ShipRight
Design and Construction

Additional Design Procedures

Risk Based Designs
(RBD)

January 2018
**Document History**

<table>
<thead>
<tr>
<th>Date</th>
<th>Notes</th>
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<tbody>
<tr>
<td>January 2018</td>
<td>Updates including (i) further systems integration advice, (ii) inclusion of LR risk criteria and (iii) reference to newly issued IACS risk assessment guidance</td>
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<tr>
<td>CHAPTER</td>
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</tbody>
</table>
Section 1

1.1 Introduction

1.1.1 This procedure provides additional guidance in satisfying the requirements of Classification Rules and Statutory Conventions when using risk based techniques. This requirement may be for designs which deviate from existing specific Rule and Regulation requirements, or for novel or complex designs where prescriptive Rules and Regulations do not currently apply. The use of risk based techniques will involve the production of documents detailing the technical outcome of the risk assessment. Such documents should be considered as supporting evidence and be marked accordingly. Where risk based techniques are used in design, the generic description is Risk Based Designs (RBD).

1.1.2 Before accepting a Risk Based Design, Lloyd’s Register (LR) must be satisfied that the hazards of a technology or system are robustly identified and the immediate equipment consequences mitigated to an appropriate level.

Section 2

2.1 Process Overview

2.1.1 Class and Statutory Rules and Regulations increasingly require ‘risk studies’ to be undertaken to identify hazards and to assess and control the corresponding risks, not least Lloyd’s Register’s Pt 7, Ch 14 Requirements for Machinery and Engineering Systems of Unconventional Design of the Rules and Regulations for the Classification of Ships (commonly referred to as the Rules for Ships).

2.1.2 One mechanism of demonstrating equivalence with SOLAS Alternative Designs and Arrangements (II-1 Reg. 55, II-2 Reg. 17 and III, Reg. 38) is by the use of risk based techniques. Irrespective of how equivalence is to be demonstrated, Stage 1 of this process is to be used. Typically, risk based studies are required for designs which deviate from existing Rules and Regulations or for novel or complex designs for which prescriptive Rules and Regulations do not currently exist.

2.1.3 To ensure that such studies are undertaken consistently, with an appropriate degree of rigour and in a manner consistent with applicable Classification and Statutory requirements, unless stated otherwise in such requirements, risk studies should be undertaken according to the process described below and illustrated in Figure 1.3.1 Generic Process for Risk Based Designs (RBD).

2.1.4 The process is scalable according to the degree of novelty/deviation, design complexity and safety considerations. Hence, the time and effort for each stage will vary. In short, the process comprises the following stages:

- Stage 1 – Design and Safety Statement.
- Stage 2 – Risk Assessment.
2.1.5 Where risk assessment is required, there is a distinct shift in the design process, from passive compliance with prescriptive Rules, to active demonstration, by the designer/builder/yard with regard to how the hazards and consequences of the design are to be managed. This includes demonstrating how systems are safely integrated.

2.1.6 Responsibility for conducting the studies for each of the stages lies with the organisation seeking approval or approval-in-principle (AIP) from LR. Each stage is concluded by a report which should be appraised by LR (and generally the National Administration) before commencing the next stage. It should be appreciated that the appraisal process aims to ensure that all reasonably foreseeable hazards associated with a particular design are adequately controlled, irrespective of whether they may eventually fall within the scope of Classification approval or within the scope of Statutory approval.

2.1.7 Where a design submitted for approval is based on a design previously approved by LR using a risk based approach, then the risk studies to be undertaken may reference previous risk studies. The risk based work to be undertaken should focus on the differences in the design and/or in the application of its use.

2.1.8 It is conceivable that the design appraisal may be split, with Stages 1 and 2 being undertaken separately, for example as part of a Joint Development Project (JDP), and Stages 3 and 4 as part of a new construction or retrofit project.

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Section 3

Process Application

3.1 Process application

3.1.1 Table 1.4.1 Stage 1 Appraisal, Design and Safety Statement shows the various roles and activities associated with any design developed using a risk based justification. Often clients seek support from LR with regard to design development, particularly when it involves new, novel or complex technology. In such cases, LR becomes involved in design development. To ensure the integrity and independence of LR, as a Classification Society and when acting on behalf of an administration, different staff must be engaged in the design development activities, which are referred to as consultancy services in Table 1.4.1 Stage 1 Appraisal, Design and Safety Statement to Table 1.4.4 RBD – Stage 4 Appraisal, Final Design Assessment. See the separate guidance on ensuring in dependence between Classification/Statutory approval and design consultancy.

