Chapter Contents

PART 1 REGULATIONS
PART 2 RULES FOR THE MANUFACTURE, TESTING AND CERTIFICATION OF MATERIALS
PART 3 DESIGN PRINCIPLES AND CONSTRUCTIONAL ARRANGEMENTS
PART 4 MILITARY DESIGN AND SPECIAL FEATURES
  Chapter 1 Military Design
    2 Military Load Specification
    3 Special Features
PART 5 ENVIRONMENTAL LOADS
PART 6 HULL CONSTRUCTION IN STEEL
PART 7 ENHANCED STRUCTURAL ASSESSMENT

© Lloyd’s Register Group Limited 2015. All rights reserved.
Except as permitted under current legislation no part of this work may be photocopied, stored in a retrieval system, published, performed in public, adapted, broadcast, transmitted, recorded or reproduced in any form or by any means, without the prior permission of the copyright owner. Enquiries should be addressed to Lloyd’s Register Group Limited, 71 Fenchurch Street, London, EC3M 4BS.
## Contents

### Volume 1, Part 4

#### CHAPTER 1 MILITARY DESIGN

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Subsections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>General requirements</td>
<td>General, Plans, Signature, Materials and welding</td>
</tr>
<tr>
<td>2.1</td>
<td>Survivability</td>
<td>General, Vulnerability</td>
</tr>
<tr>
<td>3.1</td>
<td>Military distinction notations</td>
<td>General, Above water threats, Underwater threats, Analysis levels</td>
</tr>
<tr>
<td>4.1</td>
<td>Military design guidance</td>
<td>Radar signature, Use of aluminium alloys</td>
</tr>
<tr>
<td>5.1</td>
<td>Military design requirements</td>
<td>RAS seating and support structure, Vehicle and equipment holding down arrangements, Masts and externally mounted sensors or equipment, Towed arrays, towed bodies and towing points, Crane support arrangements</td>
</tr>
<tr>
<td>6.1</td>
<td>Magazine design and construction</td>
<td>General, Definitions, Arrangement of magazines, Structure, Environmental conditions and ventilation, Detail arrangements, Openings, Piping, cabling and electrical systems, Fire protection, Testing</td>
</tr>
<tr>
<td>7.1</td>
<td>Design guidance for nuclear, biological and chemical defence</td>
<td>General, Definitions, NS1 and NS2 ship requirements, NS3 ship requirements, Zones, CBRN hardening, Structural requirements</td>
</tr>
<tr>
<td>8.1</td>
<td>Design guidance for the reduction of radiated noise underwater due to sea-inlets or other openings</td>
<td>General</td>
</tr>
</tbody>
</table>

#### CHAPTER 2 MILITARY LOAD SPECIFICATION

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Subsections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>General requirements</td>
<td>General</td>
</tr>
<tr>
<td>Section</td>
<td>2</td>
<td>External blast</td>
</tr>
<tr>
<td>---------</td>
<td>---</td>
<td>----------------</td>
</tr>
<tr>
<td>2.1</td>
<td>General</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>Threat level determination</td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>Notation assessment levels and methodology</td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>Definitions</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>Blast pressure loads</td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>Nuclear threats</td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>Fuel air pressure loads</td>
<td></td>
</tr>
<tr>
<td>2.8</td>
<td>Conventional explosive pressure loads</td>
<td></td>
</tr>
<tr>
<td>2.9</td>
<td>Structural assessment</td>
<td></td>
</tr>
<tr>
<td>2.10</td>
<td>Design considerations</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>3</th>
<th>Internal blast</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>General</td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>Threat level determination</td>
<td></td>
</tr>
<tr>
<td>3.3</td>
<td>Notation assessment levels and methodology</td>
<td></td>
</tr>
<tr>
<td>3.4</td>
<td>Materials</td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>Quasi static pressure</td>
<td></td>
</tr>
<tr>
<td>3.6</td>
<td>Structural resistance</td>
<td></td>
</tr>
<tr>
<td>3.7</td>
<td>Bulkhead arrangements</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>4</th>
<th>Fragmentation protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>General</td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>Threat level determination</td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>Notation assessment levels and methodology</td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td>Information required</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>Structural requirements</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>5</th>
<th>Underwater explosion (shock)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>General</td>
<td></td>
</tr>
<tr>
<td>5.2</td>
<td>Threat level determination</td>
<td></td>
</tr>
<tr>
<td>5.3</td>
<td>Notation assessment methodology</td>
<td></td>
</tr>
<tr>
<td>5.4</td>
<td>Local strength assessment</td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>Detail design guidance</td>
<td></td>
</tr>
<tr>
<td>5.6</td>
<td>Seat design</td>
<td></td>
</tr>
<tr>
<td>5.7</td>
<td>Shock mounts</td>
<td></td>
</tr>
<tr>
<td>5.8</td>
<td>Design guidance for hull valves, piping and seals</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>6</th>
<th>Whipping</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>General</td>
<td></td>
</tr>
<tr>
<td>6.2</td>
<td>Threat level determination</td>
<td></td>
</tr>
<tr>
<td>6.3</td>
<td>Notation assessment levels and methodology</td>
<td></td>
</tr>
<tr>
<td>6.4</td>
<td>Simple 2D beam model</td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>Advanced assessment</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>7</th>
<th>Residual strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1</td>
<td>General</td>
<td></td>
</tr>
<tr>
<td>7.2</td>
<td>Threat level determination</td>
<td></td>
</tr>
<tr>
<td>7.3</td>
<td>Notation assessment levels and methodology</td>
<td></td>
</tr>
<tr>
<td>7.4</td>
<td>Definition of damage</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>8</th>
<th>Strengthening requirements for beach landing operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1</td>
<td>General</td>
<td></td>
</tr>
<tr>
<td>8.2</td>
<td>Minimum plate thickness</td>
<td></td>
</tr>
<tr>
<td>8.3</td>
<td>Bottom stiffening</td>
<td></td>
</tr>
<tr>
<td>8.4</td>
<td>Global strength</td>
<td></td>
</tr>
<tr>
<td>8.5</td>
<td>Rubbing strakes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>9</th>
<th>Military installation and operational loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.1</td>
<td>Weapon recoil, blast and efflux loads</td>
<td></td>
</tr>
<tr>
<td>9.2</td>
<td>Replenishment at sea loads</td>
<td></td>
</tr>
</tbody>
</table>
## Contents

### Section 10 Aircraft operations
- 10.1 General
- 10.2 Definitions
- 10.3 Documentation
- 10.4 Flight deck arrangements
- 10.5 Loading
- 10.6 Determination of $\lambda$ for fixed wing aircraft
- 10.7 Determination of $\lambda$ for helicopters
- 10.8 Deck plating design
- 10.9 Deck stiffening design
- 10.10 Parking and manoeuvring areas
- 10.11 Assisted take off
- 10.12 Arrested landing
- 10.13 Vertical recovery
- 10.14 Tie down forces

### Chapter 3 Special features

#### Section 1 General
- 1.1 Application
- 1.2 Symbols and definitions

#### Section 2 Vehicle decks and fixed ramps
- 2.1 General
- 2.2 Definitions
- 2.3 Deck plating
- 2.4 Secondary stiffening
- 2.5 Primary stiffening
- 2.6 Securing arrangements
- 2.7 Access
- 2.8 Hatch covers
- 2.9 Heavy and special loads
- 2.10 Tracked and steel wheeled vehicles
- 2.11 Openings in main vehicle deck
- 2.12 Direct calculations

#### Section 3 Bow doors
- 3.1 Application
- 3.2 General
- 3.3 Symbols and definitions
- 3.4 Construction and testing
- 3.5 Strength criteria
- 3.6 Design loads
- 3.7 Scantlings of bow doors
- 3.8 Scantling of inner doors
- 3.9 Securing and supporting of bow doors
- 3.10 Securing and locking arrangements
- 3.11 Operating and Maintenance Manual

#### Section 4 Side, stern doors and other shell openings
- 4.1 Symbols
- 4.2 General
- 4.3 Construction and testing
- 4.4 Scantlings
- 4.5 Doors serving as ramps
- 4.6 Closing, securing and supporting of doors
- 4.7 Systems for operation
- 4.8 Systems for indication and monitoring
- 4.9 Design loads
- 4.10 Design of securing and supporting devices
- 4.11 Operating and Maintenance Manual
<table>
<thead>
<tr>
<th>Section</th>
<th>Movable decks, lifts, internal and external ramps</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Classification</td>
</tr>
<tr>
<td>5.2</td>
<td>Arrangements and design</td>
</tr>
<tr>
<td>5.3</td>
<td>Loading</td>
</tr>
<tr>
<td>5.4</td>
<td>Movable decks</td>
</tr>
<tr>
<td>5.5</td>
<td>External deck ramps and lifts</td>
</tr>
<tr>
<td>5.6</td>
<td>External shell ramps</td>
</tr>
<tr>
<td>5.7</td>
<td>Aircraft lifts</td>
</tr>
</tbody>
</table>
Section 1

General requirements

1.1 General

1.1.1 This Section is aimed primarily at assessing structure such that it can resist the military loads imposed upon it; however, it is essential in naval ship design to consider the effects an item of equipment or structure can have on a variety of parameters. For example a winch support and mount may adequately resist the forces imposed upon it during normal operation and absorb shock loads but have an unacceptably high noise or radar signature.

1.1.2 Chapter 1 gives guidance on some of the additional issues that the designer must consider in the design of a naval ship. Whilst it does not always give the definitive answer on these topics, it will help identify the impact of structural design on the subject. An example is radar signature reduction. The guidance gives the geometric properties to avoid but it will not give detail on radar absorbent coatings.

1.1.3 Information is classified in two types. Firstly, design guidance for which further approval has to be sought once a suitable standard is specified, and secondly, design requirements which have to be met as part of the LA(N) notation or a specific notation such as LA(N).

1.2 Plans

1.2.1 Plans are to be submitted showing the manner in which the requirements have been met and the location of the structure within the vessel for those features that have either a special notation or are required as part of the notation LA(N).

1.2.2 Details on the loadings applied to individual items, and by these items to the support structure are to be included. In some cases stiffness requirements will also need to be included, e.g., mast mounted equipment.

1.2.3 Plans and, where requested, calculations should be submitted for the following features as appropriate:

- Replenishment at sea arrangements.
- Aircraft and vehicle tie down arrangements.
- Movable decks, ramps and lifts.
- Masts and support arrangements.
- Towed array or towed body arrangement.
- Weapon recoil and thrust loadings.

1.2.4 Arrangements for the following features are to be included with the hull structural plans listed in Pt 6, Ch 2. In addition calculations are to be supplied where requested:

- Vehicle decks.
- Helicopter decks.
- Berthing.
- Docking loads.
- Beach landing or grounding.
- Holding down arrangements.

1.2.5 Plans and supporting calculations should be submitted for the following notations:

- External blast (EB1, EB2, EB3, EB4).
- Internal blast (IB1, IB2).
- Fragmentation (FP1, FP2).
- Small arms protection (SP).
- Underwater explosion (Shock) (SH).
- Whipping (WH1, WH2, WH3).
- Residual strength (RSA1, RSA2, RSA3).

1.3 Signature

1.3.1 A naval vessel will generally require some form of signature control and the operational requirement will determine the extent to which this is necessary. Signature control can be achieved using a variety of methods both active and passive. This Section deals with the passive methods that structure can influence.

1.3.2 With good structural design the signature of the vessel can be controlled to a certain degree with little cost. The methods listed in Table 1.1.1 can help achieve this.

1.3.3 It is beyond the scope of the Rules to provide further detail on signatures, however on request, Lloyd's Register (hereinafter referred to as 'LR') is able to provide information on suitable organisations who are able to give specialist advice as necessary.

1.3.4 Special features notations for signature control will not normally be assigned. Some of the above features will form part of the Naval Ship notation 100A1 NS and are detailed in Section 3.
1.4 Materials and welding

1.4.1 In addition to the requirements of Pt 6 Ch 2, ships having the following military distinction notations are to comply with the requirements of this Section for the designated areas unless specified otherwise. The requirements apply to plates, stiffeners, fillet welds, butt welds and welded attachments:

- **EB1, EB2, EB3, EB4** Above water portion of the hull, superstructure and upper decks assessed against external blast requirements.
- **IB1, IB2** Blast bulkheads.
- **SH** Hull envelope plating.
- **WH1, WH2, WH3** Sheerstrake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts.
- **RSA1, RSA2, RSA3** Sheerstrake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts.

1.4.2 Crack arresting strakes of minimum Grade E are to be fitted in the following locations, from \(0.2L_R\) to \(0.8L_R\), according to the notation assigned:

- **SH** Sheerstrake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts in these areas.
- **WH1, WH2, WH3** Sheerstrake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts in these areas.
- **RSA1, RSA2, RSA3** Sheerstrake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts in these areas.

Where the hull envelope is made entirely from Grade D steel, crack arresting strakes of minimum Grade E need not be fitted in the specified locations.

1.4.3 Generally, for joints between steels of different strength levels the welding consumable may be of a type suitable for the lesser strength.

1.4.4 For joints between steels of different toughness levels, the welding consumable is to be of a type suitable for the higher grade being connected.

1.4.5 The consumable used is to comply with the requirements of Table 1.1.2. Other grades of steel will be specially considered, but in general, the toughness in the upward vertical direction is not to be significantly less than that of the parent plate, measured in the direction of rolling.

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Normal electrode grade</th>
<th>Military requirement grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AH32</td>
<td>1Y</td>
<td>2Y</td>
</tr>
<tr>
<td>AH36</td>
<td>1Y</td>
<td>2Y</td>
</tr>
<tr>
<td>AH40</td>
<td>2Y40</td>
<td>2Y40</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>DH32</td>
<td>2Y</td>
<td>3Y</td>
</tr>
<tr>
<td>DH36</td>
<td>2Y</td>
<td>3Y</td>
</tr>
<tr>
<td>DH40</td>
<td>3Y40</td>
<td>3Y40</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>EH32</td>
<td>3Y</td>
<td>4Y</td>
</tr>
<tr>
<td>EH36</td>
<td>3Y</td>
<td>4Y</td>
</tr>
<tr>
<td>EH40</td>
<td>4Y40</td>
<td>4Y40</td>
</tr>
</tbody>
</table>

1.4.6 Where armour plating consisting of steels with a specified tensile strength of 1000 MPa or above is integrated into the ship’s structure by welding, consideration should be given to the susceptibility of these materials to hydrogen cracking. The use of normal strength or higher strength steel of toughness grade D or higher in terms of Charpy V-notch fracture toughness should be considered as an intermediate transition material where the adjacent material is not already of this grade.

1.4.7 The proposed welding procedures are to be submitted for review, and are to be chosen to minimise the risk of hydrogen cracking. The following is recommended:

(a) The use of welding consumables and electrodes with low hydrogen content (less than 5 ml/100 g of deposited weld metal).
(b) The weld preparation and welding apparatus, consumables and electrodes are to be clean, dry and free from other sources of hydrogen such as lubricants and grease.
(c) Controlled preheat, interpass temperatures, cooling rates and post-heat treatment chosen in accordance with manufacturers’ guidance and recognised welding standards.
(d) Weld sequence chosen to minimise the formation of residual stresses.
(e) The use of welding consumables of a higher strength than necessary should be avoided.
(f) Non-destructive examination should not be carried out before a period of 48 hours has elapsed from the time welding is completed.

1.4.8 The use of mechanical fasteners to secure armour plating should be considered as a means of removing the risk of hydrogen embrittlement as a result of the welding process. Where higher strength steel fasteners with Vickers hardness above 320 HV are used, consideration should also be given to the susceptibility of these materials to hydrogen cracking.
Survivability

2.1 General

2.1.1 Survivability is defined as the probability that a ship can remain operational to some degree following an attack. The elements of whole ship survivability are shown in Fig. 1.2.1. Survivability is divided into two main aspects:

- Vulnerability, the probability of a threat acquiring, reaching and detonating on a ship.
- Susceptibility, the probability that a ship will be able to survive a successful attack and operate at a certain level.

Survivability is normally calculated as the product of susceptibility and vulnerability. Recoverability is an important aspect as it has a significant influence on the vulnerability of the overall ship as a system. It can be defined as a measure of the ability of the ship to reach a particular level of operation higher than that immediately following the hit. A variety of levels of operation required following damage can be defined, see 2.2.

2.1.2 Generally, there are four basic phases in the classification of naval ships with respect to survivability:

- Concept phase.
- Assessment phase.
- Build phase.
- Maintenance phase.

2.1.3 The concept phase is not normally part of classification and is a discussion between the Owner, Naval Administration, designer and those specialists able to perform the appropriate calculations. It is used to identify the potential threats, requirements for the ship structure, machinery and systems with respect to those threats.

2.1.4 The concept phase will apply all of the elements shown in Fig. 1.2.1:

(a) Identification of the threat is first and this is usually determined for current and future threats. Several threats will be identified which affect the ship in a variety of ways, they may be underwater or above water, far field, close in, or contact weapons. Typical threat groups are given in Table 1.3.1.

(b) The susceptibility is the ability of the threat to reach the ship and detonate and is a function of the capability of the threat, the ship's signatures and the ship's defence systems. Various computer codes and simulations are available for determining the susceptibility of a hull and the capability of weapon systems. Consideration should be given to the degradation of a threat by a ship's defence systems.

(c) If a threat detonates, damage may result. The extent and amount of damage is a function of the vulnerability of the ship, see 2.2. A vulnerability assessment may be used to determine the consequences of the threat detonation. The consequences are likely to be in the form of fire, flood and physical damage as shown in Fig. 1.2.1. The assessment tools used in the design stage for vulnerability analysis generally employ simple design formulae which are then verified during the assessment phase.

(d) The consequences of damage can be limited through recoverability, the ability to repair damage to structure, equipment and systems. This is mainly an operational matter though it will have an impact on ship design. Damage control operational procedures will make certain demands on structure and equipment.

2.1.5 It is beyond the scope of the Rules to provide further detail on the concept phase. However, on request, LR is able to provide details of suitable organisations who are able to give specialist advice as necessary.

2.1.6 The assessment phase looks in more detail at the vulnerability of the ship and uses explicit calculations to assess the capability of the ship based upon the relevant effects of threats such as blast pressure or fragment size. It is not necessary to define the actual weapon, just the consequences or effects of threats. A threat can produce a variety of effects, the manner in which the Rules currently address these effects is detailed in Chapter 2. In naval ship classification, notations are used to denote that a calculation for a particular threat has been reviewed. Currently, these are concerned with structural aspects only, though some aspects of machinery are indirectly addressed through other notations such as propulsion machinery redundancy, PMR, steering gear machinery redundancy, SMR and fire safety, FIRE.

2.1.7 The build phase ensures that the requirements of the assessment phase are put in place on board the ship. It is identical to the normal classification requirements for construction, installation and testing of structure and equipment under LR survey, verifying that the correct materials, welding fabrication and testing procedures are used.
2.1 Maintenance phase is applied by maintaining a ship in class through life. It verifies that the original standard to which the ship was built is maintained and that any new rule requirements are implemented. It also verifies that modifications to the ship do not compromise the integrity of the structure, equipment or systems.

2.1.9 It is the responsibility of the Naval Administration to ensure that each of the phases is implemented, to define the requirements that are to be met and advise the Owner on the manner in which particular threats can be dealt with.

2.2 Vulnerability

2.2.1 The resistance of a vessel to loadings from military threats can be described by the term vulnerability which is the probability that once hit by a specified threat a vessel will lose capability.

2.2.2 This Chapter deals separately with the effects of a threat on the structure but when considering the total vulnerability of the ship it will be necessary to combine all the effects of a weapon detonation to determine the total damage to the ship as a system. This is normally done very early in the design stage at a low level of complexity, see 2.1.4. Several computer codes are available to determine the consequence of weapon threats on the ship system.

2.2.3 The damage to a ship is likely to occur by three mechanisms; fire, flood and physical damage, see Fig. 1.2.1. The direct effect of threats on the ship’s crew is not included in this Section but some features such as shelter stations and CBRN protection will reduce the risk. Indirect damage caused by the threat should also be considered and a vulnerability analysis can be used to site magazines such that they are offered the maximum protection.

2.2.4 The methods used to control the spread of fire will have an effect on structural design, materials, fire insulation, fire divisions and openings, and must all be considered. One method used to control the spread of fire is zones and some guidance on the philosophy and structural requirements is provided in Section 7. However, the precise requirements for fire detection, protection and extinction are to be provided in the specified fire safety standard(s). Where this is examined by LR in accordance with Pt 1, Ch 3.4.9 a FIRE notation may be assigned. Other methods include the use of smoke tight boundaries, insulation and fire-fighting systems.

2.2.5 The stability of a vessel and flooding following damage is not covered in this Chapter. The specified subdivision and stability standard should define the extent of damage that the vessel is required to survive and remain stable. All structure and watertight closing appliances will need to be assessed to this level. Pt 3, Ch 1.5 defines how the minimum extent of watertight subdivision is to be determined. Pt 3, Ch 4 contains details on requirements for closing appliances. For such an extreme event as flooding, plastic type analysis is appropriate for watertight structure and this is recognised in the relevant rule requirements.

2.2.6 For the hull, the effect of the threat can be limited in two ways:
- Ensuring that there is adequate global strength following damage using a residual strength analysis. Where appropriate a whipping analysis may also be necessary.
- Ensuring that local structure can contain the threat or limit the damage. Individual items of structure can be hardened or strengthened in certain areas to achieve this.

2.2.7 Physical damage may occur to cables, piping, equipment and machinery, and other systems. The duplication or protection of these items is dealt with in Vol 2, Pt 1, Ch 3.4.9. Where protection is required, e.g., armour, the impact on the structural design of the hull is to be considered.

2.2.8 Different levels of vulnerability can be represented, as illustrated in Fig. 1.2.2. Each will have different acceptance criteria for the hull structure. For an internally detonating threat, the increasing levels can be visualised as a threat of increasing magnitude rather than increasing distance.

2.2.9 Level A is that, closer than which the hull structure will fail due to the detonation of a threat. The failure can occur in a number of ways as detailed in Chapter 2. At this level the assessment will normally be performed using plastic criteria which will result in permanent deformation. The ship may no longer function effectively but it should remain afloat and not rupture or fail catastrophically.

Fig. 1.2.2
Vulnerability contours for a given threat level
2.2.10 Level B is that, closer than which the majority of the ship's machinery and equipment is damaged such that it will not operate effectively and the ship can no longer continue to navigate. The hull must therefore not deform permanently and elastic assessment criteria may be necessary to determine the global strength of the hull (local deformation may be sustained).

2.2.11 Level C is that, closer than which the ship's weapon systems begin to fail and the vessel is no longer able to operate with full effectiveness. Normally the global and local criteria would be assessed against elastic criteria.

2.2.12 Levels B and C for underwater threats are primarily dealt with by adopting a suitable shock policy for the ship.

2.2.13 It is the responsibility of the Owner to specify the levels at which these should be set. In theory, they could be made to be coincident but this would provide little reserve within the vessel for recovery by damage control and repair. Conversely, they should not be set too far apart as this represents unnecessary armament and strengthening which is not effectively protecting the equipment and machinery from attack.

