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GUIDELINES FOR EVALUATION OF ALTERNATIVE DESIGN OF LNG CARRIER BASED ON RISK ASSESSMENT

2025

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CHAPTER 1 GENERAL

1.1 General Provisions

1.1.1 The Guidelines provide a general design process, engineering analysis methods, and evaluation technical points for the alternative design and arrangement of liquefied natural gas carriers (hereinafter referred to as LNG carriers) to ensure that the alternative design and arrangement of LNG carriers meet the safety and environmental objectives and functional requirements specified in relevant technical documents of the International Maritime Organization (IMO) and the International Ship Classification (ISC). Relevant technical documents include but are not limited to:

(1) International Convention for the Safety of Life at Sea (SOLAS);

(2) International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code);

(3) ISC Rules for Classification of Steel Sea-going Ships;

(4) ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk;

(5) ISC Rules for Liquefied Natural Gas Bunkering Ships;

(6) ISC Rules for Ships Using Natural Gas Fuel.

1.1.2 The alternative design described in the Guidelines refers to measures that deviate from the prescriptive requirements of IMO IGC Code and ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, however, meet the relevant prescriptive requirements (goals and functional requirements) through alternative methods. It involves a wide range of measures, including both innovative or special designs, as well as conventional ship structures and systems installed in alternative arrangements or constructions.

1.1.3 For newbuildings, application for alternative design is to be submitted to ISC at the early stages of LNG carrier design. The alternative design documents and analysis reports are to be submitted as a part of the drawing and materials for ISC verification and review.

1.1.4 Due to the uniqueness of alternative design, LNG carrier alternative design generally is to implement a "one application for one ship in principle" approach, meaning that one application can only be made for one ship. If multiple LNG carriers with the identical design and consistent applicable requirements of rules are constructed, alternative designs and evaluations can be applied for and carried out at one time.

1.1.5 The implementation of alternative design is also to comply with the relevant provisions of the flag State Administrations, such as Article 6.2 "Equivalent and Alternative Design" and its appendix "Requirements for Implementation of Ship Alternative Design" of the China Maritime Safety Administration's "Technical Regulations for Statutory Surveys of Ships Engaged on International Voyages", etc.

1.2 Terms and Definitions

For the purposes of the Guidelines, the following definitions and terms apply:

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

1.2.2 Design casualty scenario means a set of conditions that defines the development and severity of a casualty within and through LNG carrier spaces or systems and describes specific factors relevant to a casualty of concern.

1.2.3 Applicant means the relevant party who submits LNG carrier alternative design for ISC approval, which can be the shipowner, designer or shipyard.

1.2.4 Administration means the government of flag State.

1.2.5 Prescriptive requirements means the specific technical terms and requirements provided by the international conventions, codes and rules.

1.2.6 Functional requirements means explanation, in general terms, what function the LNG carrier or system under consideration is to provide to meet the safety objectives of the international conventions, codes or rules.

1.2.7 Risk assessment criteria means the formally recognized objective criteria defining the acceptable risk.

1.2.8 Performance criteria means the measurable quantities to be used to evaluate the adequacy of trial designs.

1.2.9 Risk identification means a process of identifying, listing and describing the risk characteristics of a ship.

1.2.10 Prescriptive based design means a design of safety measures which comply with the prescriptive requirements of the international conventions, regulations and rules.

1.2.11 Risk-based design means 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.

1.2.12 Preliminary design means the design developed at the preliminary qualitative analysis stage. Preliminary design generally considers high-level design of the general arrangement, main systems, equipment, etc. of the ship.

1.2.13 Final design means the elaboration of the preliminary design. The final design complies with the results of the preliminary analysis, e.g. with respect to risk control options already identified, the requirements of the Administration, etc.

1.2.14 Quantitative risk assessment means an analysis carried out for the identified potential hazards, probability of occurrence and the potential consequences.

1.2.15 Risk control measure means 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.

1.2.16 Safety margin means adjustments made to compensate for uncertainties in the methods and assumptions used to evaluate the alternative design.

1.3 Responsibilities of Parties

1.3.1 The submitter (shipowner, designer or shipyard) is responsible for submitting the LNG carrier alternative design application (format as shown in Annex 1), establishing an alternative design project team and organizing implementation, and submitting alternative design documents to ISC.

1.3.2 The alternative design project team is responsible for the development and analysis of alternative design, organizing safety and environmental evaluation, and assisting in the training of operators and the preparation of onboard documents related to alternative design.

The project team is composed of competent personnel designated by the shipowner, designer and shipyard, and is also to include technical experts on ship survey, operation, safety engineering, equipment manufacturing, human factors, naval architecture and marine engineering or similar fields. The technical level of project team members is to be commensurate with the complexity of the alternative design to be applied for. Due to the potential impact of alternative design on specific security domains, at least one professional technician with relevant knowledge and experience in the security field who has been continuously engaged in the industry for more than 5 years is to be the member of the project team. The main responsibilities of all parties involved are as follows:

(1) Shipowners are to provide the information on the functional, service and operational requirements of LNG carriers;

(2) Designers are to be responsible for implementing alternative design for the LNG carrier;

(3) Shipyards/subcontractors are to provide information that may affect equipment procurement, production plans, etc.;

(4) Technical experts are to assist the project team in risk identification and provide professional technical support in risk assessment.

1.3.3 ISC is to conduct a review and necessary compliance verification of alternative design for LNG carriers in accordance with the relevant processes and requirements specified in the Guidelines, and issue an "Approval Form for Alternative Design" (format as shown in Annex 2).

1.4 Documents and Information

1.4.1 The alternative design evaluation report is to be submitted as a part of the drawing materials for ISC review, generally including:

(1) Introduction of various units and designer personnel involved in the design of LNG carriers, including:

 ① Ship construction commissioning party;
 ② Ship design undertaking unit;
 ③ Alternative design evaluation undertaking unit;
 ④ Resumes and qualification certificates (if any) of the person in charge of alternative design evaluation and key personnel.

(2) The contents and scope of alternative design or arrangement engineering, including drawings and specifications:

 ① An explanation of prescriptive technical requirements involved;
 ② An explanation on the trial alternative design and arrangement for evaluation, including the objectives and functional requirements of the alternative design.

(3) Qualitative analysis report of preliminary design:

 ① Detailed arrangement and design drawings.
 ② Risk identification: including the current condition evaluation on design and arrangement of ship's spaces and related systems, as well as the identification, listing and selection of hazards.
 ③ Explanation on design casualty scenario:
  a. Pre-casualty situation, including ship design and arrangement, navigation scenarios, environmental conditions, etc.;

        - b. Potential initial events and their causes;
        - c. Critical factors of casualty: environment, operation, time, etc.;
        - d. Casualty location and potential extension;
        - e. Relevant statistical data: past casualty history, failure probability, frequency, and severity, etc.
    - ④ Analysis plan for the next stage.
    - ⑤ Identify issues of special concerns in operation and survey.
- (4) Final design quantitative analysis report:
    - ① Identifying hazards related to alternative design (updating preliminary design analysis) and safety technical measures already considered.
    - ② Analysis results of various casualty scenarios:
        - a. Theoretical calculation process;
        - b. Input and output data of the calculation model;
        - c. Test data and measurement reports;
        - d. Limitations and uncertainty analysis of design methods.
    - ③ Performance criteria that characterize safety objectives.
    - ④ Comparative evaluation between alternative design solutions and performance criteria.
    - ⑤ Safety management measures.
    - ⑥ Identifying issues that require further analysis and test (if any).
    - ⑦ Identifying issues that require special attention in terms of operation and survey (if any).
    - ⑧ Final alternative design and arrangement instructions, including drawings and specifications;
    - ⑨ References and sources of cited analysis methods and data.

