CPNI
Centre for the Protection of National Infrastructure



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# Impact Testing of Vehicle Security Barriers

## An overview of vehicle impact test standards

# Contents



Hostile Vehicle Mitigation

## Purpose

This guidance is for security professionals and specifiers of Vehicle Security Barriers (VSBs), to provide clarity and answer recurring queries that circulate across the industry. It gives an overview of the publicly available vehicle impact test methods, known colloquially as 'standards', which are used to classify the performance of VSBs when subjected to a vehicle impact test. It seeks to assist with the procurement process: key differences between the standards, understanding VSB performance and getting the most appropriate level of protection.

Readers are encouraged to read the most current impact test standards referenced within this document so as to familiarise and be fully aware of the differences in the test methods, criteria and outcome. Ultimately, understanding the level of protection afforded by a VSB will help define the residual risk of a vehicle attack.

## Why were standards developed?

Both the UK and USA governments identified a requirement to develop a consistent approach to assess how VSBs performed when impacted by unmodified road vehicle travelling at a specified speed. The first standard was developed by the USA Department of State in 1985 (DoS SD-STD-02.01[1]), which was later handed over to the American Society for Testing and Materials, now known as ASTM. Subsequent standards published by UK, USA and Europe enable products to be compared, and for impact performance requirements to be specified using common terminology.

As a result of the development of the vehicle-borne improvised explosive device (VBIED) threat worldwide and the need to have a common standard to which products could be tested and specified by local vehicle type, CPNI sponsored the ISO International Workshop Agreement (IWA) with the USA DoS as Co-Chair, which collaborated with test houses and industry to define the impact test standard, IWA 14-1[2].

The objective was to consolidate the requirements of the respective vehicle impact test standards into a harmonised document with global reach. For this reason, CPNI advocates the use of IWA 14-1. Additionally, refinements and improved accuracy in test tolerances means it is the most consistent and comprehensive standard currently available.

The way in which a VSB is selected and installed (foundation design etc.) is as important as its fabrication in delivering the desired performance. The impact test method, Part 1, is therefore essentially supported by guidance in the form of Part 2, IWA 14-2[3] (in the same way as PAS 69[4] supports PAS 68[5]). All these standards are applicable to security; they are significantly different to road safety barrier standards[6]. There is a timeline of their publication at the end of this document.

[1] DoS – SD-STD-02.01 – Test Method for Vehicle Crash Testing of Perimeter Barrier and Gates, Revision A, 2003
[2] ISO – IWA 14-1:2013 – Vehicle security barriers – Part 1: Performance requirement, vehicle impact test method and performance rating
[3] ISO – IWA 14-2:2013 – Vehicle security barriers – Part 2: Application
[4] BSI – PAS 69:2013 – Guidance for the selection, installation and use of vehicle security barrier systems
[5] BSI – PAS 68:2013 – Impact test specifications for vehicle security barrier systems
[6] CPNI – Differences between Vehicle Security Barriers and Road Safety Barriers, January 2020

## What standards are available?

Various standards are used to assess the vehicle impact performance of VSBs. CPNI led the development of PAS 68 (and PAS 69) to ensure that the impact test standard was representative of the UK vehicle fleet (vehicle type and mass). Similarly, ASTM F2656[7] focuses on vehicle types used in America. Subsequently, CPNI led the development of a European specification: CWA 16221[8].

VSBs that have been tested to older standards are still available. They retain their rating/classification despite older standards being withdrawn (taken out of use) or superseded by newer standards. Care should be taken when selecting VSBs to meet project requirements: they should be rated to a relevant standard, with later standards generally favoured by the industry. A VSB holding a rating to an older or newer standard should not be automatically disregarded if it meets the requirements in terms of impact performance (e.g. vehicle classification, impact speed, impact angle, penetration distance etc.).

To maximise the range of products available, specifiers should include all appropriate standards applicable to their geographical region or local vehicle fleet (e.g. UK, Europe, North America, Asia etc.) in the procurement tender.

