Rules for Classification and Construction

V Analysis Techniques

2 Risk Analyses

1 Guidelines for the Analysis of Alternative Design and Arrangements

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Premise

1. General

1.1 Alternative design and arrangements are solutions which deviate from the prescriptive requirements of SOLAS regulations, but which are suitable to satisfy the intent of the respective regulations. Such designs and arrangements – "equivalents" as defined in SOLAS I.5 – include a wide range of measures, such as alternative shipboard structures and systems based on novel or unique designs, as well as traditional shipboard structures and systems that are installed in alternative arrangements or configurations.

1.2 With respect to aspects covered in SOLAS chapters II-1, II-2 and III, alternative design and arrangements for selected design aspects and installations may be accepted, for a particular ship or group of ships, provided that the alternative design and arrangements meet the intent of the requirements concerned and provide an equivalent level of safety to the relevant SOLAS requirements.

1.3 Alternative design and arrangements as specified in SOLAS can extent to the whole concept of the ship, or can be focused on particular systems, subsystems or individual components.

1.4 The process for analysing safety equivalency for alternative designs and arrangements is outlined in IMO circulars MSC/Circ. 1002 "Guidelines on Alternative Design and Arrangements for Fire Safety ", and its Corrigendum MSC.1/Circ. 1002/Corr.1, as well as MSC.1/Circ. 1212 "Guidelines on Alternative Design and Arrangements for SOLAS Chapters II-1 and III".

1.5 While circulars MSC/Circ. 1002 and MSC.1/Circ. 1212 differ with respect to their field of application, the same process for analysing safety equivalency for alternative designs and arrangements is defined.

1.6 This process can be applied during the design and construction of new ships as well as for the modification of existing ships.

1.7 The application of this process may have an effect on the approval. In particular, if results of the analyses that are performed in the course of the process make use of assumptions, in order for approval to be granted, the Administration[1] may ask for the validity of these assumptions to be demonstrated during design, building and operation of the vessel.

[1] As specified in SOLAS I, Part A, Reg. 2 "Administration means the Government of the State whose flag the ship is entitled to fly." In the focus of these Guidelines this could also include any entity authorized by the Administration to act on their behalf.

2. Purpose

2.1 These Guidelines address the application of the process of analysing safety equivalency for alternative designs and arrangements for individual design solutions, as outlined in aforementioned IMO circulars.

2.2 These Guidelines are <u>not</u> intended to be applied to obtain type approval of individual materials, components or portable equipment.

2.3 The objectives of these Guidelines are:

– with regard to owners, yards and designers: to provide an overview on the objectives and working tasks of the alternative design process

– with regard to designers: to provide technical recommendations considering the implementation of individual process steps

– with regard to yards: to provide recommendations on the implementation of the alternative design process

2.4 The process of alternative design analysis – as is described in these Guidelines – is based on a holistic risk assessment. This approach is recommended by Germanischer Lloyd (GL), because of its benefits with respect to the quality and safety of the design. It is acknowledged that other approaches may also be acceptable to demonstrate compliance with the requirements set out in MSC/Circ. 1002 and MSC.1/Circ. 1212. The extent to which each step of the risk assessment is to be elaborated depends on the individual application and should be agreed with the responsible Administration in each case.

2.5 It is highly recommended to read these Guidelines completely prior to commencing the process of analysing safety equivalency for alternative designs and arrangements.

3. Comments on Formatting of these Guidelines

3.1 *These guidelines incorporate the text in full of circulars MSC/Circ 1002 and MSC.1/Circ. 1212 (in the following called "IMO circulars"). The wording and numeration of MSC.1/Circ. 1212 is used as reference and, if applicable, significant differences*[2] *to MSC/Circ. 1002 are indicated by brackets [as in this*

[2] Note that MSC.1/Circ. 1212 uses the more general terms "hazards" and "design casualty scenarios", while MSC/Circ. 1002 specifically addresses "fire hazards" and "design fire scenarios", respectively. For readability purposes, this difference is not always indicated in the quoted guideline text.

example]. SOLAS Regulation 17 is attached as separate text in Annex B. The text of the IMO documents is printed in italics, in the same manner as this item 3.1.

3.2 Supplementary comments, explanations and suggestions additional to the provisions of MSC/Circ. 1002 and MSC.1/Circ. 1212 are printed in Roman characters as used for this item 3.2, and the relevant section number is prefixed by the letter C, indicating commentary. The numeration of comments integrates with the original numeration of the IMO circulars. Items are inserted on the respective level of the document hierarchy and the content they refer to. If a comment is an interpretation of a particular section of the IMO guidelines, the original numeration is duplicated in the immediate subsequent paragraph (e.g. an item "C3.2" would be inserted following this item 3.2). In case a comment enhances a text passage of the IMO circulars, additional level of numeration is introduced (e.g. items "C3.2.1", "C3.2.2" … would be inserted following this item 3.2).

3.3 Where necessary, additional explanatory notes are given at the beginning of each Section.

4. Related Rules and Guidelines

4.1 All basic requirements to be fulfilled will rest upon internationally recognized regulations and representatives. A minimum set is defined by the following requirements, insofar relevant for the ship and its systems:

- International Convention for the Safety of Life at Sea (SOLAS), Chapter II-2, Regulation 17, 2004; in particular including amendments:
  - IMO Res. MSC.99(73) "Adoption of Amendments to the International Convention for the Safety of Life at Sea, 1974, as amended", December 2000.
  - IMO Res. MSC.216(82) "Adoption of Amendments to the International Life-Saving Appliance (LSA) Code", December 2006.
- IMO Guidelines on Alternative Design and Arrangements for Fire Safety, MSC/Circ.1002, June 2001.
- Corrigendum to IMO Guidelines on Alternative Design and Arrangements for Fire Safety, MSC.1/Circ.1002/Corr.1, October 2005.
- IMO Guidelines on Alternative Design and Arrangements for SOLAS Chapters II-1 and III, MSC.1/Circ 1212, December 2006.

5. Structure of these Guidelines

5.1 These Guidelines address general recommendations for the application of the process for the equivalency analysis of alternative design and arrangements, as defined in MSC/Circ. 1002 and MSC.1/Circ. 1212.

5.2 For ease of reference these Guidelines follow the structure of the IMO guidelines addressing the following sections:

- Application,
- Definitions,
- Engineering analysis,
- Design team,
- Preliminary analysis in qualitative terms,
- Quantitative analysis,
- Documentation.

5.3 Specific guidance on the application of this process is provided in separate GL Technical Publications containing application examples, see Annex F, 3.4.1.

Section 1

Application

C1. This Section defines the field of application of the IMO guidelines.

C1.0 Definition of Scope

C1.0.1 Application of alternative design and arrangements currently is restricted to selected aspects and installations (see Table 1.1), including, for vessels keel-laid or major conversions on or after 1 July 2002 (SOLAS regulation II-2/17):

- Fire safety (SOLAS chapter II-2)

C1.0.2 Furthermore, with an expected starting date of 1 July 2010, approval of alternative design and arrangements may further be sought (according to SOLAS regulation II-1/55) for vessels keel-laid on or after 1 July 1986 with respect to

- Machinery and periodically unattended machinery spaces (SOLAS chapter II-1, parts C and E) and
- Electrical Installations (SOLAS chapter II-1, part D),

and (according to SOLAS regulation III/38) for vessels keel-laid on or after 1 July 1998 with respect to

- Life-saving appliances (LSA) and arrangements (SOLAS chapter III).

C1.0.3 Safety equivalency of the alternative design and arrangements is to be demonstrated to the Administration by means of an engineering analysis following the process outlined in IMO circulars MSC/Circ. 1002, with respect to amendments considering fire safety, and MSC.1/Circ. 1212, with respect to amendments considering Machinery, Electrical Installations or LSA arrangements.

1.1 *These [IMO] Guidelines are intended for application of safe engineering design to provide technical justification for alternative design and arrangements to SOLAS chapters II-1 (parts C, D and E) and III [as well as SOLAS chapter II-2, in case of MSC/Circ. 1002]. The [IMO] Guidelines serve to outline the methodology for the engineering analysis required by Part F of SOLAS regulation II-1 and Part C of SOLAS chapter III "Alternative design and arrangements" [or: required by SOLAS regulation II-2/17 "Alternative design and arrangements", in case of MSC/Circ. 1002], applying to a specific safety system, design or arrangements for which the approval of an alternative design deviating from the prescriptive requirements of SOLAS chapters II-1 and III [or: SOLAS chapter II-2, in case of MSC/Circ. 1002] is sought.*

1.2 *These [IMO] Guidelines are not intended to be applied to the type approval of individual materials, components or portable equipment.*

1.3 *These [IMO] Guidelines are not intended to serve as a stand-alone document, but should be used in conjunction with the appropriate engineering design guides and other literature [MSC/Circ. 1002: "... examples of which are references in section 3"].*

Table 1.1 Scope and application dates of affected guidelines

Affected regulation	**In force since / into force on**	**All vessels keel-laid on or after**	**Corresponding IMO resolution and guidelines**
SOLAS regulation II-2/17 Focus: Fire safety	1 July 2002		IMO Res. MSC.99(73), MSC/Circ. 1002
SOLAS regulation II-1/55 Focus: Machinery and electrical installations	1 July 2010 (expected)	1 July 1986	IMO Res. MSC.216(82), MSC.1/Circ.1212
SOLAS regulation III/38 Focus: Life-saving appliances	1 July 2010 (expected)	1 July 1998	IMO Res. MSC.216(82), MSC.1/Circ.1212

1.4 *For the application of these [IMO] Guidelines to be successful, all interested parties, including the Administration or its designated representative [1], owners, operators, designers and classification societies, should be in continuous communication from the onset of a specific proposal to utilize these [IMO] Guidelines. This approach usually requires significantly more time in calculation and documentation than a typical regulatory prescribed design because of increased engineering rigor. The potential benefits include more options, cost effective designs for unique applications and an improved knowledge of loss potential.*

C1.5 It is recommended that the Administration or its designated representative[1] and any other party that may be involved in the approval process are contacted

- initially, as early as possible prior to commencing any analysis work, and
- once the process is started, are contacted sufficiently early before each phase of the alternative design and arrangement process commences, in order to agree on the scope and to achieve a common understanding of the content of each step of the alternative design analysis.

C1.6 In case of an application to a new-build ship, the alternative design and approval process should be initiated as early as possible, in the concept phase of a project, in order to

- reduce the effort of introducing design changes that may be required at later stages of the development process as consequence of this alternative design and arrangements analysis, and
- to provide sufficient amount of time for the increased engineering effort.

See Section 3 for a discussion of further timing considerations.

[1] In lack of a formal IMO definition, the term *"designated representative"* is interpreted by GL as *"any entity authorized by the Administration to act on their behalf"*.

Section 2

Definitions

C2.0 Introductory comments

C2.0.1 It is recommended that all parties participating in the analysis shall agree on a common set of definitions and terminology to be used in the alternative design process.

C2.0.2 The following definitions are defined in section 2 of the Annexes to MSC/Circ. 1002 and MSC.1/Circ. 1212.

2.1 Alternative Design and Arrangements

Alternative design and arrangements means measures which deviate from the prescriptive requirement(s) of SOLAS chapters II-1 or III [MSC/Circ. 1002: "SOLAS chapter II-2"], but are suitable to satisfy the intent of that chapter. The term includes a wide range of measures, including alternative shipboard structures and systems based on novel or unique designs, as well as traditional shipboard structures and systems that are installed in alternative arrangements or configurations.

C2.1 In addition to application for new designs, an application of the process for the adaptation or conversion of existing vessels is also technically feasible.

2.2 Design Casualty

Design casualty means an engineering description of the development and severity of a casualty for use in a design scenario.

2.3 Design Casualty Scenario

A set of conditions that defines the development and severity of a casualty within and through ship space(s) or systems and describes specific factors relevant to a casualty of concern.

2.4 Design Fire

Design fire means an engineering description of the development and spread of fire for use in a design fire scenario. Design fire curves may be described in terms of heat release rate versus time.

2.5 Design Fire Scenario

Design fire scenario means a set of conditions that defines the fire development and the spread of fire within and through ship space(s) and describes factors such as ventilation conditions, ignition sources, arrangement and quantity of combustible materials and fire load accounting for the effects of fire detection, fire protection, fire control and suppression and fire mitigation measures.

2.6 Functional Requirements

Functional requirements explain, in general terms, what function the system under consideration should provide to meet the safety objectives of SOLAS.

2.7 Performance Criteria

Performance criteria are measurable quantities [MSC/Circ. 1002: "…stated in engineering terms…"] to be used to evaluate the adequacy of trial designs.

2.8 Prescriptive Based Design, or Prescriptive Design

Prescriptive based design or prescriptive design means a design of safety measures which comply with the regulatory requirements set out in parts C, D and E of SOLAS chapter II-1 and/or chapter III, as applicable.

[MSC/Circ 1002: "Prescriptive based design or prescriptive design means a design of fire safety measures which comply with the prescriptive regulatory requirements set out in parts B, C, D, E or G of SOLAS chapter II-2."]

C2.8.1 The term "reference design" is also commonly used. The reference design provides a set of safety functions required by **SOLAS**, against which the proposed alternative design and arrangement is compared. Subject to agreement by the Administration, the reference design could either be an implemented design or it could be a **SOLAS**-compliant design proposal that is developed to a sufficient level of maturity and detail. If a design is used as reference that has not been implemented yet, then systems, components and parts of the reference design that are directly affected by the changes in focus of the alternative design should satisfy at least all of the following requirements:

– They should have an acceptable safety level and quality for approval by the Administration, evidenced by service experience;

– they should have similar characteristics to the alternative design (depending in the design feature in focus of the individual analysis these characteristic could be expressed, for example, in terms of functions, structure, interfaces);

– they should have been used under similar operational conditions as the alternative design; and

– they should have been used under similar environmental conditions as the alternative design.

C2.8.2 Acceptance of the reference design should be agreed with the Administration prior to use.

2.9 Safety Margin

Adjustments made to compensate for uncertainties in the methods and assumptions used to evaluate the alternative design and arrangements, e.g. in the determination of performance criteria or in the engineering models used to assess the consequences of a casualty [MSC/Circ. 1002: "consequences of fire"].

2.10 Sensitivity Analysis

An analysis to determine the effect of changes in individual input parameters on the results of a given model or calculation method.

2.11 SOLAS

The International Convention for the Safety of Life at Sea, 1974, as amended.

C2.12 Further definitions of terms that are applied in these Guidelines are listed in Annex C of these Guidelines.

