National Protective Security Authority

## NPSA TEST STANDARD

# Explosion Resistance of Windows and Curtain Walling

# Part 1: Requirements and Classification

**Version 1: February 2024**

# Contents

# Foreword

The NPSA Test Standard for the Explosion Resistance of Windows and Curtain Walling consists of two complementary documents:

Part 1: Requirements and Classification

Part 2: Test Method

This part of the Test Standard provides a method of specifying the criteria which windows and curtain walling systems must satisfy when submitted to the test described in Part 2.

The Test Standard does not purport to include all the necessary provisions of a contract for testing and evaluation services, and it is limited to the methodology and specifications of the tests themselves. Users of this Test Standard and the guidance set out in it, whether test clients or test facilities, are responsible for its correct application and remain entirely responsible for compliance with any applicable law and regulations.

**Compliance with this test standard does not necessarily, or of itself, confer immunity from any legal obligations and your attention is drawn to the important disclaimer on the back page of this document.**

This standard supersedes the CPNI Test Standard for Curtain Walling[1].

In cases where sufficiently detailed information is held in existing test records, it may be appropriate for systems previously tested in accordance with other test standards to be reclassified in accordance with this test method as a user-defined loading category (VXRU) by the original test house. Such reclassification will be subject to demonstrating that the test specimen, test set up and reporting have all fully met the requirements stated in this standard.

[1] The CPNI Test Standard: Explosion Resistance of Curtain Walling: October 2020
Part 1: Requirements and Classification
Part 2: Test Method
The standard was developed by the Defence Science and Technology Laboratory (Dstl) as part of a programme of work funded and directed by CPNI.

# 1 Introduction

## 1.1 Background

Several test standards have been published which cover range or arena testing. They have been designed to test glazing panes and/or complete windows (with dimensions less than approximately 1.5 m by 1.2 m) and so are not directly applicable to the larger sizes of pane and the framing arrangements used in modern glazed facades.

This test standard is a development of the CPNI Test Standard for the Explosion Resistance of Curtain Walling and has been modified so that it is suitable for testing both windows and curtain walling systems.

Other standards include, but are not limited to, the following:

- BS EN 13123 – 2:2004, Windows, doors, and shutters – Explosion Resistance – Requirements and Classification – Part 2: Range Test.
- BS EN 13124 – 2:2004, Windows, doors, and shutters – Explosion Resistance – Test Method – Part 2: Range Test.
- BS EN 13541 – 2012, Glass in building -Testing and classification of resistance against explosion pressure
- ISO 16933:2007, Glass in building – Explosion-resistant security glazing – Test and classification for arena air-blast loading.
- GSA-TS01-2003, US General Services Administration, Standard Test Method for Glazing and Window Systems Subject to Dynamic Overpressure Loadings.
- ASTM International, F 1642-17, Standard Test Method for Glazing and Glazing Systems Subject to Air-blast Loadings.
- ASTM International, F 2912-17, Standard Specification for Glazing and Glazing Systems Subject to Air-blast Loadings.

This has led to users with a requirement to test products either having them tested “broadly in accordance with” the nearest applicable standard or developing a bespoke test for a particular product. This, in turn, can cause difficulties in comparing the performance of similar systems which may have been tested under different regimes.

This test standard presents a framework for determining the explosion resistance of windows, and curtain walling by arena testing.

This Requirements and Classification document and the Test Method described in Part 2 of this standard provide a structured testing procedure to determine the resistance of windows and curtain walling, installed vertically (to ± 15°) and normal to the charge, to blast loading against a range of explosion threats located externally to a structure. It also provides a structured assessment procedure to determine the hazard levels created by the test specimens, both internal to and external to the test specimen.

This standard also incorporates the general recommendations for testing[2] developed by the European Research Network for Critical Infrastructure Protection (ERNCIP) Resistance of Structures to Explosion Effects Thematic Group.

## 1.2 Loading categories

The method includes standard loading categories which represent typical design threats from vehicle-borne improvised explosive devices (VBIED) detonated in the open.

It also permits user-defined loading categories to allow flexibility for project-specific requirements to be tested and assessed using the same method.

The test client should ensure that the selected loading category takes due account of any blast reinforcement that may be caused by recesses and overhangs, adjacent buildings or other structures.

The loading categories present typical blast parameters to assess test specimens. The specimens may be complete windows or curtain walling assemblies. A curtain walling specimen must be a whole system spanning at least one floor, complete with structural connections and individual components (such as transoms, mullions, glazing and fixing components). The blast parameters are based on the loading that would be experienced by the test specimen when forming part of a full-scale building. The test method does not consider the effects of fragment impact or the loading from the negative phase of the blast wave.