| Standard | Region | Latest Version | Purpose and vehicle types used |
|---|---|---|---|
| ISO IWA 14-1:2013 | Global  | 2013 | To provide a single international standard for impact testing and performance classification of VSBs. To achieve this, the vehicle categories assessed have UK, European and North American vehicle types present. |
| ISO IWA 14-2:2013 | Global  | 2013 | In support of IWA 14-1, designed to provide guidance on the selection, installation and use of VSBs. |
| BSI PAS 68:2013 | UK  | 2013 | Defines a standard method for testing the impact performance and protection rating of a VSB when impacted by different categories of UK vehicles travelling at specified speeds. |
| BSI PAS 69:2013 | UK  | 2013 | Guidance on the selection, installation and use of VSBs rated using PAS 68. |
| ASTM F2656/F2656M – 20 | USA  | 2020 | Defines the method for impact testing and assigning performance ratings for a VSB when impacted by different categories of North American vehicles. Now includes a UK/European style vehicle type: C7. |
| CEN CWA 16221:2010 | Europe  | 2010 (Withdrawn 2018) | Derived from PAS 68 and PAS 69, this document covers both impact testing (using European vehicle types) and guidance on selection, installation and use of VSBs. |
| DoS SD-STD-02.01 | USA  | Rev. A, 2003 (Withdrawn) | Forerunner of ASTM F2656, includes only USA vehicles and defines 'K' classifications. |

[7] ASTM F2656 / F2656M – Standard Test Method for Crash Testing of Vehicle Security Barriers, 2020
[8] CEN – CWA 16221:2010 – Vehicle security barriers. Performance requirements, test methods and guidance on application (withdrawn)

## Differences between standards

While all these standards define test methods and performance ratings for VSBs, there are some key differences:

| IWA 14-1:2013 | PAS 68:2013 | ASTM F2656/F2656M – 20 | CWA 16221:2010 (withdrawn) |
|---|---|---|---|
| **9** vehicle type categories | **6** vehicle type categories | **6** vehicle categories | **6** vehicle type categories |
| Impact speed **16-112** km/h | Impact speed **16-112** km/h | Impact speed **48-100** km/h | Impact speed **16-112** km/h |
| **Vehicle penetration distance** from ***front*** edge of product structure and is **exact** | **Vehicle penetration distance** from ***rear*** edge of product structure and is **exact** | **Vehicle penetration distance** from ***front*** edge of product structure and is **banded**: <1m, 1-7m, 7-30m | **Vehicle penetration distance** from ***rear*** edge of product structure and is **exact** |
| Major debris is reported but not part of rating | Major debris dispersion from rear edge of product structure is part of rating | Major debris is reported but not part of rating | Major debris dispersion from rear edge of product structure is part of rating |

## Vehicle type

UK and European standards have been developed using test vehicles commonly found on UK and European roads, whereas the American standard is relevant to vehicles typical to that continent. Vehicle shape is the most apparent difference between commercial vehicles and has a bearing on its construction (e.g. chassis rail design and height; positions of axle, engine block and load bed). These differences are evident between the most commonly compared impact test vehicle types across the standards:

| IWA 14-1: N2A<br>PAS 68 & CWA 16221: N2 | IWA 14-1: N3C<br>PAS 68 & CWA 16221: N3 | ASTM F2656: C7 | | ASTM F2656: M<br>IWA 14-1: N2B & N3E |
|---|---|---|---|---|
|  |  | Image: https://www.machine4u.com.au/view/advert/isuzu-FTR900-Tray-Truck/537946/ |  |  |
| *Euro Cab*<br>*i.e. Cab over engine* | *Euro Cab*<br>*i.e. Cab over engine* | | *Euro Cab*<br>*i.e. Cab over engine* | *Conventional USA Cab*<br>*i.e. Cab behind engine* |

With these inherent differences, a **VSB tested** at the ***same*** **impact speed** ***against*****…**

**… a *USA commercial vehicle*,** may perform ***differently*** against a ***European commercial vehicle*.**

Also…

… an ***N2*** **vehicle** type may impact a VSB ***differently*** compared to an ***N3*** **vehicle** type, and vice versa**.**

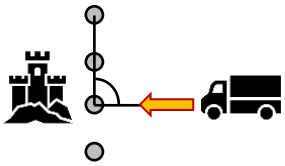
This may **change** the **impact performance of a VSB.**

## Vehicle mass

IWA 14-1 has consolidated the impact test masses defined in PAS 68, CWA 16221 and F2656 standards, by stating tolerances that accommodate these standards, enabling VSBs, whether tested to a previous or current version of these standards, to be recognised. As a result there are some minor differences in the test mass of the vehicles.

## Vehicle speed and impact angle

Other important factors are the speed the vehicle impacts the VSB and the angle this occurs. The performance of the VSB will vary depending on these factors. The end user should be aware of this and understand the importance of conducting a Vehicle Dynamics Assessment (VDA) prior to the selection of VSBs. This should be carried out by a suitably qualified and experienced person, to identify the VSB requirement at the location. Refer to the CPNI guidance document on procurement of a specialist security consultant[9] for more information.




