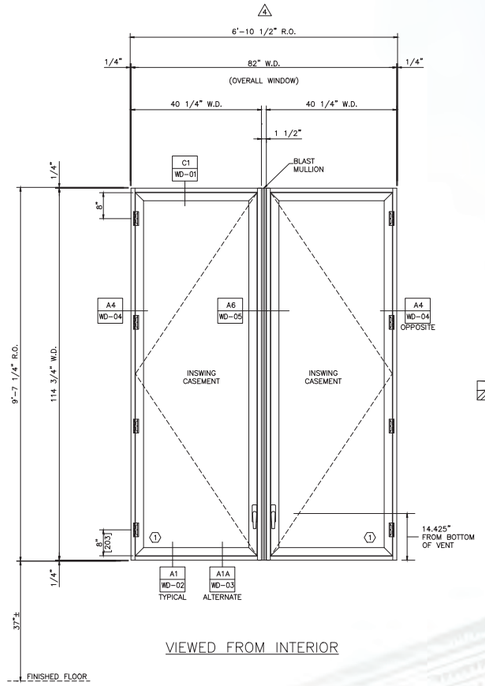
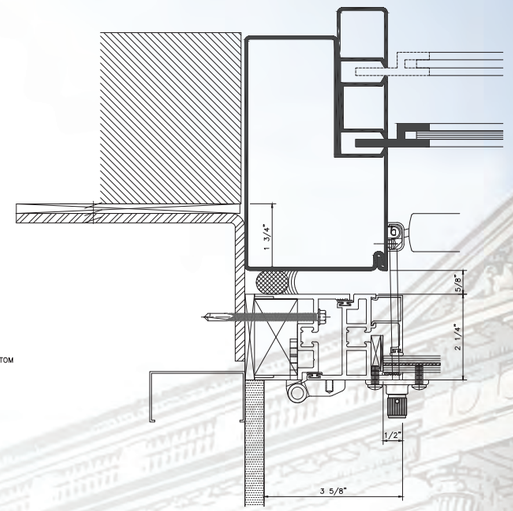
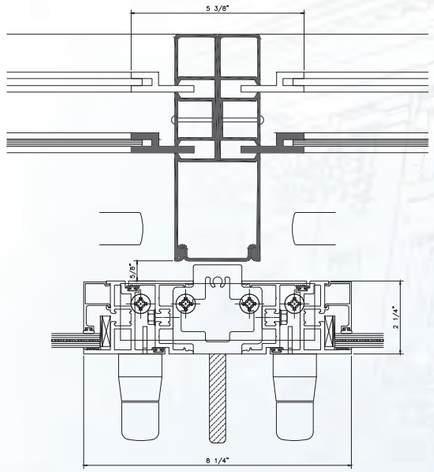
GRAHAM
ARCHITECTURAL PRODUCTS

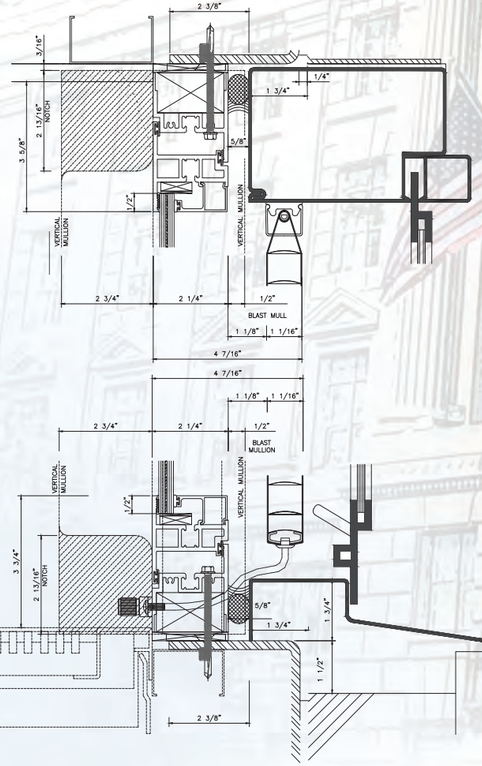
BLAST-RESISTANT WINDOWS & DOORS

YOUR VISION. OUR EXPERIENCE.™









HERBERT C. HOOVER BUILDING
Washington, D.C.