CHAPTER 2 ALTERNATIVE DESIGN AND EVALUATION PROCESSES

2.1 Alternative Design Processes

2.1.1 The alternative design of LNG carriers is a risk-based design, and its processes can generally be divided into the following stages, as shown in Fig. 2.1.1:

(1) Preparation of alternative design (conceptual design);
(2) Preliminary design stage (preliminary design and qualitative preliminary analysis);
(3) Final design state (final design and quantitative analysis);
(4) Testing and engineering analysis.

2.2 Preparation of Alternative Design

2.2.1 At the early stage of LNG carrier design, due to specific functional requirements of the ship or the introduction of novel technologies or designs, the applicant is to provide alternative design requirements and subsequently carries out preliminary preparations for alternative design, including:

(1) Composition plan for the proposed alternative design project team;
(2) Determine the scope of analysis for alternative design;
(3) Analyze the relationship between alternative design and prescriptive requirements;
(4) Analyze the novelty level of alternative design;
(5) Applicable evaluation criteria (if any);
(6) Risk assessment, verification and approval plans for alternative design.

2.2.2 After the preliminary preparation has been conducted, the submitter is to send an alternative design application, together with conceptual design documents and necessary technical specifications to ISC for review.

2.2.3 ISC is to conduct a preliminary review of whether the alternative design deviates from the prescriptive requirements. If confirmed, ISC is to hold a review meeting to evaluate the necessity and feasibility of the alternative design application, as well as the completeness of the application materials. The review experts are generally composed of technical experts in maritime management, ship management, ship design and construction, as well as related professional fields.

2.2.4 The submitter is to improve the relevant technical documents based on the opinions of the review meeting and submit them to ISC.

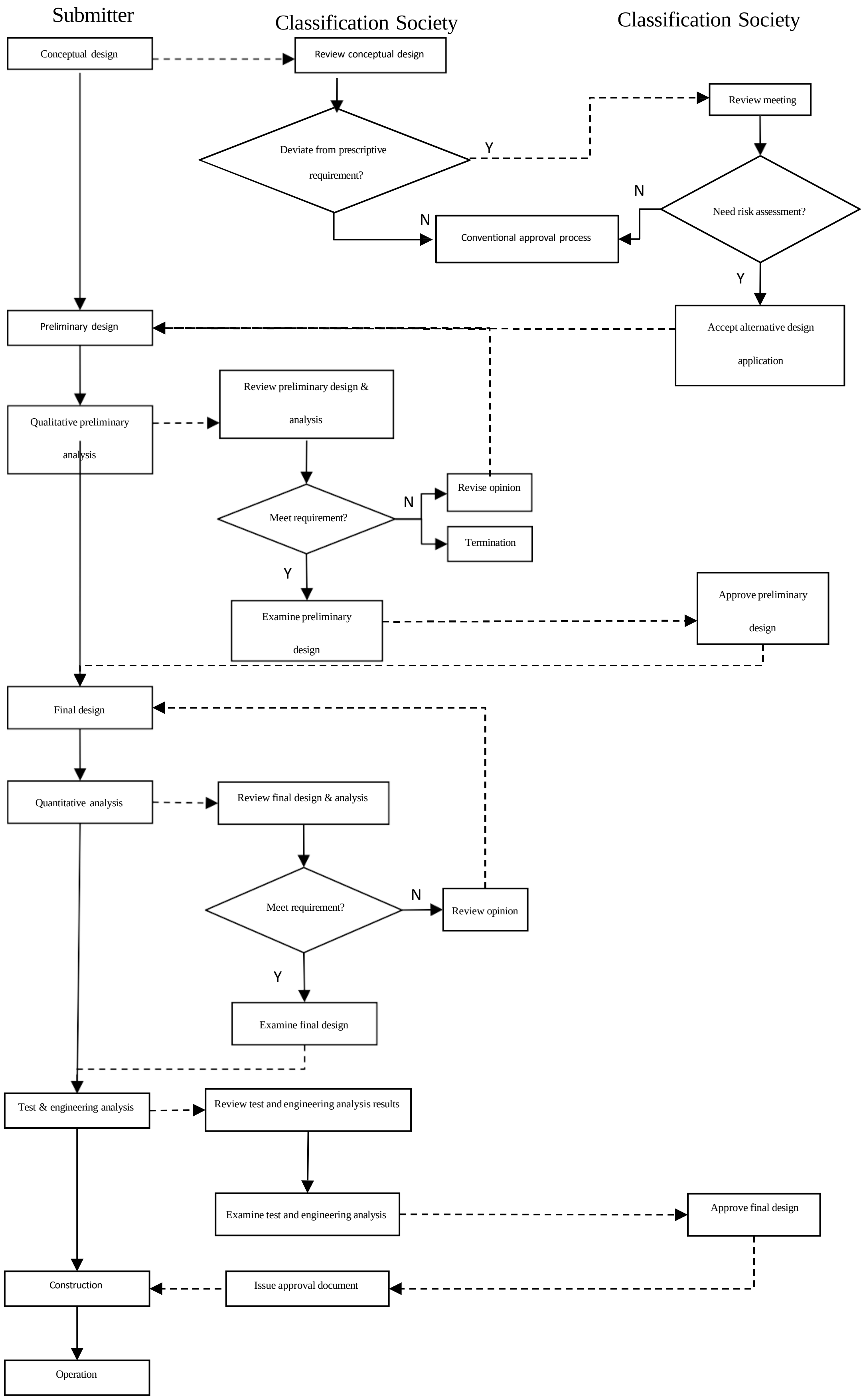

Submitter
Classification Society
Classification Society
Conceptual design
Review conceptual design
Review meeting
Deviate from prescriptive requirement?
Y
N
Need risk assessment?
N
Conventional approval process
Y
Preliminary design
Accept alternative design application
Qualitative preliminary analysis
Review preliminary design & analysis
Meet requirement?
N
Revise opinion
Termination
Y
Examine preliminary design
Approve preliminary design
Final design
Quantitative analysis
Review final design & analysis
Meet requirement?
N
Review opinion
Y
Examine final design
Test & engineering analysis
Review test and engineering analysis results
Examine test and engineering analysis
Approve final design
Construction
Issue approval document
Operation

Fig. 2.1.1 Alternative design processes

2.3 Preliminary Design Analysis

2.3.1 After the alternative design application is accepted, the alternative design project team can officially carry out the alternative design and evaluation work. During this process, according to the risk assessment plan for alternative design, the applicant is to closely cooperate with ISC to develop, analyze and verify alternative design.

2.3.2 During the qualitative preliminary analysis, the alternative design project team is to further analyze and determine the related space and system arrangements of LNG carrier affected by the alternative design, as well as the main service and operational scenarios. On this basis, risk identification is carried out, which involves identifying various hazards and their casualty scenarios, and ranking them according to their risk levels related to the issues concerned, in order to select the main hazards and casualty scenarios for more detailed quantitative analysis in the future. For those casualty scenarios with high risk levels, corresponding risk control measures can be initially proposed, and one or more alternative design schemes can be developed.

2.3.3 After the qualitative analysis of the preliminary design has been carried out, the applicant is to submit a preliminary design analysis report to ISC as specified in 1.4.1 (3). The risk identification report is to explain the process of risk identification, the list of participants and their technical background, all identified hazards and consequences, as well as the risk control measures considered in the design.