2.2.14 For an assessment of a threat which also produces effects on machinery, two structural calculations may have to be performed. One at the equipment level of failure using failure criteria that result in little or no deformation (platting only for example) and one approaching a structural failure level using ultimate strength or plastic collapse criteria. The requirements in Chapter 2 generally deal with ultimate strength or plastic criteria, the conventional rule calculations in Pt 6, Ch 2 and Chapter 5 set elastic failure criteria. For normal naval ship construction, the hull is usually able to withstand the threat level at which equipment and systems fail with little or no permanent deformation, though some check calculations may be necessary on critical areas.

3.1.3 Unless specifically requested these notations will be assigned at an appropriate level which will remain confidential to the Owner. It is the responsibility of the Owner to specify the threat levels suitable for their requirements. The agreed threat levels will not appear in the Register Book or be published in any other form. Only the notation *MD will be used to show that some military features have been incorporated and constructed in accordance with LR's Rules and Regulations for the Classification of Naval Ships.

3.1.4 A distinction is made between:
- levels of threat, describing the magnitude of the missile, torpedo, mine or bomb; and
- method of analysis which may be performed at differing levels of complexity.

3.1.5 In an effort to establish links between the different military loads, default levels of threat have been assigned. A distinction is made between levels of above water and underwater threats, as certain ships may be at greater risk from one or the other depending upon their operational requirements. They are summarised in Table 3.1.1.

3.1.6 In addition to the hull class notations defined in Pt 1, Ch 2, ships complying with the requirements of this Chapter will be eligible to be assigned the additional class notations defined in Pt 1, Ch 2.2.1 and Ch 2.2.3 or descriptive notes as defined in Pt 1, Ch 2.2.6.

3.2 Above water threats

3.2.1 As described in Table 1.3.1 the external blast notation is normally independent of the internal blast and fragmentation notations as the threats that produce a survivable blast effect usually have a reasonable stand-off. Typically, significant blast loading will arise from externally detonating threats such as far field nuclear at large stand-offs and fuel air explosions at moderate stand-offs. For an externally detonating conventional weapon, the blast will normally be insignificant but there will usually be a fragmentation threat. The external blast notation may also be independent of the residual strength notation unless the plastic deformation from an external blast renders certain structure ineffective with respect to global strength, e.g., a superstructure which contributes to longitudinal strength.

3.2.2 Usually, both internal blast and fragmentation will result from an internally detonating threat and are therefore linked, for example, a missile threat as shown in Table 1.3.1. For a particular threat it is recommended that both fragmentation and internal blast assessments will be made to the same level of threat for the structure adjacent to the point of detonation. Consideration should be given to the precise nature of the blast loading and fragmentation pattern of the threat.

3.2.3 If transverse bulkheads are used to limit the longitudinal spread of damage then the decks and side shell will probably be damaged such that a residual strength assessment is required to ensure that the global strength is not compromised. This should be to the same threat level as the internal blast threat. Longitudinal blast resistant bulkheads, box girders or service tunnels could be used to maintain the longitudinal effective material of the hull girder.
3.2.4 A residual strength assessment of the above water structure can be carried out for any threat level under any threat, independently of the other above water threat notations. This is because the ship may still retain function even though it has not been specifically armoured against the internal blast or fragmentation arising from such a threat. The residual strength notation is normally required for sea skimming missile threats that may remove significant areas of above water structure.

3.3 Underwater threats

3.3.1 Shock enhancement should be aimed at providing ruggedness and to verify at a low level, equipment and system operation is maintained and at a higher level, equipment is retained and the hull does not rupture. Notation is currently confined to structure and concentrates on local damage that can be addressed by close attention to quality of construction and by adopting good constructional detail. Shock effects give rise to equipment and system damage. Shock is a different mechanism from whipping, therefore a whipping assessment will not generally be required to the same level of a shock assessment, though it may be necessary to check that the shock threat assessed will not have a significant whipping load. Residual strength assessments may be appropriate for shock threats depending on the extent of local damage.

3.3.2 Whipping is caused by proximity detonation of a charge that excites the main hull girder at a low-order (two node) natural frequency which may cause significant structural damage at a relatively low charge weight. Shock effects therefore may be relatively low order and it will not always be necessary to undertake a shock analysis. In addition a whipping analysis may not be necessary for threats which detonate on contact or for steel ships under 70 m in length. Due to the nature of whipping effects (usually the plastic collapse at a section of the hull), a residual strength calculation is not normally appropriate for a whipping threat because the damage from the direct shock is usually limited.

3.3.3 Residual strength assessments of underwater threats are normally concerned with contact mines or torpedo impacts. These will remove a certain amount of hull structure the effect of which is to be assessed by the residual strength calculation. Shock or whipping threats will only require a residual strength notation where there are significant amounts of local deformation to the hull girder. Significant damage is defined as that which reduces the global strength below the design margins.

3.4 Analysis levels

3.4.1 In addition to levels of capability determined by the threat level specified, there are also different methods of assessment. The method of assessment will depend on three aspects:
- The level of the threat. At higher levels of threat, the requirements of the Rules may become uneconomical or impractical and a more in-depth analysis is required.

---

**Table 1.3.1 Relationship between notations**

<table>
<thead>
<tr>
<th>Above water weapons</th>
<th>Underwater weapons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small arms</td>
<td>Mine or charge</td>
</tr>
<tr>
<td>Contact</td>
<td>Rocket</td>
</tr>
<tr>
<td>Proximity</td>
<td>Mine or charge</td>
</tr>
<tr>
<td>Contact</td>
<td>Rocket</td>
</tr>
<tr>
<td>Proximity</td>
<td>Rocket</td>
</tr>
<tr>
<td>Contact</td>
<td>Rocket</td>
</tr>
<tr>
<td>Proximity</td>
<td>Rocket</td>
</tr>
<tr>
<td>Far field (2)</td>
<td>Contact</td>
</tr>
<tr>
<td>Proximity</td>
<td>Rocket</td>
</tr>
<tr>
<td>Contact</td>
<td>Rocket</td>
</tr>
<tr>
<td>Proximity</td>
<td>Rocket</td>
</tr>
</tbody>
</table>

**Symbols**

- **R** = Required threats to be considered in the absence of a specific requirement.
- **O** = Optional threats to be identified by the Owner and dependent on the characteristic of the threat.

**NOTES**

1. It remains the responsibility of the Owner to determine the appropriate military notation and the appropriate levels of threat and analysis.
2. For nuclear threats, consideration should be given to CBRN requirements for structure, see Section 7, filtration and ventilation. The ability of the structure to screen an electromagnetic pulse should also be considered.
Military Design

- Applicability of the Rule formulations. If the threat level is outside the range of applicability of the Rule formulations further analysis will have to be undertaken.
- Acceptance criteria, dependent upon whether the threat is to be assessed against elastic or plastic collapse criteria.

3.4.2 Three methods of assessment are shown in Fig. 1.3.1. In general the same threat level can be specified in each case, however, it is the responsibility of the Owner to specify the correct levels to meet their specific requirements.

(a) The analysis of military loads can most simply be assessed using the elastic model created for rule analysis. This will result in an acceptable but conservative solution.
(b) The next more complex method uses an elasto-plastic or ultimate strength model.
(c) Finally more complicated processes such as 3D dynamic analysis can be used to determine the loading for the elasto-plastic model. Normally this will be carried out for local areas of interest.

3.4.3 Once an ultimate strength model has been created for the appropriate sections along the hull it may be utilised for a variety of military notation calculations, as shown in Fig. 1.3.1(b).

3.4.4 The damage required for the residual strength calculation can be defined in a variety of ways for a variety of threats, collisions or groundings. Non-military damage is defined in Pt 6, Ch 4,4 and military damage by the damage radii in Ch 2,7 or specifically from external blast and vulnerability calculations. The results from a vulnerability analysis can be used for input to a variety of military notations and, in general, formal vulnerability assessments will be required for higher threat levels, see 2.1.4.
4.1.5 Flare and tumblehome as defined in Fig. 1.4.1 are to be used where possible on all otherwise vertical surfaces. The angle used should be greater than 6°. Consideration should be given to using a single or multiple elevation angles, see 4.1.3. This practice also eliminates the dihedral reflector potentially formed between a horizontal and a vertical surface.

4.1.6 Orthogonal corners give rise to high radar returns in the direction of the originating antenna. Creating dihedral or trihedral right angled reflectors should be avoided. This applies equally to disconnected orthogonal corners, where two (or three) surfaces do not meet but are orthogonal and a clear line of sight exists between them. This can include items such as: boat bays, reception areas, superstructure overhangs, sponsons and equipment mounts.

4.1.7 Corners which would otherwise be orthogonal should be made non-orthogonal by a minimum of 4°, i.e., avoiding an internal angle of between 86° and 94°. Any shaping which uses angles less than 4° could inadvertently be made ineffective by local plate deformation or build tolerances.

4.1.8 Where doors providing access to the deck penetrate sloped structure, it will be desirable for the door itself to be hung vertically on its hinges. To achieve this it is necessary to recess the door into the sloped plate. Where this approach is adopted, the structure of the door recess should be made non-orthogonal by rotating the vertical sides of the recess by a minimum of 4°.

4.1.9 Avoid single curved surfaces (such as cylinders or cones) with diameters greater than 30 mm. Consideration should be given to replace these items by combinations of flat plates (with appropriate orientations), shielding or choice of appropriate material property.

4.1.10 The use of lattice type masts and equipment supports should be avoided.

4.1.11 Consideration should be given to reducing the amount of clutter (microgeometry) by design, hiding it behind bulkheads or shielding (i.e., shutters for when equipment is not in use).

4.1.12 Where the use of homogenous reflective material is impractical for shielding, a mesh of electrical conductive fibres with an appropriate mesh spacing to simulate a reflective surface over the radar frequency range of interest can be used. This can also be applied to windows and non-structural bulkheads. Where a mesh is applied to windows which may be used for navigation purposes consideration should be given to the effects on visibility.

4.1.13 The number of external ladders should be kept to a minimum. Where they are unavoidable, ladder uprights should be rotated to avoid forming dihedral corners with the bulkheads on which they are mounted. As an alternative, external ladders could be constructed from a material translucent to radar.

4.1.14 Consideration should be given to the use of radar absorbent materials either as appliqués or more preferably as an inherent part of the structure, i.e., Structural Radar Absorbent Material (SRAM).

4.1.15 Composites are generally semi-transparent to radar and therefore attention should be paid to equipment/structures placed behind composite structures. Alternatively, consideration can be given to altering the composite properties, applying a metallic backing to the composite or by using SRAM.

4.1.16 The use of lattice type masts and equipment supports should be avoided.

4.2 Use of aluminium alloys

4.2.1 Due to the poor performance of aluminium alloys at high temperatures they are generally not to be used for items of main hull structure unless suitable insulation is arranged. Safety critical items such as life boat davits, ladders, fire main supports, emergency escape route bulkheads and floor plates, etc., are not to be constructed of aluminium alloys.

---

Military design requirements

5.1 RAS seating and support structure

5.1.1 The strength of seats and supporting structure is to be sufficient to withstand the forces imposed by the equipment for all possible operating conditions and loads from ship motions, see Pt 5, Ch 3.5.3. Design calculations are to be submitted.

5.1.2 The seating and supporting structure is to be tested in accordance with a specified standard, see also Vol 3, Pt 1, Ch 5.3.1.4. Care is to be taken to ensure that the test arrangements represent the actual magnitude and direction of loads, and that the loading is applied to all relevant parts of the supporting structure rather than local items only.

5.1.3 Guidance on the loads and requirements for replenishment at sea operations are given in Ch 2.9.2.
5.1.4 A sufficient deck area clear of projections and equipment suitably strengthened for impact loading is to be provided for the landing of stores and equipment.

5.1.5 RAS equipment is to be designed in accordance with a specified standard, see also Vol 3, Pt 1, Ch 5.3.1.4.

5.2 Vehicle and equipment holding down arrangements

5.2.1 The strength and stiffness of the holding down arrangements and the supporting structure under is to be sufficient to withstand the forces imposed by the vehicle(s) and or equipment for all possible operating conditions and loads from ship motions, see Pt 5, Ch 3.5.4. The design calculations are to be submitted.

5.3 Masts and externally mounted sensors or equipment

5.3.1 Masts are to be of adequate strength and stiffness for the equipment they support. The design calculations are to be submitted.

5.3.2 Plated mast structure is to be treated as superstructure and the structural requirements for superstructure as defined in Tables 3.3.9 and 3.3.10 in Pt 6, Ch 3 for NS1 type vessels and Pt 6, Ch 3,4,8.4 and 4.8.5 for NS2 and NS3 type vessels are to be applied. Minimum requirements are given in Pt 6, Ch 3,2 and Pt 6, Ch 2.2.9.

5.3.3 Pole mast structure is to be designed to be within the allowable stress limits defined in Pt 6, Ch 3.16.

5.3.4 The excitation of the mast by ship motions, machinery, propellers and equipment is to be specially considered and the designers calculations are to be submitted. Where possible the designer should avoid mast natural frequencies within ±20 per cent of significant global mast excitation frequencies. Where this is not possible the vibration amplitudes should be calculated to confirm they are within acceptable limits for the mast structure and equipment. In general, ship motions can be estimated from Pt 5, Ch 3.2. See also Pt 6, Ch 2.4. It is recommended that the frequency of the first mode of vibration of a pole mast be not less than 3.0 Hz to prevent potential excitation from the first vertical hull girder vibration mode in the range 1-2.5 Hz. The frequency of the first mode of vibration of a pole mast should be a minimum of 1 Hz above the first vertical girder mode.

5.3.5 Structure supporting radar or equipment critical to the operation of ship systems is to be of adequate stiffness to maintain the alignment of the equipment within the tolerance agreed with the manufacturer.

5.3.6 The mast should be designed and sited such that it produces minimum interference with the ships sensors and equipment.

5.3.7 Suitable permanent access arrangements are to be provided inside and on the exterior of the mast for maintenance of the structure and equipment. Provision is to be made for the drainage of water from all parts of the mast, both internal and external. Where applicable, protective coatings are to be applied in accordance with the requirements of Pt 6, Ch 6.2.6. For corrosion margins, see Pt 6, Ch 6.2.10.

5.3.8 Mast support arrangements are to be of suitable strength and stiffness and fully integrated into the hull or superstructure. The design calculations and arrangements are to be submitted.

5.3.9 For equipment distributed along the length of the ship, consideration is to be given to the global stiffness of the ships’ hull girder in relation to the alignment tolerances required for the equipment (increasing hull stiffness is not normally an efficient option).

5.3.10 High powered transmitting equipment where fitted is to be considered for the effects of electromagnetic influence on adjacent equipment and manned spaces.

5.4 Towed arrays, towed bodies and towing points

5.4.1 The support structure of towed systems is to be suitably integrated into the main hull structure. Any additional primary stiffening is to be extended for at least three frame spaces forward and aft of the equipment.

5.4.2 The towing point and associated equipment is to be located over a primary longitudinal girder and preferably supported by a transverse web frame. The designers calculations are to be submitted for the supporting structure using the 1.5 times the maximum breaking load of the cable.

5.4.3 Towed array handling equipment is to be designed in accordance with a specified standard. The seating of array handling equipment is to be adequately supported.

5.5 Crane support arrangements

5.5.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

5.5.2 The scantlings of masts and derrick posts, intended to support derrick booms, conveyor arms and similar loads, and of crane pedestals are to be designed in accordance with a specified standard. When submitting plans for the proposed foundation, the design calculations are to be included.

5.5.3 Deck plating and underdeck structure are to be reinforced under masts, derrick posts or crane pedestals, and where the deck is penetrated the deck plating is to be suitably increased.
5.5.4 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the ship's heel and trim. The designer's calculations are to be submitted.

5.5.5 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

5.5.6 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but in no case is to be taken as less than 1,5 times the thickness of the adjacent attached plating.

5.5.7 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

---

**Section 6**

**Magazine design and construction**

6.1 **General**

6.1.1 The design, construction and maintenance of magazines are to be in accordance with the specified magazine safety standard, see Pt 1, Ch 2,1.1.13. All Regulations, recommendations and requirements are to be confirmed to have been applied.

6.1.2 Where standards have not been specified the following requirements apply. A Risk Assessment, in accordance with Vol 2, Pt 1, Ch 3,17, may be used to justify alternative arrangements. This is to be approved by the Owner and Naval Administration. All recommendations and requirements are to be demonstrated to have been applied.

6.1.3 A statement of magazine requirements is to be defined and is to include:

(a) Armaments requirement; listing the expected munitions and material to be carried in magazines. Identifying the items which can or are to be co-located and those which must be stored separately or separated. Any special requirements for the storage of particular items are also to be listed including:
   (i) environmental conditions; and
   (ii) conductive deck coating requirements.

(b) Construction materials requirement; describing the permissible materials or required alternatives for magazine structures and munition stowages.

(c) Magazine Labelling requirement; describing the required labels and their locations.

(d) Fluid Systems requirement; describing the operating fluids and operating pressures of all fluid systems within the magazine boundaries.

(e) Munition handling requirement; describing the equipment and space requirements to enable the munitions to be safely handled, maintained and stowed.

6.1.4 Munition securing and handling equipment is to be in accordance with requirements of the Armaments Requirement or, with special consideration, LR's LAME Code. Explosive stores are to be classified and stowed in accordance with the armament requirement, see 6.1.3.

6.1.5 Ready use magazines are not be used for the permanent stowage of munitions. They are to comply with the requirements of this Section for the appropriate magazine type.

6.2 **Definitions**

6.2.1 Munitions are a complete device (e.g., missile, shell, mine, demolitions store, etc., charged with explosives, propellant, pyrotechnics, or initiating composition), for use in conjunction with offensive, defensive, training, or non-operational purposes, including those parts of the weapon systems containing explosives.

6.2.2 Explosives are all weapons, missiles or stores containing substances especially designed to produce an explosive, propulsive, incendiary or pyrotechnic effect for use in conjunction with offensive, defensive, training, or non-operational purposes.

6.2.3 Integral magazines are those which are bounded by the elements of the main hull structure. They are specifically designed and constructed for the safe permanent stowage of the main outfit of designated munitions defined in the armaments requirement, see 6.1.3.

6.2.4 Independent magazines are those that are non-integral, portable magazines greater than 3 m³ and the requirements for integral magazines are to be applied where applicable.

6.2.5 Small magazines are compartments opening off the upper deck which are of shape and size which does not permit walk-in and where the contents are handled from outside. Small magazines are to be specifically designed and constructed for the safe permanent or ready use stowage of munitions defined in the armaments requirement, see 6.1.3.

6.2.6 Magazine lockers are magazines less than or equal to 3 m³, designed and constructed for the safe stowage of explosive stores for which in-built magazine facilities have not been provided. They are to be free standing and surrounded by an air gap such that they do not have an adjacent compartment.

6.2.7 Magazine boxes are non-integral, portable magazines with a capacity less than or equal to 3 m³ and capable of being jettisoned overboard.

6.2.8 Pyrotechnics lockers are to comply with the requirements for small magazines, magazine lockers or boxes as appropriate.

6.2.9 Class A fire divisions are those divisions formed by bulkheads and decks which comply with the requirements of IMO Resolution MSC 61 (67) Fire test procedures code, Annex 1, Part 3.
6.2.10 Flash is a product of an explosion embracing transient flame and associated pressure wave and the electromagnetic wave.

6.2.11 Designated danger areas are compartments and spaces not fitted out specifically for the stowage of munitions, but where munitions are occasionally present.

6.3 Arrangement of magazines

6.3.1 Integral magazines and small magazines containing munitions or propellant are not to be sited adjacent to high fire risk and other compartments of high fire risk listed below:
   (a) Machinery spaces of category A.
   (b) Galley.
   (c) Switch boards or electrical control rooms.
   (d) Tanks containing liquids with a flashpoint lower than 60°C or with a temperature above 32°C.
   (e) Compartments containing liquid oxygen.
   (f) Fuel, petrol, oil or lubricant pump spaces.
   (g) Accommodation spaces.
   (h) Control Spaces.

6.3.2 Access is not permitted from any of the spaces defined in 6.3.1, to the magazine.

6.3.3 For ships where the above arrangement is completely impracticable the magazine is to be separated from the high risk space by a minimum 600 mm wide cofferdam and constructed of steel or an A-30 fire division. Cofferdams are to comply with the requirements of Pt 3, Ch 2,4.9, are to be ventilated and are not to be designed or used for stowage purposes.

6.3.4 No gasoline or pressurised bottle stowage is to be within a 6 m radius of any magazine or locker.

6.3.5 Integral magazines and small magazines containing munitions may be sited adjacent to the following compartments of moderate fire risk provided that they are separated by an A-30 fire division:
   (a) Auxiliary machinery spaces including pump-rooms air condition plant spaces, refrigeration compartment spaces and hydraulic compartments not containing flammable hydraulic fluids.
   (b) Service spaces, including laundries and workshops.
   (c) Uptakes and downtakes.
   (d) Hangars, docks and vehicle decks.
   (e) Paint, flammable, battery and acid stores.
   (f) Tanks or compartments containing independent tanks, of liquids other than sea or fresh water.

6.3.6 Magazine lockers are to be sited in a safe location on a weather deck, surrounded by an air gap of at least 300 mm on all sides and where applicable protected from direct sunlight by fitting solar cladding over top and sides with an air gap of at least 25 mm.

6.3.7 Within magazines arrangements are to be such to ensure that all munitions, including those in transit packaging, are safely stowed and suitably restrained in their stowage for predicted motions and environmental conditions as identified in the armaments requirement. Separate stowage is to be provided for each type of explosive except where specified by the armaments requirement, see 6.1.3.

6.3.8 Magazines are to provide suitable electromagnetic screening and earthing arrangements for munitions as identified in the armaments requirement, see 6.1.3.

6.3.9 Magazine boxes are to be sited on a weather deck with an air gap of at least 300 mm between the box and the deck or surrounding deck houses. They are to be located in a position suitable for jettisoning of the contents and capable of remote release.

6.3.10 Detonators are to be stowed separately from other explosives in dedicated lockers or storerooms, such spaces are to be treated as designated danger areas. Co-location may be allowed as identified in the armaments requirement, see 6.1.3 (a).

6.4 Structure

6.4.1 Integral magazines are to be of permanent watertight or gastight construction (see Pt 3, Ch 2,1.3 and 7.7) and formed by permanent A-15 class divisions. A-0 class divisions may be allowed if spaces adjacent to the magazine do not contain flammable products.

6.4.2 Independent magazines are to be of weathertight metal construction, see Pt 3, Ch 2,1.3. The interior is to be insulated with a non-combustible insulation providing an A-15 standard.

6.4.3 Magazine lockers and magazine boxes are to be constructed of steel. Other material may be accepted as identified in the construction materials requirement, see 6.1.3.

6.4.4 The scantlings of integral magazine boundaries are to be determined from Table 3.3.15 in Pt 6, Ch 3 for NS1 ships and the general plating and stiffening equations in Pt 5, Ch 3,5.8 for other ships. The design pressure, \( P_{mag} \), is to be derived as shown in Pt 5, Ch 3,5.11.