Test clients may wish to engage a competent blast engineer[3] for support in confirming or developing the appropriate loading categories.

## 1.3 Hazard assessment

The hazard assessment process is defined separately for the internal hazard behind the test specimen and for the external hazard in front of it.

The internal hazard ratings are:

- A - No Break
- B - No Hazard
- C - Minimal Hazard
- D - Very Low Hazard
- E - Low Hazard
- F – High Hazard

The external hazard ratings are:

- X – No Hazard
- Y – Limited Hazard
- Z – High Hazard

[2] Recommendations for the improvement of existing European norms for testing the resistance of windows and glazed facades to explosive effects, European Commission Joint Research Centre (JRC) Ispra, 2015, ISBN 978-92-79-53394-5

[3] A competent blast engineer should be a member of the Register of Security Engineers and Specialists (www.rses.org.uk) or be able to demonstrate a similar level of competence.

## 1.4 Classification

Classifications and ratings are based on the performance of the system loaded by the blast parameters applied during the test and are specific to those conditions.

Test clients and test facilities can follow this test method when conducting tests to either a pre-defined standard loading category or to a user-defined loading category.

Windows or curtain walling that have been tested in accordance with this method and have received a classification and rating based on the method are suitable for use in blast-resistant applications only for blast loadings of comparable characteristics to the original test and only if the system is installed in the same manner that was used for the test.[4]

## 1.5 Number of test samples

NPSA recognises that a single test for the purposes of classification of a system is not statistically valid and, whilst it is recommended that multiple specimens are tested, it is acknowledged that economic pressures may restrict users to testing a single specimen.

To gain a classification, a minimum of one test specimen shall be tested. If multiple test specimens are tested only the worst classification achieved is applicable to the test specimen system

It is the test client's responsibility to identify the number of test specimens to be tested. However, testing a single target may be considered acceptable by the test client due to cost and may be considered to demonstrate a reasonable assessment of the likely performance of the system, as far as is reasonably practicable.

## 1.6 Applicability

The test method has been developed for flat, vertical (to ± 15°) windows and curtain walling with the charge normal to the centre of the test specimen. If it is necessary to test a system against an oblique blast wave, or if the system includes significant overhangs or recesses that may enhance the blast loading, then specialist advice should be sought from a competent blast engineer[3] to develop a suitable test set up.

This test method only gives information on the performance of the test specimen subjected to explosive blast loading. It gives no information on the behaviour, when subjected to any other type of loading, of the test specimen as a whole or of individual components.

This test method is appropriate for all types of windows and curtain walling systems.

The test method specifies that the internal and external surfaces of the glazing in the test specimen should be at a temperature of 20 °C ± 10 °C at the time of the test unless the test client has other requirements.

[4] A test client, with suitable specialist advice provided by a competent blast engineer may decide that the system is appropriate for use in other situations. Any such decision will include an element of risk which must be fully assessed. Extrapolation of test results is generally discouraged.

# 2 Scope

This document specifies the criteria which windows or curtain walling, installed vertically (to ± 15°), shall satisfy to achieve a classification when subjected to the associated test method described in Part 2 of this standard.

This method gives no information on the explosion resistance capacity of any structural element or components not forming an integral part of the window or curtain walling assembly being tested.

It is the test client's responsibility to confirm the competence of the chosen test facility to conduct the required test(s) safely and effectively. This can be demonstrated by being accredited to ISO/IEC 17025[5] with a recognised accreditation organisation such as UKAS[6]. The accreditation should include this NPSA standard.

A test client must specify the blast loading category against which the window or curtain wall should be tested.

# 3 Normative references

This document incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed in the bibliography.

For dated references, subsequent amendments to or revisions of any of these publications apply to this test standard only when incorporated in this standard by amendment or revision.

For undated references the latest edition of the referenced publication applies (including amendments).

# 4 Terms & definitions

For the purposes of this part of the Test Standard, the terms and definitions given in Part 2 of this standard.

# 5 Requirements

To achieve a particular classification for explosion resistance, the test specimen shall be subjected to peak reflected pressure and peak reflected specific impulse loading for the relevant loading category as specified in Table 1 and in full accordance with the method described in Part 2 of this standard and subject to the tolerances in that document.

[5] ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories.
[6] United Kingdom Accreditation Service www.ukas.com

# 6 Classification of explosion resistance

The classification is based on the test loading and the assessment of damage to the test specimen after the test.

The loading categories VXR1 to VXR7 in Table 1 are listed in order of increasing explosion resistance with respect to the peak reflected specific impulse parameter.