BLAST MITIGATION – REDUCING RISK & SAVING LIVES

Despite our best efforts to prevent acts of terrorism both homegrown and foreign, the reality is that the threat remains. Although terrorist attacks garner the most attention, non-terrorist blast threats are also a serious concern for some building owners. Blast resistant windows are a key factor in mitigating incidental injuries in the event of an accidental explosion.

Reducing Risk

While complete protection from bomb blasts and explosions is not possible, there are steps we can take to mitigate damage and injury. Blast-resistant windows and doors have long been used in a variety of applications where the obvious need existed. However, modern times have seen a shift in the methods and targets of terrorist acts, creating the need for blast protection on additional structures not typically targeted in the past.

Why Use Blast Windows And Entry Systems?

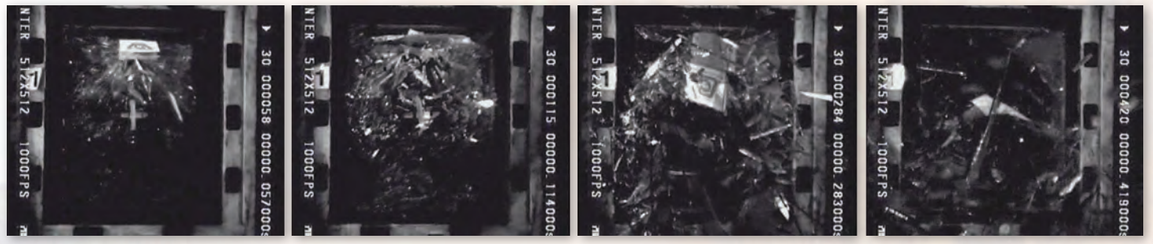
Since the 1995 bombing of the Oklahoma Federal Building, blast-resistant windows for high-profile buildings have become a way of life. As technology improves and we learn more about the wide-ranging effects of bomb blasts, it has become apparent that a larger scope of buildings, in addition to high-profile buildings and their occupants, could benefit from blast and ballistic-resistant windows and doors.

Effects Of Flying Glass From Blast Attacks

The debris generated and the collapse of structures produced during an explosion cause the majority of injuries and deaths in a bombing event. For example, over 5,000 people were injured by flying glass and debris in the 1998 bombings of two American embassies in Africa. The types of injuries that occurred included deep lacerations and eye injuries. Approximately 90 people were blinded in the attack on the U.S. Embassy in Kenya.

When designing window systems to resist blast forces, it is important that the glazing, framing, and anchorage all be designed to withstand the required forces and absorb some of the blast force. Generally, the glazing should be the weak link (i.e., it is not desirable for the entire window system to blow into occupied spaces due to frame anchorage failure). This approach is referred to as balanced design.

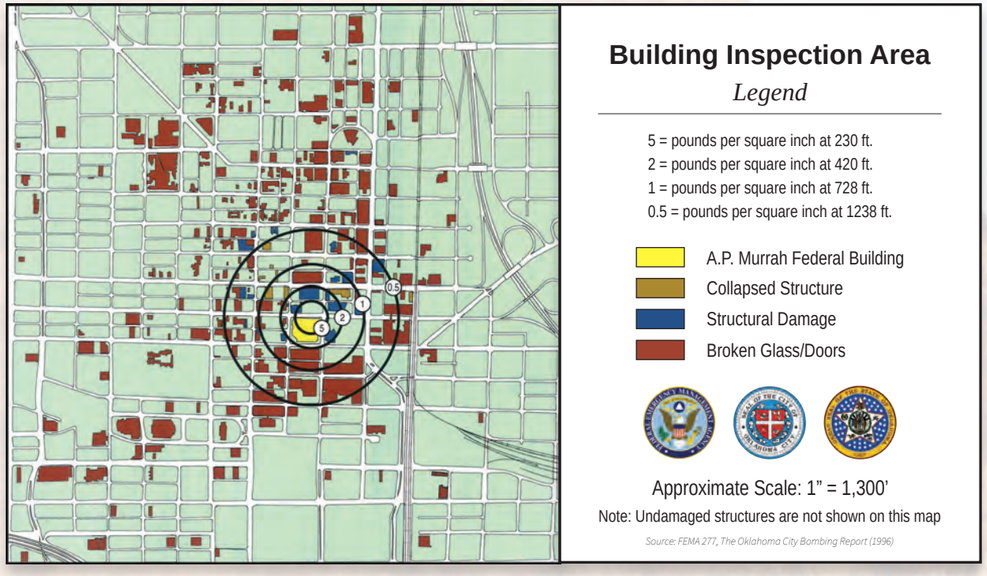
Today, primarily because of the increased threat of terrorism, all U.S. federal buildings require enhanced levels of protection from the hazards of glass. Approximately 75 percent of all damage and injury from bomb blasts can be attributed to flying and falling glass following the explosion. Even high-profile private buildings and places of public assembly are now routinely evaluated for enhanced glazing protection measures. Protective glazing is a key component of “hardened” buildings for which the ultimate goal is to provide security for building occupants and assets.