6.4.5 If venting from the magazine space is via a vent trunk, the required scantlings for the vent trunk structure are to be calculated as for magazine boundary requirements.

6.4.6 Vent plate structure and fittings are to be designed to meet the appropriate deck or bulkhead pressure requirements according to location.

6.5 Environmental conditions and ventilation

6.5.1 The temperature of the magazine is to be maintained at the environmental conditions required by the armaments requirement, see 6.1.3. Generally munitions are to be stored at temperatures greater than 7°C and less than 35°C with a relative humidity between 30 and 70 per cent. Munitions with propellant are to be maintained below 32°C.
Military Design

Volume 1, Part 4, Chapter 1

Section 6

6.5.2 The air conditioning may be recirculatory if confined to the ventilation of magazines only. If the magazine is to be ventilated with other compartments then the magazine is to vent to atmosphere. High fire risk and high value compartments should not share ventilation with magazines.

6.5.3 Where a magazine or magazine complex may require to be manned, fresh air make up, via the Air Filtration Unit is to be provided.

6.5.4 Emergency life support apparatus is to be sited in magazines where personnel are required to be permanently working.

6.5.5 Ventilation trunking is to be of an equivalent fire integrity standard as the magazine.

6.5.6 Air conditioning and ventilation systems are to be designed to maintain watertight integrity and flash.

6.6 Detail arrangements

6.6.1 Clear labelling of all magazine openings and equipment is to be maintained in accordance with the magazine labelling requirement, see 6.1.3. The following requirements are to be applied as a minimum:

(a) Integral, small and independent magazines:
   (i) the space is a magazine.
   (ii) open lights and flame are to be kept away.
   (iii) the magazine door is to be kept shut.
   (iv) sources of ignition such as matches, lighters and pocket torches are to be removed prior to entry.
   (v) not to lift with contents (in the case of independent magazines).
   (vi) magazine otherside markings in adjacent compartments.

(b) Magazine lockers and boxes:
   (i) the container is a magazine locker or box.
   (ii) open lights and flame are to be kept away.
   (iii) the box is to be kept shut.
   (iv) not to lift with contents.

6.6.2 Magazines are to be insulated with non-combustible material as necessary to prevent the condensation of moisture.

6.7 Openings

6.7.1 Openings in the magazine and lockers such as doors, hatches and escape scuttles are to be of equivalent strength and fire integrity as the surrounding structure.

6.7.2 Accesses to magazines are to be fitted with suitable security arrangements to prevent unauthorised access. Openings are to be capable of being secured from the inside and fitted with external locks. Emergency escapes are to be opened from the inside only.

6.7.3 Locking arrangements on all magazines and lockers are to be designed to prevent the possibility of entry by removing the hinge pins.

6.8 Piping, cabling and electrical systems

6.8.1 In order to eliminate potential sources of ignition in a magazine in which flammable mixtures are liable to collect, hazardous areas for magazines are to be identified and electrical equipment within the magazine is to be selected and installed in accordance with the requirements of Vol 2, Pt 9, Ch 5.4.

6.8.2 Lighting is to be operated from outside the space. Indication is to be provided at the switch location when circuits are energised.

6.8.3 All apparatus fitted in magazines is to be capable of being isolated on all poles from any source of electrical energy. The preferred method of isolation is by means of a multipole switch. Services that operate on low power at low voltage and are required to operate continuously do not require local isolation. Fire and flood detection and internal communications systems are included amongst such services.

6.8.4 Only services which are required for equipment in the magazine are to penetrate boundaries of the magazine.

6.8.5 Air and hydraulic systems used within magazines are to be low pressure systems only. Non-flammable hydraulic fluid is to be used.

6.8.6 Electrically controlled handling machinery may be fitted in magazines that continuous earth monitoring is provided in the control circuits of the machinery.

6.8.7 Equipment and light fixtures installed in magazines which may be subjected to mechanical damage are to be equipped with suitable protection against such damage. All protective metal guards for apparatus and cabling as well as the apparatus itself must be effectively earthed. Where required conduit is to be electrically continuous and bonded to earth to form an effective shield.

6.9 Fire protection

6.9.1 Integral and small magazines are to be fitted with a spray system capable of rapid reaction, with manual activation and a suitable permanent drainage system.

6.9.2 The spray system is to be capable of delivering 30 litres/m²/min. Large compartments may be fitted with independent spray systems covering separate areas.

6.9.3 Spray heads are to be arranged within magazines so that all stowages and boundaries are covered when sprayed.

6.9.4 Spray systems for integral magazines are to be fed from two separate sections of the ship’s water supply.

6.9.5 Magazine lockers and boxes are to be fitted with flood and drainage systems. The flood system is to be operated by a manual control adjacent to the locker but at least 5 m away or 3 m if suitably screened and fed from a pressurised water supply.
6.9.6 Compartments other than tanks or void spaces adjacent to magazines are to be fitted with smoke or fire detectors.

6.9.7 Locking arrangements are to be fitted to all spray, flooding, drain valves and cocks with the exception of spray control valves when housed in a lockable cabinet.

6.9.8 Magazines are to be provided with fire extinguishers commensurate with risk classification, size and type of vessel. Generally one extinguisher should be fitted on the inside and one on the outside of the magazine.

6.9.9 Designated danger areas (DDA) where munitions are handled such as weapon lifts, transfer passages, weapon preparation areas, hangars, flight decks, docks and RAS points are to be fitted with similar fire protection systems to the magazine, commensurate with the risk classification and type of vessel. LR may allow system requirements to be reduced to the provision of sufficient hose points based on the risk classification.

6.9.10 Magazines are to be coated with fire resistant paint and the deck covering is to be non spark and non slip. Any requirements for a conductive deck area and personnel will be identified in the armaments requirement, see 6.1.3. Where there is a conducting deck requirement an anti static precaution notice is to be displayed.

6.10 Testing

6.10.1 Magazines are to be tested in accordance with the gas tight requirements of Pt 6, Ch 6,6.8.

7.1 General

7.1.1 The arrangements of hull structure for chemical, biological, radiological and nuclear defence (CBRN) are to generally be in accordance with the requirements of this Section. The final design and arrangements are to be in accordance with a specified standard. Where specifically requested, LR can undertake the inspection and certification of CBRN arrangements or gas tight integrity, see Pt 6, Ch 6,6.8.

7.1.2 The subdivision of the ship for CBRN defence is achieved by the provision of zones which minimise the consequences of an attack. The zone boundaries provide protective barriers to resist the spread of primary and secondary weapon effects.

7.1.3 The number and location of zone boundaries and distribution of systems within those zones is best determined by carrying out a vulnerability analysis as detailed in Section 2.

7.1.4 The effect of zones on, and requirements for damage control should also be considered. This is best assessed by testing the zone arrangement with a series of ‘what if’ damage scenarios. A good zone arrangement will aid damage control.

7.1.5 An effective CBRN defence is to comprise of three distinct phases:

- Monitoring and detection by the provision of systems to detect the presence of and to identify the threat both outside the ship and within the zones.
- Protection of the ship and crew, using a pressurised citadel and zones with gastight boundaries and airlocks. Protection is also achieved with the filtration of air drawn into the ship and enclosing machinery intakes and exhausts.
- Decontamination of spaces within the ship is achieved using a suitable ventilation and filtration system. Decontamination of the ship itself is largely achieved using pre-wetting systems. For the crew and equipment, cleansing stations can be used.

7.2 Definitions

7.2.1 A citadel is the gastight envelope of the hull and superstructure. It consists of a group of interconnecting compartments enclosed by a gastight boundary with the independent systems necessary to provide a toxic free area free from any CBRN hazard. Large ships may have sub-citadels or more than one citadel.

7.2.2 A zone is a smaller group of compartments within the citadel with some or all of the independent systems necessary to provide a toxic free area that is free from any CBRN hazard.

7.2.3 An airlock is a compartment with two doors between the toxic free area and the source of the CBRN hazard or cleansing station. Airlocks are normally purged with clean air to allow personnel to pass from one area to another without contaminants entering the toxic free area.

7.2.4 A cleansing station is a group of compartments suitably arranged and equipped whereby CBRN decontamination of personnel and materials can take place.

7.2.5 Individual protective equipment is the personal clothing and equipment required to protect an individual from CBRN hazard. It normally consists of a protective suit and respirator.

7.3 NS1 and NS2 ship requirements

7.3.1 The requirements of this Section deal only with the hull structure and mainly involve the arrangement of major divisions within the hull. Provision is to be made within the layout and design of the ship for the compartments required for CBRN defence. It is recommended that they are considered from a very early stage in the design.
7.3.2 Unless specified otherwise, the citadel's length is to be divided into zones. It is recommended that the zone boundaries coincide with main transverse watertight bulkheads and extend from the keel to the highest superstructure deck.

7.3.3 A suitable pressure above atmospheric is to be maintained inside the citadel and zones. Zones with a higher risk of contamination are to be maintained at a lower pressure than the adjacent zones but higher than atmospheric. For example those containing machinery spaces with ventilation to atmosphere open during CBRN conditions.

7.3.4 For NS1 ships at least three cleansing stations are to be provided in separate zones. For NS2 ships at least two cleansing stations are to be provided in separate zones. They are to be located so that safe and direct entry is possible from the weather deck. One cleansing station is to be located close to the medical complex with access for stretcher borne casualties.

7.4 NS3 ship requirements

7.4.1 The requirements of this Section deal only with the hull structure and mainly involve the arrangement of major divisions within the hull. It is recommended that they are considered from a very early stage in the design.

7.4.2 For NS3 ships it may be impractical to provide zones and a citadel. In this case CBRN protection is to be provided by either individual protective equipment or sanctuaries.

7.4.3 Sanctuaries may be integral or temporary compartments on board the ship and are to be provided with an airlock, cleansing station and ventilation systems similar to that of a zone.

7.4.4 If individual protective equipment is provided arrangements are to be made to ensure that operation of the ship is possible such that it can reach a suitable place of refuge. For example, crew provisions, equipment and compartment accesses are to be suitable for persons wearing individual protective equipment.

7.5 Zones

7.5.1 The boundaries of zones are to be gastight and are to be tested in accordance with Pt 6, Ch 6.6.8. Ventilation and trunking is not to pass through zone boundaries.

7.5.2 Each zone is generally to be provided with a total air conditioning system. All air entering the citadel is to pass through CBRN filters. These filters may be bypassed when the ship is not in a threat situation.

7.5.3 Consideration is to be given to the provision of independent services in each zone for the following systems:
(a) Electrical power generation and distribution.
(b) Chilled water cooling.
(c) Fire pumps, piping and hydrants (including pre-wetting).
(d) Bilge pumps, piping and discharge.

7.5.4 At least two airlocks to the weather decks are to be provided in each zone. Access between zones are to be fitted with airlocks. Consideration is to be given to providing gastight connections adjacent to this access for the provision of the services listed in 7.5.3.

7.5.5 Consideration should be given to the use of materials that do not emit toxic fumes.

7.6 CBRN hardening

7.6.1 In determining the layout and design of the ship consideration should be given to the hardening of the ship to improve its capability in a CBRN environment.

7.6.2 All external compartments and equipment not included in the citadel should be sealed or designed such that residual contaminants cannot be trapped.

7.6.3 All access for operation and maintenance of equipment should be designed for personnel wearing individual protective equipment.

7.6.4 Shelters are to be provided deep within the ship for the temporary protection from radiation of the crew during nuclear attack.

7.6.5 Command and control centres should ideally be sited such that they are afforded the maximum protection against radiation from nuclear attack. All essential equipment should be designed to resist incident nuclear radiation (INR) and nuclear electromagnetic pulse (NEMP).

7.7 Structural requirements

7.7.1 The scantlings of all gastight zone, citadel and airlock boundaries are to be capable of withstanding two times the maximum differential pressure that can occur in service and the scantlings are to be calculated in accordance with the relevant Sections of Pt 6, Ch 3. Gastight boundaries are to be tested in accordance with Pt 6, Ch 6.6.8.

7.7.2 All openings in gastight boundaries are to be fitted with gastight closing appliances and tested in accordance with Pt 6, Ch 6.6.8 and are to be of equivalent strength to the structure in which they are placed.

7.7.3 Watertight and weathertight closing appliances may be considered gastight if a pressure greater than atmospheric is, and can be maintained inside the zone, citadel or airlock.
Section 8

Design guidance for the reduction of radiated noise underwater due to sea-inlets or other openings

8.1 General

8.1.1 The number of underwater openings should be kept to a minimum.

8.1.2 To aid in the reduction of underwater radiated noise, sea tubes and/or boxes are to be provided for each sea-water hull inlet or outlet. Where a number of openings are adjacent, consideration should be given to fitting a common plenum chamber with a single opening in the outer bottom. Care must be taken to avoid resonance of the chamber.

8.1.3 The outside of all underwater openings is to be flush with the surrounding hull plating. Particular care is to be taken to provide smooth surface on the inside of all sea tubes and discharges.

8.1.4 For sea openings required to be blanked, a smooth mating face surrounding the sea tube on to which the mating flange of the blank can sit is to be provided.

8.1.5 Adequate protective coating and cathodic protection should be considered at the interface of the valve and sea tube.

8.1.6 No underwater opening, at a level lower than the deep design draught, is to be fitted within 6 m of the aftermost part of the aft sonar dome.

8.1.7 Wherever possible, gratings or anti-sabotage bars fitted to underwater openings are to be arranged across and aligned with the flow of the water past the ship so as to minimise turbulence. They should be deep in section and have well radiused edges.
Section 2
External blast

2.1 General

2.1.1 Structures and their response to air blast loadings, can be considered to fall into two categories:
- Diffraction-type structures.
- Drag-type structures.

2.1.2 In a nuclear type explosion, the diffraction-type structures would be affected mainly by diffraction loading and the drag-type structures by drag loading.

2.1.3 Large flat sided structures, with few openings, will respond mainly to diffraction loading because it will take an appreciable time for the blast wave to engulf the structure and the pressure differential between front and rear exists during the whole of this period. A diffraction-type structure is primarily sensitive to the peak over-pressure in the shock wave to which it is exposed.

2.1.4 If structures are small, or have numerous openings, the pressures on different areas of the structure are quickly equalised; the diffraction forces operate only for a very short time. The response of this type of structure is then mainly due to the dynamic pressure (or drag forces) of the blast wind. This is typical of masts and funnels. The drag loading on the structure is determined not only by the dynamic pressure but also by the shape of the structure. The drag coefficient is less for rounded or streamlined structures than for irregular or sharp edged structures.

2.1.5 The relative importance of each type of loading in causing damage will depend upon the type of structure as well as the characteristics of the blast wave.

2.2 Threat level determination

2.2.1 Ships complying with the requirements of this Section will be eligible for the notation EB1, EB2, EB3 or EB4 as defined in 2.3.

2.2.2 External blast loading can come from a variety of threats the two main ones are far field from nuclear or fuel air type threats and near field from detonation by close in weapon systems. This part of the Rules is concerned only with the far field explosions.

2.2.3 The actual threat level used in the calculation of performance and the areas of the ship to be protected by this design method are to be specified by the Owner and will remain confidential to LR.

2.3 Notation assessment levels and methodology

2.3.1 Design to withstand increasing levels of blast pressure needs to employ increasing sophistication and complexity of analysis method if the structure is to be kept lightweight.
2.3.2 An EB1 assessment method may utilise the simple design methodology suggested in 2.8 for structural assessment. The design criteria should ensure that the structure behaves in an elastic perfectly plastic manner with small displacements when subjected to the proposed blast level.

2.3.3 An EB2 assessment method may utilise an extension of simple design methodology suggested in 2.8 to look at the elasto-plastic behaviour for the structural assessment. The structure is to be designed such that maximum displacements experienced by all structure does not compromise the structural integrity, water or gas-tight integrity or functioning of critical items of equipment required for operation of the ship and systems that is attached or adjacent to the structure.

2.3.4 An EB3 assessment method should employ a failure criterion based on an elasto-plastic methodology which considers the following structural responses:
- Local bending response of stiffened panels, the preferred model will be to evaluate the non-linear dynamic response of a single stiffener with an attached strip of plating modelled as a beam-column with the appropriate boundary conditions under blast pressure.
- A lumped parameter model can be employed to look at ‘overall sidesway’ response of a ship's superstructure. The structure is to be designed such that maximum displacements experienced by all structure does not compromise the structural integrity, water or gas-tight integrity or functioning of critical items of equipment required for operation of the ship and systems that is attached or adjacent to the structure.

2.3.5 An EB4 assessment method should employ a full non-linear analysis using finite element methods to predict the structural response. Using this methodology it is assumed that the ship must survive, this implies the need to retain primary hull structural integrity, water and gas-tight integrity or functioning of critical items of equipment required for operation of the ship and systems that is attached or adjacent to the structure.

2.3.6 For EB3 and EB4 notations, the assumptions made for initial deformations are to be submitted. Where these differ for normal ship building practice, the details are to be recorded on the approved plan.

2.4 Definitions

2.4.1 Atmospheric pressure \( P_0 \) is to be taken as 101.3 kN/m².

2.4.2 The dimensions of superstructure blocks are given in Fig. 2.2.1.

2.5 Blast pressure loads

2.5.1 For explosions of different magnitude, the range at which the peak blast incident and dynamic pressures occur can be scaled using the following equation:

\[
D_i = D_n \left( \frac{1000}{W} \right)^{1/3}
\]

where
- \( D_i \) = incident distance
- \( D_n \) = distance at which the pressure occurs, in metres
- \( W \) = equivalent weight of TNT for the explosive, in kg.

2.5.2 Similarly for weapons of a different magnitude, the duration, \( t_{p+} \), of a blast can be scaled using the scaling equation:

\[
t_i = t_n \left( \frac{1000}{W} \right)^{1/3}
\]

where
- \( t_i \) = incident duration
- \( t_n \) = duration the pressure occurs, in seconds
- \( W \) = equivalent weight of TNT for the explosive, in kg.

2.5.3 When a pressure shock front strikes a solid surface placed normal to the direction of shock travel there is an instantaneous rise in pressure above that of the shock front itself. The total pressure referred to as the reflected pressure is given by:

\[
P_r = 2P_i(7P_0 + 4P_i)/(7P_0 + P_i) \text{ kN/m}^2
\]

when
- \( P_i << P_0 \) (small charge at large stand off) \( P_i \) may be taken as 2\( P_i \) similarly when \( P_i >> P_0 \) (large charge at short range) \( P_i \) may be taken as 8\( P_i \)
- \( P_i \) = peak blast incident over-pressure in kN/m² from Fig. 2.2.3.

2.5.4 The reflected pressure, \( P_r \), can be assumed to diminish linearly until it reaches the stagnation pressure, \( P_s \), at time, \( t_s \), where

\[
t_s = 3d/U \text{ seconds}
\]

where
- \( d \) = is the lesser of \( h \) or \( \nu/2 \) in metres, see Fig. 2.2.1
- \( U \) = shock front velocity in m/s

\[
= U_0 \sqrt{1 + 6P_i/7P_0}
\]
$U_o = \text{speed of sound in air in m/s } = 332 + 0.6T_o$
$T_o = \text{ambient air temperature in } °C.$

2.5.5 The passage of the blast is immediately followed by a transient ‘blast wind’ that exerts a supplementary dynamic pressure which is given by:

$$q_i = 2.5 \left( \frac{P_i^2}{T_0 + P_i} \right) \text{ kN/m}^2$$

where

$P_i = \text{peak blast incident over-pressure in kN/m}^2$ from Fig. 2.2.3.

The duration of the dynamic pressure, $t_{q+}$, can be determined from Fig. 2.2.3.

2.5.6 The stagnation pressure, $P_s$, is determined for the front of the superstructure block by:

$$P_s = P_i + C_D q_i \text{ kN/m}^2$$

and for the top, sides and rear by

$$P_s = P_i - C_D q_i \text{ kN/m}^2$$

where

$P_i = \text{peak incident pressure from Fig. 2.2.3}
$q_i = \text{the dynamic pressure from 2.5.5}
$C_D = \text{the drag coefficient of the structure from Table 2.2.1.}$

2.5.7 For the top and sides of the superstructure the peak pressure will occur at time $t_t$ which is given by:

$$t_t = \frac{b}{U} \text{ seconds}$$

where

$b = \text{superstructure breadth in metres, see Fig. 2.2.1}
U = \text{shock front velocity in m/s, see 2.5.4.}$

2.5.8 For the rear of the superstructure the peak pressure will occur at time, $t_r$, which is given by:

$$t_r = \frac{b}{U} + 4d/U \text{ seconds}$$

where

$d = \text{is the lesser of } h \text{ or } U/2, \text{ in metres, see Fig. 2.2.1}
$b = \text{superstructure breadth, in metres, see Fig. 2.2.1}
U = \text{shock front velocity, in m/s.}$

2.5.9 Pressure distributions for the faces of the superstructure block are given in Fig. 2.2.2, together with the overall pressure acting on the block which is obtained by subtracting the forces on the rear face from those on the front.
Fig. 2.2.3 Blast parameters for TNT and nuclear explosions
2.8.2 For a given high explosive of an equivalent TNT mass at a direct distance from the target Section 2.3 can be used to determine the blast parameters.

2.9 Structural assessment

2.9.1 The rules for the EB1 and EB2 structural assessment are based on the assumption that the structure can be idealised as a single degree of freedom system. They assume that there is no significant loading on the superstructure or ship's sides at the time of the blast. In cases where there are significant lateral loadings or concentrated point loads or fluids, the natural frequency and strength of the structure will be specially considered.

2.9.2 The acceptance criteria contained in this Section assume that the structure is loaded beyond its elastic limit but not such that significant deformations result.

2.9.3 For plating the thickness is not to be less than:

\[ t = \frac{f_{DLF} P_p L s^2}{6 \sigma_0 (s + f_p)} \text{ mm} \]

where

- \( t \) = the length of the plate panel, in metres
- \( s \) = width of the panel, in mm (short span length)
- \( \sigma_0 \) = yield stress of the material, N/mm²
- \( f_p \) = plate aspect ratio factor, see Table 2.2.2
- \( f_\sigma \) = stress factor
  - 1.3 for \( \sigma_0 \leq 300 \text{ N/mm}^2 \)
  - 1.2 for \( \sigma_0 > 300 \text{ N/mm}^2 \)
- \( P_p \) = the peak pressure, \( P_r \), for the front of the superstructure, or \( P_s \) for the top sides and rear, as defined in 2.5, in KN/m
- \( f_{DLF} \) = dynamic load factor to be determined from Pt 6, Ch 2.5:
  - for superstructure front and ship sides using a linearly decreasing load with initially:
    \( t_1 = P_r t_s / P_s \) seconds
    - if \( t_m \) determined from Pt 6, Ch 2.5 is greater than 1.1, \( P_s t_s / P_s \) then \( f_{DLF} \) is to be recalculated such that:
      \[ t_1 = t_s + \frac{P_s}{P_r} \left( t_m - t_s \right) \left( t_p + t_m \right) \text{ seconds} \]
  - For superstructure top, sides and rear using a triangular load with:
    \( t_1 = 2t_s \) seconds
    \( t_1 = 2t_s \) seconds as appropriate

2.9.4 The minimum edge through thickness area of the plate is not to be less than:

\[ A_t = \frac{1}{100s \sigma_0} \left( f_{p1} \sigma_0 (s + f_p l) + f_{p2} P_m l s^2 \right) \text{ cm}^2 \]

where

- \( t \), \( \sigma_0 \), \( l \) and \( s \) are given in 2.9.3
- \( \tau_0 \) = shear yield stress in N/mm²
- \( P_m \) = pressure at the time of maximum displacement, \( t_m \), in kN/m² based on assumed pressure distribution
- \( f_{p1} \), \( f_{p2} \) = shear load factors, given in Table 2.2.3.