## Datum points

These are locations on the VSB and the vehicle that are used to measure how far the vehicle penetrated beyond the VSB during the impact test. They vary depending on the VSB type and vehicle class.

[9] CPNI – Procuring the Services of a Specialist Security Consultant when Undertaking a Project Relating to a Built Asset, Version 6, December 2019

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## VSB datum point

Represents the different points from where penetration distance of the vehicle is measured from in the different standards, for different types of VSB. In ASTM F2656 – 20, the VSB datum point is now at the front face of the VSB.

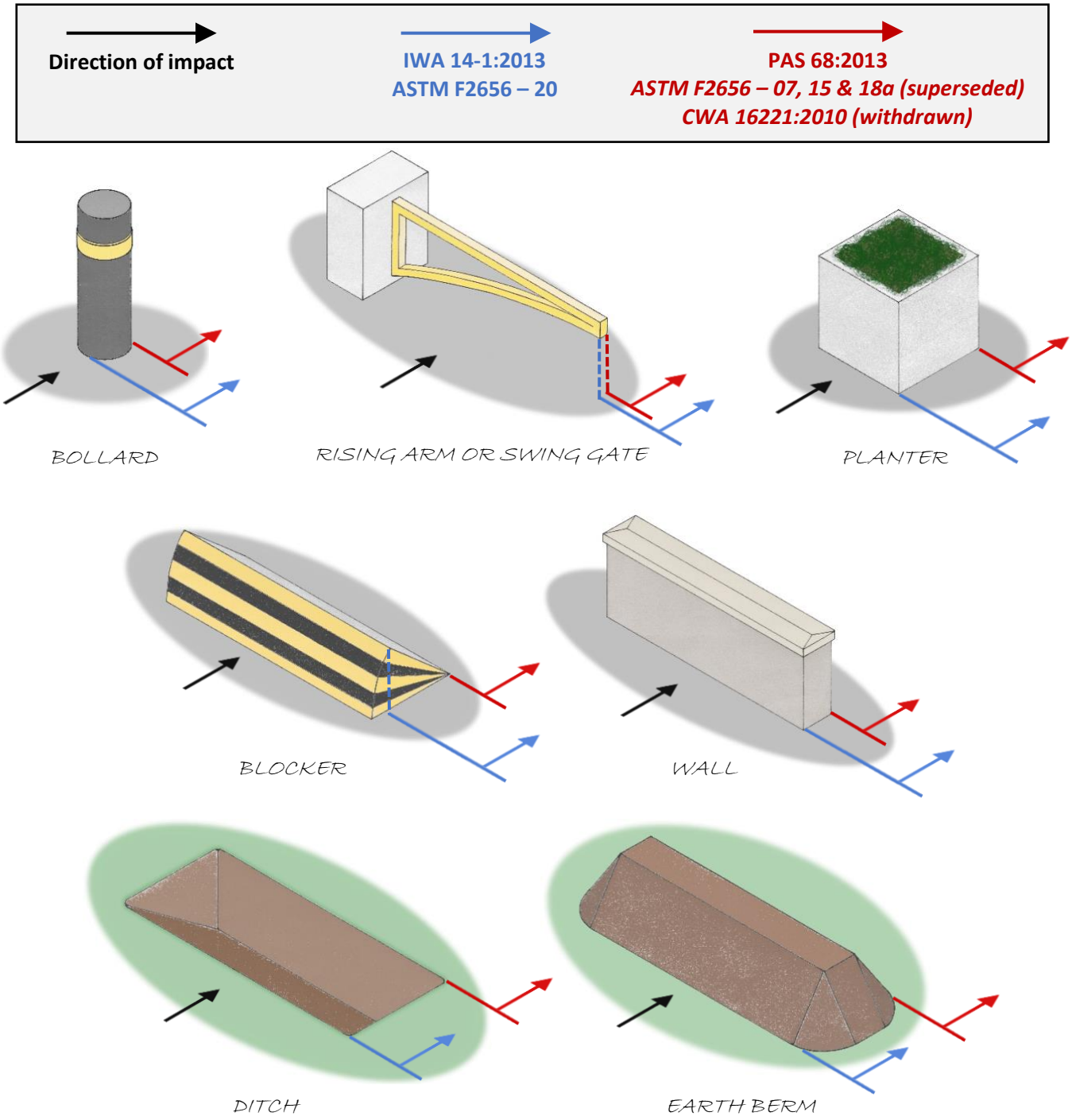



Figure 1: VSB datum point

## Vehicle datum point

Represents the point on the vehicle where penetration of the vehicle is measured to: marked as 1: the ⊕ symbol.

