GUIDE FOR BUILDING AND CLASSING

INTERNATIONAL NAVAL SHIPS
2018

PART 6
OPTIONAL NOTATIONS

(Updated June 2018 – see next page)

American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862

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Updates

June 2018 consolidation includes:

- March 2018 version plus Notice No. 2

March 2018 consolidation includes:

- January 2018 version plus Notice No. 1

Change Notice *(2018)*

The effective date of each technical change since 1993 is shown in parentheses at the end of the subsection/paragraph titles within the text of each Part. Unless a particular date and month are shown, the years in parentheses refer to the following effective dates:

(2000) and after	1 January 2000 (and subsequent years)	*(1996)*	9 May 1996
(1999)	12 May 1999	*(1995)*	15 May 1995
(1998)	13 May 1998	*(1994)*	9 May 1994
(1997)	19 May 1997	*(1993)*	11 May 1993

Listing by Effective Dates of Changes from the 2018 Guide

Notice No. 1 (effective on 1 March 2018) to the 2018 Guide is summarized below.

EFFECTIVE DATE 1 March 2018 – shown as *(1 March 2018)*
(based on the contract date for new construction between builder and Owner)

Part/Para. No.	*Title/Subject*	*Status/Remarks*
Part 6, Chapter 3 (New)	Hull Girder Ultimate Strength Assessment	To introduce a Notation **UHS** related to the evaluation of the Hull Girder Ultimate Strength of a vessel. (Incorporates Notice No. 1)
Part 6, Chapter 4 (New)	Naval Ship Safety Certificate	To introduce new service “Naval Ship Safety Certificate”. (Incorporates Notice No. 1)

Notice No. 2 (effective on 1 June 2018) to the 2018 Guide is summarized below.

EFFECTIVE DATE 1 June 2018 – shown as *(1 June 2018)*
(based on the contract date for new construction between builder and Owner)

Part/Para. No.	*Title/Subject*	*Status/Remarks*
Part 6, Chapter 5 (New)	Mission Threats Protection	To introduce the **BFP1**, **BFP2** and **BFP3** notations, which indicate ballistic and fragment hazard protection. (Incorporates Notice No. 2)

PART

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Foreword

Part 6 of the ABS *Guide for Building and Classing International Naval Ships* provides requirements regarding those optional notations offered by ABS that are most frequently requested and/or considered to be most applicable or unique to military vessels and other Government owned vessels in non-commercial service. A complete listing of available optional notations is on the ABS website (www.eagle.org). The requirements in Part 6 apply in addition to the basic requirements for Classification, and only apply for those optional notations that are requested.

At this time, the requirements for certain optional notations are included throughout the Guide (mostly in Part 3 and Part 4) as is done in the ABS *Rules for Building and Classing Steel Vessels*. Future updates to this Guide will move such optional notation requirements into separate Chapters in Part 6 so that Parts 1, 2, 3, 4, 5, and 7 will contain the basic requirements for classification and all other additional requirements for obtaining optional notations (other than the related Survey After Construction requirements, which will remain in Part 7) will be contained in Part 6.

In many cases, the requirements for optional notations have already been established for application to commercial vessels and published separately in an ABS Rules or Guides. Where this is the case, those Rules and Guides will be incorporated herein by reference, and Part 6 of this Guide will only identify the modifications needed to be made to them for their application to ships to be classed to this Guide.

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Optional Notations

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CHAPTER 1 Strengthening for Navigation in Ice

SECTION 1 General

1 Application

Part 6, Chapter 1 of the ABS *Rules for Building and Classing Steel Vessels* provides the requirements for obtaining optional notations with regard to ice strengthening classes and is incorporated, without edit, as Part 6, Chapter 1 of this Guide. The requirements are applicable to vessels of any length and are to be met in addition to the basic requirements for classification as contained elsewhere in this Guide. In certain areas it refers to rule cites in the ABS *Rules for Building and Classing Steel Vessels*; where these appear, the corresponding requirements contained in this Guide are to be followed.

It is the responsibility of the owner to determine which ice class is most suitable for the intended service; however, ABS should be consulted prior to this determination and prior to actual application or use of the requirements for any given vessel acquisition.

The attention of designers, owners and operators is directed to the optional ABS *Guide for Vessels Operating in Low Temperature Environments* for considerations not otherwise covered by the requirements for these optional notations. IMO statutory instruments having requirements specific to operation in cold regions should also be considered.

2 Notations

The ice class notations available are shown in the following table.

Ice Class Notations *(2015)*

Polar Class (6-1-1, 6-1-2, 6-1-3)	*Polar Class, Enhanced (6-1-4)*	*First-year Ice Class (6-1-5)*	*Baltic Class (6-1-6)*
PC1	**PC1, Enhanced**		
PC2	**PC2, Enhanced**		
PC3	**PC3, Enhanced**		
PC4	**PC4, Enhanced**		
PC5	**PC5, Enhanced**		
PC6	**PC6, Enhanced**		**1AA**
PC7	**PC7, Enhanced**	**A0**	**1A**
		B0	**1B**
		C0	**1C**
		D0	
		E0	

Note: The shaded ice classes are eligible for **Ice Breaker** class notation.

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CHAPTER 2 Bridge Design Notations (NBL, NBLES, NIBS)

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CHAPTER 2 Bridge Design Notations (NBL, NBLES, NIBS)

SECTION 1 General

1 Application

This Chapter establishes the requirements for obtaining optional notations related to the design of the bridge, the layout and certification of equipment on the bridge, and the degree of equipment functional and physical integration. To obtain one of the optional notations, the associated requirements to be met are in addition to those specified elsewhere in the Rules with regard to the bridge and its equipment.

3 Notations

The following notations are available:

NBL	Navigation Bridge Layout
NBLES	Navigation Bridge Layout and Equipment/Systems
NIBS	Navigation Integrated Bridge System

5 Requirements

The requirements for obtaining the optional notations are contained in the ABS *Guide for Bridge Design and Navigation Equipment/Systems.* It was originally written for application to commercial vessels and therefore contains references to organizations and standards with which commercial vessels are required to comply. For its application to military vessels and other Government-owned vessels in non-commercial service, the following understandings and modifications apply.

i) Where references are made to SOLAS and other IMO Conventions or Codes, they are to apply unless specified otherwise by the Naval Administration.

ii) Where the terms "Administration" or "flag Administration" are used, these are to be interpreted as referring to the "Naval Administration".

iii) Where reference is made to ABS *Rules for Building and Classing Steel Vessels (Steel Vessel Rules),* the corresponding requirements contained in this Guide are to be followed.

iv) Subsection A3.2 does not apply.

v) In section A7, the requirement for statutory certificates to be retained on board does not apply.

vi) In section A11, the following definitions are to be added:

Inertial Navigation System (INS) – A navigation aid that uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes) to continually calculate via dead reckoning the position, orientation and velocity of a moving object without the need for external references.

Long Range Identification & Tracking (LRIT) – system used for the identification and tracking of ships to comply with IMO resolution MSC.202(81) and SOLAS Regulation 19-1.

Multi-Function Radar (MFR) – Radar system that combines the functions provided by separate radars or systems aboard ship and performs multiple functions with inputs from other ship systems.

Navigation Data Distribution System (NDDS) – A redundant navigation system with the capability to combine all individual navigation systems into a composite survivable source of best navigation data.

Ship Security Alert System (SSAS) – A system to strengthen maritime security and suppress acts of terrorism and piracy against shipping.

Voyage Data Recorder (VDR) – A data recording system designed for all vessels required to comply with IMO Res. A.861(20).

vii) In paragraph A13.1.1, in addition to what is required, the Concept of Operations with respect to communications and navigation functions, activities, and equipment on the bridge is also to be submitted.

viii) In subsection A13.3, in addition to what is required, a Failure Modes and Effects Analysis (FMEA) is also to be submitted. The FMEA is to demonstrate that integrated bridge and navigation system networks are designed such that failure of the network will not prevent individual equipment from performing their individual functions, and that the network has sufficient redundancy such that a single failure will not disrupt distribution of navigation data to end users.

ix) In subsection B5.6, add two additional paragraphs as follows:

B5.6.11 Military Related Operations

Functions related to military operations, such as operation of weapons and weapon systems, that are performed from workstations or consoles located on the navigation bridge should not conflict with the use of workstations for safety of navigation.