2.9.5 The stiffener and plate combination is considered to be satisfactory if the plastic modulus of the beam plate combination is greater than:

\[ Z_p = \frac{f_{DLF} P_p L s^3}{f_{bx} \sigma_0} \text{ cm}^3 \]

where

- \( f_{p} \), \( f_{DLF} \), \( f_{bx} \) and \( \sigma_0 \) are given in 2.9.3
- \( Z_p \) = plastic section modulus of the stiffener and attached plate, in cm³
- \( t_e \) = effective length of the beam, in metres
- \( L \) = the length of the beam, in metres
- \( f_{bx} \) = beam support factor
  - 12 for fully fixed
  - 8 for simply supported
- \( s \) = spacing of the beams, in mm.

### Table 2.2.2 Plate factors

<table>
<thead>
<tr>
<th>Aspect ratio ((A_p))</th>
<th>( f_p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1000</td>
</tr>
<tr>
<td>0.9</td>
<td>916</td>
</tr>
<tr>
<td>0.8</td>
<td>858</td>
</tr>
<tr>
<td>0.7</td>
<td>817</td>
</tr>
<tr>
<td>0.6</td>
<td>775</td>
</tr>
<tr>
<td>0.5</td>
<td>750</td>
</tr>
<tr>
<td>&lt;0.5</td>
<td>750</td>
</tr>
</tbody>
</table>

### Table 2.2.3 Plate shear factors

<table>
<thead>
<tr>
<th>Aspect ratio (s/l)</th>
<th>short span side</th>
<th>long span side</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_p1 )</td>
<td>( f_p2 )</td>
<td>( f_p1 )</td>
</tr>
<tr>
<td>1.0</td>
<td>0.18</td>
<td>0.07</td>
</tr>
<tr>
<td>0.9</td>
<td>0.16</td>
<td>0.06</td>
</tr>
<tr>
<td>0.8</td>
<td>0.14</td>
<td>0.06</td>
</tr>
<tr>
<td>0.7</td>
<td>0.13</td>
<td>0.05</td>
</tr>
<tr>
<td>0.6</td>
<td>0.11</td>
<td>0.04</td>
</tr>
<tr>
<td>0.5</td>
<td>0.09</td>
<td>0.04</td>
</tr>
</tbody>
</table>
2.9.6 The maximum elastic deflection given by:

\[ \delta_x = 10^5 \frac{f_{\text{DLF}} P_p L \sigma_o l_s^3}{f_{\text{bd}} E I} \text{ mm} \]

is not to be greater than

\[ \delta_{\text{max}} = 1000 \text{ mm} \]

where

- \( P_p, f_{\text{DLF}}, \sigma_o, l_s, l_e \) are given in 2.9.3
- \( f_{\text{bd}} \) = beam support factor
  - 384 for fully fixed
  - 76.8 for simply supported.

2.9.7 The shear area of the stiffener web is not to be less than:

\[ A_{\tau} = \frac{1}{100 \sigma_o} \left( \frac{f_{s1} f_{s2} Z_p \sigma_o}{1000 \sigma_o} + f_{s2} P_{\text{tm}} l_s \right) \text{ cm}^2 \]

where

- \( Z_p, \sigma_o, l_s, l_e \) are given in 2.9.3
- \( f_{s1}, f_{s2} \) = shear load factors, given in Table 2.2.4
- \( f_{s2} \) is given in 2.9.5.

### Table 2.2.4 Beam shear factors

<table>
<thead>
<tr>
<th>Beam type</th>
<th>Location</th>
<th>( f_{s1} )</th>
<th>( f_{s2} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simply supported</td>
<td>Both ends</td>
<td>0.39</td>
<td>0.11</td>
</tr>
<tr>
<td>Fixed ends</td>
<td>Both ends</td>
<td>0.36</td>
<td>0.14</td>
</tr>
<tr>
<td>Simple and fixed</td>
<td>Fixed end</td>
<td>0.43</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Simple support</td>
<td>0.26</td>
<td>0.19</td>
</tr>
</tbody>
</table>

2.9.8 Direct calculations or analyses based on the elastoplastic or plastic response of structure using a dynamic load factor or finite element approach will be specially considered. The designers’ calculations are to be submitted for approval.

2.9.9 In addition to the assessment of plating and stiffeners, the global capability of superstructure and above water structure are to be assessed. The designers’ calculations are to be submitted.

### 2.10 Design considerations

2.10.1 To minimise the effects of external blast, protrusions from the superstructure are to be kept to a minimum.

2.10.2 Re-entrant corners are to be avoided, where this is impractical they are to be covered by a blast deflecting plate, or be constructed such that the included angle between orthogonal faces is to be as large as possible.

2.10.3 Where the clear air gap between superstructure blocks is less than \( 0.1L_R \), the interaction under external blast loading will be specially considered.

### Section 3 Internal blast

#### 3.1 General

3.1.1 Internal blast is defined as that which occurs from detonation of a high explosive from a hostile weapon or detonation of a ship’s own ammunition inside the hull envelope. In an internal explosive loading situation the loading on a boundary can be characterised by a series of decaying reflected pressure waves (blast impulses) followed by the rapid formation of a slowly decaying static pressure (Quasi static pressure QSP) as shown in Fig. 2.3.1.

#### 3.2 Threat level determination

3.2.1 The threat protection levels for a given vessel should be determined through a vulnerability analysis against customer specified threat weapons. In the absence of such a study the following levels may be used as a guide:

- **Level I** Watertight bulkheads at \( R_{4N} \geq 1 \) and zone bulkheads at \( R_{4N} > 1 \)
- **Level II** Watertight bulkheads at \( R_{4N} \geq 1.5 \) and zone bulkheads at \( R_{4N} > 2 \)
- **Level III** Watertight bulkheads at \( R_{4N} > 3 \) and zone bulkheads at \( R_{4N} > 3 \)

\( R_{4N} \) is the normalised blast resistance 2.5 m high, 4 mm thick, mild steel, fillet welded bulkhead.

#### 3.3 Notation assessment levels and methodology

3.3.1 The magnitudes of the initial blast impulse is related to the distance from structure under consideration to the explosion. The reflections are a function of the compartment geometry. The QSP is dependent on the compartment volume with the rate of decay related to the vent area.

![Fig. 2.3.1 Typical blast pressure time history](image-url)
3.6 Structural resistance

3.6.1 The blast resistance for a given bulkhead material, thickness and joint style can be determined as a proportion of 2.5 m high, 4 mm thick, mild steel, fillet welded bulkhead using the following formula based on a combination of explosive tests and analytical techniques:

\[ R_{4N} = \left( K_j + K_m \right) \frac{t}{l} \]

where

- \( R_{4N} \) is the normalised blast resistance 2.5 m high, 4 mm thick, mild steel, fillet welded bulkhead
- \( K_m \) is the material type factor, see Table 2.3.1
- \( K_j \) is the joint type factor, see Table 2.3.2
- \( t \) is the thickness of steel, in metres
- \( l \) is the short span length, in metres.

3.6.2 The primary mode of failure for bulkhead structures is through the edge connection. Alternatives to the basic fillet weld have been assessed and incorporated in the joint type factor presented in Table 2.3.2.

3.6.3 Alternative joint types may be used but are to be categorised using a dynamic joint test and blast assessment. For novel designs a further large scale controlled blast test of the proposed arrangement is to be tested. LR can provide details of the test and analysis requirements on request.

3.7 Bulkhead arrangements

3.7.1 Piping that passes through the bulkhead is to be fitted with expansion pieces either side of the bulkhead. In addition, piping and other penetrations are to be arranged at the edges of the bulkhead where the relative movement is less as shown in Fig. 2.3.2.

Table 2.3.1 Material type factor, \( K_m \)

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>( K_m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, D, E, AH32, AH36</td>
<td>0</td>
</tr>
<tr>
<td>DH32, EH32</td>
<td>86</td>
</tr>
<tr>
<td>DH36, EH36</td>
<td>196</td>
</tr>
</tbody>
</table>

Table 2.3.2 Joint type factor, \( K_j \)

<table>
<thead>
<tr>
<th>Joint style</th>
<th>( K_j )</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal fillet weld</td>
<td>625</td>
<td>Valid up for ( t_{bh} \leq 8 ) mm</td>
</tr>
<tr>
<td>Full penetration weld</td>
<td>665</td>
<td>Valid for ( t_{bh} \leq 12 ) mm</td>
</tr>
<tr>
<td>Austenitic fillet weld</td>
<td>701</td>
<td>Valid for ( t_{bh} \leq 6 ) mm</td>
</tr>
</tbody>
</table>

NOTE: Values of \( K_j \) up to 1200 can be achieved using blast resistant bulkhead designs.
4.1 General

4.1.1 This Section does not deal with the loss of structural strength due to material perforation. It is only concerned with fragmentation protection of equipment and personnel within critical compartments and potentially critical pipe and cable runs.

4.1.2 Fragment and small arms penetrators can be stopped by the use of structure designed to prevent penetration, either through the use of increased thickness of normal structural materials, suitable siting of compartments, addition of armour (non-structural) materials, or even the use of armour material that can take structural loads.

4.1.3 The Rules give design data based on fragment penetration equations for three representative threats. The selection and use of fragment penetration equations or computer modelling for other threats will be considered provided they are carried out by a competent body which has relevant experience and employs recognised procedures.

4.1.4 For fragmentation protection to be effective, materials within the ship forming part of the ship’s equipment and outfit shall be of a type that is not prone to the generation of secondary fragments or ‘splinters’. Materials such as wood, brittle plastics and brittle cast materials are not to be used in protected compartments. Where the use of such materials is essential, consideration may be given to the use of bonded splinter-retaining membranes.

4.1.5 RATTAM is defined as the response to attack on ammunition and describes protection fitted externally to the ship to prevent the penetration of particular threats which may cause damage, principally to magazines. Similar protection may also be fitted to protect other critical compartments, both are covered by the SP notation.

4.2 Threat level determination

4.2.1 The threat may be classified as either small arms fire or fragments from the casing of shells or warheads (‘shrapnel’ or ‘splinters’) capable of perforating the ship’s structure and thus causing damage to equipment or casualties amongst personnel.

4.2.2 Three levels of protection are shown in Table 2.4.1. They are from a combination of internally and externally detonating threats. Alternative levels will be considered in accordance with 4.5.2.

4.2.3 The actual threat level and type used in the calculation and the areas of the ship to be protected are to be specified by the Owner and will remain confidential to LR.
4.2.4 The Level I threat is assumed to detonate on impact with the ship’s structure in the act of which it will penetrate the outer skin of the vessel. Fragmentation protection will reduce the risk of fragments penetrating additional compartments. The ends, internal sides and decks of critical compartments are in general to be fitted with protection, an example of which is shown in Fig. 2.4.1(a), see also 4.3.2. The outer skin of the ship may be strengthened to resist the shell in accordance with the requirements for the SP notation, however it will usually require a significant amount of armour.

4.2.5 Level II considers a threat posed by an externally detonating shell. Strengthening is, in general, to be fitted to the external skin of the ship to protect the critical internal spaces, an example of which is shown in Fig. 2.4.1(b), see also 4.3.2. For this level of protection a stand off distance for the weapon is to be specified by the Owner.

4.2.6 The Level III threat is a generic weapon based on a sea skimming anti-ship weapon with a semi armour piercing, (SAP) warhead that detonates within the hull. Fragmentation protection is intended to reduce the risk of fragments penetrating additional compartments. The considerable amount of protection required will normally mean that protection is only fitted at zone boundaries to limit the longitudinal spread of fragments. See example in Fig. 2.4.1(c) and also 4.3.2.

4.2.7 The examples given in Figs. 2.4.1(a) to (c) show a compartment immediately under the main deck with deck-house over subject to a side-on attack. Where the critical compartment is fitted directly below an external deck, in a deckhouse or the threat is directly above the compartment, protection is to be arranged using the principles given in examples in Figs. 2.4.1(a) to (c).

4.3 Notation assessment levels and methodology

4.3.1 The fragmentation protection FP1 and FP2 notations are assigned for ships which have protection fitted to resist fragments from the casing of a shell or warhead. The small arms protection, SP notation is assigned for ships fitted with protection to resist the penetration of small arms fire into the hull. For ships where the fragmentation resistance is carried out using the Tables and graphs of this Section an FP1 notation is assigned. Where fragmentation testing or analysis is used to determine the fragmentation resistance required a FP2 notation is assigned.

4.3.2 The pressure produced by a Level I threat is such that an IB notation is not required. The Level II threat is external and of a level such that an EB notation will not be required. A Level III threat will require the effect of the internal blast pressure on the structure to be considered and IB and RSA notations will generally be required.
4.4 Information required

4.4.1 For each threat level it will be necessary to identify the critical compartments requiring protection, plus the critical pipe and cable runs where appropriate. Plans are to be provided showing the location and manner of all fragmentation and terrorist attack protection.

4.4.2 Where alternative tests or calculations have been carried out full details are to be submitted. They are to include details of the organisation involved, their experience, test or calculation procedures and the program or equations used.

4.5 Structural requirements

4.5.1 Where different threats, materials or multiple plate arrays are fitted alternative methods may be used to determine the fragmentation resistance, for example:

- Penetration equations.
- Finite element and fluid-codes.
- Experimental methods.

Ascending the levels of calculation complexity is not simply a matter of increased cost in design, the increased complexity potentially offers the reward of reduced protection requirement for the given threats.

4.5.2 Armour spaced normal to the threat can reduce the total thickness by up to 30 per cent. It may also be effective for bullets provided the gap between plates is greater than 1,0 m.

4.5.3 For Level I fragmentation protection, the equivalent thickness of steel is to be in accordance with Table 2.4.2.

Table 2.4.2 Level I fragmentation protection

<table>
<thead>
<tr>
<th>Material yield strength N/mm²</th>
<th>Transverse bulkhead or deck thickness mm</th>
<th>Longitudinal bulkhead thickness mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>235</td>
<td>6,5</td>
<td>6,0</td>
</tr>
<tr>
<td>355</td>
<td>6,0</td>
<td>5,6</td>
</tr>
<tr>
<td>550</td>
<td>5,5</td>
<td>5,0</td>
</tr>
<tr>
<td>RHA</td>
<td>5,0</td>
<td>4,5</td>
</tr>
</tbody>
</table>

NOTE
RHA is defined as rolled homogenous armour.

4.5.4 For Level II fragmentation protection, the equivalent thickness of steel is to be determined from Fig. 2.4.2.

4.5.5 For Level III fragmentation protection, the equivalent thickness of steel is to be determined from Fig. 2.4.3. Protection will normally be required to be provided by several bulkheads or specific armour and the graph can serve only as a guide. The structural protection for this type of threat will generally be specially considered based on the particular weapon characteristics and protection arrangements. It should also be noted that many modern missiles generate controlled fragments which will need special consideration.
In the meantime, the gas bubble begins to expand against the ambient hydrostatic pressure displacing water radially outward as incompressible flow. As it expands, it loses pressure and temperature but the inertia of the outwardly flowing water leads to an overshoot of the equilibrium state so that at maximum bubble radius, the gas pressure is well below the ambient. This initiates the collapse sequence, the gas bubble is recompressed, slowly at first but then rapidly, to a minimum volume by the hydrostatic forces. Because of the generation of a large pressure in the bubble during this stage the bubble begins to expand again and several other cycles may follow. The gas bubble and water interaction can be thought of as a gas spring – mass system. It has a periodicity associated with it but because of energy losses during the process, the spring constant and mass changes over each cycle leading to a change in the periodicity. At each minimum, that is, each recompression, additional pressure pulses are emitted which become weaker with each oscillation as shown in Fig. 2.5.1.

The graphs are produced based on a 50 per cent probability of perforation for penetrators perpendicular to the target.

Section 5
Underwater explosion (shock)

5.1 General

5.1.1 There are two principal loading mechanisms associated with the underwater detonation of a conventional high explosive ordnance:
- shock wave loading;
- bubble flow loading.

5.1.2 The energy released is in general, equally divided between shock wave energy and the energy contained within the superheated high pressure bubble of gaseous explosion products.

5.1.3 The shock wave generated as the detonation wave passes into the water is a highly non-linear pressure pulse which propagates at a speed well in excess of the speed of sound in water (approximately 1500 m/s). However, within a few charge radii of the detonation point, it can be mathematically defined as an acoustic pressure pulse travelling at the speed of sound. Its amplitude falls off inversely with distance and its profile can be characterised by a pulse which has an infinite rise to a peak pressure followed by an exponential decay. The peak value and decay rate at a given field point are given by the similitude equations/coefficients for the explosive material.

Fig. 2.4.3 Level III fragmentation protection

5.1.4 In the meantime, the gas bubble begins to expand against the ambient hydrostatic pressure displacing water radially outward as incompressible flow. As it expands, it loses pressure and temperature but the inertia of the outwardly flowing water leads to an overshoot of the equilibrium state so that at maximum bubble radius, the gas pressure is well below the ambient. This initiates the collapse sequence, the gas bubble is recompressed, slowly at first but then rapidly, to a minimum volume by the hydrostatic forces. Because of the generation of a large pressure in the bubble during this stage the bubble begins to expand again and several other cycles may follow. The gas bubble and water interaction can be thought of as a gas spring – mass system. It has a periodicity associated with it but because of energy losses during the process, the spring constant and mass changes over each cycle leading to a change in the periodicity. At each minimum, that is, each recompression, additional pressure pulses are emitted which become weaker with each oscillation as shown in Fig. 2.5.1.

Fig. 2.5.1 Shock wave bubble pulse
5.1.5 The bubble is pulsating in a gravitational field and will have a tendency to migrate to the water/air boundary (the free surface). However, this bodily motion of the bubble centre may be influenced by the proximity of other boundaries such as the seabed or a nearby ship structure. The rate at which a bubble will migrate to the free surface is a function of the buoyancy forces generated when it is at its maxima and of the drag forces it experiences as it moves through the water. Because these drag forces are small when the bubble is at its minima, it tends to migrate vertically upwards more rapidly when at its smallest volume.

5.1.6 The fluid flow generated by the bubble dynamics is an important loading mechanism for a structure, within its sphere of influence. Normally bubble loading can be ignored if the bubble never approaches within a distance of around ten times the maximum bubble radius. The important feature of the bubble loading is its low frequency which is ideally suited to induce ship hull girder flexural motion. This flexural motion is commonly referred to as hull girder whirling. This loading mechanism is dealt with in Section 6. If the bubble is within one bubble radius of the ship structure, it is likely to form a jet which will impact on the structure. This bubble collapse mechanism will cause extensive local damage. It is generally not possible to efficiently design against this loading event for a NS2 or NS3 ship. For a NS1 ship there may be sufficient residual strength to withstand such damage, but the extent of the damage will need to be determined by a specialist calculation and the capability of the hull using a residual strength assessment, see Section 7.

5.1.7 The shock wave loading is greatest at a point on the structure nearest to the detonation event and because of the fall-off with distance and the narrowness of the pulse width, it can be thought of as a local loading event. (In contrast, the bubble induced whipping of the hull girder is considered a global loading event.) The remainder of this Section will focus on the shock loading event only.

5.1.8 There are no simple analytical or numerical techniques for reliably determining the shock resistance of a structure. A measure of the resistance to shock loading can be achieved by good design of the details of the structure to avoid stress concentrations which may lead to rupture. It is also possible to ensure that the plating thickness is matched to the assumed performance of the joints using a simple damage law. The inertial loads on the ship’s structure caused by the equipment and its seatings can be determined by time domain analysis.

5.1.9 The shock performance of a ship’s hull structure can be assessed solely by conducting shock tests (usually at scale). However, cost usually precludes this approach and a better strategy is to combine tests to determine failure criteria with numerical modelling using Finite Element methods. This complementary experiment/numerical simulation approach reduces the amount of testing required and also provides a method for extrapolating to full scale from scaled experiments.

5.1.10 Generally, for a normal ship structure, the explosion required to cause uncontrollable flooding or total loss of propulsive power or loss of mission system effectiveness (radars, electronics, etc.) is much less than that required to cause failure of a hull designed for normal sea loads.

5.1.11 Due to operational requirements, some vessel types, such as minesweepers, will be required to resist repeated shock loading at a specified level without degradation of the system or structural performance. Such vessels will also be expected to survive a single attack at a considerably higher shock loading level.

5.2 Threat level determination

5.2.1 The actual threat level used in the calculation of performance and the areas of the ship to be protected by this design method are to be specified by the Owner and will remain confidential to LR.

5.2.2 Loading levels may be specified with varying degrees of structural and system degradation to define the shock performance of the vessel. An important consideration is the balance that has to be achieved between system functionality and structural performance.

5.2.3 Two performance bounds can be considered for the shock response of structure:
- The first performance bound (lower bound) relates to the onset of material yield (assuming that careful design has ensured that no buckling will occur before this state is reached). This level is useful to know as it may have consequences for system functionality. For example, there may be problems associated with equipment misalignment because of the permanent set of the supporting structure.
- The second performance bound (upper bound) relates to removal or rupture of material; this being the loading level at which there is no longer sufficient residual hull girder strength to resist normal environmental loading. This is addressed in a separate assessment which is defined by the residual strength notations RSA1, RSA2 or RSA3 in Section 7. In conventional naval ships, this upper bound will be significantly higher; but there will be little, if any, system functionality.

5.3 Notation assessment methodology

5.3.1 The shock performance required is to be specified by the Owner and is to include requirements for:
- Local strength assessment;
- Detailed design;
- Seat design, shock mounts and system hangers;
- Hull valve design and integration;
- Global strength assessment;
- Shock qualification/testing of equipment;
- 1st class shock trial.

It is recommended that seats, valves, piping and equipment are categorised into: essential and non essential, see also Vol 2, Pt 1, Ch 1.3.1.1.
5.3.2 Ships that comply with the minimum or enhanced requirements of this Section will be eligible for the shock notation SH.

5.3.3 For ships where the machinery is in class (LMC notation), and shock requirements for machinery and equipment are specified, the requirements of Vol 2, Pt 1, Ch 4.4.11 are to be complied with.

5.3.4 For the minimum shock capability, the design emphasis should focus on maintaining a high level of system functionality and reducing the risk of flooding.