Section 3

Engineering Analysis

C3.0 This Section provides an overview of the analysis and approval process that is performed for alternative design and arrangements. Details on each step are provided in subsequent Sections.

3.1 *The engineering analysis used to show that the alternative design and arrangements provide the equivalent level of safety to the prescriptive requirements of SOLAS chapters II-1 and III [MSC/Circ. 1002: "SOLAS chapter II-2"] should follow an established approach to safety design. This approach should be based on sound science and engineering practice incorporating widely accepted methods, empirical data, calculations, correlations and computer models as contained in engineering textbooks and technical literature.*

3.2 *Other safety engineering approaches recognized by the Administration may be used.*

[MSC/Circ. 1002:

"3.2 Two examples of acceptable approaches to fire safety engineering are listed below:

.1 *The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings, Society of Fire Protection Engineers and National Fire Protection Association, 1999.*

.2 *ISO/TR 13387-1 through 13387-8, "Fire safety engineering", International Standards Organization, 1999."*

Other fire safety engineering approaches recognized by the Administration may be used. See appendix C [1] *for guidance and a list of additional technical literature."*

C3.3 It is recommended to reach an agreement with the Administration on at least the following topics well before detailed analysis commences, that is, as early as in the design preview phase (see C3.4.3):

- An acceptable reference design;
- the scope of the analysis (system boundaries, operations in focus, risk evaluation and acceptance criteria etc.); and
- the analysis methods to be applied.

[1] Appendix C of MSC/Circ. 1002 is reproduced in Annex F. of these guidelines.

C3.4 Characterisation of the Alternative Design and Approval Process vs. the Conventional Process

C3.4.1 The development and approval of alternative design and arrangements differs from the conventional approval process in several aspects. The subsequent Subsections are intended to characterise the steps of the alternative design and approval process in general (C3.4.2) and for individual steps (C3.4.3 through C3.4.8). Guidance for aligning the alternative design process with the standard design process is provided in C3.4.9.

C3.4.2 Characteristics of the Alternative Design and Approval Process

C3.4.2.1 Safety equivalency is to be demonstrated by application of an established approach to safety design; for instance, by means of risk assessment. Where the risk assessment approach is used this is termed "risk-based design and approval". The focus of risk-based design and approval is to demonstrate that the level of risk that is inherent in the alternative design is acceptable under current SOLAS regulations. As few explicit risk acceptance criteria exist in SOLAS, safety equivalency is commonly demonstrated by a comparison of the alternative design with a SOLAS-compliant reference design. The reasoning in this approach is that the risk levels in such an accepted design implicitly represent acceptance criteria. It is common practice to demonstrate safety equivalency in one of the following ways:

- By a direct comparison of the alternative designs to an agreed reference design against a set of risk criteria that are agreed with the Administration. In this approach risks are evaluated for each design and it is ensured that, for the agreed criteria, the alternative designs perform at least as well as the SOLAS-compliant reference design.

- By evaluation of alternative designs against absolute assessment criteria. In this approach it is demonstrated that a set of absolute criteria that are fulfilled for the reference design – such as maximum tolerable risk levels – hold to at least the same extent for the alternative designs. For novel alternative designs it can be challenging to obtain absolute risk values.

C3.4.2.2 These Guidelines define the framework for the comparative risk assessment. Following agreement with the Administration, at each stage of this alternative design process, analyses of details should be performed according to accepted engineering guides and literature.

C3.4.2.3 The risk-based design and approval process differs from the conventional approval process, in particular with respect to the required effort and additional analysis steps. A typical process for a detailed alternative design and approval process is illustrated in Fig. 3.1. Application of this process should be agreed with the Administration in advance. Other approaches that are acceptable to the Administration may be used (for instance, see C3.4.3.5).

The core phases of the process shown in Fig. 3.1 are:

I. Design preview,

II. Preliminary analysis in qualitative terms,

III. Quantitative analysis,

IV. Concept refinement and construction,

V. Installation,

VI. Operation.

C3.4.2.4 Work contents of these phases are summarised in C3.4.3 through C3.4.8. The analysis process for alternative design and arrangements covered in MSC/Circ. 1002 and MSC.1/Circ. 1212 is addressed in phases I through III of the approval process.

C3.4.2.5 The design and analysis tasks are performed by a design team that consists of representatives from various stakeholders, such as yard, suppliers, operator. More detail on the design team is given in Section 4.

C3.4.3 Phase I: Design Preview

C3.4.3.1 Prior to commencing extensive analysis work, it is recommended that a design preview, termed “novel concept study”, is performed in order to identify whether an alternative design approach should be used. In the course of this review the extent of specific deviations of the proposed alternative design and arrangements from SOLAS regulations should be presented to the Administration.

C3.4.3.2 Decisions that should be sought prior to detailed analysis

.1 It is recommended that in the design preview an agreement should be reached with the Administration, establishing:

- Whether the proposed alternative design and arrangements represent a deviation from SOLAS requirements, so that the application of the process for alternative design and arrangements is required.
- That the reference design that is proposed to be used in this process in general is acceptable to the administration.
- What degree of novelty is represented in the alternative design and arrangements.
- What requirements therefore need to be placed on the design and analysis process (such as scope of the analysis, risk evaluation criteria to be used, etc.).
- That the analysis process that is proposed to be used (for instance, the comparative risk assessment process documented in these guidelines) is considered appropriate by the Administration for the purpose of demonstrating safety equivalency of the proposed alternative design and arrangement.

C3.4.3.3 Documents to be submitted in design preview phase

.1 In order to make it possible for the Administration to reach a conclusion on the decisions listed in C3.4.3.2, the owner/supplier needs to document (for each proposed alternative design or arrangement):

a) Functional and design descriptions of the reference design, as well as for the proposed alternative design(s) and arrangement(s) for which approval shall be sought. These descriptions should give full particulars of the proposed changes, as well as any SOLAS regulations that may be challenged by such changes, and including the extent of the expected deviations. The design descriptions should also cover the surroundings that may be affected by the proposed alternative design and arrangements, i.e. definitions of interfaces to other systems and processes/operations. Preliminary arrangement plans and preliminary detail drawings of subsystems should also be included.

b) A list of codes and standards applied.

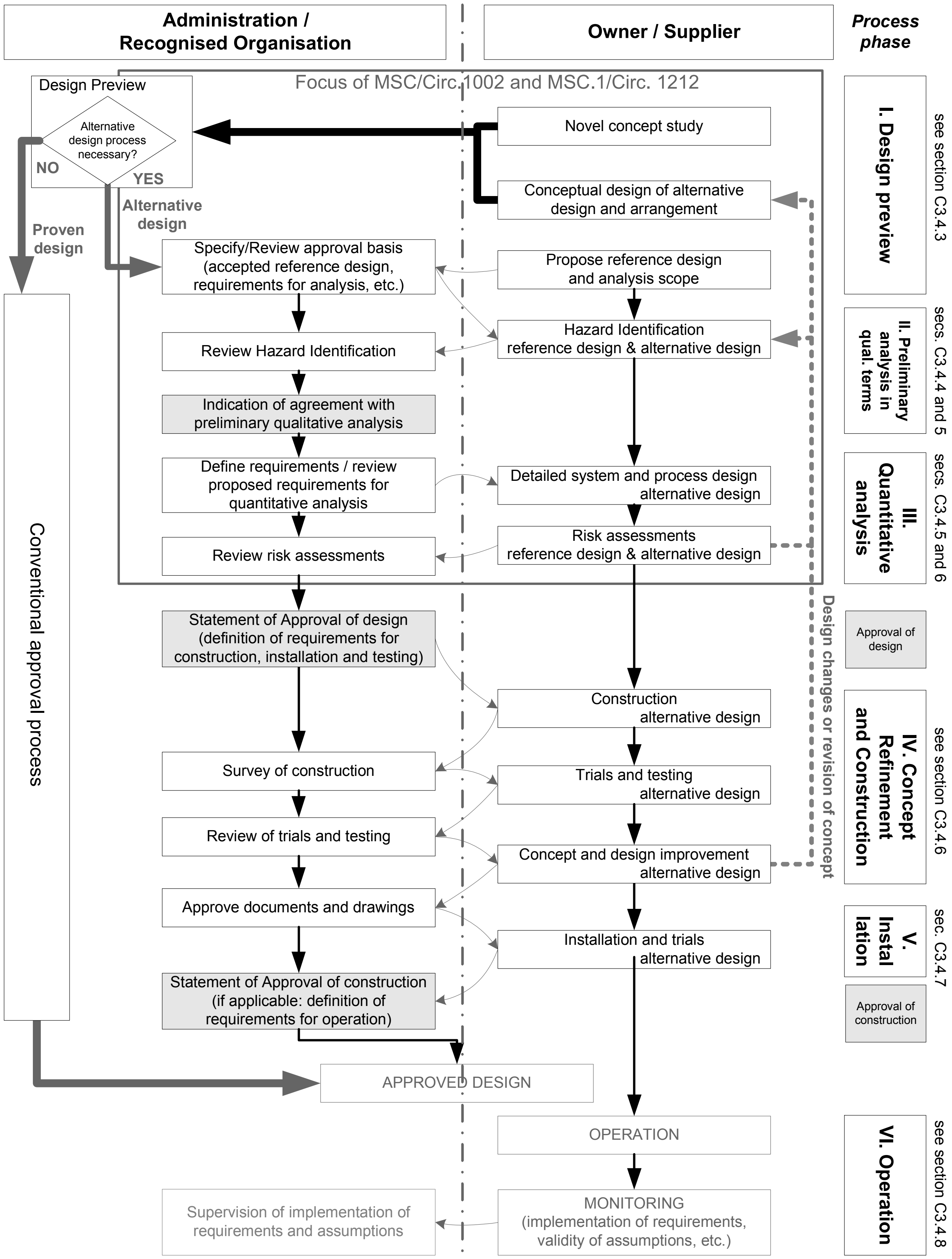
c) A list of the safety-objectives that are to be derived from the concerned SOLAS regulations.

d) A list of functional requirements that need to be fulfilled by the alternative design and arrangements to ensure that these safety-objectives are adhered to.

e) A list of arguments documenting the extent to which these functional requirements are fulfilled by the reference design.

f) A list of actions documenting how these requirements are intended to be implemented in the alternative design(s).

g) Risk assessment plans and preliminary testing and analysis plans that are intended to be applied in order to demonstrate safety equivalency. These plans should be outlined in sufficient detail (such as: analysis sequence, methods intended to be applied, risk acceptance criteria, information



Note that the primary focus of MSC/Circ. 1002 and MSC.1/Circ. 1212 are phases II ("Preliminary analysis in qualitative terms") and phase III ("Quantitative analysis").

Fig. 3.1 Interaction with Administration during alternative design process

flow, performance criteria to be used for comparison of designs). A list of codes and standards that will be applied should be provided.

.2 Additional information may be requested by the Administration, subject to each case individually.

C3.4.3.4 Recommendations on the structure of documentation

.1 The content and structure of the documentation should be agreed with the administration in the individual case; an example is given by the structure of section 3 in SOLAS II-2 regulation 17.3, reproduced in Annex B.

.2 It is recommended to include items a) through e) listed in C3.4.3.3 as a separate design description document which should be updated continuously throughout the alternative design process.

.3 Once the alternative design process commences, this design documentation should be refined and complemented by a list of all design documents that are referred to in the analyses.

.4 Descriptions should be provided for both, the reference design and the alternative design [2]. For alternative designs full preliminary particulars should be given to the highest level of detail that is available.

.5 These system descriptions form the basis for the qualitative and quantitative analyses. Such documentation will assist in defining lifelong operating, inspection and maintenance conditions for the components of the vessel that are affected by the alternative design or arrangement.

.6 Additionally, in the documentation all operational and casualty scenarios that are reviewed in the qualitative and quantitative analyses (see Sections 5 and 6) are described in terms of their processes and associated functions, as well as their relevance for each design.

C3.4.3.5 Selection of analysis strategies

.1 Based on a judgement of the degree of novelty of the proposed alternative design and arrangements, the design team will agree with the Administration requirements on the effort, focus and methods to be applied in the course of the risk analysis and the analysis and testing of the design. Possible outcomes and the associated analysis requirements include, but are not necessarily restricted to, the following:

- The proposed design can be considered a proven design:

  A conventional approval process can be followed.

- The proposed design must be considered an alternative design, but deviations from SOLAS are minor (for instance: small design deviations; use of novel but well-known materials and techniques):

  Compliance of the alternative design and arrangements is demonstrated with respect to a set of functional requirements that are derived from the safety objectives of the violated SOLAS regulations.

- The proposed design must be considered an alternative design, but the level of SOLAS deviations is moderate (for instance: significant design deviations; use of materials and techniques that are novel to the intended application, but where experience from other applications exists):

  A comparative risk analysis is performed consisting of hazard identification and (qualitative or semi-quantitative) risk assessment for the alternative design and arrangements compared to a reference design.

- The proposed design must be considered a alternative design and the level of SOLAS deviations is large (for instance: substantial design deviations; use of materials and techniques that are novel to the intended application and no experience from other applications exists):

  A comparative risk analysis is performed consisting of hazard identification and in-depth quantitative risk assessment for the identified hazard.

These strategy selection criteria are summarised in Table 3.1.

.2 The guidance in this document is focused on the implementation of the latter case, because it comprises all the requirements of the other cases.

[2] For the purpose of traceability, version numbers should be assigned to each revision of the documentation. Version information for the design description document that holds the design details that were used for a particular analysis should be quoted in the corresponding analysis report.

Table 3.1 Summary of constellations and recommended analysis strategies

Degree of novelty Proposed design is considered a …	**Required analysis** (recommendation)
Proven design	Conventional approval process may be followed
Novel or alternative design, minor SOLAS deviations	Demonstrate compliance with functional requirements derived from SOLAS
Novel or alternative design, moderate SOLAS deviations	Comparative risk assessment comprising hazard identification and qualitative risk analysis
Novel or alternative design, large SOLAS deviations	Comparative risk assessment comprising hazard identification and quantitative risk analysis

C3.4.4 Phase II: Preliminary analysis in qualitative terms

C3.4.4.1 Once it is agreed that the process for alternative design and arrangement is to be followed, the preliminary analysis commences, see Fig. 3.1. Here, the reference design and the alternative design(s) are clearly specified. Systems and processes subject to the alternative design analysis are defined. The intent of the challenged SOLAS regulations that were identified in the design preview (see C3.4.3) is documented, as well as a set of functional requirements and performance criteria that are affected by the alternative design(s). The design team identifies scenarios of main operations and develops casualty scenarios for the reference design and the alternative design.

