GUIDE FOR BUILDING AND CLASSING

INTERNATIONAL NAVAL SHIPS 2018

NOTICE NO. 2 – JUNE 2018

The following Rule Changes were approved by the ABS Rules Committee on 1 May 2018 and become **EFFECTIVE AS OF 1 JUNE 2018.**

(See http://www.eagle.org for the consolidated version of the Guide for Building and Classing International Naval Ships 2017, with all Notices and Corrigenda incorporated.)

Notes - The date in the parentheses means the date that the Rule becomes effective for new construction based on the contract date for construction, unless otherwise noted. (See 1-1-4/3.3 of the ABS Rules for Conditions of Classification (Part 1).)

(Add new Part 6, Chapter 5, as follows:)

PART 6 OPTIONAL NOTATIONS

CHAPTER 5 MISSION THREATS PROTECTION *(2018)*

SECTION 1 BALLISTIC AND FRAGMENT HAZARDS

1 General

Ballistic and fragment hazards can be mitigated by various methods, which will determine the level of protection (LOP) the ships can attain. Selection of the desired LOP for ballistic and fragment hazard protective barriers should be based on the mission requirements, anticipated threats and results of vulnerability assessments, which should account for ship resiliency under combat conditions. Mission requirements and assessments are not part of the scope of this Section.

BFP1, **BFP2** and **BFP3** are optional notations that indicate ballistic and fragment hazard protection. They are available for ships complying with the requirements in this Section. For more detail regarding the notation types refer to 6-5-1/3.

1.1 Objective

The primary objective of this Section is to provide technical guidance for achieving an LOP for Naval ships against direct fire weapons (see 6-5-1/5.1) by reducing the line of sight and hardening the exposed surfaces. Hardened exposed surfaces may include both transparent (e.g., glazed) and opaque (e.g., steel, aluminum, composite, etc.) barriers comprised of single- or multi-layer construction.

This Section is patterned after the US Department of Defense publication, Design to Resist Direct Fire Weapons Effects, UFC 4-023-07 [1] guide which has been approved for public release, distribution unlimited. Therefore, the user is advised to consult UFC 4-023-007 [1] for technical explanations and details not explicitly covered within this Guide.

3 Notations

The **BFP1**, **BFP2** and **BFP3** optional notations indicate compliance with the requirements given in this Guide. Maintenance of these notations over the operational life of the ship is subject to periodic surveys in accordance with 6-5-1/15. The assigned notation of **BFP2** or **BFP3** will correspond to the highest level of protection provided.

These notations will be listed in the ABS *Record* as private notations. The structures, assets or personnel spaces and the protection details covered by the notations are to be listed in the Line of Sight Plan or the Ballistic and Fragment Protection Plan (see 6-5-1/3.1).

BFP1 is a notation available for Basic LOP (see 6-5-1/9.1.1). It covers any arrangement on the ship that is specifically introduced to conceal structures, mission critical assets and/or personnel to provide protection from direct line of sight attack as shown in the Line of Sight Plan.

BFP2 is a notation available for Medium LOP (see 6-5-1/9.1.2). It covers any method on the ship to slow the speed of ballistic projectiles or fragments in the manner defined by the Naval Administration or agency authorized by the Naval Administration. Compliance with **BFP1** is not a prerequisite for **BFP2**. Scope and details of the LOP are to be shown on the Ballistic and Fragment Protection Plan.

BFP3 is a notation available for Enhanced LOP (see 6-5-1/9.1.3). This notation indicates that the structure, doors, windows, and openings cannot be penetrated by the designated threat (e.g., bullet or fragment). In conflict situations the threat can come from any direction, therefore this notation is intended to cover the entire structure above the waterline. Non-critical spaces may be exempted upon agreement with the Naval Administration. Scope and details of the LOP are to be shown on the Ballistic and Fragment Protection Plan.

3.1 Documents

The following documents are to be submitted:

i) Line of sight plan for **BFP1**

ii) Ballistic and Fragment Protection Plan for **BFP2** and **BFP3**, which shows the following:

a) Drawing of all protected structures/assets (including welds, gaps and openings as described in 6-5-1/9.3 and 6-5-1/9.5) and installed barriers clearly marked indicating the level of protection

b) Table that lists:

- Level of protection
- Protected structures/assets (including welds, gaps and openings as described in 6-5-1/9.3 and 6-5-1/9.5)
- Method of protection
- Ballistic threat particulars: caliber, type, projectile weight (g), diameter (mm), projectile speed (m/sec)
- Fragment threat particulars: type, projectile weight (g), diameter (mm), projectile speed (m/sec)
- Thickness of barriers or structural plate
- Material of barriers or structural plate

iii) Supporting line of sight analysis, calculations and/or test results from recognized laboratory, as applicable

Calculations and test results are to be for the most severe threats (ballistic and fragment). Calculations may be required for multiple projectiles depending on weight, diameter, and speed. When armor piercing ballistics are considered, calculations, test results or other technical justifications are to be submitted.

5 Threat Coverage

5.1 Ballistic Weapons/Ammunition

Conventional and armor piercing ballistic ammunition covered by this Guide and associated notations are those from direct fire weapons such as man-portable, small arms up to 0.50 caliber (e.g., handguns, rifles, shotguns and submachine guns).

A direct fire weapon is defined as a weapon used to launch a projectile directly at a target within the line of sight of the firer. Identification of specific weapons is not made within this Guide; however, specific ballistic ammunition details (caliber, projectile weight, and projectile speed) are defined by the various ballistic test standards cited in Appendix 6-5-A2.

5.3 Fragmentation and High Explosive Projectiles

Fragmentation types covered by this Guide and associated notations are those from explosive ammunition such as armor piercing ammunition, high explosive dual purpose and fragmentation grenades. However, protection against anti-tank weapons (e.g., rocket propelled grenades) are not included.

For fragmentation type ammunition, design basis fragment data may not be available in the public domain. For those instances, the user is to define the design basis fragment (i.e., fragment mass and velocity) and submit the appropriate methodology for qualification of the barrier to ABS for review.

7 Methodology

The methodology for achieving the desired level of protection (**BFP2**, **BFP3**) against direct fire weapons covered by this Guide may follow either of the two paths in 6-5-1/7.1 or 6-5-1/7.3.

7.1 Empirical Engineering-Based Method

The empirical engineering-based method (see 6-5-1/11) is limited to certain projectiles and barrier types (e.g., both mild steel and armor steel plates) in accordance with well-established standardized methods for sizing barriers for protection against ballistic and fragment hazards.

7.3 Qualification by Testing

Testing is to be in accordance with recognized international standards (see 6-5-1/13).

Compared to the empirical engineering based method, qualification by testing covers a more varied array of weapons and barrier types.