5.3.5 For the assignment of the SH notation, the minimum requirement is for the structure to be designed to resist normal environmental loads in accordance with the Rules. For NS1 ships the inherent ruggedness in the Rules is sufficient for the structure to resist a low level threat. For NS2 and NS3 ships the integrity of the hull plate and stiffeners is to be verified, using the simple formulae for pressure in 5.4.1, and comparing the response to a specified standard. In addition, the hull valves below the waterline are to comply with the requirements of 5.8.

5.3.6 The minimum local assessment required by 5.3.5 can be enhanced by undertaking a more complex assessment as defined in 5.4, which accurately models the physics of the rapid, dynamic, fluid structure interaction problem.

5.3.7 In addition to the analysis, the SH notation can be enhanced by selecting detail design requirements to reduce the risk of fracture initiation and structural collapse based on historical work on shock. Details are provided in 5.5.

5.3.8 The SH notation may be further enhanced by undertaking shock trials in accordance with established procedures, on the first ship in the class. The magnitude of the test is normally less than the design value for the hull and at a level that is appropriate for the equipment and systems.

5.3.9 Global assessment may be undertaken for the SH notation using the residual strength procedures outlined in Section 7 with the extent of damage being defined from the results of the local strength assessment rather than the damage radii. For the RSA1 procedure, the damaged structure is to be removed from the analysis. For the RSA2 or RSA3 procedure, if the damage is limited, the geometry of the damaged structure can be modelled and if the damage is severe, the structure is to be removed from the analysis. The structure is considered acceptable when the hull girder is able to withstand the design loads as specified in Part 5.

5.4 Local strength assessment

5.4.1 For the notation SH, a simple analysis can be performed which allows the motion response at any point in the ship to be determined. This can be derived from experimental results or the Taylor plate equations given below. Once the motion response is known, the damage potential can be determined by comparing the response to a specified standard:

\[ V_{\text{max}} = \frac{2P_m}{\rho c} z^u \text{ m/s} \]

Time to maximum velocity

\[ t_{\text{max}} = \frac{m}{\rho c} \left( \frac{1}{1-z} \right) \log_e \left( \frac{1}{z} \right) \text{ seconds} \]

where

\[ z = \frac{m}{\rho c \theta} \]

\[ u = \frac{z}{1-z} \]

\[ \theta = \text{decay constant of explosive charge in seconds} \]

\[ P_m = \text{peak pressure in N/mm}^2 \]

\[ \rho = \text{density of water in kg/m}^3 \]

\[ c = \text{speed of sound in water in m/s} \]

\[ m = \text{structural mass per unit area in kg/m}^3. \]

5.4.2 A more complex assessment method can be used to enhance the SH notation. Methods can be used which accurately model the physics of the shock event. At the simplest level, a finite element model of the structure coupled with a suitable boundary element from proprietary software may be used.

5.4.3 For complex ships such as multi-hull designs a boundary element approach may not be suitable and a volume element approach should be used. Also, if non-linear fluid behaviour is important (i.e., hull cavitation or bulk cavitation), then a volume element approach should be used unless the finite element or boundary element code used has a suitable cavitation model.

5.4.4 The assessment method or analysis used should be validated against shock trial results and the evidence made available. As an alternative to analysis, full or large-scale shock trials of a section of the ship can be used to validate the proposed design. For novel design arrangements or ship types, a combination of trials and analysis may be necessary, the requirements of which will depend on the threat level and type of structure or ship design.

5.4.5 Any finite element analysis performed for local strength assessment is to be in accordance with the requirement of this Section for assignment of the SH notation.

5.4.6 The extent of the analysis model is to be from about 0.35L to 0.5L and encompass at least two major compartments and three watertight bulkheads. It is to be sufficiently large to avoid reflections within the structure from the boundaries, for the threats considered. For the assessment of structural strength, the structure need only be modelled to 1.0 m above the design water line. If the model is to be used to determine equipment response, all structure within that section should be modelled.
5.4.7 The model, or versions of the model, should encompass representative integral tank arrangements and hull penetrations, stabiliser inserts, hull valves, the failure of which could lead to uncontrollable flooding. Penetrations, the failure of which will not lead to significant flooding or damage, need not be considered. The tanks and penetrations need not actually be in the section under consideration but should be sufficiently similar to represent structure outside the region modelled.

5.4.8 All masses above 100 kg should be included in the model together with an approximation of the mounting system if applicable.

5.4.9 The model should include at least one major machinery item or raft.

5.4.10 The response of hull panels depends upon a large number of variables which are both design and attack geometry dependent. To simplify the task, the following assumptions can be made:

- The charge detonates in the worst location, perpendicular to the structure under consideration.
- All welding is continuous and there are no manufacturing or material defects in the panels.

5.4.11 During the analysis, appropriate elements are to be used to couple the fluid medium and the structural model.

5.4.12 The shock wave can be represented by an exponentially decaying, infinite rise time pressure pulse which sweeps across the structure at the speed of sound.

5.4.13 Non-linear structural modelling can be used in finite element analyses. If used, stiffeners should be modelled explicitly using shell elements of the appropriate thickness. Stiffener flanges should be modelled with at least two elements per half width or flange. Initial imperfections in the hull plating are to be taken into account prior to the dynamic loading analysis.

5.4.14 The structure is considered acceptable when:

- Elastic deflections are less than the temporary limits of machinery and systems.
- Permanent deflections are less than the limits of machinery and systems.
- Deflections and strain are less than the limits of the structure or applicability of the analysis method.

5.5 Detail design guidance

5.5.1 For enhanced shock performance any of the following design details can be included in the design, which is based on historical shock testing and experience.

5.5.2 Tank boundaries are to be of equivalent scantlings to the hull boundaries.

5.5.3 Intermittent welding is not to be used on hull girder structure or tank boundaries below the water line or for 1 metre in way of the deck and shell connections.

5.5.4 Structural discontinuities are to be avoided and in general a minimum taper of 1:4 is to be applied to changes of structural section.

5.5.5 Bar keels are not to be fitted.

5.5.6 For structure supporting seatings of equipment above 100 kg, calculations demonstrating the capability of the tank and supporting structure are to be submitted.

5.5.7 Main machinery mounts or raft mounts are to be supported on transverse web frames or floors forming part of the transverse ring structure. See Pt 3, Ch 2,3,2.2.

5.5.8 The size of longitudinal members are unavoidable, their connection to the bulkhead will be specially considered.

5.5.9 Bottom longitudinals are to be of a uniform size. Alternate large and small longitudinals are to be avoided as they may lead to high shear forces in the bulkhead.

5.5.10 Access holes in all primary framing members are to be avoided in areas of high shear stress. Where they are essential to the operation of the ship they are to be circular and fitted with appropriate stiffening or compensation.

5.5.11 Frames on the bilge are to be provided with adequate lateral support, consideration should be given to the fitting of a shock stringer.

5.5.12 Lapped connections are not to be used to connect frames to floors.

5.5.13 All bulkhead stiffeners are to end on longitudinals, see Fig. 2.5.2.

5.5.14 In transversely framed ships, bulkhead stiffeners are to be terminated on a shock stiffener welded to the bulkhead, parallel to, and spaced 500 mm from the shell. The bulkhead plating thickness is to be suitably increased in way. The shock stringer and bulkhead plate may be replaced by a web frame of suitable scantlings.

5.5.15 Bulkhead penetrations are to be grouped, away from the side shell and kept above the water line as far as is practicable.

5.5.16 Shell frames and deck beams are to be fitted in such a way as to minimise misalignment. Brackets where fitted are to be radiused and fitted with soft toes.

5.5.17 Where the vessel is to be subject to very high levels of shock the following details can be included in the design.

5.5.18 Pillar bulkheads are to be used below the waterline in place of pillars.
5.5.20  It is recommended that symmetric stiffeners should be fitted to the underwater portion of the shell envelope.

5.5.21  Where a transverse framing system is used, the shock capability of the structure will be specially considered. Calculations supporting the use of particular design details are to be submitted.

5.5.22  All bulkhead stiffeners are to end on longitudinals, see Fig. 2.5.2. An increased thickness margin strake on bulkheads of thickness not less than 80 per cent of the adjacent shell plate thickness, the thickness of the adjacent shell stiffener or 6,5 mm. The margin plate is to have a width not less than 1,5 times the adjacent stiffener spacing or four times the depth of adjacent shell stiffeners.

5.5.23  Shell frames and deck beams are to be fitted in such a way as to minimise misalignment. The frames are to be fitted within a tolerance of 0,3\(t_f\) median line up to a maximum of 3,0 mm where \(t_f\) is the greater thickness of the frames being connected. Where this is not possible, the frame is to be released over 20\(t_f\) and realigned.

5.5.24  Where brackets are fitted, similar tolerances to 5.6.5 are to be applied subject to a suitable area being provided for weld fillet, see Fig. 2.5.3. Tripping brackets or intercostal stiffeners should be used to stabilise the frame at the bracket toes. Brackets are to be radiused and fitted with soft toes.

5.5.25  The cross-sectional area of the bulkhead stiffeners at their outer ends in way of the margin plate should not be less than 60 per cent of the area of the web of the hull longitudinals to which they are attached. To achieve this requirement the bulkhead stiffeners may be tapered between the outer end and the point at which the size is the minimum required to withstand lateral pressure. The slope of the taper is to be such that:

\[
A_x > 0,6A_L - 2t_f/3
\]

where

- \(A_x\) = cross-section area of the bulkhead stiffener at a distance \(x\) from its outer end
- \(A_L\) = web area of the longitudinal, and \(t\) is the bulkhead plating thickness at \(x\).

5.5.26  The short stiffeners above the turn of bilge should be on the same side of the bulkhead as the main bulkhead stiffeners and should end on such a stiffener, see Fig. 2.5.2. Where necessary an additional diagonal stiffener may be worked to facilitate the arrangement.

5.6  Seat design

5.6.1  The shock notation may be enhanced by specifying that some or all of the equipment seating is to be designed to resist shock loading. Seats design should take account of the acceleration and deceleration from the shock wave; the magnitude of the shock acceleration will depend on the equipment mass, position in the ship and mounting arrangements. The seat design methodology is to be in accordance with a specified standard. The selection of seats to be assessed will depend on the equipment supported and the compartment in which it is situated.

5.6.2  Minor seats should be assessed to ensure that equipment remains captive. Detail design requirements such as minimum thickness, alignment, and free edge support can be specified to improve shock performance. In the absence of information, minor seats can be considered as those with equipment mass below 100 kg.
5.6.3 Seats which are not classed as minor are to be assessed for shock loads using acceleration values appropriate to the region of the ship in which the equipment is installed. Large items of equipment where the seat is integrated into the ship’s structure will normally require a finite element analysis to assess the strength of the seat. Where these seats are adjacent to the hull or an integrated tank, the fluid structure interaction may need to be modelled. See 5.4.

5.6.4 The shock accelerations are to be specifed by the Owner. In general, accelerations will be specified for the following regions of the ship:
(a) within 2.0 m of the wetted hull;
(b) main transverse bulkheads and decks below the strength deck;
(c) above strength deck and superstructures;
Shock accelerations can be scaled using a factor for different equipment based on their category of use.

5.6.5 For each equipment seat to be assessed, a report is to be provided containing the following information:
(a) equipment mass and centre of gravity;
(b) location in vessel;
(c) mounting system;
(d) spatial clearances around the mounted equipment;
(e) captivity requirements;
(f) relevant excitation frequencies from mounted equipment in the case of reciprocating or rotational machinery;
(g) calculations demonstrating maximum stress and displacement under; vertical acceleration, vertical deceleration and athwartships accelerations. For non-linear analyses strain rates are to be provided;
(h) equipment alignment requirements, as appropriate.

5.6.6 As a minimum, the following seat load cases are to be assessed:
(a) bolts; pull through, tensile, shear and bearing strength;
(b) seat flange; flange bending and top plate weld area;
(c) seat web; buckling and overturning;
(d) deck; seat weld area if less than flange.

5.6.7 Stress and strain are to be assessed against criteria appropriate for the seat material and loading rate. The first fundamental mode of vibration of the seat including equipment is to be greater than 10 times the shock mount rated natural frequency to provide a sufficiently rigid base for the shock mount. In the absence of specific information, for steel, the following data may be used:

<table>
<thead>
<tr>
<th>Plastic deformation of seats</th>
<th>Tension</th>
<th>Bending</th>
<th>Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long loading times &gt;0,5 ms (elastic deformation only)</td>
<td>$1.0\sigma_{ps}$</td>
<td>$1.0\sigma_{ps}$</td>
<td>$0.8\sigma_{ps}$</td>
</tr>
<tr>
<td>Short loading times &lt;0.5 ms (elastic deformation only)</td>
<td>$1.2\sigma_{ps}$</td>
<td>$1.5\sigma_{ps}$</td>
<td>$0.9\sigma_{ps}$</td>
</tr>
</tbody>
</table>

where $\sigma_{ps} = \text{static 0.1\% proof stress}$

The values in this Table are applicable to mild and high tensile steel grades up to a yield strength of 400 MPa.

5.7 Shock mounts

5.7.1 All shock mounts are to be of an approved type. Approval is to be undertaken by organisations approved by the Naval Administration. Approval documentation should contain the following information in accordance with NATO document ANEP63:
(a) nature and application of the mount including: generic type, application, load range, shock displacement, environmental constraints and frequency range;
(b) description of the mount assembly, including the complete assembly, the mount and the associated components;
(c) details of the mount standard assembly and installation;
(d) physical size, mass and dimensions;
(e) performance data as listed in Table 5.8.1;
(f) details of the mount testing process, including: method of force generation, number of mounts used/shots used, mount supplier, validation, mount permanent deflection, details of test facility and date of testing;
(g) mount specific protection, installation, inspection and maintenance requirements;
(h) any applicable historic data, i.e. changes to the mount details over time. For example, changes of material, etc.

Table 5.8.1 Shock mount characterisation

<table>
<thead>
<tr>
<th>Mount size number</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal load</td>
<td>kg</td>
</tr>
<tr>
<td>Static stiffness</td>
<td>Vertical $H_A$, Horizontal $H_R$</td>
</tr>
<tr>
<td>Dynamic stiffness</td>
<td>Vertical $H_A$, Horizontal $H_R$</td>
</tr>
<tr>
<td>% of critical damping</td>
<td></td>
</tr>
<tr>
<td>Vertical static displacement at nominal load</td>
<td>mm</td>
</tr>
<tr>
<td>Natural frequencies</td>
<td>Vertical $H_A$, Horizontal $H_R$</td>
</tr>
<tr>
<td>Dynamic magnification at resonance</td>
<td>—</td>
</tr>
<tr>
<td>Shock displacement capacity</td>
<td>Vertical $H_A$, Horizontal $H_R$</td>
</tr>
<tr>
<td>Maximum transmitted acceleration at nominal load</td>
<td>Vertical $H_A$, Horizontal $H_R$</td>
</tr>
<tr>
<td>Range of validity of mount surface/best fit governing equation (where applicable) relative to unloaded condition</td>
<td>±mm</td>
</tr>
<tr>
<td>Required support stiffness</td>
<td>N/m</td>
</tr>
<tr>
<td>Required support strength</td>
<td>N</td>
</tr>
</tbody>
</table>
5.8 Design guidance for hull valves, piping and seals

5.8.1 Hull valves below the waterline are to be of an approved type. Approval is to be undertaken by organisations approved by the Naval Administration. Approval documentation should contain the following:
(a) details of the valve body, main components and securing arrangement to the hull, including bolt material grade and tightening torque;
(b) details of the valve testing process including method of force generation, number of tests, validation, details of test facility and date of testing.

5.8.2 Only materials with sufficient ductility to avoid fracture under shock conditions are to be used. Materials should be able to withstand high stresses for very short periods without exhibiting brittleness. Valve bodies are not to be made from materials with an elongation of less than 10 per cent. There should be adequate material in way of the valve seat to prevent distortion.

5.8.3 In general, the valve body should be as symmetrical as possible with no rapid changes in section; web stiffeners should not be incorporated. Spindles should be as short as possible. Square threads or sharp thread run-outs are to be avoided. Handwheels should be as light and small as possible.

5.8.4 The weight of the actuator is to be considered in the design of the valve and its connection to the hull. The actuator can form a considerable proportion of the overall weight of the valve.

5.8.5 Consideration should be given to the attached piping and its capacity to withstand shock:
(a) Detachable pipe connections should be kept to the minimum necessary for installation and maintenance requirements;
(b) Flanged and welded connections are to be used adjacent to the hull valve. Adjacent piping is to be designed to allow the valve and hull to flex under shock with limited restraint;
(c) Where necessary, piping shall be supported with shock resistant mounts at a sufficient number of locations commensurate with the design shock level. The selection of shock mounts should consider displacement capability, see 5.7. The response of the piping relative to equipment should be considered. Sufficient space between equipment and piping should be provided to ensure they do not contact each other in a shock scenario;
(d) The routing of piping should be developed to minimise the number and size of penetrations through bulkheads, see 5.5.11;
(e) The consequences of leakage from piping and fittings should be investigated;
(f) Brackets should not be welded direct to steel piping;
(g) Adequate division of vital piping systems to isolate damage should be considered;
(h) The shock resistance of flanged connections should consider bolt preload, anti-rotational locking devices where appropriate and performance of gaskets.

5.8.6 The sealing arrangement between the valve and the hull insert is to be suitable for shock loading and able to accommodate elongation of the securing studs.

5.8.7 Hull valve designs can be approved by the following methods:
(a) physical testing;
(b) semi-empirical methods;
(c) direct calculation.

5.8.8 Physical shock testing may be used to assess the valve. Physical testing is to take account of the attachment to the hull and possible combinations of hull scantlings, stiffener spacing, materials, etc.

5.8.9 Recognised semi-empirical methods may be used to assess the valve.

5.8.10 Validated numerical methods may be used to assess the valve. Where used they are to take account of the following criteria:
(a) asymmetry in the valve and piping assembly;
(b) dimensions of the hull insert/pad;
(c) use of sea tube between the valve and hull insert;
(d) hull scantlings and stiffener/frame spacing;
(e) plasticity in the hull and valve assembly;
(f) the effective mass of the valve, actuator and piping;
(g) the valve to hull securing arrangement, taking into account fit and pre-stress effects;
(h) dynamic properties of materials;
(i) the effect of any surrounding equipment or masses.

Sea tubes of unusual material, GRE for example, or unusual configuration are to be assessed by physical shock testing and not assessed by numerical simulation.

5.8.11 The potential for leakage from seals/glands under shock loading, and the consequences of leakage, are to be considered. The shock resistance of vital seals/glands, including stern-tube seals, is to be validated by shock qualification testing. The sealing efficiency of stern-tube seals should not be compromised by the anticipated axial, radial and angular shaft movements commensurate with the design shock level.

# Section 6

## Whipping

6.1 General

6.1.1 The effects of a non-contact underwater explosion are described in Section 5. Whilst the initial shock wave described in that Section initiates whipping to some degree it is the pulsation of the bubble which leads to the majority of damage to the hull. The initial shock wave causes local hull damage and shock damage to the vessels equipment. In the strain history shown in Fig. 2.6.1 the initial shock wave can be seen to be not just the free response of an elastic system to an impulse as the amplitude continues to increase. There is a typical second kick to the system which stems from the first bubble pulse and which increases the response for several more cycles.
6.1.2 The nature and behaviour of the gas bubble are dependent upon the warhead charge size, the explosive composition, the detonation depth and the influence of boundaries such as the sea bed.

6.1.3 The maximum radius of the bubble at the end of the first expansion phase is given by:

\[ R_{\text{bub}} = 3.417 \left( \frac{W}{H + 10} \right)^{1/3} \text{ m} \]

where

- \( W \) = bare charge equivalent weight of TNT, in kg
- \( H \) = depth of the charge at the time of detonation, in metres.

6.1.4 The period of duration of the first bubble pulse is given by:

\[ t_{\text{bub}} = 2.108 \frac{W^{1/3}}{(H + 10)^{5/6}} \text{ sec} \]

where

- \( W \) and \( H \) are defined in 6.1.3.

6.1.5 Even a relatively modest warhead charge size can produce a bubble which displaces a large mass of water in a very short time frame. The momentum associated with this rapid incompressible flow of a sizeable volume of water constitutes a major loading mechanism for any structure within its sphere of influence.

6.1.6 The effect on the hull is a large amplitude vertical bending and vibration. This first introduces high shear forces at the quarter points which may cause shear wrinkling, this damage will probably not be catastrophic and the hull will go on to develop high compressive forces in the keel. These may cause buckling especially as the bottom structure may already be damaged from the initial shock wave. For extreme cases whipping may lead to the ‘back breaking’ and total loss of the ship.

6.1.7 An estimate of the hull natural frequency for steel ships is given by:

\[ f_{s1} = \frac{216}{T_{\text{OA}}} \text{ Hz} \]

where

- \( T_{\text{OA}} \) = the overall length of the ship, in metres.

6.1.8 The risk of a whipping response from a particular threat can be determined using the approximation for the natural frequency and the bubble characteristics of 6.1.4.

6.1.9 If the threat is closer to the hull than \( 2R_{\text{bub}} \) then the bubble loading is to be specially considered.

6.2 Threat level determination

6.2.1 The level to which a ship will be expected to survive an attack scenario that excites hull whipping is to be specified by the Owner and will remain confidential to LR.

6.2.2 The whipping threat level may be defined for a range of warheads detonating at a given stand off distance and longitudinal (axial) location. The probability of weapon hit locations can be determined from threat analyses which can be used to select the appropriate charge locations for the assessment.

6.2.3 It is also possible to undertake a parametric study to establish the detonation location which will lead to the worst case loading scenario. In this case, all possible hit locations that will induce whipping are assessed and the worst case induced bending moments are compared with an appropriate acceptance criteria. Contours from the keel of maximum threat size to induce failure can also be determined.

6.2.4 Where a shock threat is also being assessed for whipping effects, the warhead stand off distance from the keel is set to be the same as that which induces the prescribed severity of shock. A series of axial locations are assessed to establish the worst case excitation which is compared to the appropriate acceptance criteria.

6.2.5 The non-dimensional measure of whipping severity, commonly referred to as Whipping Factor, is simply the ratio of maximum induced hull girder bending moment at a section to the critical bending moment for that section. Each threat location assessed will generate a whipping factor which can be assigned to that particular location. In this way a series of iso-Whipping Factor contours can be mapped in the fluid beneath the keel for a particular threat weapon. These contours define hit volume boundaries within which that particular weapon will induce a known level of whipping response.

6.3 Notation assessment levels and methodology

6.3.1 Ships for which a whipping assessment is performed will be eligible for a WH1, WH2 or WH3 notation as defined in 6.3.4 to 6.3.6.

6.3.2 There are two types of assessment to determine the whipping response of the hull girder:

- Simple 2D beam model.
- Advanced 3D beam model.

6.3.3 For most ships a simple analysis will be sufficient to determine the whipping capability of the hull girder. An advanced analysis will be required when:

- more detailed information is required on areas of a ship which have been shown by simple analysis to be deficient under whipping loads, for example where there are large structural discontinuities variations;
6.3.4 A WH1 analysis method uses a 2D beam representation and a failure level criterion based on the bending moment to induce material yield.