C3.4.4.2 For these scenarios a hazard identification is performed and identified hazards are ranked. The ranking is based on an assessment of consequences that can be expected in case the identified hazards lead to an accident. Hazards with the highest risk level are included in casualty scenarios for a more detailed quantitative analysis. It is recommended to also consider a first identification of risk-reduction measures at this stage. Risk-reduction measures that are introduced at an early stage of the design may be implemented with less implication for costs, whereas later on implementation of design changes may become prohibitive.

C3.4.4.3 It has proven useful to invite a representative of the Administration to participate in the preliminary analysis, as the Administration representative will be able to raise issues that are relevant for approval and that therefore should be discussed.

C3.4.4.4 Further, it has proven useful at this stage to provide a proposal of the scope of steps that will be performed in the quantitative analysis in terms of performance criteria and analysis methods that are intended to be used for the design comparison.

C3.4.4.5 The preliminary analysis is reviewed by the Administration, and, if the analysis is deemed satisfactory, agreement with preliminary analysis is indicated. The Administration also comments on the intended progression of the analysis, including proposed performance criteria, analysis methods, casualty scenarios and selected hazards, if such detail was provided (see C3.4.4.4).

C3.4.4.6 Technical details on the preliminary analysis phase are given in Section 5.

C3.4.5 Phase III: Quantitative analysis

C3.4.5.1 In general, the basis for an approval are the documents listed in C3.4.3.3. Additional documents may be required in the individual case.

C3.4.5.2 As soon as agreement with the preliminary analysis is signalled by the Administration (concluding phase II of the process in Fig. 3.1), the alternative design and arrangements need to be further detailed. Following an agreement with the Administration about the required scope of subsequent analysis steps, risk assessments of the designs are performed for a set of design casualty scenarios that address the hazards representing the biggest risk contributors. Performance criteria are defined and agreed with the Administration, and a detailed quantitative assessment is performed for the reference design and the alternative design(s). The aim of this assessment is to evaluate the performance criteria and the risk levels associated with the identified hazards in the course of these scenarios. These analyses are to be reviewed by the Administration.

C3.4.5.3 Depending on their extent, changes in the concept or design may require re-visiting the process from the design preview phase or the qualitative analysis, respectively. In Fig. 3.1, this is indicated by dashed lines.

C3.4.5.4 On conclusion of the quantitative analysis phase the Administration issues a statement of approval of the design, including a set of requirements that may arise as result of phases II and III with respect to construction, installation and testing.

C3.4.5.5 Further technical details on the quantitative analysis phase are provided in Section 6.

C3.4.6 Phase IV: Concept refinement and construction

C3.4.6.1 This phase is not covered by IMO circulars MSC/Circ. 1002 and MSC.1/Circ. 1212.

C3.4.6.2 In the course of concept refinement and construction, design requirements and risk reducing measures that originate from the results of the alternative design analysis must be implemented, analysed and tested. Some of the design requirements against which the analysis and testing is performed may result from assumptions made by the design team; see C3.4.10. It is recommended that the Administration shall be kept informed about the progress of these tasks, in order to be able to review the work.

C3.4.6.3 The review process continues throughout the construction phase, for instance by construction surveys.

C3.4.6.4 Depending on their extent, changes in the concept or design may require re-visiting the process from the design preview phase or the qualitative analysis, respectively. Again, this is indicated by dashed lines in Fig. 3.1.

C3.4.7 Phase V: Installation

C3.4.7.1 This phase is not covered by IMO circulars MSC/Circ. 1002 and MSC.1/Circ. 1212.

C3.4.7.2 In the course of installation, design requirements that originate from the results of the alternative design analysis must be implemented, analysed and tested. It is recommended that the Administration shall be kept informed about the progress of these tasks, in order to be able to review the work.

C3.4.8 Phase VI: Operation

C3.4.8.1 This phase is not covered by IMO circulars MSC/Circ. 1002 and MSC.1/Circ. 1212.

C3.4.8.2 Documentation of the analysis process and the analysis results that are relevant for the construction and operation of the vessel are to be kept on board at all times.

C3.4.8.3 Once the vessel is in service, operational requirements and assumptions that were made in the course of the alternative design analysis with respect to operations must be monitored by the operator in order to verify that all requirements are implemented and all assumptions hold. Examples of such requirements are maintenance tasks and training procedures that originate from introduction of a new type of equipment. It is recommended that two copies of the monitoring results are produced; one copy that is attached to the documentation aboard the vessel and a further copy that is supplied to the Administration in regular intervals which are to be agreed between parties.

C3.4.8.4 In case significant deviations from assumptions are detected, a revision of the concept may be required in agreement with the Administration, for instance modifications of installations or alteration of operations.

C3.4.9 Alignment of the alternative design process to the standard design process

C3.4.9.1 New and additional activities within the risk-based design and approval processes need to be aligned with the typical workflows that are performed by the yard (coordinating its own processes with the owner and suppliers).

C3.4.9.2 An exemplary alignment of the aforementioned phases of the approval process for novel and risk-based design with a typical client design and construction process is illustrated in Fig. 3.2 for the risk-based design and approval of ships and ship systems. In the upper section of this figure the typical phases of the conventional design process are shown. These steps also need to be applied when a risk-based alternative design process is performed. The novel steps of such a process, which are shown in more detail in Fig. 3.1, are aligned to these phases, distinguishing between work to be performed by the yard, owner and supplier and work to be performed by the Administration. While Fig. 3.2 indicates the sequence of work phases, the length of the boxes is not an indication for the duration of a work phase. The main part of the alternative design process in the focus of MSC/Circ. 1002 and MSC.1/Circ. 1212 (indicated by a dashed box in Fig. 3.2) ends with an evaluation of the design by the Administration and a statement of a approval of design. The process is followed by construction, testing and installation phases.

C3.4.9.3 The individual alignment of the risk-based design and approval process with standard design practice is highly variable and depends on the individual application, see (Breinholt *et al.* 2007). Depending on the degree of novelty of the alternative design, different analysis strategies will be agreed with the Administration (see C3.4.3.5). These strategies have different impact on the timeline of the risk-based development phase.

C3.4.9.4 The amount of additional time that is required for performing the risk-based analyses demanded by the alternative design and approval process is highly variable and depends on a number of parameters, such as:

– the degree of novelty of the alternative design (level of experiences and available data on novel materials, systems and components),

– the level of complexity, i.e. the extent of ship design that is affected by introducing the alternative design; as well as

– the level of planning dependability that is desired by the client.

C3.4.9.5 Depending on the intention of the client the development of the alternative design may be started before the bid requirement:

– If the degree of novelty and the level of complexity is low, or if the desired level of planning dependability is negligible, the preliminary analysis may be performed concurrently with the bid development process.

– In case the degree of novelty or the level of complexity is medium, it is recommended that the preliminary analysis is performed prior to bid development.

– For alternative designs with a high degree of novelty or a high level of complexity, or generally when a high level of planning dependability is desired after the preliminary approval, it is recommended that also the quantitative analysis is performed prior to bid development.

C3.4.9.6 The impact of the parameters and influences listed in C3.4.9.4 and C3.4.9.5 on the timeline, possibly including the project start, is indicated by larger arrows of increasing length on the left of Fig. 3.2.

C3.4.9.7 In order to ensure that work commences in agreement with the Administration, it is recommended to establish first contact with the Administration as early in the alternative design process as possible.

C3.4.10 Use of assumptions in the course of the engineering analysis

C3.4.10.1 During the engineering analysis (steps I through III of the process, see Fig. 3.2) assumptions may need to be made, for instance because sufficient detail of the final design is not available at this stage, or because of a general lack of suitable data for certain design aspects. Such assumptions should be based on sound engineering judgement. As far as practicable, application of assumptions should be kept to a minimum necessary.

C3.4.10.2 The application of assumptions should be indicated to the Administration prior to use.

C3.4.10.3 Assumptions may be rated by the Administration in different ways, including:

– Acknowledgement and acceptance by the Administration.

– Assumptions become design requirements, to be demonstrated in practice in later design stages (i.e. step IV in Fig. 3.2).

– Assumptions yield implications to be addressed by the vessel Owner by suitable operating procedures or restrictions (i.e. step V in Fig. 3.2).

C3.4.10.4 For the purpose of transparency, it is recommended that a list of such assumptions shall be developed and maintained, as a continuous task throughout the analysis process. For each of these assumptions the resulting requirements for the design and operations of systems and the vessel should be indicated, and responsibilities for addressing these requirements should be assigned to capable members of the design team.

C3.4.10.5 In case assumptions and operational restrictions that were elicited in the course of the alternative design and arrangements process are subject to change, the engineering analysis is to be revised under consideration of such alterations, and the revised analysis is to be approved by the Administration.

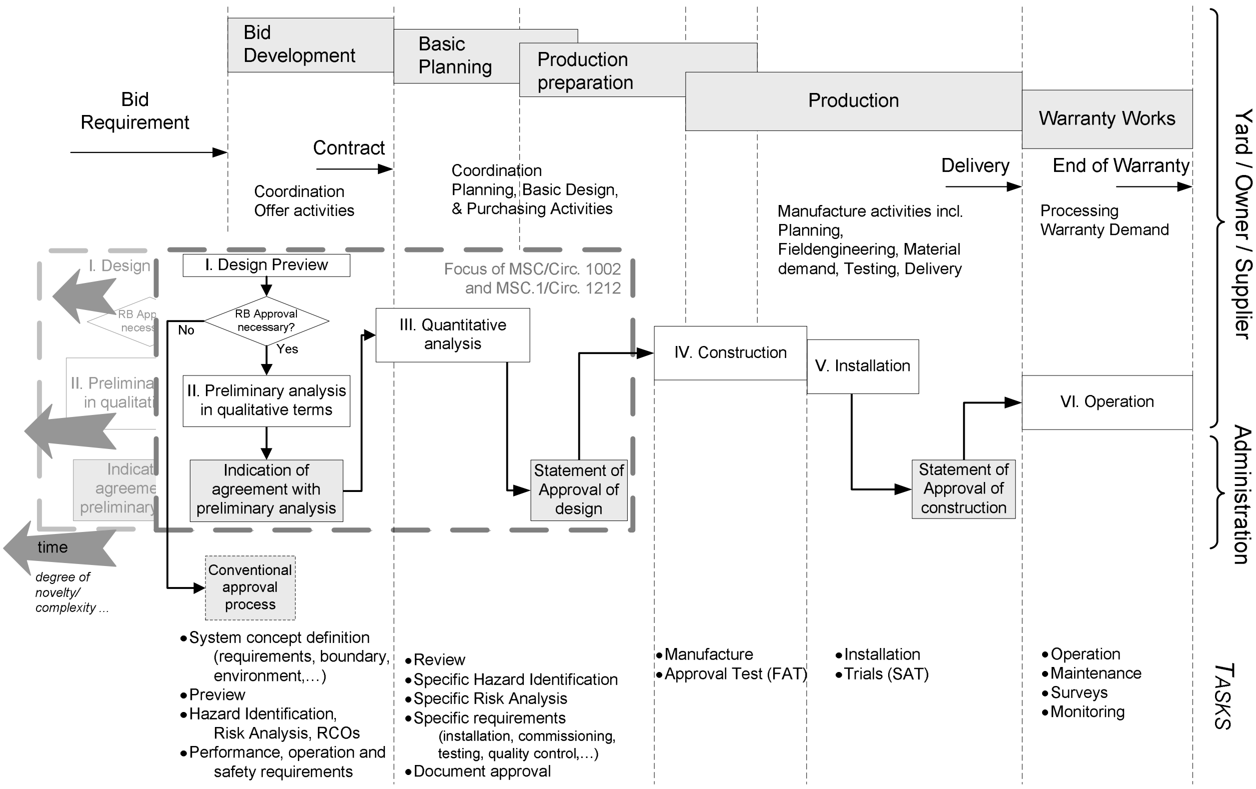


Fig. 3.2 Alignment of risk-based design and approval with typical workflow of design and construction process

Section 4

Design Team

4.1 *A design team acceptable to the Administration should be established by the owner, builder or designer and may include, as the alternative design and arrangements demand, a representative of the owner, builder or designer, and expert(s) having the necessary knowledge and experience in safety, design and/or operation as necessary for the specific evaluation at hand. Other members may include marine surveyors, ship operators, safety engineers, equipment manufacturers, human factors experts, naval architects and marine engineers.*

4.*2* *The level of expertise that individuals should have to participate in the team may vary depending on the complexity of the alternative design and arrangements for which approval is sought. Since the evaluation, regardless of complexity, will have some effect on a particular field of safety, at least one expert with knowledge and experience in that appropriate safety field should be included as a member of the team.*

4.3 *The design team should:*

.1 *appoint a co-ordinator serving as the primary contact;*

.2 *communicate with the Administration for advice on the acceptability of the engineering analysis of the alternative design and arrangements throughout the entire process;*

.3 *determine the safety margin at the outset of the design process and review and adjust it as necessary during the analysis;*

.4 *conduct a preliminary analysis to develop the conceptual design in qualitative terms.*

This includes a clear definition of the scope of the alternative design and arrangements and the regulations which affect the design; a clear understanding of the intent requirements of the relevant regulations; the development of appropriate casualty scenarios, if necessary, and trial alternative designs. This portion of the process is documented in the form of a report that is reviewed and agreed by all interested parties and submitted to the Administration before the quantitative portion of the analysis is started;

.5 *conduct a quantitative analysis to evaluate possible trial alternative designs using quantitative engineering analysis. This consists of the specification of design thresholds, development of performance criteria based upon the performance of an acceptable prescriptive design and evaluation of the trial alternative designs against the agreed performance criteria. From this step the final alternative design and arrangements are selected and the entire quantitative analysis is documented in a report; and*

.6 *prepare documentation, specifications and a life-cycle maintenance programme. The alternative design and arrangements should be clearly documented and approved by the Administration and a comprehensive report describing the alternative design and arrangements and required maintenance programme should be kept on board the ship.*

An operations and maintenance manual should be developed for this purpose. The manual should include an outline of the design conditions that should be maintained over the life of the ship to ensure compliance with the approved design

[Circular MSC/Circ. 1002 only:]

4.4 *The fire safety objectives in SOLAS regulation II-2/2 and the purpose statements listed at the beginning of each individual regulation in chapter II-2 should be used to provide the basis for comparison of the alternative design and arrangements to the prescriptive regulations.*

C4.5 In addition to the experts from the owner, builder, equipment suppliers or sub-contractors that may permanently belong to the core design team, independent experts may be consulted as temporary members, in case specialised questions arise. For instance, it is recommended to consider involvement of a trained moderator to support knowledge elicitation.