2.3.4 ISC is to review the effectiveness of the risk identification process, suitability of methods, and adequacy of results when verifying the preliminary design, and decide whether to approve the preliminary design. If significant issues are found in the preliminary design that cannot meet the evaluation criteria for alternative design, it is required to modify the design and resubmit or terminate the approval process.

2.4 Final Design Analysis

2.4.1 After ISC approves the preliminary design, the alternative design project team is to further update and deepen the alternative design, and focus on quantitative analysis, including quantifying the prescriptive design performance and quantifying the design performance of the alternative design scheme.

2.4.2 Quantifying the prescriptive design performance, that is, developing performance criteria for evaluating alternative design solutions, is a quantitative expression that reflects the intention of prescriptive requirements.

2.4.3 Quantifying the design performance of alternative design schemes means the quantitative analysis of one or more alternative design schemes formulated in the preliminary design. If they do not meet the performance criteria, the design is to be updated through the risk control measures formulated in the early stage, and the updated design is to be quantitatively analyzed again until the performance criteria are met, that is, the risk-related measures or activities are to be controlled within an acceptable range of risk.

2.4.4 On the basis of quantitative analysis, the alternative design project team is to complete the final design and analysis, and submit the final design analysis report as specified in 1.4.1 (4) to ISC.

2.4.5 During the final design verification, ISC is to review and confirm the followings:

(1) The compliance of submitted documents, clarity, completeness and sufficiency of requirements;

(2) Risk identification method adopts appropriately recognized risk assessment methods;

(3) Consider the main risk factors that affect the level of risk;

(4) When using expert judgment, the consistency of expert opinions;

(5) All assumptions, exclusions, and limitations have credible confirmation;

(6) Effectiveness and feasibility of the risk control measures adopted;

(7) Validity of historical/statistical data, i.e., it is to be updated as much as possible and relevant to the application;

(8) Applicability of the computer simulation tools and programs used has been verified;

(9) Quantitative risk calculation results can be reproduced;

(10) Confirm that the planned tests and analysis will obtain acceptable results.

2.5 Testing and Engineering Analysis

2.5.1 At the same time as approving the final design, ISC may also provide other alternative design requirements based on quantitative risk analysis results, such as tests, numerical calculations/simulations, and specific requirements for future construction and operation.

2.5.2 The alternative design project team is to carry out relevant work according to the testing and analysis requirements provided by ISC, and submit the testing and analysis results to ISC for verification and review. ISC is to verify the experimental and analytical methods and results, and determine the relevant conditions for in-service survey, measurement, monitoring and test.

2.5.3 After the verification and review of the test and analysis results have been carried out, ISC is to approve all documents and materials, including the final design, analysis report and test report. If all potential hazards and failure modes of the alternative design meet the credible safety level required for final approval, an alternative design approval statement is to be issued.

2.6 Construction and Operation

2.6.1 At the stages of LNG carrier construction and system/equipment installation, the design requirements and risk control measures proposed by alternative design analysis are to be implemented. ISC is to carry out construction surveys and keep abreast of the progress of the project.

2.6.2 When operating an LNG carrier, the operator is to monitor and confirm that the operational requirements and assumptions proposed by the alternative design are effectively implemented, including restrictions on ship operation, handling and loading, as well as additional safety procedures or measures, to ensure that the alternative design maintains the safety level determined at the time of approval.

2.6.3 For LNG carriers using alternative design, the following documents are to be kept onboard for check:

(1) Alternative design approval statement and certificate/conditional certificate of the ship;

(2) The alternative design materials include:

① Analysis and design scope, including critical design assumptions and design features;

② Explanation of alternative design, including drawings and specifications;

③ List of conventions/regulations/rules involved;
④ Engineering analysis results;
⑤ Testing, inspection and maintenance requirements.

2.6.4 In addition to the certificates and documents onboard the ship, ISC or other ship survey agency is to carry out inspection in accordance with the approved alternative design documents kept onboard and confirm that the conditions specified in the approved alternative design documents are maintained and the ship is in a good condition.

CHAPTER 3   ALTERNATIVE DESIGN OF CARGO CONTAINMENT SYSTEM

3.1   General Provisions

3.1.1   Based on the general processes of alternative design in Chapter 2 of the Guidelines, this chapter provides key evaluation points and commonly used engineering analysis methods for alternative design of cargo containment systems onboard LNG carriers.

3.1.2   According to the types of cargo containment system, LNG carriers usually have membrane cargo tanks and independent cargo tanks (Type A, B, or C).

3.1.3   The alternative design of cargo containment systems usually includes the selection of tank type for containment systems, novel design of tank type, substitution of containment system materials, etc., involving primary barriers, secondary barriers, insulation layers, structural materials, etc.

3.2   Performance Criteria

3.2.1   The safety level of alternative design is usually quantified in the form of performance criteria. The alternative design project team is to first establish safety objectives for the alternative design of the containment system and transfer these safety objectives into corresponding performance criteria.

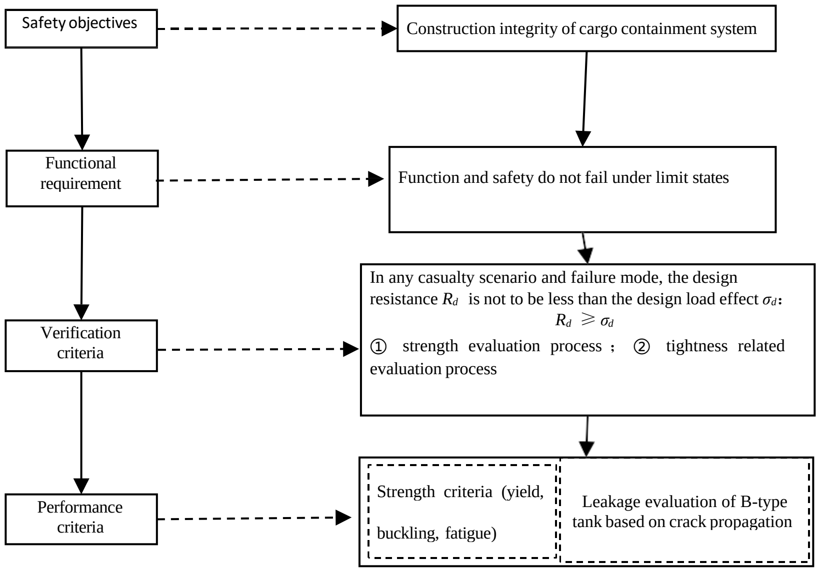


Fig. 3.2.1   Example of the process for developing performance criteria

3.2.2   The safety objective of the cargo containment system in the Guidelines is the structural integrity of the containment system to ensure the safe containment of LNG under all design and operating conditions.

3.2.3 The functional requirement is to use risk-based identification methods to determine functional elements based on safety objective.

3.2.4 The verification criteria are the evaluation process that is to be followed to implement functional requirements, which is to be equivalent to the evaluation process of conventional structures.

3.2.5 The submitter is to develop performance criteria based on the objectives and functional requirements of the prescriptive requirements, combined with the actual project. ISC can be invited to participate in the process of developing performance criteria.

3.2.6 The basic principle for developing performance criteria is "Safety and Equivalence", which means that the expected safety level of alternative design is to be equivalent to or better than the prescriptive requirements deviated from by the design. The commonly used performance criteria for alternative design of containment systems include the following categories:

(1) Structural strength: the stress of containment system is to be controlled within the allowable stress;

(2) Structural stiffness: the deformation of containment system is to be controlled within the allowable deformation;

(3) Fatigue life: the fatigue life of containment system is to be controlled within the allowable fatigue life;

(4) Functionality: it is to be able to maintain the functionality and effectiveness of the prescribed containment system.