B5.6.12 Electro-Magnetic Compatibility (EMC)

Electromagnetic compatibility can be of significant concern on naval ships which typically have high concentration of electronic equipment, transmitters and receivers located in close proximity. Electrical and electronic equipment located on the navigation bridge or in the vicinity of the navigation bridge are to be tested for electromagnetic compatibility and are to comply with the emission limits and minimum immunity requirements of IEC 60945, or equivalent requirements of the Naval Administration.

x) Paragraph C13.5.1 does not apply.

xi) In subsection C13.5, add the following paragraph:

C13.5.3 Multi-Function Radars (MFR) or other mission system related radars for use on naval vessels are to comply with performance requirements as specified by the Naval Administration. Unless otherwise required by the Naval Administration, radars required for navigation (including multi-function radars, if used in part for navigation) are to comply with IMO Res. A.477(XII), as amended by Annex 4 to MSC.64(67).

xii) In paragraph C13.8.2, the requirement for the wireless portable device for communication does not apply.

xiii) Replace subsection C13.8 with the following:

C13.8 Bridge Navigation Watch Alarm System (BNWAS)

Where required by the Naval Administration, a BNWAS is to be installed. The system is to comply with SOLAS Regulation V/19, as amended by MSC.282(86), which requires this system to be installed on all new and existing ships. The system is to meet the requirement of the performance standards set out by MSC.128(75) and IEC 62616.

xiv) In subsection C13.10, add the following: "The AIS may be provided with special modes of operation as required by the Naval Administration to support the vessel's operational mission."

xv) Add subsection C13.11 as follows:

C13.11 Inertial Navigation System (INS)

Where required by the Naval Administration, an Inertial Navigation System (INS) is to be installed to provide a separate and independent means of determining ship heading, roll, pitch and position change.

xvi) Add subsection C13.12 as follows:

C13.12 Ship Security Alert System (SSAS)

Where required by the Naval Administration, a Ship Security Alert System is to be installed. The system contributes to the IMO's efforts to strengthen maritime security and suppress acts of terrorism and piracy against shipping. It consists of a beacon that can be activated, enabling appropriate law-enforcement or military forces to be notified and dispatched.

xvii) Add subsection C13.13 as follows:

C13.13 Long Range Identification and Tracking (LRIT)

Where required by the Naval Administration, a Long Range Identification and Tracking system is to be installed. The system is used for the identification and tracking of ships and consists of installed shipboard satellite communications equipment and communication service providers. This system is separate and distinct from the Automatic Identification System (AIS) which is required.

xviii) Add subsection C13.14 as follows:

C13.14 Voyage Data Recorder (VDR)

Where required by the Naval Administration, a Voyage Data Recorder is to be installed. The VDR system is to comply with IMO Res. A.861(20). The system is to collect data from various sensors on board the vessel and then compresses and stores this information in a mounted protective tamper-proof storage unit.

xix) In Table C1, in the "Equipment" column for item A12, add: "or Multi-Function Radar".

xx) In Table C1, in the "Remarks" column for item B17, add: "ECDIS, Speed Log, Echo Sounder, Collision Avoidance, AIS, Radar/ARPA, GPS".

xxi) Add subsection D13.5 as follows:

D13.5 Navigation Data Distribution System (NDDS)

Where required by the Naval Administration, a Navigation Data Distribution System (NDDS) is to be installed to provide a redundant system with the capability to combine all individual navigation systems into a composite survivable source of best navigation data. The system is to include the real time acceptance, validation and distribution of navigation data as determined by the Naval Administration.

xxii) In subsection D15.1, in addition to ECDIS and IBS, simplified diagrams are also to include the Navigation Data Distribution System (NDDS).

xxiii) In subsection D15.2, in addition to ECDIS and IBS, periodic test procedures are also to be provided for the Navigation Data Distribution System (NDDS).

xxiv) In paragraph D19, in addition to ECDIS and IBS, the sea trial program is also to include test details for the Navigation Data Distribution System (NDDS).

xxv) In Table D1, in the "Equipment" column for item A3, add: "NDDS, INS, LRIT, SSAS, and VDR".

PART

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CHAPTER 3 Hull Girder Ultimate Strength Assessment

(1 March 2018)

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CHAPTER 3 Hull Girder Ultimate Strength Assessment

SECTION 1 General

1 Application

This Section establishes the requirement for the optional notation **UHS**.

The requirements are applicable to the hull structure within 0.4*L* amidships in sea-going conditions. If the structure of the vessel complies with the requirements in this chapter and Sections 3-2-1 to 3-2-11, it will be classed and distinguished in the *Record* by the notation **UHS** placed after the appropriate hull classification notation.

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CHAPTER 3 Hull Girder Ultimate Strength Assessment

SECTION 2 Checking Criteria

1 Vertical Hull Girder Ultimate Limit State

The vertical hull girder bending moments are to satisfy the following limit state:

$$\gamma_S M_{sw} + \gamma_W M_w \leq \frac{M_U}{\gamma_R}$$

where

M_{sw} = still water bending moment, in kN-m (tf-m), in accordance with 3-2-1/3.3

M_w = maximum wave-induced vertical bending moment, in kN-m (tf-m), in accordance with 3-2-1/3.3.3(a)

M_U = vertical hull girder ultimate bending capacity, in kN-m (tf-m), as defined in 6-3-2/3

γ_S = 1.0 partial safety factor for the still water bending moment

γ_w = partial safety factor for the vertical wave bending moment taking into account environmental and wave load prediction uncertainties

1.3 for hogging wave bending moment

1.5 for sagging wave bending moment

γ_R = 1.10 partial safety factor for the vertical hull girder bending capacity covering material, geometric and strength prediction uncertainties

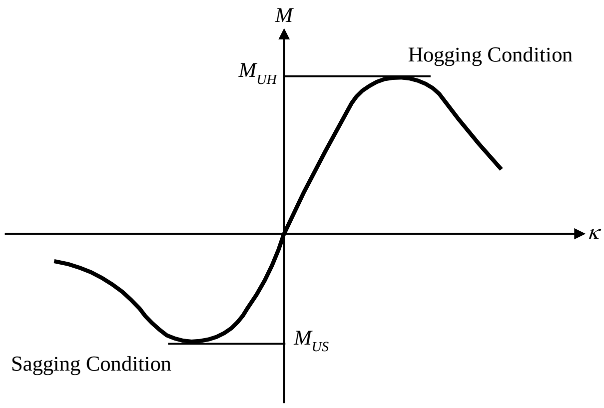
For vessels where the vertical hull girder bending capacity is evaluated with gross scantlings, γ_R is to be taken as 1.25.

3 Hull Girder Ultimate Bending Capacity

3.1 General

The ultimate bending moment capacities of a hull girder section in hogging and sagging conditions are defined as the maximum values (positive M_{UH}, negative M_{US}) on the static nonlinear bending moment-curvature relationship M-κ. See 6-3-2/Figure 1. The curve represents the progressive change and collapse behavior of the hull girder under vertical bending moments. Hull girder failure is controlled by buckling, ultimate strength and yielding of longitudinal hull girder structural elements.

FIGURE 1
Bending Moment – Curvature Curve M-κ *(1 March 2018)*



The curvature of the critical inter-frame section, κ, is defined as:

$$\kappa = \frac{\theta}{\ell} \text{ m}^{-1}$$

where:

θ = relative angle rotation of the two neighboring cross-sections at transverse frame positions

ℓ = transverse frame spacing in m, (i.e., span of longitudinals)

The calculation of the hull girder ultimate bending capacity is found by identifying the critical failure modes of all hull girder structural elements.

Hull girder structural members compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements are to be considered in order to identify the weakest inter-frame failure mode. Examples of relevant failure modes are plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling, and their interactions,

The effects of shear force, torsional loading, horizontal bending moment and lateral pressure are neglected.

3.3 Physical Parameters

For the purpose of describing the calculation procedure in a concise manner, the physical parameters and units used in the calculation procedure are given below.