C4.6 This implies that commitment may be required by the owner and builder early in the development process, with respect to the selection of equipment suppliers and sub-contractors.

C4.7 It is further recommended that the design team also includes an experienced project manager.

C4.8 Experience and expertise of all permanent and temporary design team members shall be documented (for instance, by short-CVs) and submitted as part of the documentation of the analysis.

C4.9 Throughout the analysis steps of the alternative design process the design team should continuously collect, organise and evaluate documentation of all relevant design features. It is recommended to collect such information in a separate design description document (see C3.4.3.4).

Section 5

Preliminary Analysis in Qualitative Terms

C5.0 Introductory comments

C5.0.1 The preliminary analysis in qualitative terms consists of the definition of the analysis scope, and the hazard identification by means of a method that is agreed with the Administration. Hazards that are identified are ranked, and from the ranked hazards casualty scenarios are developed for use in the quantitative analysis. Results of the analysis are documented in the preliminary analysis report.

C5.0.2 Documents and Inputs to be Provided for the Qualitative Analysis

C5.0.2.1 The set of documents that is required in order to conduct the preliminary analysis in qualitative terms will vary, depending on the particular application.

C5.0.2.2 Generally, in order to be able to perform the qualitative analysis in sufficient level of detail, definitions of the systems, components and processes need to be provided.

C5.0.2.3 Input that is required to conduct this analysis includes the documents listed in C3.4.3.3, as well as reviews of technical drawings, plans, references and change documentation, user manuals, maintenance manuals and troubleshooting guides.

C5.0.2.4 With respect to the development process it should be noted that, in order to provide these details, at this stage suppliers or sub-contractors may have to be selected.

5.1 Definitions of Scope

5.1.1 *The ship, ship system(s), Component(s), space(s) and/or equipment subject to the analysis should be thoroughly defined. This includes the ship or system(s) representing both the alternative design and arrangements and the regulatory prescribed design. Depending on the extent of the desired deviation from prescriptive requirements, some of the information that may be required includes: detailed ship plans, drawings, equipment information and drawings, test data and analysis results, ship operating characteristics and conditions of operation, operating and maintenance procedures, material properties, etc.*

C5.1.1.1 The design descriptions and specifications should cover the surroundings that may be affected by the proposed alternative design and arrangements, i.e. definitions of interfaces to other systems and processes/operations, preliminary arrangement plans and preliminary detail drawings of subsystems. Details on corresponding surrounding installations in the reference design should also be included in the design description. For practicality reasons it is recommended that the design description is established and maintained as a separate document (see C3.4.3.4).

C5.1.1.2 Changes of the design that are considered at a later stage may result in the need to revise the qualitative and quantitative analyses.

5.1.2 *The regulations affecting the proposed alternative design and arrangements, along with their functional requirements, should be clearly understood and documented in the preliminary analysis report (see 5.5). This should form the basis for the evaluation referred to in 6.4.*

C5.1.2 The comparison of the alternative design(s) to the reference design is partially performed on the basis of these functional requirements. It is recommended that the extent to which these requirements are fulfilled by the reference design should be documented, and that a list of actions is provided defining how these requirements are intended to be implemented in the alternative design(s).

5.2 Development of Casualty and Operational Scenarios

[in MSC/Circ. 1002 this is a separate section*: "5.2.1 Fire scenarios should provide the basis for analysis and trial alternative design evaluation and, therefore, are the backbone of the alternative design process. Proper fire scenario development is essential and depending on the extent of deviation from the prescribed design, may require a significant amount of time and resources."*]

Casualty or operational scenarios should provide the basis for analysis and trial alternative design evaluation and, therefore, are the backbone of the alternative design process. Proper casualty or operational scenario development is essential and, depending on the extent of deviation from the prescribed design, may require a significant amount of time and resources. This phase should outline why an alternative design may be beneficial. For life-saving arrangements, this may focus on casualty scenarios where an alternative design or arrangement will provide an equivalent (or greater) level of safety. Mechanical or electrical arrangements may focus on an operational scenario that will provide an equivalent level of safety, but may increase efficiencies or reduce cost to the operator.

C5.2 It is recommended that for the development of operational and casualty scenarios all operations should be considered that may be affected by the alternative design or arrangements; bearing in mind that further systems may be affected and that secondary uses of the alternative design may have an effect on its primary use. For instance, modification of life-saving appliances may imply modifications of launching appliances, escape routes and embarkation arrangements (see also 6.3.5). Likewise, appliances that are frequently used in training may experience wear and tear which can have an effect on their availability in case of an emergency situation.

5.3 Casualty Scenario Development

5.3.1 General

[In MSC/Circ. 1002 this is paragraph 5.2.1]

Casualty scenario development can be broken down into four areas:

.1 *identification of hazards;*

.2 *enumeration of hazards;*

.3 *selection of hazards; and*

.4 *specification of design casualty scenarios.*

5.3.2 Identification of hazards

[In MSC/Circ. 1002 this is paragraph 5.2.1.1.] *This step is crucial in the casualty scenario development process as well as in the entire alternative design methodology. If a particular hazard or incident is omitted, then it will not be considered in the analysis and the resulting final design may be inadequate. Hazards may be identified using historical and statistical data, expert opinion and experience and hazard evaluation procedures. There are many hazard evaluation procedures available to help identify the hazards including Hazard and Operability Study (HAZOP), Process Hazard Analysis (PHA), Failure Mode and Effects Analysis (FMEA), "what-if", etc. As a minimum, the following conditions and characteristics should be identified and considered:*

[For MSC/Circ. 1002]

.1 *pre-fire situation: ship, platform, compartment, fuel load, environmental conditions;*

.2 *ignition sources: temperature, energy, time and area of contact with potential fuels;*

.3 *initial fuels: state (solid, liquid, gas, vapour, spray), surface area to mass ratio, rate of heat release;*

.4 *secondary fuels: proximity to initial fuels, amount, distribution;*

.5 *extension potential: beyond compartment, structure, area (if in open);*

.6 *target locations: note target items or areas associated with the performance parameters;*

.7 *critical factors: ventilation, environment, operational, time of day, etc.; and*

.8 *relevant statistical data: past fire history, probability of failure, frequency and severity rates, etc.*

[For MSC/Circ. 1212]

.1 *pre-casualty situation: ship, platform, compartment, available potential and kinetic energy, environmental conditions;*

.2 *potential initiating events, causes;*

.3 *detailed technical information and properties of potential hazards;*

.4 *secondary hazards that might be subject to effects of initial hazard;*

.5 *extension potential: beyond compartment, structure, area (if in open);*

.6 *target locations: note target items or areas associated with the performance parameters;*

.7 *critical factors relevant to the hazard: ventilation, environment, operational, time of day, etc.; and*

.8 *relevant statistical data: past casualty history, probability of failure, frequency and severity rates, etc.*

C5.3.2.1 Hazard identification typically evaluates a set of operational and casualty scenarios that describe common uses and critical uses of the equipment that is affected by the alternative design and arrangement. This set of scenarios is agreed by the design team in order to ensure that adequate coverage is reached. The choice should consider experiences of the use of comparable designs and arrangements, as well as information on incidents and accidents that may have been experienced and that are related to particular design features.

C5.3.2.2 Suitable information sources for the detailing of operational scenarios include user manuals, maintenance manuals and troubleshooting guides. Other sources that should be considered include reviews of technical drawings, plans, references and change documentation.

C5.3.2.3 The processes underlying each of the operational scenarios are specified for the reference design and the alternative design(s). It has proven useful to clearly structure the processes that are affected by the alternative design and arrangement. This makes it possible to systematically evaluate the processes underlying a scenario. For instance, a process can be structured in terms of atomic actions, activities (which consist of several actions) and functions (which are initiated and implemented by one or several activities). The level of detail that is used in each scenario depends on the individual application. The effort in the structuring of a scenario in every detail may not be justified by generated information; therefore the level of detail in the specification of a scenario generally will be a compromise of efficiency and elaborateness.

C5.3.2.4 Hazards that may arise – usually in terms of operational deviations from the envisaged steps in operational scenarios or in terms of system failures – are then identified by a suitable hazard identification technique. The quoted hazard identification techniques HAZOP, FMECA, WHAT-IF analysis and PHA are characterised in Annex F. The identified hazards are ranked, for instance by addition or multiplication of indices for agreed categories of frequencies (frequency index, FI) and severities (severity index, SI), as shown in MSC 83/INF.2. Selected hazards are included in casualty scenarios for a more thorough consideration in the quantitative analysis phase.

5.3.3 Enumeration of hazards

[In MSC/Circ. 1002 this is paragraph 5.2.1.2] *All of the hazards [MSC/Circ. 1002: "fire hazards"] identified above should be grouped into one of three incident classes: localized, major or catastrophic. A localized incident consists of a casualty [MSC/Circ. 1002: "of a fire"] with a localized effect zone, limited to a specific area. A major incident consists of a casualty [MSC/Circ. 1002: "of a fire"] with a medium effect zone, limited to the boundaries of the ship. A catastrophic incident consists of a casualty [MSC/Circ. 1002: "of a fire"] with a large affect zone, beyond the ship and affecting surrounding ships or communities. In the majority of cases, only localized and/or major incidents [MSC/Circ. 1002: "fire incidents"] need to be considered. Examples where the catastrophic incident class may be considered would include transport and/or offshore production of petroleum products or other hazardous materials where the incident effect zone is very likely to be beyond the ship vicinity. The hazards [MSC/Circ. 1002: "fire hazards"] should be tabulated for future selection of a certain number of each of the incident classes.*

5.3.4 Selection of hazards

[In MSC/Circ. 1002 this is paragraph 5.2.1.3] *The number and type of hazards [MSC/Circ. 1002: "fire hazards"] that should be selected for the quantitative analysis is dependent on the complexity of the trial alternative design and arrangements. All of the hazards identified should be reviewed for selection of a range of incidents. In determining the selection, frequency of occurrence does not need to be fully quantified, but it can be utilized in a qualitative sense. The selection process should identify a range of incidents which cover the largest and most probable range of enumerated hazards. Because the engineering evaluation relies on a comparison of the proposed alternative design and arrangements with prescriptive designs, demonstration of equivalent performance during the major incidents should adequately demonstrate the design's equivalence for all lesser incidents and provide the commensurate level of safety. In selecting the hazards it is possible to lose perspective and to begin selecting highly unlikely or inconsequential hazards. Care should be taken to select the most appropriate incidents for inclusion in the selected range of incidents.*

C5.3.4.1 By the combination of the aforementioned systematic analysis techniques with appropriate structuring mechanisms for the processes to be analysed – such as the recommended practice of selecting a set of structuring operational scenarios that are agreed by practitioners – good coverage of all relevant situations can be reached and the hazard selection process is supported.

C5.3.4.2 Several hazard identification techniques, such as FMECA, already contain an assessment of the criticality of consequences of hazards, as well as the probability of occurrence. These assessments ideally should be based on sound statistical data, such as public accident statistics, data sheets for components, and data recorded by the operator on incidents in his fleet involving comparable designs and arrangements. Subject to agreement by the Administration, in cases where such data is not available the use of engineering judgement may be feasible for the assessment of these values. The expert reasoning underlying such judgements should be documented in such a way that it becomes possible for the Administration to assess if such judgements are reasonable. However, the extent of use of engineering judgement in this manner should be kept to a minimum.

C5.3.4.3 For ease of reference it is recommended to assign unique identifiers to each hazard and to record all hazards in a hazard log. This reference should be used throughout all analyses within the alternative design process.

C5.3.4.4 It is recommended that the qualitative analysis shall be prepared and moderated by a (permanent or temporary) design team member that is qualified and experienced in the application of the techniques.

5.3.5 Specification of design casualty scenarios

[In MSC/Circ. 1002 this is paragraph 5.2.1.4] *Based on the hazards selected, the casualty scenarios to be used in the quantitative analysis should be clearly documented. The specification should include a qualitative description of the design casualty (e.g., initiating and subsequent chain of events, location, etc.), description of the vessel, compartment or system* *of origin, safeguard systems installed, number of occupants, physical and mental status of occupants and available means of escape. The casualty scenarios should consider possible future changes to the hazards (increased or decreased) in the affected areas. The design casualty or casualties will be characterized in more detail during the quantitative analysis for each trial alternative design. Operational scenario development for a mechanical or electrical alternative design or arrangement should include the operating scenarios under which the alternative [design] will be utilized.*

5.4 Development of Trial Alternative Designs

[In MSC/Circ. 1002 this is paragraph 5.3] *At this point in the analysis, one or more trial alternative designs should be developed so that they can be compared against the developed performance criteria. The trial alternative design should also take into consideration the importance of human factors, operations and management. It should be recognized that well defined operations and management procedures may play a big part in increasing the overall level of safety.*

C5.4.1 It is common practice to develop high-level trial alternative designs early in the design preview phase (Step I in Fig. 3.1). The design that is considered "optimal" from a commercial and operational perspective then becomes the initiating design for the alternative design and arrangement process.

C5.4.2 An integral aspect in the development of trial alternative designs is to keep in mind that functional requirements originating from SOLAS safety objectives remain achievable, as well as performance criteria and customer goals.

C5.4.3 For the subsequent quantitative analysis, see Section 6, the trial alternative designs need to be refined in more detail. It is recommended that all details on the trial alternative design, such as plans, drawings etc. are added to the design description document.

C5.4.4 (Importance of design reviews:) The qualitative analysis may establish that a trial alternative design is unsatisfactory with respect to the capabilities or the safety requirements for operation, construction or the general concept. In such cases the trial alternative design either is discarded at this stage, or the design needs to be revised, redeveloped, and the qualitative analysis is repeated for the revised design.

C5.4.5 During the development of trial alternative designs it is recommended that each design is reviewed with respect to possibilities for introducing risk control measures. Risk control measures may be found that contribute to lower probability of hazard occurrence or better containment of consequences.

5.5 Preliminary Analysis Report

[In MSC/Circ. 1002 this is paragraph 5.4]

C5.5.1 On completion of the preliminary analysis in qualitative terms the Administration should be provided with sufficient information to be able to decide:

– if all relevant systems, components and processes that were identified in the preliminary analysis are covered in sufficient level of detail;

– if the preliminary analyses of the reference design and the alternative design and arrangements were performed with a satisfactory and similar level of rigor;

– if the preliminary analyses were performed by a design team that has a satisfactory level of expertise, and by use of analysis methods that are considered accepted practice;

– if assumptions that were made in the course of the analysis are feasible – judged from the present state of the art of the industry.

