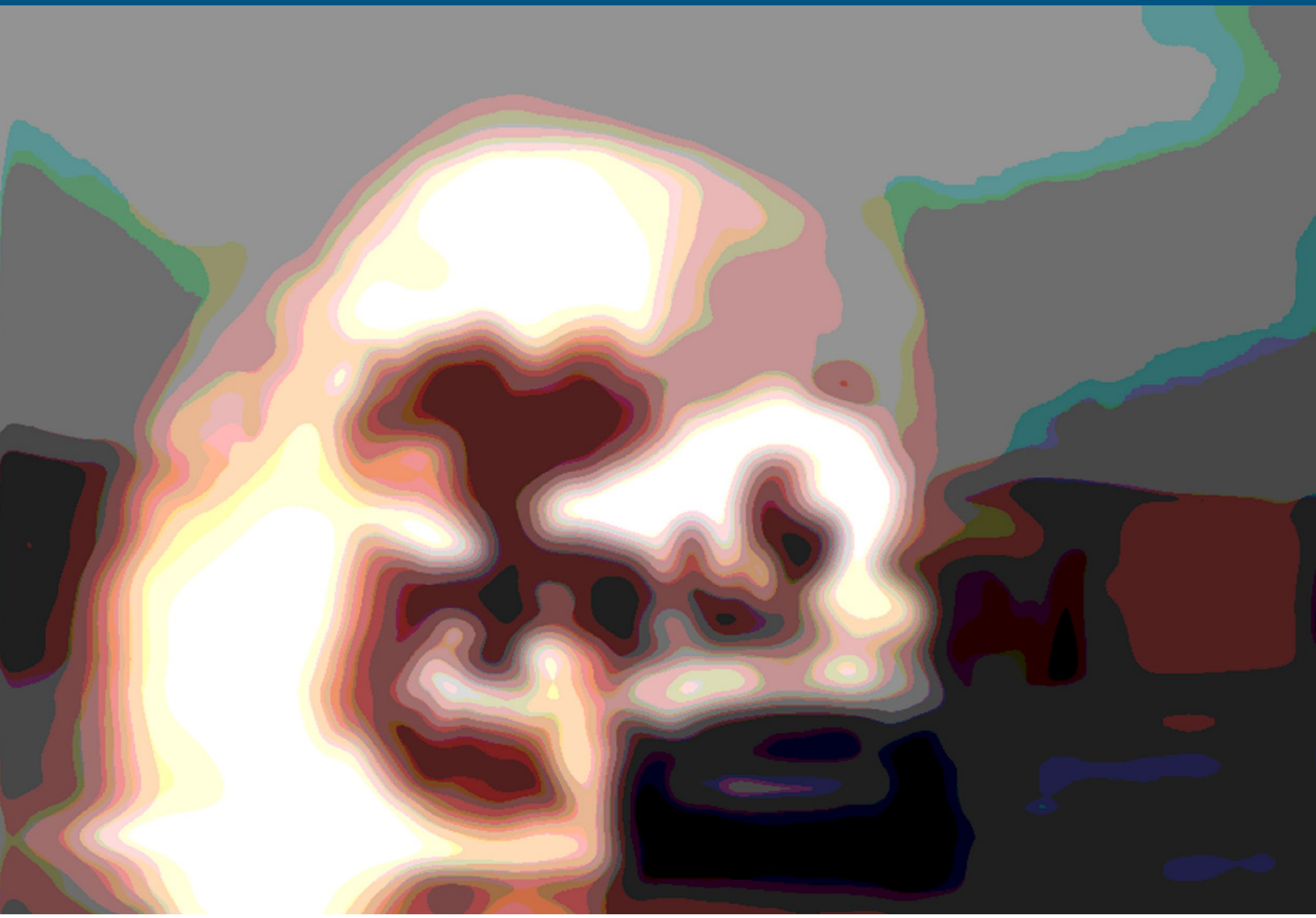
PAS 300:2015

Civilian armoured vehicle – Test methods for ballistic and blast protection



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Foreword

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Acknowledgement is also given to the members of a wider review panel who were consulted in the development of this PAS.

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Relationship with other publications

The test methods described in this PAS were developed from the *VSAG 12 Part 2: Civilian armoured vehicles – Ballistic and blast testing handbook* [1] with kind permission from the Vehicle Security Advisory Group (VSAG).

Product testing. Users of this PAS are advised to consider the desirability of third-party testing of product conformity with this PAS. Users seeking assistance in identifying appropriate conformity assessment bodies or schemes may ask BSI to forward their enquiries to the relevant association.

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It has been assumed in the preparation of this PAS that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this specification are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in italic type, and does not constitute a normative element.

Requirements in this standard are drafted in accordance with *Rules for the structure and drafting of UK standards*, subclause **J.1.1**, which states, "Requirements should be expressed using wording such as: 'When tested as described in Annex A, the product shall ...'". This means that only those products that are capable of passing the specified test will be deemed to conform to this specification.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a PAS cannot confer immunity from legal obligations.

Introduction

PAS 300 describes four test procedures that may be completed on a civilian armoured vehicle (CAV) to assess its performance against ballistic and blast levels. The test methods are set out in a manner to allow each test to be completed independently. If more than one test is required on a CAV then the test order followed is usually ballistics, side blast, under vehicle blast and then roof blast. One or multiple test vehicles may be used to complete testing assuming that all test vehicles are built to the same design specification being tested.

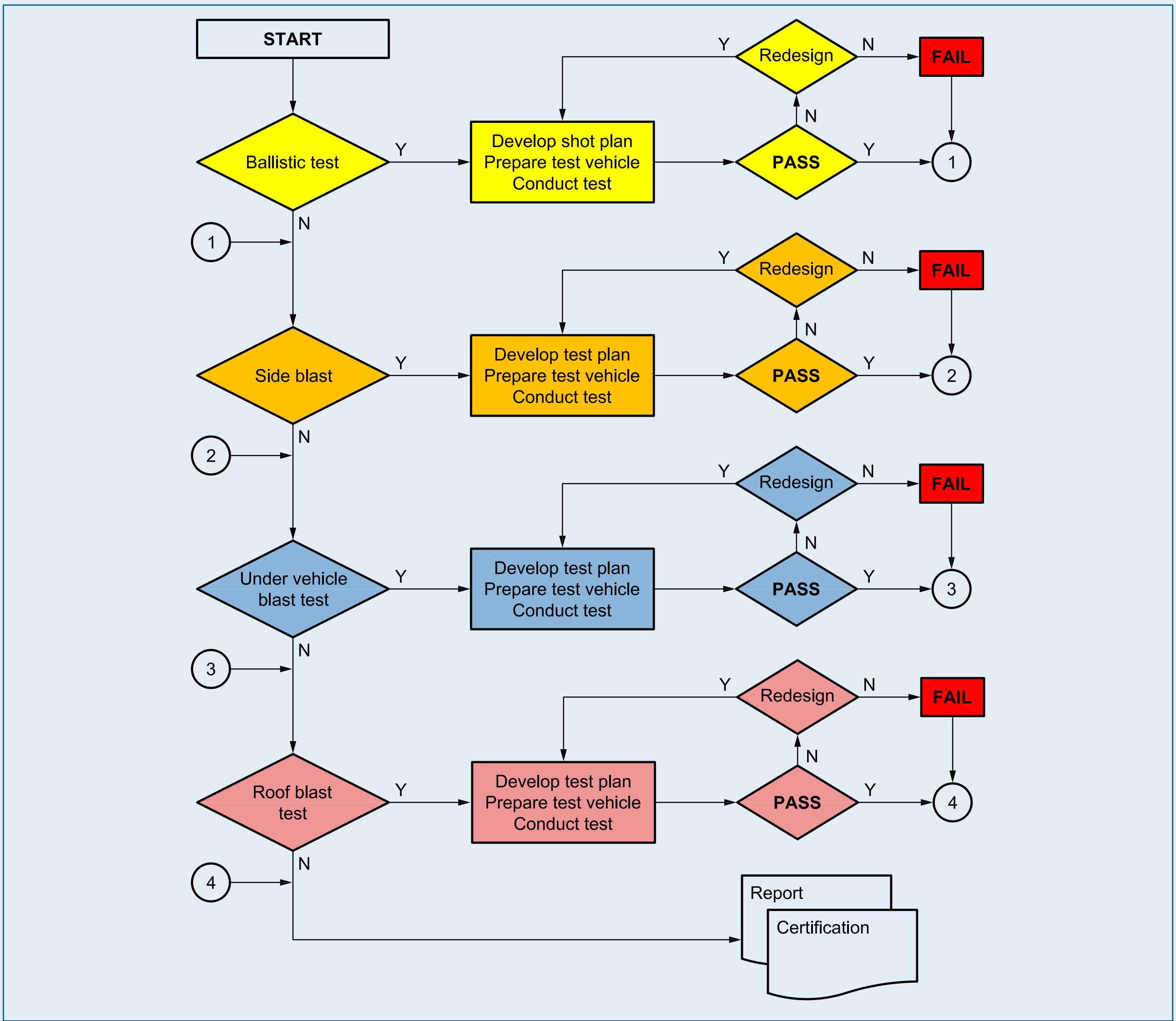
For each test, careful consideration is given to any damage sustained on the test vehicle. If there is a risk of compromising or invalidating any further testing then actions are taken to minimize this risk.

During any phase of testing it may become evident that the CAV design does not achieve a pass in accordance with the defined criteria set out in this PAS. In this situation the party requesting testing may be given the option to submit a redesign for retest. If this option is not taken the test vehicle receives a fail and the next phase of testing is conducted, if necessary.

The party requesting testing may withdraw at any time from further testing.

In line with current practice the tests may be completed with the minimum requirements set out in this PAS. The party conducting the tests seeks to test the most severe conditions. The testing process for this PAS is outlined in Figure 1 below.

Figure 1 – Testing process



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1 Scope

PAS 300 describes test methods for assessing the ballistic and/or blast performance of a civilian armoured vehicle (CAV).

This PAS defines test levels for ballistic impact (including handgun, shotgun and rifle), side blast, under vehicle blast and roof blast.

It also includes fragment simulating projectile (FSP) tests as part of the ballistic test.

2 Terms, definitions and abbreviations

2.1 Terms and definitions

For the purpose of this PAS the following terms and definitions apply.

2.1.1 armour shell

structure to protect the occupant space or critical components

NOTE *For example engine parts, fuel tank, fuel lines, auxiliary battery or communication equipment.*

2.1.2 attack angle

specified angle between the reference horizontal or vertical plane of the test vehicle (**2.1.21**) and trajectory of the test projectile (**2.1.19**)

2.1.3 chest wall velocity predictor (CWVP)

parameter used to assess the likelihood of injury in the human body from blast pressure

2.1.4 complete involuntary unlatching

vehicle door opens as a result of physical damage and/or loading, other than human intervention

2.1.5 data acquisition system (DAS)

equipment used to record experimental data

2.1.6 firing system

weapon or equipment that is capable of achieving the specified test levels

NOTE *See Table 1 for ballistic (BA) test levels.*

2.1.7 fragment

2.1.7.1 primary fragment

fragment from the test device

NOTE *For example, grenade casing fragments.*

2.1.7.2 secondary fragment

fragment that might detach from the test vehicle and enter the occupant space

NOTE *For example, armour spalling, or heavy, light and soft parts from the test vehicle.*

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2.1.8 fragment simulating projectile (FSP)

design fragment used to define a test level

2.1.9 ground plate

steel plate used between the hard standing and the test device

***NOTE** The ground plate reduces damage to the hard standing, reduces uncertainties in the test results and improves repeatability.*

2.1.10 lock failure

locked door that can be opened utilizing the outside test vehicle door handle

2.1.11 occupant space

area protected by the armour shell (**2.1.1**) where the passengers and driver are positioned

2.1.12 opaque armour panel

armour material not constructed from glass

2.1.13 plated axle mass

maximum allowable mass specified for each axle and gross vehicle mass

2.1.14 shot angle

angle between the ballistic trajectory and normal to the armour surface at the impact point

2.1.15 shot distance

measured distance between the barrel muzzle of the firing system and nearest impact surface of the test vehicle

2.1.16 shot spacing

distance on the armour specimen surface between two shots

***NOTE** The shot spacing is measured between the centre of each impact.*

2.1.17 test cell

temporary or permanent construction around the test vehicle to maintain the specified test conditions

2.1.18 test level

predefined level used to specify a minimum ballistic or blast requirement

***NOTE** For ballistic test levels this covers bullet specification/type, mass, measured velocity and shot distance. For blast test levels this covers charge type, size and stand-off.*

2.1.19 test projectile

projectile fired at the test vehicle

2.1.20 test site

location where a test is conducted

2.1.21 test vehicle

2.1.21.1 complete vehicle

civilian armoured vehicle with at least a fully integrated and completed armour shell, including all trim, door seals, door latches and locks, seats, steering wheel and front dash

***NOTE** A record may be made of items included in the test vehicle.*

2.1.21.2 test specimen

specimen comprising one or more vehicle components that represent parts of a CAV constructed using the same materials, hardware, construction techniques, fixing and mounting method that would be used in the complete vehicle

***NOTE** Examples of vehicle components include, a door section, part of a door aperture, or door latch and lock mechanism.*

2.1.22 transparent armour panel

protection material constructed from glass

2.1.23 vision block

transparent armour panel (**2.1.22**) where there is a higher likelihood the eye position could be ≤50 mm from the back surface of the panel

2.1.24 witness sheet

specified material that is placed behind a test vehicle surface to determine the extent of test projectile perforation and/or test vehicle damage

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2.1.25 witness sheet perforation

2.1.25.1 full perforation

hole, of any size, that light is able to pass through in the witness sheet, caused by the test projectile fired at the test vehicle, a fragment of the test projectile or test vehicle debris

2.1.25.2 partial perforation

damage present on the witness sheet, caused by the test projectile fired at the test vehicle, a fragment of the test projectile or test vehicle debris

NOTE *Damage may include any scratch, dent or deformation that is visually seen or felt. Slight dusting on the witness sheet is not considered damage.*

2.1.25.3 no perforation

neither full perforation nor partial perforation found on the witness sheet

2.2 Abbreviations

For the purposes of this PAS, the following abbreviations apply.

AIS	abbreviated injury score
BA	ballistic test level
CAV	civilian armoured vehicle
CWVP	chest wall velocity predictor
DAS	data acquisition system
FR	fragment test level
FSP	fragment simulating projectile
GVM	gross vehicle mass
HRC	rockwell hardness C scale
RB	roof blast test level
SB	side blast test level
SUV	sport utility vehicle
UB	under vehicle blast test level
VSAG	vehicle security advisory group

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3 Ballistic (BA) test method

3.1 Principle

A test vehicle (**2.1.21**) is fired at, using a firing system and ballistic (BA) test levels selected in accordance with Table 1. A witness sheet positioned behind the test vehicle impact surface is then inspected to determine the level of damage and assessed against the pass/fail criteria.

Fragment testing, using fragment simulating projectiles (FSPs) is included in the ballistic shot plan when specified in the requirement. Where an FSP test is specified a test vehicle is fired at using a firing system and test levels selected in accordance with Table 2 and fragment measured velocity test levels, in accordance with Table 3.

3.2 Ballistic (BA) test levels

3.2.1 The BA test levels shall be selected in accordance with Table 1.

NOTE *For example, a 7.62×39 AK47 PS Ball is test level BA-F. A 7.62×51 AP is BA-M. A 7.62×39 API BZ is BA-L.*

3.2.2 For any test level selected, the likelihood of any lesser test level presenting an additional hazard shall be assessed and additional tests conducted, if necessary.

