ShipRight
Design and Construction

Additional Design Procedures

Assessment of Risk Based Designs (ARBD)

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**ASSESSMENT OF RISK BASED DESIGNS (ARBD)**  

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Assessment of Risk Based Designs (ARBD)

Section 1: Introduction

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 Rules and Regulations, or for novel or complex designs for which prescriptive Rules and Regulations do not currently apply. The generic term used for the process of approval where risk based techniques are used in design is the Assessment of Risk Based Designs (ARBD).

Section 2: Process Overview

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 15 of the Rules and Regulations for the Classification of Ships (Requirements for Machinery and Engineering Systems of Unconventional Design) (hereinafter referred to as the Rules for Ships). 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, such 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.

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.

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.
- Stage 3 – Revision and Supporting Studies.
- Stage 4 – Final Design Assessment.
Where risk assessment is required, there is a distinct shift in the approval 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.

Responsibility for conducting the studies for each of the stages lies with the organisation requesting full approval or approval-in-principle (AIP) from Lloyd’s Register (LR). Each stage is concluded by a report which should be approved by LR (and generally the National Administration) before commencing the next stage. It should be appreciated that the assessment 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.

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 approval (and risk studies) and focus on the differences in the design and/or in the application of its use.

It is conceivable that the full process of assessment 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.

### Section 3: Process Application

Table 1 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 have to be engaged in the design development activities, which are referred to as consultancy services in Tables 1-4.

### Section 4: Process Description

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

**ARBD – Stage 1 Assessment, Design and Safety Statement**

A checklist of items to be considered at each stage is also given in Table 1.

Items to be considered:

1.1 **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 15,1.7.3 of LR’s Rules for Ships.
1.2 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 15,1.4.3 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.

1.3 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.

1.4 Identify Classification and Statutory requirements not complied with:
- Fire Safety.
- Mechanical.
- Structural.
- Electrical.
- Control, Alarm and Safety Systems.

1.5 Determine safety objectives of Classification and Statutory requirements:
- Fire Safety.
- Mechanical.
- Structural.
- Electrical.
- Control, Alarm and Safety Systems.

1.6 Determine functional requirements to satisfy safety objectives:
- Fire Safety.
- Mechanical.
- Structural.
- Electrical.
- Control, Alarm and Safety Systems.
1.7 Describe overall extent of deviation from Classification and Statutory requirements:
- Extent of deviation from functional requirements.
- Extent of deviation from prescriptive requirements.

1.8 Prepare Stage 1 Assessment 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.

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

Items to be considered:

2.1 Propose assessment team:
- Stakeholder representation:
  - Ship Operator.
  - Ship designer.
  - Equipment designer.
  - Classification.
  - National Administration.
  - Port Authority.

2.2 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:
  - Appendix 2 – Information Requirements for Stages 2 and 4.
  - IMO MSC Circ.1002, 5.2.1.1.
  - IMO MSC Circ.1212, 5.2.1.1.
  - ISO 31010 Risk Assessment Techniques.

2.3 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.

Table 2 ARBD – Stage 2 Assessment, Risk Assessment

<table>
<thead>
<tr>
<th>Stage 2 – Risk Assessment</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Propose assessment team</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.2 Propose assessment method</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.3 Propose acceptance criteria</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.4 Identify hazards</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.5 Identify how hazards can occur</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.6 Determine consequences (accident/casualty scenarios)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.7 Estimate likelihood (accidental/casualty scenarios)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.8 Categorise risk (accidental/casualty scenarios)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.9 Determine if acceptance criteria are satisfied</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.10 Identify additional measures to satisfy acceptance criteria</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.11 Justify appropriate safety or need for further assessment</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2.12 Prepare Stage 2 Assessment Report</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

1 Client responsibility for development and submission to LR for Classification purposes.
2 Documents that LR Classification need to see on completion.
3 Areas where LR might support the Client with design development consultancy.
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- Acceptance criteria to take account of Stage 1 Assessment 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.
- Relevant requirements:
  - IMO MSC Circ.1002, 5.4.2 and 6.3.
  - IMO MSC Circ.1212, 5.3.1.4 and 6.3.

2.4 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.
- Relevant requirements:
  - LR Rules
  - IMO MSC Circ.1002, 5.2.1.1.
  - IMO MSC Circ.1212, 5.3.2.