Information to base these decisions on is provided in the preliminary analysis report.

5.5.1 *A report of the preliminary analysis should include clear documentation of all steps taken to this point, including identification of the design team, their qualifications, the scope of the alternative design analysis, the functional requirements to be met, the description of the casualty scenarios and trial alternative designs selected for the quantitative analysis.*

5.5.2 *The preliminary analysis report should be submitted to the Administration for formal review and agreement prior to beginning the quantitative analysis. The report may also be submitted to the port State for informational purposes, if the intended calling ports are known during the design stage.*

The key results of the preliminary analysis should include:

.1 a secured agreement from all parties to the design objectives and engineering evaluation;

.2 specified design casualty scenario(s) acceptable to all parties; and

.3 trial alternative design(s) acceptable to all parties.

C5.5.3 It is recommended to prepare the following documentation for the Administration (and port State, if required):

– Description of the system that is in focus of the analysis as well as descriptions of any systems and processes that may be affected by the operation of the proposed changes of this system. It is recommended to collect and maintain all system documentation in a separate design description document (cf. C3.4.3.4).

- Documentation of preliminary qualitative analyses of the alternative design and the reference design. This document should include a description of the applied analysis methods and findings of the analysis. The experience of the design team participating in the analysis should also be documented.

  Further parts of the analysis documentation should contain:

- A list of identified hazards (for instance, a hazard log, including unique hazard IDs) and an outline of how these hazards are intended to be addressed in the course of the quantitative analysis, such as the analysis approach and methods to be used.
- A list of all assumptions made in the analysis, as well as the justifications of these assumptions provided by the design team.

C5.5.4 These results form the foundation for the quantitative analysis phase of the alternative design and arrangements process. It is recommended that the preliminary analysis report is concluded by a statement of agreement by all members of the design team with respect to the scope and results of the preliminary analysis and the intended scope of the quantitative analysis.

C5.5.5 Further documentation may be requested by the Administration in each case individually.

Section 6

Quantitative Analysis

C6.0 Documents and inputs to be provided for the quantitative analysis

C6.0.1 In the quantitative analysis particulars of selected design aspects are investigated, that – according to the results of the preliminary analysis – were identified as requiring further exploration. Compared to the previous analysis steps, in general more detailed input is required to conduct this analysis. The set of documents that is required in order to conduct the analysis will vary, depending on the particular application. Typical inputs that are required at this stage of the analysis include failure rates for components and systems, accident frequencies, usage statistics, probabilistic calculations of structural strength, heat and smoke distributions.

C6.0.2 Subject to their respective fields of expertise these details will be procured and provided by members of the design team. Suitable input to the analysis may need to be generated by supporting analyses which may not be part of the typical design and construction work.

C6.0.3 It is recommended that all data sources, as well as the validation, verification and justification of all data items that are utilized in the course of the analysis, shall be documented in the analysis report or its supporting documents.

C6.1 General

The aim of the quantitative analysis is to assess for the reference design and the alternative design the level of safety for the system or process under consideration. This can be achieved by conducting the following steps:

– An elaborated investigation of the level of risk that is associated with hazards which were identified in the qualitative analysis, by means of:

  a) a quantification of the probabilities of these hazards for reference and alternative designs and

  b) a quantification of the consequences of these hazards for reference and alternative designs.

– The definition of an acceptable set of quantifiable safety objectives and performance criteria and evaluation of these criteria for the reference and alternative designs.

– The identification and evaluation of risk-reducing measures, i.e. mechanisms for preventing failures and/or for containing consequences of failures.

6.1.1 *The quantitative analysis is the most labour intensive from an engineering [MSC/Circ. 1002: "fire safety engineering"] standpoint. It consists of quantifying the design casualty scenarios [MSC/Circ. 1002: "design fire scenarios"], developing the performance criteria, verifying the acceptability of the selected safety margins and evaluating the performance of trial alternative designs against the prescriptive performance criteria.*

6.1.2 *The quantification of the design casualty scenarios may include calculating the effects of casualty detection systems, alarm and mitigation methods, generating timelines from initiation of the casualty until control of the casualty or evacuation, and estimating consequences in terms of damage to the vessel, and the risk of harm to passengers and crew. This information should then be utilized to evaluate the trial alternative designs selected during the preliminary analysis.*

[corresponding paragraph in MSC/Circ. 1002: *"6.1.1 The quantification of the design fire scenarios may include calculating the effects of fire detection, alarm and suppression methods, generating time lines from initiation of the fire until control or evacuation, and estimating consequences in terms of fire growth rate, heat fluxes, heat release rates, flame heights, smoke and toxic gas generation, etc. This information should then be utilised to evaluate the trial alternative designs selected during the preliminary analysis."]*

6.1.3 *Risk assessment may play an important role in this process. It should be recognized that risk cannot ever be completely eliminated. Throughout the entire performance based design process, this fact should be kept in mind. The purpose of performance design is not to build a fail safe design, but to specify a design with reasonable confidence that it will perform its intended function(s) when necessary and in a manner equivalent to or better than the prescriptive requirements of SOLAS chapters II-1 and III.*

[corresponding paragraph in MSC/Circ. 1002: *"6.1.2 Risk assessment may play an important role in this process. It should be recognized that risk cannot ever be completely eliminated. Throughout the entire performance based design process, this fact should be kept in mind. The purpose of performance design is not to build the fail safe design, but to specify a design* *with reasonable confidence that it will perform its intended function(s) when necessary and in a manner equivalent to or better than the prescriptive fire safety requirements of SOLAS chapter II-2."]*

C6.1.3.1 In the approach that is recommended here, the quantitative analysis is based on risk assessment, supported by probabilistic engineering analyses of specific design aspects.

C6.1.3.2 In the context of a comparative analysis, the focus of the risk assessment is to investigate, for each casualty scenario, whether the general risk level determined for the alternative design is equal or lower than for the reference design. In the course of this assessment, for each scenario influencing factors and their contributions to the overall risk level of the scenario are investigated.

6.2 Quantification of Design Casualty Scenarios

6.2.1 *After choosing an appropriate range of incidents, quantification of the casualties should be carried out for each of the incidents. Quantification will require specification of all factors that may affect the type and extent of the hazard. The casualty scenarios should consider possible future changes to the affected systems and areas. [MSC/Circ. 1002: "The fire scenarios should consider possible future changes to the fire load and ventilation system in the affected areas."] This may include calculation of specific casualty parameters, ship damage, passenger exposure to harm, time-lines, etc. It should be noted that, when using any specific tools, the limitations and assumptions of these models should be well understood and documented. This becomes very important when deciding on and applying safety margins. Documentation of the alternative design should explicitly identify the models used in the analysis and their applicability. Reference to the literature alone should not be considered as adequate documentation. The general procedure for specifying design casualties includes casualty scenario development completed during the preliminary analysis, timeline analysis and consequence estimation which is detailed below.*

6.2.2 *For each of the identified hazards, a range of casualty scenarios should be developed. Because the alternative design approach is based on a comparison against the regulatory prescribed design, the quantification can often be simplified. In many cases, it may only be necessary to analyse one or two scenarios if this provides enough information to evaluate the level of safety of the alternative design and arrangements against the required prescriptive design.*

6.2.3 *A timeline should be developed for each of the casualty scenarios beginning with initiation. Timelines should include the entire chain of relevant events up to and including escape times (to assembly stations, evacuation stations and lifeboats, as appropriate). This timeline should include personnel response, activation of damage control systems or active damage control measures, untenable conditions, etc. The timeline should include a description of the extent of the casualty throughout the scenario, as determined by using the various correlations, models and data from the literature or actual tests.*

[In case of MSC/Circ. 1002: "6.2.3 A time-line should be developed for each of the fire scenarios beginning with fire initiation. Timelines should include one or more of the following: ignition, established burning, fire detection, fire alarm, fire suppression/control system activation, personnel response, fire control, escape times (to Assembly stations, evacuation stations and lifeboats as necessary), manual fire response, untenable conditions, etc. The timeline should include fire size throughout the scenario, as determined by using the various correlations, models and fire data from the literature or actual fire tests."]

6.2.4 *Consequences of various casualty scenarios should be quantified in relevant engineering terms. This can be accomplished by using existing correlations and calculation procedures for determining the characteristics of a casualty. In certain cases, full scale testing and experimentation may be necessary to properly predict the casualty characteristics.*

[In case of MSC/Circ. 1002: "6.2.4 Consequences of various fire scenarios should be quantified in fire engineering terms. This can be accomplished by using existing correlations and calculation procedures for determining fire characteristics such as heat release rate curves, flame height, length, tilt, radiant, conductive and convective heat fluxes, etc. In certain cases, live fire testing and experimentation may be necessary to properly predict the fire characteristics."]

Regardless of the calculation procedures utilized, a sensitivity analysis should be conducted to determine the effects of the uncertainties and limitations of the input parameters.

C6.2.5 For the quantification of casualty scenarios a two-step process that is based on risk assessment has proven suitable (see Fig. 6.1):

C6.2.5.1 Step 1:
Formal modelling of the process that underlies a casualty scenario. For instance, event trees (see Annex F) are a suitable modelling technique; which specify the sequence of events and possible deviations. Events in such a model represent system or operator actions, which may either be intended or unintended, as well as environmental effects.

C6.2.5.2 Step 2:
Determination of failure probability for each process step in the scenario (i.e. each event in the event tree). Depending on the level of detail of the event tree model as well as the available data, this step can be addressed in various ways:

– With respect to failures of components and systems, ideally failure data should be provided by supplier – it should be checked that any data that is used is statistically sound.

– For complex failures, and in case failure data cannot be provided by the supplier, events can be decomposed into basic failures (and possible combinations thereof) – for instance, by fault tree analysis (see Annex F) – to a level of detail where suitable calculations or expert judgements can be made for "basic events". At this stage, probabilistic analyses need to be performed to quantify the failure probabilities of basic events, as well as their contribution to the overall consequences. Techniques for the quantification of failure probabilities are manifold and depend on the application. Examples are illustrated in separate GL technical publications, see Annex F, 3.4.1.

– In cases where no data is available and probabilistic analyses cannot be performed, expert judgement may be applied to estimate event probabilities on experience – the justification for each judgement should be documented.

C6.2.6 The result of this process is a probability for completing a scenario successfully, as well as probabilities for casualty scenarios with various degrees of severity, which result from deviations in individual scenario steps. This process is performed for each scenario.

C6.2.7 Sensitivity analysis

6.2.7.1 In order to estimate the effect of uncertainty on the analysis results, it is recommended that by means of a sensitivity analysis the effect of changes in individual input parameters is determined that influence the results of a given model or calculation method. The risk analysis may contain some degree of uncertainty, for instance because it is performed at a design stage where little detail is available. In the modelling approach illustrated in Fig. 6.1 such uncertainty is particularly reflected in the assignment of success and failure probabilities to basic events in event trees and fault trees, respectively. In the sensitivity analysis those input parameters of the risk analysis are of particular interest for which values are determined by means of expert judgement.

6.3 Development of Performance Criteria

6.3.1 *Performance criteria are quantitative expressions of the intent of the requirements of the relevant SOLAS regulations. The required performance of the trial alternative designs are specified numerically in the form of performance criteria. Performance criteria may include tenability limits or other criteria necessary to ensure successful alternative design and arrangements.*

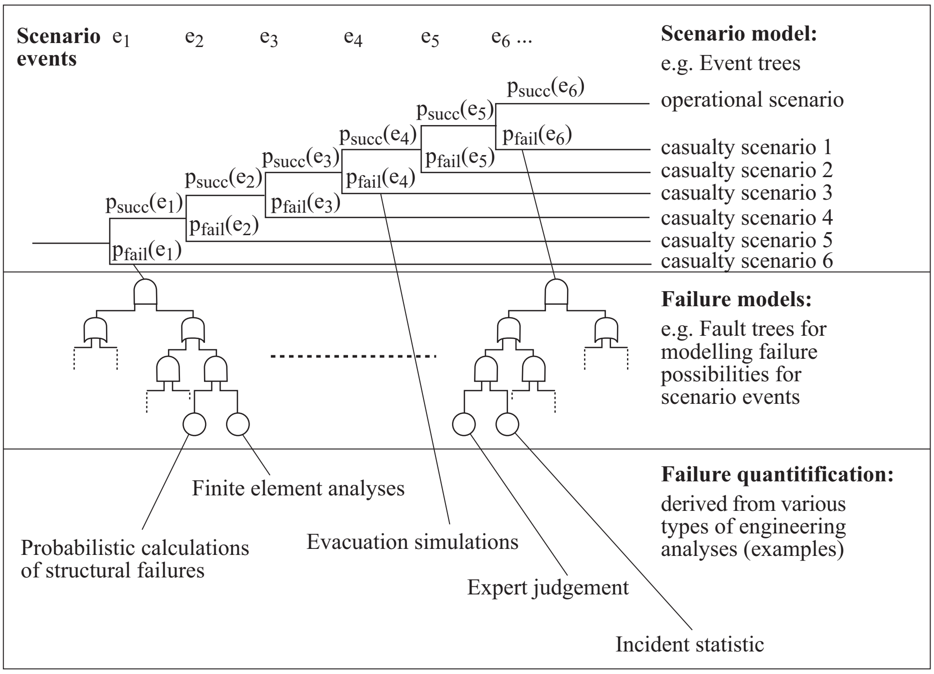


Fig. 6.1 Example illustrating possibilities of modelling and quantification of casualty scenarios

6.3.2 *[In case of MSC/Circ. 1002: "Each of the regulations in SOLAS chapter II-2 state the purpose of the regulation and the functional requirements that the regulation meets."] Compliance with the prescriptive regulations is one way to meet the stated functional requirements. The performance criteria for the alternative design and arrangements should be determined, taking into consideration the intent of the regulations.*

[In case of MSC/Circ.1002: "The performance criteria for the alternative design and arrangements should be determined, taking into consideration the fire safety objectives, the purpose statements and the functional requirements of the regulations. The following example is an illustration of this:

> *"Example of a performance criterion drawn directly from the regulations in SOLAS chapter II-2:*
> *Assume that a design team is developing performance criteria for preventing fire spread through a bulkhead separating a galley from an accommodation space. They are seeking a numerical form for this criteria.*
>
> *(e.1) Regulation II-2/2 contains the fire safety objective "to contain, control, and suppress fire and explosion in their compartment of origin."*
>
> *(e.2) One of the functional requirements in which this objective is manifest is "separation of accommodation spaces from the remainder of the ship by thermal and structural boundaries."*
>
> *(e.3) Regulation II-2/9 contains the prescriptive requirements to achieve this functional requirement; in particular it requires an "A-60" class boundary between areas of high fire risk (like a machinery space or galley) and accommodation spaces.*
>
> *(e.4) Regulation II-2/3 contains the definition of an "A" class division, which includes the maximum temperature rise criteria of 180 °C at any one point, after a 60 minute fire exposure.*
>
> *(e.5) Therefore, one possible performance criterion for this analysis is that "no point on the other side of the bulkhead shall rise more than 180°C above ambient temperature during a 60 minute fire exposure."]*

C6.3.2 Further examples for the elicitation of performance criteria are provided in GL Technical publications, see Annex F, 3.4.1.