6.3.5 A WH2 method of analysis uses a 2D beam representation and a failure level criterion based on the section ultimate bending moments. This will require assessment using ultimate strength calculations at each of the discrete sections of the hull girder beam model.

6.3.6 A WH3 method of analysis uses a 3D definition of a section of the hull girder and geometric and material failure criteria implicit in the chosen finite element code.

6.3.7 In each case, it is to be demonstrated that the hull section remains below the defined failure limits for all threat scenarios.

6.3.8 For certain ship types such as minesweepers, it will be necessary to carry out several levels of analysis. An elastic analysis is required for threat levels which are expected to be survived on a regular basis. An elasto-plastic analysis is required at a higher threat level for which the ship is expected to survive.

6.4 Simple 2D beam model

6.4.1 The modelling of ship interaction with explosion bubbles conveniently breaks down into a set of distinct sub-models.

6.4.2 The hull girder model is usually subdivided into at least twenty equal sections, each of which is assumed to form a ‘Timoshenko’ beam element. Since the stiffness and mass distributions may vary considerably along the length of a ship, a lumped mass/weightless beam representation is appropriate rather than a consistent mass model. The effect of shear deflection is to be included in the model.

6.4.3 The hull hydrodynamics may be modelled using standard strip theory to represent the effect of the inertia of surrounding water. At any lumped mass representing the hull girder, the added mass of water may be assumed using ‘Lewis’ forms coefficients. The added mass correction can be assumed to be constant for each mode of vibration.

6.4.4 For the bubble hydrodynamics it is assumed that the flow around the explosion bubble is inviscid and incompressible, that gaseous products obey ideal gas law, and that the bubble itself remains spherical. As a first approximation it may also be assumed that the bubble remains stationary but in general the migration is significant and should be considered. It is also assumed that the bubble motion is not modified by the presence of either the ship or the water surface. The loading model is to account for the dissipation of shock wave energy at the outset of detonation, generally achieved by using a modified initial radius for the bubble calculation.

6.4.5 The interaction hydrodynamics may also be assumed to be incompressible and inviscid consistent with the bubble hydrodynamics. The bubble radial flow may be resolved at the ship axis (the intersection line of the waterplane and the vertical centreline plane) at each lumped mass, into three components. Normally only the vertical z and athwartships y components need to be considered as the bubble is assumed to be some distance from the ship. It may also be assumed that at each lumped mass, the transverse velocity around the whole section will be uniform in magnitude and direction.

6.4.6 The force acting on a strip is to account for this motion, plus the uniform pressure gradient assumed in the fluid which induces a buoyant force proportional to the displaced volume of water. Wave generation and Bernoulli pressure effects may be neglected but the accelerations should account for the free surface reflection of the bubble.

6.4.7 Several assessment codes are available and calculation should be performed by a competent and experienced body with relevant experience and using recognised codes.

6.5 Advanced assessment

6.5.1 Advanced whipping assessments will normally be performed using a hybrid 3D/2D structural model for computational efficiency. However, care is to be exercised in the coupling of the 2D beam elements to the 3D section to ensure that this artificial boundary condition does not adversely influence the analysis. As an alternative, the ship may be defined as a full 3D shell model. In which case, it may be possible to invoke symmetry to reduce the problem size and reduce the computational burden.

6.5.2 More than one option exists for modelling the fluid domain. It may be modelled using a boundary element approach and coupled to the structural domain using a Doubly Asymptotic Approximation. Alternatively, a computationally intensive volume fluid element approach employing an Eulerian code may be used. This fluid domain model would have to be coupled to the Lagrangian structural domain through a general or arbitrary coupling scheme. The detonation process and the bubble development would be physically modelled in this approach. A combined approach would entail modelling an island of fluid around the ship, truncated by a boundary element surface on which a bubble loading model would be applied.

6.5.3 For surface ship problems, whichever solution strategy is adopted, the fluid solver must be able to cope with the proximity of the bubble to the free surface and where appropriate reflections from the sea bed. Analysis is to be undertaken by a competent and experienced body using recognised techniques and with the relevant expertise necessary to establish the correct interface strategy between structural and fluid element meshes.
Section 7
Residual strength

7.1 General

7.1.1 This Section details the determination of the threat levels and methodology to be adopted in the attainment of an RSA1, RSA2 or RSA3 notation.

7.2 Threat level determination

7.2.1 The level to which a ship will be expected to structurally survive an attack scenario that results in weapon damage is to be specified by the Owner and will remain confidential to LR.

7.2.2 The threat level may be defined for a range of warheads detonating at given internal positions or UNDEX stand off distances with defined longitudinal locations. The probability of weapon hit locations can be determined from threat analyses which can be used to select the appropriate charge locations for the assessment.

7.2.3 Generally, fragmentation scenarios are not included in residual strength assessments since the damage is usually localised. However, any significant structural damage resulting from fragmentation (as determined in Ch 2.4) must be considered. Similarly, any damage from an external blast threat weapon must also be included (Ch 2.2). In addition, residual strength calculations must be used in conjunction with level 2 whipping analysis (Ch 2.6).

7.2.4 Where the STAB notation is assigned, the damage scenarios included in the residual strength assessment are to include grounding/raking and collision damages which are consistent with the compartment damage criteria specified by the subdivision and stability standard, see Vol 3, Pt 1, Ch 6.1.

7.3 Notation assessment levels and methodology

7.3.1 Ships for which a residual strength assessment is carried out will be eligible for a RSA1, RSA2 or RSA3 notation as defined in 7.3.6 to 7.3.8.

7.3.2 The assessment of the residual strength capability of a ship is to be performed as defined in Pt 6, Ch 4.4.

7.3.3 There are three methods of assessment that may be used to determine the damaged residual strength of the hull girder:
   - Simple 2D cross-section elastic model.
   - 2D ultimate strength model.
   - Advanced 3D Finite Element Methods.

7.3.4 In the case of a mine warfare ship or NS3 ships, a 2D elastic analysis will normally be sufficient. For most other naval ships, a 2D ultimate strength analysis would normally be required to determine the damaged residual strength at a particular frame location along the hull girder.

7.3.5 An advanced 3D analysis incorporating initial deformations and residual stresses will be required when:
   - More detailed information is required throughout one or more compartments along the length of the ship which have been shown by the more simplified 2D ultimate strength analysis to be inadequate. This may be necessary, for example, where there are large structural discontinuities in hull girder strength.
   - The ship design cannot be reduced to a 2D beam or ultimate strength description, for example, when it has an unusual structural configuration.

7.3.6 A RSA1 analysis method uses a 2D elastic cross-section representation and a failure level criterion based on the calculated bending moment being greater than both the design hogging and sagging bending moments at the sections considered to be most critical.

7.3.7 A RSA2 method of analysis uses a 2D ultimate strength beam representation and a failure level criterion based on the section ultimate bending moments being satisfactory compared to the design bending moments in both hogging and sagging. This will require assessment using ultimate strength calculations at no less than three damaged positions along the length of the hull.

7.3.8 A RSA3 method of analysis uses a 3D definition of a section of the hull girder and relies on geometric and material failure criteria implicit in the chosen finite element code. It could also include coupled Euler-Lagrange formulations to specifically account for internal and external blast effects, UNDEX shock and whipping.

7.3.9 In each case, it is to be demonstrated that the hull girder remains below the defined design hogging and sagging design bending moment failure limits for all prescribed threat scenarios.

7.3.10 For certain ship types, such as minesweepers, it will be necessary to carry out several levels of analysis. An elastic analysis should be carried out for threat levels which are expected to be survived on a regular basis and geometric and material non-linear analysis at higher threat levels for which the ship is expected to survive.

7.4 Definition of damage

7.4.1 The damage radius is a measure of the extent of the damage caused by specific above water attack scenarios. This is shown diagrammatically in Fig. 2.7.1, where the assumption of a detonation mid-compartment is shown and the extent of damage is indicated by the extent of the damage radii. Assumptions about position and extent of damage radii are dependent on warhead characteristics. In general, the radii is to be vertically positioned such that it removes the maximum amount of material or has the greatest effect on the sectional inertia.

7.4.2 The damage radii can be determined from:

\[ r = f_2 W^{1/3} \text{ m} \]

where

\[ f_2 = \text{scaled distance dependent on ship type} \]

\[ W = \text{equivalent weight of TNT, in kg} \]
7.4.3 Once a damage radius has been determined, the simplest method of accommodating damage is to remove all structure within and touching the damage radii from the residual strength calculation.

7.4.4 For underwater shock (UNDEX), hull plating failure can be derived from angle hull shock factor, as defined in Fig. 2.7.2, exceeding appropriate hull lethality levels. The angled shock factor may be determined from:

\[ SF = \frac{W^{0.5}}{R} f(\theta) \]

where
- \( W \) = equivalent charge weight of TNT, in kg
- \( R \) = distance from charge, in metres
- \( f(\theta) \) = threat angle function, see Fig. 2.7.2.

7.4.5 Special consideration will be given to the effects of damage to box type strengthening structure, armour plating, high yield strength materials, double skin hulls and blast strengthened bulkheads.

7.4.6 Generic damage can be generated using pseudo-random hit probability algorithms and repeated application of such algorithms can be used to represent successive weapon hits. Specific damage is difficult to quantify but can be estimated by using damage radii techniques for above water structure and by assuming critical shock factor levels for below water structure.
8.3.3 Primary and secondary structure is to be continuously welded throughout areas subject to grounding.

8.3.4 Lugged connections or fully welded collars of the type shown in Fig. 2.8.1 are to be used. Alternative equivalent arrangements will be individually considered.

8.3.5 Transverse floors are not to be spaced more than 1.25 m for transversely framed structure or 1.85 m for longitudinal framed structure.

8.3.6 One side girder each side of the centreline is to be fitted in addition to the requirements of Pt 3, Ch 2,3.5 or 3.6.

8.3.7 Transverse floors and girders are to be suitably stiffened with web stiffeners spaced not more than 1.25 m apart.

8.4 Global strength

8.4.1 For ships with $L_R > 50$ m grounding conditions in addition to the loading conditions of Pt 6, Ch 4 are to be assessed. The number and type of loading conditions will be determined by the operational requirements of the ship. In some cases residual strength calculations will be required.

8.4.2 If $L_R > 50$ m and areas of the bottom shell within 0.3 to 0.5 $L_R$ are at risk from grounding the thickness of the bottom shell and longitudinal structure will be specially considered.

8.5 Rubbing strakes

8.5.1 Rubbing strakes or barwhales are to be fitted to the bottom shell. In longitudinally framed ships they are to be placed directly below longitudinals. Typical arrangements of rubbing strakes are shown in Fig. 2.8.2. Usually they consist of a steel frame welded to the hull supports with a bolted connection to softer material but rubbing strips can be constructed of solid steel sections. They are to be free of projections or other discontinuities which could lead to damage of the shell plating.

8.5.2 Rubbing strakes are to be spaced not less than 1.5 m apart. For closer spacing the thickness of the bottom shell will be specially considered.
8.5.3 The rubbing strake housing both internally and externally is to be efficiently coated to prevent corrosion. Where different materials are used the materials are to be selected or insulated to ensure that there is no galvanic corrosion.

8.5.4 Rubbing strakes are to be continuously welded to the hull. Butts between sections of rubbing strake are to be butt welded together before being welded to the hull. Where this is not possible, ceramic rather than copper backing strips are to be used.

8.5.5 Rubbing strakes are to be of the same grade of steel as the shell plate to which they are attached.

8.5.6 The ends of rubbing strakes are to be tapered at an angle of not less than 1 in 3 with no discontinuities in the welding in this region. Where not supported by internal longitudinals, the ends of strakes are to be arranged to pass 30 to 50 mm over the end of transverse frames or floors.

8.5.7 Due consideration is to be given to the depth of the rubbing strakes with regard to the nature of the beach. In no case are they to be less than 100 mm projection.

Section 9
Military installation and operational loads

9.1 Weapon recoil, blast and efflux loads

9.1.1 Loads resulting from weapon launch may include recoil effects, blast and missile efflux pressures, and in general will be impulsive. These three types of load are estimated in different ways and will be covered in turn.

9.1.2 Gun and mortar recoil loads will generally be obtained from the manufacturer’s documentation. If the natural frequency of the supporting structure is more than four times the firing rate and at least 50 per cent higher than the frequency derived from the time to maximum force, then a dynamic load factor of 1.6 may be used for a first estimate. If the gun is mounted immediately above an effective bulkhead then the structural resonant frequencies will be much higher and a dynamic load factor of 1.2 may be assumed. The stiffness of the supporting structure should be adequate for the loads imposed and in accordance with the manufacturer’s recommendations.

9.1.3 The assessment of structure is to be made at the azimuth and elevation of the gun that produces the maximum demands on each component of the support structure. These will usually be ahead and abeam and at 0° and maximum elevation, although additional calculations should be made at the 45° positions vertically and horizontally against the resolved in-plane and normal elements of the load which occur simultaneously.

9.1.4 The load on the structure due to gun blast is in the form of a short-lived transient over-pressure; values of this over-pressure should be available in the manufacturer’s documentation for the weapon as curves of pressure against distance from the gun muzzle. The pressure will act only for a time of the order of 10 ms so the structure, with a much higher natural response period, is unable to react to the full over-pressure and it is sufficient to design to an equivalent static pressure using the dynamic load factors specified in Pt 6, Ch 2.5. Guns with a high rate of fire, typically greater than 30 rounds per minute, may induce a forced vibration and will be specially considered.

9.1.5 Should blast pressure curves not be available then a spherical approximation to the equivalent static design pressure \( P_g \) can be found from the following equation for \( \phi_m \) values in the range 80 mm to 120 mm

\[
P_g = 2 \left( 1 + \cos \theta \right)^2 \left( \frac{\phi_m}{x} \right)^{1.5} \times 10^3 \text{ kN/m}^2
\]

where

- \( \phi_m \) = the bore of the gun, in mm
- \( x \) = the distance from the muzzle of a point at which the pressure is required, in mm
- \( \theta \) = the angle to the centre-line of the barrel

As shown in Fig. 2.9.1.
9.1.6 Missile efflux blast loading can be predicted by considering the rate of change of momentum of the efflux where it strikes the structure under consideration. However, when calculating the equivalent design load allowance must also be made for the dynamic response of the structure. For practical purposes therefore it is sufficient to design for the thrust averaged over a cone of semi-angle \( b \) and the resultant equivalent static pressure \( P_m \) may be found from

\[
P_m = f_{DLF} \left( \frac{T_m}{A} \right) \left( \frac{\sin \alpha}{\sin \alpha + \tan \beta \cos \alpha} \right) \text{kN/m}^2
\]

where

- \( f_{DLF} \) = a dynamic load factor relating to variations in the efflux pressure and can be taken as 1.5
- \( T_m \) = thrust, in kN
- \( A \) = projected area of cone, in m\(^2\)
- \( \alpha \) = angle (25° < \( \alpha < 90° \)) to the structure, in degrees
- \( \beta \) = the efflux cone semi-angle in degrees and can be taken as 3°

As shown in Fig. 2.9.2.

Fig. 2.9.2  Missile thrust geometry

9.2.3 In the absence of any specific information the RAS jackstay point is to be designed for 160 kN at 20° either side of the vertical and 20° either side of the horizontal. Theouthaul securing point and hose pendant securing point are to be designed for 40 kN 20° either side of the vertical and 0° to 45° below the horizontal.

9.2.4 The structure is to be designed such that the stress from RAS operations in no part of the structure exceeds 70 per cent of the yield stress of the material under test conditions and 35 per cent of the yield stress of the material under normal working conditions.

9.2.5 For structure supporting RAS equipment, materials are to be in accordance with Table 6.2.1 in Pt 6, Ch 6.

9.2.6 Where tripods, gantries or masts are used for RAS operations the buckling strength of members in compression is to be specially considered.

9.2.7 A clear area is to be provided for RAS operations and the landing area for RAS operation is to be suitably strengthened for impact loading and concentrated equipment loads.

9.2.8 The design load used in the determination of scantlings for tanks used in RAS operation are to take due account of the maximum loads experienced in service. See Pt 5, Ch 3,5.
Section 10

Aircraft operations

10.1 General

10.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the ship structure. All ships operating aircraft are to comply with the requirements of this Section and will be assigned an AIR notation.

10.1.2 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the ship. Consideration is to be given to air flow over the landing area and the impingement of hot exhaust gases on equipment in the flight path.

10.1.3 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

10.1.4 Equipment and vehicles using the landing area will also need to be assessed to identify the most onerous load in accordance with Pt 5, Ch 3.

10.1.5 Special consideration is to be given to the insulation standard if the space below the aircraft deck is a high fire-risk space.

10.1.6 These Rules assume that the aircraft are fitted with oil/gas dampers and pneumatic types, different undercarriage arrangements will be specially considered.

10.1.7 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

10.1.8 Suitable fire-fighting equipment and services should be arranged on the landing deck, manoeuvring and parking areas, in accordance with the specified fire safety standard. Arrangements are to be made for drainage of the platform, including drainage of spilt fuel. Fire protection should also be arranged between spaces containing aircraft and other areas of the ship. Special consideration should be given to aircraft handling arrangements and the possible passage of spilt fuel.

Fig. 2.9.3 Replenishment at sea loads
10.2 Definitions

10.2.1 OLEO load is defined as the load which will cause the damper and tyre combination to reach the end of their travel. OLEO loads should not generally be used to determine loads from the undercarriage on the flight deck. OLEO loads do not always reflect the loads that can be imposed by an aircraft landing on a ship. Loads should be derived using the vertical velocities specified in Table 2.10.3. The ratios of OLEO loads may be used to determine the dynamic distribution of load from the undercarriage.

10.2.2 The all up weight (AUW) is the maximum that will be encountered for the specific application under consideration. It includes the maximum weight of aircraft, personnel fuel and payload:

- For helicopters the AUW is to be taken as the maximum weight of aircraft, personnel, fuel and payload at all times.
- For manoeuvring of fixed wing aircraft the AUW is to be taken as the maximum weight of aircraft, personnel, fuel and payload.
- For take off of fixed wing aircraft the fuel weight is to be the maximum less the fuel required to transit to the take off position.
- For landing of fixed wing aircraft the AUW is to be as above except that the fuel weight is to be the maximum less that consumed by the shortest possible flight.

10.3 Documentation

10.3.1 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of aircraft to be used are also to be indicated.

10.3.2 Details of arrangements for securing the aircraft to the deck are to be submitted for approval.

10.3.3 A landing guide should be provided as part of the ship’s documentation. This is to contain all the relevant design information on the aircraft for the ship, identification of landing parking and manoeuvring areas, tie down arrangements, weights and a summary of the design calculations. It is also to provide guidance on the suitability of the landing areas for other aircraft. The information is to be presented in a graphical form similar to that shown in Fig. 2.10.1. Unrestricted landings are aircraft weights which can occur up to the design sea state. Restricted landings are aircraft weights with higher than the design can occur but in a reduced sea state and are to be indicated on the diagram. Prohibited landings are aircraft weights that may not take place in any sea state. Different diagrams will be required for twin and single rotor helicopters and for aircraft as appropriate.

10.4 Flight deck arrangements

10.4.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the aircraft, and is to be approached by a clear landing and take off sector complying in extent with any applicable regulations.
10.5 Loading

10.5.1 The load cases to be applied to all parts of the structure are defined in Table 2.10.6. in which:

\[ f = 1.15 \] for landing decks over magazines or permanently manned spaces, e.g., deckhouses, bridges, control rooms, etc.

\[ f = 1.0 \] elsewhere

\[ \lambda = \text{reaction factor for the aircraft considered} \]

\[ W_{auw} = \text{the maximum all up weight of the aircraft, in kN} \]

\[ W_{ty} = \text{landing or static load, on the tyre print, in kN; with the centre of gravity in a position that causes the highest load. In the absence of specific aircraft manufacturers’ information on the static or dynamic distribution of load, } W_{ty} \text{ is to be taken as } W_{auw} \text{ divided equally between the two main undercarriages ignoring the nose or tail wheel. For helicopters with twin main rotors, } W_{ty} \text{ is to be taken as } W_{auw} \text{ distributed between all main undercarriages in accordance with the static load distribution.} \]

10.5.2 The reaction factor, \( \lambda \), may be determined from Table 2.10.1 where manufacturers’ information is not available. Otherwise the information in 10.6 or 10.7 as appropriate may be used to estimate \( \lambda \).

### Table 2.10.1 Landing reaction factor

<table>
<thead>
<tr>
<th>Aircraft type</th>
<th>( \lambda )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helicopters</td>
<td>2.5</td>
</tr>
<tr>
<td>VSTOL aircraft</td>
<td>3.5</td>
</tr>
<tr>
<td>Fixed wing aircraft</td>
<td>5</td>
</tr>
</tbody>
</table>

**NOTE**: Reaction factors are derived from the average values for marinised versions of aircraft.

10.5.3 The reaction factor for helicopters using recovery systems will be specially considered.

10.6 Determination of \( \lambda \) for fixed wing aircraft

10.6.1 The reaction factor can be calculated by simulation, testing or estimated from the following formulae:

\[ \lambda = \frac{V_L^2}{2 \eta_T \delta_T + \eta_S \delta_S} \]

where

\[ \lambda = \text{reaction factor} \]

\[ \delta_S, \delta_T = \text{deflection of the shock absorber or tyre, in metres} \]

\[ V_L = \text{vertical landing velocity including ship motions, in m/s} \]

\[ \eta_T = \text{efficiency of the tyre typically assumed to be 0.47} \]

\[ \eta_S = \text{efficiency of the shock absorber, see Table 2.10.2.} \]

10.6.2 The vertical velocity is the maximum landing velocity derived from trials or simulation and is to include the effects of ship motion. In no case is it to be taken less than 6 m/s. If landing operations are to be carried out in sea states greater than six then the minimum vertical velocity will be further considered.

10.7 Determination of \( \lambda \) for helicopters

10.7.1 The reaction factor can be calculated by simulation, testing or estimated from the following formulae:

\[ \lambda = \frac{V_L^2}{2 \eta_T \delta_T + \eta_S \delta_S} + (1 - f_L) \left( \delta_T + \delta_S \right) \eta_T \delta_T + \eta_S \delta_S \]

where

\[ \lambda, \delta_S, \delta_T, V_L, \eta_T, \eta_S \] are defined in 10.6

\[ f_L = \text{the percentage of lift carried by the rotors at the time of landing typically 66 per cent.} \]

10.7.2 The vertical velocity is the maximum landing velocity derived from ship trials or simulation and is to include the effects of ship motion. In no case is it to be taken less than 3.72 m/s. If landing operations are to be carried out in sea states greater than six then the minimum vertical velocity will be further considered.

10.7.3 For ships where helicopter operations are restricted to sea states lower than six the vertical velocities defined in Table 2.10.3 can be used.

### Table 2.10.2 Shock absorber efficiency

<table>
<thead>
<tr>
<th>Material</th>
<th>Steel spring</th>
<th>Rubber</th>
<th>Air</th>
<th>Liquid spring</th>
<th>OLEO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency ( \eta )</td>
<td>0.5</td>
<td>0.6</td>
<td>0.48</td>
<td>0.76</td>
<td>0.8</td>
</tr>
</tbody>
</table>

10.7.4 Using a vertical velocity lower than the design given in this Section, for example a land based helicopter, will result in higher probabilities of exceedance. The derivation of vertical velocity is such that it includes the effects of ship motions and pilot action and is independent of the design vertical velocity of the undercarriage.