There is no such thing as blast proof

You often see or hear terms like “blast-proof,” “bulletproof,” “fireproof” and “waterproof.” What do they really mean? In the case of “blast-proof” it would mean that the window would have to withstand any blast impact with no exception. This is not only impossible but impractical. Creating a blast-proof window would mean that it would potentially be stronger than the structure itself. A window that survives an explosion is of little use in a building that does not. Windows and doors are built to withstand certain threat levels, to withstand pressures/impulses that model the effects of an explosion within predetermined parameters.

Blast-resistant windows are designed to withstand a specific blast load, not to defend against all blast loads.



1995 Oklahoma City Bombing Damage Assessment

Why Graham?

- **Our Vision —** Graham Architectural Products (Graham) is the company architects seek first when faced with large, complex fenestration challenges. We earn their trust by demonstrating our experience, expertise and collaborative spirit, while providing innovative solutions to their most difficult problems.
- **Our Mission —** Graham manufactures the most innovative and highest quality products in the fenestration industry. We achieve this by developing customized, performance-based products, and by providing our customers with answers to their fenestration challenges. We earn and retain the architectural community’s trust by virtue of our competence, proficiency, and our reputation for standing behind our work.
- **Our Position —** For ARCHITECTS, BUILDING OWNERS, INSTALLERS, GENERAL CONTRACTORS, AND DEALERS, Graham is the commercial and architectural grade window manufacturer that leading architects around the U.S. turn to when facing their most challenging design projects. For more than 40 years we have been producing, delivering and standing behind the highest quality products in the fenestration industry. Nobody in the industry has more experience, is more reliable, or commands a higher level of trust than Graham.

BLAST HAZARD CLASSIFICATIONS

The General Services Administration (GSA), American Society for Testing and Materials (ASTM), and United Facilities Criteria (UFC) have testing methods and rating levels for fenestration products and glazings subjected to blast loads. The information here summarizes each for comparison.