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Figure 1.3.1 Generic Process for Risk Based Designs (RBD)

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Section 4

Process Description

4.1 Process description

4.1.1 The following figures provide a description of the process steps within each stage of the appraisal of Risk Based Designs (RBD) together with an example of assigned responsibilities.

4.2 RBD – Stage 1 Appraisal, Design and Safety Statement

4.2.1 A checklist of items to be considered at each stage is also given in Table 1.4.1 Stage 1 Appraisal, Design and Safety Statement.
## Table 1.4.1 Stage 1 Appraisal, Design and Safety Statement

<table>
<thead>
<tr>
<th>Stage 1 – Design and Safety Statement</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propose Development Team (see Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.2)</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Define novel or alternative design (see Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.3)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Define scope of novel or alternative design (see Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.4)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify Classification and Statutory requirements not complied with (see Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.5)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Determine safety objectives of Classification and Statutory requirements (see Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.6)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Determine functional requirements to satisfy safety objectives (see Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.7)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Determine integration requirements to meet safety objectives and functional requirements (see Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.6 and Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.7; see also Ch 1, 8 System Integration)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Describe extent of deviation from Classification and Statutory requirements (see Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.8)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Prepare Stage1 Appraisal Report (see Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.9)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Note 1. Client responsibility for development and submission to LR for Classification purposes.
Note 2. Documents that LR Classification need to see on completion.
Note 3. Areas where LR might support the Client with design development consultancy.

### Items to be considered:

**4.2.2 Propose Development Team:**

- Development team composition:
  - Team coordinator.
  - Shipowner/operator.
  - Shipyard.
  - Equipment supplier/designer.
  - Class, Flag, Port Authority.
- Qualifications and experience.
- Roles and responsibilities.
- Plan of engagement with Class and National Administration:
Contact persons.
Schedules.

- Relevant requirements:
  - IMO MSC Circ.1002, 4.1-4.3.
  - IMO MSC Circ.1212, 4.1-4.3.
  - Pt 7, Ch 14, 1.7.3 Risk management of LR’s Rules for Ships.
  - MSC-MEPC.2/Circ12/Rev.1 IMO FSA Guidelines 18th June 2015, Table 1 page 46.
  - IACS Rec 46 Risk Assessment as required by the IGF Code.
  - Ch 1, 7 Acceptable Risk Criteria.

4.2.3 Define novel or alternative design:

- Functional requirements including underway, manoeuvring, berthing and alongside and other operational modes as required by the operational profile of the vessel.

- System design:
  - Requirements.
  - Description.
  - Block diagram.
  - Rules, Regulations, Codes and Standards applied.

- Operational modes:
  - Start-up.
  - Shutdown.
  - Normal operation.
  - Abnormal operation.
  - Emergency shutdown*.

- Relevant requirements:
  - IMO MSC Circ.1002, 4.3 and 5.1.1.
  - IMO MSC Circ.1212, 4.3 and 5.1.1.
  - Pt 7, Ch 14, 1.4.3 of LR’s Rules for Ships.

*Where emergency is any situation which presents an immediate threat to life or the vessel. Abnormal operation is any other degraded state outside of Normal or Emergency.

4.2.4 Define scope of novel or alternative design:

- Systems and arrangements.
- Spaces, separation, containment, ventilation.
- Consumers (e.g. Main engines, boilers).
- Control, alarm and safety systems (e.g. gas detection).
- Fire protection.
- Fire detection.
- Fire-extinguishing.
- Relevant requirements.

4.2.5 Identify Classification and Statutory requirements not complied with:

- Fire Safety.
- Mechanical.
- Structural.
- Electrical.
- Control, Alarm and Safety Systems.

4.2.6 Determine safety objectives of Classification and Statutory requirements:

- Fire Safety.
- Mechanical.
• Structural.
• Electrical.
• Control, Alarm and Safety Systems.
• Systems integration – see Ch 1, 8 System Integration.

4.2.7 Determine functional requirements to satisfy safety objectives:
• Fire Safety.
• Mechanical.
• Structural.
• Electrical.
• Control, Alarm and Safety Systems.
• Systems integration – see Ch 1, 8 System Integration.