10.7.5 Information on the probability of encountering a particular sea state for a sea area can be found in Pt 5, Ch 2.2.

10.7.6 For helicopters with skids, determination of the reaction factor will be specially considered.

### Table 2.10.3 Vertical velocity

<table>
<thead>
<tr>
<th>Sea state</th>
<th>Vertical velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>3.72</td>
</tr>
<tr>
<td>5</td>
<td>3.35</td>
</tr>
<tr>
<td>4</td>
<td>2.97</td>
</tr>
<tr>
<td>3</td>
<td>2.60</td>
</tr>
<tr>
<td>2</td>
<td>2.23</td>
</tr>
</tbody>
</table>

**NOTE**: Reaction factors are derived from the average values for marinised versions of aircraft.
10.8 Deck plating design

10.8.1 The deck plate thickness, \( t_p \), within the landing area is to be not less than:

\[
t_p = \frac{\alpha \cdot s}{1000 \sqrt{k_s}} - t_c \text{ mm}
\]

where

- \( \alpha \) = thickness coefficient obtained from Fig. 3.2.1 in Ch 3,2
- \( \beta \) = tyre print coefficient used in Fig. 3.2.1 in Ch 3,2
- \( k_s \) = higher tensile steel factor defined in Pt 6, Ch 5
- \( F_{typ} \) = tyre force, in kN
- \( \gamma \) = a location factor given in Table 2.10.4
- \( \phi_1, \phi_2, \phi_3 \) = are patch load correction factors determined from Table 2.10.5
- \( t_c \) = permanent set correction in mm, see 10.8.2
- \( a, s \) = the panel dimensions in mm, see Fig. 2.10.2
- \( u, v \) = the patch dimensions in mm, see Fig. 2.10.2.

### Table 2.10.4 Location factor, \( \gamma \)

<table>
<thead>
<tr>
<th>Location</th>
<th>( \gamma )</th>
</tr>
</thead>
<tbody>
<tr>
<td>On decks forming part of the hull girder</td>
<td>1.18</td>
</tr>
<tr>
<td>(a) within 0.4( L_R ) amidships</td>
<td>1.18</td>
</tr>
<tr>
<td>(b) at the FP or AP</td>
<td>1.18</td>
</tr>
<tr>
<td>Values for intermediate locations are to be determined by interpolation</td>
<td></td>
</tr>
<tr>
<td>Elsewhere</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Table 2.10.5 Patch load corrections \( \phi_1, \phi_2, \phi_3 \)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \phi_1 = \frac{2v_1 + 1.1s}{u_1 + 1.1s} ) if ( v_1 = v ), but ( s \leq a )</td>
<td></td>
</tr>
<tr>
<td>( \phi_2 = 1,0 ) for ( u \leq (a - s) )</td>
<td></td>
</tr>
<tr>
<td>( \phi_2 = 1,0 ) for ( a \geq u &gt; (a - s) )</td>
<td></td>
</tr>
<tr>
<td>( \phi_3 = 1,0 ) for ( \phi &lt; s )</td>
<td></td>
</tr>
<tr>
<td>( \phi_3 = 1,0 ) for ( 1,5 &gt; (\phi/v) &gt; 1,0 )</td>
<td></td>
</tr>
<tr>
<td>( \phi_3 = 1,0 ) for ( (\phi/v) \geq 1,5 )</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2.10.6 Design load cases for primary and secondary deck stiffening and supporting structure

<table>
<thead>
<tr>
<th>Condition</th>
<th>Loading</th>
<th>Stiffening</th>
<th>Support structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency landing</td>
<td>( \lambda \cdot f_{W_{ty}} )</td>
<td>0.2</td>
<td>DLF ( \lambda \cdot f_{W_{ty}} ) (1 + ( a_i )) ( W_s )</td>
</tr>
<tr>
<td>Normal landing</td>
<td>0.6 ( \lambda \cdot W_{ty} )</td>
<td>0.5</td>
<td>0.6DLF ( \lambda \cdot W_{ty} ) (1 + ( a_i )) ( W_s )</td>
</tr>
<tr>
<td>Take off (fixed wing)</td>
<td>2.65( W_{ty} )</td>
<td>0.5</td>
<td>2.65( W_{ty} ) (1 + ( a_i )) ( W_s )</td>
</tr>
<tr>
<td>Manoeuvring internal</td>
<td>1.6( W_{ty} )</td>
<td>0.5</td>
<td>1.6( W_{ty} ) (1 + ( a_i )) ( W_s )</td>
</tr>
<tr>
<td>Manoeuvring external</td>
<td>1.75( W_{ty} )</td>
<td>0.5</td>
<td>1.75( W_{ty} ) (1 + ( a_i )) ( W_s )</td>
</tr>
<tr>
<td>Parking internal</td>
<td>( (1 + 0.6a_z) W_{ty} )</td>
<td>2</td>
<td>( 1,1 (1 + 0.6a_z) W_{ty} ) (1 + ( a_i )) ( W_s )</td>
</tr>
<tr>
<td>Parking external</td>
<td>1.1 (1 + 0.6a_z) ( W_{ty} )</td>
<td>2</td>
<td>1.1 (1 + 0.6a_z) ( W_{ty} ) (1 + ( a_i )) ( W_s )</td>
</tr>
</tbody>
</table>

### Table 2.10.5 Weight factors

- \( W_{sys} \) = structural weight of aircraft platform, in kN
- \( W_s \) = structural weight of stiffener and supported structure, in kN
- \( F_{typ} \) = uniformly distributed vertical load over entire landing area, kN/m²
- \( DLF \) = Dynamic load factor
- \( a_z \) = defined in Pt 5, Ch 3,2

**NOTES**

1. The design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads.
2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.
3. Stiffening members may have more than one load acting at one time.
10.8.11 For steel decks in frequent use and where no suitable protective sheathing or coating is used, it is recommended that the thickness of the plating is increased, see Pt 6, Ch 6.2.10.

10.9 Deck stiffening design

10.9.1 The aircraft deck stiffening is to be designed for the load cases given in Table 2.10.6 with the aircraft being positioned so as to produce the most severe loading condition for each structural member under consideration. All possible positions and orientations are to be considered that can occur during aircraft operations.

10.9.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with the requirements of Table 3.2.3 in Pt 4, Ch 3, using the load cases defined in Table 2.10.6.

10.9.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures are used to determine the scantling requirements in association with the limiting permissible stress criteria given in Table 5.3.2 in Pt 6, Ch 5. The calculation is to be submitted for consideration.

10.9.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with Pt 6, Ch 5.

10.10 Parking and manoeuvring areas

10.10.1 For areas designed for parking and manoeuvring of aircraft the maximum take off weight of the aircraft is to be used with the maximum fuel and payload.

10.10.2 For areas where only manoeuvring occurs and parking is restricted to designated and clearly marked areas then the scantlings of structure are to be calculated in accordance with 10.8 and 10.9 using the manoeuvring and parking loads given in Table 2.10.6 as appropriate. If parking areas are not clearly marked then the parking loads in Table 2.10.6 are to be applied to all areas of aircraft operation in accordance with the requirements of Table 3.2.3 in Pt 4, Ch 3, using the load cases defined in Table 2.10.6.

10.10.3 Parking areas may not be taken less than two frame spaces or the tyre width plus 500 mm whichever is the greater. Consideration should be given to the use of removable lagging around these areas and at the adjacent beam bulkhead connection.

10.10.4 Additional forces from tie down arrangements on the structure need only be considered if the tensioning force applied exceeds that imposed by the forces from ship motions as defined in 10.14.

10.10.5 Decks subjected to a combination of parking and significant in-plane stresses will be specially considered.
10.11 Assisted take off

10.11.1 Where the aircraft jet is not parallel to the deck at the moment of launch or jet blast deflectors are used the structure is to be capable of withstanding the thermal loads imposed on the deck.

10.11.2 The structure of ramps used to assist take off are to be specially considered.

10.11.3 Structure surrounding catapults is to be effectively supported and designed for the maximum forces imposed by the launch system using the stress criteria given in Table 5.3.2 in Pt 6, Ch 5.

10.12 Arrested landing

10.12.1 Structure surrounding arresting gear is to be effectively supported and designed for the maximum forces imposed by the arrested aircraft using the stress criteria given in Table 5.3.2 in Pt 6, Ch 5.

10.13 Vertical recovery

10.13.1 The structure in way of the landing area and approach path is to be capable of withstanding the thermal loads imposed by hot exhaust gases.

10.14 Tie down forces

10.14.1 The force to be used in assessing the tie down points is to be determined from the calculations for the securing arrangements, in accordance with LR's LAME Code.
2.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, guidance for wear and tear allowances is given in 2.3. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and embarked personnel routes.

2.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

2.1.6 If wheeled vehicles are to be used on insulated decks or tanks tops, consideration will be given to the permissible loading in association with the insulation arrangements and the plating thickness.

2.1.7 Suitable fire fighting equipment and services should be provided in the vehicle space. Arrangements should be made for ventilation and drainage of spilt fuel.

2.2 Definitions
2.2.1 Load area. The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

2.3 Deck plating
2.3.1 The thickness, $t_p$, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha s}{1000\sqrt{k_s}} \text{ mm}$$

where

- $\alpha$ = thickness coefficient obtained from Fig. 3.2.1 using a value of $\beta$ given by
- $\beta = \log_{10} \left( \frac{F_{typ} k_s^2}{9.81 s^2} \times 10^7 \right)$

$s$ = secondary stiffener spacing, in mm
$F_{typ}$ = corrected patch load for plating, in kN obtained from Table 3.2.1, see also Fig. 3.2.1 and Table 3.2.2
$s$ and $k_s$ are as defined in 1.2.

2.3.2 Where transversely framed decks contribute to the hull girder strength or where secondary stiffening is fitted perpendicular to the direction of vehicle lanes, the thickness, $t_p$, derived from 2.3.1 is to be increased by 1.0 mm.

2.3.3 In the absence of a specific requirement the thickness, $t_p$, derived from 2.3.1 is to be increased by a wear and wastage allowance of 1.5 mm for strength decks, weather decks, tank tops and inner bottom or 0.75 mm elsewhere.
Table 3.2.1 Deck plate thickness calculation

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$, $s$, $u$, and $v$ as defined in Fig. 3.2.1</td>
<td>$F_{\text{typ}} = \Phi_1 \Phi_2 \Phi_3 \lambda W_{ty}$</td>
</tr>
<tr>
<td>$n$ = tyre correction factor as detailed in Table 3.2.2</td>
<td></td>
</tr>
<tr>
<td>$F_{\text{typ}} = \text{corrected patch load for plating, in kN}$</td>
<td></td>
</tr>
<tr>
<td>$\lambda = \text{dynamic magnification factor}$</td>
<td></td>
</tr>
<tr>
<td>$W_{ty} = \text{load, in kN, on the tyre print. For closely spaced wheels}$</td>
<td>the area shown in Fig. 2.10.2 may be taken as the combined print</td>
</tr>
<tr>
<td>$\Phi_1 = \text{patch aspect ratio correction factor}$</td>
<td></td>
</tr>
<tr>
<td>$\Phi_2 = \text{panel aspect ratio correction factor}$</td>
<td></td>
</tr>
<tr>
<td>$\Phi_3 = \text{wide patch load factor}$</td>
<td></td>
</tr>
<tr>
<td>$v \leq s$</td>
<td>$\nu_1 = v$, but $u \leq a$</td>
</tr>
<tr>
<td>$s = 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6$</td>
<td></td>
</tr>
<tr>
<td>$0.8 \leq v/s &lt; 1.0$</td>
<td>$\nu_1 = u$, but $a \leq s$</td>
</tr>
<tr>
<td>$s = 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6$</td>
<td></td>
</tr>
<tr>
<td>$\beta = \text{tyre print coefficient}$</td>
<td></td>
</tr>
<tr>
<td>$\Phi_2 = 1.0$, for $u \leq (a - s)$</td>
<td></td>
</tr>
<tr>
<td>$= \frac{1}{1 - \frac{0.3}{s}(a - u)}$, for $a \geq u &gt; (a - s)$</td>
<td></td>
</tr>
<tr>
<td>$= 0.77 \frac{a}{u}$, for $u &gt; a$</td>
<td></td>
</tr>
<tr>
<td>$\Phi_3 = 1.0$, for $v &lt; s$</td>
<td></td>
</tr>
<tr>
<td>$= 0.6 \left(\frac{s}{v}\right) + 0.4$, for $1.5 &gt; (v/s) &gt; 1.0$</td>
<td></td>
</tr>
<tr>
<td>$= 1.2 \left(\frac{s}{v}\right)$, for $(v/s) \geq 1.5$</td>
<td></td>
</tr>
<tr>
<td>$\lambda = 1.25$ for harbour conditions</td>
<td></td>
</tr>
<tr>
<td>$= (1 + 0.7n)$ for sea-going conditions</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 3.2.1 Tyre print chart**
### 2.4 Secondary stiffening

2.4.1 The scantlings of vehicle deck stiffeners are to satisfy the most severe arrangement of print wheel loads.

2.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with Table 3.2.3 using the loads defined in Table 3.2.4.

2.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

### 2.5 Primary stiffening

2.5.1 Generally the scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the loads defined in Table 3.2.4 and the limiting permissible stresses and deflection criteria contained in Pt 6, Ch 5.

### Table 3.2.2 Tyre correction factor, \( n \)

<table>
<thead>
<tr>
<th>Number of wheels in idealised patch</th>
<th>Pneumatic tyres correction factor, ( n )</th>
<th>Solid rubber tyres correction factor, ( n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>2 or more</td>
<td>0.75</td>
<td>0.9</td>
</tr>
</tbody>
</table>

### Table 3.2.3 Secondary stiffener requirements

<table>
<thead>
<tr>
<th>Scantling requirement</th>
<th>Load case</th>
<th>( d \leq l )</th>
<th>( d &gt; l )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section modulus ( Z ) ( (cm^3) )</td>
<td>( Z = \left( k_w F_{\text{sys}} \frac{3d^2}{2} - \frac{F_{\text{sys}} \frac{2d^2}{2} + \frac{F_{\text{sym}} l^2}{10}}{10} \right) 10^3 ) ( \frac{\sigma_o}{F_{\text{sys}}} )</td>
<td>( Z = \left( k_w F_{\text{sys}} \frac{2d^2}{2} + \frac{F_{\text{sys}} l^2}{10} \right) 10^3 ) ( \frac{\sigma_o}{F_{\text{sys}}} )</td>
<td></td>
</tr>
<tr>
<td>Inertia ( I ) ( (cm^4) )</td>
<td>( I = \left( k_w F_{\text{sys}} \frac{2d^2}{2} - \frac{F_{\text{sys}} l^2}{288} \right) 10^5 ) ( \frac{\sigma_o}{F_{\text{sys}}} )</td>
<td>( I = \left( k_w F_{\text{sys}} \frac{l^2}{2} + \frac{F_{\text{sys}} l^2}{288} \right) 10^5 ) ( \frac{\sigma_o}{F_{\text{sys}}} )</td>
<td></td>
</tr>
<tr>
<td>Web area ( A_w ) ( (cm^2) )</td>
<td>( A_w = \left( k_w F_{\text{sys}} \frac{m^2 - 2m^2}{2} + \frac{P_{\text{sys}} s l}{2} + \frac{F_{\text{sym}} l^2}{288} \right) ) ( \frac{\sigma_o}{F_{\text{sys}}} )</td>
<td>( A_w = \left( k_w F_{\text{sys}} \frac{l^2}{2} + \frac{P_{\text{sys}} s l}{2} + \frac{F_{\text{sym}} l^2}{288} \right) ) ( \frac{\sigma_o}{F_{\text{sys}}} )</td>
<td></td>
</tr>
</tbody>
</table>

where \( m = d/l \)

**Symbols**

- \( d \) = overall secondary stiffener length, in metres
- \( s \) = stiffener spacing, in metres
- \( d \) = dimension of load area parallel to stiffener axis, in metres
- \( E \) = Youngs Modulus of elasticity of material, in N/mm²
- \( w \) = dimension of load area perpendicular to stiffener axis, in metres
- \( k_w \) = lateral loading factor
- \( = 1 \) for \( w \leq s \)
- \( = s/w \) for \( w > s \)
- \( F_{\text{sys}} \) = point load given in Table 3.2.4, in kN
- \( F_{\text{sym}} \) = self weight load given in Table 3.2.4, in kN
- \( F_{\text{tyw}} \) = weather deck load given in Table 3.2.4, in kN/m²
- \( \sigma_o \) = specified minimum yield strength of the material, in N/mm²
- \( t_o \) = shear strength of the material, in N/mm²

### 2.6 Design load cases for primary and secondary stiffening and supporting structure

<table>
<thead>
<tr>
<th>Condition</th>
<th>Loading</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manoeuvring internal</td>
<td>Point loads, ( F_{\text{sys}} ) kN</td>
<td>Self weight, ( F_{\text{sym}} ) kN</td>
</tr>
<tr>
<td>Manoeuvring external</td>
<td>0.5 ( W_{\text{ty}} )</td>
<td>(1 + ( a_z )) ( W_{s} )</td>
</tr>
<tr>
<td>Parking internal</td>
<td>(1 + ( n ) ( a_z )) ( W_{\text{ty}} )</td>
<td>(1 + ( a_z )) ( W_{s} )</td>
</tr>
<tr>
<td>Parking external</td>
<td>2 ( (1 + n a_z) W_{\text{ty}} )</td>
<td>(1 + ( a_z )) ( W_{s} )</td>
</tr>
</tbody>
</table>

NOTES

1. For the design of the supporting structure for vehicle decks, the applicable self weight and horizontal loads are to be added to the parking area loads.
2. The vehicles are to be positioned so as to produce the most severe loading condition for each structural member under consideration.
3. Stiffening members may have more than one point load acting at any time.
2.6 Securing arrangements

2.6.1 The strength and stiffness of the holding down arrangements and supporting structure are to be in accordance with Ch 1,5.2.

2.6.2 Deck fittings in way of vehicle lanes are to be recessed.

2.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

2.7 Access

2.7.1 Bow doors are to comply with the requirements of Section 4.

2.7.2 Where access to the vehicle deck is provided by side and stern doors, the doors are to have scantlings equivalent to the structure in which they are fitted, see also Pt 3, Ch 4,5.

2.7.3 Doors providing access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the specified fire safety standard.

2.8 Hatch covers

2.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

2.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck hatch cover, as applicable.

2.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations. The designer’s calculations are to be submitted.

2.9 Heavy and special loads

2.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

2.9.2 Due account is to be taken of the acceleration levels due to ship motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

2.10 Tracked and steel wheeled vehicles

2.10.1 Where it is proposed to carry tracked vehicles the patch dimensions may be taken as the track print dimensions and \( F_w \) is to be taken as half the total weight of the vehicle. Deck fittings in way of vehicle lanes are to be recessed.

2.10.2 Where it is proposed to carry tracked vehicles, the total weight of the vehicle is to be used when determining the section modulus of the transverse at the top of a ramp or at other changes of gradient.

2.10.3 A wear and tear allowance is to be added to the plating thickness and it is not to be less than that defined in 2.3.3.

2.11 Openings in main vehicle deck

2.11.1 Items such as portable plates in main vehicle deck for the removal of machinery parts, etc., may be arranged flush with the deck, provided they are secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters.

2.11.2 Scuppers from vehicle or cargo spaces fitted with an approved fixed pressure water spray fire-extinguishing system are to be led inboard to tanks. Alternatively they may be led overboard providing they comply with Pt 3, Ch 3,8.1.3

2.11.3 Inboard draining scuppers do not require valves but are to be led to suitable drain tanks (not engine room or hold bilges) and the capacity of the tanks should be sufficient to hold approximately 10 minutes of drenching water. The arrangements for emptying these tanks are to be approved and suitable high level alarms provided.

2.11.4 Air pipes from cofferdams or void spaces may terminate in the enclosed ‘tween deck space on the main vehicle deck provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

2.11.5 In addition, the requirements of 3.10.8 to 3.10.10 are to be complied with.

2.12 Direct calculations

2.12.1 Lloyd’s Register (hereinafter referred to as ‘LR’) will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.
Section 3

Bow doors

3.1 Application

3.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure, or to a long non-enclosed superstructure which is fitted to attain minimum bow height equivalence.

3.1.2 Other types of bow door will be specially considered.

3.1.3 Where the operational requirements dictate that the doors and ramps be deployed at sea or in the surf zone, the strength and operation will be specially considered.

3.2 General

3.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be required by the subdivision and stability standard.

3.2.2 Bow doors are to be located above the vertical limit of watertight integrity. A watertight recess is normally permitted below the vertical limit of watertight integrity located forward of the collision bulkhead and above the deepest waterline, for the arrangement of ramps or other related mechanical devices. For any ship where bow doors may be open at sea or located below the vertical limit of watertight integrity, the enclosed spaces protected by the door or ramp are to be considered open as well as closed in damage stability or flooding conditions.

3.2.3 An inner door is to be fitted which is to be gasketed and weathertight. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, see Pt 3, Ch 2.4. A vehicle ramp may be arranged for this purpose, provided its position complies with Pt 3, Ch 2.4 and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2.3 m above the vertical limit of watertight integrity may extend forward of the limit specified in Pt 3, Ch 2.4. If this is not possible a separate inner weather-tight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

3.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the vehicle space and arranged with fixed sealing supports on the aft side of the doors.

3.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 3.2.3.

3.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

3.2.7 The scantlings and arrangements of side shell and stern doors are to be in accordance with the requirements of Pt 6, Ch 3.

3.3 Symbols and definitions

3.3.1 The symbols used in this Section are defined as follows:

\[ A_s = \text{area stiffener web, in cm}^2 \]

\[ A_x = \text{area, in m}^2, \text{of the transverse vertical projection of the bow door, between the bottom of the door and the top of the door or between the bottom of the door and the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser, see Fig. 3.3.2. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded.} \]

\[ A_y = \text{area, in m}^2, \text{of the longitudinal vertical projection of the bow door, between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser, see Fig. 3.3.2. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is the lesser.} \]

\[ A_z = \text{area, in m}^2, \text{of the horizontal projection of the bow door, between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser, see Fig. 3.3.2. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is the lesser.} \]

\[ a_{DV} = \text{vertical distance, in metres, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig. 3.3.2} \]

\[ b_{DV} = \text{horizontal distance, in metres, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig. 3.3.2} \]

\[ c_{DV} = \text{horizontal distance, in metres, from visor pivot to the centre of gravity of visor mass, as shown in Fig. 3.3.2} \]

\[ d_{DV} = \text{vertical distance, in metres, from bow door pivot to the centre of gravity of the bow door, see Fig. 3.3.2} \]
3.3.2 **Locking device.** A device that locks a securing device in the closed position.