3.3.1 Hull Girder Load and Cross Section Properties

M_i = hull girder bending moment, in kN-m (tf-m)

F_i = hull girder longitudinal force, in kN (tf)

I_v = hull girder moment of inertia around the horizontal neutral axis of intact section, in m^4

SM = hull girder section modulus, in m^3

SM_{dk} = elastic hull girder section modulus at deck at side, in m^3

SM_{kl} = elastic hull girder section modulus at bottom, in m^3

κ = curvature of the ship cross section, in m^{-1}

z_j = distance from baseline, in m

3.3.2 Material Properties

σ_{yd} = specified minimum yield stress of the material, in N/cm^2 (kgf/cm^2)

E = Young's modulus for steel, 2.06×10^7 N/cm^2 (2.1×10^6 kgf/cm^2)

ν = Poisson's ratio, may be taken as 0.3 for steel

Φ = edge function as defined in 6-3-2/3.9.2

ε = relative strain defined in 6-3-2/3.9.2

3.3.3 Stiffener Sectional Properties

The properties of a longitudinal cross section are shown in 6-3-2/Figure 2.

A_s = sectional area of the longitudinal or stiffener, excluding the associated plating, in cm^2

b_1 = smaller outstanding dimension of flange with respect to centerline of web, in cm

b_f = total width of the flange/face plate, in cm

d_w = depth of the web, in cm

t_p = net thickness of the plating, in cm

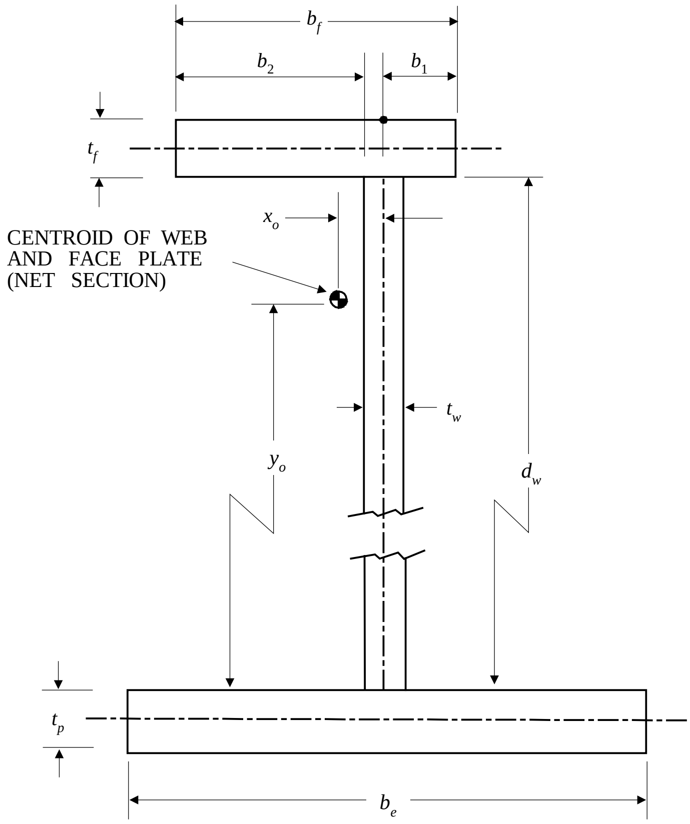
t_f = net thickness of the flange/face plate, in cm

t_w = net thickness of the web, in cm

x_o = distance between centroid of the stiffener and centerline of the web plate, in cm

y_o = distance between the centroid of the stiffener and the attached plate, in cm

FIGURE 2
Dimensions and Properties of Stiffeners *(1 March 2018)*



3.5 Calculation Procedure

The hull girder ultimate bending capacity M_U (M_{UH} or M_{US}) is defined as the peak value of the curve with vertical bending moment M versus the curvature κ of the ship cross section as shown in 6-3-2/Figure 1.

The curve M-κ is obtained by means of an incremental-iterative approach. The steps involved in the procedure are given below.

The bending moment M_i which acts on the hull girder transverse section due to the imposed curvature κ_i is calculated for each step of the incremental procedure. This imposed curvature corresponds to an angle of rotation of the hull girder transverse section about its effective horizontal neutral axis, which induces an axial strain ε in each hull structural element.

The stress σ induced in each structural element by the strain ε is obtained from the stress-strain curve σ-ε of the element, which takes into account the behavior of the structural element in the nonlinear elasto-plastic domain.

The force in each structural element is obtained from its area times the stress and these forces are summed to derive the total axial force on the transverse section. Note the element area is taken as the total net area of the structural element. This total force may not be zero as the effective neutral axis may have moved due to the nonlinear response. Hence, it is necessary to adjust the neutral axis position, recalculate the element strains, forces and total sectional force, and iterate until the total force is zero.

Once the position of the new neutral axis is known, the correct stress distribution in the structural elements can be obtained. The bending moment M_i about the new neutral axis (due to the imposed curvature κ_i) is then obtained by summing the moment contribution given by the force in each structural element.

The main steps of the incremental-iterative approach are summarized as follows:

Step 1 Divide the hull girder transverse section into structural elements, (i.e., longitudinal stiffened panels (one stiffener per element), hard corners and transversely stiffened panels). See 6-3-2/3.7.

Step 2 Derive the stress-strain curves (also known as the load-end shortening curves) for all structural elements. See 6-3-2/3.9.

Step 3 Determine the curvature step size $\Delta\kappa$:

$$\Delta\kappa = \frac{\max\left(SM_{dk}\sigma_{yd}, SM_{kl}\sigma_{yd}\right)}{100EI_v}$$

The curvature for the first step $\kappa 1$ is to be taken as $\Delta\kappa$.

Derive the neutral axis $z_{NA\text{-}i}$ for the first incremental step (i = 1) with the value of the elastic hull girder section modulus. See 3-2-1/9.

Step 4 For each element (index j), calculate the strain $\varepsilon_{ij} = \kappa_i(z_j - z_{NA\text{-}i})$ corresponding to κ_i, the corresponding stress σ_j, and hence the force in the element $\sigma_j A_j$. The stress σ_j corresponding to the element strain ε_{ij} is to be taken as the minimum stress value from all applicable stress-strain curves σ-ε for that element.

Step 5 Determine the new neutral axis position $z_{NA\text{-}i}$ by checking the longitudinal force equilibrium over the whole transverse section. Hence, adjust $z_{NA\text{-}i}$ until:

$$F_i = 10^{-3}\ \Delta A_j \sigma_j = 0$$

Note σ_j is positive for elements under compression and negative for elements under tension. Repeat from Step 4 until equilibrium is satisfied. Equilibrium is satisfied when the change in neutral axis position is less than 0.0001 m.

Step 6 Calculate the corresponding moment by summing the force contributions of all elements as follows:

$$M_i = 10^{-3} \sum \sigma_j A_j \left|\left(z_j - z_{NA-i}\right)\right|$$

Step 7 Increase the curvature by $\Delta\kappa$, use the current neutral axis position as the initial value for the next curvature increment and repeat from Step 4 until the peak value *Mu* occurs on the M-κ curve. The ultimate capacity is the peak value M_u from the M-κ curve.

3.7 Assumptions and Modeling of the Hull Girder Cross-section

In applying the procedure described in this Chapter, the following assumptions are to be made:

i) The ultimate strength is calculated at a hull girder transverse section between two adjacent transverse webs.

ii) The hull girder transverse section remains plane during each curvature increment.

iii) The material properties of steel are assumed to be elastic and perfectly plastic.

iv) The hull girder transverse section can be divided into a set of elements which act independently of each other.

v) The elements making up the hull girder transverse section are:

- Longitudinal stiffeners with attached plating, with structural behavior given in 6-3-2/3.9.2 through 6-3-2/3.9.6
- Transversely stiffened plate panels, with structural behavior given in 6-3-2/3.9.7
- Hard corners, as defined below, with structural behavior given in 6-3-2/3.9.1

vi) The following structural areas are to be defined as hard corners:

- The plating area adjacent to intersecting plates
- The plating area adjacent to knuckles in the plating with an angle greater than 30 degrees
- Plating comprising rounded gunwales

An illustration of hard corner definition for girders on longitudinal bulkheads is given in 6-3-2/Figure 3.

