry.

Table 6 – Single Pane Glazing Layup 2[1]

Window Number[2]	Level of Protection	Reflected Pressure: Explosive Weight I: Required Standoff (m)	Reflected Pressure: Explosive Weight I: Out-of-Plane Reaction (N/mm)	Reflected Pressure: Explosive Weight II: Required Standoff (m)	Reflected Pressure: Explosive Weight II: Out-of-Plane Reaction (N/mm)
1	Low	23	12.5	12	12.4
	Very Low	-[4]	-[4]	12	12.6
2	Low	23	15.5	12	15.9
	Very Low	22	16.3	11	16.3
3	Low	19	25.9	10	26.0
	Very Low	-[4]	-[4]	-[4]	-[4]
4	Low	26	14.4	13	14.4
	Very Low	16	14.6	13	14.6
5	Low	21	26.1	11	25.7
	Very Low	21	26.1	10	26.1
6	Low	29[3]	3.2	13	14.4
	Very Low	-[4]	-[4]	-[4]	-[4]
7	Low	29	12.6	14	12.6
	Very Low	29[3]	3.2	13	12.6
8	Low	29	13.8	14	13.6
	Very Low	29[3]	3.6	13	13.9
9	Low	29[3]	3.6	13	16.1
	Very Low	-[4]	-[4]	-[4]	-[4]
10	Low	31	13.5	15	12.7
	Very Low	29	13.6	13	13.6
11	Low	33	12.4	15	12.4
	Very Low	29[3]	5.2	13[3]	5.2
12	Low	33	13.1	15	12.9
	Very Low	29[3]	5.7	13	13.4

1 - See Table 3 for glazing layup description.
2 - See Table 4 for window geometry.
3 - Standoff controlled by operable frame and meets MLOP per paragraph 3-3.2
4 - Level of Protection values overlap, only the highest LOP is shown

Table 7 – IGU Glazing Layup 3[1]

Window Number[2]	Level of Protection	Reflected Pressure: Explosive Weight I: Required Standoff (m)	Reflected Pressure: Explosive Weight I: Out-of-Plane Reaction (N/mm)	Reflected Pressure: Explosive Weight II: Required Standoff (m)	Reflected Pressure: Explosive Weight II: Out-of-Plane Reaction (N/mm)
1	Low	31	8.7	17	8.3
	Very Low	30	8.7	15	8.2
2	Low	29	8.2	16	8.2
	Very Low	28	8.1	14	8.13
3	Low	26	13.0	12	12.9
	Very Low	24	13.1	12	13.0
4	Low	35	7.3	16	7.3
	Very Low	32	7.3	14	7.3
5	Low	27	13.1	13	13.1
	Very Low	26	13.0	12	13.0
6	Low	35	8.1	16	8.1
	Very Low	32	7.3	14	7.3
7	Low	37	6.3	17	6.3
	Very Low	32	6.3	14	6.3
8	Low	36	7.0	17	7.0
	Very Low	32	7.0	15	7.0
9	Low	35	8.2	16	8.2
	Very Low	32	8.2	14	8.2
10	Low	39	6.8	16	6.8
	Very Low	32	6.8	15	6.8
11	Low	40	6.1	20	6.1
	Very Low	32[3]	6.1[3]	15[3]	6.1[3]
12	Low	47[3]	6.3[3]	20[3]	6.3[3]
	Very Low	36[3]	6.3[3]	15[3]	6.3[3]

1 - See Table 3 for glazing layup description.
2 - See Table 4 for window geometry.
3 - Analysis only considers the 6mm laminated inner pane due to software limitations

Table 8 – IGU Glazing Layup 4[1]

Window Number[2]	Level of Protection	Reflected Pressure: Explosive Weight I: Required Standoff (m)	Explosive Weight I: Out-of-Plane Reaction (N/mm)	Explosive Weight II: Required Standoff (m)	Explosive Weight II: Out-of-Plane Reaction (N/mm)
1	Low	23	12.5	13	12.6
	Very Low	23	12.6	12	12.5
2	Low	21	16.3	11	15.9
	Very Low	21	16.3	10	16.3
3	Low	18	26.1	9	25.7
	Very Low	18	26.1	9	26.1
4	Low	24	14.5	12	14.4
	Very Low	23	14.6	11	14.6
5	Low	20	25.9	10	25.9
	Very Low	20	26.1	9	26.1
6	Low	29[3]	2.8	13[3]	2.8
	Very Low	29[3]	2.8	13[3]	2.8
7	Low	29[3]	3.2	13[3]	3.2
	Very Low	29[3]	3.2	13[3]	3.2
8	Low	29[3]	3.6	13[3]	3.6
	Very Low	29[3]	3.6	13[3]	3.6
9	Low	29[3]	3.9	13[3]	3.9
	Very Low	29[3]	3.9	13[3]	3.9
10	Low	29[3]	4.4	13	13.5
	Very Low	29[3]	4.4	13[3]	4.4
11	Low	31	12.2	15[4]	12.2[4]
	Very Low	29[3]	5.2	13	12.2
12	Low	33[4]	12.6[4]	15[4]	12.6[4]
	Very Low	29[4]	12.6[4]	13[4]	12.6[4]