3.3 Qualitative Analysis

3.3.1 The qualitative analysis of alternative design for containment systems mainly includes risk identification, design limit state, and design casualty scenarios.

3.3.2 Risk identification is the process of identifying the risk factors and corresponding failure modes of alternative containment systems. Historical and statistical data, expert opinions and experience are to be used to identify the risk factors of LNG containment systems in accordance with risk identification procedures (see ISC Guidelines for Application of Formal Safety Assessment to Ships). At least the following conditions and characteristics are to be identified and considered:

(1) Pre-casualty situation: ship, containment system, structural components, environmental conditions;

(2) Potential initial events and the causes;

(3) Detailed technical information and potential risk characteristics;

(4) Secondary risks that may have an impact on the initial risk;

(5) Arrangement of containment system: pay attention to target items or areas related to performance parameters;

(6) Potential extension of the casualty outside the cargo area: outside the tanks, structures or areas (if in open);

(7) Critical factors corresponding to risk: ventilation, environment, operation, time, etc;

(8) Related statistical data: previous casualty history, failure probability, frequency, severity, etc.

3.3.3 All identified risks are to be reviewed and explained in a form, and an appropriate number and type of risks are to be selected to design limit states and design casualty scenarios.

Typical format for a risk identification worksheet **Table 3.3.3**

No.	Guiding word	Risk event	Cause	Frequency	Consequence	Severity	Risk level	Recommendation on risk control measures

3.3.4 Based on risk identification, the conditions under which the containment system no longer meets the requirements are identified to design the limit states of the alternative containment system so as to facilitate quantitative assessment based on these limit states in the future.

3.3.5 The limit states of containment systems are usually to be divided as the following three categories:

(1) Ultimate load limit state (ULS), which corresponds to the maximum loading capacity under intact (undamaged) conditions, or in some cases, to structural instability caused by maximum applicable strain, deformation or buckling, and plastic failure;

(2) Fatigue limit state (FLS), corresponding to degradation caused by cyclic loading effects;

(3) Accidental limit state (ALS), corresponding to accidents, is related to the structural ability to withstand unexpected conditions.

3.3.6 Based on risk identification, the corresponding accidents, including collision, grounding, contacting, flooding, etc. are to be identified to design the casualty scenarios so as to facilitate quantitative assessment based on the casualty scenarios in the future.

3.3.7 The casualty scenarios are to be clearly documented, including qualitative descriptions of the scenarios (such as initial and subsequent chain of events, location, etc.), description of the ship involved, compartment or system of origin, safeguard systems, etc. The casualty scenarios should consider possible future changes to the hazards (increased or decreased) in the affected areas.

3.4 Quantitative Analysis

3.4.1 All data and information generated in qualitative analysis, as well as design limit states and casualty scenarios, are to be used as input parameters in quantitative analysis.

3.4.2 Each selected alternative design scheme is to be quantitatively analyzed based on the design limit state and casualty scenario to verify its compliance with performance criteria and safety margin requirements.

3.4.3 The quantitative analysis of the containment system is to comply with the following principles:

(1) The operating environment of the containment system is not to be changed, i.e.: the load mode and operating scenario (calculated loading conditions) of the alternative containment system are to be consistent with the technical requirements in the IGC Code or ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk;

(2) An appropriate evaluation model is to be selected, i.e.: the model of alternative containment system is closely related to the failure mode of the structure to be analyzed. If it is finite element analysis, the size of the element mesh is to be consistent with the technical requirements of the alternative structure in the rules, and the scope of the model is to be as large as possible to reduce the influence of boundary conditions on the analysis area.

3.4.4 For quantitative analysis of the ultimate limit state, the requirements are as follows:

(1) Three-dimensional finite element analysis is tobe carried out as an integrated model of cargo tank and ship hull, including applicable support members and keying systems. All failure modes are to be identified to avoid unexpected failures. Hydrodynamic analysis is to be conducted to determine specific ship accelerations and motions in irregular waves, as well as the response of the ship and its cargo containment system to these forces and motions.

(2) Buckling strength analysis is to be carried out for the liquid cargo tanks subjected to external pressure and other compressive stresses in accordance with recognized standards. The method is to fully consider the difference between theoretical and actual buckling stress values. This difference is caused by flatness of plating, misalignment of the plating edges, straightness, ovality, and out of circular form over a specified arc or chord length range.

3.4.5 The leakage assessment analysis based on fatigue crack propagation can be carried out according to the analysis method in Appendix 3, Section 4 of Part 2 of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

3.4.6 For quantitative analysis of accident casualty scenarios, applicable methods can be used for nonlinear analysis. For example, quantitative analysis of collision accidents can be conducted in accordance with the requirements of “Additional Requirements for Assessment of Anti-collision Capacity of Ships” in Chapter 34 of PART EIGHT of the ISC Rules for Classification of Steel Sea-going Ships. If a risk-based reliability assessment of C-type independent tanks is carried out, it can be carried out according to the ISC Guidelines for Yielding Strength Assessment of Type C Independent Tanks Based on Load-Resistance Factors (LRFD) Design Criteria.

CHAPTER 4　ALTERNATIVE DESIGN OF MANIFOLDS ARRANGEMENT

4.1　General Provisions

4.1.1　Based on the general process of alternative design in Chapter 2 of the Guidelines, this chapter provides evaluation points and commonly used engineering analysis methods for alternative design of manifolds arrangement onboard LNG carriers.

4.1.2　Alternative design of the manifolds arrangement usually includes the design and arrangement of the manifolds, as well as the enclosure type of bunkering station (when applicable).

4.1.3　The evaluation of alternative design for manifolds arrangement is to require the collection of relevant information and materials, which generally include but are not limited to the following:

(1)　General arrangement, including the arrangement of related systems and piping systems;
(2)　Hazardous area division;
(3)　Ventilation system arrangement;
(4)　Fire control, including emergency fire and escape;
(5)　Equipment manual;
(6)　Ship operating manual;
(7)　Risk acceptance criteria;
(8)　Data on previous accidents, incidents, and malfunctions (if any).

4.2　Performance Criteria

4.2.1　The safety objective of the manifolds arrangement in the Guidelines is to ensure the safety of LNG carriers, personnel onboard, and the environment under all design and operating conditions.

4.2.2　The safety performance criteria for alternative design of manifolds arrangement are usually to take into account of the thermal and physical properties of LNG exposed to the environment, as well as the harmful behaviors that may occur from its interaction with ship structures, equipment and the environment, including but not limited to: vapor cloud diffusion, flash fire, jet fire, pool fire, explosion, etc.

4.2.3　Generally, the followings are to be considered:

(1)　Vapor cloud diffusion concentration and range;
(2)　Fire temperature field and thermal radiation intensity;
(3)　Pressure of explosive shock wave.

4.2.4　The acceptance criteria of vapor cloud diffusion volume concentration are to comply with the provisions in the following table.

Acceptance criteria of vapor cloud diffusion concentration

Table 4.2.4

	Volume concentration	**Remark**
Vapor cloud diffusion	2.5%	50% of the lower limit of methane combustion

4.2.5 The acceptance criteria of fire temperature field and thermal radiation intensity are to comply with the provisions in the following table.