4.2.8 Describe overall extent of deviation from Classification and Statutory requirements:
• Extent of deviation from functional requirements.
• Extent of deviation from prescriptive requirements.

4.2.9 Prepare Stage 1 Appraisal Report:
• Above information to be included.
• Further Risk Assessment Stages anticipated with justification.
• Relevant requirements:
  IMO MSC Circ. 1002, Annex, 7.1.1-7.1.3.3.
  IMO MSC Circ. 1212, Annex, 7.1.1-7.1.3.3.

4.3 RBD – Stage 2 Appraisal, Risk Assessment

4.3.1 A checklist of items to be considered at each stage is also given in Table 1.4.2 RBD – Stage 2 Appraisal, Risk Assessment.

<table>
<thead>
<tr>
<th>Stage 2 – Risk Assessment</th>
<th>1</th>
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<tbody>
<tr>
<td>Propose assessment team (see Ch 1, 4.3 RBD –</td>
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<td>✓</td>
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<td>Stage 2 Appraisal, Risk Assessment 4.3.2)</td>
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<tr>
<td>Propose assessment method (see Ch 1, 4.3 RBD –</td>
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<tr>
<td>Stage 2 Appraisal, Risk Assessment 4.3.3)</td>
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<tr>
<td>Propose acceptance criteria (see Ch 1, 4.3 RBD</td>
<td>✓</td>
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<td>✓</td>
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<tr>
<td>Stage 2 Appraisal, Risk Assessment 4.3.4)</td>
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<tr>
<td>Identify hazards (see Ch 1, 4.3 RBD – Stage 2</td>
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<tr>
<td>Appraisal, Risk Assessment 4.3.5)</td>
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<td></td>
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<tr>
<td>Identify how hazards can occur (see Ch 1, 4.3 R</td>
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<td></td>
<td>✓</td>
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<tr>
<td>BD – Stage 2 Appraisal, Risk Assessment 4.3.6)</td>
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<td></td>
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<tr>
<td>Determine consequences (accident/casualty</td>
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<td></td>
<td>✓</td>
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<tr>
<td>scenarios) (see Ch 1, 4.3 RBD – Stage 2</td>
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<tr>
<td>Appraisal, Risk Assessment 4.3.7)</td>
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<tr>
<td>Estimate likelihood (accident/casualty</td>
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<td>✓</td>
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<td>scenarios) (see Ch 1, 4.3 RBD – Stage 2</td>
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<td>Appraisal, Risk Assessment 4.3.8)</td>
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<tr>
<td>Categorise risk (accidental/casualty scenarios)</td>
<td>✓</td>
<td></td>
<td>✓</td>
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<td>(see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk</td>
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<tr>
<td>Assessment 4.3.9)</td>
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</tr>
</tbody>
</table>
Determine if acceptance criteria are satisfied (see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.10)  ✓  ✓  ✓

Identify additional measures to satisfy acceptance criteria (see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.11)  ✓  ✓  ✓

Justify appropriate safety or need for further assessment (see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.12)  ✓  ✓  ✓

Prepare Stage 2 Appraisal Report (see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.13)  ✓  ✓  ✓

| Note 1. Client responsibility for development and submission to LR for Classification purposes. |
| Note 2. Documents that LR Classification need to see on completion. |
| Note 3. Areas where LR might support the Client with design development consultancy. |

**Items to be considered:**

**4.3.2 Propose assessment team:**

- **Stakeholder representation:**
  - Ship Operator.
  - Ship designer.
  - Equipment designer.
  - Classification.
  - National Administration.
  - Port Authority.

- **Technical expertise:**
  - Fire Safety.
  - Engineering (Mechanical, Structural, Electrical and Control).
  - Risk Assessment Facilitation.

**4.3.3 Propose assessment method:**

- Hazard identification and risk ranking according to ISO 31010 or similar.
- Alternative and appropriate recognised technique(s) for hazard identification/risk ranking.
- Relevant requirements:
  
  - *Ch 1, 6 Information Requirements for Stages 2 and 4*
  - IMO MSC Cir.1002, 5.2.1.1.
  - IMO MSC Cir.1212, 5.2.1.1.
  - ISO 31010 Risk Assessment Techniques.

