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GUIDELINES ON ALTERNATIVE DESIGN AND ARRANGEMENTS FOR FIRE SAFETY

1 The Maritime Safety Committee, at its seventy-fourth session (30 May to 8 June 2001), approved Guidelines on alternative design and arrangements for fire safety, as set out in the annex, developed to provide further guidance on SOLAS regulation II-2/17, which was adopted by resolution MSC.99(73) as part of the revised SOLAS chapter II-2 and is expected to enter into force on 1 July 2002.

2 The Guidelines serve to outline the methodology for the engineering analysis required by SOLAS regulation II-2/17 on Alternative design and arrangements, applying to a specific fire safety system, design or arrangements for which the approval of an alternative design deviating from the prescriptive requirements of SOLAS chapter II-2 is sought.

3 Member Governments are invited to bring the annexed Guidelines to the attention of ship owners, ship builders and designers for the facilitation of fire safety engineering design in the framework of SOLAS regulation II-2/17.

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ANNEX

GUIDELINES ON ALTERNATIVE DESIGN AND ARRANGEMENTS FOR FIRE SAFETY

1 Application

1.1 These guidelines are intended for application of fire safety engineering design to provide technical justification for alternative design and arrangements to SOLAS chapter II-2. The guidelines serve to outline the methodology for the engineering analysis required by SOLAS regulation II-2/17 "Alternative design and arrangements", applying to a specific fire safety system, design or arrangements for which the approval of an alternative design deviating from the prescriptive requirements of SOLAS chapter II-2 is sought.

1.2 These guidelines are not intended to be applied to the type approval of individual materials and components.

1.3 These guidelines are not intended to serve as a stand-alone document, but should be used in conjunction with the fire safety engineering design guides and other literature, examples of which are referenced in section 3.

1.4 For the application of these guidelines to be successful, all interested parties, including the Administration or its designated representative, owners, operators, designers, and classification societies, should be in continuous communication from the onset of a specific proposal to utilise these 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.

2 Definitions

For the purposes of these guidelines, the following definitions apply:

2.1 *Alternative design and arrangements* means fire safety measures which deviate from the prescriptive requirement(s) of SOLAS chapter II-2, but are suitable to satisfy the fire safety objective(s) and the functional requirements 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.

2.2 *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.

2.3 *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.

2.4 *Functional requirements* explain, in general terms, what function the ship should provide to meet the fire safety objectives of SOLAS.

2.5 *Performance criteria* are measurable quantities stated in engineering terms to be used to judge the adequacy of trial designs.

2.6 *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.

2.7 *Safety margin* means adjustments made to compensate for uncertainties in the methods and assumptions used to evaluate the alternative design, e.g. in the determination of performance criteria or in the engineering models used to assess the consequences of fire.

2.8 *Sensitivity analysis* means an analysis to determine the effect of changes in individual input parameters on the results of a given model or calculation method.

2.9 *SOLAS* means the International Convention for the Safety of Life at Sea, 1974, as amended.

3 Engineering analysis

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 chapter II-2 should follow an established approach to fire safety design. This 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.

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 for guidance and a list of additional technical literature.

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 fire safety, design, and/or operation as necessary for the specific evaluation at hand. Other members may include marine surveyors, vessel 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 fire safety, at least one expert with knowledge and experience in fire safety 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 objectives and functional requirements of the regulations; the development of fire scenarios, 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 fires, 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, approved by the Administration, and a comprehensive report describing the alternative design and arrangements and required maintenance program 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.

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.

5 Preliminary analysis in qualitative terms

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, fire test data and analysis results, ship operating characteristics and conditions of operation, operating and maintenance procedures, material properties, etc.

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 paragraph 5.4). This should form the basis for the comparative analysis referred to in paragraph 6.4.

5.2 *Development of fire scenarios*

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. This process can be broken down into four areas:

.1 identification of fire hazards;

.2 enumeration of fire hazards;

.3 selection of fire hazards; and

.4 specification of design fire scenarios.

5.2.1.1 Identification of fire hazards

This step is crucial in the fire scenario development process as well as in the entire alternative design methodology. If a fire hazard or incident is omitted, then it will not be considered in the analysis and the resulting final design may be inadequate. Fire 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 fire hazards including HAZOP, PHA, FMEA, "what-if", etc. As a minimum, the following conditions and characteristics should be identified and considered:

.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.