NOTE *For example, test level BA-G may present a higher hazard against textile/composite armour compared to test level BA-H. Lead core bullets, for example BA-H and BA-J, may present a higher hazard in terms of splash leakage around door apertures compared to the armour piercing bullet BA-L.*

3.3 Fragment (FR) test levels

3.3.1 The FR test levels and measured velocity test levels shall be selected in accordance with Table 2 and Table 3.

NOTE 1 *For example, a 0.3" FSP with 400 m/s measured velocity is FR-CB. A 20.0 mm FSP with 960 m/s measured velocity is FR-FG.*

NOTE 2 *Fragment testing may be included as part of the ballistic tests and pass/fail determination. The tests may be conducted using gun-fired FSPs.*

NOTE 3 *The FR test levels are representative of primary fragments (**2.1.7.1**) generated from blast threats (including artillery engagement) detonated at different distances.*

NOTE 4 *Multi-hit testing is not required with FSPs. This is based on the assumption that blast threats are at a sufficient distance so that discrete impacts are more likely.*

NOTE 5 *Some of the fragment specifications and velocities have been extracted from* STANAG 2920 *[2] and* AEP – 55 Vol.1 (Edition 2) *[3].*

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Table 1 – Ballistic (BA) test levels

Test level	Type of weapon	Bullet specification	Bullet type	Mass g	Measured velocity m/s	Shot distance m	Notes
BA-A	hand gun	9×19 mm	FMJs/RN/SC	8.0 ±0.1	400.0 ±10.0	5.0 ±0.5	
BA-B	hand gun	0.357″ magnum (9×33 mm R)	FMJc/CT/SC	10.2 ±0.1	430.0 ±10.0	5.0 ±0.5	
BA-C	hand gun	0.44″ magnum (11.1×32.6 mm R)	FMJc/FN/SC	15.6 ±0.1	440.0 ±10.0	5.0 ±0.5	
BA-D	Reserved						
BA-E	Reserved						
BA-F	rifle	7.62×39 mm PS Ball	FMJs/PB/FeC	8.0 ±0.1	720.0 ±15.0	10.0 ±0.5	
BA-G	rifle	5.56×45 mm NATO Ball	FMJc/PB/SCP	4.0 ±0.1	950.0 ±15.0	10.0 ±0.5	For example, SS109
BA-H	rifle	7.62×51 mm NATO Ball	FMJs/PB/SC	9.55 ±0.1	830.0 ±15.0	10.0 ±0.5	
BA-J	rifle	5.56×45 mm M193	FMJc/PB/SC	3.56 ±0.1	990.0 ±15.0	10.0 ±0.5	
BA-K	Reserved						
BA-L	rifle	7.62×39 mm API BZ	FMJs/PB/HC-I	7.7 ±0.2	740.0 ±15.0	10.0 ±0.5	Nominal core hardness 65 HRC
BA-M	rifle	7.62×51 mm AP	FMJs/PB/HC	9.7 ±0.2	820.0 ±15.0	10.0 ±0.5	Nominal core hardness 63 HRC
BA-N	rifle	7.62×54 mm R B32 API	FMJs/PB/HC-I	10.3 ±0.3	860.0 ±15.0	10.0 ±0.5	Nominal core hardness 63 HRC
BA-P	rifle	7.62×51 mm AP (WC)	FMJs/PB/WC	12.7 ±0.1	810.0 ±15.0	10.0 ±0.5	Nominal core hardness 76 HRC
BA-SG	solid lead slug	18.5 ±0.5 (12 gauge cylinder bore)	L	31.0 ±0.5	420.0 ±20.0	10.0 ±0.5	For example, Brenneke slug

Key

AP	armour piercing	API	armour piercing incendiary
CT	coned truncated	FeC	mild-steel core
FMJs	full metal jacket (steel)	FMJc	full metal jacket (copper)
FN	flat nose	HC	hard core
I	incendiary	L	full lead
PB	pointed bullet	R	rimmed
RN	round nose	SC	lead-soft core
SCP	lead-soft core with steel penetrator	WC	tungsten (wolfram) carbide

***NOTE** Other common ballistic standards are listed for comparison in Annex A.*

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Table 2 – Fragment (FR) test levels

Test level	FSP	Diameter mm	Mass g	Distance m	HRC kgf
FR-A	0.22" FSP	5.5 ±0.10	1.10 ±0.03	10.0 ±0.50	30 ±2
FR-B	0.25" ball	6.5 ±0.06	1.13 ±0.03	10.0 ±0.50	55 ±3
FR-C	0.3" FSP	7.5 ±0.10	2.84 ±0.03	10.0 ±0.50	30 ±2
FR-D	10 mm ball	10.0 ±0.10	4.11 ±0.03	10.0 ±0.50	55 ±3
FR-E	0.5" FSP	12.5 ±0.10	13.39 ±0.13	10.0 ±0.50	30 ±2
FR-F	20 mm FSP	20.0 ±0.10	52.73 ±0.26	10.0 ±0.50	30 ±2

Table 3 – Fragment measured velocity test levels

Index	A	B	C	D	E	F	G	H	I	J	K
Measured velocity m/s	300 ±20	400 ±20	520 ±20	630 ±20	700 ±20	770 ±20	960 ±20	1 000 ±20	1 250 ±20	1 500 ±20	1 800 ±20

3.4 Test vehicle

A complete vehicle (**2.1.21.1**) shall be used to complete the ballistic test procedure.

*NOTE A complete vehicle or test specimens (**2.1.21.2**) may be used for retesting.*

3.5 Apparatus

3.5.1 *Bullet or FSP loading equipment*, capable of achieving the bullet and FSP specified measured velocities

3.5.2 *Firing system*, capable of firing the full range of BA and/or FR test levels in accordance with Tables 1, 2 and 3. The firing system shall have the capacity to be rotated to any angle in the horizontal and vertical planes specified in the shot plan (**3.6.1**)

3.5.3 *Mass measuring equipment*, that is calibrated and capable of measuring to an accuracy of at least ($\pm1.0 \times 10^{-5}$) kg

3.5.4 *Shot angle measuring equipment*, capable of measuring the angles given in the shot plan to an accuracy of at least ±1.0°

3.5.5 *Temperature and humidity measuring equipment*, capable of measuring temperature with an accuracy of at least ±0.5 °C and ±1% humidity respectively

3.5.6 *Test cell*, temporary or permanent construction around the test vehicle capable of protecting the test vehicle from adverse weather conditions and achieving a temperature of (20 ±10) ˚C

3.5.7 *Velocity measuring equipment,* that is calibrated and capable of measuring the velocities given in Table 1 or Table 3, to an accuracy of at least ±0.5%

3.5.8 *Witness sheet 1*, consisting of an aluminium alloy sheet 2024 T3 or T4, AlCuMg ISO/R209 with a thickness of (0.5 ±0.05) mm and a tensile strength of (440 ±40) N/mm

*NOTE 1 Witness sheet 1 is used for all ballistic testing, except when testing vision blocks (**2.1.23**).*

NOTE 2 Alternative materials may be used (e.g. polycarbonate) provided it can be demonstrated they have similar characteristics to the material stated above. For example the impact velocity required to perforate (0.5 ±0.05) mm 2024 T4 Al using a 4.4 mm 0.36 g spherical steel pellet, with at least 0.99 probability, is (175 ±25) m/s.

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3.5.9 *Witness sheet 2*, consisting of an aluminium alloy foil with a thickness of (0.05 ±0.01) mm

***NOTE** Witness sheet 2 is used for testing vision block in test vehicles where there is a higher likelihood the eye position could be ≤50 mm from the back surface of the vision block.*

3.6 Test set up

3.6.1 Shot plan

3.6.1.1 The party completing the testing shall be responsible for the approval of the shot plan after inspection of the CAV design and the test vehicle. As a minimum, the inspection shall include a close examination of the design to identify potential vulnerabilities around the following areas:

a) door apertures;

b) handles;

c) latches;

d) locks;

e) armour joints;

f) hole cover plates;

g) bolt fixings;

h) welds;

i) wheel arches;

j) glass structural supports (e.g. internal framing to support side door glass);

k) glass framing/supports and overlaps with the opaque armour;

l) fuel line protection;

m) fuel tank protection;

n) auxiliary battery; and

o) any engine component protection.

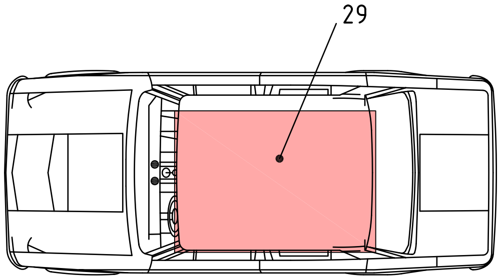
For shots on the door armour the exact location of the internal framing and other components shall be identified so they can be taken into consideration.

3.6.1.2 Each shot shall be assigned a unique number.

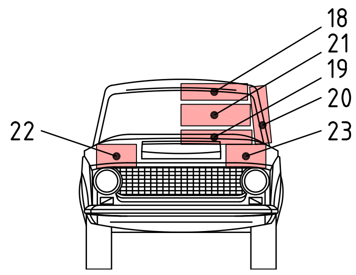
***NOTE** An example ballistic shot plan-test log template is given in Annex B. The ballistic shot plan-test log includes shot number, shot zone, armour material, bullet or FSP type, specified horizontal and vertical attack angles, specified measured velocity, actual measured velocity, result and shot validity.*

3.6.1.3 The test vehicle shall be zoned in accordance with Figure 2 for a saloon CAV, or in accordance with Figure 3 for a sport utility vehicle (SUV) CAV. For any other CAV types zoning shall follow a similar approach.

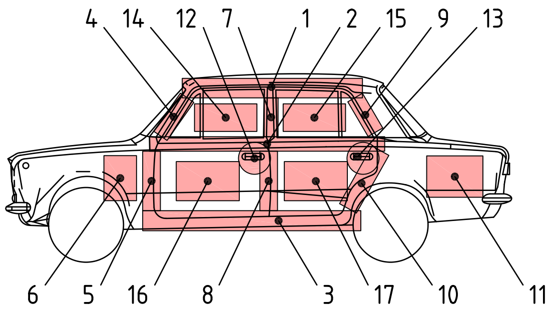
Figure 2 – Shot zones for saloon type CAV



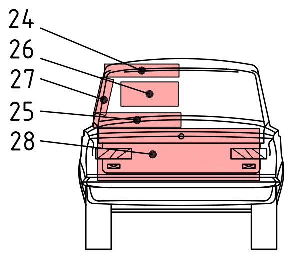
a) Plan



b) Front elevation



c) Elevation



d) End elevation

Shot zones		**Minimum number of shots**
1	Cant rail	8
2	Door body glass joint	8
3	Door sill	8
4	"A" post upper	4
5	"A" post lower	4
6	Side front fender	3
7	"B" post upper	8
8	"B" post lower	8
9	"C" post upper	4
10	"C" post lower	4
11	Rear fender	3
12	Front door latch and lock	5
13	Rear door latch and lock	5
14	Front door glass	3
15	Rear door glass	3
16	Front door panel	6
17	Rear door panel	6
18	Front glass/roof joint	4
19	Front glass/fire wall joint	4
20	Front glass "A" post joint	4
21	Front glass	3
22	Fire wall left	3
23	Fire wall right	3
24	Rear glass/roof joint	4
25	Rear glass/fire wall joint	4
26	Rear glass	3
27	Rear glass "C" post joint	4
28	Rear fire wall	6
29	Roof	6
	Total	**138**

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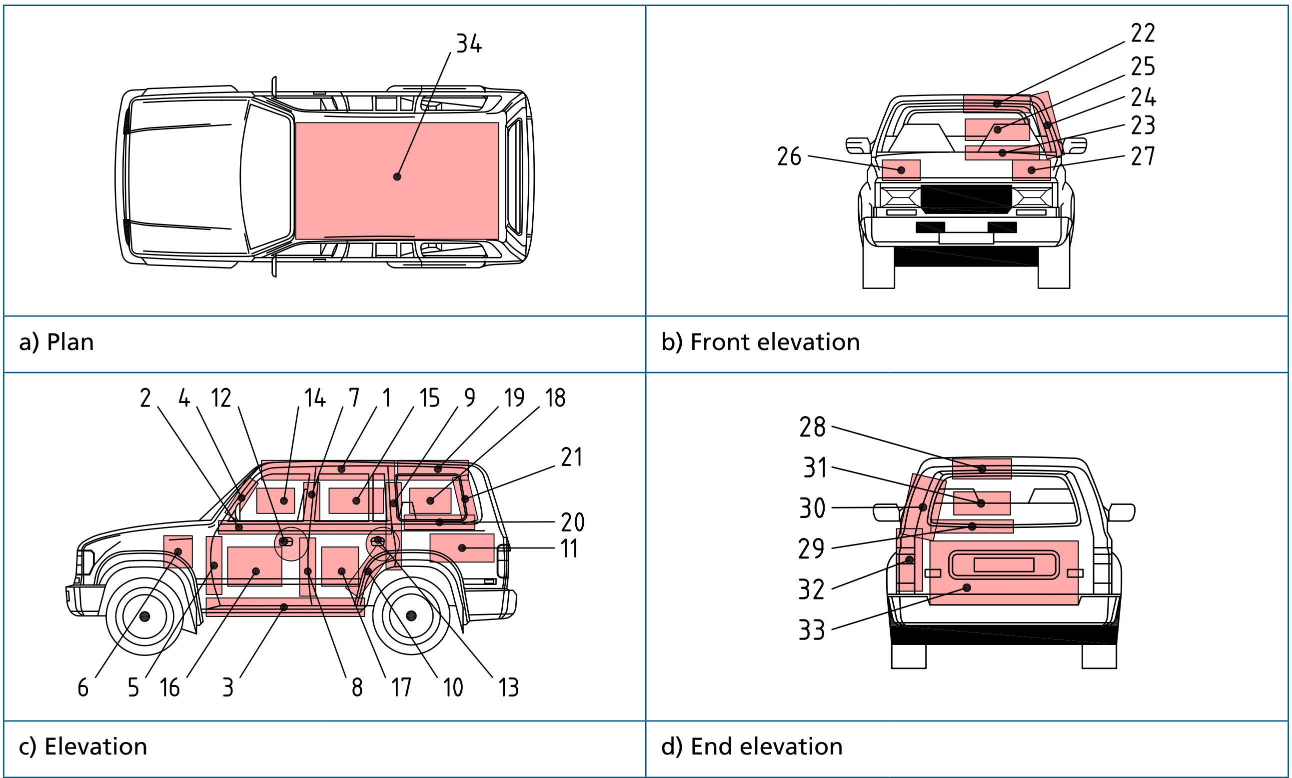
Figure 3 – Shot zones for SUV type CAV



a) Plan

b) Front elevation

c) Elevation

d) End elevation

Shot zones		Minimum number of shots
1	Cant rail	8
2	Door body glass joint	8
3	Door sill	8
4	"A" post upper	4
5	"A" post lower	4
6	Side front fender	3
7	"B" post upper	8
8	"B" post lower	8
9	"C" post upper	4
10	"C" post lower	4
11	Rear fender	3
12	Front door latch and lock	5
13	Rear door latch and lock	5
14	Front door glass	3
15	Rear door glass	3
16	Front door panel	6
17	Rear door panel	6
18	Rear light glass	3
19	Rear cant rail	4
20	Rear light/fender joint	4
21	"D" post upper	4
22	Front glass/roof joint	4
23	Front glass/fire wall joint	4
24	Front glass "A" post joint	4
25	Front glass	3
26	Fire wall left	3
27	Fire wall right	3
28	Rear glass/roof joint	4
29	Rear glass/rear door joint	4
30	Rear door aperture upper	4
31	Rear glass	3
32	Rear door aperture lower	4
33	Rear door panel	6
34	Roof	6
	Total	**157**

NOTE *If the rear load space is not armoured, the shot zones for a saloon type CAV apply.*

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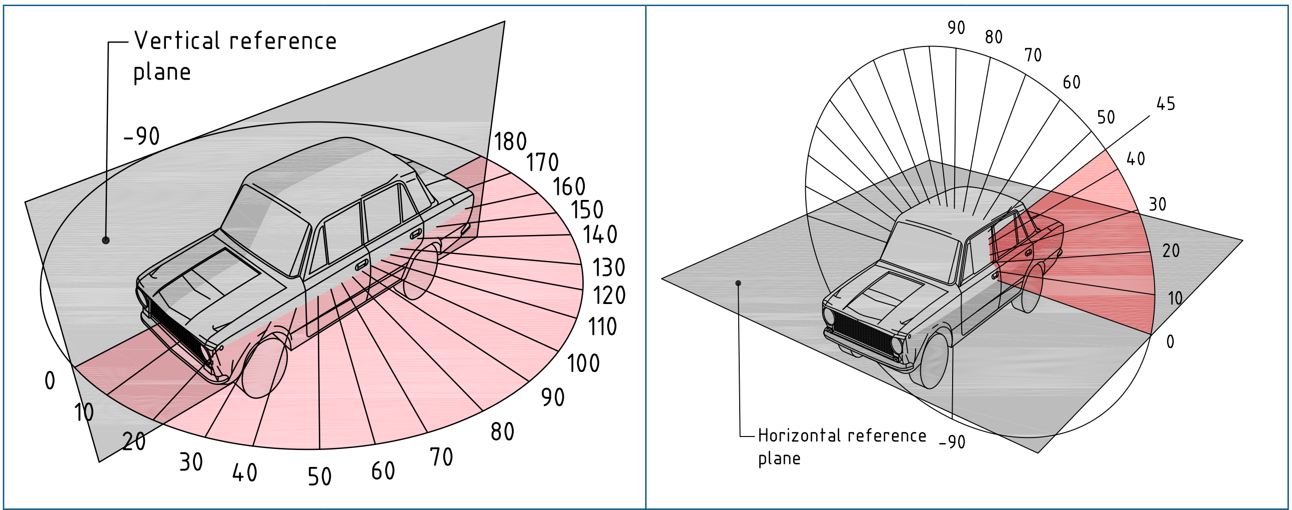
Figure 4 – Minimum requirement for attack angles



Direction	Angle	Direction	Angle
Horizontal (Azimuth)	[(0 ±180) ±1]°	Vertical (Elevation)	[(0 +45)±1]°

3.6.1.4 The BA test levels shall be selected in accordance with **3.2**.

3.6.1.5 Where FSP testing is specified, the FR test levels shall be selected in accordance with **3.3**.

3.6.1.6 Shot angles (**2.1.14**) shall be selected to assess the ballistic performance of the armour and to test the most vulnerable angles. To facilitate the firing system placement relative to the test vehicle the shot angle shall be transposed into the attack angle (**2.1.2**) that is relative to the horizontal and vertical reference planes defined for the test vehicle.