9 Protective Design

9.1 Levels of Protection (LOP)

9.1.1 Basic LOP

Basic LOP is achieved through elimination of the line of sight for weaponry from all threats. The specific strategy is that if the asset cannot be seen, the adversary will not fire upon it.

Refer to UFC 4-023-07 [1] for guidance and examples of protection of assets using elimination of line of sight techniques. Although this reference discusses the techniques for land-based assets, the philosophy is useful in developing elimination of line of sight techniques for marine-based assets.

9.1.2 Medium LOP

Medium LOP is achieved through implementation of sacrificial barriers and/or pre-detonation screens that reduce, but do not totally eliminate, the effect of the projectile (or its fragments) impacting the protected asset.

9.1.3 Enhanced LOP

Enhanced LOP is achieved by preventing the projectiles from reaching the protected asset. Hardening against weaponry projectiles may be achieved through one or more protective barriers with appropriate engineering analyses or test results.

Protective barrier systems encompass transparent (e.g., glazed) and opaque (e.g., steel plate) armor, single- or multi-layer configurations, with or without air gaps, and may be constructed of various materials including composites.

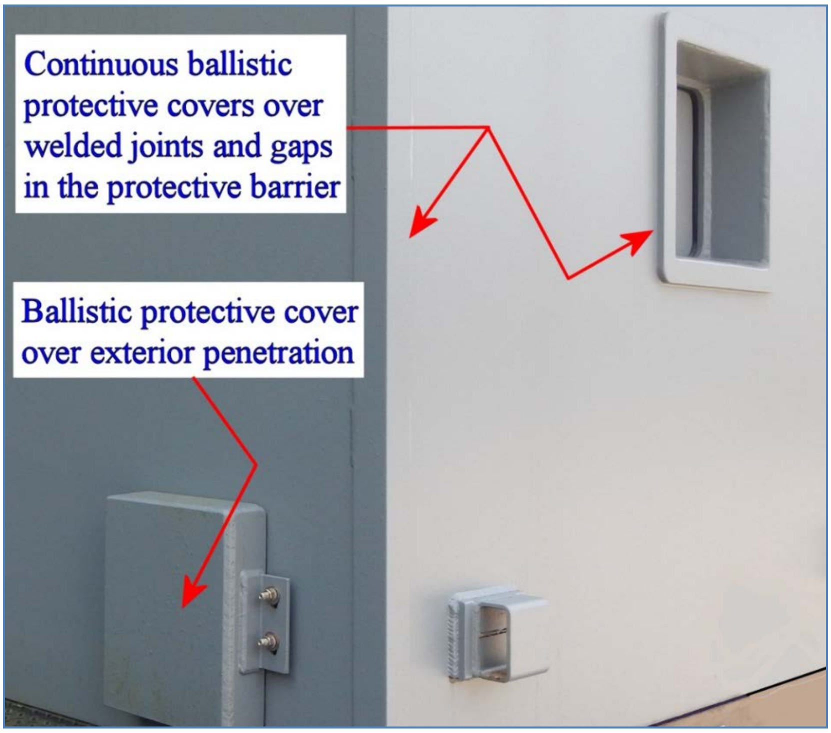
9.3 Protection of Exposed Protective Material Welds, Gaps, and Openings

Achieving Medium or Enhanced LOPs requires coverage of all exposed potential pathways for projectiles reaching the protected area. Medium LOP protective covers are to be designed so that the protected asset or space cannot be hit after a single ricochet of a ballistic projectile. Total denial of the projectile into the protected space is required to achieve an Enhanced LOP. These protective requirements also apply to ballistic-resistant louvers used for protection of vent openings that provide potential projectile pathways into the protected space.

Quenched and tempered steel of high hardness is commonly used in many armor applications. When these steels are exposed to weld thermal cycles they exhibit heat affected zone softening, this softening leads to degradation of ballistic performance. Therefore, exposed welded joints of quenched and tempered high hardness steel are to be protected.

6-5-1/Figure 1 illustrates this concept for an exterior wall penetration, exposed welded joints between protective barrier plates and gaps in the barrier occurring at discontinuities such as gun ports. The materials used as covers are to have the same ballistic rating as the surrounding protective barrier.

FIGURE 1
Example Ballistic Protective Covers for Exterior Penetrations, Exposed Welds, and Gaps *(1 June 2018)*



9.5 Ballistic and Fragment Protection of Windows

Enhanced LOP windows are required to provide the same level of protection as provided by the surrounding protective barrier in which the window is mounted. Ballistic resistant windows are commonly qualified by testing (e.g., ASTM F1233-08 [7]).

11 Barrier Qualification by Analysis

11.1 Ballistic Projectiles

The analytical methodology for determining the minimum required protective barrier system to prevent perforation of ballistic projectiles may be based on Section 5.3.4.2 of UFC 4-023-07 [1] or other standard recognized by the Naval Administration.

11.1.1 Required Steel Thickness

The following expression provides the minimum required steel plate ballistic barrier thickness (t_b) for a given projectile and steel barrier material.

$$t_b = \left(D_p\right)\left[\frac{V_o\sqrt{m_p}}{C\left(D_p\right)^{1.5}\log\left(BHN\right)}\right]^{5/4} \quad \text{mm (in.)}$$

where

t_b	=	minimum required barrier plate thickness to prevent perforation, in mm (in.)
D_p	=	projectile diameter, in mm (in.)
V_o	=	impact velocity, in m/sec (ft/sec); design basis weapon muzzle velocity may conservatively be used
m_p	=	mass of the projectile, in kg (lb)
C	=	1.127 mm (703.1 in.)
BHN	=	Brinell Hardness Number of the barrier plate steel determined in accordance with ASTM E110-14 [8]. The BHN for the specific steel barrier plate is to be used and is to be representative of the entire thickness (i.e., considered homogeneous).

11.1.2 Residual Speed

If the barrier plate thickness provided (t_{p1}) is less than the calculated t_b, the projectile will perforate the barrier with a residual velocity, V_{b1}.

$$V_{b1} = \sqrt{V_o^2 - \left[\frac{C\left(\frac{t_{p1}}{D_p}\right)^{0.8}\left(D_p\right)^{1.5}\log\left(BHN\right)}{\sqrt{m_p}}\right]^2} \quad \text{m/sec (ft/sec)}$$

where

V_{b1}	=	residual velocity of the projectile as it exits the barrier plate, in m/sec (ft/sec)
V_o	=	impact velocity, in m/sec (ft/sec); design basis weapon muzzle velocity may conservatively be used
C	=	1.127 mm (703.1 in.)
t_{p1}	=	provided barrier thickness, in mm (in.)

D_p = projectile diameter, in mm (in.)