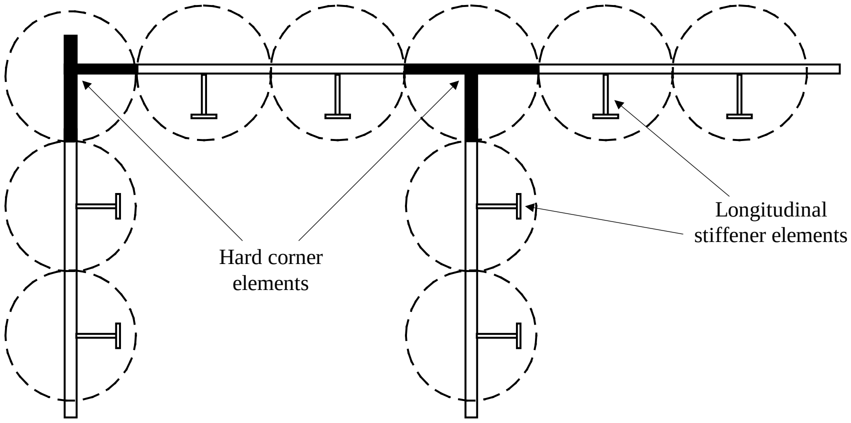
vii) The size and modeling of hard corner elements is to be as follows:

- It is to be assumed that the hard corner extends up to $s/2$ from the plate intersection for longitudinally stiffened plate, where s is the stiffener spacing
- It is to be assumed that the hard corner extends up to $20t_{grs}$ from the plate intersection for transversely stiffened plates, where t_{grs} is the gross plate thickness

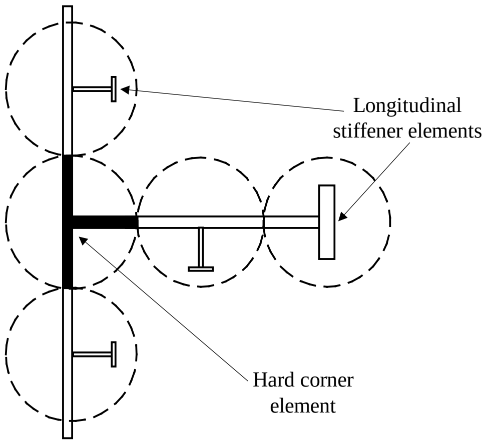
Note: For transversely stiffened plate, the effective breadth of plate for the load shortening portion of the stress-strain curve is to be taken as the full plate breadth (i.e., to the intersection of other plates – not from the end of the hard corner). The area is to be calculated using the breadth between the intersecting plates.

FIGURE 3
Example of Defining Structural Elements *(1 March 2018)*

a) Example showing side shell, inner side and deck



b) Example showing girder on longitudinal bulkhead



3.9 Stress-strain Curves σ-ε (or Load-end Shortening Curves)

3.9.1 Hard Corners

Hard corners are sturdier elements which are assumed to buckle and fail in an elastic, perfectly plastic manner. The relevant stress strain curve σ-ε is to be obtained for lengthened and shortened hard corners according to 6-3-2/3.9.2.

3.9.2 Elasto-Plastic Failure of Structural Elements

The equation describing the stress-strain curve σ-ε of the elasto-plastic failure of structural elements is to be obtained from the following formula, valid for both lengthened and shortened hard corners (6-3-2/Figure 4A) and lengthened stiffeners (6-3-2/Figure 4B):

$$\sigma = \Phi \, \sigma_{yd} \quad \text{kN/cm}^2 \text{ (kgf/cm}^2\text{)}$$

where

Φ = edge function

= -1 for $\varepsilon < -1$

= ε for $-1 < \varepsilon < 1$

= 1 for $\varepsilon > 1$

ε = relative strain

$= \dfrac{\varepsilon_E}{\varepsilon_{yd}}$

ε_E = element strain

ε_{yd} = strain corresponding to yield stress in the element

$= \dfrac{\sigma_{yd}}{E}$

Note: The signs of the stresses and strains in this Section are opposite to those in the rest of the Rules.

FIGURE 4A
Example of Stress Strain Curves σ-ε *(1 March 2018)*

Stress strain curve σ-ε for elastic, perfectly plastic failure of a hard corner

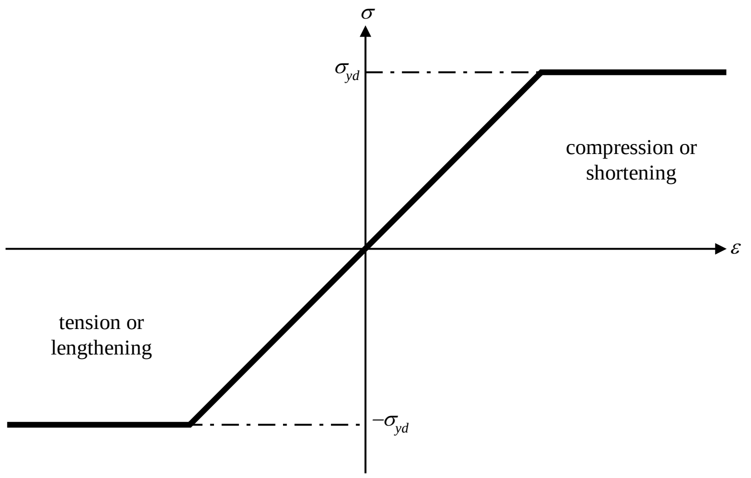
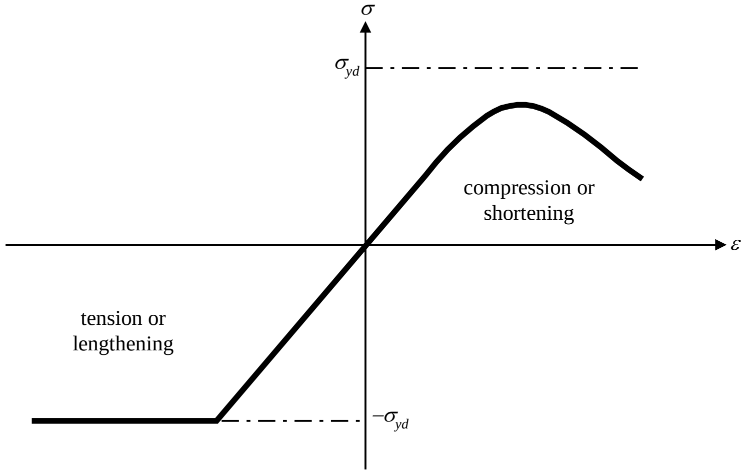


FIGURE 4B
Example of Stress Strain Curves σ-ε *(1 March 2018)*

Typical stress strain curve σ-ε for elasto-plastic failure of a stiffener



3.9.3 Beam Column Buckling

The equation describing the shortening portion of the stress strain curve σ_{CR1}-ε for the beam column buckling of stiffeners is to be obtained from the following formula:

$$\sigma_{CR1} = \Phi \sigma_{C1} \left(\frac{A_s + b_{eff-p} t_p}{A_s + s t_p} \right) \quad \text{kN/cm}^2 \text{ (kgf/cm}^2\text{)}$$

where

σ_{C1} = critical stress, in kgf/cm² (kgf/cm²)

= $\dfrac{\sigma_{E1}}{\varepsilon}$ for $\sigma_{E1} \le \dfrac{\sigma_{yd}}{2}\varepsilon$

= $\sigma_{yd}\left(1 - \dfrac{\sigma_{yd}\varepsilon}{4\sigma_{E1}}\right)$ for $\sigma_{E1} > \dfrac{\sigma_{yd}}{2}\varepsilon$

σ_{E1} = Euler column buckling stress, in kgf/cm² (kgf/cm²)

= $\pi^2 E \dfrac{I_E}{A_E \ell^2}$

ℓ = unsupported span of the longitudinal, in cm

s = plate breadth taken as the spacing between the stiffeners, in cm

I_E = net moment of inertia of stiffeners, in cm⁴, with attached plating of width b_{eff-s}

b_{eff-s} = effective width, in cm, of the attached plating for the stiffener

= $\dfrac{s}{\beta_p}$ for $\beta_p > 1.0$

= s for $\beta_p \le 1.0$

β_p = $\dfrac{s}{t_p}\sqrt{\dfrac{\varepsilon \sigma_{yd}}{E}}$

A_E = net area of stiffeners, in cm², with attached plating of width b_{eff-p}

b_{eff-p} = effective width, in cm, of the plating

= $\left(\dfrac{2.25}{\beta_p} - \dfrac{1.25}{\beta_p^2}\right)s$ for $\beta_p > 1.25$