6.3.3 *If the performance criteria for the alternative design and arrangements cannot be determined directly from the prescriptive regulations because of novel or unique features, they may be developed from an evaluation of the intended performance of a commonly used acceptable prescriptive design, provided that an equivalent level of safety is maintained.*

C6.3.3 In this context, the risk value that is determined for the reference design for a particular scenario represents an acceptance and performance criterion for the alternative design for that same scenario. This can be justified by the interpretation that the reference design is a SOLAS-compliant design and therefore implements an acceptable level of safety and an acceptable risk value. In order to apply this approach, the reference design and the alternative design(s) need to be analysed quantitatively with the same level of rigour and with due reference to the uncertainties.

6.3.4 *Before evaluating the prescriptive design, the design team should agree on what specific performance criteria and safety margins should be established. Depending on the prescriptive requirements to which the approval of alternative design or arrangements is sought, these performance criteria could fall within one or more of the following areas:*

.1 *Life safety criteria – These criteria address the survivability of passengers and crew and may represent the effects of flooding, fire, etc.*

.2 *Criteria for damage to ship structure and related systems – These criteria address the impact that casualty might have on the ship structure, mechanical systems, electrical systems, fire protection systems, evacuation systems, propulsion and manoeuvrability, etc. These criteria may represent physical effects of the casualty.*

.3 *Criteria for damage to the environment – These criteria address the impact of the casualty on the atmosphere and marine environment. [With respect to MSC/Circ. 1002: " These criteria may represent thermal effects, fire spread, smoke damage, fire barrier damage, degradation of structural integrity, etc."]*

6.3.5 *The design team should consider the impact that one particular performance criterion might have on other areas that might not be specifically part of the alternative design. For example, the failure of a particular safeguard may not only affect the life safety of passengers and crew in the adjacent space, but it may result in the failure of some system affecting the overall safety of the ship. [With respect to MSC/Circ. 1002: "For example, the failure of a fire barrier may not only affect the life safety of passengers and crew in the adjacent space, but it may result in structural failure, exposure of essential equipment to heat and smoke, and the involvement of additional fuel in the fire."]*

6.3.6 *Once all of the performance criteria have been established, the design team can then proceed with the evaluation of the trial alternative designs (see section 6.4).*

6.4 Evaluation of Trial Alternative Designs

6.4.1 *All of the data and information generated during the preliminary analysis and specification of design casualty should serve as input to the evaluation process. The evaluation process may differ depending on the level of evaluation necessary (based on the scope defined during the preliminary analysis), but should generally follow the process illustrated in Fig. 6.2 [figure 6.4.1 in MSC/Circ. 1002].*

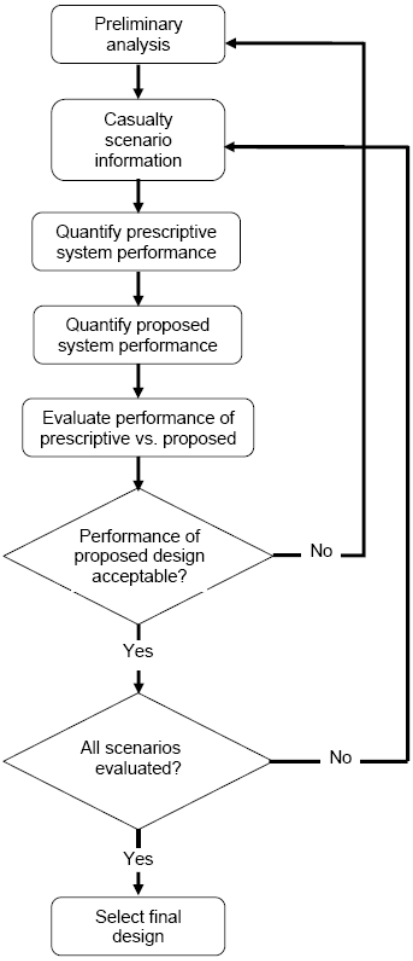


Fig. 6.2 Alternative design and arrangement process flowchart [1]

6.4.2 *Each selected trial alternative design should be analysed against the selected design casualty scenarios to demonstrate that it meets the performance criteria with the agreed safety margin, which in turn demonstrates equivalence to the prescriptive design.*

6.4.3 *The level of engineering rigor required in any particular analysis will depend on the level of analysis required to demonstrate equivalency of the proposed alternative design and arrangements to the prescriptive requirements. Obviously, the more components, systems, operations and parts of the ship that are affected by a particular alternative design, the larger the scope of the analysis.*

6.4.4 *The final alternative design and arrangements should be selected from the trial alternative designs that meet the selected performance criteria and safety margins.*

C6.4.5 The process of the alternative design and arrangements process as depicted in the IMO guidelines is shown in Fig. 6.2. This process is inherent to the alternative design and approval process in Fig. 3.1.

C6.5 Documentation of Quantitative Analysis

C6.5.1 On completion of the quantitative analysis the Administration should be in a position to decide:

– If hazards that were identified in the course of the preliminary analysis were addressed in sufficient detail, and if the investigated scenarios cover a sufficient part of the design.

– If the analyses of the reference design and the alternative design were performed with a comparable level of rigor.

– If the analyses were performed by a design team that has a satisfactory level of expertise and with state-of-the-art analysis methods.

– If assumptions that were made in the course of the analysis are feasible, judged from the present state of the art.

– How these assumptions should be addressed in the course of the building, commissioning and operation of the vessel in order to achieve a required and acceptable level of safety.

C6.5.2 In order to be able to reach these decisions, at least the following information should be provided to the Administration:

– Documentation of quantitative analyses of the alternative design and the reference design. In addition to descriptions of the applied analysis methods and findings of the analysis, the documentation should also state where the hazards are addressed that were identified in the preliminary analysis. Further, the experience of the design team should be documented.

– A summary of findings from the complete analysis process.

– A list of all assumptions that were made in the course of the qualitative and quantitative analysis, including proposals of how to address these assumptions in the design and operation of the vessel.

C6.5.3 Further information may be requested by the Administration in the individual case.

[1] Source: MSC.1/Circ. 1212 – The process in (MSC/Circ. 1002) is analogously but step "Casualty scenario information" is termed "Fire scenario information".

Section 7

Documentation

C7.0 Introductory comments

C7.0.1 At each stage of the analysis process the design team should provide different types of documentation to the Administration; in particular:

– Documentation of preliminary design: prior to analysis (see C3.4.3).

– Documentation of refined design and preliminary analysis: on completion of preliminary analysis in qualitative terms (see Section 5).

– Documentation of specific design and quantitative analysis: on completion of the quantitative risk assessment (see Section 6).

– Ship documents: after approval by the Administration.

Details depend on the system in scope of the application of this guideline.

C7.0.2 Specifics on documentation for alternative design and arrangements for fire safety and lifeboats are outlined in GL technical publications, see Annex 7, 3.4.1 and 3.4.2. It is recommended that the extent of the documentation should be agreed with the Administration.

C7.0.3 All required drawings, documents, calculations and supporting documentation are to be submitted in English language.

7.1 Because the alternative design process may involve substantial deviation from the regulatory prescribed requirements, the process should be thoroughly documented. This provides a record that will be required if future design changes to the ship are proposed or the ship transfers to the flag of another State and will also provide details and information that may be adapted for use in future designs. The following information should be provided for approval of the alternative design or arrangements:

.1 scope of the analysis or design;

.2 description of the alternative design(s) or arrangements(s), including drawings and specifications;

.3 results of the preliminary analysis, to include:

.3.1 members of the design team (including qualifications);

.3.2 description of the trial alternative design and arrangements being evaluated;

.3.3 discussion of affected SOLAS regulations and their requirements;

.3.4 hazard identification;

.3.5 enumeration of hazards;

.3.6 selection of hazards; and

.3.7 description of design casualty scenarios;

.4 results of quantitative analysis:

.4.1 design casualty scenarios:

.4.1.1 critical assumptions;

.4.1.2 initial conditions [in case of MSC/Circ. 1002: "amount and composition of fire load"]

.4.1.3 engineering judgements;

.4.1.4 calculation procedures;

.4.1.5 test data;

.4.1.6 sensitivity analysis; and

.4.1.7 timelines;

.4.2 performance criteria;

.4.3 evaluation of trial alternative designs against performance criteria;

.4.4 description of final alternative design and arrangements;

.4.5 test, inspection and maintenance requirements; and

.4.6 references.

C7.1 GL reserves the right to demand further documents where these submitted are not adequate to provide an evaluation of the system.

7.2 Documentation of approval by the Administration and the following information should be maintained onboard the ship at all times:

.1 scope of the analysis or design, including the critical design assumptions and critical design features;

.2 description of the alternative design and arrangements, including drawings and specifications;

.3 *listing of affected SOLAS regulations;*

.4 *summary of the results of the engineering analysis and basis for approval; and*

.5 *test, inspection and maintenance requirements.*

C7.2.1 This documentation shall also contain an operations manual listing any requirement which may need to be implemented during ship operations as a consequence of the introduction of the alternative design and arrangement. Such requirements may arise as a result of the analysis of the alternative design, or in order to demonstrate that assumptions hold that were made in the course of the analysis. For instance, such operational requirements may include particular operations that may need to be carried out regularly or additional pieces of equipment to be carried on board – such as: “additional training of use of novel equipment required for new crew members”, “more frequent maintenance required”, “performance and documentation of regular checks of system conditions”.

C7.2.2 A copy of the documentation, as approved by the Administration, indicating that the alternative design and arrangements comply with the respective SOLAS regulation (for fire safety SOLAS II-2 Reg. 17, for machinery and Electrical Installations SOLAS II-1 Reg. 55 and for life-saving appliances and arrangements SOLAS III Reg. 38), should be maintained on board the ship at all times (cf. 7.2).

C7.2.3 The purpose of the ship documents is:

– To demonstrate that the alternative design has been thoroughly analysed and was approved by the Administration.

– To document the design areas that affected by risk-based design and any operational requirements that arise as consequences thereof.

– To make it possible for port state control and classification societies to monitor that the test, inspection and maintenance requirements that were assigned by the Administration, classification society, and system suppliers are adhered to during operations.

– To indicate the extent of risk-based design features that may need to be considered in the case of a change of flag.

7.3 Reporting and Approval Forms

7.3.1 *When the Administration approves alternative design and arrangements under these [IMO] guidelines, pertinent technical information about the approval should be summarized on the reporting form given in appendixes 1 or 2 [of MSC.1/Circ. 1212; and appendix A of MSC/Circ. 1002, respectively, reproduced in Annexes D and E of these Guidelines, respectively], as appropriate, and should be submitted to the Organization for circulation to the Member Governments.*

7.3.2 *When the Administration approves alternative design and arrangements under these [IMO] guidelines, documentation should be provided as indicated in appendixes 3 or 4 [for MSC.1/Circ. 1212, and appendix B for MSC/Circ. 1002], as appropriate. The documentation should be in the language or languages required by the Administration. If the language is neither English, French or Spanish, a translation into one of those languages should be included.*[1]

[1] Note that Germanischer Lloyd requires that all documents are submitted in English language, see C7.0.3.

Annex A

SOLAS I, Regulation 5

Equivalents

(a) Where the present regulations require that a particular fitting, material, appliance or apparatus, or type thereof, shall be fitted or carried in a ship, or that any particular provision shall be made, the Administration may allow any other fitting, material, appliance or apparatus, or type thereof, to be fitted or carried, or any other provision to be made in that ship, if it is satisfied by trial thereof or otherwise that such fitting, material, appliance or apparatus, or type thereof, or provision, is at least as effective as that required by the present regulations.

(b) Any Administration which so allows, in substitution, a fitting, material, appliance or apparatus, or type thereof, or provision, shall communicate to the Organization particulars thereof together with a report on any trials made and the Organization shall circulate such particulars to other Contracting Governments for the information of their officers.

Annex B

SOLAS II-2, Regulation 17

Regulation 17

Alternative design and arrangements

1. Purpose

The purpose of this regulation is to provide a methodology for alternative design and arrangements for fire safety.

2. General

2.1 *Fire safety design and arrangements may deviate from the prescriptive requirements set out in parts B, C, D, E or G, provided that the design and arrangements meet the fire safety objectives and the functional requirements.*

2.2 *When fire safety design or arrangements deviate from the prescriptive requirements of this chapter, engineering analysis, evaluation and approval of the alternative design and arrangements shall be carried out in accordance with this regulation.*

3. Engineering analysis

The engineering analysis shall be prepared and submitted to the Administration, based on the [IMO] guidelines developed by the Organization [1]*, and shall include, as a minimum, the following elements:*

.1 *determination of the ship type and space(s) concerned;*

.2 *identification of prescriptive requirement(s) with which the ship or the space(s) will not comply;*

.3 *identification of the fire and explosion hazards of the ship or the space(s) concerned, including:*

- ***.3.1*** *identification of the possible ignition sources;*
- ***.3.2*** *identification of the fire growth potential of each space concerned;*
- ***.3.3*** *identification of the smoke and toxic effluent generation potential for each space concerned;*
- ***.3.4*** *identification of the potential for the spread of fire, smoke or of toxic effluents from the space(s) concerned to other spaces;*

.4 *determination of the required fire safety performance criteria for the ships or the space(s) concerned addressed by the prescriptive requirement(s), in particular:*

- ***.4.1*** *performance criteria shall be based on the fire safety objectives and on the functional requirements of this chapter;*
- ***.4.2*** *performance criteria shall provide a degree of safety not less than that achieved by using the prescriptive requirements; and*
- ***.4.3*** *performance criteria shall be quantifiable and measurable;*

.5 *detailed description of the alternative design and arrangements, including a list of the assumptions used in the design and any proposed operational restrictions or conditions; and*

.6 *technical justification demonstrating that the alternative design and arrangements meet the required fire safety performance criteria.*

4. Evaluation of the alternative design and arrangements

- ***.4.1*** *The engineering analysis required in paragraph 3 shall be evaluated and approved by the Administration, taking into account the [IMO] guidelines developed by the Organization* [1]*.*
- ***.4.2*** *A copy of the documentation, as approved by the Administration, indicating that the alternative design and arrangements comply with this regulation shall be carried on board the ship.*

5. Exchange of information

The Administration shall communicate to the Organization pertinent information concerning alternative design and arrangements approved by them for circulation to all Contracting Governments.