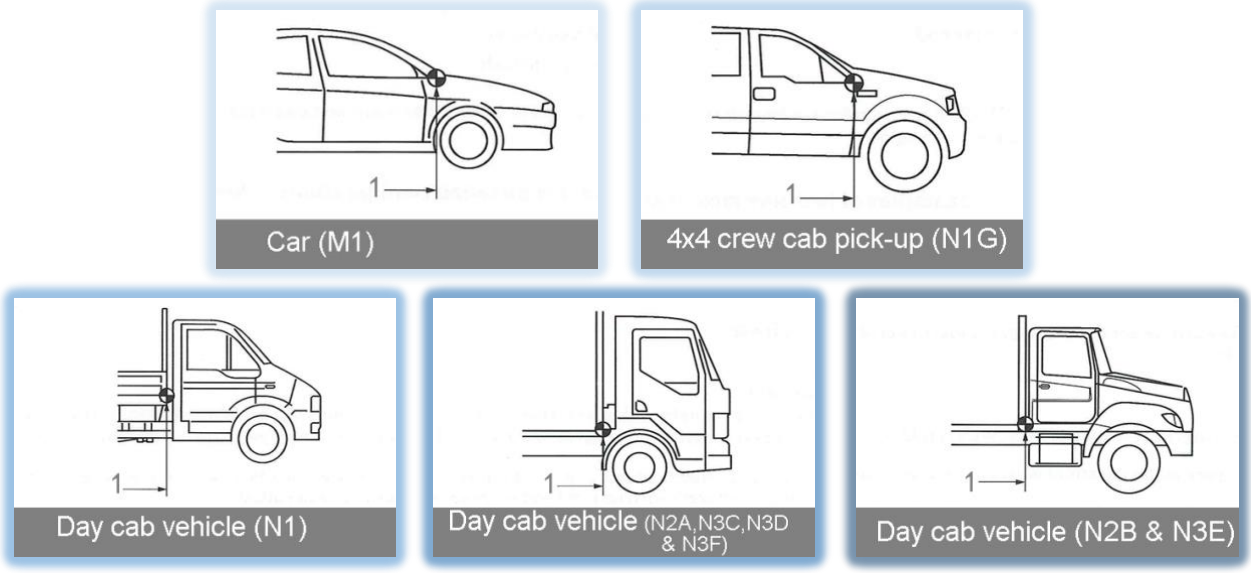



Figure 2: Vehicle Datum and IWA 14-1:2013 vehicle types (credit ISO IWA 14-1:2013)

## Performance rating classification code

The result of a test will be stated in a code.

A VSB that has been allocated one by an independent test house should have it clearly stated in marketing material.

To help understand the performance rating classification code, there are two subtle differences between those given by PAS 68:2013 and IWA 14-1:2013 that are highlighted below:

- VSB datum point (see Figure 1)
  - PAS 68:2013 – is on the *rear* face (defensive side) of the VSB
  - IWA 14-1:2013 – is on the *front* face (impact side) of VSB

The different VSB datum point locations mean the recorded vehicle penetration distances are different even though the position of the vehicle is the same in reality (see Figure 3).

*A detached lorry cab is major debris*

- Major debris distance (from the vehicle or VSB, items ≥25kg travelled upon impact)
  - PAS 68:2013 – stated in the code
  - IWA 14-1:2013 – not stated in the code; recorded in the test report

It is possible for the same VSB to have been allocated (by an accredited test house) both PAS 68 and IWA 14-1 ratings, if it has been specifically planned for and assessed by the test house against both standards, although the ratings will differ (see Figure 3).