BHN = Brinell Hardness Number of the barrier plate steel determined in accordance with ASTM E110-14 [8]

m_p = mass of the projectile, in kg (lb)

The expression for the residual velocity given above can then be used as the impact velocity for a second steel plate in a multi-layer ballistic barrier assembly. This incremental process can be used in succession to determine the minimum required thicknesses of each layer or the number of layers in order to prevent perforation of the barrier assembly. This approach conservatively assumes that the projectile retains all of its mass and suffers negligible deformation.

11.3 Fragment Projectiles

The analytical methodology for determining the minimum protective barrier thickness necessary to prevent perforation of projectiles from fragmentation weapons is based on Section 5-49 of UFC 3-340-02 [4]. Specifically, fragment weight (W_f) and velocity (V_o) are to be defined by the user based on the design basis weaponry characteristics specified in the Ballistic and Fragment Protection Plan (see 6-5-1/3.1).

11.3.1 Required Steel Thickness

The thickness required to prevent perforation of a mild steel plate by an armor piercing steel fragment can be determined as follows ([4], Equation 5-64):

$$t_f = C_1 W_f^{(1/3)} \left(\frac{V_o}{1000} \right)^{1.22} \quad \text{mm (in.)}$$

The thickness required to prevent perforation of a mild steel plate by a mild steel fragment can be determined as follows ([4], Equation 5-65):

$$t_f = C_2 W_f^{(1/3)} \left(\frac{V_o}{1000} \right)^{1.22} \quad \text{mm (in.)}$$

where

t_f = minimum required thickness of barrier steel plate, in mm (in.)

C_1 = 10.65 mm (0.30 in.)

C_2 = 7.454 mm (0.21 in.)

W_f = fragment weight, in g (oz)

V_o = impact velocity, in m/sec (ft/sec)

If the barrier plate thickness provided (t_{f1}) is less than t_f calculated using either of the above equations as appropriate for the fragment material type, the projectile will perforate the barrier with a residual velocity, V_{f1}. In such cases, the residual velocity upon perforation may be used as the impact velocity on the next barrier plate in a multi-layer barrier assembly. This incremental process can be used in succession to determine the minimum required thicknesses of each layer or the number of layers required to prevent perforation of the entire fragment protective barrier assembly. This approach conservatively assumes that the projectile retains all of its mass and suffers negligible deformation.

11.3.2 Residual Speed

The residual velocity, V_{f1}, of steel fragments upon perforation of the steel barrier plates can be determined as follows ([4], Equation 5-66):

$$V_{f1} = V_o \frac{\sqrt{1-\left(\frac{V_{cr}}{V_o}\right)^2}}{\left(1+\frac{t_{f1}}{d}\right)} \quad \text{m/sec (ft/sec)}$$

where

V_{f1}	=	fragment residual velocity upon perforation of barrier plate, in m/sec (ft/sec)
V_o	=	impact velocity, in m/sec (ft/sec)
V_{cr}	=	velocity required to perforate barrier, critical velocity, in m/sec (ft/sec)
t_{f1}	=	thickness of provided barrier, in mm (in.)
d	=	fragment diameter, in mm (in.)

The fragment diameter can be calculated using 6-5-1/Figure 2 as follows:

$$d = \left(\frac{W_f}{D}\right)^{1/3} \quad \text{mm (in.)}$$

where

W_f	=	fragment weight, in g (oz)
D	=	caliber density
	=	0.0052 g/mm^3 (2.98 oz/in^3)

The critical velocity of an armor piercing steel fragment upon perforation of a mild steel barrier plate can be determined as follows:

$$V_{cr} = \frac{C_1 t_f^{0.82}}{W_f^{0.273}} \quad \text{m/sec (ft/sec)}$$

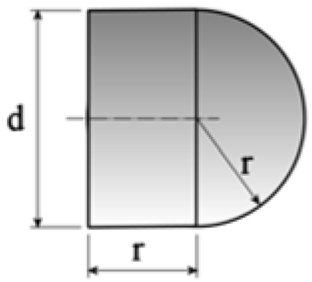
The critical velocity of a mild steel fragment upon perforation of a mild steel barrier plate can be determined as follows:

$$V_{cr} = \frac{C_2 t_f^{0.82}}{W_f^{0.273}} \quad \text{m/sec (ft/sec)}$$

where

C_1	=	143.6 m/sec (2683 ft/sec)
C_2	=	192.4 m/sec (3594 ft/sec)
t_f	=	thickness of provided barrier thickness, in mm (in.)
W_f	=	fragment weight, in g (oz)

FIGURE 2
Longitudinal Cross-Section of a Standard Primary Fragment
[Ref 4, Figure 4-77] *(1 June 2018)*



d = diameter of fragment cylindrical body (mm, in)
r = radius of hemispherical fragment head (mm, in)
D = caliber density (g/mm³, oz/im³)
W_f = fragment weight (g, oz)

$D = W_f/d^3$

$= 0.005148\ g/mm^3\ ,\ 2.976\ oz/in^3$

11.5 Material

This Subsection is intended for vessels of welded construction using steels complying with the requirements of the ABS *Rules for Materials and Welding (Part 2)*. Use of steels other than those in the ABS *Rules for Materials and Welding (Part 2)* will be specially considered.

11.7 Other Method of Analysis

Analysis using a method based on a recognized standard other than what is described in this Guide may be used upon approval by ABS.

13 Barrier Qualification by Testing

13.1 Ballistic Weapons/Ammunition

See 6-5-A2/Table 1 for a sample of internationally recognized ballistic test standards. Qualification of ballistic protective barriers via testing by a certified testing laboratory is an acceptable means of achieving the required LOP as described in 6-5-1/9.1. Technical documentation describing the test and results is to contain all information required by the test standard.

13.3 Fragmentation and High Explosive Projectiles

Although most ballistic test standards cover only projectiles fired by small arms, MIL-STD-662F [9] covers testing of protective barriers using projectiles designed to simulate fragmenting munitions when such fragments strike a target. This test standard is not included in 6-5-A2/Table 1 because it lacks specificity in the acceptance criteria. Qualification of barriers for effects of fragmentation and high explosive projectiles in accordance with MIL-STD-662F is acceptable provided the test specimen representing the barrier(s) and the simulated projectile(s) accurately or conservatively represents the design conditions. In addition, the technical documentation describing the test and results is to contain all information required by the test standard.

15 Surveys

15.1 Initial Survey

Verification by the Surveyor that the protected structures have been built in accordance with the Ballistic and Fragment Protection Plan including material certification.

15.3 Surveys after Construction

15.3.1 Annual Surveys

Verification by the Surveyor that the protected structures, as accessible, in the Ballistic and Fragment Protection Plan remain in satisfactory condition.

17 Damage, Failure and Repair

17.1 Examination and Repair

Damage, failure, deterioration or repair to the protected structures is to be submitted by the Owners or their representatives for examination by a Surveyor at first opportunity. All repairs found necessary by the Surveyor are to be carried out to the Surveyor's satisfaction.