6. Re-evaluation due to change of conditions

If the assumptions, and operational restrictions that were stipulated in the alternative design and arrangements are changed, the engineering analysis shall be carried out under the changed condition and shall be approved by the Administration.

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[1] Refer to the Guidelines on alternative design and arrangements for fire safety (MSC/Circ.1002).

Annex C

Definitions

In addition to the key definitions in Section 2 in these Guidelines the following definitions apply, which predominantly are based on IACS FSA glossary [1].

1. Accident

An unintended event involving fatality, injury, ship loss or damage, other property loss, damage or environmental damage.

2. Availability

Availability of a system or equipment is the probability that it is not in a failed state at a point in time.

3. Casualty

Serious or fatal accident.

4. Consequence

The outcome of an accident, there may be different possible consequences, e.g. human fatalities (or injuries), environmental pollution, loss / damage to property.

5. Design

All relevant plans, documents and calculations describing the performance, installation and manufacturing of a product.

6. Error

A departure from acceptable or desirable operation (for example of a component or system) that can result in unacceptable or undesirable consequence.

7. Event Tree Analysis (ETA)

A method of exploring the development or escalation of an accident, a failure or an unwanted event using a diagram which, commencing with the initiating event, branches at each point of influence of a controlling or mitigating measure until the final outcomes are identified. The probability (or frequency) of success of these measures is indicated allowing for the evaluation of the likelihood of each consequence. (For further details see Annex F.)

8. Failure

An occurrence in which a part, or parts of a system ceases to perform the required function.

9. Failure Mode & Effect Analysis (FMEA)

A process for hazard identification where all conceivable failure modes of components or features of a system are considered in turn and undesired outcomes are noted.

10. Failure Mode Effect and Criticality Analysis (FMECA)

An FMEA where additionally the criticality of a failure mode or failure cause is assessed by estimating the severity, probability and detectability of the failure. Severity and probability are each expressed as ranking indices. A proposal for assigning severity and frequency indices can be found in MSC83/INF.2. (For further details see Annex F.)

11. Failure Probability

Probability of occurrence of a specific failure, specified as value in the open interval between 0 and 1.

12. Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA) is a logic diagram showing the causal relationships between events, which singly or in combination result in the occurrence of a higher-level event. It is used to determine the frequency of a “top event” which may be a type of accident or an unintended hazardous outcome. (For further details see Annex F.)

13. Frequency

The number of occurrences per unit time (e.g. per year).

14. Function

An aspect of the intended purpose/task of a system.

15. Hazard

A potential to threaten human life, health, property or the environment, e.g.

– Hazards external to the ship: storms, lightning, poor visibility, uncharted submerged objects, other ships, war, sabotage etc.

[1] http://www.iacs.org.uk

- Hazards on board a ship:
  - In accommodation areas: combustible furnishings, cleaning material in stores, oil/fat in galley equipment etc.
  - In deck areas: cargo, slippery deck due to paint / oils / grease / water, hatch covers, electrical connections etc.
  - In machinery spaces: cabling, fuel & diesel oil for engines, boilers, fuel oil piping & valves, oily bilge, toxic gases, explosive gases, refrigerants etc.
  - Sources of ignition: naked flame, electrical appliances, hot surface, sparks from hot work or funnel exhaust, deck & engine room machinery.
- Operational hazards to personnel: Long working hours, life boat drill, working on deck at sea, cargo operation, tank surveys, on-board repairs, etc.

16. Hazard and Operability Study (HAZOP)

A study performed by application of guidewords to identify the deviations from the intended functions of a system which have undesirable causes and effects for safety and operability. (For further details see Annex F.)

17. Hazardous situation

A situation with a potential to threaten human life, health, property or the environment.

18. Human Factor

The discipline concerned with the design & operation of technological and organizational systems to achieve proper adaptation of human tasks (F.P. Lees, "*Loss Prevention in the Process Industries*", Vol. 1, Chapter 14, 14/5). Human Factors are dealt with through ergonomic principles.

19. Human Reliability

The probability that a person (a) correctly performs some system related activity within the specific time period and (b) does not perform any extraneous activity that can degrade the system

20. Human Reliability Analysis (HRA)

A process comprising a set of activities as well as the potential use of a number of techniques to derive the human error probabilities (HEPs) so as to incorporate them into a qualified or quantified system model e.g. a fault tree or an event tree.

21. Incident

An unforeseen or unexpected event which may have the potential to become an accident but in which injury to personnel and/or damage to ship or to the environment does not materialize or remained minor.

22. Individual Risk

Risk as experienced by an individual e.g. onboard a ship (crew or passenger or belonging to third parties that could be affected by a ship accident).

23. Initiating event

The first of a sequence of events leading to a hazardous situation or accident.

24. Life-saving appliance (LSA)

Any device, arrangement or apparatus intended to sustain the lives of people in distress, or to signal their distress, or to alert people on board a ship to an emergency (for instance, lifebuoys, lifejackets, survival craft, rescue boats, evacuation systems, line-throwing appliances, and general alarm and public address systems).

25. Process Hazard Analysis (PHA)

A process hazard analysis (PHA) is a systematic effort to identify and analyse the significance of potential hazards associates with the processing or handling of highly hazardous chemicals. It provides requirements for analysis and the methods (such as HAZOP, FME(C)A and What-If analysis), report contents, team composition, and analysis follow-up. (For further details see Annex F.)

26. Reliability

Reliability is a probability of desired performance over time in a specified condition e.g. machinery or system reliability, structural reliability, human reliability.

Reliability = 1 - Failure Probability

27. Risk

Risk is a measure of the likelihood that an undesirable event will occur together with a measure of the resulting consequence within a specified time i.e. the combination of the frequency and the severity of the consequence. (This can be either a quantitative or qualitative measure.)

28. Risk Acceptance Criteria

Standards, which represent a value-judgment opinion, usually that of a regulation, of how much risk is tolerable. These values are determined by risk evaluation criteria agreed with the Administration, and are used as limits for risk acceptance. For examples of risk acceptance criteria [2], see MSC 83/INF.2.

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2 In FSA guidelines these acceptance criteria are termed "risk evaluation criteria".

29. Risk Assessment

An integrated array of analytical techniques, e.g. reliability, availability & maintainability engineering, statistics, decision theory, systems engineering, human behaviour etc. that can successfully integrate diverse aspects of design and operation in order to assess risk.

30. Risk-Based Design

Risk-Based Design (RBD) is a design, where the design process has been supported by a risk assessment or the design basis has resulted from a risk assessment. That is, it is a structured and systematic methodology, aimed at ensuring safety performance and cost effectiveness, by using risk analysis and cost-benefit assessment.

31. Risk Control Measure (RCM)

A means of controlling a single element or risk; typically, risk control is achieved by reducing either the consequences or the frequencies; sometimes it could be a combination of the two.

32. Risk Control Option (RCO)

An appropriate combination of risk control measures RCMs

33. Risk Evaluation Criteria

A set of agreed criteria to be used to assess the level of risk that is associated with a hazard. Examples include criteria for evaluating the individual risk (minor or severe injuries, fatalities), as well as the societal risk.

34. Safety

Absence of unacceptable levels of risk to life, limb and health (from unwillful acts).

35. Safety Function

A function to be implemented by a safety-related system which is intended to achieve or maintain a safe state for the equipment with respect to a specific hazard.

36. Security

Absence of risk to life, health, property and environment from wilful acts of individual(s).

37. Societal Risk

Average risk, in terms of fatalities, of groups of people (e.g., port employees, crew or even society at large) exposed to an accident scenario (see individual risk) usually presented in form of F-N Curve (see above definition).

38. Task Analysis (TA)

A collection of techniques used to compare the demands of a system with the capabilities of the operator, usually with a view to improving performance, e.g. by reducing errors.

39. Technique for Human Error Rate Prediction (THERP)

A comprehensive methodology covering task analysis, human error identification, human error modelling and human error quantification. It is best known for its human error quantification aspects through its human error probability (HEP) data tables and data quantifying the effects of various performance shaping factors (Puffs) that influence human errors at the operator level. (For further details see Annex F.)

40. What-if Analysis

An approach in which a group of experts identify hazards and their consequences, safeguards and possible risk reduction measures related to a function or system based on answering questions that begin with "What if...". (For further details see Annex F.)

Annex D

Report Templates from MSC/Circ. 1002

REPORT ON THE APPROVAL OF ALTERNATIVE DESIGN ARRANGEMENTS FOR FIRE SAFETY

The Gouvernment of ………………………. has approved on ………………………. an alternative design and arrangement in accordance with provisions of regulation II-2/17.5 of the International Convention for Safety of Life at Sea (SOLAS), 1974, as amended, as described below:

Name of ship	…………………………………………………………….
Port of registry	…………………………………………………………….
Ship type	…………………………………………………………….
IMO Number	…………………………………………………………….

1. Scope of the analysis or design, including the critical design assumptions and critical design features:

2. Description of the alternative design and arrangements:

3. Conditions of approval, if any:

4. Listing of affected SOLAS chapter II-2 regulations:

5. Summary of the result of the engineering analysis and basis for approval, including performance criteria and design fire scenarios:

6. Test, inspection and maintenance requirements:

DOCUMENT OF APPROVAL OF ALTERNATIVE DESIGN AND ARRANGEMENTS FOR FIRE SAFETY

Issued in accordance with provisions of regulations II-2/17.4 of the International Convention for Safety of Life at Sea (SOLAS), 1974, as amended, under the authority of the Gouvernment of

……………………..…………………. by …………………………..…………….
(Name of State) (Person or organization authorized)

Name of ship ……………………………………………………………….

Port of registry ……………………………………………………………….

Ship type ……………………………………………………………….

IMO Number ……………………………………………………………….

THIS IS TO CERTIFY that the following alternative design and arrangements applied to the above ship have been approved under the provisions of SOLAS regulation II-2/17.

1. **Scope of the analysis or design, including the critical design assumptions and critical design features:**
2. **Description of the alternative design and arrangements:**
3. **Conditions of approval, if any:**
4. **Listing of affected SOLAS chapter II-2 regulations:**
5. **Summary of the result of the engineering analysis and basis for approval, including performance criteria and design fire scenarios:**
6. **Test, inspection and maintenance requirements:**
7. **Drawings and specifications of the alternative design and arrangement:**

Issued at ……………………. on …………………………

…………………………………………..
(Signature of authorized official
issuing the certificate)

Annex E

Report Templates from MSC.1/Circ. 1212

REPORT ON THE APPROVAL OF ALTERNATIVE DESIGN AND ARRANGEMENTS FOR MACHINERY AND ELECTRICAL INSTALLATIONS

The Gouvernment of ………………………. has approved on ………………………. an alternative design and arrangement in accordance with provisions of regulations II-1/55 of the International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended, as described below:

Name of ship	……………………………………………………….
Port of registry	……………………………………………………….
Ship type	……………………………………………………….
IMO Number	……………………………………………………….

1. **Scope of the analysis or design, including the critical design assumptions and critical design features:**
2. **Description of the alternative design and arrangements:**
3. **Conditions of approval, if any:**
4. **Listing of affected SOLAS chapter II-1 regulations in part C, D and E:**
5. **Summary of the result of the engineering analysis and basis for approval, including performance criteria and design casualty scenarios:**
6. **Test, inspection and maintenance requirements:**

REPORT ON THE APPROVAL OF ALTERNATIVE DESIGN AND ARRANGEMENTS FOR LIFE-SAVING APPLIANCES AND ARRANGEMENTS

The Gouvernment of ………………………. has approved on ………………………. an alternative design and arrangement in accordance with provisions of regulation III/38 of the International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended, as described below:

Name of ship ……………………………………………………………

Port of registry ……………………………………………………………

Ship type ……………………………………………………………

IMO Number ……………………………………………………………

1. **Scope of the analysis or design, including the critical design assumptions and critical design features:**

2. **Description of the alternative design and arrangements:**

3. **Conditions of approval, if any:**

4. **Listing of affected SOLAS chapter III regulations:**

5. **Summary of the result of the engineering analysis and basis for approval, including performance criteria and design casualty scenarios:**

6. **Test, inspection and maintenance requirements:**

DOCUMENT OF APPROVAL OF ALTERNATIVE DESIGN AND ARRANGEMENTS FOR MACHINERY AND ELECTRICAL INSTALLATIONS

Issued in accordance with provisions of regulations II-1/55.4 of the International Convention for Safety of Life at Sea (SOLAS), 1974, as amended, under the authority of the Gouvernment of

……………………..…………………. by …………………………..…………….
(Name of State) (Person or organization authorized)

Name of ship ……………………………………………………………….

Port of registry ……………………………………………………………….

Ship type ……………………………………………………………….

IMO Number ……………………………………………………………….

THIS IS TO CERTIFY that the following alternative design and arrangements applied to the above ship have been approved under the provisions of SOLAS regulation II-1/55:

1. **Scope of the analysis or design, including the critical design assumptions and critical design features:**
2. **Description of the alternative design and arrangements:**
3. **Conditions of approval, if any:**
4. **Listing of affected SOLAS chapter II-1 regulations:**
5. **Summary of the result of the engineering analysis and basis for approval, including performance criteria and design casualty scenarios:**
6. **Test, inspection and maintenance requirements:**
7. **Drawings and specifications of the alternative design and arrangement:**

Issued at ……………………. on …………………………

…………………………………………..
(Signature of authorized official
issuing the certificate)

(Seal or stamp of issuing authority, as appropriate)

DOCUMENT OF APPROVAL ALTERNATIVE DESIGN AND ARRANGEMENTS FOR LIFE-SAVING APPLIANCES AND ARRANGEMENTS

Issued in accordance with provisions of regulations III/38.4 of the International Convention for Safety of Life at Sea (SOLAS), 1974, as amended, under the authority of the Gouvernment of

…………………..…………………. by ………………………..…………….
(Name of State) (Person or organization authorized)

Name of ship ……………………………………………………………….