The horizontal and vertical reference planes and attack angles shall be defined in accordance with Figure 4. The horizontal plane shall be parallel with the test arena surface and the vertical plane shall be at a right angle to the horizontal plane.

The horizontal attack angle shall be measured from the vertical plane and defined from (0 ±180)° with 0° oriented on the front of the test vehicle. The vertical attack angle shall be measured from the horizontal plane and defined from (0 +90)°.

NOTE 1 *If the test vehicle presented for the test does not have sufficient area to complete all the ballistic and FSP testing then a second complete vehicle, or test specimens may be used.*

NOTE 2 *The sequence of shots and location should be arranged in a manner so as not to compromise or invalidate later shots. Where the same test vehicle is used for blast testing then the ballistic testing should be confined to the front, rear and opposite side of the intended blast tests so the shot positions do not present a risk of invalidating blast testing.*

NOTE 3 *This method assumes the CAV is tested in the horizontal plane, if the test vehicle is tilted to achieve the vertical attack angle then CAV suspension movement should be accounted for.*

The minimum number of shots in each zone shall be selected in accordance with Figure 2 or Figure 3. The minimum requirement for attack angles (**2.1.2**) shall be horizontal (0 ±180)° and vertical (0 +45)° selected in accordance with Figure 4. The shot validity shall conform to the ballistic validity criteria in accordance with Annex I. The sequence of five shots on the latch, lock and door handles shall start with the most vulnerable locations.

NOTE 4 *The minimum number of shots in a zone may be either all of one ammunition level or multiple levels if testing lesser threats, including FSPs. For example, if a minimum of four shots are required, it may include one for each test level or all the same test level, it does not mean to test four shots at each test level.*

3.6.2 Test condition

The ballistic test shall be carried out within a temperature range of (20 ±10) °C.

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NOTE 1 There are no humidity constraints.

*NOTE 2 If necessary the test vehicle may need to be enclosed within a test cell (**3.5.6**) to achieve the correct temperature.*

3.6.3 Preparation of test vehicle

3.6.3.1 The test vehicle (**3.4**) shall be visually inspected without magnification, to determine if there are defects or other damage that affect the test procedure or results. If any defects or damage are present these shall be rectified prior to testing.

NOTE 1 Examples of defects or damage may include dents or cracks in the armour, cracked glass, or incorrect door aperture closure.

NOTE 2 The test vehicle may need to be drained of fluids.

3.6.3.2 The test vehicle shall be conditioned at a temperature in accordance with **3.6.2** for at least 12 hrs prior to testing.

3.6.3.3 The test vehicle mass shall be configured to achieve the normal operational driving stance in the horizontal and vertical planes. This shall ensure the test vehicle is correctly orientated with the reference horizontal and vertical planes (**3.6.1.6**) and the attack angles are consistent with the shot plan.

3.6.4 Preparation of bullet and/or FSP

Bullets, FSPs, and cartridges (including primers) shall be undamaged.

3.6.5 Firing system placement

The firing system (**3.5.2**) shall be placed at the shot distance specified by the test levels given in Table 1 or Table 2. The distance shall be measured from the muzzle of the barrel to the impact surface of the test vehicle. The attack angle specified in the shot plan shall be within ±1°.

NOTE In exceptional circumstances the shot distance may be altered provided a valid shot can be achieved (see Annex I). An example of an exceptional circumstance may be where restrictions on space do not allow the firing system to be placed within the shot distance specified.

3.6.6 Velocity measuring equipment placement

The velocity measuring equipment (**3.5.7**) shall determine a velocity at a point ≤2.5 m from the impact surface of the test vehicle.

3.6.7 Witness sheet placement

Witness sheet 1 (**3.5.8**) aluminium alloy sheet for testing opaque and transparent zones shall be placed internally ≤150 mm behind and parallel to the back face surface at the impact point.

Witness sheet 2 (**3.5.9**) aluminium alloy foil for testing vision block (**2.1.23**) zones shall be placed internally at a reduced distance of (50 ±5) mm behind and parallel to the back face surface at the impact point.

For all shots, and where possible, the witness sheet coverage shall extend a minimum (500 ±10) mm radially from the impact point.

NOTE If there is any doubt on the extent of coverage for the witness sheet then the complete surface behind the test position should be covered.

3.6.8 Shot spacing

The shot spacing on all armour panels (including transparent panels) for bullets and FSPs shall be three impacts arranged in an equilateral triangle with a side length of (120 ±10) mm.

The shot spacing on apertures or joints that contain transparent armour panels shall be (120 ±10) mm.

The shot spacing for apertures and joints that do not contain transparent armour panels shall have spacing to facilitate the shot plan but not less than three bullet calibres for the bullet being fired.

The shot spacing on door handles, latches and locks shall have spacing to facilitate the shot plan but not less than three bullet calibres for the bullet being fired.

3.7 Test procedure

NOTE Testing should conform with the test site local safety procedures at all times.

3.7.1 Using the temperature and humidity measuring equipment (**3.5.5**) measure the temperature and humidity and record results in the ballistic shot plan-test log (see Annex B). The test temperature shall be in accordance with **3.6.2** and **3.6.3.2**.

NOTE There are no humidity constraints but humidity should be recorded in the ballistic shot plan-test log.

3.7.2 Visually inspect the test vehicle for damage in accordance with **3.6.3.1**.

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3.7.3 Mark all shot impact locations on the test vehicle with the unique shot number specified in the shot plan (**3.6.1**).

3.7.4 Select a shot from the shot plan. Record the shot number, shot zone, armour material, bullet or FSP type, specified horizontal and vertical attack angles and specified measured velocity in the ballistic shot plan-test log (see Annex B).

3.7.5 Position the firing system (**3.5.2**) and velocity measuring equipment (**3.5.7**) in accordance with **3.6.5** and **3.6.6**.

NOTE Firing at the specified horizontal and vertical angles may be achieved by moving the firing system, moving the test vehicle or both. The methods chosen for moving the firing system or test vehicle should be capable of achieving the stated ballistic validity criteria (see Annex I).

3.7.6 Position the witness sheet(s) (**3.5.8** or **3.5.9**) in accordance with **3.6.7**.

3.7.7 Check the test vehicle is correctly configured.

*NOTE 1 Correctly configuring the test vehicle reduces the risk of invalidating the shot. For example the test vehicle doors should be correctly closed, or the test vehicle has the correct driving stance (**3.6.3.3**).*

NOTE 2 The door latch mechanism may require power to engage the lock.

3.7.8 Prepare the bullet or FSP specified in the shot plan in accordance with **3.6.4**.

3.7.9 Check the velocity measuring equipment (**3.5.7**) is correctly positioned in accordance with **3.6.6** and set to record.

3.7.10 Fire the shot selected from the shot plan.

NOTE The bullet or FSP may be fired using any suitable means, provided the ballistic validity criteria (see Annex I) is fulfilled.

3.7.11 Inspect the witness sheet(s) (**3.5.8** or **3.5.9**) for any evidence of a full perforation, partial perforation or damage and record results in the ballistic shot plan-test log (see Annex B).

*NOTE 1 Damage to the door latch and lock is made by observation and physical examination to check for complete involuntary unlatching (**2.1.4**) or door latch and lock failure (**2.1.10**).*

NOTE 2 Additional observations may be recorded in the notes section of the ballistic shot plan-test log (see Annex B).

3.7.12 Number the evidence found on the witness sheet(s) (**3.7.11**) linked to the unique shot number identified in **3.7.3**.

3.7.13 Remove the witness sheet(s) and replace with new witness sheet(s) if necessary.

3.7.14 Record the bullet actual measured velocity in the ballistic shot plan-test log (see Annex B).

3.7.15 Check for a valid shot in accordance with Annex I and record in the ballistic shot plan-test log (see Annex B).

NOTE If the shot is not valid, record result in the ballistic shot plan-test log and amend shot plan so the shot can be repeated later in the procedure.

3.7.16 Repeat steps **3.7.4** to **3.7.15** until the shot plan is complete.

3.7.17 Assess the test results in accordance with **3.8**.

3.8 Expression of results

When the shot plan has been completed in accordance with **3.7**, classify the test vehicle as a pass or fail in accordance with the criteria given in Table 4. Where any aspect of the assessment is determined as a fail there is the option to submit a redesign for ballistic testing.

NOTE The results only apply to the design submitted as the test vehicle. If at any stage changes are made to the design, then the results become void until the design changes are submitted for evaluation which could result in additional testing.

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Table 4 – Ballistic (BA) test pass/fail criteria

	Armour shell (based on witness sheet damage)		Door latch and lock	
	Full perforation (FP)	**Partial perforation (PP)**	**Complete involuntary unlatching** (criteria used when doors are locked or unlocked, based on 5 shots)	**Lock failure** (criteria used when doors are locked, based on 5 shots)
Fail	FP ≥1	PP >8	Shots 1 to 5 Complete involuntary unlatching	Shots 1 to 5 Lock disengages
Pass	FP =0	PP ≤8	Shots 1 to 5 No complete involuntary unlatching	Shots 1 to 5 Lock remains engaged

NOTE 1 *The integrity of the armour shell is assessed using witness sheet damage and the number of full perforations (FP) and partial perforations (PP). The witness sheet damage criteria may be considered a measure of the acceptable risk from ballistic perforation of the armour shell and any potential associated injury.*

NOTE 2 *The door latch and lock designs are specifically assessed by the ability of the door latch and lock to withstand a reasonable number of multiple impacts. See also **2.1.4** and **2.1.10**.*

3.9 Report

As a minimum requirement the party completing the testing shall submit a ballistic shot plan-test log and summary of the pass/fail results. An example ballistic shot plan-test log and results summary is given in Annex B.

NOTE *In addition, supporting evidence may be included, for example test reports including photographs, armour material matrix showing armour material and location in test vehicle and other relevant test data.*

If a pass is achieved a certificate shall be issued stating, as a minimum:

- certificate number;
- test vehicle number/identifier;
- date of test;
- test party details (organization);
- test level;
- test report number; and
- a statement that the test only applies to the CAV design tested.

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4 Side blast (SB) test method

4.1 Principle

The test method is designed to assess the performance of a CAV against threats from a side blast using a surrogate test device selected in accordance with Table 5. The chest wall velocity predictor (CWVP, calculated from internal pressure), and witness sheets are used to determine level of damage and assessed against the pass/fail criteria.

4.2 Side blast (SB) test levels

The SB test level shall be selected in accordance with Table 5. The surrogate test device shall be a cube constructed in accordance with Annex C and contain a C4 bare charge. Where an alternative explosive material is used this shall conform to Annex D.

NOTE 1 For example, a 12.0 kg C4 charge and stand-off distance of 3.0 m is SB-C. C4 is listed as the test explosive; however, an equivalent explosive may be used, provided it can be demonstrated that it produces similar peak incident static overpressure and impulse values, as given in Annex D.

*NOTE 2 FR test levels are not included in the side blast testing but may be assessed separately during ballistic testing using single shot FSPs (see **3.3**).*

Table 5 – Side blast (SB) test levels

Test level	Explosive	Explosive mass kg	Stand-off m
SB-A	C4	12.0 ±0.025	5.0 ±0.02
SB-B	C4	12.0 ±0.025	4.0 ±0.02
SB-C	C4	12.0 ±0.025	3.0 ±0.02
SB-D	C4	12.0 ±0.025	2.0 ±0.02
SB-E	C4	12.0 ±0.025	1.0 ±0.02

4.3 Test vehicle

A complete vehicle shall be used to complete the side blast test procedure.

NOTE The test vehicle used for ballistic testing may be used for the side blast test.

4.4 Apparatus

4.4.1 *Data acquisition system (DAS)*, capable of recording pressure data in accordance with Table 6

Table 6 – DAS specification

Parameter	Value
Sample frequency	≥100 kS/sec (kilo samples per second)
Hardware (analogue) anti-aliasing low pass band limited filter	≥10 kHz
Resolution	≥12 bit (digital word length)
Bandwidth	≥anti-aliasing low pass band limited filter
Time base range	at least 1 000 ms
Pre-trigger range	at least 100 ms

NOTE 1 Sample frequency is defined as the frequency at which data is captured. Additional information on sample frequency and filters is provided in Annex E.

NOTE 2 Anti-aliasing low pass band limited filter is defined as the frequency (based on -3 dB attenuation) at which higher frequencies are filtered out.

NOTE 3 DAS resolution is defined by the full scale voltage output range of the amplifier and the digital word length. For example, a full scale voltage range of ±5 V with a 12 bit digital word length would give a minimum resolution of 2.44 mV (e.g. $10 \div 2^{12}$). So the minimum resolution recorded by the pressure transducer (assuming a gain of 1.0) is [$(2.44 \times 10^{-3})\times$ transducer calibration factor (provided with the transducer)].

NOTE 4 Bandwidth is defined as the ability of the analogue to digital conversion process to pass a signal without significant attenuation over a range of frequencies. Bandwidth is measured between the lower and upper frequencies where the signal amplitude falls to -3 dB below the pass-band frequency of the digitizer.

NOTE 5 Time base range is defined as the recording time.

NOTE 6 Pre-trigger range is defined as the time duration for recording base line data prior to the actual trigger time.

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4.4.2 *Ground plate*, made from mild steel, square and with a size of at least
1 000 mm × 1 000 mm × 25 mm ±5 mm

4.4.3 *Mass measuring equipment 1*, that is calibrated and capable of measuring to an accuracy of at least (±1 × 10^{-3}) kg

***NOTE** Equipment used for measuring the mass of explosive materials and the test device.*

4.4.4 *Mass measuring equipment 2*, that is calibrated and capable of measuring to an accuracy of at least ±5.0 kg

***NOTE** Equipment used for measuring mass of the test vehicle.*

4.4.5 *Pressure transducers*, that are calibrated and used with a DAS to record external and internal blast pressure in accordance with Table 7

Table 7 – Pressure transducer specification

Parameter	Value
Full scale range	(0 to 500) kPa (absolute)
Resonance frequency	≥50 kHz
Transducer resolution	≤0.1kPa
Non-linearity	≤1.0%

***NOTE 1** Additional information on the DAS is given in **4.4.1**.*

***NOTE 2** Full scale range is defined as the operating range of the transducer.*

***NOTE 3** Resonance frequency is defined as the frequency above which the transducer is susceptible to resonance.*

***NOTE 4** Transducer resolution is defined as the smallest measurable value.*

***NOTE 5** Non-linearity based on full scale, zero base, least-square, best fit straight line method.*

4.4.6 *Temperature and humidity measuring equipment*, capable of measuring temperature with an accuracy of at least ±0.5 °C and ±1% humidity respectively

4.4.7 *Tyre pressure gauge*, capable of measuring tyre pressure with an accuracy of at least ±0.1 bar

4.4.8 *Witness sheet*, consisting of an aluminium alloy sheet 2024 T3 or T4, AlCuMg ISO/R209 having a thickness of (0.5 ±0.05) mm and tensile strength of (440 ±40) N/mm

***NOTE** Alternative materials may be used (e.g. polycarbonate) provided it can be demonstrated they have similar characteristics to the material stated above. For example the impact velocity required to perforate (0.5 ±0.05) mm 2024 T4 Al using a 4.4 mm 0.36 g spherical steel pellet, with at least 0.99 probability, is (175 ±25) m/s.*

4.5 Test set up

4.5.1 Preparation of test vehicle

4.5.1.1 The test vehicle (**4.3**) shall be visually inspected without magnification, to determine if there are defects or other damage.