Where repairs to the protected structures are planned in advance to be carried out, a complete repair procedure including the extent of proposed repair and the need for Surveyor's attendance is to be submitted to and agreed upon by ABS reasonably in advance.

The above paragraph is not intended to include maintenance to the protected structures however, any repair as a result of such maintenance is to be noted in the ship's log and submitted to the Surveyor.

Material and components are to be provided with the required certificates.

19 Alterations

No alterations or repairs that affect or may affect the protected structures are to be made unless plans of the proposed alterations or repairs are submitted to and approved by ABS before the work is commenced. Such work, when approved, is to be carried out to the satisfaction of the Surveyor.

21 References

1. US DOD, Unified Facilities Criteria (UFC) – Design To Resist Direct Fire Weapons Effects, UFC 4-023-07, US Department of Defense, Washington, D.C., 07-July-2008 (Change 1, 01-Feb-2017).
2. US DOD, Department Of Defense Test Method Standard: Test Methods for Ballistic Defeat Materials, MIL-STD-3038, US Department of Defense, Washington, D.C., 18-May-2011.
3. UL, UL Standard for Safety for Bullet Resisting Equipment; UL 752, Underwriters Laboratories Inc., Northbrook, IL (USA), 11th ed., 2005.
4. US DOD, Unified Facilities Criteria (UFC) –Structures To Resist The Effects Of Accidental Explosions, UFC 3-340-02, US Department of Defense, Washington, D.C., 05-Dec-2008 (Change 2, 01-Sep-2014).
5. E. J. Conrath, T. Krauthammer, K. A. Marchand and P. F. Mlakar, Structural Design For Physical Security – State Of The Practice, American Society of Civil Engineers, Reston, VA (USA), 1999.
6. US DOE, A Manual for the Prediction of Blast and Fragment Loadings on Structures, DOE/TIC-11268, US Department of Energy/Albuquerque Operations Office, Albuquerque, NM (USA), July 1992.
7. ASTM, Standard Test Method for Security Glazing Materials and Systems; ASTM F1233-08 (2013), ASTM International, Inc., West Conshohocken, PA (USA), 2013.
8. ASTM, Standard Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers; ASTM E110-14, ASTM International, Inc., West Conshohocken, PA (USA), 2014.
9. US DOD, Department Of Defense Test Method Standard: V_{50} Ballistic Test For Armor, MIL-STD-662F, US Department of Defense, Washington, D.C., 18-Dec-1997.

PART 6 OPTIONAL NOTATIONS

CHAPTER 5 MISSION THREATS PROTECTION

APPENDIX 1 SIGNATURE

1 General

ABS offers no notation for Signature. This Appendix provides information and discusses the importance of the signature of ships and methods to reduce it.

Survivability is a critical consideration for a vessel. For commercial vessels, this entails the ability to withstand loads due to inclement environments and operate even if critical components or systems fail. Naval vessels have the additional burden of surviving in combat environments. Both offensive and defensive measures can be taken to improve the survivability of the vessel. This section discusses defensive measures such as minimizing the electromagnetic signature of the vessel.

3 Signature

Each naval ship has unique signature characteristics in various regions of the electromagnetic spectrum. The spectrums most commonly used for identification and detection purposes are visual, microwave and infrared. Reducing or modifying the various signatures such that they match the operating environment can enhance the survivability of the vessel. Techniques used to alter RADAR, infrared, acoustic and electromagnetic signatures are discussed in this Appendix.

3.1 RADAR Signature

In recent years, RADAR signature reduction has been a primary consideration in the design of military aircraft. The objective of a naval ship is to reduce its RADAR signature so that it appears to be a much smaller vessel. The primary means used to achieve a smaller RADAR signature are by shaping the vessel and using RADAR absorbing materials.

One can quantify the RADAR signature of a vessel by calculating its RADAR Cross-Section (RCS). An object's RCS is defined as the cross-sectional area of a perfectly reflecting sphere that would reflect the same amount of energy as the defined object. The distance from which a vessel is detectable by RADAR varies with the fourth root of its RCS. This means that to decrease the detection distance by an order of magnitude, the RCS would have to be reduced by a factor of ten thousand. To minimize its RADAR signature, the vessel's shape (and thus its RCS) must be considered during the design phase.

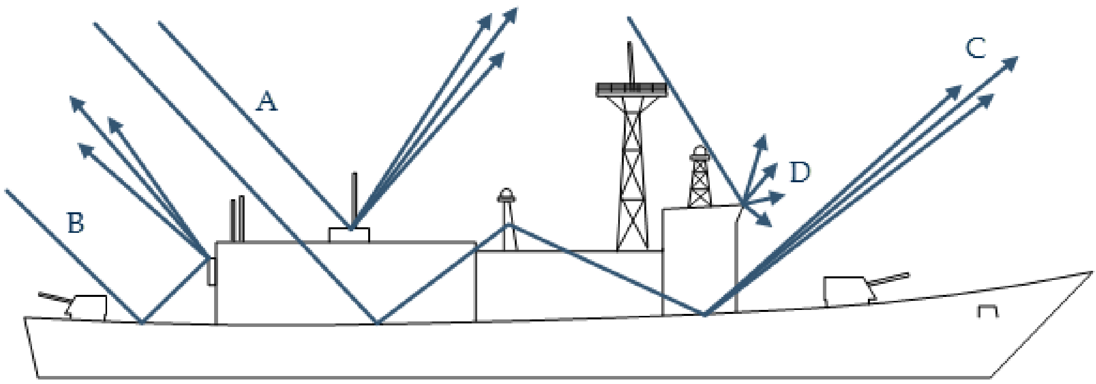
3.1.1 Shape Modification

Modifying the shape of the vessel is the primary recommended technique to reduce RCS. 6-5-A1/Figure 1 shows a comparison between standard and stealth ship designs.

FIGURE 1
Comparison of Standard (left) and Stealth (right) Ship Designs *(1 June 2018)*

The vessel should be designed such that longitudinal and transverse cross-sections are minimized. Surface angles should be inclined at various angles to scatter RADAR beams. Right angles should be avoided. Masts, antennas, and armament should be hidden from view. 6-5-A1/Figure 2 demonstrates various RADAR responses for a conventional warship.

FIGURE 2
Important Scattering Mechanisms on Warships *(1 June 2018)*



A= Single Reflection B= Double Reflection
C= Triple Reflection D= Edge Reflection

RADAR absorbing materials should be selected in the vessel design process. Carbon fiber reinforced plastic is commonly used to reduce RADAR signature.

3.3 Electromagnetic Signature

Each vessel has a unique electromagnetic signature due to the strong electric field surrounding it. The main source of the electric field is the current passing through the water via active cathodic protection systems. Most of the current passes through the propeller and its shaft, returning to the vessel ground by way of its bearings or a passive shaft grounding system. Variability in the electrical connections through the bearings and degradation of the passive shaft grounding system over time causes the current to vary as the shaft turns. This current oscillation can be used to determine the shaft frequency [2].