When a system achieves a particular VXR classification it also automatically achieves all other classes where both the peak reflected pressure and the peak reflected specific impulse parameters were exceeded, with the same internal and external hazard classifications achieved in the original test being applied.

**Table 1: Minimum loading requirements for standard loading categories**[7]

| Loading category | Peak reflected pressure, $P_r$ (kPa) | Peak reflected specific impulse, $I_r$ (kPa-ms) |
|---|---|---|
| VXR1 | 50 | 370 |
| VXR2 | 65 | 440 |
| VXR3 | 90 | 540 |
| VXR4 | 140 | 690 |
| VXR5 | 275 | 960 |
| VXR6 | 185 | 1370 |
| VXR7 | 295 | 1690 |
| VXRU | User defined | User defined |

The allowable tolerances are:

| | |
|---|---|
| Peak reflected pressure | -0 % and +20 % |
| Peak reflected specific impulse | -0 % and +20 % |

To ensure clearing effects are managed the impulse measured at the top corners of the test specimen must be no more than 10 % lower than the expected impulse at that location on a large (semi-infinite) façade.

For information, nominal charge mass and stand-off distance pairs for each standard loading category are shown in Table A.1 at Annex A.

After the test, damage to the test specimen will be assessed against the internal and, if required, the external Hazard Levels specified in Part 2 of this standard.

[7] The load category pressure and impulse parameters were derived using the Kingery-Bulmash equations based on a hemispherical surface burst loading the test specimen as if mounted in a large (semi-infinite) facade. They have been rounded up, $P_r$ to the next 5 kPa and $I_r$ to the next 10 kPa-ms.

The classification will be reported as a series of alphanumeric sets identifying the predefined loading category, the internal hazard rating and the external hazard rating, e.g. VXR2/C/X.

For a user-defined loading category, the classification will be reported as the relevant peak reflected pressure (kPa) and peak reflected specific impulse (kPa-ms) achieved in the test, quoted in parentheses and prefixed VXRU, followed by alphanumeric sets defining the internal hazard rating and the external hazard rating, such as VXRU (235/1130) /C/Z.

However, if a test specimen meets all the requirements for a lower loading category it may be classified with that category of explosion resistance and the internal and external hazard ratings recorded.

# References


1. CPNI Test Standard – October 2020, Explosion resistance of curtain walling
    a. Part 1, Requirements and classification
    b. Part 2, Test method
2. BS EN 13123 – 2:2004, Windows, doors, and shutters – Explosion Resistance – Requirements and Classification – Part 2: Range Test.
3. BS EN 13124 – 2:2004, Windows, doors, and shutters – Explosion Resistance – Test Method – Part 2: Range Test.
4. BS EN 13541 – 2012, Glass in building -Testing and classification of resistance against explosion pressure
5. ISO 16933:2007, Glass in building – Explosion-resistant security glazing – Test and classification for arena air-blast loading.
6. GSA-TS01-2003, US General Services Administration, Standard Test Method for Glazing and Window Systems Subject to Dynamic Overpressure Loadings.
7. JRC 98372 Recommendations for the improvement of existing European norms for testing the resistance of windows and glazed façades to explosive effects, ERNCIP Resistance of Structures to Explosion Effects Thematic Group, 2015.
8. ASTM International, F 1642-17, Standard Test Method for Glazing and Glazing Systems Subject to Air-blast Loadings.
9. ASTM International, F 2912-17, Standard Specification for Glazing and Glazing Systems Subject to Air-blast Loadings.
10. ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories.
11. C Kingery and G Bulmash, Air blast Parameters from TNT Spherical Air Burst and Hemispherical Surface Burst, ARBRL-TR-02555, Ballistic Research Laboratory, 1984.
12. Conventional Weapons Effects Programme (ConWEP) software by D Hyde, ConWEP v. 2.1.0.8, Geotechnical/Structures Laboratory, USACE Engineer Research & Development Center, Vicksburg, Mississippi.

# Annex A (Informative) Nominal charge masses and stand-off distances

The test loadings should always be specified by the required peak reflected pressure and peak reflected specific impulse. Table A.1 provides nominal values for the charge mass and stand-off distance pairs that are likely to create the blast loads for the standard loading categories on a large (semi-infinite) facade.

**Table A.1: Equivalent charge masses and stand-off distances**

| Loading category | Charge mass (kg $_{\text{TNT Equivalent}}$) | Stand-off (m) |
|---|---|---|
| VXR1 | 100 | 34 |
| VXR2 | 100 | 30 |
| VXR3 | 100 | 25 |
| VXR4 | 100 | 20 |
| VXR5 | 100 | 15 |
| VXR6 | 500 | 30 |
| VXR7 | 500 | 25 |

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