Acceptance criteria of fire temperature field and thermal radiation

Table 4.2.5

	Criteria value	**Remark**
Temperature	60℃	Skin burn
Thermal radiation	2.5kW/m^2	Beyond this, the tolerance time is not exceed 20 seconds
	32 kW/m^2	During continuous combustion, the strength loss of steel structures exposed to fire (significantly reduced loading capacity)

4.2.6 The acceptance criteria of the shock wave pressure of explosion are to comply with the provisions of the following table.

Acceptance criteria of shock wave pressure of explosion

Table 4.2.6

	Damage corresponds to overpressure value （N/m^2）		**Damage type**
	Lower limit	Upper limit	
Explosion	250	4000	Glass window damaged
	5000	10000	Doors and coverings damaged and personnel injured
	15000	20000	Structures seriously damaged
	25000	50000	Personnel seriously injured

4.3 Qualitative Analysis

4.3.1 The qualitative analysis of alternative design for manifolds arrangement mainly includes risk identification and design casualty scenarios to determine the LNG leakage source and corresponding hazardous characteristics and casualty scenarios.

4.3.2 Risk identification is the use of standardized identification methods to identify all potential risk factors that may affect LNG handling or bunkering systems, and to find the causes and potential consequences of accidents. All identified risk factors and hazard characteristics are to be reviewed and explained in a form, and the hazard level of each risk is to be ranked. See ISC Guidelines for Application of Formal Safety Assessment to Ships.

4.3.3 Common analysis methods include hazard identification analysis (HAZID), Check-lists, What-If analysis, Failure Modes and Effects Analysis (FMEA), hazard and operability analysis (HAZOP), and task analysis. For a detailed introduction of the methods, see ISC Guidelines for Application of Formal Safety Assessment to Ships.

4.3.4 Appropriate risk identification methods are to be selected based on the specific conditions of alternative design. In general, where the available data and information are not sufficient, What-If analysis can be used; Where the specific design information is provided, FMEA and HAZOP methods can be used.

4.3.5 The risks to be considered in the assessment may include but are not limited to:

(1) Fire and explosion, including pool fire, flash fire, jet fire, explosion, etc.;

(2) Personnel operational errors;

(3) Extension of hazardous areas;

(4) Discharge of pressurized gas onto the shore;

(5) High pressure gas emissions;

(6) Due to the failure of LNG handling or bunkering piping systems, the continuous presence of liquid and vapor in the cargo, including pipeline damage and leakage, valve leakage, leakage at pipeline joints, etc.;

(7) Failure of handling during the ship to ship transferring, including failure of handing arms/hoses, detachment of connections, etc;

(8) Collision risk, including collision between two ships during berthing/mooring process; Contact between ships and docks during berthing/mooring process; collisions with adjacent passing vessels during ship operations.

4.3.6 In the actual ship environment, LNG handling or bunkering systems, ships and personnel constitute a very complex system, which may result in many LNG casualty scenarios. Alternative design cannot and does not need to evaluate all scenarios. Therefore, through risk identification, representative and high-risk casualty scenarios are selected.

4.3.7 Selection of casualty scenarios. Based on identifying all potential risk factors, casualty scenarios that require detailed quantitative analysis are to be selected according to the most unfavorable principle. All potential risks with reasonableness, severity and frequency are to be considered, and leakage accidents with high frequency and low risk, low frequency and high risk, and special circumstances are to be taken into account. For LNG carriers, it is usually necessary to consider LNG handling or bunkering leakage scenarios caused by design defects or personnel operation errors. Generally, where the probability of a leakage scenario being considered is less than 10^{-8}/year or the probability of death caused by a casualty scenario is less than 1%, this scenario may not be considered in subsequent risk analysis.

4.3.8 When designing the casualty scenarios, the initial event is to be determined first: this includes determining the location and leakage parameters of the LNG leakage source. The leakage process and consequences of different leakage accidents vary greatly. Determining the initial event of a leakage accident can guide the construction and hazard assessment of LNG casualty scenario event trees, and is also necessary for subsequent quantitative analysis.

4.3.9 In the initial event analysis of a leakage accident, the leakage rate is to be determined based on pressure, leakage size and the phase state of the leaked material (liquid, gas or gas-liquid two-phase), and then the leakage amount is to be determined based on the duration of the leakage. Whether the concentration of the gas cloud formed by the leaked gas exceeds its lower flammability limit (LFL) is crucial for determining the ignition of the leak. The leakage size can be defined according to the leakage aperture, and typical size definitions are shown in the following table.

Example of leakage size definition based on aperture **Table 4.3.9**

Leakage size	Range of aperture	Representative value
Small	Diameter: 3-10mm	10mm
Medium	Diameter: 10-50mm	50mm
Large	Diameter: 50-150mm	150mm
Broken	Diameter: >150mm	Diameter of pipeline

4.3.10 Determine the path factors of casualty scenario event tree: path factors are events that occur after the initial event, representing the conditional state and time effect. For LNG carriers, the conditions of LNG safety devices and various fire protection systems are usually to be selected as the path factors of the casualty scenario event tree.

Example of event tree path factors of casualty scenarios

Table 4.3.10

Safety system	Current conditions
Detection system	Normal work, abnormal work
Alarm system	Normal work, abnormal work
ESD system	Normal work, abnormal work
Fire extinguisher system	Success or failure of fire extinguishing
	Success or failure in controlling the scale of the fire
Fire division	Whether to achieve the designed separation effect or not

4.3.11 The casualty scenarios are to be clearly documented, including qualitative descriptions of the scenarios (such as initial and subsequent chain of events, location, etc.), description of the ship involved, compartment or system of origin, safeguard systems, etc. The casualty scenarios should consider possible future changes to the hazards (increased or decreased) in the affected areas.

4.4 Quantitative Analysis

4.4.1 All data and information generated in qualitative analysis, as well as the design casualty scenarios, are to be used as input parameters in quantitative analysis.

4.4.2 Each selected alternative design scheme is to be quantitatively analyzed based on the design casualty scenario to verify its compliance with performance criteria and safety margin requirements.

4.4.3 A complete quantitative analysis is generally to comply with the process shown in the following figure.

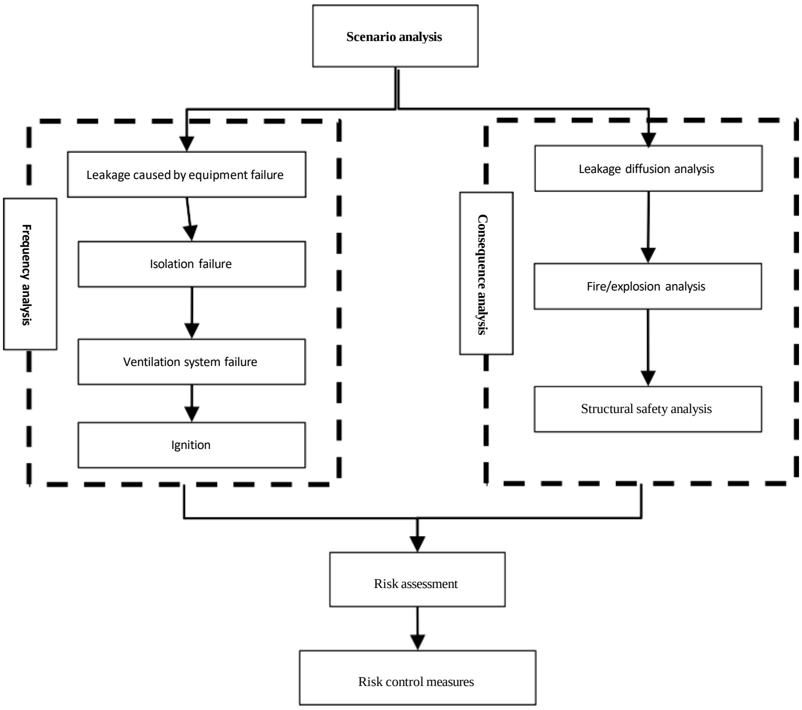


Fig. 4.4.3 Quantitative analysis process

4.4.4 The probability of failure is generally to be determined based on industry standard data, and the data sources including:

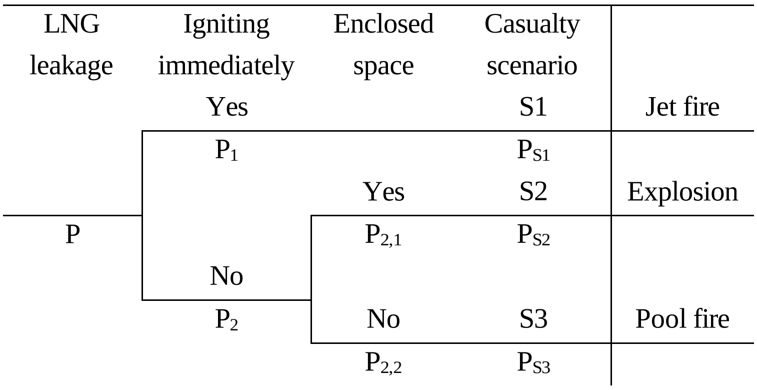
(1) Failure databases applicable to the LNG industry, such as the Dutch Quantitative Risk Assessment Purple Book Database, the International Association of Oil and Gas Producers Database, the UK HSE Database, the US Federal Energy Regulatory Commission Database, etc.;

(2) Historical statistical data, including previous failure/accident statistics of Administrations, industry organizations or shipping companies;

(3) Reliability based failure probability model;

(4) Other data sources.

4.4.5 Based on the failure of the initial leakage event, the probability of the event tree path factor is to be considered according to the established event tree, and the probability of the casualty scenario is finally to be calculated by the conditional probability of each branch event in the event tree. The example is as follows:



Where, the probability of casualty scenario 2 is as following:

$$P_{S2}=P\cdot P_2\cdot P_{2,1}$$

4.4.6 Quantitative analysis (CFD method) is to be carried out for accident consequences to determine the scope and extent of impact. Based on the actual situation of alternative design, LNG leakage and diffusion analysis, fire/explosion analysis, and/or structural safety analysis may be conducted for the accident consequence analysis.

4.4.7 Due to the fact that many simulation calculation software can be used for LNG leakage and diffusion analysis, as well as fire/explosion analysis, the calculation methods, models or software are to be used with the consent of ISC. Currently, the commonly used include FLACS, PHAST, Exfire, etc.

4.4.8 The accuracy of simulation calculation results strongly depends on the rationality of input data. Therefore, when conducting LNG leakage diffusion analysis and fire/explosion simulation, the basic parameters determined when designing the casualty scenario are to be used as input parameters and boundary conditions, including leakage volume, leakage direction, tank ventilation conditions, environmental wind speed and direction conditions, etc. These design conditions are to be described in the analysis report for ISC review.

APPENDIX   APPLICATION EXAMPLES

1   Alternative Design Case Study of Cargo Containment System

1.1   Overview

This case is an LNG carrier that uses a certain type of independent cargo tanks as the LNG cargo containment system. At the same time, the arrangement and design of the cargo tanks are carried out in accordance with the requirements of 2G type in 2.4, Chapter 2 of the IGC Code. This design and arrangement do not meet the relevant requirements developed by the Administration.

In response to the fact that the design and arrangement of cargo containment system for the target ship do not meet the prescriptive requirements, a risk-based alternative design method and evaluation is carried out to ensure that the intent (objectives and functional requirements) of the prescriptive requirements are met. Navigation safety risk identification is conducted to identify risk points and casualty scenarios around the navigation and operation scenarios of the target ship in complex navigation environments; Based on the alternative design scheme of the target ship type and cargo tanks, quantitative analysis of design casualty scenarios is carried out, corresponding safety technical measures and emergency plans are to be researched and formulated to ensure that the target ship operates with sufficient safety in the expected navigation environment and meets the safety objectives of navigation.

Considering that the design and arrangement of hull and cargo tanks of the ship have already met the relevant requirements of the IGC Code, this case does not further evaluate the limit state of the cargo containment system, but only considers the quantitative analysis of accidental casualty scenarios.

1.2   Performance Criteria

The safety objective of this case is to ensure the structural integrity of the cargo containment system, and the design objective is to ensure that the functionality and safety of the containment system do not fail in the event of casualty scenario. The corresponding performance criteria are to maintain the structural integrity of the inner shell longitudinal bulkheads.

1.3   Risk Identification

Based on the operating mode and navigation area of the target ship, the typical navigation scenarios of the ship are to be determined, including:

(1) Arrival and departure;

(2) River estuary;

(3) Waterway waters (including bridge waters, converging waters, crossing waters, narrow curved waters, straight waters and anchorage waters);

(4) Natural gas terminal.

Among them, waters with complex navigation conditions and frequent ship crossing activities, such as confluence waters, crossing waters and narrow curved waters, including navigation warning zones.

The risk identification of the target ship is firstly to determine which hazards may cause the hull to lose its watertight integrity, mainly including:

(1) Collision: being collided or colliding with other ship during navigation, including being

collided by other ship while anchoring;

(2) Contact: a possible impact on a floating or fixed object other than collision and grounding;

(3) Grounding: stranding, colliding with riverbanks or underwater objects;

(4) Fire: an accident that may occur with a fire as the initial trigger;

(5) Explosion: an accident that may occur with an explosion as the initial trigger.

Statistical analysis of accidents in the expected navigation waters of the target ship, and marking the accident locations as upstream midstream, and downstream, reveals that ship accidents have regional characteristics, with collision accidents occurring more downstream compared to upstream, and stranding accidents occurring more upstream compared to downstream. This is closely related to the water level and channel conditions in the upstream and downstream. Contacting and grounding are more prominent in the midstream, while fire/explosion accidents are less affected by the location of the accident, with a relatively even distribution in the upstream, midstream, and downstream.

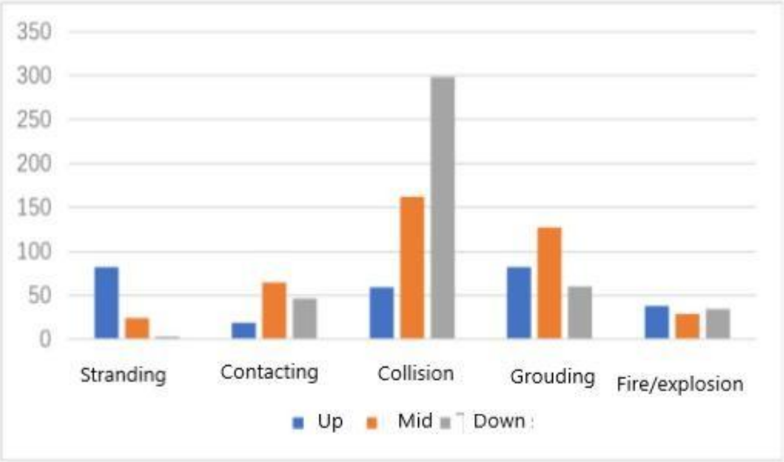


Fig. 1.3-1 Statistical analysis of accident types in the different areas

Further dividing the waterway into different water areas reveals that there are relatively more traffic accidents in the curved water area and the diverging water area.