ASTM

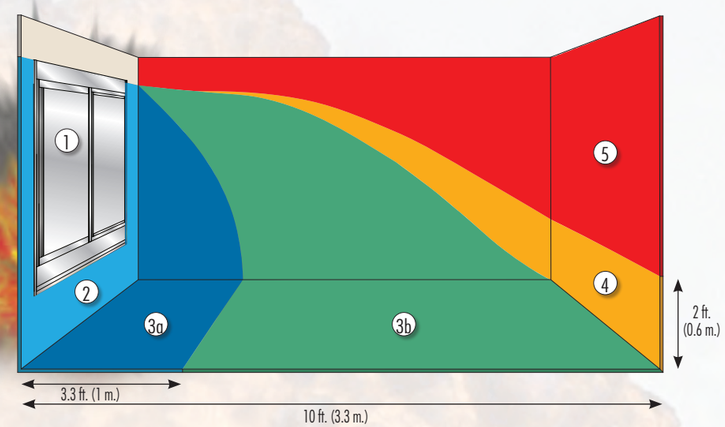
ASTM Rating	ASTM Description
No Break	The glazing is observed not to fracture and there is no visible damage to the glazing system.
No Hazard	The glazing is observed to fracture but is fully retained in the facility test frame or glazing system frame, and the rear surface (the surface opposite the air-blast loaded side of the specimen) is intact.
Minimal Hazard	The glazing is observed to fracture, and the total length of tears in the glazing plus the total length of pullout from the edge of the frame is less than 20% of the glazing sight perimeter. Also, there are less than 3 pinhole perforations and no fragment indents anywhere in a vertical witness panel located 3 m (120 in.) from the interior face of the specimen, and there are fragments with a sum total united dimension of 25 mm (1.0 in.) or less on the floor between 1 m (40 in.) and 3 m (120 in.) from the interior face of the specimen. Glazing dust and slivers are not accounted for in the rating.
Very Low Hazard	The glazing is observed to fracture, and is located within 1 m (40 in.) of the original location. Also, there are three or less pinhole perforations and no fragment indents anywhere in a vertical witness panel located 3 m (120 in.) from the interior face of the specimen, and there are fragments with a sum total united dimension of 25 mm (1.0 in.) or less on the floor between 1 m (40 in.) and 3 m (120 in.) from the interior face of the specimen. Glazing dust and slivers are not accounted for in the rating.
Low Hazard	The glazing is observed to fracture, but glazing fragments generally fall between 1 m (40 in.) of the interior face of the specimen and 0.5 m (20 in.) or less above the floor of a vertical witness panel located 3 m (120 in.) from the interior face of the specimen. Also, there are ten or fewer perforations in the area of a vertical witness panel located 3 m (120 in.) from the interior face of the specimen and higher than 0.5 m (20 in.) and none of the perforations penetrate through the first layer of the witness panel.
High Hazard	Glazing is observed to fracture, and there are more than ten perforations in the area of a vertical witness panel located 3 m (120 in.) from the interior face of the specimen and higher than 0.5 m (20 in.) above the floor, or there are one or more perforations in the same witness panel area with a fragment penetration into the second layer of the witness panel.

UFC

Level of Protection	Potential Building Damage/Performance	Potential Door & Glazing Hazards	Potential Injury
Below AT Standards	Severe damage. Progressive collapse likely. Space in and around damaged area will be unusable.	Windows will fail catastrophically and result in lethal hazards. (High hazard rating) Doors will be thrown into rooms. (Category V)	Majority of personnel in collapse region suffer fatalities. Potential fatalities in areas outside of collapsed area likely.
Very Low	Heavy damage -- Onset of structural collapse, but progressive collapse is unlikely. Space in and around damaged area will be unusable.	* Glazing will fracture, come out of the frame, and is likely to be propelled into the building, with potential to cause serious injuries. (Low hazard rating) * Doors will become dislodged from the structure but will not create a flying debris hazard. (Category IV)	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.
Low	Moderate damage -- Building damage will not be economically repairable. Progressive collapse will not occur. Space in and around damaged area will be unusable.	* Glazing will fracture, potentially come out of the frame, but at reduced velocity, does not present a significant injury hazard. (Very low hazard rating) * Doors will experience non-catastrophic failure, but will have permanent deformation and may be inoperable. (Category III)	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 minor to moderate injuries.
Medium	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 repairs.	* Glazing will fracture, remain in the frame and results in a minimal hazard consisting of glass dust and slivers. (Minimal hazard and No Hazard ratings) * Doors will be operable but will have permanent deformation. (Category II)	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.
High	Minimal damage. No permanent deformations. The facility will be immediately operable.	* Innermost surface of glazing will not break. (No Break hazard rating) * Doors will be substantially unchanged and fully operable. (Category I)	Only superficial injuries are likely.

GSA Condition	Protection Level	Hazard Level	GSA Description
1	Safe	None	Glazing does not break. No visible damage to glazing or frame.
2	Very High	None	Glazing cracks but is retained by the frame. Dusting or very small fragments near sill or on floor acceptable.
3a	High	Very Low	Glazing cracks. Fragments enter space and land on floor no further than 3.3 ft. from the window.
3b	High	Low	Glazing cracks. Fragments enter space and land on floor no further than 10 ft. from the window.
4	Medium	Medium	Glazing cracks. Fragments enter space, land on floor and impact a vertical witness panel at a distance of no more than 10 ft. from the window at a height no greater than 2 ft. above the floor.
5	Low	High	Glazing cracks and window system fails catastrophically. Fragments enter space impacting a vertical witness panel at a distance of no more than 10 ft. from the window at a height greater than 2 ft. above the floor.