= s for $\beta_p \le 1.25$

3.9.4 Torsional Buckling of Stiffeners

The equation describing the shortening portion of the stress-strain curve σ_{CR2}-ε for the lateral-flexural buckling of stiffeners is to be obtained according to the following formula:

$$\sigma_{CR2} = \Phi \left(\frac{A_s \sigma_{C2} + s t_p \sigma_{CP}}{A_s + s t_p} \right) \quad \text{kN/cm}^2 \text{ (kgf/cm}^2\text{)}$$

where

σ_{C2} = critical stress

$= \dfrac{\sigma_{E2}}{\varepsilon}$ for $\sigma_{E2} \le \dfrac{\sigma_{yd}}{2}\varepsilon$

$= \sigma_{yd}\left(1 - \dfrac{\sigma_{yd}\varepsilon}{4\sigma_{E2}}\right)$ for $\sigma_{E2} > \dfrac{\sigma_{yd}}{2}\varepsilon$

σ_{CP} = ultimate strength of the attached plating for the stiffener

$= \left(\dfrac{2.25}{\beta_p} - \dfrac{1.25}{\beta_p^2}\right)\sigma_{yd}$ for $\beta_p > 1.25$

$= \sigma_{yd}$ for $\beta_p \le 1.25$

β_p = coefficient defined in 6-3-2/3.9.3

σ_{E2} = Euler torsional buckling stress, in kN/cm^2 (kgf/cm^2), equal to reference stress for torsional buckling σ_{ET}

σ_{ET} = $E[K/2.6 + (n\pi/\ell)^2\Gamma + C_o(\ell/n\pi)^2/E]/I_o[1 + C_o(\ell/n\pi)^2/I_o f_{cL}]$

K = St. Venant torsion constant for the longitudinal's cross section, excluding the associated plating

$= [b_f t_f^3 + d_w t_w^3]/3$

I_o = polar moment of inertia of the longitudinal, excluding the associated plating, about the toe (intersection of web and plating)

$= I_x + mI_y + A_s(x_o^2 + y_o^2)$ in cm^4

I_x, I_y = moment of inertia of the longitudinal about the x- and y-axis, respectively, through the centroid of the longitudinal, excluding the plating (x-axis perpendicular to the web), in cm^4

m = $1.0 - u(0.7 - 0.1d_w/b_f)$

u = asymmetry factor

$= 1 - 2b_1/b_f$

C_o = $E t_p^3/3s$

Γ = warping constant

$\cong mI_{yf}\, d_w^2 + d_w^3\, t_w^3/36$

I_{yf} = $t_f\, b_f^3\,(1.0 + 3.0\, u^2 d_w t_w/A_s)/12$

f_{cL} = critical buckling stress for the associated plating, corresponding to n-half waves

$= \pi^2 E(n/\alpha + \alpha/n)^2(t_p/s)^2/12(1 - \nu^2)$

α = ℓ/s

ℓ = unsupported span of the longitudinal, in cm

s = plate breadth taken as the spacing between the stiffeners, in cm

n = number of half-wave which yield a smallest σ_{ET}

3.9.5 Web Local Buckling of Stiffeners with Flanged Profiles

The equation describing the shortening portion of the stress strain curve σ_{CR3}-ε for the web local buckling of flanged stiffeners is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi\sigma_{yd}\left(\frac{b_{eff-p}t_p + d_{w-eff}t_w + b_f t_f}{st_p + d_w t_w + b_f t_f}\right) \quad \text{kN/cm}^2\ (\text{kgf/cm}^2)$$

where

s = plate breadth taken as the spacing between the stiffeners, in cm

$b_{eff\text{-}p}$ = effective width of the attached plating in cm, defined in 6-3-2/3.9.3

$d_{w\text{-}eff}$ = effective depth of the web, in cm

$= \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right)d_w$ for $\beta_w > 1.25$

$= d_w$ for $\beta_w \le 1.25$

$\beta_w = \frac{d_w}{t_w}\sqrt{\frac{\varepsilon\sigma_{yd}}{E}}$

3.9.6 Local Buckling of Flat Bar Stiffeners

The equation describing the shortening portion of the stress-strain curve σ_{CR4}-ε for the web local buckling of flat bar stiffeners is to be obtained from the following formula:

$$\sigma_{CR4} = \Phi\left(\frac{A_s\sigma_{C4} + st_p\sigma_{CP}}{A_s + st_p}\right) \quad \text{kN/cm}^2\ (\text{kgf/cm}^2)$$

where

σ_{CP} = ultimate strength of the attached plating, in kN/cm² (kgf/cm²)

σ_{C4} = critical stress, in kN/cm² (kgf/cm²)

$= \frac{\sigma_{E4}}{\varepsilon}$ for $\sigma_{E4} \le \frac{\sigma_{yd}}{2}\varepsilon$

$= \sigma_{yd}\left(1 - \frac{\sigma_{yd}\varepsilon}{4\sigma_{E4}}\right)$ for $\sigma_{E4} > \frac{\sigma_{yd}}{2}\varepsilon$

σ_{E4} = Euler buckling stress

$= \frac{0.44\pi^2 E}{12(1-\nu^2)}\left(\frac{t_w}{d_w}\right)^2$

3.9.7 Buckling of Transversely Stiffened Plate Panels

The equation describing the shortening portion of the stress-strain curve σ_{CR5}-ε for the buckling of transversely stiffened panels is to be obtained from the following formula:

$$\sigma_{CR5} = \min\begin{cases}\sigma_{yd}\left[\frac{s}{\ell_{stf}}\left(\frac{2.25}{\beta_p} - \frac{1.25}{\beta_p^2}\right) + 0.115\left(1 - \frac{s}{\ell_{stf}}\right)\left(1 + \frac{1}{\beta_p^2}\right)^2\right] \\ \sigma_{yd}\Phi\end{cases} \quad \text{kN/cm}^2\ (\text{kgf/cm}^2)$$

where

β_p = coefficient defined in 6-3-2/3.9.3

s = plate breadth taken as the spacing between the stiffeners, in cm

ℓ_{stf} = span of stiffener equal to spacing between primary support members, in cm

PART
6

CHAPTER 4 Naval Ship Safety Certificate *(1 March 2018)*

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PART 6

CHAPTER 4 Naval Ship Safety Certificate

SECTION 1 General

1 Application

The Naval Ship Safety Certificate and **NavalSafe(x)** notation are issued based on compliance with The Naval Ship Code (NSC). The NSC is published by the North Atlantic Treaty Organization (NATO) as ANEP (Allied Naval Engineering Publication) 77, and is approved by the nations in the NATO Naval Armaments Group. It is a non-classified document intended to address naval surface ship safety and is based on IMO conventions, resolutions and other sources.

The Code is applicable to all surface craft used for non-commercial government service, such as Navy, Coast Guard, Border Patrol, and Customs. It applies principally to conventionally powered, non-nuclear ships.

When applying the Code, consideration is to be given to determine how the ship will continue to be verified to the Code for recertification during its service operation, in order to avoid unintended safety degradation due to modifications or modernization measures applied to the ship over its life.

The Code requires that a Concept of Operations Statement (or ConOpS) be developed to compare the applicability of the criteria and standards chosen. The ConOpS may change over the service life of a government ship, perhaps several times. Criteria may need to be reconsidered over the life of the ship as the ConOpS evolves. Once this is determined, the Code can provide a path for a ship to be certified by a Naval Administration, along with recognized organizations (RO) such as classification societies, to establish that a ship complies with the design and construction aspects of the code to operate in accordance with the ConOpS provided, as well as within the safety policies, and safety organization, of the government organization in which it will operate.

While the goal-based nature of the Code allows the Naval Administration and ROs to consider alternatives to the typical safety requirements applied to commercial ships, it is important to emphasize two limitations:

1. The Naval Ship Code is not intended as a complete and all inclusive safety management system for a ship or fleet. It is, rather, a tool for the safe operation for a ship or fleet, and may fill an important role in the fleet or administration's safety policy.

2. It includes processes and potential solutions for the defined technical areas which can be applied to any naval ship, within the context of its operational requirements. While fully intended to apply to operating conditions and foreseeable damage scenarios applicable to peacetime and maritime security (as determined in the ConOpS), the Code is not intended to apply to combat operations, or its associated threat conditions. While an important part of a government operated ship intended for military or defense related operations, these are outside of the scope of the Code, and intended to be addressed separately by the appropriate departments within a Naval Administration.