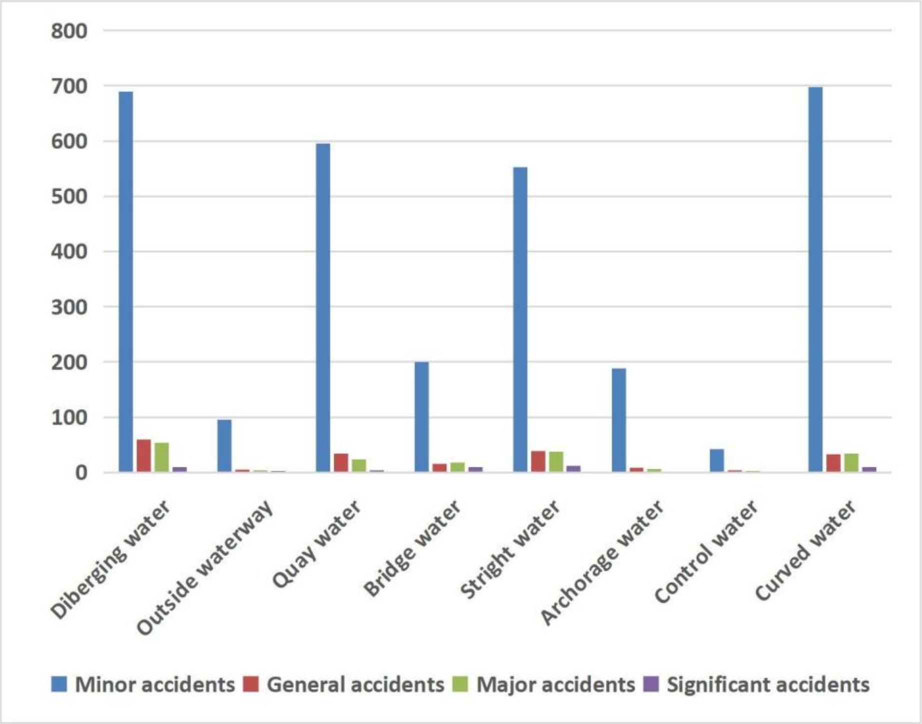


Fig. 1.3-2 Statistical analysis of accidents in the different waters

An evaluation team is established to carry out risk identification. The team includes experts in various appropriate professional fields, including senior masters and operational experts of LNG carriers, and ultimately forms a working mode of joint participation from all parties. The expert team comes from the following aspects:

(1) Designer/construction unit;
(2) Shipowner;
(3) Technical experts and masters;
(4) Administration;
(5) Coordinator/recorder.

The brainstorming meeting for risk identification focuses on discussing risk events, causes and consequences, as well as risk control measures in various navigation scenarios. It identifies risk sources in each navigation scenario, provides corresponding risk control measures, and proposes decision-making recommendations on relevant measures. These decision-making recommendations involve ship design, construction, operational safety management, etc., effectively improving the navigation safety level of ships.

Risk identification worksheet (Partial) Table 1.3-1

Navigation scenario	Event	Cause	Probability	Consequence	Severity		Risk level		Existing safety measures	Recommendation
					Ship	personnel	Ship	personnel		
Crossing waters	Collision with a ferry carrying passengers and vehicles	Human factors: lack of observation, insufficient skills, illegal navigation, improper collision prevention measures, poor communication, inconsistent collision prevention intentions	3	Damage to ships/ equipment; Natural gas leakage; Fire/explosion; Personnel falling into the water, casualties; Water pollution; Blocking the waterway; Water ingress/ capsizing /sinking; Vehicles onboard the other ship falling into the water/casualties occurred	3	3	6	6	1. Double hull 2. High reserve buoyancy 3. High redundancy of the propeller system 4. Sufficient longitudinal strength 5. Warning signals of lights/shapes 6. ISM/NSM management systems 7. Relevant requirements of the Administration - Regulations on Ship Routing System 8. Compulsory pilotage 9. Insulation of the cargo containment system is arranged on independent tanks (which can significantly reduce the possibility of damage to the insulation caused by hull damage) 10. Double propeller full azimuthing + bow thruster	1. Add intelligent navigation function 2. Add CCTV 3. Personnel specialized skills training (certificates) 4. Strengthen the bridge resource management 5. Strengthen communication and unify the ship avoidance intentions
		Other ship factors: Other ship' s illegal navigation, , not maintaining a safe distance, and failing to maintain a safe speed	2		4	4	6	6		
		Ship: Generator/rudder propeller/bow thruster malfunction	1		2	2	3	3		
		Environment: ship flow, restricted navigable waters, visibility, severe extreme weather, wind, waves, currents, water levels/ tides, etc	1		2	2	3	3		

The summary of the evaluation results is shown in the following table.

Risk identification result statistics Table 1.3-2

Navigation scenario	Number of risks	Number of recommendations on improvement
Arriving or departing ports	16	23
River estuary	8	11
Bridge waters	5	10
Converging waters	4	5
Crossing waters	4	5
Narrow curved waters	8	11
Straight waters	4	5
Anchorage waters	5	10
Natural gas terminal	7	14

Navigation scenario	Number of risks	Number of recommendations on improvement
Total	**61**	**94**

1.4 Design casualty scenarios

Through risk identification, it is determined that the target ship has the highest risk of transverse collision in the crossing waters. Therefore, a 90 degree collision between the target ship and a ferry carrying passengers and vehicles is selected as the design casualty scenario.

Based on the investigation of the ferry carrying passengers and vehicles in the crossing water, a certain ship with the maximum tonnage is selected as the colliding ship, and the ship type parameters are omitted. Full load and ballast are typical loading conditions for LNG carriers. Due to the scarcity of LNG cargo onboard during ballast navigation, only the consequences of collision accidents when the ship is fully loaded with LNG cargo are considered. According to the loading manual, the loading condition with the maximum displacement at full load is selected as the most dangerous assessment condition, and the details of loading condition are omitted.

1.5 Quantitative analysis

Quantitative analysis is carried out for the consequences of collision accidents based on the design casualty scenario. For the simulation calculation of collision accidents, this analysis adopts the method of rigid body and elastic body collision to determine the elastic-plastic deformation and damage of the target ship during the impact process. This method assumes that the impact kinetic energy during the collision process is completely absorbed by the elastic-plastic deformation of the target ship, so the damage to the collided ship is more severe and is generally considered the most conservative method.

A finite element model is established based on the bow shape of the colliding ship, as shown in the following figure. The velocity of the colliding ship is taken as the design speed of 8 knots, and the added water mass is set by taking the consideration of the dynamic influence of the surrounding fluid medium on the collision.