The GSA criteria define five injury hazard performance conditions to indicate whether and how far glass shards penetrate into a room when the window and wall segment are subjected to a blast of calculated impact pressure. The protection performance conditions are numerically defined from 1 through 5.



TEST METHODS

Shock Tube

The shock tube test is a method that uses an air cannon powered by high pressure air or nitrogen. It provides a controlled simulation of the positive phase of the blast waveform at a relatively low cost, but still does not address negative and rebound phases of the blast wave.

- High pressure air pulses are released through a pipe or tube directed at the test specimen
- Can be performed safely in a controlled accredited laboratory setting
- Three samples must pass in order for a product to be considered as “passing“ or acceptable

Photo courtesy of Intertek

Open Arena

Arena, or open-air blast testing, is done using actual explosive charges at specified charge weights and stand-off distances. The test specimens are installed into very strong (usually concrete) test chambers that will resist the blast and the installed windows or doors are observed during and after the blast event with high speed cameras.

- Detonation of an actual explosive device is required
- Cannot be safely done on a project site
- Should always be performed by an experienced blast engineering firm

GRAHAM'S CAPABILITIES

Experience

Graham Architectural Products has been making blast-resistant products and supplying them to government and private customers since shortly after the 9/11 terrorist attacks. Our staff has extensive knowledge of government specifications and application processes that ensure proper design for the intended purpose.

Quality

Graham is known in the industry for our work supplying custom historic replications that require exacting details and the highest quality standards. We apply those same standards to everything we make, including the multitude of new construction and retrofit projects Graham has been involved with. When you specify Graham, you are assured a quality product that's right for the job.

Custom Engineered

Each and every job we do is custom engineered at our facility to meet your specifications. From structural design to hardware application and historic replication, your Graham windows and doors are built for just one customer: you.

Blast Testing & Calculations

Graham has one of the most complete lines of tested blast-resistant window and door products. We believe that thorough testing is essential in providing a greater assurance that our products will perform as expected in real-world situations.

Each blast project is individually assessed by our engineers to assure compliance with your specific requirements. In addition to base model physical testing, blast calculations are performed on project-specific details inclusive of anchorage and fenestration sizes. When Graham supplies blast-resistant products, rest assured that we have done our homework to provide you with a high quality custom solution that meets your specific blast requirements.

Unified Facilities Criteria (UFC)

DoD Minimum Antiterrorism Standards for Buildings

U.S. General Services Administration

Standard Test Method for Glazing & Window Systems Subject to Dynamic Overpressure Loadings

Designation: F 1642 – 034

Standard Test Method for Glazing & Glazing Systems Subject to Airblast Loadings

AAMA 510-14

Voluntary Guide Specification for Blast Hazard Mitigation for Vertical Fenestration Systems

BLAST-RESISTANT WINDOWS & DOORS

Model	Operation	Depth	Condition/ Hazard Response	Design Blast Pressure (psi)	Positive Phase Impulse (psi-msec)	Window Size	Test Method
B0300	Sliding	3.25	Minimal	6 psi	42	66 x 48	ASTM F 1642
B0360	Sliding	3.25	UFC & GSA Calculated	As Req'd	As Req'd	Various	UFC & GSA Calculated
B1200	Fixed (Nail Fin)	3.25	N/A	Minimum UFC 4-010-01	Minimum UFC	49.75 x 67.75	UFC Calculation
B1200	Fixed (Standard)	3.25	Minimal	6.1	41	48 x 66	ASTM F 1642
B1400H	Fixed	4	Minimal	6.7	47	48 x 66	ASTM F 1642
B2000	Single Hung (Nail Fin)	3.25	Minimal	6.6	48	45.50 x 63.375	ASTM F 1642
B2000	Single Hung (Standard)	3.25	Minimal	4.4	34.3	48 x 66	ASTM F 1642
B2200H	Double Hung	4	Low	6.2	42	49.75 x 67.75	ASTM F 1642
B6500	Casement	2.25	Minimal	5.9	48	48 x 66	ASTM F 1642
B6500	Fixed	2.25	Minimal	6.4	48	48 x 66	ASTM F 1642
B6500	Projected	2.25	Minimal	5.9	48	48 x 66	ASTM F 1642
B6500IBG	In-Swing Casement (Single)	2.25	Minimal	7	44	48 x 85	ASTM F 1642
B6500IBG	In-Swing Casement (Twin)	2.25	No Break	5.3	32.8	88 x 96.75	ASTM F 1642
B6800	Casement	3.5	Minimal	6	42	49.75 x 67.75	ASTM F 1642
B6800	Fixed	3.5	Minimal	5.8	41	49.75 x 67.75	ASTM F 1642
B6800	Projected	3.5	Minimal	6	42	49.75 x 67.75	ASTM F 1642
B6800HP	Casement/Projected	3.5	Low	10.8 & 23.5	96 & 100	49.75 x 67.75	ASTM F 1642
B6800HP	Fixed	3.5	No Break	10.4 & 24.2	91 & 116	49.75 x 67.75	ASTM F 1642
B7600	Entry Door	6.375	Minimal	6.4	50	44.50 x 88.25	ASTM F 1642