3 Notation

As a recognized Class Society, ABS acts on behalf of the Naval Administration to verify compliance and issue the Naval Ship Safety Certificate (NSSC). This is discussed further in 6-4-1/5.7.

NavalSafe(x) is an optional notation assigned to the ship once the performance requirements of the defined chapter(s) of NSC are met and the Naval Ship Safety Certificate is issued. The index **x** in **NavalSafe(x)** notation represents: **S** (Structure), **BSC** (Buoyancy, Stability and Controllability, **ES** (Engineering Systems), **SS** (Seamanship Systems), **FS** (Fire Safety), **EER** (Escape, Evacuation and Rescue, **C** (Communication), **N** (Navigation), **DG** (Dangerous Goods), **All** (if all entries are applicable).

5 The Process for NSC Certification

The main regulatory elements in the certification process are shown in 6-4-1/Figure 1. The certification of the ship is to be based on a Concept of Operations Statement (ConOpS) defining the ship's function, operational areas and characteristics. The Standards Plan is a list of the technical standards used as based on the goals, functional objectives, and performance requirements for the ship. The Technical File is a compiled list of all the ship specific information. A Naval Ship Safety Certificate and the **NavalSafe(x)** notation is to be issued upon a ship's confirmed compliance with the overall requirements.

FIGURE 1
Process for NSC Certification Simplified *(1 March 2018)*

5.1 Concept of Operations (ConOps) Statement

As seen in 6-4-1/Figure 1 above, the process for certification of a government ship begins with the concept of operations statement, or ConOpS. The ConOpS defines the ship's function, operational areas and characteristics, and serves as the basis for certification. The ConOpS is a list of the ship particulars. Examples are:

i) Mission or roles of the ship

ii) Ship attributes

iii) Displacement measurements

iv) Speed and endurance

v) Post damage capability (non-combat or threat related)

vi) Operational area

vii) Operational Philosophy

viii) Crew description

ix) Environmental operational limits:

  a) Including navigation in ice

x) NSC related engineering equipment:

a) Propulsion machinery/equipment

b) Fire safety related systems and gear

c) Communications and navigation equipment

xi) Maintenance and survey schemes/periodicities

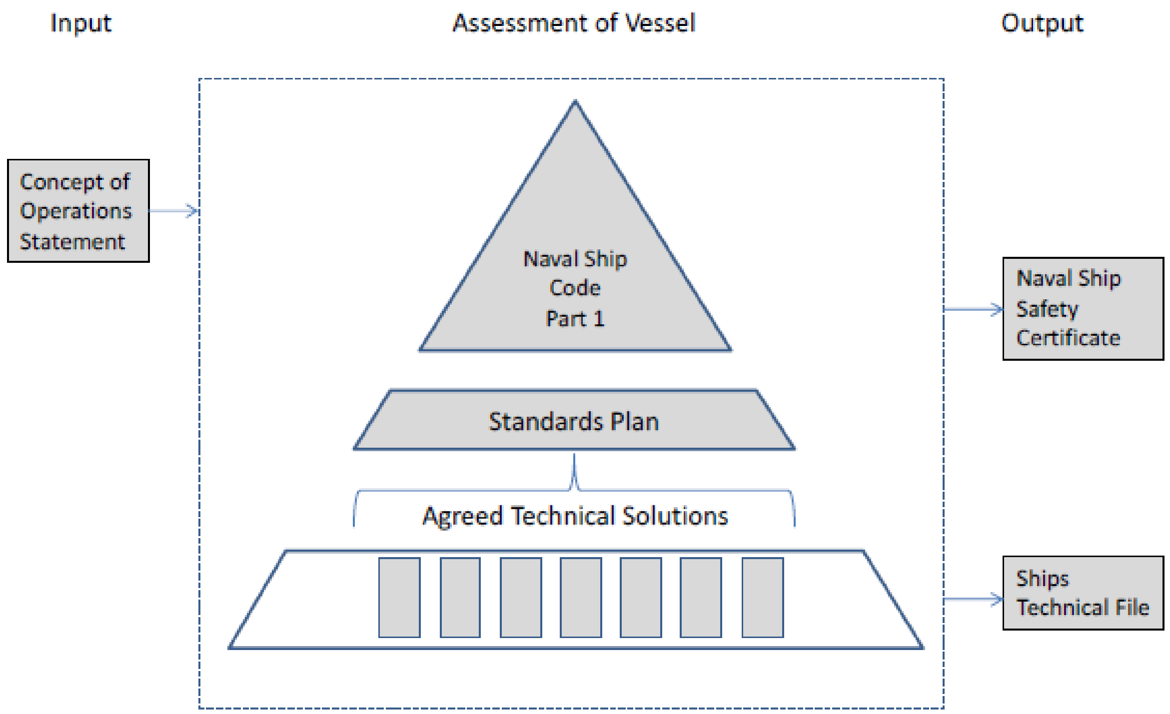
The above is the primary input for the assessment of the ship (see 6-4-1/Figure 2). Once established, the ConOpS is used to begin assessing the ship to Part 1 of the NSC (from Goals to Performance Requirements). Part 2 may be applied to determine agreed upon Solutions to satisfy Tier 1. NSC tier level expansion can be found below, see 6-4-1/7.

An example of a ConOpS form is presented in Part 3, Chapter I, Annex A of the NSC.

5.3 Standards Plan

The Standards Plan is comprised of a listing of technical standards. These are used to verify that the ship meets the Goals, Functional Objectives, and Performance Requirements as verified by the Naval Administration or its recognized organization(s), within the defining parameters of the ConOpS. For example, these may include industry or government design standards for safety equipment, IMO conventions either applied in part or in whole, the applicable rules of a classification society, or other options for solutions deemed appropriate for use as determined by the Naval Administration. This plan is essentially a list or spreadsheet and forms the basis for the Tier 4 Solutions. An example of a Standards Plan form is presented in Part 3, Chapter I, Annex B of the NSC.

FIGURE 2
Main Regulatory Elements in the Certification Process of Ships *(1 March 2018)*



(Source: Naval Ship Code, ANEP 77, Figure P1-I-1)

As the NSC certification process is in progress, documentation is to be created to maintain configuration control of the overall process. These documents will eventually be collected to create the Technical File.

5.5 Technical File

The ship technical file contains information showing how the requirements of the Code have been applied to the ship design and construction. The file is to be complete at delivery of a new ship, provided all aspects of the Code being invoked for this design have been addressed. A typical Technical File may include, but is not limited to, the following:

