TECHNICAL GUIDE

# Blast-Resistant Glazing

Explained and simplified

In most explosive incidents the greatest cause of injury is not the blast itself — it is flying glass.

Blast-resistant glazing does not stop a blast. It controls **where the glass goes**. Getting that right depends on describing the load properly, and on understanding that the glass is only one part of what has to survive.

## 1 · What actually arrives at the window

An explosion sends out a shock front. Ahead of it the air is undisturbed; behind it the pressure jumps almost instantly to a peak, then decays back to ambient. It then falls *below* ambient before recovering. That second part matters, and it is routinely ignored.

- **The positive phase** pushes the glazing inwards. It is short, sharp and carries most of the energy.
- **The negative phase** follows, as air rushes back to fill the partial vacuum at the seat of the explosion. It is weaker but lasts longer, and it pulls the glazing *outwards*.

**WHY THE NEGATIVE PHASE MATTERS**

Rebound during the negative phase is a genuine failure mode, not a footnote. In published trial records, glazing has been drawn out of its opening on the way back after surviving the way in. Anchorage and fixings have to work in both directions.

## 2 · Incident or reflected — ask this first

This is the most common and most expensive misunderstanding in facade blast work, and it is worth settling before any other conversation.

| | What it is | Where it is measured |
|---|---|---|
| **Incident (side-on)** | The pressure in the free-field wave as it passes | By a gauge oriented edge-on to the wave, so the flow passes it |
| **Reflected** | The pressure when the wave is stopped dead by a surface facing it | On the face of the building — which is what the glazing actually experiences |

Reflected pressure is always higher than incident. At the low overpressures typical of process facility design the reflection factor is around **2**; as the peak pressure rises the factor rises sharply, and at close-in high-explosive loads it can be several times that.

**THE QUESTION THAT CHANGES THE ANSWER BY 100%**

If a specification states a pressure without saying whether it is incident or reflected, the difference between the two readings is at least a factor of two on the design load. We ask, every time. Where it cannot be established we take the stated figure as incident and apply a reflection factor, and we say so on the face of the calculation.

## 3 · The three numbers

**P** PRESSURE

### Peak reflected overpressure

How hard the wave hits the face of the glazing. Written as Pr, in kPa, bar, mbar or psi.

**t** DURATION

### Positive phase duration

How long the push lasts before the pressure returns to ambient. Written as td, in milliseconds.

**i** IMPULSE

### Reflected positive-phase impulse

Pressure integrated over time — the energy delivered. Written as ir, in kPa·ms or psi·ms.

The three are related. Idealising the decay as a straight line — the standard simplification for design — gives $\mathbf{i_r \approx ½ \times P_r \times t_d}$. So any two of the three define the third. That is why a specification giving pressure and duration is complete, and one giving pressure alone is not, unless the duration can be inferred.

## 4 · Which number governs, and why

A window is not a static object. It has mass and stiffness, so it has a natural period — the time it takes to complete one cycle of vibration. For architectural glazing that period is typically in the range of roughly ten to thirty milliseconds, depending on size, thickness and support.

What governs the design is the **ratio of the load duration to that natural period**. Blast engineers describe three regimes, and they are usually drawn on a pressure–impulse diagram.

| Regime | When | What governs | Typical source |
|---|---|---|---|
| **Impulsive** | The load is over before the glass has finished responding | **Impulse.** Peak pressure alone tells you very little | High-explosive detonation, close in |
| **Dynamic** | Load duration and response period are comparable | **Both.** The full pressure–time history is needed | High-explosive detonation at moderate standoff |
| **Quasi-static** | The load is still applied long after the glass has fully deflected | **Peak pressure.** The element sees it almost as a sustained load | Vapour cloud explosion or gas deflagration |

As a rule of thumb, a load lasting less than about a third of the natural period behaves impulsively, and one lasting more than about three times the natural period behaves quasi-statically. Between those, both parameters matter.

## 5 · Why a process specification can give one number

A vapour cloud explosion is a large volume of gas burning relatively slowly. Its positive phase runs to tens or hundreds of milliseconds — far longer than a window's natural period. The response is quasi-static, and peak pressure is the governing parameter.

A high-explosive detonation is the opposite. The positive phase may be only a few milliseconds. The response is impulsive, and two events with the same peak pressure and different durations produce entirely different outcomes.

> **THE PRACTICAL CONSEQUENCE**
>
> This is why a process facility specification stating a peak pressure and nothing else is usually workable, while a security specification stating a peak pressure and nothing else is not. The first implies a long-duration deflagration. The second implies a detonation, where the duration could be two milliseconds or twenty — and those demand entirely different glazing.

Where only a peak pressure is given and the source is not obvious, we ask for the positive phase duration. If it cannot be obtained we adopt a conservative assumption, state it plainly on the calculation, and flag it for the project engineer to confirm. We do not quietly invent the missing figure.