4.5.1.2 Where the test vehicle was used for ballistic testing, particular attention shall be paid to the ballistic damaged areas to ensure no defects or damage affect the test procedure or results. If any defects or damage are present that might affect the test procedure or results, these shall be rectified prior to testing.

***NOTE 1** Examples of defects or damage may include dents or cracks in the armour, cracked glass, or incorrect door aperture closure.*

***NOTE 2** If tyre pressure can be maintained each wheel should be inflated to the manufacturer's specified pressure.*

4.5.1.3 The test vehicle doors shall be closed and either locked or unlocked.

***NOTE 1** Each CAV may have standard operating procedures that dictate whether the doors should be locked or unlocked during testing.*

***NOTE 2** If the doors are unable to close correctly they may be held closed using a suitable method, for example ratchet straps.*

4.5.1.4 The test vehicle shall be loaded to its maximum allowable mass without exceeding GVM or individual plated axle mass ±5.0 kg.

***NOTE** Ballast (sand bags) may be placed in the test vehicle to achieve the correct mass distribution.*

4.5.1.5 The height between the test arena surface and the test vehicle door sill (see zone 3 in Figure 2 or Figure 3) shall be measured and corrected accordingly to achieve the manufacturer's specified height when the test vehicle is loaded in accordance with **4.5.1.4**.

***NOTE** For example, if the tyres were damaged and deflated in previous tests the height of the test vehicle may be adjusted using timber spacers under the wheels.*

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4.5.2 Explosive test device placement

4.5.2.1 The test device shall be positioned in accordance with Figure 5. The test device flat surface shall be parallel to the test vehicle vertical reference plane (**3.6.1.6**). The centre of the test device shall be aligned with the test vehicle "B" post (see zones 7 and 8 in Figure 2 or Figure 3) at a height ±0.02 m half way between the test vehicle top and bottom surface measured on the blast side.

4.5.2.2 The test device shall be supported on a test stand, using lightweight non-metal frangible material that does not significantly influence the blast pressures on the test vehicle or generate undesirable primary fragments (**2.1.7.1**).

4.5.2.3 The test shall be conducted on flat and horizontal hard standing that does not absorb the blast pressure or generate a crater.

NOTE If necessary a ground plate (4.4.2) may be placed on the ground under the test device to reduce cratering.

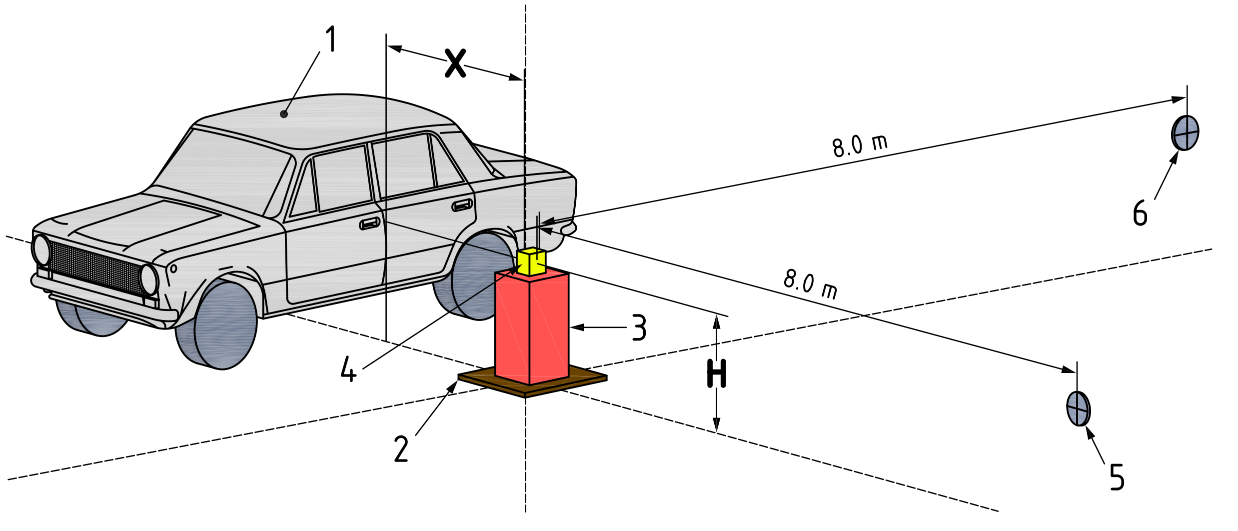
4.5.3 Pressure transducer placement

4.5.3.1 Two pressure transducers shall be positioned externally to the test vehicle in accordance with Figure 5. Each transducer centre shall be placed at the same height as the test device centre, one transducer opposite each test device vertical surface. The distance between each transducer centre and the test device surface shall be (8.0 ±0.02) m.

NOTE 1 The pressure transducers are used to measure the external incident static overpressure and impulse in order to confirm a full detonation.

NOTE 2 The 8.0 m stand-off is used to avoid unpredictable data generated by the fireball.

Figure 5 – Side blast (SB) test setup



Key

1	Test vehicle
2	Ground plate
3	Explosive test stand (constructed from lightweight non-metal frangible material)
4	Explosive test device
5	External pressure transducer positioned at height (H) ±0.02 m and (8.0 ±0.02) m from the surface of the charge
6	External pressure transducer positioned at height (H) ±0.02 m and (8.0 ±0.02) m from the surface of the charge
X	Stand-off between the test device and the test vehicle, measured from the nearest surface of the explosive material to the outside skin of the test vehicle at height (H) ±0.02 m
H	Vertical height from the centre of the test device to the hard standing aligned half way between the test vehicle top surface and bottom surface measured on the test vehicle blast side

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4.5.3.2 At least two pressure transducers shall be positioned inside the test vehicle on the blast side. The transducers are positioned in a manner to represent the reflecting surface on the front of the chest at the front and rear passenger positions.

NOTE The following methods may be used to define the chest position for the pressure transducers:

(a) a 50 percentile mannequin or test dummy, seated in a normal position with the back of the torso firmly against the back of the seat, the pressure transducer may be mounted flush on a flat plastic plate (dimensions shown) and strapped to the chest centre as indicated in Figure 6a); or

(b) a polystyrene cylinder as defined in Figure 6b), the pressure transducer may be imbedded flush with the cylinder surface and facing forward. The cylinder is placed on the seat vertically, pressed firmly against the back of the seat and secured with straps.

4.5.4 Witness sheet placement

The witness sheet (**4.4.8**) shall be positioned internally parallel to the test vehicle vertical reference plane (**3.6.1.6**), along the centre line of the test vehicle extending from front to rear and floor to roof.

4.6 Test procedure

NOTE Testing should conform with the test site local safety procedures at all times.

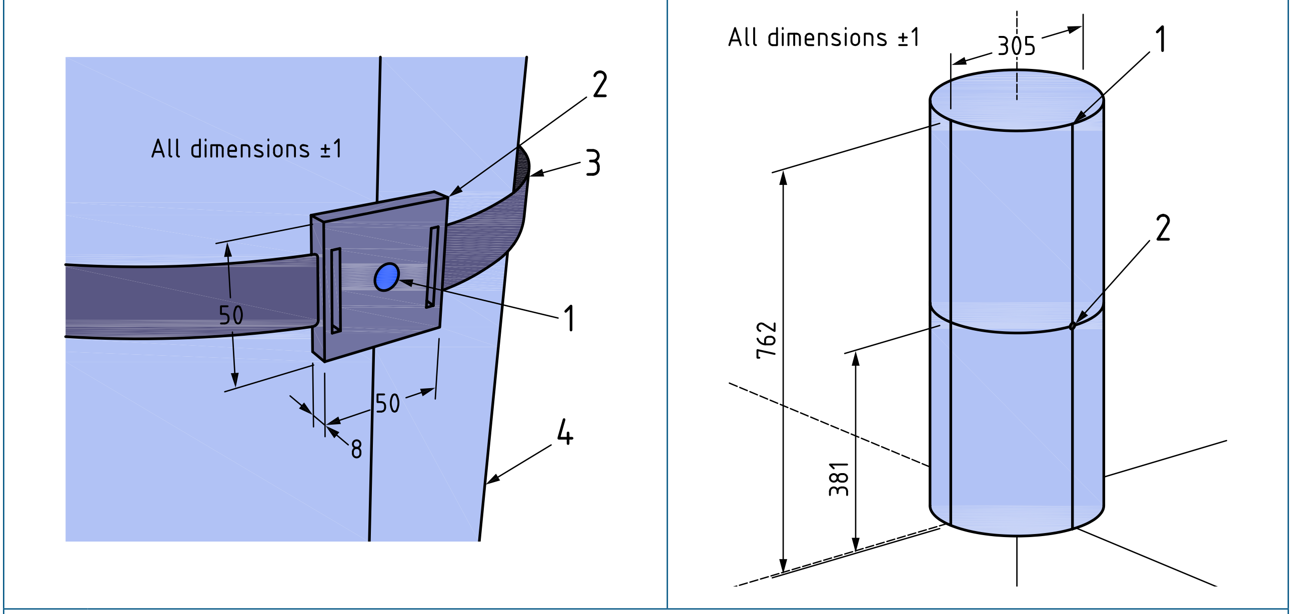
4.6.1 Using the temperature and humidity measuring equipment (**4.4.6**) measure the temperature and humidity and record results in the blast test log (see Annex F).

NOTE 1 There are no temperature or humidity constraints but both should be recorded in the blast test log.

NOTE 2 An example blast test log is given in Annex F.

Figure 6 – Pressure transducer placement in mm

a) b)



Key (a)

1 Pressure transducer
2 Transducer mounting plate
3 Fixing strap
4 Dummy chest

Key (b)

1 Polystyrene cylinder
2 Pressure transducer

4.6.2 Visually inspect the test vehicle for damage in accordance with **4.5.1.1** to **4.5.1.2**.

4.6.3 If the tyres are inflated, check pressure using the tyre pressure gauge (**4.4.7**) and adjust to the manufacturer's specified pressure. Record the state of the tyres and pressures in the blast test log (see Annex F).

4.6.4 Using the mass measuring equipment 2, (**4.4.4**) weigh the test vehicle in accordance with **4.5.1.4** and record results in the blast test log (see Annex F). Check the test vehicle height is in accordance with **4.5.1.5**.

4.6.5 Position the pressure transducers (**4.4.5**) in accordance with **4.5.3**.

4.6.6 Check the pressure transducers are ready for recording.

4.6.7 Position the witness sheet (**4.4.8**) in accordance with **4.5.4**.

4.6.8 Check the test vehicle is correctly configured in accordance with **4.5.1.3**.

NOTE Correct configuration of the test vehicle reduces the risk of invalidating the test. For example the test vehicle doors are correctly closed.

4.6.9 Using the mass measuring equipment 1 (**4.4.3**) verify that the explosive test device conforms to **4.2**.

4.6.10 Position the test device in accordance with **4.5.2**.

4.6.11 Check the pressure transducers are ready for trigger.

4.6.12 Fire the explosive test device.

4.6.13 Check the pressure data has correctly recorded and saved.

4.6.14 Examine the witness sheet for any full perforations and record results in the blast test log (see Annex F).

4.6.15 Process the external pressure data and record the peak incident static overpressure and positive impulse at each gauge position in the blast test log.

NOTE The external peak incident static overpressure and positive impulse values can help make an informed opinion that a complete detonation of the test device was achieved.

4.6.16 Process the test vehicle internal pressure data and determine the CWVP value for each pressure data set in accordance with Annex G. Select the highest of the CWVP values for the pass/fail assessment.

4.6.17 Assess the test results in accordance with **4.7**.

4.7 Expression of results

When the side blast test has been completed in accordance with **4.6**, classify the test vehicle as a pass or fail in accordance with the criteria given in Table 8. Where any aspect of the assessment is determined as a fail there is the option to submit a redesign for side blast testing.

NOTE The results only apply to the design submitted as the test vehicle. If at any stage changes are made to the design, then the results become void until the design changes are submitted for evaluation which could result in additional testing.

Table 8 – Side blast (SB) pass/fail criteria

	CWVP m/s	**Witness sheet damage**
Fail	>3.6	FP ≥1
Pass	≤3.6	FP =0

NOTE 1 The CWVP criteria is a means of assessing the likelihood of injuries caused by blast static overpressure generating complex reflected waves inside the test vehicle (see Annex G).

NOTE 2 Witness sheet damage criteria may be considered a measure of the acceptable risk from secondary fragments inside the test vehicle and any potential associated injury. The criteria is based on full perforation (FP) of the witness sheet.

4.8 Report

As a minimum requirement the party completing the testing shall submit a blast test log and summary of the pass/fail results. An example blast test log and results summary is given in Annex F.

NOTE In addition, supporting evidence may be included, for example test reports including photographs, armour material matrix showing armour material and location in test vehicle and other relevant test data.

If a pass is achieved a certificate shall be issued stating, as a minimum:

- certificate number;
- test vehicle number/identifier;
- date of test;
- test party details (organization);
- test level;
- test report number; and
- a statement that the test only applies to the CAV design tested.

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5 Under vehicle (UB) blast test method

5.1 Principle

The test method is designed to assess the performance of a CAV against threats from an under vehicle blast using a surrogate test device selected in accordance with Table 9. The test method includes three tests at different positions underneath or within a specified distance from the test vehicle. Witness sheets are used to determine level of damage and assessed against the pass/fail criteria.

5.2 Under vehicle (UB) blast test levels

5.2.1 The test level shall be selected in accordance with Table 9.

NOTE 1 *For example, a M67, HG85 or DTG5 is UB-B. Two DM51s taped together is UB-A.*

NOTE 2 *The DM51, M67 and HG85 grenade casings are all military specification grenades and for the purposes of testing are filled with C4 or equivalent.*

NOTE 3 *DM31 surrogate testing is not included in the scope of this PAS. For testing DM31 surrogate see* AEP–55 Vol. 2 (edition 2) *[4].*

5.2.2 The DTG5 surrogate grenade, if used, shall be constructed in accordance with Annex H.

5.3 Test vehicle

A complete vehicle shall be used to complete the under vehicle blast test procedure.

NOTE 1 *The test vehicle used for ballistic testing or side blast may be used for the under vehicle blast test.*

NOTE 2 *A complete vehicle or test specimens (**2.1.21.2**) may be used for retesting.*

5.4 Apparatus

5.4.1 *Ground plate*, made from mild steel, square and with a size of at least 500 mm × 500 mm × 15 mm ±5 mm

5.4.2 *Mass measuring equipment 1*, that is calibrated and capable of measuring to an accuracy of at least (±1.0 × 10^{-3}) kg

NOTE *Equipment used for measuring the mass of explosive materials and the test device.*

5.4.3 *Mass measuring equipment 2*, that is calibrated and capable of measuring to an accuracy of at least ±5.0 kg

NOTE *Equipment used for measuring the mass of the test vehicle.*

Table 9 – Under vehicle (UB) blast test levels

Test level	Surrogate	Explosive mass g	Notes
UB-A	2 x DM51 with fragmentation case	120 (combined)	Filled with C4
UB-B	1 x M67 or	185	Filled with C4
	1 x RUAG HG85; or	155	Filled with C4
	1 x DTG5	200	Filled with C4. Fragments are 5.0 mm AISI 420, (55 ±3) HRC Rockwell, grade 100, stainless steel balls

NOTE 1 *For in service grenades, the central detonator cavity should be filled with C4 or equivalent explosive to aid the detonation process.*

NOTE 2 *The test device may be detonated with a suitable detonator that fits into the central cavity.*

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5.4.4 *Temperature and humidity measuring equipment*, capable of measuring temperature with an accuracy of at least ±0.5 °C and ±1% humidity respectively

5.4.5 *Witness sheet*, consisting of an aluminium alloy sheet 2024 T3 or T4, AlCuMg ISO/R209 having a thickness of (0.5 ±0.05) mm and tensile strength of (440 ±40) N/mm

***NOTE** Alternative materials may be used (e.g. polycarbonate) provided it can be demonstrated they have similar characteristics to the material stated above. For example, the impact velocity required to perforate (0.5 ±0.05) mm 2024 T4 Al using a 4.4 mm 0.36 g spherical steel pellet, with at least 0.99 probability, is (175 ±25) m/s.*

5.5 Test set up

5.5.1 Preparation of test vehicle

5.5.1.1 The test vehicle (**5.3**) shall be visually inspected without magnification, to determine if there are defects or other damage.