i) A copy of ConOpS

ii) Applicable NSC Parts/Chapters being invoked

iii) Applicable NSC Tier level being invoked

iv) The complete Standards Plan

v) Interpretations/Justifications made during the NSC certification process

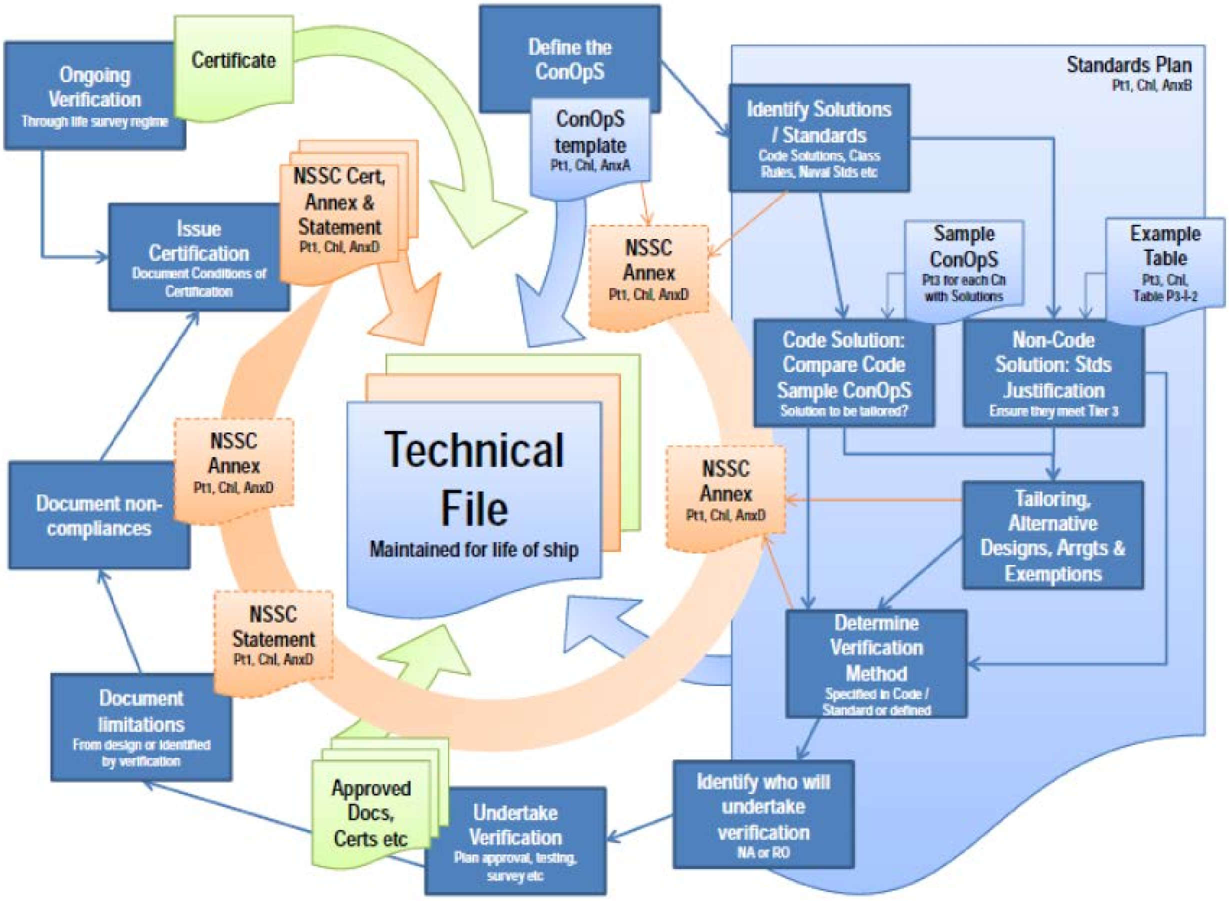
vi) Classification Society information (Rule sets, notations, etc.)

vii) Statutory certificates

viii) Other information as needed

The Technical File is a living document and must be updated to address events such as modifications and modernization initiatives throughout the ship's operational life. The process for technical file compilation is shown in 6-4-1/Figure 3 below.

FIGURE 3
Process for Compilation of a Technical File *(1 March 2018)*



(Source: Naval Ship Code, ANEP 77, Figure P3-I-2)

5.7 Naval Ship Safety Certification (NSSC)

Upon completion of the verification process, the ship may be issued a Naval Ship Safety Certificate (NSSC). This may be issued by the Naval Administration, or jointly with ABS as the recognized organization. The NSSC is to refer to information found in the ConOpS, Standards Plan, and ship construction files maintained by the classification society or Naval Administration. The NSSC contains the certificate itself, an Annex containing key design and verification information, and supporting data related to design information. Once completed, the NSSC then becomes part of the Technical File.

Much like a class certificate issued by a classification society, the NSSC is to be endorsed and renewed at regular intervals as determined by the Naval Administration.

The NSSC should be as clear as practicable in describing the technical standards used, and any determinations or major assumptions made during the NSC process. An example of a NSSC form is provided in Part 3, Chapter I, Annex C of the NSC.

7 Framework of the NSC

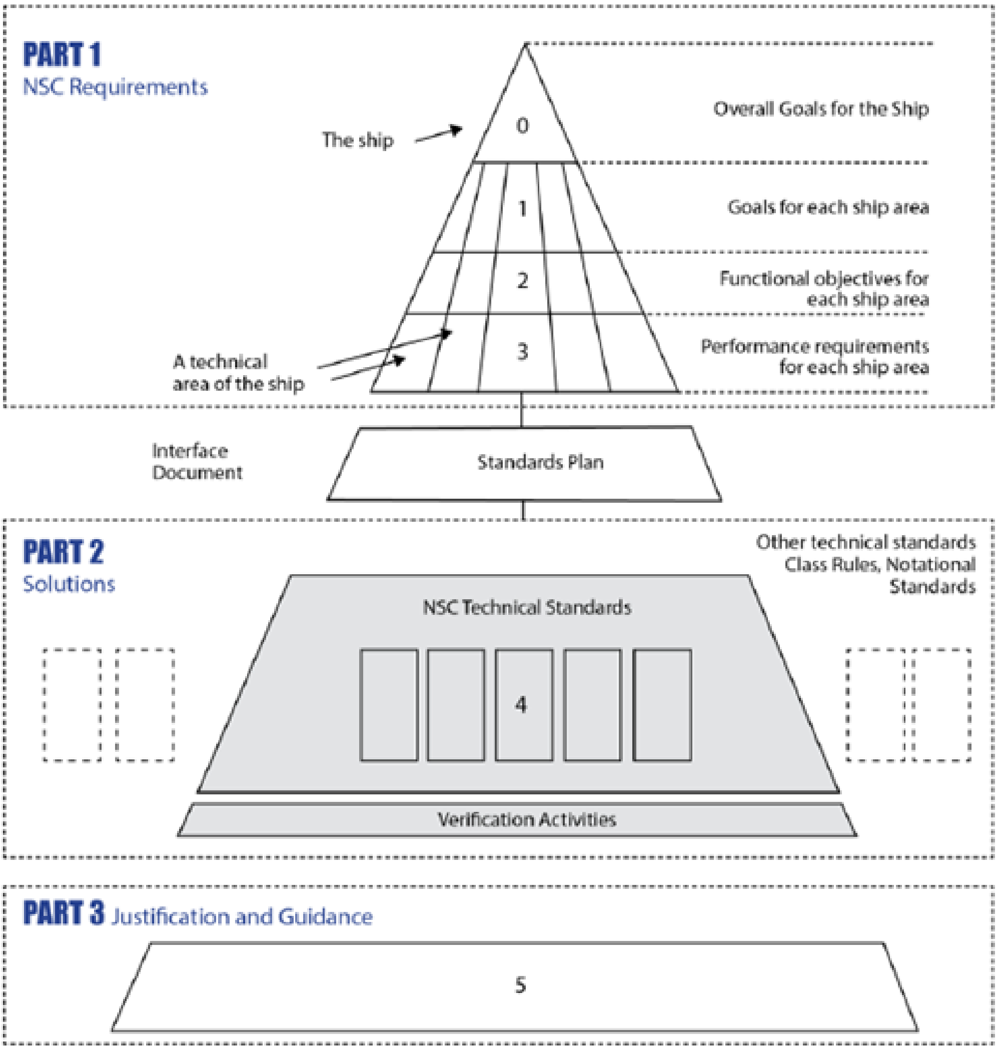
The Naval Ship Code includes three distinct Parts:

- Part 1: NSC Requirements
- Part 2: Solutions
- Part 3: Justification and Guidance

See 6-1-4/Figure 4 below. The increasing width of the triangle as the Naval Ship Code descends through the tiers implies an increasing level of detail. In addition, the vertical diagonals within the triangle refer to different technical areas within the ship, as addressed within the chapters. Each Part of the NSC contains essentially the same Chapters:

- Chapter 0 – Using the Naval Ship Code
- Chapter I – Naval Ship Safety Certification
- Chapter II – Structure
- Chapter III - Buoyancy, Stability and Controllability
- Chapter IV - Engineering Systems
- Chapter V - Seamanship Systems
- Chapter VI - Fire Safety
- Chapter VII - Escape, Evacuation and Rescue
- Chapter VIII - Communications
- Chapter IX - Navigation
- Chapter X - Dangerous Goods

FIGURE 4
Arrangement of the Naval Ship Code *(1 March 2018)*



(Source: Naval Ship Code, ANEP 77, Figure P1-0-3)

7.1 Part 1

Part 1 contains the overall goals for the ship, and is found in Regulation 1 of Part 1, Chapter 1 ("Naval Ship Safety Certification"). The ship is to be designed, built and maintained so that when operated within the determined ConOpS, the ship:

i) Is safe to operate and prevents injury of crew onboard and

ii) Possesses essential safety functions for crew in foreseeable damage circumstances.