## 6 · The units

The same load appears in different units depending on where the specification was written, not on which industry it belongs to. Process and security work both use both systems, and it is common to see them mixed within a single project.

| | Metric | Imperial |
|---|---|---|
| **Pressure** | kPa · bar · mbar | psi |
| **Impulse** | kPa·ms · bar·ms · Pa·s | psi·ms |
| **Where it is normal** | European and international standards, and engineering practices originating outside North America | Standards and criteria of North American origin, including the recognised petrochemical and antiterrorism design references |
| **Conversion** | 1 bar = 100 kPa = 1,000 mbar<br>1 kPa = 0.145 psi | 1 psi = 6.895 kPa = 68.95 mbar |

### Common values, both ways

| kPa | mbar | psi | Broadly represents |
|---|---|---|---|
| **3.5** | 35 | 0.50 | Low-level process design accidental load |
| **5.0** | 50 | 0.73 | A very common process facility design load |
| **7.0** | 70 | 1.02 | Moderate process design accidental load |
| **21** | 210 | 3.0 | A common minimum antiterrorism criterion |
| **34** | 340 | 5.0 | Elevated process load, or moderate security threat |
| **48** | 480 | 7.0 | Vehicle-borne threat at medium standoff |

| kPa | mbar | psi | Broadly represents |
|---|---|---|---|
| **62** | 620 | 9.0 | Vehicle-borne threat at closer standoff |
| **69** | 690 | 10.0 | Upper end of common process facility design |

Conversions are exact; the descriptions are indicative. The governing figures are always those stated in the project's own design basis. Note also that these are ranges people commonly quote without stating whether they are incident or reflected — see Section 2.

## 7 · Where the numbers come from

The threat level is set by the client's security consultant or blast engineer, and by the authority having jurisdiction. It is not our decision, and not the architect's. In practice the figures appear in one of these places:

- The project's **blast design basis**, security design report or facility siting study
- The **facade performance specification**, which normally carries a blast clause
- For process facilities, the **operator's own engineering practice**, stating design accidental loads by building category
- For defence and government work, the applicable **antiterrorism design criteria**, which set the required level of protection

If none of these is available, a **charge weight, its TNT equivalent and the standoff distance** is enough — pressure, duration and impulse can all be derived using the established scaled-distance relationships, provided the detonation geometry is also stated. A surface burst at grade produces a substantially higher load than the same charge in free air.

> **THE CHEAPEST DECISION ON THE PROJECT**
>
> Confirm the **standoff distance** available on site before anything else. Blast pressure falls away rapidly with distance, so standoff is by a wide margin the cheapest protection available — and once the site layout allows it, it costs nothing.

## 8 · How much glass is acceptable — hazard ratings

The second half of a blast specification is the outcome you will accept. The American system measures it directly: a witness panel is set three metres behind the opening, and the rating records how far the glass travelled.

| Condition | What happened to the glass | Protection |
|---|---|---|
| **1** | Not cracked. Fully retained. No fragments either side | Very high |
| **2** | May crack, but stays in the frame. Only dusting or very small fragments near the sill | Very high |
| **3A** | Glass fails and is not retained. Fragments land within about 1 m of the window | High |
| **3B** | Glass fails. Fragments land within about 3 m of the window | High |
| **4** | Fragments travel beyond 3 m and strike a wall below 600 mm height | Medium |
| **5** | Catastrophic. Glass strikes the wall above 600 mm — head and body height | Low |

**WHAT THE NUMBERS MEAN IN PRACTICE**

Conditions 1 and 2 are the usual target for occupied buildings. The step from Condition 4 to Condition 5 is the difference between glass on the floor and glass at the height of a person standing at a desk.

## 9 · The classification systems

| | European (EN) | American (US) |
|---|---|---|
| **Glass on its own** | EN 13541 — classes ER1 to ER4, with NS (no splinters) or S | ASTM F1642 — hazard ratings from No Break to High Hazard |
| **Complete window or door** | EN 13123 / EN 13124 — classes EPR1–EPR4 (shock tube) and EXR1–EXR5 (open range) | GSA-TS01-2003 — Performance Conditions 1 to 5<br>ASTM F2912 for full assemblies |
| **International** | ISO 16933 — open arena; vehicle bomb (EXV) and satchel bomb (SB) classes | ISO 16934 — shock tube |

The EN classes make the point of Section 3 explicit: they are defined by pressure *and* impulse together, over a positive phase of at least 20 milliseconds. ER1 covers 50 to 100 kPa with 370 to 900 Pa·s; ER2 covers 100 to 150 kPa with 900 to 1,500 Pa·s. A load meeting the pressure band but not the impulse band does not fall in the class.

**WORTH KNOWING**

An EN 13541 ER2 classification does not carry a GSA Performance Condition, and a GSA Condition 2 does not carry an EN class. Where a project cites both, each has to be evidenced separately.

## 10 · The glass alone is never the rating

A blast rating belongs to a **complete assembly** — the glass, the frame, the bite and gaskets, the beads or pressure plate, the hardware, and the anchorage into the structure. The load has to travel all the way from the glass surface into the building frame, and it will find the weakest link on the way.