5.5.1.2 Where the test vehicle was used for ballistic or side blast testing, particular attention shall be paid to the ballistic or blast damaged areas to ensure no defects or damage affect the test procedure or results. If any defects or damage are present, that might affect the test procedure or results, these shall be rectified prior to testing.

***NOTE** Examples of defects or damage may include dents or cracks in the armour, cracked glass, or incorrect door aperture closure.*

5.5.1.3 The test vehicle doors shall be closed and either locked or unlocked.

***NOTE 1** Each CAV may have standard operating procedures that dictate whether the doors should be locked or unlocked during testing.*

***NOTE 2** If the doors are unable to close correctly they may be held closed using a suitable method, for example ratchet straps.*

5.5.1.4 The test vehicle shall be loaded to its maximum allowable mass without exceeding GVM or individual plated axle mass ±5.0 kg.

***NOTE** Ballast (sand bags) may be placed in the test vehicle to achieve the correct mass distribution.*

5.5.1.5 The height between the test arena surface and the test vehicle door sill (see zone 3 in Figure 2 or Figure 3) shall be measured and corrected accordingly to achieve the manufacturer's specified height when the test vehicle is loaded in accordance with **5.5.1.4**.

***NOTE** For example, if the tyres were damaged and deflated in previous tests the height of the test vehicle may be adjusted using timber spacers under the wheels.*

5.5.2 Test device placement

5.5.2.1 The test devices shall be oriented towards the test vehicle surface to maximize fragment impacts and positioned in accordance with Table 10 and to test under the most severe conditions.

Table 10 – Under vehicle (UB) blast test device placement

Test	Position
1	Place the test device on the centre of the ground plate under a front or rear foot well of the test vehicle.
2	Place the test device on the centre of the ground plate, not less than 500 mm from test 1, anywhere under the test vehicle not already tested.
3	Place the test device on the centre of the ground plate, not less than 500 mm from test 1 or 2, at any position extending outwards to a maximum distance of (500 ±5) mm from any side of the test vehicle.

5.5.2.2 All three tests shall be conducted on flat and horizontal hard standing that does not absorb the blast pressure or generate a crater. The test device shall be placed centrally on a ground plate (**5.4.1**).

5.5.3 Witness sheet placement

5.5.3.1 For tests 1 and 2 (see Table 10) the witness sheet (**5.4.5**) shall be placed internally ≤150 mm behind and parallel to the back face surface of the test vehicle directly above the detonation point.

5.5.3.2 For test 3 (see Table 10) the witness sheet shall be placed internally ≤150 mm behind and parallel to the back face surface of the test vehicle closest to the detonation point.

5.5.3.3 For all tests, and where possible, the witness sheet coverage shall extend a minimum (500 ±10) mm measured radially on the internal surface of the test vehicle closest to the detonation point.

***NOTE** If there is any doubt on the extent of coverage for the witness sheet then the complete surface behind the test position should be covered.*

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5.6 Test procedure

NOTE Testing should conform with the test site local safety procedures at all times.

5.6.1 Using the temperature and humidity measuring equipment (**5.4.4**) measure the temperature and humidity and record results in the blast test log (see Annex F).

NOTE There are no temperature or humidity constraints but both should be recorded in the blast test log.

5.6.2 Visually inspect the test vehicle for damage in accordance with **5.5.1.1** to **5.5.1.2.**

5.6.3 Using the mass measuring equipment 2 (**5.4.3**), weigh the test vehicle in accordance with **5.5.1.4** and record in the blast test log (see Annex F). Check the test vehicle height in accordance with **5.5.1.5**.

5.6.4 Position the witness sheet (**5.4.5**) in accordance with **5.5.3**.

5.6.5 Check the test vehicle is correctly configured in accordance with **5.5.1.3**.

NOTE A correctly configured test vehicle reduces the risk of invalidating the test. For example the test vehicle doors are correctly closed.

5.6.6 Using the mass measuring equipment 1 (**5.4.2**), verify that the explosive test device conforms to **5.2**.

5.6.7 Position the test device in accordance with Table 10.

5.6.8 Fire the explosive test device.

5.6.9 Examine the witness sheets for any full perforations and assess the results in accordance with **5.7**. Record results in the blast test log (see Annex F).

5.6.10 Remove the witness sheet(s) and replace with new witness sheet(s) if necessary.

5.6.11 Repeat **5.6.4** to **5.6.10** for test 2.

5.6.12 Repeat **5.6.4** to **5.6.10** for test 3.

5.7 Expression of results

When the three under vehicle blast tests have been completed in accordance with **5.6**, classify the test vehicle as a pass or fail in accordance with the criteria given in Table 11. Where any aspect of the assessment is determined as a fail there is the option to submit a redesign for under vehicle blast testing.

NOTE The results only apply to the design submitted as the test vehicle. If at any stage changes are made to the design, then the results become void until the design changes are submitted for evaluation which could result in additional testing.

Table 11 – Under vehicle (UB) blast pass/fail criteria

	Witness sheet damage (results from tests 1, 2 and 3 inclusive)
Fail	FP ≥1
Pass	FP =0
NOTE Witness sheet damage criteria maybe considered a measure of the acceptable risk from primary and secondary fragments inside the test vehicle and any potential associated injury. The criteria is based on full perforation (FP) of the witness sheet	

5.8 Report

As a minimum requirement the party completing the testing shall submit a blast test log and summary of the pass/fail criteria results. An example blast test log and results summary is given in Annex F.

NOTE In addition, supporting evidence may be included, for example test reports including photographs, armour material matrix showing armour material and location in test vehicle and other relevant test data.

If a pass is achieved a certificate shall be issued stating, as a minimum:

- certificate number;
- test vehicle number/identifier;
- date of test;
- test party details (organization);
- test level;
- test report number; and
- a statement that the test only applies to the CAV design tested.

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6 Roof blast (RB) test method

6.1 Principle

The test method is designed to assess the test level of a CAV against threats from a roof blast using a surrogate test device selected in accordance with Table 12. The method includes two tests at different positions on the roof. Witness sheets are used to determine level of damage and assessed against the pass/fail criteria.

6.2 Roof blast (RB) test levels

6.2.1 The test level shall be selected in accordance with Table 12.

NOTE 1 *For example, a M67, HG85 or DTG5 is RB-B. Two DM51s taped together is RB-A.*

NOTE 2 *The DM51, M67 and HG85 grenade casings are all military specification grenades and for the purposes of testing are filled with C4 or equivalent.*

6.2.2 The DTG5 surrogate grenade, if used, shall be constructed in accordance with Annex H.

6.3 Test vehicle

A complete vehicle shall be used to complete the roof blast test procedure.

NOTE 1 *The test vehicle used for ballistic testing, side blast or under vehicle testing may be used for the roof blast test.*

NOTE 2 *A complete vehicle or test specimens (**2.1.21.2**) may be used for retesting.*

6.4 Apparatus

6.4.1 *Mass measuring equipment*, that is calibrated and capable of measuring to an accuracy of at least ($\pm 1.0 \times 10^{-3}$) kg

NOTE *Measuring equipment for measuring the mass of explosive materials and the test device.*

6.4.2 *Temperature and humidity measuring equipment,* capable of measuring temperature with an accuracy of at least ±0.5 °C and ±1% humidity respectively

Table12 – Roof blast (RB) test levels

Test level	Surrogate	Explosive mass g	Notes
RB-A	2 × DM51with fragment casing	120 combined	Filled with C4
RB-B	1 × M67; or	185	Filled with C4
	1 × RUAG HG85; or	155	Filled with C4
	1 × DTG5	200	Filled with C4. Fragments are 5.0 mm AISI 420, (55 ±3) HRC Rockwell, grade 100, stainless steel balls.

NOTE 1 *For in service grenades, the central detonator cavity may be filled with C4 or equivalent explosive to aid the detonation process.*

NOTE 2 *The test device may be detonated with a suitable detonator that fits into the central cavity.*

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6.4.3 *Witness sheet*, consisting of an aluminium alloy sheet 2024 T3 or T4, AlCuMg ISO/R209 having a thickness of (0.5 ±0.05) mm and tensile strength of (440 ±40) N/mm

NOTE *Alternative materials may be used (e.g. polycarbonate) provided it can be demonstrated they have similar characteristics to the material stated above. For example, the impact velocity required to perforate (0.5 ±0.05) mm 2024 T4 Al using a 4.4 mm 0.36 g spherical steel pellet, with at least 0.99 probability, is (175 ± 25) m/s.*

6.5 Test set up

6.5.1 Preparation of test vehicle

6.5.1.1 The test vehicle (**6.3**) shall be visually inspected without magnification, to determine if there are defects or other damage.

6.5.1.2 Where the test vehicle was used for ballistic, side blast or under vehicle testing, particular attention shall be paid to the ballistic or blast damaged areas to ensure no defects or damage affect the test procedure or results. If any defects or damage are present, that would affect the test procedure or results, these shall be rectified prior to testing.

NOTE *Examples of defects or damage may include dents or cracks in the armour, cracked glass, or incorrect door aperture closure.*

6.5.1.3 The test vehicle doors shall be closed and either locked or unlocked.

NOTE 1 *Each CAV may have standard operating procedures that dictate whether the doors should be locked or unlocked during testing.*

NOTE 2 *If the doors are unable to close correctly they may be held closed using a suitable method, for example ratchet straps.*

6.5.2 Test device placement

6.5.2.1 The test device should be orientated towards the test vehicle surface to maximize fragment impacts and positioned in accordance with Table 13 and to test under the most severe conditions.

Table 13 – Roof blast (RB) test device placement

Test	Position
1	Place the test device on the roof of the test vehicle over the head position of a seated passenger.
2	Place the test device anywhere on the roof of the test vehicle but not less than 500 mm from the position in test 1.

6.5.3 Witness sheet placement

For each test the witness sheet (**6.4.3**) shall be placed internally ≤150 mm behind and parallel to the back face surface of the test vehicle directly below the detonation point.

For all tests and where possible the witness sheet coverage shall extend a minimum (500 ±10) mm measured radially on the internal surface of the test vehicle closest to the detonation point.

NOTE *If there is any doubt on the extent of coverage for the witness sheet then the complete surface behind the test position should be covered.*

6.6 Test procedure

NOTE *Testing should conform with the test site local safety procedures at all times.*

6.6.1 Using the temperature and humidity measuring equipment (**6.4.2**) measure the temperature and humidity and record results in the blast test log (see Annex F).

NOTE *There are no temperature or humidity constraints but both should be recorded in the blast test log.*

6.6.2 Visually inspect the test vehicle for damage in accordance with **6.5.1.1** and **6.5.1.2**.

6.6.3 Position the witness sheet (**6.4.3**) in accordance with **6.5.3**.

6.6.4 Check the test vehicle is correctly configured in accordance with **6.5.1.3**.

NOTE *A correctly configured test vehicle reduces the risk of invalidating the test. For example, the test vehicle doors are correctly closed.*

6.6.5 Using the mass measuring equipment (**6.4.1**), verify that the explosive test device conforms to **6.2**.

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6.6.6 Position the test device in accordance with Table 13.

6.6.7 Fire the explosive test device.

6.6.8 Examine the witness sheets for any full perforations and assess the results in accordance with **6.7**. Record results in the blast test log (see Annex F).

6.6.9 Remove the witness sheet(s) and replace with new witness sheet(s), if necessary.

6.6.10 Repeat steps **6.6.3** to **6.6.9** for test 2.

6.7 Expression of results

When the two roof blast tests have been completed in accordance with **6.6**, classify the test vehicle as a pass or fail in accordance with the criteria given in Table 14. Where any aspect of the assessment is classed as a fail there is the option to submit a redesign for roof blast testing.

***NOTE** The results only apply to the design submitted as the test vehicle. If at any stage changes are made to the design, then the results become void until the design changes are submitted for evaluation which could result in additional testing.*

Table 14 – Roof blast (RB) pass/fail criteria

	Witness sheet damage (results from tests 1 and 2 inclusive)
Fail	FP ≥1
Pass	FP =0
***NOTE** Witness sheet damage criteria maybe considered a measure of the acceptable risk from primary and secondary fragments inside the test vehicle and any potential associated injury. The criteria is based on full perforation (FP) of the witness sheet.*	

6.8 Report

As a minimum requirement the party completing the testing shall submit a blast test log and summary of the pass/fail results. An example blast test log and results summary is given in Annex F.

***NOTE** In addition, supporting evidence may be included, for example test reports including photographs, armour material matrix showing armour material and location in test vehicle and other relevant test data.*

If a pass is achieved a certificate shall be issued stating, as a minimum:

- certificate number;
- test vehicle number/identifier;
- date of test;
- test party details (organization);
- test level;
- test report number; and
- a statement that the test only applies to the CAV design tested.

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Annex A (informative) Common ballistic standards

A.1 Table A.1 outlines ballistic test levels in European and international standards.

Table A.1 – Common ballistic test levels

Bullet specification	PAS 300	BS EN 1522/ 1523	BS EN 1063	BRV 1999 VPAM [5]	BRV 2009 VPAM [6]	VSAG 12 [1]	NIJ [7]	STANAG 4569 [8]
0.22 LR		FB1 (360)	BR1 (360)	VR1 (360)	VR1 (360)	VS1 (360)		
9 mm					VR2 (360)		IIA (373)	
9 mm	BA-A (400)	FB2 (400)	BR2 (400)	VR2 (400)	VR3 (415)	VS2 (400)		
0.357″ magnum	BA-B (430)	FB3 (430)	BR3 (430)	VR3 (430)	VR4 (430)	VS3 (430)	II (436)	
0.44″ magnum	BA-C (440)	FB4 (440)	BR4 (440)	VR4 (440)	VR4 (440)	VS4 (440)	IIIA (436)	
0.357″ magnum					VR5 (580)			
7.62×39 mm PS Ball	BA-F (720)				VR6 (720)	VS4+ (720)		
5.56×45 mm NATO Ball	BA-G (950)	FB5 (950)	BR5 (950)	VR5 (950)	VR7 (920)	VS6 (950)		L1 (900)
7.62×51 mm NATO Ball	BA-H (830)	FB6 (830)	BR6 (830)	VR6 (830)	VR7 (830)	VS6 (830)	III (847)	L1 (833)
5.56×45 mm M193	BA-J (990)					VS6+ (965)		L1 (937)
7.62×39 mm API BZ	BA-L (740)				VR8 (740)	VS7 (740)		L2 (695)
7.62×51 mm AP	BA-M (820)	FB7 (820)	BR7 (820)	VR7 (820)	VR9 (820)	VS7 (820)		
7.62×54 mm R B32 API	BA-N (860)				VR10 (860)			L3 (854)
7.62×63 mm AP M2							IV (878)	
7.62×51 mm AP (WC)					VR11 (930)			L3 (930)
0.308″ Win Swiss P AP	BA-P (810)				VR12 (810)			
0.5″ Swiss P Pen					VR13 (930)			
14.5×114 mm API B32					VR14 (911)			L4 (911)

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Annex B (informative)
Ballistic shot plan – test log

B.1 General

An example ballistic shot plan-test log and final scoring is set out in Table B.1 and Table B.2.

Table B.1 – Ballistic shot plan – test log

Test ID:			**Project/Vehicle ID:**					**Test level:**		
Date:			**Temperature:**		**Humidity:**			**Assessor name:**		
Shot no	**Shot zone**	**Ar. Mat. Index** A)	**Bullet or FSP type**	**Specified horizontal attack angle** degree (°)	**Specified vertical attack angle** degree (°)	**Specified measured velocity** m/s	**Actual measured velocity** m/s	**Result** B) NP PP FP	**Shot validity** V (valid) NV (not valid)	**Notes Index** C)

A) *List of armour materials and nominal thickness with index number.*

B) *Ballistic damage scoring:*

No Perforation (NP) – no damage or hole on the witness sheet.
Partial Perforation (PP) –damage present on the witness sheet, caused by the test projectile fired at the test vehicle, a fragment of the test projectile or test vehicle debris.
Full Perforation (FP)–hole, of any size, that light is able to pass through in the witness sheet, caused by the test projectile fired at the test vehicle, a fragment of the test projectile or test vehicle debris.