It is important to note that, for "special ship concepts", these goals may be modified if agreed to by the Naval Administration; but risks are to be kept as low as practicable. However, in addition to these stated goals, the Naval Administration may add additional goals. As visually demonstrated by the pyramid in 6-4-1/Figure 4, the top goal is achieved through the achievement of the goals found in each chapter; these in turn are met through the successful completion of the Functional Objectives and Performance Requirements for each ship technical area. This plan provides flexibility as to the manner in which certification may be achieved. And, while it is emphasized that the Code is not mandatory, and it is not required to be invoked in its entirety, use of only parts of the Code are not recommended as hazards can be interdependent on one another.

It is noted that between Part 1 and Part 2, 6-4-1/Figure 4 refers to an "interface document" described as the "Standards Plan"; this item is discussed in 6-4-1/5, "The Process for NSC Certification".

- *Tier 0 and 1 – Aim Goals:* High-level objectives to be met.
- *Tier 2 – Functional Objectives:* Criteria to be satisfied in order to conform to the goals.
- *Tier 3 – Performance Requirements:* Detailed requirements for meeting Tiers 1 and 2 for each technical area of the ship.

7.3 Part 2

Part 2 contains suggested solutions for the functional objectives and performance requirements found in Part 1.

Options are also provided for verification. The solutions provided may be followed; or as an alternative the rules of a classification society, international convention (such as IMO SOLAS), or a suitable additional standard may be used to facilitate verification of the performance requirements. The Code allows the Naval Administration to continue to use the existing standards, systems and equipment used previously, should these items meet the requirements. In most cases in Part 2, these solutions may either be verified by the Naval Administration, or by an RO (such as a classification society).

- *Tier 4 – Solutions:* Detailed requirements (such as standards and class rules) applied by national Administrations and/or recognized organizations acting on their behalf, in order to verify compliance with the above Tiers. These solutions are not mandatory and can be substituted with other solutions by the Naval Administration, that are agreed as appropriate for the ship and Justified as meeting the Functional Objectives and Performance Requirements set out in Part 1.

7.5 Part 3

Part 3 contains the final tier of the pyramid, and provides justification and guidance to support the Naval Ship Code Performance Requirements and Solutions to adequately satisfy the Goals. In addition, and perhaps even more critical, it provides the history and reference data provided by all applicable parties who contributed to each part and chapter. It discusses the origin of many of the sections and is presented in a tabular format. In this way, the guidance provides the foundation for future development for the NSC.

- *Tier 5 – Justification and Guidance:* This section is principally composed of the historical background for each corresponding section in Naval Ship Code Parts 1 and 2, including standards referenced and codes of practice, as well as safety and quality systems for shipbuilding, ship operation, maintenance, training, and manning, which may be incorporated into or referenced in Tier 4.

9 Survey

The surveys after construction for Naval Ship Safety are to be in accordance with the applicable requirements in the NSC.

The vessel and applicable systems are to be generally examined based on the submitted and reviewed survey plan, which is required to achieve the optional class notation **NavalSafe(x)** and the Naval Ship Safety Certification as prescribed by Naval Ship Code.

No alterations that affect or may affect the awarded **NavalSafe(x)** notation are to be made to the ship unless plans of the proposed alterations are submitted to and approved by ABS before the work is commenced. If ABS determines that the alteration will affect the **NavalSafe(x)** notation, the altered ship may be subject to the review and verification requirements of this Guide.

PART

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CHAPTER 5 Mission Threats Protection *(1 June 2018)*

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CHAPTER 5 Mission Threats Protection

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.

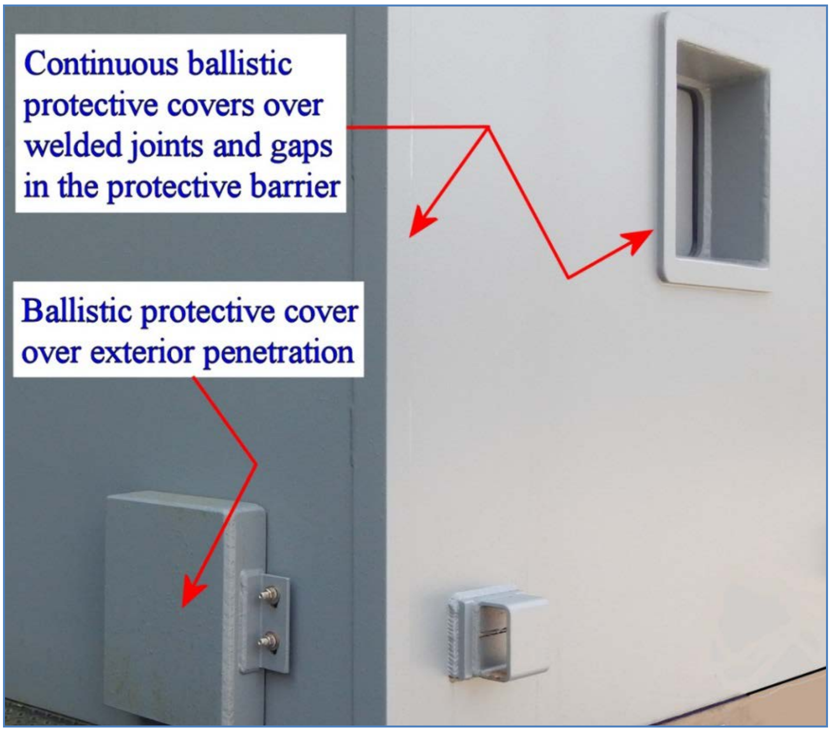
9.3 Protection of Exposed Protective Material Welds, Gaps, and Openings

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.

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

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}.

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

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

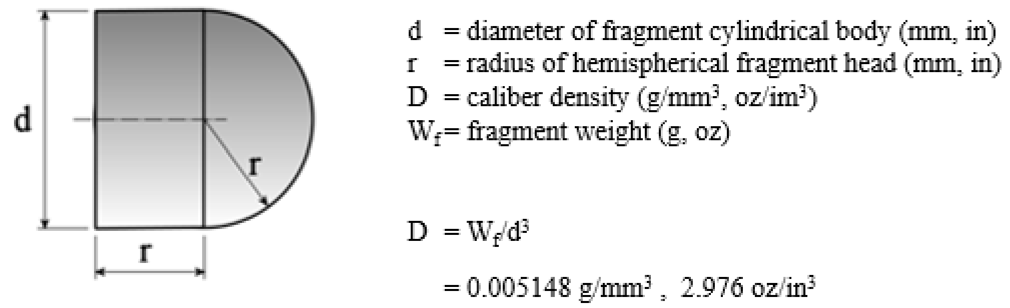
C_1 = 143.6 m/sec (2683 ft/sec)

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)*



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.

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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.

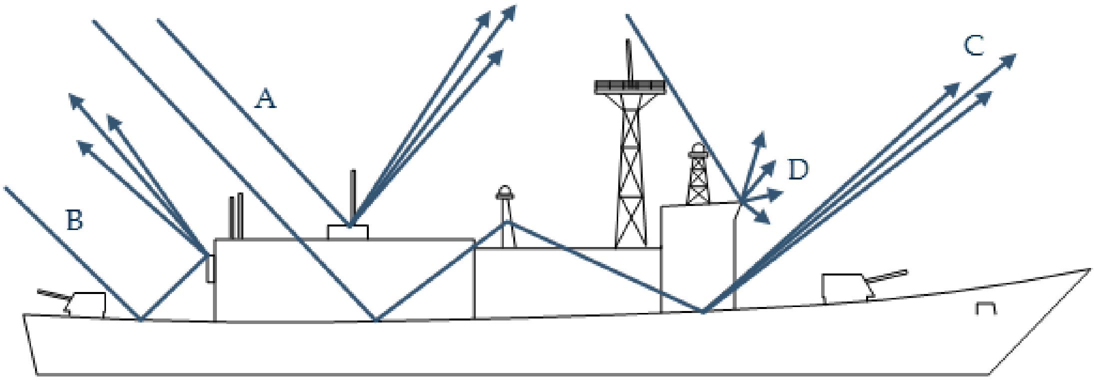
3.1.1 Shape Modification

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.

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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*
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 2³/₄ in. Shot	493 gr (31.95 g)	n/a	1289-1355 ft/s (393-413 m/s)	3
	S1	12 Gauge 2³/₄ 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.