5.2.1.2 Enumeration of fire hazards

All of the fire hazards identified above should be grouped into one of three incident classes: localised, major, or catastrophic. A localised incident consists of a fire with a localised affect zone, limited to a specific area. A major incident consists of a fire with a medium affect zone, limited to the boundaries of the ship. A catastrophic incident consists of a fire with a large affect zone, beyond the ship and affecting surrounding ships or communities. In the majority of cases, only localised and/or major 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 fire hazards should be tabulated for future selection of a certain number of each of the incident classes.

5.2.1.3 Selection of fire hazards

The number and type of 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 fire 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 utilised in a qualitative sense. The selection process should identify a range of incidents which cover the largest and most probable range of enumerated fire 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 fire 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.

5.2.1.4 Specification of design fire scenarios

Based on the fire hazards selected, the fire scenarios to be used in the quantitative analysis should be clearly documented. The specification should include a qualitative description of the design fire (e.g., ignition source, fuel first ignited, location, etc.), description of the vessel, compartment of origin, fire protection systems installed, number of occupants, physical and mental status of occupants and available means of escape. The fire scenarios should consider possible future changes to the fire load and ventilation system in the affected areas. The design fire(s) will be characterised in more detail during the quantitative analysis for each trial alternative design.

5.3 *Development of trial alternative designs*

At this point in the analysis, one or more trial alternative designs should be developed so that it 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 as reflected in part E of SOLAS chapter II-2. It should be recognized that well defined operations and management procedures may play a big part in increasing the overall level of safety.

5.4 *Preliminary analysis report*

5.4.1 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 fire scenarios and trial alternative designs selected for the quantitative analysis.

5.4.2 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 fire scenario(s) acceptable to all parties; and

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

6 Quantitative analysis

6.1 The quantitative analysis is the most labour intensive from a fire safety engineering standpoint. It consists of quantifying the 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.

6.1.1 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 will then be utilised to evaluate the trial alternative designs selected during the preliminary analysis.

6.1.2 Risk assessment may play an important role in this process. It should be recognised 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.

6.2 *Quantification of design fire scenarios*

6.2.1 After choosing an appropriate range of fire incidents, quantification of the fires should be accomplished for each of the incidents. Quantification will require specification of all factors that may affect the type and extent of the fire hazard. The fire scenarios should consider possible future changes to the fire load and ventilation system in the affected areas. This may include calculation of heat release rate curves, flame height, length, and tilt, radiant, conductive, and convective heat fluxes, smoke production rate, pool fire size, duration, time-lines, etc. References on suggested example correlations and models that may be of use are listed in appendix C. It should be noted that when using any of these or other 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 fire 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 fires includes fire scenario development completed during the preliminary analysis, time-line analysis and consequence estimation which is detailed below.

6.2.2 For each of the identified fire hazards, a range of fire 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 time-line should be developed for each of the fire scenarios beginning with fire initiation. Time-lines 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 time-line 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 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 utilised, a sensitivity analysis should be conducted to determine the effects of the uncertainties and limitations of the input parameters.

6.3 *Development performance criteria*

6.3.1 Performance criteria are quantitative expressions of the fire safety objectives and functional requirements of the 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 such as smoke obscuration, temperature, height of the smoke and hot gas layer in a compartment, evacuation time or other criteria necessary to ensure successful alternative design and arrangements.

6.3.2 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 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."*

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 fire safety is maintained.

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 heat, smoke, toxicity, reduced visibility and evacuation time.

.2 Criteria for damage to ship structure and related systems - These criteria address the impact that fire and its effluents might have on the ship structure, mechanical systems, electrical systems, fire protection systems, evacuation systems, propulsion and manoeuvrability, etc. These criteria may represent thermal effects, fire spread, smoke damage, fire barrier damage, degradation of structural integrity, etc.

.3 Criteria for damage to the environment - These criteria address the impact of heat, smoke and released pollutants on the atmosphere and marine environment.

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 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 fires 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 figure 6.4.1.