**4.3.4 Propose acceptance criteria:**

- Acceptance criteria based on either:
  - Equivalence with current arrangements.
  - Risk being As Low As Reasonably Practicable (ALARP).
- Acceptance criteria to account for likelihood and consequence.
- Acceptance criteria to take account of Stage 1 Appraisal Report.
- Acceptance criteria to distinguish risk by a minimum of three groupings:
  - Unacceptable or intolerable;
  - Tolerable if ALARP; and
  - Acceptable, tolerable or negligible.
• Acceptance criteria to ensure appropriate safety margin.
• For Classification items the risk criteria detailed in Ch 1, 7 Acceptable Risk Criteria or criteria as agreed with LR are to be used. For statutory items, e.g. AD&A, Flag will need to agree to the criteria proposed. The default criteria should be those given in Ch 1, 7 Acceptable Risk Criteria.
• Relevant requirements:
  - IMO MSC Circ.1002, 5.4.2 and 6.3.
  - IMO MSC Circ.1212, 5.3.1.4 and 6.3.
  - MSC-MEPC.2/Circ12/Rev.1 IMO FSA Guidelines 18th June 2015, Table 1 page 46.
  - IACS Rec 46 Risk Assessment as required by the IGF Code.
  - Ch 1, 7 Acceptable Risk Criteria.

4.3.5 Identify hazards:
Hazards are system, design and application specific. Examples include:
• Cryogenic burns.
• Rapid Phase Transition.
• Low temperature embrittlement.
• Fire.
• Explosion.
• Asphyxiation.
• Burns.
• Pressure release.
• Electric shock.
• Structural failure.
• Flooding.
• Loss of essential functionality, e.g., propulsion, auxiliary power.
• Integration of the system and sub-systems into the ship must be considered in each case, see Ch 1, 8 System Integration.
• Relevant requirements:
  - LR Rules
  - IMO MSC Circ.1002, 5.2.1.1.
  - IMO MSC Circ.1212, 5.3.2.

4.3.6 Identify how hazards can occur:
• Normal ship conditions
  - Ship motions (e.g., inclination, shock, vibration).
  - Equipment degradation.
  - Equipment failure.
  - Control system failure/error.
  - Operational error.
  - Maintenance error.
  - Fuel characteristics.
• Abnormal/emergency ship conditions:
  - Fire outside of the space.
  -Flooding of the space.
  - Ship collision.
  - Grounding.
• Operational modes:
  - Start-up.
  - Shutdown.
  - Normal operation.
  - Abnormal operation.
Emergency shutdown.

- System Integration needs to be considered for normal and abnormal/emergency ship conditions and operational modes. See Ch 1, 8 System Integration.
- Relevant requirements:
  - LR Rules
  - IMO MSC Circ.1002, 5.2.1.1.
  - IMO MSC Circ.1212, 5.3.2.
  - MSC-MEPC.2/Circ12/Rev.1 IMO FSA Guidelines 18th June 2015, Table 1 page 46.
  - IACS Rec 46 Risk Assessment as required by the IGF Code.
  - Ch 1, 7 Acceptable Risk Criteria.

4.3.7 Determine consequences (accident/casualty scenarios):

- Safety of:
  - Ship.
  - Ship’s occupants.
  - Ship’s machinery and equipment.
  - Environment.

- Severity category:
  - Localised hazards (localised).
  - Major hazards (ship wide).
  - Catastrophic hazards (beyond ship).

- Relevant requirements:
  - IMO MSC Circ.1002, 5.2.1.2.
  - IMO MSC Circ.1212, 5.3.3.

4.3.8 Estimate likelihood (accident/casualty scenarios):

- Incident/Accident history:
  - Owner.
  - Ship type.
  - Ship routes (e.g., Europe, Asia, North America).

- Other factors:
  - Complexity of equipment and layout.
  - Competency of crew.

- Relevant requirements:
  - IMO MSC Circ.1002, 5.2.1.3.
  - IMO MSC Circ.1212, 5.3.4.

4.3.9 Categorise risk (accident/casualty scenarios):

- The sensitivity of risk categorisation to small changes in consequence and likelihood judgements (see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.7 and Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.8).

- Relevant requirements:
  - IMO MSC Circ.1002, 5.2.1.3.
  - IMO MSC Circ.1212, 5.3.5.