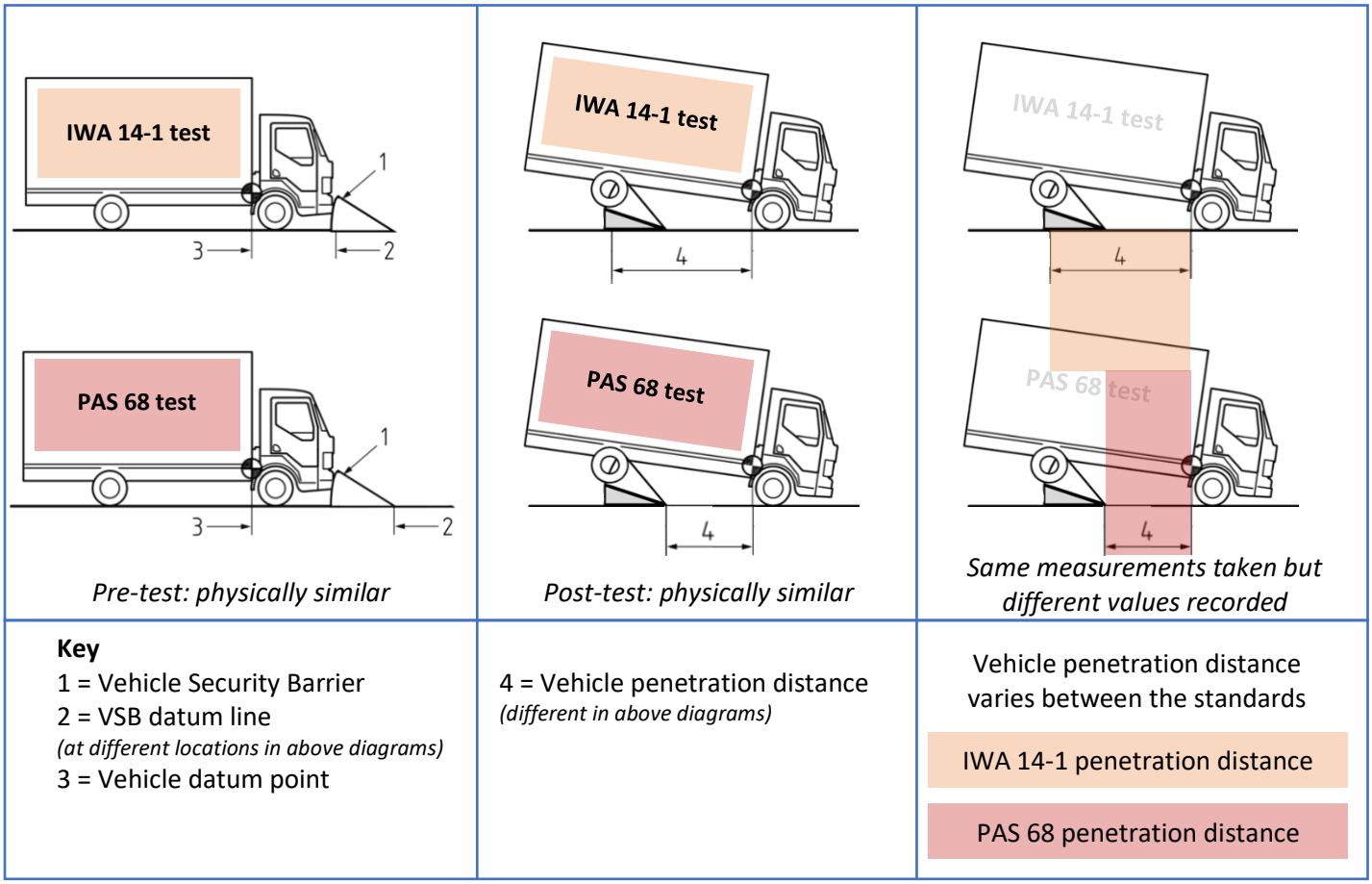



Figure 3: Example showing the physical similarities and different vehicle penetration distances for IWA 14-1 and PAS 68. Different VSB datum line locations (2) means the vehicle penetration distance (4) is different. (credit BSI PAS 68:2013 and ISO IWA 14-1:2013; modified by CPNI)

## Comparing performance rating classification codes

A VSB that meets the performance requirements of the standard will be awarded a performance rating. As a minimum, the rating code will include the vehicle type/classification, impact speed, impact angle (except ASTM F2656) and vehicle penetration distance or band.

The differences in performance ratings between IWA 14-1, PAS 68 and ASTM F2656 standards are shown below. These examples demonstrate how the codes are displayed; the examples stated are not equivalent.

| IWA 14-1:2013 example performance rating | | | | |
|---|---|---|---|---|
| Vehicle Impact | Vehicle Mass (class) | Impact Speed | Impact Angle | Vehicle penetration distance |
| V | 7200 kg [N2A] | 64 km/h | 90˚ | 0.0 m |
| **IWA 14-1:2013 Bollard V / 7200 [N2A] / 64 / 90 : 0.0** | | | | |