BULLET-RESISTANT WINDOWS

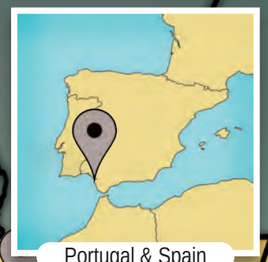
Model	Operation	Depth	Rating
BR6800	Fixed	3.5	UL 752 Level 3 (.44 Magnum Rated)

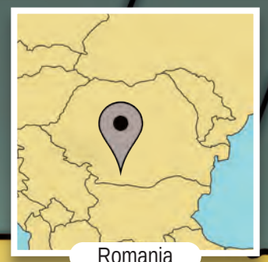
All information current as of publication date.

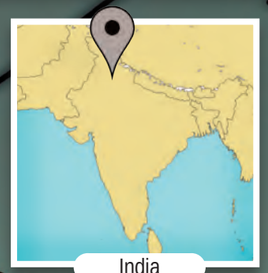
SELECTED PROJECTS

Here is an illustration of the many blast-resistant projects Graham has completed in North America and around the world.

Name	Location
Naval Base Kitsap	Bangor, WA
Marine Corps Base Camp Pendleton	Camp Pendleton, CA
Naval Base Point Loma	Point Loma, CA
Naval Air Station North Island	Coronado, CA
Fort MacArthur	San Pedro, CA
Fort Bliss	El Paso, TX
Fort Sam Houston	San Antonio, TX
Naval Air Station Corpus Christi	Corpus Christi, TX
Mesa Springs Psychiatric Hospital	Fort Worth, TX
US Customs House	Denver, CO
MN Armories	Madison, MN
Albert Lea Armory	Albert Lea, MN
Offutt Air Force Base	Omaha, NE
Benton County Courthouse	Bentonville, AR
Dobbins Air Force Base	Atlanta, GA
Fort Gordon, U.S. Army Installation	Augusta, GA
Robert S. Vance Federal Building & Courthouse	Birmingham, AL
Scott Air Force Base	Shiloh, IL
UIUC USACE Research Lab	Champaign, IL
Joint Base Little Creek-Fort Story	Chicago, IL
FBI Office Bldg.	Indianapolis, IN
TACOM Military Base	Warren, MI
Ohio Air National Guard	Swanton, OH
Wright-Patterson Air Force Base	Dayton, OH
Dept. of Commerce Herbert Hoover Bldg.	Washington, D.C.
Naval Support Facility Dahlgren	Dahlgren, VA