Port of registry ……………………………………………………………….

Ship type ……………………………………………………………….

IMO Number ……………………………………………………………….

THIS IS TO CERTIFY that the following alternative design and arrangements applied to the above ship have been approved under the provisions of SOLAS regulation II-1/55:

1. **Scope of the analysis or design, including the critical design assumptions and critical design features:**
2. **Description of the alternative design and arrangements:**
3. **Conditions of approval, if any:**
4. **Listing of affected SOLAS chapter III regulations:**
5. **Summary of the result of the engineering analysis and basis for approval, including performance criteria and design casualty scenarios:**
6. **Test, inspection and maintenance requirements:**
7. **Drawings and specifications of the alternative design and arrangement:**

Issued at ……………………. on …………………………

…………………………………………..
(Signature of authorized official
issuing the certificate)

(Seal or stamp of issuing authority, as appropriate)

Annex F

Technical References and Resources

1. Technical References and Resources from MSC/Circ. 1002

[Appendix C of MSC/Circ. 1002]

.1 Section 3 of the [IMO] guidelines states that the fire safety engineering approach should be "based on sound fire science and engineering practice incorporating widely accepted methods, empirical data, calculations, correlations and computer models as contained in engineering textbooks and technical literature." There are literally thousands of technical resources that may be of use in a particular fire safety design. Therefore, it is very important that fire safety engineers and other members of the design team determine the acceptability of the sources and methodologies used for the particular applications in which they are used.

.2 When determining the validity of the resources used, it is helpful to know the process through which the document was developed, reviewed and validated. For example, many codes and standards are developed under an open consensus process conducted by recognised professional societies, codes making organisations or governmental bodies. Other technical references are subject to a peer review process, such as many of the technical and engineering journals available. Also, engineering handbooks and textbooks provide widely recognised and technically solid information and calculation methods.

.3 Additional guidance on selection of technical references and resources, along with lists of subject-specific literature, can be found in:

.1 The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings, Society of Fire Protection Engineers and National Fire Protection Association, 1999.

.2 ISO/TR 13387-1 through 13387-8, "Fire safety engineering", International Standards Organization, 1999.

.4 Other important references include:

.1 SFPE Handbook of Fire Protection Engineering, 2nd Edition, P. J. DiNenno, ed., The Society of Fire Protection Engineers, Boston, MA, 1995.

.2 Fire Protection Handbook, 18th Edition, A. E. Cote, ed., National Fire Protection Association, Quincy, MA, 1997.

.3 Custer, R.L.P., and Meacham, B.J., Introduction to Performance-Based Fire Safety, Society of Fire Protection Engineers, USA, 1997.

.4 NFPA 550, Guide to the Use of the Fire Safety Concepts Tree, National Fire Protection Association, 1995.

2. Characterisation of selected methods for hazard identification and risk analysis

Name of method	Event Tree Analysis (ETA)
Summary	Event Tree Analysis is a method for exploring the development or escalation of a scenario that starts from some initiating event, such as an accident, a failure or an unwanted event. Commencing with the initiating event, branches are introduced at each point of influence of a controlling or mitigating measure until the final outcomes are identified. This inductive approach is often visualised by a tree structure where the initiating event forms the root of the tree and the final outcomes form the leaves. The probability (or frequency) of success of these measures is indicated allowing for the evaluation of the likelihood of each consequence.
Useful for stage …	Quantitative analysis: Modelling of operational and casualty scenarios
References	Kristiansen, S.: *"Maritime Transportation- Safety Management and Risk Analysis"*, Elsevier Butterworth-Heinemann, 2005. Stephans R, Talso W. *System Safety Analysis Handbook*, System Safety Society, 1998.

Name of method	Failure Mode Effects (and Criticality) Analysis – FME(C)A
Summary	FMECA is a method in which a group of analysts identifies and evaluates the impact of potential failures in products or processes. The initial step of the analysis process is to define the boundaries of the system or process to be analysed as well as the tasks it shall perform. Then possible failures of each task – either due to component failure or due to processing failure, including human error – are identified. For each listed failure, the frequency, consequences and possibilities of detection are assessed by means of semi-quantitative scales defined by some selected criteria. From these criteria a risk index (i.e. the sum of the frequency and consequence indices) or risk priority number (i.e. the product of frequency, consequence and detection indices) is calculated. The risk index or risk priority number is used to rank all potential failures with the ultimate aim to decide which hazards have to be taken into consideration for the quantitative analysis upon actions leading to reduce the risk. The technique may be used to evaluate risk management priorities for mitigating known threat-vulnerabilities. FMECA helps in selecting remedial actions that reduce cumulative impacts of life-cycle risks from a system failure. In this method connections between causes and consequences are recorded in a standard format.
Useful for stage …	Qualitative analysis: Hazard identification and hazard evaluation (frequency, consequence)
References	US Department of Defense (1984): Procedures for Performing a Failure Mode Effects and Criticality Analysis (Mil-Std-1629A), Washington DC British Standards Institute (1988): BS 5760 Reliability, Availability, Maintainability and Failure Modes and Effects Analysis CEI/IEC International Standard (1998): IEC 61508 – Functional Safety of Electrical/ Electronic/ Programmable Systems, IEC Publications

Name of method	Fault Tree Analysis
Summary	In Fault Tree Analysis (FTA) the causal relationships between events are specified logically. This specification can be visualised in a tree structure. The root of the tree contains the “top event”, which may be a type of accident or an unintended hazardous outcome. In search of its causes each event is decomposed into its immediate predecessors, that is, a single event or a combination of events which result in the occurrence of a higher-level event. This deductive search can be repeated for each of the identified causal events until a root cause or some initiating “basic” event is determined on a predefined level of detail. Apart from identifying and specifying the causal relationships, Fault Tree Analysis can be applied quantitatively by assigning probabilities (or frequencies) to the “basic” events and calculating the probability (or frequency) of a “top event” by utilising the fact that each fault tree can be defined by Boolean logic formula.
Useful for stage …	Quantitative analysis: Decomposition of events/complex failures
References	NUREG-0492 “Fault Tree Handbook”, U.S. Nuclear Regulatory Commission, 1981. Stephans R, Talso W. *System Safety Analysis Handbook*, System Safety Society, 1998.

Name of method	Hazard and Operability Study (HAZOP)
Summary	HAZOP is a detailed evaluation of components within a system to determine what would happen if that component were to operate outside its normal design mode. Each component will have one or more parameters associated with its operation. The HAZOP study is performed by a team of experts who investigate each parameter sequentially. A set of pre-defined guidewords is used to identify possible deviations from intended behaviour which have undesirable causes and effects for safety and operability. The effects of such behaviour are then assessed and recorded in standardised forms.
Useful for stage …	Qualitative analysis: Hazard identification
References	Kristiansen, S.: *"Maritime Transportation- Safety Management and Risk Analysis"*, Elsevier Butterworth-Heinemann, 2005. Stephans R, Talso W. *System Safety Analysis Handbook*, System Safety Society, 1998.

Name of method	Process Hazard Analysis (PHA)
Summary	A process hazard analysis (PHA) is a systematic effort to identify and analyse the significance of potential hazards associated with the processing or handling of highly hazardous chemicals. It provides requirements for analysis and the methods (such as HAZOP, FMECA and What-If analysis), report contents, team composition, and analysis follow-up.
Useful for stage …	Qualitative analysis: Hazard identification
References	Stephans R, Talso W. *System Safety Analysis Handbook*, System Safety Society, 1998.

Name of method	Technique for Human Error Rate Prediction (THERP)
Summary	The purpose of the THERP technique is to provide a quantitative measure of human operator error in a process. The method is a means of quantitatively estimating the probability of an accident being caused by a procedural error. The steps for the analysis of an operation are as follows: 1. The proposed procedure for the operation is prepared 2. Each procedure is broken down into the simplest task possible 3. Each task is broken down further into basic actions (e.g. manual actions such as opening a valve, visual actions such as observing a gauge etc.) 4. Each action is assigned a probability of success (reliability). Where alternatives (or deviations) of an action are possible, suitable assignment of values is possible. 5. The probability of successful accomplishment of each task is obtained by multiplying the probabilities for each action. 6. The probability of successful accomplishment of each procedure is obtained by multiplying the probabilities for each task. Depending upon analyst and the analysis review process, this method can be very detailed and provide provide discrete quantitative results.
Useful for stage …	Qualitative analysis: Hazard identification Quantitative Analysis
References	Swain A.D. and Guttman, H.E., "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications" NUREG/CR-1278, Sandia National Laboratories, Albuquerque, NM, August 1983.

Name of method	What-If analysis
Summary	The WHAT-IF analysis technique is a brainstorming approach in which a group of experienced individuals familiar with a process ask questions or voice concerns about possible undesired events in the process. The analysis concept encourages a team of analysts to debate "What-if" questions. The analysis team reviews deviations from a given process, with the focus of review ranging from individual steps to the final result. At each step "what if" questions are placed, dealing with procedural errors or hardware failures. Through this questioning process, an experienced group of individuals identify possible accident situations, their consequences, and existing safeguards; in a further step alternatives for risk reduction are proposed. The potential accidents that are identified are neither ranked nor assigned quantitative implications. Application of this technique usually results in a tabular listing of hazardous situations, their consequences, safeguards and possible options for risk reduction.
Useful for stage …	Qualitative analysis: Hazard identification
References	Stephans R, Talso W. *System Safety Analysis Handbook*, System Safety Society, 1998.

3. References

.1 IMO regulations on alternative design

.1 MSC.99(73) "Adoption of Amendments to the International Convention for the Safety of Life at Sea, 1974, as amended", December 2000.

.2 MSC/Circ.1002, "IMO Guidelines on Alternative Design and Arrangements for Fire Safety", June 2001, and

MSC.1/Circ.1002/Corr.1, "Corrigendum to IMO Guidelines on Alternative Design and Arrangements for Fire Safety", October 2005.

.3 MSC.216(82) "Adoption of Amendments to the International Life-Saving Appliance (LSA) Code", December 2006.

.4 MSC.1/Circ 1212, "IMO Guidelines on Alternative Design and Arrangements for SOLAS Chapters II-1 and III", December 2006.

.2 IMO documents related to risk assessment

.1 MSC 83/INF.2 "FORMAL SAFETY ASSESSMENT, Consolidated text of the Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process (MSC/Circ.1023 −MEPC/Circ.392)", note by the Secretariat, May 2007.

.2 Examples of recent applications of risk assessment in the context of Formal Safety Assessment for various ship types:

NAV 51/10, "FSA - Large Passenger Ships - Navigation Safety", 2005.

MSC 83/21/1, "FSA − Liquefied Natural Gas (LNG) carriers", July 2007.

MSC 83/INF.3, "FSA − Liquefied Natural Gas (LNG) Carriers; Details of the Formal Safety Assessment", July 2007.

MSC 83/21/2, "FSA – Container vessel", July 2007.

MSC 83/INF.8, "FSA – Container vessels, Details of the Formal Safety Assessment", July 2007.

MEPC 85/17/2, "FSA – Crude oil tankers", July 2008.

MEPC 85/INF.2, "FSA – Crude oil tankers, Details of the Formal Safety Assessment", July 2008.

MSC 85/17/1, "FSA – Cruise ships", July 2008.

MSC 85/INF.2, "FSA – Cruise ships, Details of the Formal Safety Assessment", July 2008.

MSC 85/17/2, "FSA – RoPax ships", July 2008.

MSC 85/INF.3, "FSA – RoPax ships, Details of the Formal Safety Assessment", July 2008.

.3 Recommended reading on the general topic of technical risk assessment foundations and methods:

.1 Germanischer Lloyd, *"Technical Risk Analysis in Ship Building and Ship Operation"*, Course handbook, revision 8, April 2008.

.2 Breinholt, C., W. Hensel, A. Perez de Lucas, P.C. Sames, R. Skjong, T., Strang, and D. Vassalos, *"Risk-based ship and ship system design and their approval"*, Proc. of RINA-conference "Developments in Classification & International Regulations", London, 2007.

.3 Kristiansen, S. "Maritime Transportation - Safety Management and Risk Analysis", Elsevier Butterworth-Heinemann, 2005.

.4 Papanikolaou A. D. (Ed.), *"Risk based Ship Design – Methods, Tools and Applications"*, Springer-Verlag, Berlin, in print.

.5 Bedford, T. and Cooke, R. *"Probabilistic Risk Analysis - Foundations and Methods"*, Cambridge University Press, 2001.

.6 Stephans, R.A. and Talso, W. (eds.), *"System Safety Analysis Handbook"*, System Safety Society, 2nd Edition, 1997.

.7 Braband 2006: Braband , J., "Risk Assessment: As Simple As Possible (and No Simpler)", System Safety 2006, Proc. 1st Institution of Engineering and Technology International Conference, pp. 285-300, June 2006.

.8 Linstone and Turoff 1975: Linstone, H.A.; Turoff, M. (Eds.), "The Delphi Method. Techniques and Applications", Reading/Mass, 1975.

.4 Application of process of alternative design and arrangements

.1 "Application of the Guidelines for the Analysis of Alternative Design and Arrangements – Worked Example: Lifeboats". GL Technical Publication, 2009

.2 Loer, K., Hamann, R. and Boekholt, T., "*Risk-based LSA analysis opens up design possibilities*", Passenger Ship Technology" Aug/Sept 2008.

.3 Schreiter, J., Voelker, J.-M., Nusser, S, Meyer-König, T., "*Demonstrating Regulatory Compliance of Alternative Designs – A Framework Concept*", RINA Passenger Ship Safety conference, London 2003.

.5 Methods for quantification of human element

.1 Swain A.D. and Guttman, H.E., "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications" NUREG/CR-1278, Sandia National Laboratories, Albuquerque, NM, August 1983. (THERP-technique)

.2 Williams, J.C., "A data-based method for assessing and reducing human error to improve operational performance", IEEE Fourth Conference on Human Factors and Power Plants (pp.436-450), 1988. (HEART technique)

.3 Embrey, D.E., "SLIM-MAUD: A Computer-Based Technique for Human Reliability Assessment", International Journal of Quality & Reliability Management Vol. 3(1), pp. 5-12, Emerald Insight, 1986.

.6 Methods for root cause analysis and incident investigation

.1 Johnson, C., "Failure in Safety-Critical Systems: A Handbook of Incident and Accident Reporting", Glasgow University Press, 2003.

.2 Ladkin, P., "Causal System Analysis", Springer Verlag, Berlin, 2005.