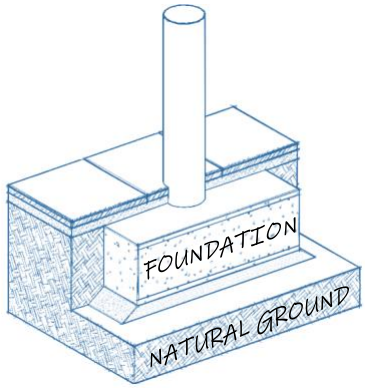
| PAS 68:2013 example performance rating | | | | | |
|---|---|---|---|---|---|
| Vehicle Impact | Vehicle Mass (class) | Impact Speed | Impact Angle | Vehicle penetration distance | Major debris distance |
| V | 2500 kg (N1G) | 80 km/h | 90˚ | 0.0 m | 3.6 m |
| **PAS 68:2013 Bollard V / 2500 (N1G) / 80 / 90 : 0.0 / 3.6** | | | | | |

| ASTM F2656 – 20 example performance rating | | |
|---|---|---|
| Vehicle Category | Impact Speed | Penetration Rating |
| M | 40 mph | P2 |
| **F2656 – 20 M:40 - P2** | | |

## Ground conditions

In addition to differences between vehicles and impact test parameters, there are also differences in the ground conditions the VSB is installed into for a vehicle impact test.

- IWA 14-1:2013 describes using a rigid or non-rigid foundation.
- PAS 68:2013 does not define an installation configuration.
- ASTM F2656 – 20 states the product must be installed into a low cohesive compacted soil (unless specified for a site specific installation).




The end user should be aware of the ground conditions used for the impact test and assess whether they are comparable with their site ground conditions. CPNI recommends that appraisals of ground conditions and modifications to VSB foundations are only carried out by suitably qualified and experienced engineers. Calculations and foundation design should be signed off by a Principal Grade member of the Register of Security Engineers and Specialists in the category of Hostile Vehicle Mitigation (www.rses.org.uk).

CPNI's *Guidance note on vehicle security barrier foundations* provides more insight into this area.

## Standards to use when specifying VSBs

**IWA 14-1:2013 is the most current and comprehensive standard against which VSBs may be tested; consequently, CPNI advocates its use.** However, there are a significant number of VSBs available that have been tested against PAS 68, ASTM F2656 and CWA 16221. These should not be discounted provided the difference between the individual standards is recognised.

When specifying products, CPNI's *'Level 2 Operational Requirements For Hostile Vehicle Mitigation Measures'* document will help you to identify: the threat vehicle, the vehicle speed derived from a Vehicle Dynamics Assessment (VDA) and the impact angle. This will enable a range of suitably rated VSBs to be selected that meet site requirements.

When issuing procurement tenders for VSBs as part of a planned HVM scheme in the UK or where the predominant vehicles types are European style, **CPNI recommends that VSBs rated to IWA 14-1 or an equivalent impact test standard (i.e. PAS 68) are specified**. Each site should be assessed against the composition of the local vehicle fleet (e.g. the site might be in a region where USA fleet vehicles are driven), potential impact angle and vehicle speed.

VSBs solely tested to previous versions of ASTM F2656 (or its predecessor SD-STD-02.01) will not have been tested using UK/European vehicles types, therefore their performance may not meet the site or security requirements. The only exception is the recently added C7 class vehicle to ASTM F2656, which is a European style vehicle.

## Low Energy Impact Test Standard – Bollards

In addition to the above standards, PAS 170-1[10] was developed to provide an alternative assessment method for bollards by subjecting them to a low speed impact (16 and/or 32km/h) from an impact trolley (replicating an N1G [4x4] vehicle).

PAS 170-1 provides a proportionate method for assessing bollards designed to be installed at sites to protect against accidental low speed impact or a lower speed 'ram raid' attack. It does not replace any of the standards listed above and bollards tested to PAS 170-1 should not be used where there is a requirement to protect against higher speed and/or larger vehicle attack.

ASTM have published a similar standard, F3016 – 19: 'Standard Test Method for Surrogate Testing of Vehicle Impact Protective Devices at Low Speeds'.

## Non-equivalence between standards

A performance rating allocated to a VSB tested against one standard should not be duplicated or adjusted in an attempt to provide equivalence to another standard. The differences stated in this guidance strongly suggest a VSB will perform differently when tested to a different standard e.g. IWA 14-1 and ASTM F2656. There is significant risk when disregarding this information.

## Next steps for the end user


CPNI's *Due diligence in the selection and procurement of vehicle security barriers* document can help end users satisfy themselves that a VSBs performance is accurate and meets their requirements.

It reinforces CPNI's position that a VSB deployed for the purposes of countering terrorism to protect assets against vehicle-borne threats should be a 'Rated Vehicle Security Barrier' that has undergone formal vehicle impact testing to a recognised standard.

That testing should match or exceed the threat vehicle scenarios to the site identified in the operational requirements process.