C) *Notes index to include any observation or notes from the test.*

NOTE *Witness sheet damage includes any scratch, dent or deformation that can be visually seen or felt. Slight dusting on the witness sheet is not considered damage.*

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Table B.2 – Ballistic test pass/fail criteria

	Armour shell (witness sheet damage)		Door latch and lock	
	Full perforation (FP)	**Partial perforation (PP)**	**Complete involuntary unlatching** (criteria used when doors are locked or unlocked based on 5 shots)	**Lock failure** (criteria used when doors are locked based on 5 shots)
Fail	FP ≥1	PP >8	Shots 1 to 5 Complete involuntary unlatching	Shots 1 to 5 Lock disengages
Pass	FP =0	PP ≤8	Shots 1 to 5 No complete involuntary unlatching	Shots 1 to 5 Lock remains engaged
Actual value				
Result				

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Annex C (normative)
Side blast (SB) surrogate test device specification

C.1 General

A surrogate test device shall be used to conduct the side blast test in accordance with Clause **4**.

***NOTE** See Figure C.1 for a schematic of the surrogate test device.*

C.2 Test device assembly

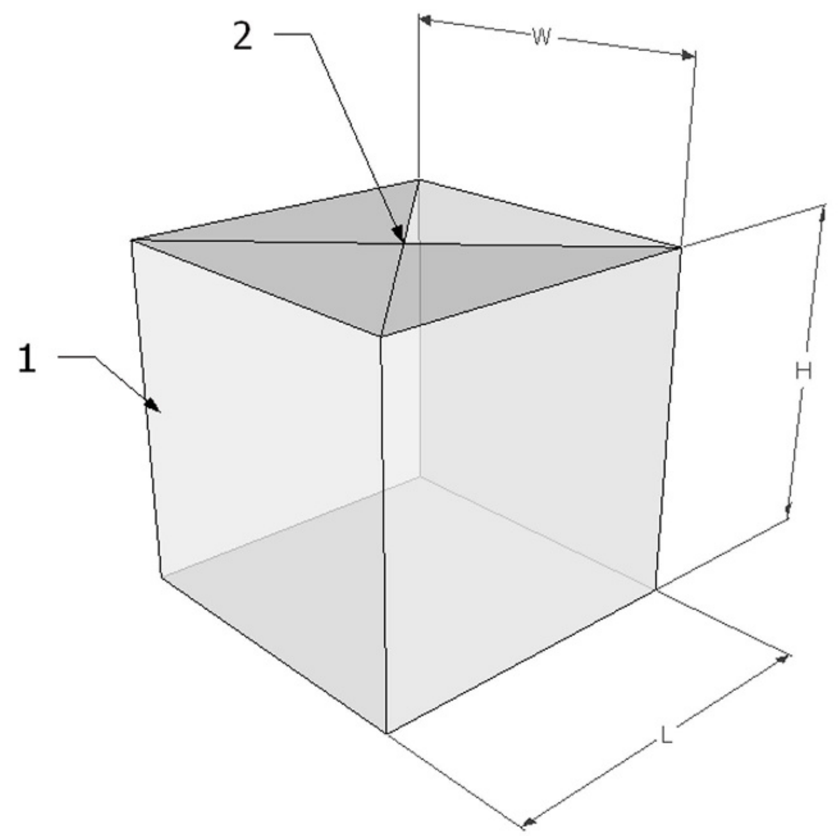
The test device shall consist of 12 kg of C4 formed into a cube and contained in a light weight frangible nonmetal container approximately 205 mm × 205 mm × 205 mm.

The explosive shall be packed as uniformly as possible.

The container shall not generate undesirable fragments or significantly change, by ±5% the blast forces generated from an equivalent bare charge.

The detonator shall be inserted from the top placing the tip of the detonator into the volumetric centre of the device.

Figure C.1 – Side blast (SB) test device specification



Key

1	Cube, explosive charge contained in frangible wrapping (L=W=H)
2	Detonator inserted from the top placing the tip of the detonator into the volumetric centre of the test device

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Annex D (normative) Explosive equivalency

D.1 General

Where an alternative explosive material is used for conducting the side blast test, the party testing shall use the following method to demonstrate that the explosive charge delivers a overall peak incident static overpressure and positive phase impulse in accordance with **D.3**.

NOTE *Peak incident static overpressure and positive phase impulse are key parameters when assessing the dynamic response of a CAV.*

D.2 Method

D.2.1 Apparatus

D.2.1.1 *Data acquisition system (DAS)*, capable of recording pressure data in accordance with (**4.4.1**)

D.2.1.2 *Ground plate*, made from mild steel, square and with a size of at least 1 000 mm × 1 000 mm × 25 mm ±5 mm

D.2.1.3 *Mass measuring equipment*, that is calibrated and capable of measuring to an accuracy of at least (±1 × 10^{-3}) kg

NOTE *Equipment used for measuring the mass of explosive materials and the test device.*

D.2.1.4 *Pressure transducers*, capable of recording pressure data in accordance with (**4.4.5**)

D.2.1.5 *Temperature and humidity measuring equipment*, capable of measuring temperature to an accuracy of at least ±0.5 °C and ±1% humidity respectively

D.2.2 Test setup

D.2.2.1 Explosive test device placement

The test device shall be set at a height of (1.2 ±0.02) m measured from the test arena surface and charge centre.

The test shall be conducted on flat and horizontal hard standing that does not absorb the blast pressure or generate a crater and be free of obstructions out to a radius of (12.0 ±0.1) m.

The test device shall be supported at the required height using a lightweight non-metal frangible material that does not significantly influence the blast static overpressures or generate undesirable primary fragments (**2.1.7.1**).

NOTE 1 *The test device is constructed as near as possible to the specification described in Annex C.*

NOTE 2 *A hollow cardboard cylinder or box may be used to support the charge at the required height.*

NOTE 3 *If necessary a ground plate (**D.2.1.2**) may be placed on the ground under the test device to reduce cratering.*

D.2.2.2 Pressure transducer placement

Two pressure transducers shall be positioned in accordance with the side blast testing (see Figure 5, key 5 and 6). Each transducer centre shall be placed at the same height as the test device centre, one transducer opposite each test device vertical surface. The distance between each transducer centre and the test device surface shall be (8.0 ±0.02) m.

NOTE *The 8.0 m stand-off was chosen to avoid unpredictable data generated by the fireball.*

D.2.3 Procedure

D.2.3.1 Using the temperature and humidity measuring equipment (**D.2.1.5**) measure the temperature and humidity and record results.

NOTE *There are no temperature or humidity constraints but both should be recorded.*

D.2.3.2 Position the pressure transducers (**D.2.1.4**) in accordance with **D.2.2.2** and check the DAS recording apparatus (**D.2.1.1**) is ready to record.

D.2.3.3 Position the explosive test device in accordance with **D.2.2.1**.

D.2.3.4 Check the pressure transducers are ready for trigger.

D.2.3.5 Fire the explosive test device.

D.2.3.6 Check the pressure data is correctly recorded and saved.

D.2.3.7 Repeat **D.2.3.1** to **D.2.3.6** at least four times.

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D.2.3.8 Determine the average peak incident static overpressure and positive phase impulse from the four tests. The average values shall be based on at least six sets of data.

D.2.3.9 Check the values determined in step **D.2.3.8** are in accordance **D.3**.

D.2.3.10 If the values are within the limits specified in **D.3** the explosive charge is used for testing, otherwise adjust the explosive charge and repeat steps **D.2.3.1** to **D.2.3.9**.

D.3 Expression of results

Where alternative explosives are used for testing then the party testing shall demonstrate, using the method in **D.2**, that the equivalent explosive charge with the same 8.0 m stand-off generates mean peak incident static overpressure and mean positive impulse values within the limits specified for C4 (see Table D.1).

Table D.1 – 12 kg C4 at 8.0 m stand-off, peak incident static overpressure and positive impulse

Sample	Peak incident static overpressure at 8.0 m kPa	Positive impulse at 8.0 m kPa.ms
1. 200314-1-ch1	101	163
2. 200314-3-ch1	104	163
3. 270614-1-ch1	82	145
4. 270614-1-ch2	101	138
5. 270614-2-ch1	93	139
6. 270614-2-ch2	80	159
7. 270614-3-ch1	96	151
8. 270614-3-ch2	87	144
Sample mean	**93 ±5**	**150 ±5**
Sample standard deviation	**≤15**	**≤15**

*NOTE 1 The values are based on a series of eight benchmark pressure time histories. The pressure data was recorded in accordance with the method described in **D.2**.*
NOTE 2 Figure D.1 and Figure D.2 show the recorded incident static overpressure traces and positive impulse respectively.
NOTE 3 The pressure time histories were derived from C4 characterization trials, conducted by VSAG, 2014.

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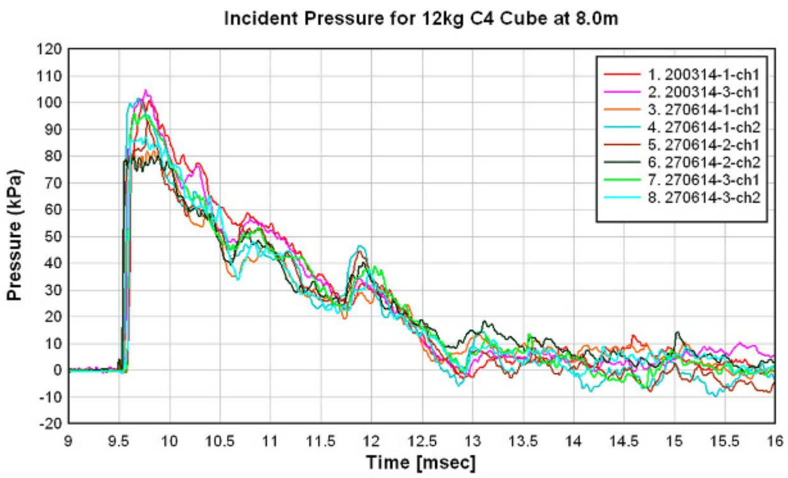
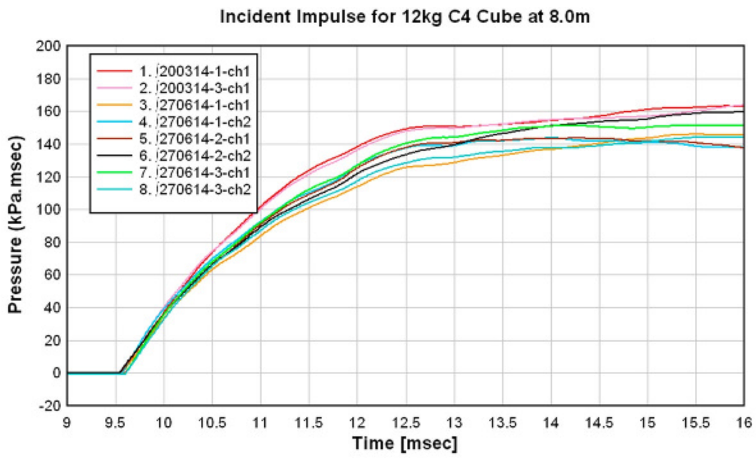
Figure D.1 – Example incident static overpressure time histories, 12 kg C4 (cube) at 8.0 m



Sample			
1.	200314-1-ch1	5.	270614-2-ch1
2.	200314-3-ch1	6.	270614-2-ch2
3.	270614-1-ch1	7.	270614-3-ch1
4.	270614-1-ch2	8.	270614-3-ch2

Figure D.2 – Example positive impulse time histories, 12 kg C4 (cube) at 8.0 m



Sample			
1.	200314-1-ch1	5.	270614-2-ch1
2.	200314-3-ch1	6.	270614-2-ch2
3.	270614-1-ch1	7.	270614-3-ch1
4.	270614-1-ch2	8.	270614-3-ch2

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Annex E (informative) Pressure data filters

E.1 General

Lower sample frequencies may be used provided the sample rate is capturing the required real data present in the signal. Analogue anti-aliasing filters (prior to analogue to digital conversion) are used to filter out unnecessary higher frequencies and so allow a lower sample frequency to be used without introducing the risk of aliasing errors in the data signal.

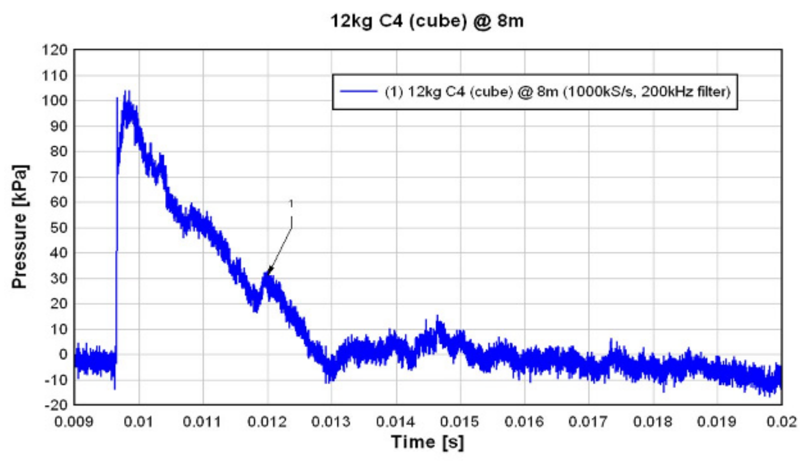
E.2 Method

The analogue anti-aliasing filter is usually built into the DAS hardware prior to digitizing the analogue signal and the user should familiarize themselves with the particular DAS being used and how the filters are setup. Further information on aliasing theory can be found from the Harris' Shock and vibration handbook [9].

The Nyquist–Shannon criterion to reduce the risk of anti-aliasing errors states, "Exact reconstruction of a continuous – time base signal from its samples is possible if the signal is band limited (i.e. bandwidth) and the sampling frequency is greater than twice the signal bandwidth" [9].

Figure E.1 shows a single pressure time history recorded from a 12 kg C4 cube charge at 8.0 m. The data was captured with a sample frequency of 1 000 kS/s (kilo samples/second) and band limited 200 kHz low pass filter. The 8.0 m stand-off was chosen to avoid unpredictable data generated by the fire ball.

Figure E.1 – Pressure time history, 12 kg C4 (cube) at 8.0 m



Key

1 12 kg C4 at 8.0 m incident static overpressure time history

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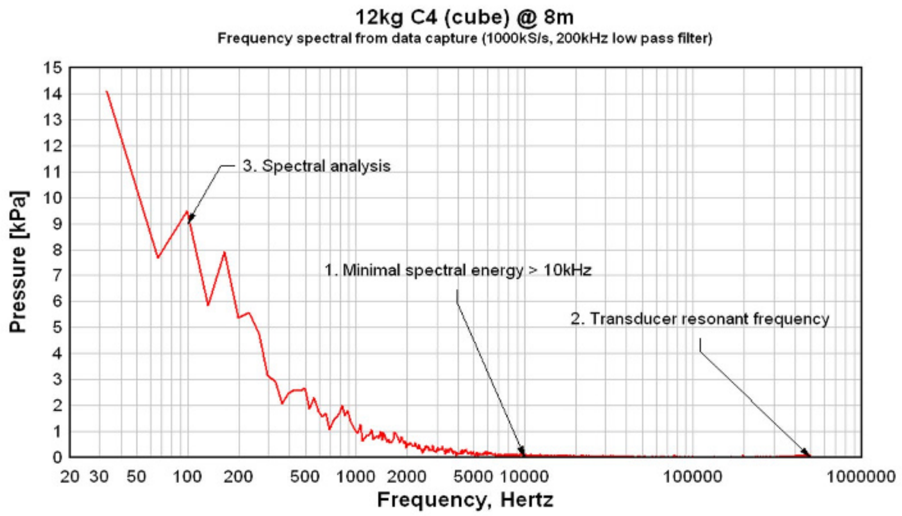
Figure E.2 – Spectral analysis, 12 kg C4 (cube) at 8.0 m



Key

1	Minimal spectral energy >10 kHz
2	Transducer resonant frequency
3	Spectral analysis for 12 kg C4 at 8.0 m incident static overpressure time history

Figure E.2 shows the same pressure data plotted in the frequency domain (the frequency domain is plotted on a log scale for clarity). Key frequencies can be identified and it is clear the majority of the frequency spectral energy is below 10 kHz indicating higher frequencies make minimal contribution. The 500 kHz anomaly is the natural frequency threshold for the pressure transducer and may be ignored.