- **The weak link is rarely the glass.** In published blast trials the failures are overwhelmingly failures of fixings, bolts, screws and adhesive bonds.
- **Everything must work in reverse too.** The negative phase reverses the reaction at every fixing. A detail that only bears in compression is not adequate.
- **The reactions have to go somewhere.** Every blast-rated element delivers a load into the surrounding structure. That structure must be verified to receive it — which is why we state the anchorage reactions in every submittal.
- **Glass edge cover and bite are part of the design.** Too little bite and the pane pulls out of the rebate before the glass has done any work at all.

## 11 · New build or retrofit

| | New or replacement systems | Retrofit to existing glazing |
|---|---|---|
| **What it is** | A complete blast-rated window, door or curtain wall — laminated blast glass in an engineered frame with designed anchorage | High-tensile safety film applied to the existing glass, held to the frame by an edge-retention anchoring system |
| **Best for** | New buildings, full facade replacement, and any high blast load | Occupied buildings, fast programmes, and where replacing the glazing is not practical |
| **Typical outcome** | The highest performance available; the glass can be designed to remain intact | A significant improvement over untreated glass at a fraction of the cost and disruption |

**THE POINT MOST OFTEN MISSED ON RETROFIT**

Film on its own, with no edge-retention anchoring, holds the broken glass together but does not hold it in the opening. The anchoring is what turns film into a blast system.

## 12 · The six things that go wrong most often

| | The mistake | Why it matters |
|---|---|---|
| **1** | A pressure with no statement of incident or reflected | At least a factor of two on the design load, and the error runs through everything downstream |
| **2** | A short-duration threat given as a peak pressure only | In the impulsive regime the impulse governs. Two events at the same peak behave completely differently |
| **3** | A duration assumed rather than stated | The same peak over 5 ms and over 150 ms are different design problems. If it must be assumed, say so on the calculation |
| **4** | A hazard rating with no load, or a load with no hazard rating | One states the outcome with no demand; the other states the demand with no target |
| **5** | Ignoring the negative phase | Fixings that work in compression only will release the glazing on rebound |
| **6** | Ignoring the structure behind the anchorage | A correctly built window fixed into inadequate construction is not a blast-rated installation |

## 13 · Quick reference

| If you… | You need |
|---|---|
| **Have a pressure but do not know if it is incident or reflected** | Establish that first — it is worth a factor of two |
| **Have a peak pressure only, from a process facility deflagration** | Usually workable — quasi-static regime, pressure governs |
| **Have a peak pressure only, for a high-explosive threat** | Not sufficient — ask for duration or impulse, or charge weight and standoff |
| **Want the glass intact and fully in the frame** | GSA Performance Condition 1 · or an EN 13541 ER class with NS |

| If you… | You need |
|---|---|
| **Will accept cracking but no glass in the room** | GSA Performance Condition 2 · ASTM F1642 “Minimal Hazard” |
| **Need to upgrade an occupied building quickly** | Retrofit film **plus** edge-retention anchoring — film alone is not a system |

## 14 · The range at British Aluminium

We supply the complete range across both certification systems — EN and US — as certified assemblies, not assembled from separately rated parts.

| Range | Products | Standards |
|---|---|---|
| **Fire-rated doors** | Hinged, pivoted, sliding and automatic sliding; solid and glazed | EN 13501-2 / EN 1634-1 · UL 10C / NFPA 252 |
| **Fire-rated windows and screens** | Fixed and operable windows, glazed screens and partitions | EN 13501-2 / EN 1364-1 · UL 9 / NFPA 257 / ASTM E119 |
| **Fire-rated curtain wall** | Stick-built and unitised, internal and external | EN 1364-3 · ASTM E119 / UL 263 |
| **Blast-resistant systems** | Curtain wall, windows, aluminium and steel blast doors, bunker and hangar doors | EN 13123 / 13124 / 13541 · GSA-TS01 / ASTM F1642 / UFC |
| **Ballistic-resistant systems** | Aluminium and steel framed glazing, doors and public counters | EN 1522 / EN 1063 · UL 752 / NIJ 0108.01 |
| **Acoustic systems** | 80 mm and 100 mm double-glazed partitions, acoustic doors and screens | EN ISO 10140 / EN ISO 717-1 · ASTM E90 / E413 / E1332 |
| **Combined performance** | Fire with blast, ballistic with acoustic, and other multi-requirement assemblies | Certified per configuration |

**The easiest way to start:** send us the blast design basis — or the peak pressure, whether it is incident or reflected, and the charge weight and standoff if you have them — with the elevation and window schedule. We will confirm the load in both metric and imperial, tell you whether the duration needs to be established, and identify which of our systems meets it.

BRITISH ALUMINIUM
FIRE & SECURITY GLAZING EXPERTS

ADDRESS
Street 12, Pink Zone
New Industrial Area
Doha, Qatar

EMAIL
info@british-aluminium.com

WEBSITE
www.british-aluminium.com

TELEPHONE
+974 4488 7159

MOBILE
+974 6699 7568

**Issued for information.** Selection of the design threat, the blast load and the required hazard rating is the responsibility of the project's security consultant, blast engineer and the authority having jurisdiction. This document does not constitute blast engineering advice. Standards are cited as at the date shown and this guide is revised without notice; always work from the current issue.