1 - See Table 3 for glazing layup description.
2 - See Table 4 for window geometry.
3 - Standoff controlled by operable frame and meets MLOP per paragraph 3-3.2
4 - Analysis only considers the 6mm laminated inner pane due to software limitations

Table 9 – IGU Glazing Layup 5[1]

Window Number[2]	Level of Protection	Reflected Pressure			
		Explosive Weight I		Explosive Weight II	
		Required Standoff (m)	Out-of-Plane Reaction (N/mm)	Required Standoff (m)	Out-of-Plane Reaction (N/mm)
1	Low	28	7.7	14	7.1
	Very Low	27	7.5	13	7.0
2	Low	28	10.4	14	8.2
	Very Low	27	9.6	13	10.6
3	Low	24	13.0	12	13.0
	Very Low	23	13.1	12	13.1
4	Low	33	7.3	14	7.5
	Very Low	30	7.4	14	7.3
5	Low	26	13.1	12	12.9
	Very Low	25	13.1	11	13.0
6	Low	33	7.3	14	7.5
	Very Low	30	7.4	14	7.3
7	Low	37	6.3	16	6.3
	Very Low	31	6.3	14	6.3
8	Low	34	7.0	16	7.3
	Very Low	31	7.4	14	7.0
9	Low	32	8.2	15	8.2
	Very Low	30	8.2	13[3]	3.9
10	Low	33	6.8	15	7.1
	Very Low	30	6.8	13[3]	3.2
11	Low	36	6.1	15	6.1
	Very Low	29	6.1	13[3]	5.2
12	Low	35	6.3	15	6.3
	Very Low	29[3]	5.7	13[3]	5.7

1 - See Table 3 for glazing layup description.
2 - See Table 4 for window geometry.
3 - Standoff controlled by operable frame and meets MLOP per paragraph 3-3.2

Table 10 – IGU Glazing Layup 6[1]

Window Number[2]	Level of Protection	Reflected Pressure			
		Explosive Weight I		Explosive Weight II	
		Required Standoff (m)	Out-of-Plane Reaction (N/mm)	Required Standoff (m)	Out-of-Plane Reaction (N/mm)
1	Low	21	12.6	11	12.3
	Very Low	21	12.6	11	12.6
2	Low	21	16.2	11	16.3
	Very Low	20	16.3	10	16.3
3	Low	18	26.1	9	25.9
	Very Low	18	26.1	9	25.9
4	Low	23	14.6	12	14.3
	Very Low	23	14.6	12	14.6
5	Low	19	26.1	9	26.1
	Very Low	19	26.1	8	26.1
6	Low	29[3]	2.8	13[3]	2.8
	Very Low	29[3]	2.8	13[3]	2.8
7	Low	29[3]	3.2	13[3]	3.2
	Very Low	29[3]	3.2	13[3]	3.2
8	Low	29[3]	3.6	13[3]	3.6
	Very Low	29[3]	3.6	13[3]	3.6
9	Low	29[3]	3.9	13[3]	3.9
	Very Low	29[3]	3.9	13[3]	3.9
10	Low	29[3]	4.4	13[3]	4.4
	Very Low	29[3]	4.4	13[3]	4.4
11	Low	29[3]	5.2	13[3]	5.2
	Very Low	29[3]	5.2	13[3]	5.2
12	Low	29[3]	5.7	13[3]	5.7
	Very Low	29[3]	5.7	13[3]	5.7

1 - See Table 3 for glazing layup description.
2 - See Table 4 for window geometry.
3 - Standoff controlled by operable frame and meets MLOP per paragraph 3-3.2

APPENDIX A

STANDOFF CALCULATION PROCEDURE FOR OPERABLE WINDOWS

Charge Weight I

$$SO = \left(\frac{STP}{233}\right)^{-0.893}$$

$$1 < STP < 4$$

Equation 1

$$SO = \left(\frac{STP}{327}\right)^{-0.82}$$

$$4 < STP < 9$$

Equation 2

Charge Weight II

$$SO = \left(\frac{STP}{88.3}\right)^{-0.893}$$

$$1 < STP < 4$$

Equation 3

$$SO = \left(\frac{STP}{230}\right)^{-0.69}$$

$$4 < STP < 9$$

Equation 4

Where:
STP = Structural Test Pressure
SO = Standoff (m)

Out-of-Plane Load

$$Out - of - Plane\ Load = 2 * STP * Area/Perimeter$$

Equation 5

Where:
STP = Structural Test Pressure
Area = Rough Opening Area
Out-of-Plane Load = Connection Line Load along Frame (N/mm)
Perimeter = Rough Opening Perimeter

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