The vessel's signature is comprised of static electric and alternating electric components. The fluctuations in the electric field create an induced alternating magnetic field. Software can be used to predict the static electric, alternating electric, and alternating magnetic signatures and allow the designer to evaluate the effectiveness of design changes and countermeasures. One effective electromagnetic countermeasure is the use of an active shaft grounding unit, which actively detects fluctuations in resistance between the shaft and the hull and adjusts a low resistance current control device (i.e., shunt) to maintain a constant resistance. The resulting constant current virtually eliminates the alternating electric signature created by the current running through the shaft [2].

3.5 Infrared Signature

The infrared signature of the vessel is comprised of both internal sources (e.g., rejected heat from engines and equipment, engine exhaust, ventilation system exhaust and heated internal spaces) and external sources (e.g., ship surfaces absorbing and/or reflecting radiation from the sun, sky or sea). The drive engines and electrical generators are the largest contributors to the internal portion of the infrared signature. Five internal hot-spots to consider when designing to minimize the infrared signature are:

- Warm areas of the hull denoting the locations of the engine compartments
- Funnel spaces (which are heated by engine exhaust and engine room ventilation air)
- Funnel exteriors which have a similar temperature to the hot portions of the ship hull
- Exhaust uptake metal, which is the largest single component of the internal infrared signature; typically, its temperature is 300-400°C (570-750°F)
- Communications mast, which is typically heated by the exhaust plume

Effective infrared signature reduction is not solely dependent on minimizing the temperatures of the vessel hot-spots. Although ship surface temperatures are typically significantly lower than the internal hot-spots, even a small temperature difference over the large surface area of the vessel can yield a large infrared signature. In addition to internal and external sources, effective infrared signature suppression must consider the ranges of expected operating conditions and threats. Modeling software is available to aid in vessel design that accounts for both threats and countermeasures.

The thermal design of the vessel should use proper ventilation and insulation of exterior bulkheads to reduce temperature differences of the warm hull sections and the funnel sides. Cooling the main machinery exhaust is the most effective way to eliminate the other internal hot-spots (i.e., hot uptake metal, plume). The exhaust plume should be cooled to 200-250°C (392-482°F) with the exhaust metal uptake being about 20-30°C (68-86°F) above ambient temperature.

Methods used to control surface temperatures due to external heat sources include using paints designed to reduce infrared emission, spraying the entire vessel in a heavy water mist cloud and using sea water to cool hot surfaces. Currently, the use of sea water is the method that has been proven most effective. Much of the data regarding the use of special paints is classified and the effectiveness of water mist has not yet been proven [2].

Infrared signature can also be modified by altering the directions in which the infrared radiation is emitted, one such example is positioning the outer surfaces of hull and superstructures at selected angles [1].

3.7 Acoustic Signature

Underwater acoustic signals are unique for each type of vessel. These signals can be used to identify and track the vessel. Modern underwater weapons such as mines and torpedoes can be programmed to respond to specific acoustic signals. The acoustic signature of a vessel is usually a combination of a number of noises including machinery, cavitation, and hydrodynamics noise.

There are several ways to reduce the acoustic signature of a vessel. Noise created by the machinery can be addressed by reducing the propagation of noise from the machinery to the hull. These can be done by using rubber blocks between machine foundation and the hull. To further reduce noise coming out from the hull (especially in submarines), damping material can be fitted. An example of such material is anechoic tiles made of rubber or synthetic polymer tiles containing thousands of tiny voids, which reduce the sound emitted from the vessel, typically its engines, and absorb the sound waves of active sonar, reducing and distorting the return signal. Research suggests that rather than tile several centimeters thick, a few millimeters of soft material containing regularly spaced air pockets can absorb well over 99 percent of the acoustic-wave energy impinging on it [3]. Discussion on generic treatments to reduce shipboard noise can be found in the ABS *Guidance Notes on Noise and Vibration Control for Inhabited Spaces* [4].

Noise created by cavitation can be addressed by proper propeller design or by use of a non-propeller thrust device.

Noise created by hydrodynamics is addressed by minimizing water disturbance caused by the ship moving through it. This is done by having an efficient hydrodynamic body and minimizing any protrusions from the hull.

5 References

1. S. Milewski et al, Modification of Infrared Signature of Naval Vessels, Proceeding of SPIE- The International Society for Optical Engineering, May 2013

2. J. Thompson, D. Vaitekunas and B. Brooking, Signature Management – The Pursuit of Stealth; Lowering Warship Signatures – Electromagnetic and Infrared. Presented at the SMi “Signature Management - The Pursuit of Stealth” Conference, 21 & 22 February, 2000.

3. Thinner Coating, a Stealthier Sub. Paintsquare News, January 2015

4. *Guidance Notes on Noise and Vibration Control for Inhabited Spaces*, ABS July 2014.

PART 6 OPTIONAL NOTATIONS

CHAPTER 5 MISSION THREATS PROTECTION

APPENDIX 2 INTERNATIONAL BALLISTIC TESTING STANDARDS

1 General

A tabulation of international ballistic test standards is provided in 6-5-A2/Table 1. This list of sample standards has been extracted from UFC 4-023-07 [1], Appendix 2, and reproduced with the addition of new standards, deletion of outdated standards and minor edits of updated standards. Note that some of the listed ballistic test standards apply to only transparent armor (e.g., ASTM F-1233). Following 6-5-A2/Table 1 is a list of abbreviations used in the table and a list of the standards cited. Other ballistic test standards may be used provided measurable results for specific ballistic armor materials are attainable and documented, and the selected test level/rating encompasses the design basis threat.