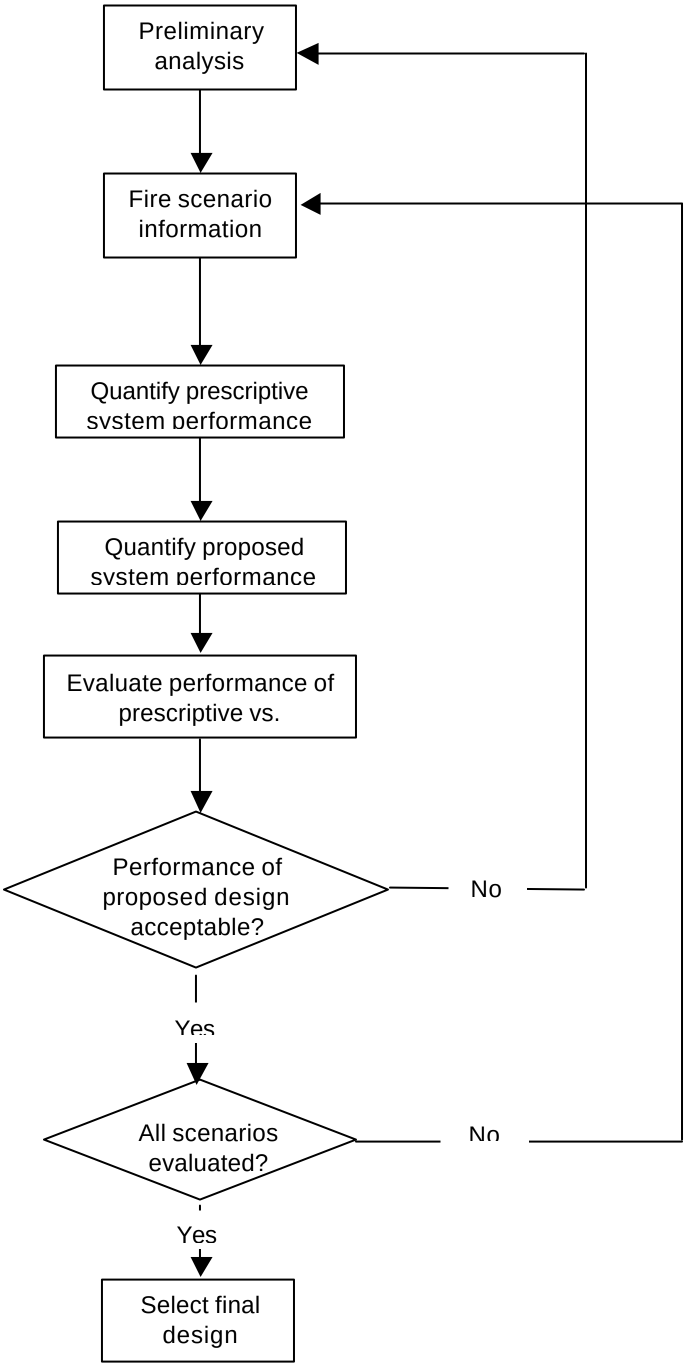

Figure 6.4.1 Alternative design and arrangements process flowchart

6.4.2 Each selected trial alternative design should be analysed against the selected design fire 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.

7 Documentation

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 chapter II-2 regulations and their functional requirements;

3.4 fire hazard identification;

3.5 enumeration of fire hazards;

3.6 selection of fire hazards; and

3.7 description of design fire scenarios;

.4 results of quantitative analysis:

4.1 design fire scenarios:

4.1.1 critical assumptions;

4.1.2 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 time-lines;

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.

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 chapter II-2 regulations;

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

.5 test, inspection, and maintenance requirements.

7.3 *Reporting and approval forms*

7.3.1 When the Administration approves alternative design and arrangements for fire safety, pertinent technical information about the approval should be summarized on the reporting form given in appendix A and should be submitted to the International Maritime Organization for circulation to the Member Governments.

7.3.2 When the Administration approves alternative design and arrangements on fire safety, documentation should be provided as indicated in appendix B.

7.4 *Reference in SOLAS certificates*

A reference to the approved alternative design and arrangements should be included in the appropriate SOLAS certificate.

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APPENDIX A

REPORT ON THE APPROVAL OF ALTERNATIVE DESIGN AND ARRANGEMENTS FOR FIRE SAFETY

The Government 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:**

APPENDIX B

DOCUMENT OF APPROVAL OF ALTERNATIVE DESIGN AND ARRANGEMENTS FOR FIRE SAFETY

Issued in accordance with provisions of regulation II-2/17.4 of the International Convention for Safety of Life at Sea (SOLAS), 1974, as amended, under the authority of the Government 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 arrangement applied to the above ship had 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)

(Seal or stamp of issuing authority, as appropriate)

APPENDIX C

TECHNICAL REFERENCES AND RESOURCES

1 Section 3 of the 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.

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