3.3.3 **Securing device.** A device used to keep the door closed by preventing it from rotating about its hinges.

3.3.4 **Side-opening doors.** Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

3.3.5 **Supporting device.** A device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship’s structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship’s structure.

3.3.6 **Visor doors.** Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

### 3.4 Construction and testing

3.4.1 Plans are to be of sufficient detail for plan approval purposes. Plans showing the proposed scantlings and arrangement of the bow door are to be submitted. Bow doors are to be constructed under survey.

3.4.2 Bow doors fitted below the limit of watertight integrity are to be subject to a pressure test of a prototype to confirm the design pressure head.

3.4.3 As an alternative to prototype testing, the integrity of the door may be demonstrated by calculation and representative testing in accordance with IMO MSC/Circular 1176 – *Unified Interpretations to SOLAS Chapters II-1 and XII and to the Technical Provisions for Means of Access for Inspections*. For doors fitted above the vertical limit of watertight integrity, the doors only require testing following installation, in accordance with Table 6.6.1 in Pt 6, Ch 6.
3.5 Strength criteria

3.5.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 3.6. The shear, bending and equivalent stresses are not to exceed $80/k_N$, $120/k_N$ and $150/k_N$ respectively.

3.5.2 The buckling strength of primary members is to be verified as being adequate, see Pt 6, Ch 2,3.

3.5.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer’s specification.

3.5.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_N$.

3.6 Design loads

3.6.1 The design external pressure, $P_{e}$, for the determination of scantlings for primary members, securing and supporting devices of bow doors is to be taken not less than the following:

$$P_{e} = 2.75 \times C_{H} \times \frac{0.22 + 0.15 \tan \alpha_{F}}{0.4V_{max} \sin \beta_{e} + 0.6L_{R}^{0.5}} kN/m^2$$

where

- $V_{max}$ = maximum speed, in knots, as defined in Pt 1, Ch 2.2.2.4
- $L_{R}$ = Rule length of ship, in metres, as defined in Pt 3, Ch 1.5.2.2
- $\lambda_{G}$ = service area factor for mono-hull ships, see Pt 1, Ch 2.3.6
- $\alpha_{F}$ = flare angle, in degrees, at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, see Fig. 3.3.1
- $\beta_{e}$ = entry angle, in degrees, at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, see Fig. 3.3.1.

3.6.2 The design external forces, $F_{x}$, $F_{y}$ and $F_{z}$, in kN, for the determination of scantlings of securing and supporting devices of bow doors are to be not less than $P_{s}$, $A_{x}$, $P_{s}$, $A_{y}$ and $P_{s}$, $A_{z}$ respectively. Where $P_{s}$ is the external pressure, defined in 3.6.1, with the flare angle, $\alpha_{F}$, and the entry angle, $\beta_{e}$, measured at the point on the bow door, $l_{d/2}$ aft of the stem line on the plane $h/2$ above the bottom of the door, as shown in Fig. 3.3.1. $A_{x}$, $A_{y}$, $A_{z}$ and $h$ as defined in 3.3.1.

3.6.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

3.6.4 For visor doors the closing moment, $M_{v}$, under external loads, is to be taken as:

$$M_{v} = F_{x} a_{bv} + 10 W_{dv} c_{dv} - F_{z} b_{dv} kNm$$

where $W_{dv}$, $a_{bv}$, $b_{dv}$ and $c_{dv}$ as defined in 3.3.1, $F_{x}$ and $F_{z}$ as defined in 3.6.2.

3.6.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1.5 kN/m² is to be taken.

3.6.6 The design external pressure, in kN/m², for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of 0.45$L_{R}$ and 10$h^{2}$, where $h^{2}$ is the distance, in m, from the load point to the top of the space enclosed by the visor, $L_{R}$, as defined in Pt 3, Ch 1.5.2.2.

3.6.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is to be taken less than 25 kN/m².

3.6.8 On ships with rounded nose bow and a large stem angle with the waterline, strengthening against horizontal impact loads is to be considered. Similarly, in ships with a flare angle of less than 60° with the waterline, strengthening against vertical impact loads to be considered.

3.7 Scantlings of bow doors

3.7.1 The strength of bow doors is to be equivalent to the surrounding structure.

3.7.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

3.7.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.
3.7.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where bow doors are stiffened, to fixity between ship’s frames and bow doors stiffeners.

3.7.5 The stiffener webs are to have a net sectional area, $A_s$, not less than:

$$
A_s = \frac{23.5Q_{bd}}{\sigma_o} \text{ cm}^2
$$

where $A_s$, $Q_{bd}$ and $\sigma_o$ as defined in 3.3.1.

3.7.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

3.7.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

3.7.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 3.6.1 and permissible stresses given in 3.5.1. In general, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections.

3.7.9 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

3.8 Scantling of inner doors

3.8.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 3.6.1 and permissible stresses given in 3.5.1. In general, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections.

3.8.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

3.8.3 The distribution of forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

3.9 Securing and supporting of bow doors

3.9.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

3.9.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in 3.9.8. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in 3.9.9 and 3.9.10 and the available space for adequate support in the hull structure.

3.9.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment, $M_y$, as given in 3.6.4 is to be not less than:

$$
M_y = 10W_{bv}c_{dv} + 0.1(a_{bv}^2 + b_{dv}^2)^{0.5} \left( F_{x}^2 + F_{z}^2 \right)^{0.5}
$$

where $W_{bv}$, $a_{bv}$, $b_{dv}$, and $c_{dv}$ as defined in 3.3.1, $F_{x}$ and $F_{z}$ as defined in 3.6.2.

3.9.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 3.5.1.

3.9.5 For visor doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1 $F_x$ and $F_z$

Case 2 $0.7F_y$ acting on each side separately together with $0.7F_x$ and $0.7F_z$

where $F_x$, $F_y$, and $F_z$ are to be determined as indicated in 3.6.2 and applied at the centroid of projected areas.

3.9.6 For side-opening doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1 $F_x$, $F_y$ and $F_z$ acting on both doors

Case 2 $0.7F_x$ and $0.7F_y$ acting on both doors and $0.7F_z$ acting on each door separately

where $F_x$, $F_y$, and $F_z$ are to be determined as indicated in 3.6.2 and applied at the centroid of projected areas.

3.9.7 The support forces as determined according to 3.9.5 and 3.9.6 are generally to give rise to a zero moment about the transverse axis through the centroid of the area, $A_x$. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.
3.9.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

3.9.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in 3.5.1.

3.9.10 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 3.5.1. The opening moment, \( M_o \), to be balanced by this reaction force, is not to be taken less than:

\[
M_o = 10W_{bv}a_{bv} + 5A_k a_{bv} \text{ kNm}
\]

where \( W_{bv}, A_k, a_{bv} \) and \( a_{bv} \) as defined in 3.3.1.

3.9.11 For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force \( F_z = 10W_{bv} \), in kN, within the permissible stresses given in 3.5.1.

3.9.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the ship structure, including welded connections, are to be the same strength. These elements include pins, supporting brackets and back-up brackets. Where cut-outs are made in the supporting structure, the strength and stiffness will be specially considered.

3.9.13 For side-opening doors, thrust bearings have to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, see Fig. 3.3.3. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangement serving the same purpose is to be submitted for appraisal.

3.9.14 The spacing for side and top cleats should not exceed 2.5 m and there should be cleats positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

### 3.10 Securing and locking arrangements

3.10.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

3.10.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the vertical limit of watertight integrity, of:
(a) the closing and opening of the doors, and
(b) associated securing and locking devices for every door. Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

3.10.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in closed position.

3.10.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, further, arrangements are to be such that it is not possible to turn off these lights in service.

3.10.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.
3.10.6 The indication panel on the navigation bridge is to be equipped with a mode selection function ‘harbour/sea voyage’, so arranged that audible alarm is given if the ship leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

3.10.7 A water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

3.10.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the machinery control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

3.10.9 A drainage system is to be arranged in the area between bow door and ramp, or where no ramp is fitted, between the bow door and inner door. The system is to be equipped with an audible and visual alarm function to the navigation bridge being set off when the water levels in these areas exceed 0.5 m or the high water level alarm, whichever is the lesser. If not discharged by a bilge suction, scuppers or freeing ports are to be provided port and starboard having a diameter of not less than 50 mm. Valves are to be fitted.

3.10.10 If the main vehicle deck is not totally enclosed, scuppers or freeing ports are to be provided consistent with the requirements of Pt 3, Ch 4.9.

3.10.11 Air pipes from cofferdams or void spaces may terminate in the enclosed ‘tween deck space on the main vehicle deck provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

3.11 Operating and Maintenance Manual

3.11.1 An Operating and Maintenance Manual for the bow doors and inner doors is to be provided on board. The manual is to contain the following information:

(a) main particulars and design drawings,
- special safety precautions;
- details of vessel, class and statutory certificates;
- equipment and design loading for ramps;
- key plan of equipment for doors and ramps;
- manufacturers’ recommended testing for equipment; and
- a description of the following equipment:
  - bow doors;
  - inner bow doors;
  - bow ramp/doors;
  - central power pack;
  - bridge panel;
  - ramps leading down from the main deck;
  - engine control room panel.

(b) service conditions:
- limiting heel and trim of the ship for loading/unloading;
- limiting heel and trim for door operations;
- operating instructions for doors and ramps; and
- emergency operating instructions for doors and ramps.

(c) maintenance:
- schedule and extent of maintenance;
- trouble shooting and acceptable clearances; and
- manufacturers’ maintenance procedures.

(d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This Manual is to be submitted for approval and is to contain a note recommending that recorded inspections of supporting and securing devices carried out by the ship’s staff at monthly intervals, or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

3.11.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

Section 4

Side, stern doors and other shell openings

4.1 Symbols

4.1.1 The symbols used in this Section are defined as follows:

- \( d \) = distance between closing devices, in metres
- \( k_a \) = material factor, see Pt 6, Ch 5.3.1.1 but is not to be taken less than 0.72 unless demonstrated otherwise by a direct strength analysis with regard to relevant modes of failure.
- \( I \) = moment of inertia, in cm\(^4\), of the stiffener or girder, in association with an effective width of attached plating determined in accordance with Pt 6, Ch 2.5
- \( \sigma \) = bending stress, in N/mm\(^2\)
- \( \sigma_o \) = equivalent stress, in N/mm\(^2\)
- \( \sigma_0 \) = minimum yield stress of the bearing material, in N/mm\(^2\)
- \( \tau \) = shear stress, in N/mm\(^2\).

4.2 General

4.2.1 These requirements cover service doors in the ship side (abait the collision bulkhead) and stern area, below the weather deck and in enclosed superstructures.

4.2.2 For the requirements of bow doors, see Section 3.

4.2.3 Side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure, see also Pt 3, Ch 1.5.

4.2.4 In general, the lower edge of door openings is not to be below a line drawn parallel to the design draught.
4.2.5 When the lower edge is below the design draught or doors below the vertical limit of watertight integrity are to be opened at sea, the arrangements will be specially considered. In general, the enclosed spaces protected by the door are to be considered open as well as closed in damage stability or flooding conditions.

4.2.6 Doors are generally to be arranged to open outwards, however inward opening doors will be considered provided strongbacks are fitted when the doors are situated in the first two lower decks above the waterline.

4.2.7 For ships complying with the requirements of this Section, the securing, supporting and locking devices are defined in 3.3.

4.3 Construction and testing

4.3.1 Plans are to be of sufficient detail for plan approval purposes. Plans showing the proposed scantlings and arrangements of any side and stern doors or other shell openings are to be submitted. Side and stern doors or other shell openings are to be constructed under survey.

4.3.2 Side and stern doors fitted below the limit of watertight integrity are to be subject to a pressure test of a prototype to confirm the design pressure head.

4.3.3 As an alternative to prototype testing, the integrity of the door may be demonstrated by calculation and representative testing in accordance with IMO MSC/Circular 1176 – Unified Interpretations to SOLAS Chapters II-1 and XII and to the Technical Provisions for Means of Access for Inspections. For doors fitted above the vertical limit of watertight integrity, the doors only require testing following installation, in accordance with Table 6.6.1 in Pt 6, Ch 6.

4.4 Scantlings

4.4.1 In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

4.4.2 Door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below, see Pt 3, Ch 1.5.

4.4.3 Doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship structure.

4.4.4 The thickness of the door plating is to be not less than the shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum adjacent shell thickness.

4.4.5 Where stern doors are protected against direct wave impact by a permanent external ramp, the thickness of the stern door plating may be reduced by 20 per cent relative to the requirements of 4.4.4. Those parts of the stern door which are not protected by the ramp are to have the thickness of plating in full compliance with 4.4.4.

4.4.6 Where higher tensile steel is proposed, the plating thickness required in 4.4.4 and 4.4.5 may be reduced by $\sqrt{k_s}$.

4.4.7 The section modulus of horizontal or vertical stiffeners is to be not less than required for the adjacent shell framing using the actual stiffener spacing. Consideration is to be given, where necessary, to differences in fixity between ship’s frames and door stiffeners.

4.4.8 Where necessary, door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

4.4.9 The scantlings of such primary members are to be based on direct strength calculations. Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections. The design load is the uniformly distributed external sea pressure, $p_e$, as defined in 4.9.1. For minimum scantlings, $p_e$ is to be taken as 25 kN/m$^2$ and the permissible stresses as follows:

\[
\tau = \frac{80}{k_s} \text{ N/mm}^2
\]

\[
\sigma = \frac{120}{k_s} \text{ N/mm}^2
\]

\[
\sigma_e = \frac{150}{k_s} \text{ N/mm}^2
\]

4.4.10 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

4.4.11 The stiffness of the edges of the doors and the hull structure in way are to be sufficient to ensure weathertight integrity. Edge stiffeners/girders are to be adequately stiffened against rotation and are to have a moment of inertia not less than:

\[
I = 0.8P_L \frac{d^4}{d^4} \text{ cm}^4
\]

where

\[
P_L = \text{packing line pressure along edges, not to be taken less than 50 N/cm.}
\]

For edge girders supporting main door girders between securing devices, the moment of inertia is to be increased in relation to the additional force.

4.4.12 The buckling strength of primary members is to be specially considered.
4.4.13 All load transmitting elements in the design load path from door through securing arrangements and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets. Where cut-outs are made in the supporting structure, the strength and stiffness will be specially considered.

4.5 Doors serving as ramps

4.5.1 Where doors also serve as vehicle ramps, the plating and stiffeners are to be not less than required for vehicle decks, see Section 2.

4.5.2 The design of the hinges for these doors should take into account the ship angle of trim or heel which may result in uneven loading of the hinges.

4.6 Closing, securing and supporting of doors

4.6.1 Doors are to be fitted with adequate means of closing, securing and support so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

4.6.2 Devices are to be simple to operate and easily accessible. They are to be of an approved type.

4.6.3 Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangements), or are to be of gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in a proper sequence.

4.6.4 Means are to be provided to enable the doors to be mechanically fixed in the open position taking into account the self weight of the door and a minimum wind pressure of 1.5 kN/m² acting on the maximum projected area in the open position.

4.6.5 The spacing for cleats or closing devices should not exceed 2.5 m and there should be cleats or closing devices positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

4.7 Systems for operation

4.7.1 Doors with a clear opening area of 12 m² or greater are to be provided with closing devices operable from a remote control position. Doors which are located partly or totally below the vertical limit of watertight integrity with a clear opening area greater than 6 m² are to be provided with an arrangement for remote control from a position above the vertical limit of watertight integrity. This remote control is provided for the:
(a) Closing and opening of the doors.
(b) Associated securing and locking devices.

4.7.2 The location of the remote control panel is to be such that the opening/closing operation can be easily observed by the operator or by other suitable means such as closed circuit television.

4.7.3 A notice is to be displayed at the operating panel stating that the door is to be fully closed and secured preferably before, or immediately after the ship leaves the berth and that this operation is to be entered in the ship’s log.

4.7.4 Means are to be provided to prevent unauthorised operation of the doors.

4.7.5 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of hydraulic system failure, the securing devices will remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.8 Systems for indication and monitoring

4.8.1 The following requirements apply to doors in the boundaries of special category spaces or vehicle spaces, through which such spaces may be flooded. For ships where no part of the door is below the design waterline, doors that are to be opened at sea are above the vertical limit of watertight integrity, and the area of the door opening is not greater than 6 m², then the requirements of this Section need not be applied.

4.8.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

4.8.3 The indicator system is to be designed on the fail safe principle and is to indicate by visual alarms if the door is not fully closed and not fully locked, and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.
4.8.4 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the vessel leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.

4.9 Design loads

4.9.1 The design force considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be taken not less than:

(a) Design forces for securing or supporting devices of doors opening inwards:
   - External force: $F_e = A p_o + F_p$ kN
   - Internal force: $F_i = F_o + 10 W$ kN

(b) Design forces for securing or supporting devices of doors opening outwards:
   - External force: $F_e = Ap_o$ kN
   - Internal force: $F_i = F_o + 10 W + F_p$ kN

(c) Design forces for primary members:
   - External force: $F_e = Ap_o$ kN
   - Internal force: $F_i = F_o + 10 W$ kN whichever is the greater.

The symbols used are defined as follows:

- $p_o$, external sea pressure, in kN/m², determined at the centre of gravity of the door opening and is not to be taken less than:
  - for $Z_G < T$: $10 (T - Z_G) + 25$ kN/m²
  - for $Z_G ≥ T$: 25 kN/m²

- $F_o$ is not to be taken less than:
  - $P_{min} = 0.65 C_H (0.8 + 0.6 \sqrt{\lambda})^2$ kN/m²
  - $T = \sigma_0 + 100\lambda T_{min}$
  - $Z_G = height$ of the centre of area of the door, in metres, above the baseline
  - $L_R = length$ of ship, but need not be taken greater than 200 m
  - $\lambda = coefficient$ depending on the area where the ship is intended to be operated:
    - 1 for sea-going ships with service area notation SA1, SA2 and SA3
    - 0.5 for ships operated in sheltered waters with service area notation SA4
  - $C_H = 0.0125 L_R$ for $L_R < 80 m$
  - 1 for $L_R ≥ 80 m$
  - $A = area$, in m², of the door opening
  - $W = weight$ of the door, in tonnes
  - $F_p = total$ packing force, kN. When packing is fitted, the packing line pressure is to be specified, normally not to be taken less than 5 kN/m²
  - $F_o = \text{the greater of} F_e$ and 5.0A kN

$F_c = \text{accidental force}$, in kN, due to loose cargo, etc., to be uniformly distributed over the area $A$ and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of $P_c$ may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental force due to loose items.

4.10 Design of securing and supporting devices

4.10.1 Securing devices and supporting devices are to be designed to withstand the forces given above using the following permissible stresses:

- The terms ‘securing device’ and ‘supporting device’ are defined in Section 3.
- $\tau = \frac{80}{k_s}$ N/mm²
- $\sigma = \frac{120}{k_s}$ N/mm²
- $\sigma_c = \frac{150}{k_s}$ N/mm²

4.10.2 The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces. The maximum tensile stress in way of threads of bolts, not carrying support forces, is not to exceed:

$$\frac{125}{k} \text{ N/mm}^2$$

4.10.3 For steel to steel bearings in securing and supporting devices, the normal bearing pressure is not to exceed 0.8$\sigma_o$, see 4.1.1. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The normal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

4.10.4 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not generally to be included in these calculations.

4.10.5 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be considered in the calculation of the reaction forces acting on the devices.

4.10.6 The number of securing and supporting devices is generally to be the minimum practicable whilst complying with 4.6.3 and taking account of the available space in the hull for adequate support.
4.10.7 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, without exceeding, by more than 20 per cent, the permissible stresses as defined in 4.10.1.

4.11 Operating and Maintenance Manual

4.11.1 An Operating and Maintenance Manual for the doors is to be provided on board. The manual is to contain the following information:

(a) main particulars and design drawings:
   - special safety precautions;
   - details of vessel, class and statutory certificates;
   - equipment and design loading for ramps;
   - key plan of equipment for doors and ramps;
   - manufacturers’ recommended testing for equipment; and
   - a description of the following equipment:
     - side doors;
     - stern doors;
     - central power pack;
     - bridge panel;
     - ramps leading down from the main deck;
     - engine control room panel.

(b) service conditions:
   - limiting heel and trim of the ship for loading/unloading;
   - limiting heel and trim for door operations;
   - operating instructions for doors and ramps; and
   - emergency operating instructions for doors and ramps.

(c) maintenance:
   - schedule and extent of maintenance;
   - trouble shooting and acceptable clearances; and
   - manufacturers’ maintenance procedures.

(d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

4.11.2 The Manual is to be submitted for approval, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the ship’s staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

4.11.3 Documented operating procedures for closing and securing the doors are to be kept on board and posted at an appropriate place.

Section 5

Movable decks, lifts, internal and external ramps

5.1 Classification

5.1.1 Where required by the LA Notation, see Vol 1, Pt 1, Ch 2,1.1.12 or specified by the Owner, movable decks will be included as a classification item. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.1.2 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.1.3 The operating and securing equipment or machinery is to be in accordance with all specified standards.

5.2 Arrangements and design

5.2.1 Positive means of control are to be provided to secure decks, ramps and lifts in the raised and lowered position.

5.2.2 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer’s specifications.

5.2.3 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed 125/k N/mm².

5.3 Loading

5.3.1 Details of the deck, ramp or lift loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, see Section 2.

5.3.2 Where it is proposed also to use the decks, ramps or lifts for general cargo, the design loadings are to be submitted for consideration.

5.3.3 The forces imposed on the decks, ramps or lifts are to take due account of the ship motion for all the conditions in which they will be operated, see Pt 5, Ch 3,6.2.
5.3.4 The scantlings and arrangements are to be not less than those required by the Rules for the supporting or surrounding structure in which the decks ramps or lifts are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.3.5 The buckling strength of primary members is to be verified as being adequate, see Pt 6, Ch 2,3.

5.3.6 Decks, ramps or lifts and their supporting structure are to be designed for the maximum load that is to be carried; this may include loadings from emergency situations where they are specified by the Owner.

5.4 Movable decks

5.4.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.4.2 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.4.3 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

5.4.4 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during vehicle operations.

5.5 External deck ramps and lifts

5.5.1 In addition to the loading specified in 5.3, ramps and lifts are to be assessed using weather deck loading in the closed position, see Pt 5, Ch 3,5.

5.6 External shell ramps

5.6.1 In addition to the loading specified in 5.3, unprotected ramps are to be assessed using side shell loading in the closed position, see Pt 5, Ch 3,3.

5.6.2 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 3.6. The shear, bending and equivalent stresses are not to exceed 80/k N/mm², 120/k N/mm² and 150/k N/mm² respectively.

5.7 Aircraft lifts

5.7.1 The aircraft lift platform deck alignment is to be provided by keeps at the flight deck and stops at the hangar deck.

5.7.2 If the ship has an underwater shock notation, latches are also to be provided at the flight and hangar deck levels to restrain the aircraft lift platform when stationary.

5.7.3 When transferring the aircraft or equipment to, or from, the lift platform with the keeps engaged the deflection of the platform edge is not to be greater than 25 mm.