TABLE 1
International Ballistic Testing Standards Examples *(1 June 2018)*

Organization and Standard ID	*Test Standard or Rating*	*Ammunition Caliber and Type*	*Bullet Weight*	*Bullet Diameter*	*Velocity*	*Number of Shots*
US DOD MIL-STD-3038	Type I Class A	9 mm x 19 mm FMJ RN M882	124 gr (8.0 g)	.355 in. (9.02 mm)	1263 ± 30 ft/s (385 ± 9.1 m/s)	Grade S = 1 Grade M = 3
	Type II Class A	.44 Magnum (11 mm x 41 mm) SWC gas checked	240 gr (15.55 g)	.427 in. (11.18 mm)	1400 ± 30 ft/s (426 ± 9.1 m/s)	
	Type III Class A	7.62 mm x 39 mm PS M67	124 gr (8.0 g)	0.30 in. (7.82 mm)	2300 ± 30 ft/s (700 ± 9.1 m/s)	
	Type III Class B	7.62 mm x 39 mm API BZ M43	120 gr (7.8 g)	0.30 in. (7.82 mm)	2340 ± 30 ft/s (715 ± 9.1 m/s)	
	Type IV Class A	5.45 mm x 39 mm 5N7	50 gr (3.2 gr)	.220 in. (5.60 mm)	3000 ± 30 ft/s (915 ± 9.1 m/s)	
	Type IV Class B	5.45 mm x 39 mm 7N22 AP	57 gr (3.7 gr)	.220 in. (5.60 mm)	2910 ± 30 ft/s (887 ± 9.1 m/s)	
	Type V Class A	5.56 mm x 45 mm M855	62 gr (4.0 g)	0.223 in. (5.66 mm)	3117 ± 30 ft/s (950 ± 9.1 m/s)	
	Type V Class B	5.56 mm x 45 mm M995 WC AP	52 gr (3.4 g)	0.223 in. (5.66 mm)	3380 ± 30 ft/s (1030 ± 9.1 m/s)	
	Type VI Class A	7.62 mm x 63 mm M2	152 gr (9.8 g)	0.30 in. (7.82 mm)	2900 ± 30 ft/s (880 ± 9.1 m/s)	
	Type VI Class B	7.62 mm x 63 mm AP M2	166 gr (10.8 g)	0.30 in. (7.82 mm)	2880 ± 30 ft/s (878 ± 9.1 m/s)	
	Type VII Class A	7.62 mm x 51 mm M80	147 gr (9.6 g)	0.30 in. (7.82 mm)	2750 ± 30 ft/s (838 ± 9.1 m/s)	
	Type VII Class B	7.62 mm x 51 mm AP M993	128 gr (8.3 g)	0.30 in. (7.82 mm)	2986 ± 30 ft/s (910 ± 9.1 m/s)	

TABLE 1 (continued)
International Ballistic Testing Standards Examples *(1 June 2018)*

Organization and Standard ID	*Test Standard or Rating*	*Ammunition Caliber and Type*	*Bullet Weight*	*Bullet Diameter*	*Velocity*	*Number of Shots*

Organization and Standard ID	*Test Standard or Rating*	*Ammunition Caliber and Type*	*Bullet Weight*	*Bullet Diameter*	*Velocity*	*Number of Shots*
US DOD MIL-STD-3038 (continued)	Type VIII Class A	7.62 mm x 54 mm LPS	147 gr (9.6 gr)	0.30 in. (7.82 mm)	2840 ± 30 ft/s (865 ± 9.1 m/s)	Grade S = 1 Grade M = 3
	Type VIII Class B	7.62 mm x 54 mm B32	155 gr (10.0 g)	0.30 in. (7.82 mm)	2801 ± 30 ft/s (854 ± 9.1 m/s)	
	Type IX Class B	12.7 mm x 108 mm API B32	740 gr (48.0 g)	0.51 in. (12.9 mm)	2800 ± 30 ft/s (853 ± 9.1 m/s)	
	Type X Class A	12.7 mm x 99 mm M33	662 gr (42.9 g)	0.51 in. (12.9 mm)	2910 ± 30 ft/s (887 ± 9.1 m/s)	
	Type X Class B	12.7 mm x 99 mm MK 263 AP	750 gr (48.6 g)	0.51 in. (12.9 mm)	2910 ± 30 ft/s (887 ± 9.1 m/s)	
	Type XI Class B	14.5 mm x 114 mm API B32	990 gr (64.0 g)	.586 in. (14.88 mm)	3000 ± 30 ft/s 914 ± 9.1 m/s	
	Type XII Class B	20 mm x 102 mm M53	1574 gr (102 g)	n/a	3380 ± 30 ft/s (1030 ± 9.1 m/s)	
	Type XIII Class B	23 mm x 152 mm API-T BZT	2885 gr (187 gr)	n/a	3300 ± 30 ft/s (1000 ± 9.1 m/s)	
	Type XIV Class B	25 mm x 137 mm APDS-T M791	2300 gr (149 g)	n/a	4412 ± 30 ft/s (1344 ± 9.1 m/s)	
	Type XV Class B	30 mm x 113 mm M789 HEDP	3534 gr (229 g)	n/a	2641 ± 30 ft/s (805 ± 9.1 m/s)	
	Type XVI Class B	30 mm x 165 mm M789 HEDP	6175 gr (400 g)	n/a	2900 ± 30 ft/s (880 ± 9.1 m/s)	
	Type XVII Class B	30 mm x 173 mm APFSDS-T	3627 gr (235 g)	n/a	4544 ± 30 ft/s (1385 ± m/s)	
ASTM International ASTM F1233	HG1 Handgun Low	.38 Special Lead	158 gr (10.2 g)	.357 in. (9 mm)	850-900 ft/s (259-274 m/s)	3
	HG2 Handgun Medium, SP	.357 Magnum JSP	158 gr (10.2 g)	.357 in. (9 mm)	1350-1450 ft/s (411-422 m/s)	3
	HG3 Handgun, Medium, Jacketed	9 mm FMC	124 gr (8.0 g)	.355 in. (9 mm)	1200-1300 ft/s (365-396 m/s)	3
	HG4 Handgun, High	.44 Magnum LGC	240 gr (15.6 gr)	.429 in. (10.9 mm)	1400-1500 ft/s (427-442 m/s)	3
	SMG Submachine gun	9 mm FMC	124 gr (8.0 g)	.355 in. (9 mm)	1350-1450 ft/s (411-422 m/s)	3
	R1 Rifle - Light	.223 (5.56 mm) M193 Ball, FMC	55 gr (3.6 gr)	.223 in. (5.56 mm)	3200-3300 ft/s (975-1006 m/s)	3
	R2 Rifle - Heavy, SP	.30-‘06 SP	180 gr (11.7 gr)	.308 in. (7.8 mm)	2850-3000 ft/s (867-914 m/s)	3

TABLE 1 (continued)
International Ballistic Testing Standards Examples *(1 June 2018)*