[10] BSI – PAS 170-1:2017 – Vehicle security barriers. Low speed impact testing. Trolley impact test method for bollards

## Attempts to compare vehicle impact test standards

The table below lists frequent assumptions made when comparing test vehicles across standards and, in particular, whether different vehicles are equivalent and test results. Comparisons between older standards are also listed.

| Comparison Scenario | Vehicle | Vehicle | Possible? | Reason |
|---|---|---|---|---|
| **IWA 14-1 N2A and ASTM F2656 M** |  IWA 14-1 N2A |  ASTM F2656 M | No | The vehicles are of significantly different layout and construction |
| **IWA 14-1 N2B and ASTM F2656 M** |  IWA 14-1 N2B |  ASTM F2656 M | Yes | The vehicles match. Additional requirements of each standard must be carefully adhered to. For example, ASTM requires install into low cohesive soil with compaction measurement, IWA 14-1 requires a test vehicle less than 10 years old. |
| **IWA 14-1 N3C and ASTM F2656 C7** |  IWA 14-1 N3C |  ASTM F2656 C7 Image: https://www.machines4u.com.au/view/advert/Isuzu-FTR900-Tray-Truck/537946/ | No | The required Gross Vehicle Weights are different. The vehicles are NOT equivalent. |
| **IWA 14-1 N3C and PAS 68 N3 and CWA 16221 N3** |  IWA 14-1 N3C |  PAS 68 & CWA 16221 N3 | Yes | The vehicle types, Gross Vehicle Weight and test masses overlap. Care must be taken with respect of tolerances on impact speed etc |
| **Publications of PAS 68:2005 PAS 68:2007 PAS 68:2010 PAS 68:2013 CWA 16221:2010** | PAS 68 2005, 2007, 2010, 2013 | CWA 16221 | Yes | A VSB holding a rating to an older (or newer) standard should be deemed equivalent if it meets the requirements in terms of impact performance e.g. vehicle classification, impact speed, impact angle, vehicle penetration distance etc. |
| **ASTM F2656 and 'K' ratings e.g. 'K12'** | ASTM F2656 | DoS SD-STD-02.01 | No | 'K' ratings have never existed in F2656. The 'K' ratings were from the original DoS standard that was replaced by ASTM F2656 in 2007. However, there are corresponding ratings: K12 ~ M50 \| K8 ~ M40 \| K4 ~ M30 |

# Frequently Asked Questions

*CPNI have gathered these from the UK test house, HORIBA-Mira, and the Perimeter Security Suppliers Association.*

**Why can I not have a rating to IWA 14-1:2013 at N2A or N3C level and ASTM F2656 M level?**
The IWA 14-1:2013 N2A/N3C vehicles are European style trucks with the cab over the engine and the F2656 M truck has the cab behind the engine. Therefore, the vehicle specifications are **NOT** compatible.

**Is it possible to issue a rating to cover PAS 68:2013 and IWA 14-1:2013?**
**Yes**, it is possible to cover both standards with a single test as the trucks are all the same specification. Care must be taken over the test mass requirements to ensure meeting the tolerances of all of the regulations. Additionally, a reputable Test House should ensure that they are not deliberately making testing easier by choosing the lowest end of the tolerance of any of the regulations. For example, the Test House should conduct the test to PAS 68:2013 with a test mass as close to 7500kg as possible, and subsequently assess the test against IWA 14-1:2013.

**Why can I not have a rating to IWA 14-1:2013 at N3C level and ASTM F2656 C7 level?**
A rating to cover both these is **NOT** possible even though they are both cab-over vehicles with a test mass of 7200kg as the GVW of the N3 and C7 vehicles do not match in the standards, and the vehicles are deemed **NOT** equivalent.

Image: https://www.machines4u.com.au/view/advert/Isuzu-FTR900-Tray-Truck/537946/

**Why can I not have a rating to PAS 68:2013 at N3 level and ASTM F2656 C7 level?**
The GVW of the N3 and C7 vehicles do **NOT** match in the standards, and the vehicles are deemed **NOT** equivalent.

The lower limit of test mass of PAS 68 is 7350kg and the upper limit of mass for F2656 is 7350kg. However, as there is no overlap of the tolerances, the accuracy/uncertainty of measurement of apparatus means that even with a reported test mass of exactly 7350kg, when the measurement accuracy/tolerance is taken into account the actual mass must be out of specification of one or other standard.