Portugal & Spain


Romania


India


Japan


Afghanistan


Hawaii

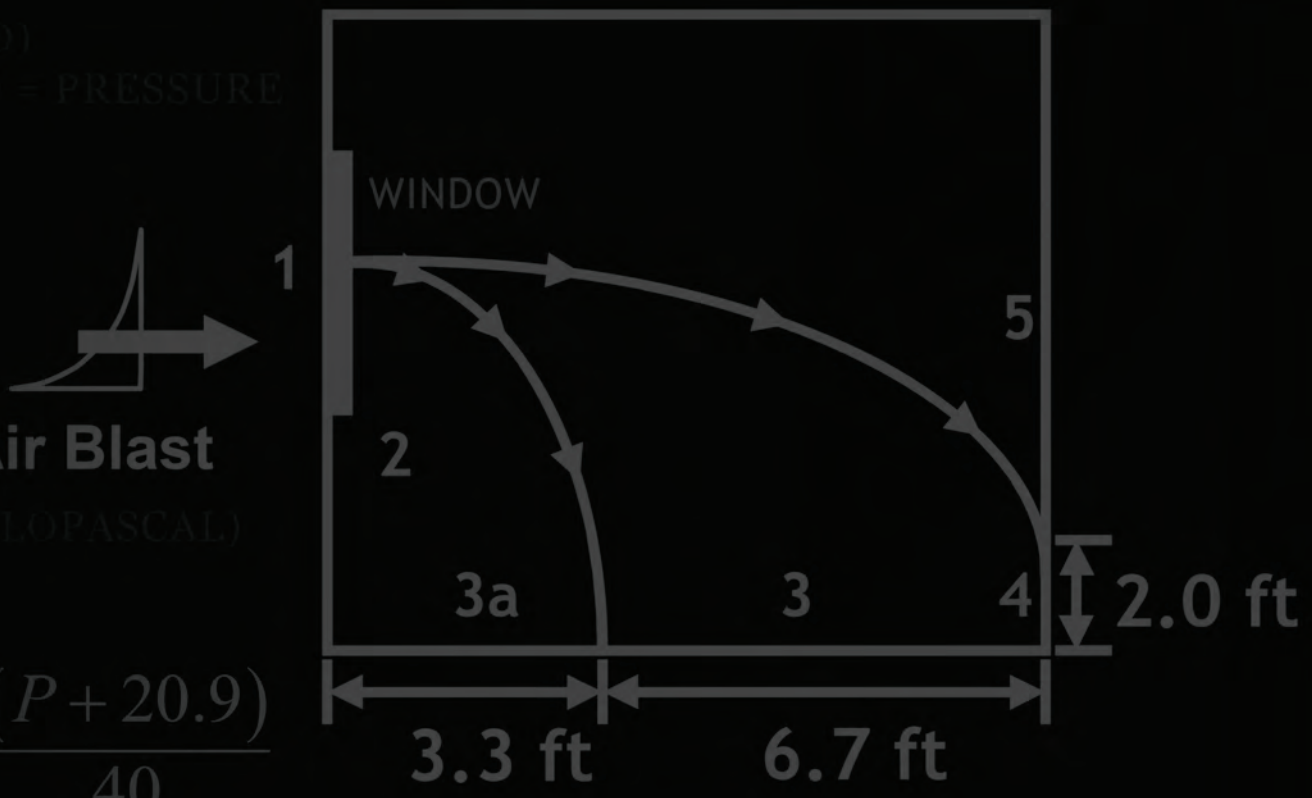

Honduras


Guam


Diego Garcia

Name	Location
Great Lakes Naval Base	Norfolk, VA
Camp LeJeune	Jacksonville, NC
U.S. Coast Guard Station	St. Inigoes, MD
MacDill Air Force Base	Tampa, FL
Pensacola Naval Air Station	Pensacola, FL
Eglin Air Force Base	Niceville, FL
Joint Base Lakehurst	Lakehurst, NJ
Cherry Hill Armory	Cherry Hill, NJ
United States Military Academy, West Point	West Point, NY
Watervliet Arsenal	Watervliet, NY
Naval Station Newport	Newport, RI
Youth Challenge Academy	Hilo, HI
Helemano Military Reservation	Wahiawa, HI
Schofield Military Barracks	Schofield, HI
Soto Cano Air Force Base	Comayagua, Honduras
William C. McCool Elementary/Middle School	Rita, Guam
Navy Gateway Inns & Suites	Diego Garcia
Lajes Field	Azores, Portugal
Navel Station Rota	Rota, Spain
Naval Support Facility Deveselu	Deveselu, Romania
N500 HP (Military Installation)	New Delhi, India
Misawa Air Force Base	Misawa, Japan
Bagram Air Base	Afghanistan

$$\Delta p_m = 1.02\frac{q^{1/3}}{r} + 4.36\frac{q^{2/3}}{r^2} + 14\frac{q}{r^3} \text{ (bar)}$$



$$\Theta = \frac{(P + 20.9)}{40}$$

$$\left)^3 + E(\ln Z)^4\right)(4)$$