Organization and Standard ID	*Test Standard or Rating*	*Ammunition Caliber and Type*	*Bullet Weight*	*Bullet Diameter*	*Velocity*	*Number of Shots*
ASTM International ASTM F1233 (continued)	R3 Rifle - Heavy, J	.308 Winchester M80 Ball, FMC	147 gr (9.5 gr)	.308 in. (7.8 mm)	2700-2800 ft/s (823-853 m/s)	3
	R4-AP Rifle, AP	.30-‘06 M2-AP	166 gr (10.8 g)	.308 in. (7.8 mm)	2715-2850 ft/s (828-867 m/s)	1
	R5 Rifle, Jacketed	.50 Ball, FMC	709.5 gr (45.9 g)	.510 in. (12.7 mm)	2760-2860 ft/s (841-867 m/s)	1
	SH1 Shotgun – Buck Shot	12 gauge 3-in Magnum	00 Buckshot 15 pellets	n/a	1150-1250 ft/s (350-381 m/s)	1
	SH2 Shotgun - Slug	12 gauge Rifled slug	1 oz (28.3 gr)	n/a	1600-1700 ft/s (487-518 m/s)	3
Councils of Standards Australia and New Zealand AS/NZ 2343	G0	9 mm Parabellum FMJ	115 gr 7.45 g	.355 in. (9 mm)	1294-1362 ft/s (394-415 m/s)	3
	G1	.357 Magnum SWC	158 gr (10.24 g)	.357 in. (9.07 mm)	1467-1532 ft/s (447-467 m/s)	3
	G2	.44 Magnum SWC	240 gr (15.55 g)	.427 in. (11.18 mm)	1568-1634 ft/s (478-498 m/s)	3
	R1	.223 caliber, 5.56 mm NATO M193	55 gr (3.56 g)	.223 in. (5.66 mm)	3182-3248 ft/s (970-990 m/s)	3
	R2	.308 caliber, 7.62 mm NATO M80	147 gr (7.53 g)	.308 in. (7.82 mm)	2766-2831 ft/s (843-863 m/s)	3
	S0	12 Gauge $2^3/_4$ in. Shot	493 gr (31.95 g)	n/a	1289-1355 ft/s (393-413 m/s)	3
	S1	12 Gauge $2^3/_4$ in. Shot	382 gr (24.75 g)	n/a	1532-1598 gr. (467-487 g)	2
European Standard EN 1063	BR1	.22 LR RNL	40 gr (2.59 g)	.222 in. (5.63 mm)	1048-1214 ft/s (319-370 m/s)	3
	BR2	9 mm Luger FSJ-RNSC	124 gr (8.04 g)	.354 in. (9 mm)	1280-1345 ft/s 390-410 m/s	3
	BR3	.357 Magnum FSJ-CNSC	158 gr (10.24 g)	.357 in. (9.07 mm)	1378-1444 ft/s 420-440 m/s	3
	BR4	.44 Magnum FCJ-FNSC	240 gr (15.55 g)	.427 in. (11.18 mm)	1411-1476 ft/s 430-450 m/s	3
	BR5	5.56 x 45 NATO (.223 Remington) SS 109 steel penetrator	62 gr (4.02 g)	.223 in. (5.66 mm)	3084-3150 ft/s 940-960 m/s	3
	BR6	7.62 x 51 NATO M80 FSJ	147 gr (9.53 g)	.308 in. (7.82 mm)	2690-2756 ft/s 820-840 m/s	3
	BR7	7.62 x 51 NATO AP SHC	150 gr (9.72 g)	.308 in. (7.82 mm)	2657-2723 ft/s 810-830 m/s	3
	SG1	12 Gauge shotgun solid lead Brenneke slug	478 gr (30.97 g)	n/a	1312-1444 ft/s (400-440 m/s)	1
	SG2	12 Gauge shotgun solid lead Brenneke slug	478 gr (30.97 g)	n/a	1312-1444 ft/s (400-440 m/s)	3

TABLE 1 (continued)
International Ballistic Testing Standards Examples *(1 June 2018)*

Organization and Standard ID	*Test Standard or Rating*	*Ammunition Caliber and Type*	*Bullet Weight*	*Bullet Diameter*	*Velocity*	*Number of Shots*
German Deutche Institut fur Normung DIN52-290	C1-SF and C1-SA	9 mm Parabellum FMJ	124 gr (8.04 g)	.355 in. (9 mm)	1165-1198 ft/s (355-365 m/s)	3
	C2-SF and C2-SA	.357 Magnum FMJ	158 gr (10.24 g)	.357 in. (9.07 mm)	1362-1394 ft/s (415-425 m/s)	3
	C3-SF and C3-SA	.44 Magnum FMJ	240 gr (15.55 g)	.427 in. (11.18 mm)	1427-1460 ft/s (435-445 m/s)	3
	C4-SF and C-4 SA	.308 caliber, 7.62 mm NATO M80	147 gr (9.53 g)	.308 in. (7.82 mm)	2575-2608 ft/s (785-795 m/s)	3
	C5-SF and C5-SA, .30, 7.62 NATO	.308 caliber , 7.62 mm NATO M61 AP	150 gr (9.72 g)	.308 in. (7.82 mm)	2625-2657 ft/s (800-810 m/s)	3
HP White Laboratories HPW-TP 0500.02	A	.38 Special RNL	158 gr (10.24 g)	.357 in. (9.07 mm)	700-800 ft/s (213-274 m/s)	3
	B	9 mm x 19 FMJ	124 gr (8.04 g)	.355 in. (9 mm)	1100-1180 ft/s (335-360 m/s)	3
	C	.44 Magnum JSP	240 gr (15.55 g)	.427 in. (11.18 mm)	1350-1450 ft/s (411-442 m/s)	3
	D	7.62 x 51 NATO M80, Ball	147 gr (9.53 g)	.308 in. (7.82 mm)	2725-2825 ft/s (831-861 m/s)	3
	E	.30-06 M2 AP	165 gr (10.69 g)	.308 in. (7.82 mm)	2725-2825 ft/s (831-861 m/s)	3
MIL-SAMIT (Military Small Arms Multiple Impact Test)	Part 1	.308 caliber, 7.62 mm NATO M80	147 gr (9.53 g)	.308 in. (7.82 mm)	2750-2850 ft/s (838-869 m/s)	25
	Part 2	.308 caliber, 7.62 mm NATO M61 AP	150 gr (9.72 g)	.308 in. (7.82 mm)	> 2800 ft/sec (> 853 m/s)	25
US National Institute of Justice NIJ 0108.01	Type I	.22 long rifle LRHV Lead	40 gr (2.6 g)	.222 in. (5.64 mm)	1010-1090 ft/s (308-332 m/s)	5
		.38 Special RN Lead	158 gr (10.2 g)	.357 in. (9.07 mm)	800-900 ft/s (244-274 m/s)	5
	Type IIA	.357 Magnum JSP	158 gr (10.2 g)	.357 in. (9.07 mm)	1200-1300 ft/s (366-396 m/s)	5
		9 mm FMJ	124 gr (8.0 g)	.355 in. (9 mm)	1050-1130 ft/s (320-344 m/s)	5
	Type II	.357 Magnum JSP	158 gr (10.2 g)	.308 in. (7.82 mm)	1345-1445 ft/s (410-440 m/s)	5
		9 mm FMJ	124 gr (8.0 g)	.355 in. (9 mm)	1135-1215 ft/s (346-370 m/s)	5
	Type IIIA	.44 Magnum Lead SWC Gas Checked	240 gr (15.55 g)	.427 in. (11.08 mm)	1350-1450 ft/s (411-442 m/s)	5
		9 mm FMJ	124 gr (8.0 g)	.355 in. (9 mm)	1350-1450 ft/s (411-442 m/s)	5
	Type III	7.62 mm (.308 Winchester) FMJ	150 gr (9.7 g)	.308 in. (7.82 mm)	2700-2800 ft/s (823-853 m/s)	5
	Type IV	30-06 AP	166 gr (10.8 g)	.308 in. (7.82 mm)	2800-2900 ft/s (853-884 m/s)	1