4.3.10 Determine if acceptance criteria are satisfied:

- For Classification items the risk criteria detailed in Ch 1, 7 Acceptable Risk Criteria, or criteria of an equivalent standard is the minimum to be used. For statutory items e.g. AD&A, Flag will need to agree to the criteria proposed. The starting point should be the criteria in Ch 1, 7 Acceptable Risk Criteria, or equivalent.

- Acceptance criteria, see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.4.
• Sensitivity of risk categorisation to small changes in consequence and likelihood (e.g., does a ‘small’ change in consequence or likelihood change the risk grouping from ‘tolerable if ALARP’ to ‘unacceptable’?).

4.3.11 Identify additional measures to satisfy acceptance criteria:
• Risk control hierarchy:
  - Inherently safer design.
  - Prevention measures.
  - Mitigation measures.

4.3.12 Justify appropriate safety or need for further assessment:
• Safety objectives and functional requirements, see Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.6 and Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.7.
• Risks equivalent or ALARP.
• Risk unknown or uncertain.

4.3.13 Prepare Stage 2 Assessment Report:
• Above information to be included.
• Risk Assessment Study report.
• Required approvals:
  - Class.
  - National Administration.

• Relevant requirements:
  - IMO MSC Circ. 1002, 5.4 and Annex, 7.1.1-7.1.3.
  - IMO MSC Circ. 1212, 5.5 and Annex, 7.1.1-7.1.3.
  - MSC-MEPC.2/Circ12/Rev.1 IMO FSA Guidelines 18th June 2015, Table 1 page 46.
  - IACS Rec 46 Risk Assessment as required by the IGF Code.
  - Ch 1, 7 Acceptable Risk Criteria.
Recommendations/considerations/actions are considered and a convincing/appropriate justification is given for those not implemented.

4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies
4.4.1 A checklist of items to be considered at each stage is also given in Table 1.4.3 RBD – Stage 3 Appraisal, Revision and Supporting Studies

<table>
<thead>
<tr>
<th>Stage 3 – Revision and Supporting Studies</th>
<th>1</th>
<th>2</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Define objective and scope of assessment(s) (see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.2)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Identify acceptance criteria (see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.3)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Propose assessment team(s), method(s) and technique(s) (see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.4)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Undertake assessment(s) (see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.5)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Justify appropriate safety (see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.6)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
Preparation of Stage 3 Appraisal Report (see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.7)

Revise Stage 2 Appraisal Report or Provide Addendum/Supplement (see Ch 1, 4.4 RBD – Stage 3 Appraisal, Revision and Supporting Studies 4.4.8)

Note 1. Client responsibility for development and submission to LR for Classification purposes.
Note 2. Documents that LR Classification need to see on completion.
Note 3. Areas where LR might support the Client with design development consultancy.

Items to be considered:

4.4.2 Define objective and scope of assessment:
- Study(ies) and revision as determined necessary by Stage 2, such as:
  - The control, alarm and safety system is to be assessed using an appropriate and relevant risk based analysis tool.
  - Gas dispersion.
  - Ship collisions and groundings.
  - Fire spread (e.g., from one space to another and to adjacent equipment).
  - Explosion.
  - Equipment reliability.

4.4.3 Identify acceptance criteria:
- Acceptance criteria as determined by Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment and sufficient to facilitate justification of appropriate safety.

4.4.4 Propose assessment team(s), method(s) and techniques(s):
- Refer to Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.2, and relevant International Standards for proposed methods and techniques.

4.4.5 Undertake assessment:
- Reference to International Standards and use of recognised methods/techniques.

4.4.6 Justify appropriate safety:
- Safety objectives and functional requirements, see Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.6 and Ch 1, 4.2 RBD – Stage 1 Appraisal, Design and Safety Statement 4.2.7.
- Risks equivalent or ALARP.
- Risk unknown or uncertain.

4.4.7 Prepare Stage 3 Appraisal Report:
- Above information to be included.
- Required approvals:
  - Class.
  - National Administration.
- Relevant requirements:
  - IMO MSC Circ. 1002, 5.4 and Annex, 7.1.1-7.1.3.
  - IMO MSC Circ. 1212, 5.5 and Annex, 7.1.1-7.1.3.
  - MSC-MEPC.2/Circ12/Rev.1 IMO FSA Guidelines 18th June 2015, Table 1 page 46.
  - IACS Rec 46 Risk Assessment as required by the IGF Code.
  - Ch 1, 7 Acceptable Risk Criteria.