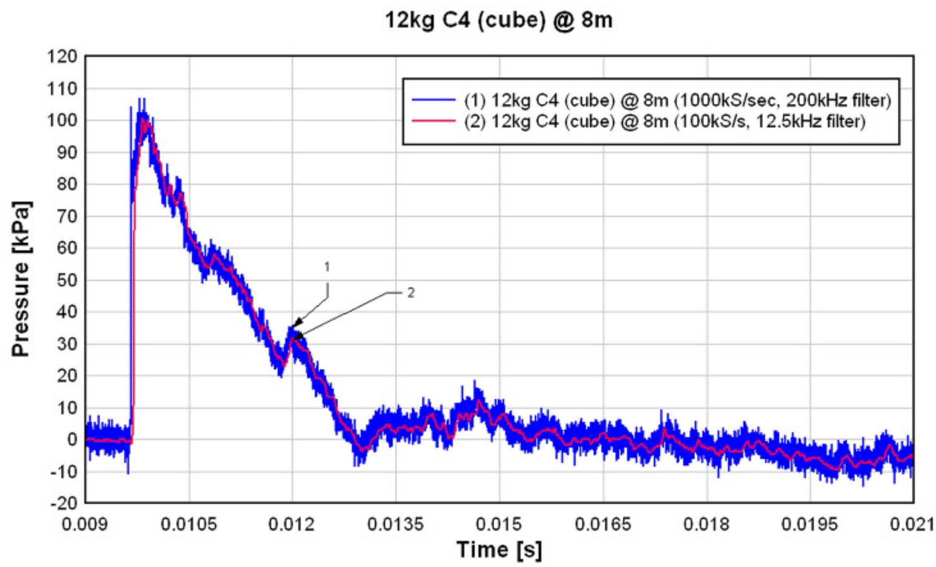
Based on the above findings and compliance with the Nyquist–Shannon criterion it is reasonable to specify the minimum DAS capture requirements as:

- minimum sample frequency ≥100 kS/s; and
- minimum band limited (i.e. bandwidth) low pass filter ≥10 kHz.

***NOTE** For example, Figure E.3 shows the same pressure history shown in Figure E.1, but recorded with 100 kS/s and a 12.5 kHz low pass filter. The small time delay is due to the filtering process. These values are based on external incident static overpressures.*

Internal CAV pressures may have a degree of filtering induced by the pressure waves passing through the test vehicle into the occupant space so the sample frequency and filter values specified for external pressure recording are considered acceptable for recording internal pressure data.

Figure E.3 – Pressure time history recorded from same incident static overpressure transducer with different sample rates and low pass filters



Key

1	12 kg C4 at 8.0 m (1 000 kS/sec, 200 kHz filter)
2	12 kg C4 at 8.0 m (100 kS/sec, 12.5 kHz filter)

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Annex F (informative)
Blast test log

F.1 General

An example blast test log and scoring is shown in Tables F.1 to F.5.

Table F.1 – Blast test log

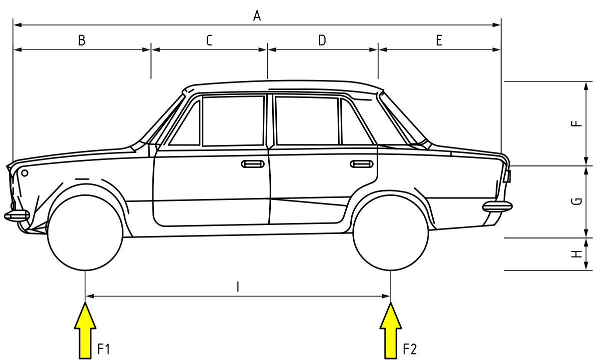
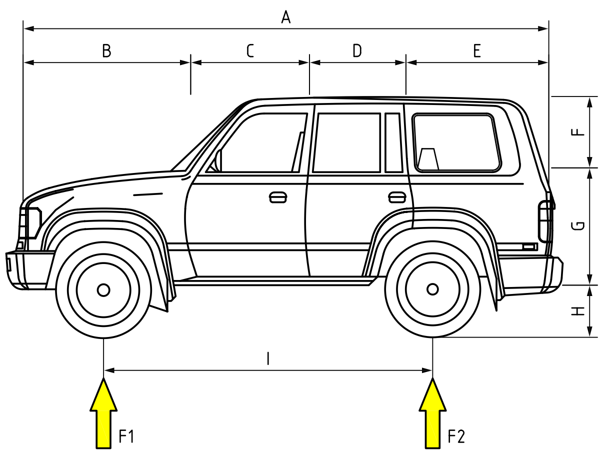
<table>
<tr><td colspan="3">Test ID:</td><td colspan="6">Project/Vehicle ID:</td><td colspan="2">Test level:</td></tr>
<tr><td colspan="3">Date:</td><td colspan="3">Temperature:</td><td colspan="3">Humidity:</td><td colspan="2">Assessor name:</td></tr>
<tr><td colspan="11">Internal pressure, CWVP values (Side blast only, maximum value recorded is used to determine pass/fail)</td></tr>
<tr><td colspan="3">CVWP position 1</td><td colspan="3">CVWP position 2</td><td colspan="3">CVWP position 3</td><td colspan="2">CVWP position 4</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td colspan="11">External peak pressure and positive impulse at 8.0m (Side blast only)</td></tr>
<tr><td colspan="3">P1: kPa</td><td colspan="3">I1: kPa.ms</td><td colspan="3">P2: kPa</td><td colspan="2">I2: kPa.ms</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td colspan="11">Number of recorded witness sheet damage points</td></tr>
<tr><td colspan="6">FP</td><td colspan="5">Notes:</td></tr>
<tr><td colspan="9">CAV dimensions (optional)
mm</td><td colspan="2">CAV plated axle mass
kg</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td>G</td><td>H</td><td>I</td><td>F1</td><td>F2</td></tr>
<tr><td colspan="5"></td><td colspan="6"></td></tr>
<tr><td colspan="5"></td><td colspan="6"></td></tr>
<tr><td colspan="11">Notes</td></tr>
</table>

Table F.2 – CAV internal blast pressure (CWVP) pass/fail criteria

	CWVP m/s
Fail	>3.6
Pass	≤3.6
Actual value	
Result	

Table F.3 – Side blast (SB) fragment hazard pass/fail criteria

	Witness sheet damage
Fail	FP ≥1
Pass	FP =0
Actual value	
Result	

Table F.4 – Under vehicle blast (UB) fragment hazard pass/fail criteria

	Witness sheet damage (results from tests 1, 2 and 3 inclusive)
Fail	FP ≥1
Pass	FP =0
Actual value	
Result	

Table F.5 – Roof blast (RB) fragment hazard pass/fail criteria

	Witness sheet damage (results from tests 1 and 2 inclusive)
Fail	FP ≥1
Pass	FP =0
Actual value	
Result	

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Annex G (normative)
Chest wall velocity predictor

G.1 General

G.1.1 The pass/fail injury criterion for blast static overpressure inside a test vehicle shall be based on methods described in *Test methodology for protection of vehicle, occupants against anti-vehicular, landmine effects* [10] and *Procedures for evaluating the protection level of armoured vehicles, mine threat, Volume 2 AEP–55* [4].

G.1.2 The pressure injury assessment shall only focus on internal organ injuries.

***NOTE 1** Although the ears are the most vulnerable body part to blast overpressure, ear injuries have an abbreviated injury score (AIS) of only 1 (defined as minor), even when they result in permanent hearing loss.*

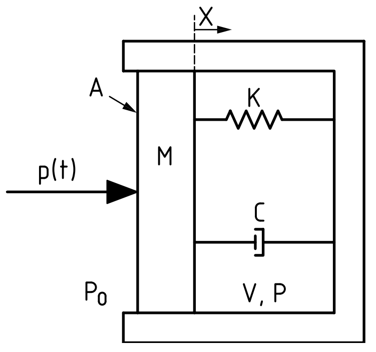
***NOTE 2** Static overpressure caused by blast waves may generate life-threatening injuries to non-auditory internal organs/systems (e.g. lung or bowel) and non-life-threatening auditory injuries (e.g. ear).*

G.2 Method

G.2.1 A summary of the available models for internal organ injury assessment are shown in Table G.1. It shall be assumed that a complex waveform is present inside the test vehicle and an assessment for all internal organs is required.

***NOTE** On this basis the Axelsson and Yelverton model [11] is considered the most appropriate. The parameters used in this model are for a 70 kg body. The model is a single degree of freedom system in which the chest wall response (displacement, velocity and acceleration) and intra-thoracic (lung) pressure may be calculated for different complex blast waves and ideal blast waves (see Figure G.1).*

Figure G.1 – Axelsson, Yelverton model (70 kg body)



Key		Value
A	Effective area (m^2)	0.082
M	Effective mass (kg)	2.03
V	Initial gaseous volume of the lungs (m^3)	0.00182
C	Damper coefficient (N.s/m)	696
K	Spring constant (N/m)	989
γ	Polytropic exponent for gas in lungs	1.2
Po	Ambient pressure (Pa)	
p(t)	Overpressure for the duration of the test (Pa)	
P	Lung pressure (Pa)	
x	Displacement (m)	

Table G.1 – Injury models for non-auditory injury assessment

Model	Applicable to ideal waves	Applicable to complex waves	Organs taken into consideration
Bowen	Yes	No	Lungs
Stumiller	Yes	Yes	Lungs
Axelsson and Yelverton	Yes	Yes	All internal organs

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G.2.2 The input for the model shall be a pressure time history. The pressure transducer shall be mounted on a reflecting surface representative of the chest wall and recorded with a minimum sample frequency of 100 kS/sec and a 10 kHz band limited low pass filter.

***NOTE** The below equation represents the solution for this model.*

$$M.\frac{d^2x}{dt^2} + C.\frac{dx}{dt} + K.x = A.\left(p(t) + P_0 - \left(\frac{V}{V - A.x}\right)^{\gamma}.P_0\right)$$

G.2.3 A forward step numerical "predictor" method shall be used to solve the acceleration, velocity and displacement of the chest wall. The equation shall be solved for each pressure history recorded. The injury level (CWVP) shall be determined from the maximum velocity evaluated from the data.

***NOTE** Table G.2 shows the CWVP levels, and the approximate abbreviated injury score (AIS) is also shown for reference.*

Table G.2 – Chest wall velocity predictor (CWVP) levels

CWVP m/s	AIS
>12.8	6 (>50% Lethality)
>9.8, ≤12.8	5 (Moderate to extensive)
>7.5, ≤9.8	3 - 4 (Slight to moderate)
>3.6, ≤7.5	1 - 2 (Trace to slight)
>1.5, ≤3.6	0 (No injury)
≥0, ≤1.5	0 (No injury)

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Annex H (normative)
Design threat grenade DTG5

H.1 General

This annex presents a surrogate grenade, DTG5, as an alternative to the M67 or HG85 military grenades. Fragment energy density shall be used as the basis to compare the DTG5 with the M67 and HG85 and a validation test is presented for the DTG5.

NOTE *The energy density data for each grenade is shown in Figure H.1. The data is based on trials conducted by VSAG in which fragment mass, area, and velocity data were captured for the DTG5, M67, and HG85. Averaging this data it was possible to characterize the fragment energy density values for each device. The DTG5 using the 5 mm steel ball presents a reasonable comparison using fragment energy density.*

H.2 DTG5 casing design and assembly

H.2.1 The casing design and assembly shall follow the below process:

- manufacture the casing base in one part;
- manufacture the cap and ring in two parts;
- position an 8 mm hole centrally in the cap for a detonator;
- load the fragments, consisting of 5 mm stainless steel balls [AISI 420 (55 ±3) HRC Rockwell, grade 100, stainless, 13 rows of 39 balls] into the side wall cavity;
- place the ring over the fragments and glue into position;
- fill the surrogate central cavity with (200 ±5) g of C4 prior to testing, and place the cap over the explosive flush with the top and hold in position with adhesive tape; and
- insert the detonator into the explosive through the hole in the cap with the tip of the detonator positioned at the volumetric centre of the explosive.

H.2.2 The casing shall be manufactured in accordance with Figure H.2. The material shall be translucent so the position of the steel balls can be checked.

NOTE *DTG5 drawings are shown in Figure H.2 and an example DTG5 grenade is shown in Figure H.3.*

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Figure H.1 – Fragment energy density, M67, HG85, DTG5

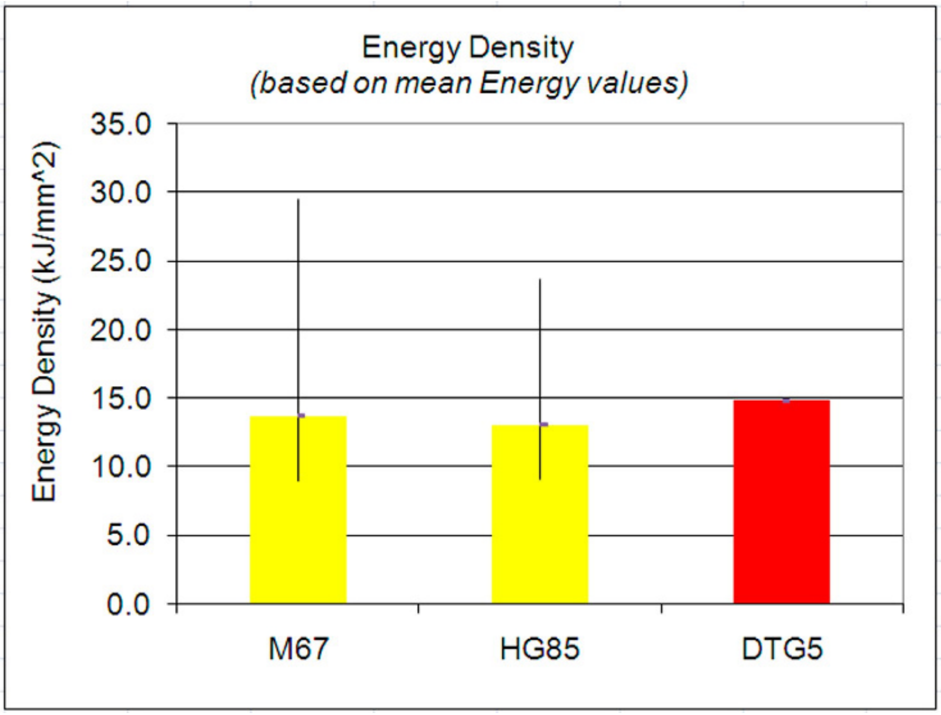
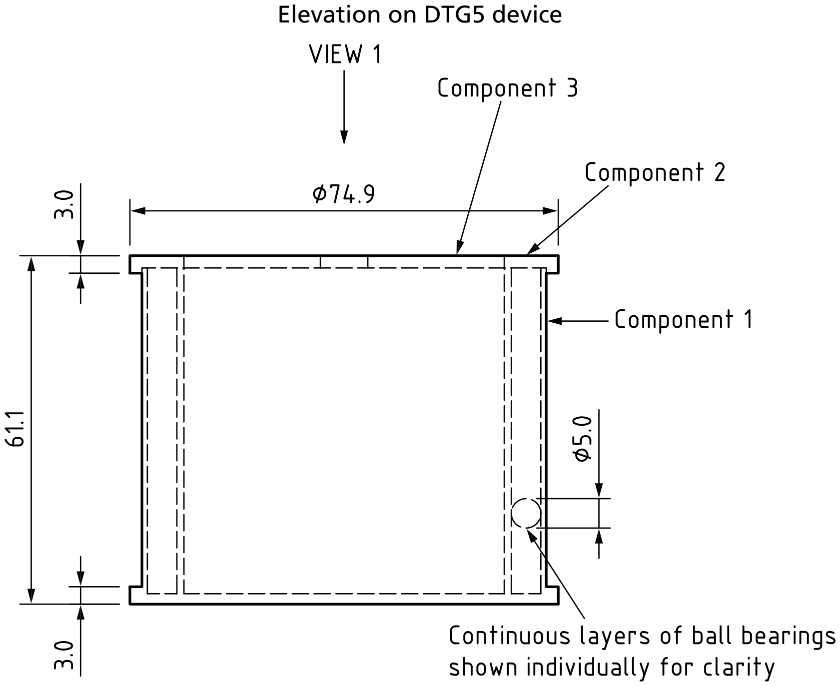


Figure H.2 – DTG5 drawings



Key

Component 1	Casing base
Component 2	Ring
Component 3	Cap

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Figure H.2 – DTG5 drawings *(continued)*