TABLE 1 (continued)
International Ballistic Testing Standards Examples *(1 June 2018)*

Organization and Standard ID	*Test Standard or Rating*	*Ammunition Caliber and Type*	*Bullet Weight*	*Bullet Diameter*	*Velocity*	*Number of Shots*
Underwriters Laboratories UL 752	Level 1	9 mm FMCJ w/lead core	124 gr (8.0 g)	.354 in. (9 mm)	1175-1293 ft/s (358-394 m/s)	3
	Level 2	.357 Magnum JSP	158 gr (10.2 g)	.357 in. (9.07 mm)	1250-1375 ft/s (381-419 m/s)	3
	Level 3	.44 Magnum lead SWC, gas checked	240 gr (15.6 g)	.427 in. (11.18 mm)	1350-1485 ft/s (411-453 m/s)	3
	Level 4	.30-06 Rifle LC SP	180 gr (11.7 g)	.308 in. (7.82 mm)	2540-2794 ft/s (774-852 m/s)	1
	Level 5	7.62 mm Rifle LC FMCJ, Military Ball	150 gr (9.7 g)	.308 in. (7.82 mm)	2750-3025 ft/s (838-922 m/s)	1
	Level 6	9 mm FMCJ with LC	124 gr (8.0 g)	.354 in. (9 mm)	1400-1540 ft/s (427-469 m/s)	5
	Level 7	5.56 rifle FMCJ with LC	55 gr (3.56 g)	.223 in. (5.66 mm)	3080-3388 ft/s (939-1033 m/s)	5
	Level 8	7.62 mm Rifle LC FMCJ, Military Ball	150 gr (9.7 g)	.308 in. (7.82 mm)	2750-3025 ft/s (838-922 m/s)	5
	Level 9	.30-06 AP rifle SC LP filler, FMJ	166 gr (10.8 g)	.308 in. (7.82 mm)	2715-2987 ft/s (828-910 m/s)	1
	Level 10	.50 caliber Rifle LC FMCJ Military Ball, M2	709.5 gr (45.9 g)	.51 in. (12.95 mm)	2810-3091 ft/s (856-942 m/s)	1
	Supplementary Shotgun	12-gauge Rifled lead slug	437 gr (28.3 g)	n/a	1585-1744 ft/s (483-531 m/s)	3
		12 gauge 00 Buck Shot	650 gr (42 g)	n/a	1200-1320 ft/s (366-402 m/s)	3
US State Department SD-STD-01.01	Rifle, Military (R)	7.62 mm M80 Ball	147 gr (9.53 g)	.308 in. (7.82 mm)	2700-2800 ft/s (823-854 m/s)	1
		5.56 mm M193 Ball	55 gr (3.56 g)	.223 in. (5.66 mm)	3135-3235 ft/s (956-986 m/s)	1
		5.56 mm M855 Ball	62 gr (4.02 g)	.223 in. (5.66 mm)	2950-3050 ft/s (899-930 m/s)	1
	Shotgun (SH)	12 gauge 2$^3/_4$-in.	No. 4 Buckshot	n/a	1275-1375 ft/s (389-419 m/s)	1

1.1 Abbreviations

AP	armor piercing
APDS	armor piercing discarding sabot
APFSDS	armor piercing fin stabilized discarding sabot
API	armor piercing incendiary
API BZ	armor piercing incendiary, steel core
C	calculation required
CNSC	Conical Nosed Soft Core
FCJ	Full Copper Jacket

FMC	Full Metal Casing
FMCJ	Full Metal Copper Jacket
FMJ	Full Metal Jacket
FSJ	Full Steel Jacket
HEDP	high explosive, dual purpose
J	Jacketed
JSP	Jacketed Soft Point
L/LN	Lead, long nose
LC	Lead Core
LGC	Lead Gas-Check
LR	Long Rifle
n/a	not applicable
N_{sc}	Nose Shape Coefficient
RN	Round Nosed
RNL	Round Nosed Lead
RNSC	Round Nosed Soft Core (lead)
SHC	Steel Hard Core
SP	Soft Point
SWC	Semi Wad Cutter
ft/s	feet per second
m/s	meters per second
gr	grains
g	grams
in.	inches
mm	millimeters

3 References

1. US DOD, Department Of Defense Test Method Standard: Test Methods For Ballistic Defeat Materials, MIL-STD-3038, US Department of Defense, Washington, D.C., 18-May-2011.
2. ASTM, Standard Test Method for Security Glazing Materials and Systems; ASTM F1233-08 (2013), ASTM International, Inc., West Conshohocken, PA (USA), 2013.
3. UL, UL Standard for Safety for Bullet Resisting Equipment; UL 752, Underwriters Laboratories Inc., Northbrook, IL (USA), 11th ed., 2005.
4. *Australia/New Zealand Standard:* Bullet-Resistant Panels and Elements, AS/NZS 2343: 1997, Published jointly by Standards Australia (Homebush NSW, Australia) and Standards New Zealand (Wellington, New Zealand), 1997.

5. British Standards Institution, Standard BS EN 1063:2000 Glass in Building - Security Glazing - Testing and Classification of Resistance Against Bullet Attack, 2000.

   Notes:

   a. BS EN 1063:2000 replaces BS-5051 (1988).

   b. EN 1063:1999 (see Item 7 below) is the same as BS EN 1063:2000.

   c. See also complimentary test standards:

      - BS EN 1522:1999, Windows, doors, shutters and blinds – Bullet resistance – Requirements and classification
      - BS EN 1523:1999, Windows, doors, shutters and blinds – Bullet resistance – Test method

6. Deutches Institut fur Normung (DIN), Standard 52 290, Security Glazing, 1988.

7. *European Standard EN 1063:1999:* Glass in Building – Security Glazing – Testing and Classification of Resistance Against Bullet Attack, 1999.

8. HPW, Test Procedure: Transparent Materials for Use in Forced Entry or Containment Barriers, Procedure No. HPW-TP-0500.03, H.P. White Laboratory, Inc., Street, MD (USA), March 2003.

9. US DOJ/National Institute of Justice, Ballistic Resistant Protective Materials NIJ Standard 0108.01, US Department of Justice, Washington, D.C., 1985.

10. U.S. DOS, Certification Standard – Forced Entry and Ballistic Resistance of Structural Systems, Standard No. SD-STD-01.01, US Department of State, Washington, D.C., Revision G (Amended), April 30, 1993.