4.4.8 Revise Stage 2 Appraisal Report or provide Addendum/Supplement:
4.5 **RBD – Stage 4 Appraisal, Final Design Assessment**

4.5.1 A checklist of items to be considered at each stage is also given in Table 1.4.4 RBD – Stage 4 Appraisal, Final Design Assessment.

<table>
<thead>
<tr>
<th>Stage 4 – Final Design Assessment</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define objective and scope (see Ch 1, 4.5 RBD –</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Stage 4 Appraisal, Final Design Assessment 4.5.2)</td>
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</tr>
<tr>
<td>Propose assessment team(s), method(s) and</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>technique(s) (see Ch 1, 4.5 RBD – Stage 4 Appraisal, Final Design Assessment 4.5.3)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Undertake assessment (see Ch 1, 4.5 RBD – Stage 4</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Appraisal, Final Design Assessment 4.5.4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare Stage 4 Appraisal Report (see Ch 1, 4.5</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>RBD – Stage 4 Appraisal, Final Design Assessment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5.5)</td>
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</tbody>
</table>

Note 1. Client responsibility for development and submission to LR for Classification purposes.

Note 2. Documents that LR Classification need to see on completion.

Note 3. Areas where LR might support the Client with design development consultancy.

Items to be considered:

4.5.2 **Define objective and scope of assessment:**

- Describe the purpose of the assessment.

4.5.3 **Propose assessment team(s), method(s) and techniques(s):**

- Refer to Stage 2, Ch 1, 4.3 RBD – Stage 2 Appraisal, Risk Assessment 4.3.2.
- Ch 1, 6 Information Requirements for Stages 2 and 4 – Information Requirements for Stages 2 and 4.

4.5.4 **Undertake assessment:**

- Reference to an acceptable standard.

4.5.5 **Prepare Stage 4 Appraisal Report:**

- Recommendations/considerations/actions are considered and a convincing/appropriate justification is given for those not implemented.

---

**Section 5**

Reference Rules, Regulations, Standards and Guidance

5.1 **Reference Rules, Regulations, Standards and Guidance**

*Pt 7, Ch 14, 1 of the Rules and Regulations for the Classification of Ships.*

SOLAS Chapter II-1, Part F, Reg. 55.

SOLAS Chapter II-2, Part F, Reg. 17.

MSC Circ.1002 Guidelines on Alternative Design and Arrangements for Fire Safety.

MSC Circ.1212 Guidelines on Alternative Design and Arrangements for SOLAS Chapters II-1 and III.

IMO Circ.1455 Guidelines for the Approval of Alternative and Equivalents as Provided for in Various IMO Instruments.
Section 6
Information Requirements for Stages 2 and 4

6.1 Information Requirements for Stages 2 and 4

Below is an illustrative list of information that is typically required, as a minimum input, to undertake a Stage 2 Risk Assessment and a Stage 4 Final Design Assessment for an LNG fuel system. Other projects will require suitably scoped information at Stages 2 & 4 which reflect the scale of the inherent hazards involved. Project specific information and requirements should be established prior to each stage.

Stage 2 – Risk Assessment:
(a) Technical description of how the design/system/equipment is intended to operate, start-up and shutdown both normally and in an emergency situation.
(b) Process Flow Diagrams (PFDs) or process flow schematics detailing process conditions of equipment and pipework (e.g., temperature and pressure).
(c) Scaled layout drawings illustrating equipment and pipework arrangements, size and location.

Stage 4 – Final Design Assessment:
(a) Detailed technical description of how the design/system/equipment is intended to operate, start-up and shutdown both normally and in an emergency situation.
(b) Process Flow Diagrams (PFDs) or process flow schematics detailing process conditions of equipment and pipework (e.g., temperature and pressure).
(c) Scaled layout drawings/plans illustrating equipment and pipework arrangements, size and location. This should include insulation, ducting, valves and fittings, pressure relief, depressurisation, expansion, ventilation and purging/inerting arrangements.
(d) Process and Instrumentation Diagrams (P&IDs).
(e) General Arrangement (GA) drawing of the vessel.
(f) Description of fire mitigation, protection and fire-fighting systems.
(g) Description and plans of gas fuel control and monitoring systems and fuel changeover arrangements for dual fuelled machinery.
(h) Plans detailing Hazardous Areas.
(i) List of electrical equipment fitted within designated Hazardous Areas.
(j) Line diagrams of control circuits.