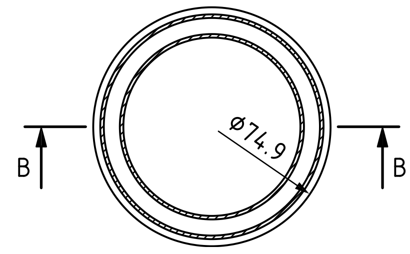
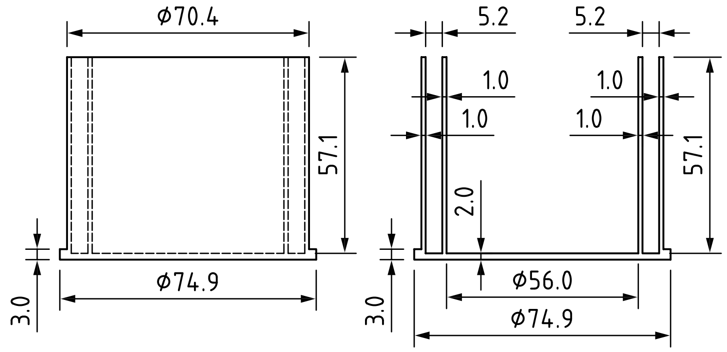
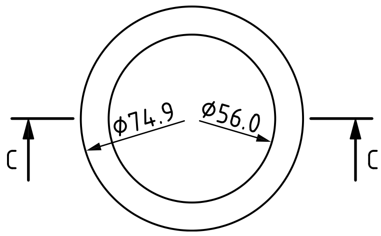
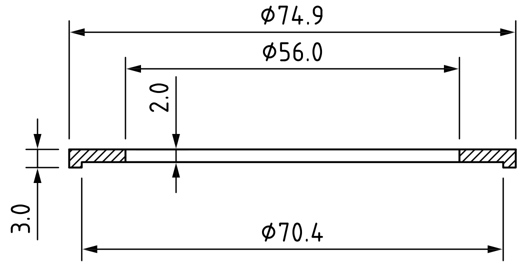
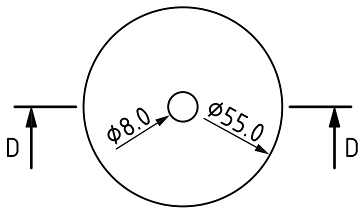
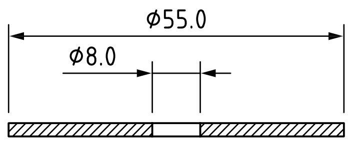
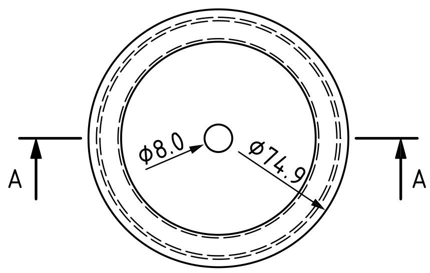
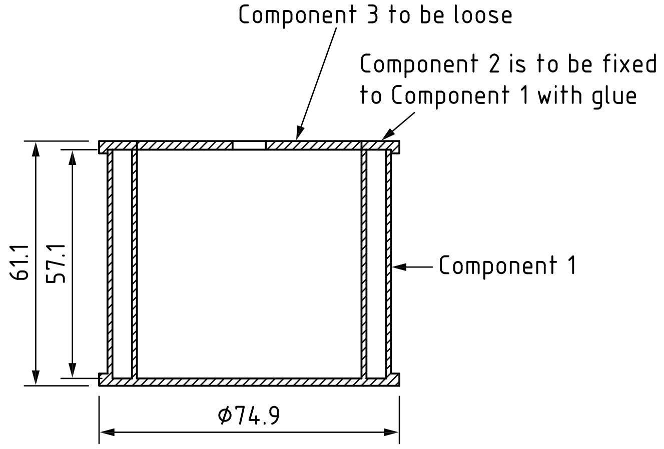
Plan on component 1 (view 1)	Elevation on component 1 Section B-B component 1
	
Plan on component 2 (view 1)	Section C-C component 2
	
Plan on component 3 (view 1)	Section D-D component 3
	
Plan on DTG5 device (view 1)	Section A-A DTG5 device
	

Figure H.3 – Example DTG5

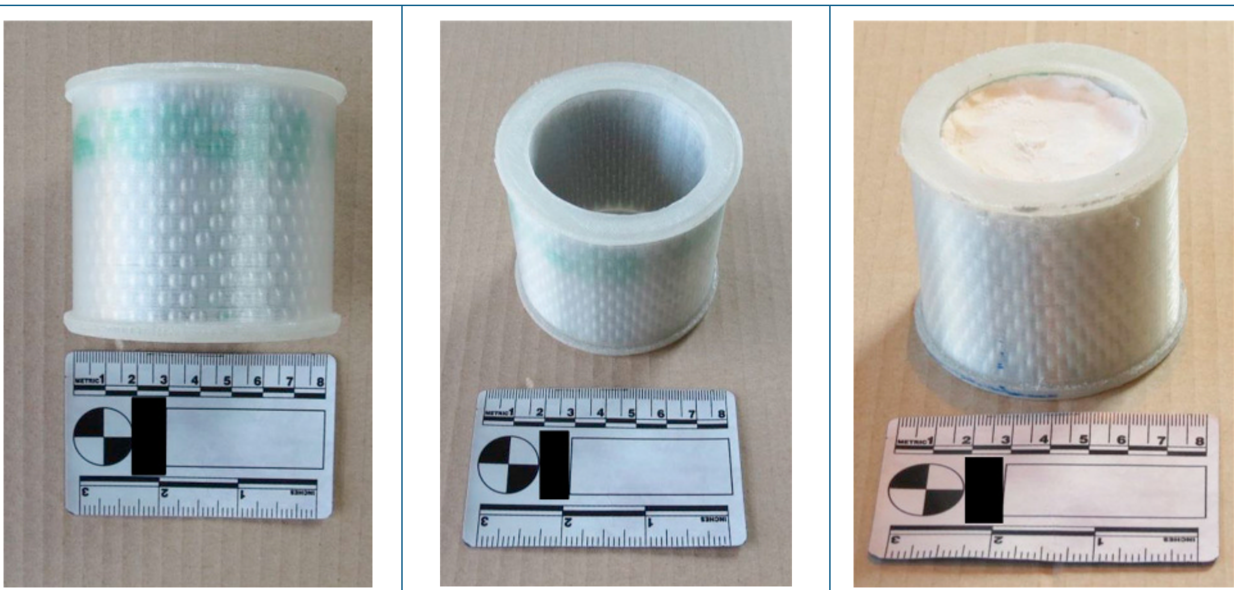
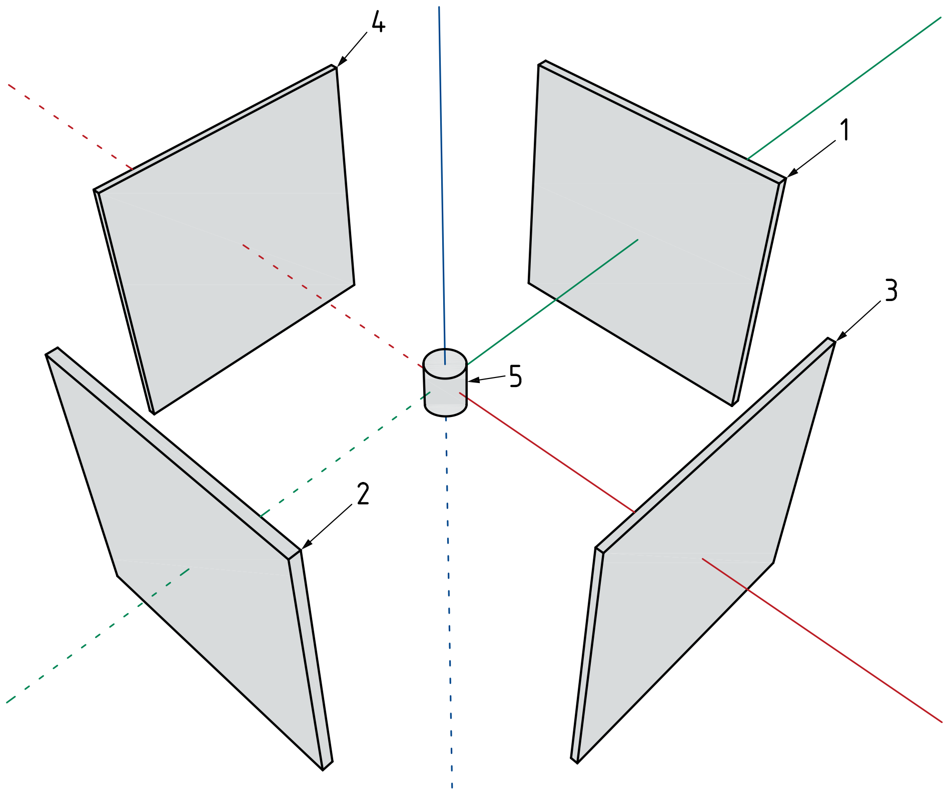


Figure H.4 – Validation test set up



Key

1 (12.7 ±0.3) mm 6082 aluminium alloy plate (alternative, 0.5”)

2 (12.7 ±0.3) mm 6082 aluminium alloy plate (alternative, 0.5”)

3 (8.0 ±0.3) mm 6082 aluminium alloy plate

4 (8.0 ±0.3) mm 6082 aluminium alloy plate

5 DTG5 test device

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H.3 DTG5 validation test

H.3.1 When using the grenade for the first time at least one validation test shall be completed in accordance with **H.3.2** to **H.3.6**.

***NOTE** Validation tests ensure that the manufactured grenade is correct.*

H.3.2 The grenade fragment cylindrical face shall be aligned centrally in the vertical and horizontal with four target plates clamped into a test frame (see Figure H.4).

H.3.3 Each plate shall be made from (6082 aluminium alloy) and be 350 mm × 350 mm ±5 mm square with the target area measuring 300 mm × 300 mm ±5 mm square, clearly marked centrally on each plate. The target area shall be used to determine the number of impacts and perforations (**H.3.6**).Two plates shall have a thickness of (12.7 ±0.3) mm and the remaining two (8.0 ±0.3) mm.

***NOTE** The plate thickness 12.7 mm is the nominal thickness for the equivalent 0.5" plate. The 0.5" plate may be more widely available.*

H.3.4 The stand-off between the outer surface of the grenade and the four test plates shall be (300 ±5) mm (see Figure H.4).

H.3.5 The grenade shall be detonated by a small commercial detonator, inserted from the top placing the tip of the detonator into the volumetric centre of the grenade.

***NOTE** An example of a small detonator is RP83.*

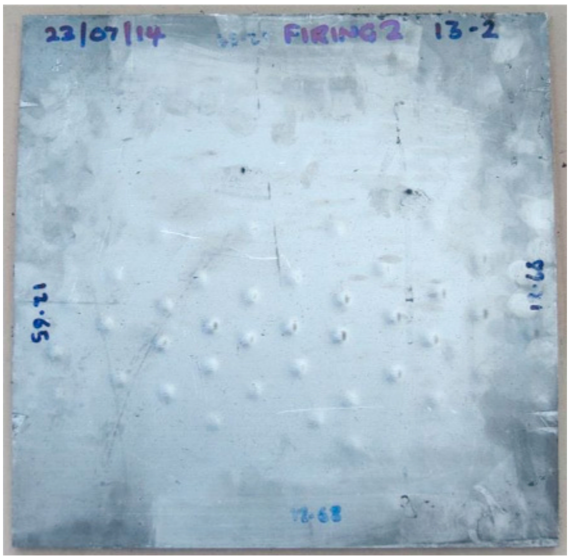
H.3.6 The validation test shall consist of a minimum of two plates of each thickness that meet the following criteria for each plate:

- 0% perforation on the (12.7 ±0.3) mm plate; and
- greater than 50% perforations on the (8.0 ±0.3) mm plate.

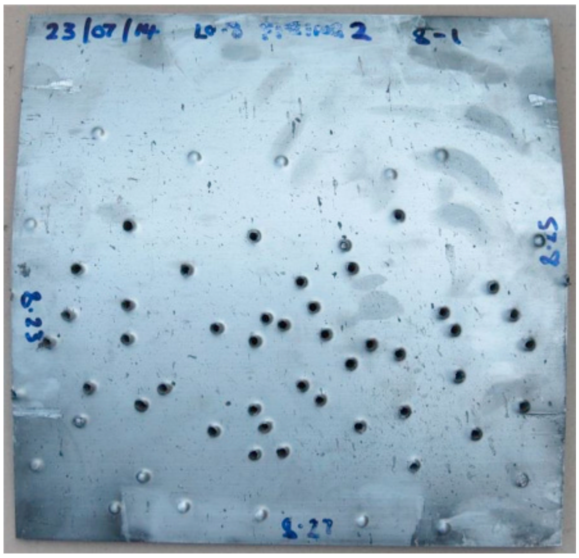
The perforation percentage shall be calculated as [(fragment perforations ÷ fragment impacts) × 100] on the 300 mm × 300 mm ±5mm target area for each plate. A perforation shall be defined as a hole of any size in the target area that light is able to pass through.

***NOTE** The results from an example validation test are shown in Figure H.5.*

Figure H.5 – DTG5 validation test example result



12.65 mm plate, 0% perforations



8.21 mm plate, 78% perforations

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Annex I (normative) Valid shot determination

I.1 General

This annex sets out criteria that shall be used to determine the validity of any single shot and/or a multi-shot sequence (e.g. three shot triangle or five shot into door latch) in accordance with Table I.1.

I.2 Single shot validity

For a single shot, if all criteria in Table I.1 are within the limits specified then the shot shall be considered valid. If any of the criteria are outside the specified limits then additional checks shall be made to assess validity depending on the severity of the shot.

NOTE *For example, if the result is a full perforation or partial perforation then each criterion needs to be checked to determine whether or not it indicates a more severe condition (see Table I.1). If any criterion is found to be more severe the shot is not valid, otherwise it is valid. Alternatively, if the shot results in no perforation then each criterion needs to be checked to determine whether or not it indicates a less severe condition (see Table I.1). If any criterion is found to be less severe the shot is not valid, otherwise it is valid.*

I.3 Multi shot sequence validity

NOTE *Special cases may occur during a multi-shot sequence, for example three shot triangle or five shot sequence into door latch.*

If any shot (apart from the first shot) in a multi-shot sequence results in a partial or full perforation and is determined to be valid (see **I.2**), and any previous shot was valid (with more severe conditions only) then the whole multi-shot sequence is rejected and shall be repeated.

The shots recorded in the rejected multi-shot sequence shall not contribute to the overall ballistic assessment.

NOTE *For example, a three shot sequence on glass, shot 1 results in no perforation, meets all criteria except the velocity is above the upper specified limit (see Table I.1) therefore is more severe, so is still considered valid. Shot 2 perforates, meets all criteria (see Table I.1) so is valid. Although both shots were valid at the time, the multi-shot sequence is rejected (i.e. the shot sequence is not considered a failure but the test must be repeated) because the first shot may have introduced more damage due to the higher more severe velocity. In this same example if the second and third shots do not perforate and are valid, then the more severe conditions in the first shot becomes irrelevant and the three shot sequence is accepted.*

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Table I.1 – Shot validity criteria, specified limits and severity conditions

Criteria	Limits	More severe condition	Less severe condition
(a) shot measured velocity	shall be in accordance with the specified ballistic test levels and limits	greater than the maximum limit specified	less than the minimum limit specified
(b) three shot triangle spacing on armour panels (including transparent panels)	shall be arranged in an equilateral triangle with a side length of (120 ±10) mm	<110 mm	>130 mm
(c) shot spacing for apertures or joints that contain transparent armour panels	shall be (120 ±10) mm	<110 mm	>130 mm
(d) shot spacing for apertures or joints that do not contain transparent armour panels	shall have spacing to facilitate shot plan but not less than three bullet calibres for the bullet being fired	less than three bullet calibres for the bullet being fired	not applicable
(e) shot spacing for door handles, latches and locks	shall have spacing to facilitate shot plan but not less than three bullet calibres for the bullet being fired	less than three bullet calibres for the bullet being fired	not applicable
(f) shot attack angle	shall be in accordance with the specified horizontal and vertical attack angle ±1.0°	any horizontal or vertical angle outside the specified limits resulting in a trajectory with decreased ballistic resistance	any horizontal or vertical angle outside the specified limits resulting in a trajectory with increased ballistic resistance
(g) distance from the impact point and aim point	shall be less than one bullet calibre when testing apertures/joints/ handles/ latches/locks and less than three bullet calibres all other times	distance from impact and aim point is greater than the specified limits and presents a more severe impact, (e.g. criteria b,c,d, e and f)	distance from impact and aim point is greater than the specified limits and presents a less severe impact(e.g.If the aim point is on a aperture/ joint/handle/ latch/lock and is missed resulting in a ballistic trajectory into the armour with higher ballistic resistance.)

NOTE 1 Shot spacing is measured between centres of impact.

NOTE 2 Distance between impact point and aim point is measured from the centre of impact.

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