2.5 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.
- Relevant requirements:
  - LR Rules
  - IMO MSC Circ.1002, 5.2.1.1.
  - IMO MSC Circ.1212, 5.3.2.

2.6 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.

2.7 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.

2.8 Categorise risk (accident/casualty scenarios):
- The sensitivity of risk categorisation to small changes in consequence and likelihood judgements (see 2.6 and 2.7).
- Relevant requirements:
  - IMO MSC Circ.1002, 5.2.1.3.
  - IMO MSC Circ.1212, 5.3.5.

2.9 Determine if acceptance criteria are satisfied:
- Acceptance criteria, see 2.3.
- 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’?).

2.10 Identify additional measures to satisfy acceptance criteria:
- Risk control hierarchy:
  - Inherently safer design.
  - Prevention measures.
  - Mitigation measures.
### 3.1 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.

### 3.2 Identify acceptance criteria:
- Acceptance criteria as determined by Stage 2 and sufficient to facilitate justification of appropriate safety.

### 3.3 Propose assessment team(s), method(s) and technique(s):
- Refer to Stage 2, 2.1, and relevant International Standards for proposed methods and techniques.

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

### 3.5 Justify appropriate safety:
- Safety objectives and functional requirements, see Stage 1, 1.5 and 1.6.
- Risks equivalent or ALARP.
- Risk unknown or uncertain.

### 2.11 Justify appropriate safety or need for further assessment:
- Safety objectives and functional requirements, see 1.5 and 1.6.
- Risks equivalent or ALARP.
- Risk unknown or uncertain.

### 2.12 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.
  - Recommendations/considerations/actions are considered and a convincing/appropriate justification is given for those not implemented.

### ARBD – Stage 3 Assessment, Revision and Supporting Studies
A checklist of items to be considered at each stage is also given in Table 3.

### Table 3 ARBD – Stage 3 Assessment, Revision and Supporting Studies

<table>
<thead>
<tr>
<th>Stage 3 – Revision and Supporting Studies</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Define objective and scope of assessment(s)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>3.2 Identify acceptance criteria</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>3.3 Propose assessment team(s), method(s) and technique(s)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>3.4 Undertake assessment(s)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>3.5 Justify appropriate safety</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>3.6 Prepare Stage 3 Assessment Report</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3.7 Revise Stage 2 Assessment Report or Provide Addendum/Supplement</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

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

3.7 Revise Stage 2 Assessment Report or provide Addendum/Supplement:
- Above information to be included.
- See Stage 2, 2.12.

ARBD – Stage 4 Assessment, Final Design Assessment

A checklist of items to be considered at each stage is also given in Table 4.

<table>
<thead>
<tr>
<th>Items to be considered:</th>
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<tbody>
<tr>
<td>1 Client responsibility for development and submission to LR for Classification purposes.</td>
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<tr>
<td>2 Documents that LR Classification need to see on completion.</td>
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<tr>
<td>3 Areas where LR might support the Client with design development consultancy.</td>
</tr>
</tbody>
</table>

Table 4 ARBD – Stage 4 Assessment, 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>4.1 Define objective and scope</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>4.2 Propose assessment team(s), method(s) and technique(s)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>4.3 Undertake assessment</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>4.4 Prepare Stage 4 Assessment Report</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Appendix 1: Reference Rules, Regulations, Standards and Guidance

Pt 7, Ch 15.1 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.

ISO 31010 Risk Assessment Techniques.

Appendix 2: 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:

1. Technical description of how the design/system/equipment is intended to operate, start-up and shutdown both normally and in an emergency situation.

2. Process Flow Diagrams (PFDs) or process flow schematics detailing process conditions of equipment and pipework (e.g., temperature and pressure).

3. Scaled layout drawings illustrating equipment and pipework arrangements, size and location.

Stage 4 – Final Design Assessment:

1. Detailed technical description of how the design/system/equipment is intended to operate, start-up and shutdown both normally and in an emergency situation.

2. Process Flow Diagrams (PFDs) or process flow schematics detailing process conditions of equipment and pipework (e.g., temperature and pressure).

3. 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.


5. General Arrangement (GA) drawing of the vessel.

6. Description of fire mitigation, protection and fire fighting systems.

7. Description and plans of gas fuel control and monitoring systems and fuel changeover arrangements for dual fuelled machinery.

9. List of electrical equipment fitted within designated Hazardous Areas.

10. Line diagrams of control circuits.