Section 7
Acceptable Risk Criteria

7.1 Acceptable Risk Criteria

Risk acceptance criteria may be used in supporting a design when either Classification or Statutory approval is sought. If Classification approval is sought then Lloyd’s Register are the sole party that need to be satisfied that the risk acceptance criteria is adequate. If it is Statutory approval which is sought, possibly in pursuing an AD&A, then the Flag state must approve the design, and hence be satisfied with the risk acceptance criteria. Lloyd’s Register may be asked by Flag for a professional view of the risk criteria, which can be given. The final acceptance and approval, however, are the Flag State’s.

Figure 1.7.1 Acceptable Risk Criteria, reflecting aversion to escalating fatalities & Figure 1.7.2 Acceptable Risk Criteria, with a simple approach to escalating fatalities are two examples of acceptable risk criteria. It is important to note that the risk acceptance criteria for single fatality are the same in both cases, as are the risk acceptance criteria for minor and major injuries. For escalating consequences of two or more fatalities there are a number of items to consider;
• How many people could be impacted? For a passenger vessel this might be hundreds or even thousands of people. For other vessel types, it will be tens of people, the ship’s crew.
• If the risk criteria are for statutory use, then the Flag state may want to reflect what their country uses when considering multiple fatalities for land based industry. Acceptance criteria for large numbers of fatalities do vary from country to country.
• However it is proposed to consider multiple fatalities, a multiple fatality consequence is a very serious scenario. Focusing on reducing the scale of magnitude through engineering design is fundamental, irrespective of the number of evaluated fatalities.

Figure 1.7.1 Acceptable Risk Criteria, reflecting aversion to escalating fatalities & Figure 1.7.2 Acceptable Risk Criteria, with a simple approach to escalating fatalities contain examples of acceptable risk criteria that would be appropriate to use from a Classification perspective.

Table 1.7.1 Useful measures for evaluating likelihoods illustrates examples of useful measures for evaluating likelihoods. When likelihood bands are measuring very infrequent periods, it is quite difficult for people to be able to effectively judge the time period being considered. Table 1.7.1 Useful measures for evaluating likelihoods gives four different ways of expressing the same likelihood, supported by definitions to help visualise likelihood using practical measures. As the likelihood reduces, using the likelihood measures towards the right of the table become easier to visualise and understand. For instance judging whether an incident will happen within a time span of (1E-5 to 1E-6) one hundred thousand years to one million ship years is quite difficult. In this case it’s easier to think of the likelihood dimension in terms of world ship years. It is easier, for instance, to judge that an incident would happen once, during a period of total world ship operation during 1.67 years to 16.67 years.

Table 1.7.1 Useful measures for evaluating likelihoods

<table>
<thead>
<tr>
<th>Definitions:</th>
<th>Ship life = 25 yrs</th>
<th>10 ships per Fleet</th>
<th>Flt life = 250 ship yrs (25 ship yrs x 10 ships)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>World fit yr = 60,000 ship yrs</td>
<td>World fit life = 1,500,000 ship yrs (60,000 x 25)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ship years</td>
<td>Ship/Fleet lives</td>
<td>World Fleet lives</td>
</tr>
<tr>
<td>E0 ~ 1E-1</td>
<td>10 yrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1E-1 ~ 1E-2</td>
<td>&lt;10 – 100 yrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1E-2 ~ 1E-3</td>
<td>&lt;100 – 1000 yrs</td>
<td>4 ship lives – 4 Flt lives</td>
<td></td>
</tr>
<tr>
<td>&lt;1E-3 ~ 1E-4</td>
<td>&lt;1000 – 10000 yrs</td>
<td>&lt;4 Flt lives – 40 Flt lives</td>
<td>0.167 world ship yrs</td>
</tr>
<tr>
<td>&lt;1E-4 ~ 1E-5</td>
<td>&lt;10000 – 100000 yrs</td>
<td>&lt;40 Flt Lives – 400 Flt Lives</td>
<td>&lt;0.167 - 1.67 World ship yrs</td>
</tr>
<tr>
<td>&lt;1E-5 ~ 1E-6</td>
<td>&lt;1000000 – 1000000 yrs</td>
<td>&lt;400 Flt lives – 4000 Flt Lives</td>
<td>&lt;1.67 – 16.67 World ship yrs</td>
</tr>
<tr>
<td>&lt;1E-6</td>
<td>&lt;1000000 yrs</td>
<td>&lt;4000Flt lives</td>
<td>&lt;16.67 World ship yrs</td>
</tr>
</tbody>
</table>
### Risk Based Design (RBD)