**Is there a vehicle I can use in a test to get a rating to both an international/European and ASTM F2656 standard?**
The IWA 14-1:2013 N2B vehicle is a direct equivalent of the ASTM F2656 Medium duty truck. To qualify at this category the vehicle should be a USA style cab-behind-engine and **NOT** a European style cab-over the engine.

To be compliant with F2656 as well as IWA 14-1, the product installation should be undertaken in accordance with the F2656 specification (non-cohesive soil surrounding the foundation). ASTM F2656 also has a site-specific ground condition which could be used for a test; this must be specified and recorded.

**"My client wants an ASTM K12 test"**
**'K' ratings have never existed in ASTM F2656.** 'K' ratings were superseded in 2007 by the introduction of ASTM F2656. The Department of State K12 rating should be stated as a corresponding ASTM F2656 rating: M50. This also applies to K8 and K4 ratings, which have corresponding F2656 ratings: K8 ~ M40; K4 ~ M30.

**What is the equivalent of an ASTM F2656 M50 test in PAS 68?**
There is **no equivalent**. The closest test specification is PAS 68:2013 V/7500(N3)/80/90. This is the N3 class vehicle (18,000kg GVW at a test mass of 7500kg) at 80km/h and 90 degrees, however, there are **significant differences** in the vehicle structure that will mean markedly different vehicle impact test results.

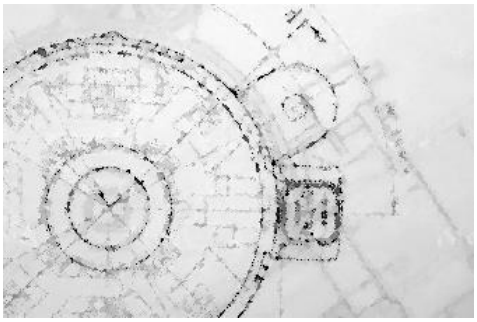
**Does the presence of IWA 14-1 negate previous test standards or render them obsolete?**
**No**, IWA 14-1 does not negate testing carried out to the PAS 68 or CWA 16221: those tests are still valid. IWA 14-1 is a progression of these standards and combines elements of ASTM F2656 & PAS 68 to produce a cohesive standard.


**Does the presence of IWA 14-1 negate previously tested *products* or render them obsolete?**
**No**, products tested to superseded/withdrawn standards retain a valid performance rating and may still be considered by the end user. The end user should satisfy themselves that the product meets their requirements, whether it should be tested against a current impact test standard or an alternative product should be used.

**I have read that a VSB has been 'designed to IWA 14-1', 'engineered to PAS 68' or similar; what does this mean?**
End users should be aware that the vast majority of products which claim to have been *designed or engineered* to a recognised impact test standard **may not have been**:

- **tested to the stated standard**; or
- **allocated a performance rating** although it has been tested (informally known as a **"failure"**)

A small number of VSBs may have been allocated a **PAS 68 Design Rating**. Quoting from Clause 6 in PAS 68:2013:
*"The design method is used for variations or modifications in design to a previously classified VSB. Full-scale test data is used for interpolation and finite element analysis (FEA) may form part of this method."*



Additionally, **IWA 14-2:2013** has a similar mechanism:
**Design Method**. Quoting from the standard:
*"A design rating is determined using the maximum penetration distance from a minimum of two full-scale vehicle impact test results conducted on a VSB with one variable between the tests (e.g. gate aperture)."*

For both standards, this implies that **other vehicle impact tests must have been conducted in order to substantiate the allocation of a Design Rating**.

As with foundation design, an independent and suitably qualified engineer should be tasked with the assessment and reporting, with sign off by a Principal Grade member of the Register of Security Engineers and Specialists in the category of Hostile Vehicle Mitigation (www.rses.org.uk).

A VSB that has been allocated a Design Rating should have it clearly stated in marketing material.

An example Design Rating is:

| IWA 14-2:2013 example Design Rating | | | | |
|---|---|---|---|---|
| Design Method | Vehicle Mass [class] | Impact Speed | Impact Angle | Vehicle penetration distance |
| D | 7200 kg [N2A] | 64 km/h | 90˚ | 0.0 m |
| **IWA 14-1:2013 Bollard D / 7200 [N2A] / 64 / 90 : 0.0** | | | | |

| PAS 68:2013 example Design Rating | | | | |
|---|---|---|---|---|
| Design Method | Vehicle Mass (class) | Impact Speed | Impact Angle | Impact energy |
| D | 2500 kg (N1G) | 80 km/h | 90˚ | 617 kJ |
| **PAS 68:2013 Bollard D / 2500 (N1G) / 80 / 90 / 617** | | | | |

## Vehicle impact test standards timeline