**Chapter 1**

**Section 7**

#### Figure 1.7.1 Acceptable Risk Criteria, reflecting aversion to escalating fatalities

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Consequence</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
</tr>
</thead>
<tbody>
<tr>
<td>L7</td>
<td>Extremely Likely</td>
<td>$\leq 10^0$ to $10^1$</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>L6</td>
<td>Very Likely</td>
<td>$\leq 10^1$ to $10^2$</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>L5</td>
<td>Likely</td>
<td>$\leq 10^2$ to $10^3$</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>L4</td>
<td>Unlikely</td>
<td>$\leq 10^3$ to $10^4$</td>
<td>Yellow</td>
<td>Green</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>L3</td>
<td>Very Unlikely</td>
<td>$\leq 10^4$ to $10^5$</td>
<td>Yellow</td>
<td>Green</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>L2</td>
<td>Extremely Unlikely</td>
<td>$\leq 10^5$ to $10^6$</td>
<td>Yellow</td>
<td>Green</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>L1</td>
<td>Remote</td>
<td>$\leq 10^6$</td>
<td>Green</td>
<td>Green</td>
<td>Green</td>
<td>Green</td>
</tr>
</tbody>
</table>

**Figure 1.7.2 Acceptable Risk Criteria, with a simple approach to escalating fatalities**

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Consequence</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>L7</td>
<td>Extremely Likely</td>
<td>$\leq 10^0$ to $10^1$</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>L6</td>
<td>Very Likely</td>
<td>$\leq 10^1$ to $10^2$</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>L5</td>
<td>Likely</td>
<td>$\leq 10^2$ to $10^3$</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>L4</td>
<td>Unlikely</td>
<td>$\leq 10^3$ to $10^4$</td>
<td>Yellow</td>
<td>Green</td>
<td>Red</td>
</tr>
<tr>
<td>L3</td>
<td>Very Unlikely</td>
<td>$\leq 10^4$ to $10^5$</td>
<td>Yellow</td>
<td>Green</td>
<td>Red</td>
</tr>
<tr>
<td>L2</td>
<td>Extremely Unlikely</td>
<td>$\leq 10^5$ to $10^6$</td>
<td>Yellow</td>
<td>Green</td>
<td>Red</td>
</tr>
<tr>
<td>L1</td>
<td>Remote</td>
<td>$\leq 10^6$</td>
<td>Green</td>
<td>Green</td>
<td>Green</td>
</tr>
</tbody>
</table>
Section 8
System Integration

8.1 System integration considerations
System integration should ensure individual sub-systems, equipment and components of each system and the system as a whole function correctly following integration, under normal and reasonably foreseeable abnormal conditions.

8.2 Function
Functional considerations include:

- Systems, their sub-systems, equipment and components to be integrated should be clearly defined and compatible.
- Overall responsibility for the integration of sub-systems, equipment and components should be assigned and managed.
- Integration should be carried out in accordance with an agreed and defined procedure which includes verification and validation.

8.3 Performance
Performance considerations include:

- Interfaces between sub-systems, equipment and components should be clearly identified and include electrical, mechanical, software, data and physical interfaces.
- Interfaces with humans, equipment and components should be identified and verified according to the intended functional requirements for both normal operation and reasonably foreseeable abnormal operation.
- The integration procedure should identify the roles, responsibilities and requirements associated with the integration of the individual sub-systems, equipment and components and their interfaces.
- The integration procedure should define the sequence and stages for integrating individual sub-systems, equipment and components and the points at which verification is to be carried out.
- The integration procedure should verify the correct integration of individual sub-systems, equipment and components and validate the functionality of the system.
- The integration procedure should consider any integration issues critical to the performance of the system.