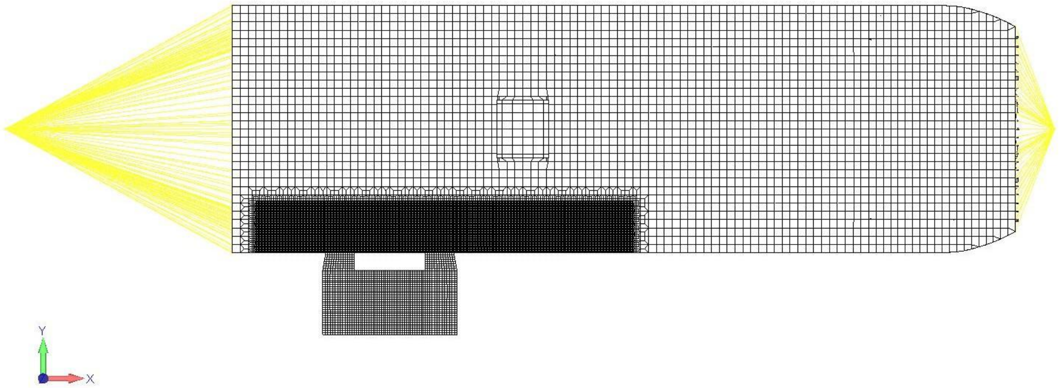


Fig. 1.5-1 Collision analysis model

The following figure shows the variation curves of the velocities of the colliding ship and the target ship over time. It can be seen from the figure that as the collision progresses, the velocity of the colliding ship decreases sharply, while the velocity of the target ship gradually increases. The rate of velocity change of both ships is directly related to their own mass. At around 0.5s, the velocities of the two ships is equal, and then the velocities of the two ships continue to change. Around 0.58s, the velocity direction of the colliding ship changes, indicating that the colliding ship is completely ejected, without further collision contact between the two ships.

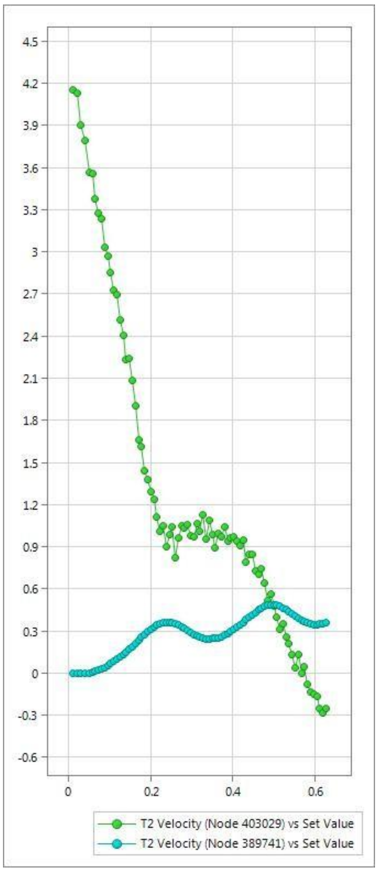


Fig. 1.5-2 Velocity changes during the collision of two ships (green represents the velocity of the colliding ship, blue represents the velocity of the target ship, in m/s)

The following figure shows the structural deformation and stress distribution of the shell plating in the final collision state (0.6275s). It can be seen from the figure that the shell plating within the collision area has been torn and damaged (as indicated by the red box in the figure).

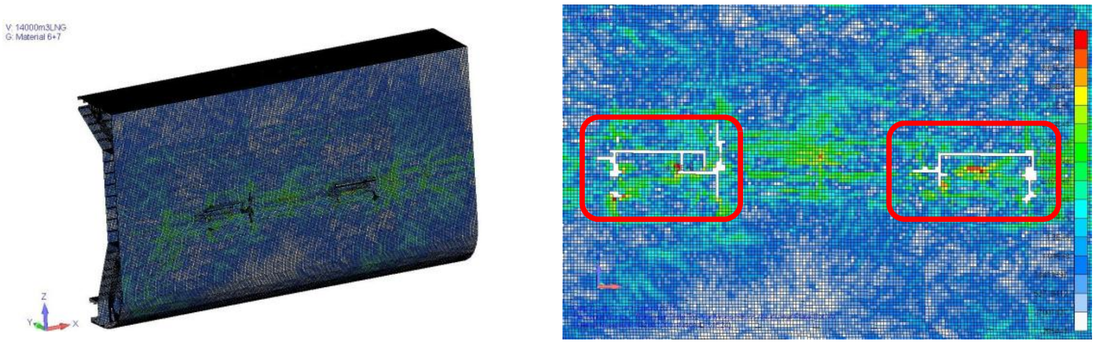


Fig. 1.5-3 Damage to the shell plating of the target ship in the final collision state

Fig. 1.5-4 shows the structural deformation and stress distribution of the inner shell longitudinal bulkheads after collision. From the figure, it can be seen that the longitudinal bulkhead of the inner shell still maintains its structural integrity after collision, without causing any damage to the LNG cargo tank.

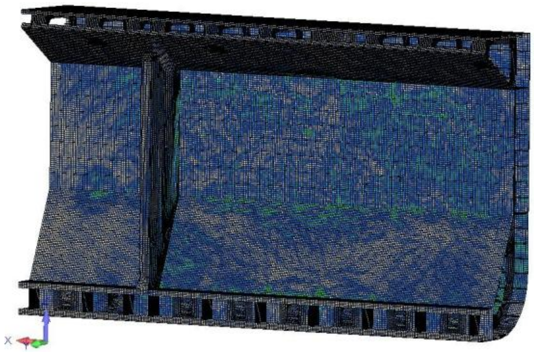


Fig. 1.5-4 The inner shell longitudinal bulkhead of the target ship remains intact in the final collision state

1.6 Conclusions

This case takes a certain LNG carrier as the research object, identifies the risks in the entire navigation scenario of the ship, and determines that the collision between crossing ferry carrying passengers and vehicles is the biggest risk source for the carrier. A representative ferry carrying passengers and vehicles is selected as the collided object, assuming that the colliding ship has a design velocity of 8 knots and collides with the side structure at a 90 degree angle as the casualty scenario. Quantitative calculations is conducted on the collision accident of the ship during full load navigation, analyzing the dynamic response of the structure and evaluating the extent of structural damage. The results shows that for the collision scenario between the ship and the ferry carrying passengers and vehicles in crossing waters, the transverse collision only causes certain damage to the shell plating of the target ship, and does not damage the integrity of the inner shell structure and LNG cargo tanks, proving the collision safety of the ship sailing in the target waters and meeting the target safety navigation requirements of the Administration for LNG carriers.

2 Alternative Design Case Study of Manifolds Arrangement

2.1 Overview

This case is an LNG carrier. A safety risk assessment is carried out for the LNG manifolds arrangement to determine the leakage casualty scenario based on qualitative analysis, and determine the range of combustible gas impact area after LNG leakage in the manifolds based on quantitative calculation, in order to evaluate whether it has an impact on the design and arrangement (such as fire class) of manned spaces, such as superstructures, etc.

The target ship is equipped with an LNG handling or bunkering system, which is provided with ERC/QCDC and low-temperature hoses. The main equipment is as follows:

(1) Hydraulic power unit;

(2) VSD: vessel distance detection;

(3) QCDC: quick connect disconnect coupling;
(4) ERC: emergency release coupling;
(5) Saddle with anti-fall device.

Pipeline connection sequence: fixed pipe manifolds of LNG handling or bunkering terminal → emergency release device → hose → quick connector → fixed pipe manifolds of LNG receiving terminal, which are all connected by flanges.

2.2 Performance criteria

The safety objective of this case is to ensure the structural integrity of the front bulkhead facing the manifolds, and the design objective is to ensure that the functionality and safety of the front bulkhead spaces do not fail in the event of a casualty scenario. The corresponding performance criteria are that the vapor cloud diffusion concentration at the front bulkhead spaces is less than 2.5% (50% of the lower limit of methane combustion).

2.3 Risk identification

According to the LNG handling process, risk identification is divided into the following nodes:

(1) Preparation prior to the operation;
(2) Connection of communication system;
(3) Connection of VSD;
(4) Connection of LNG handling or bunkering system;
(5) Inerting of LNG handling or bunkering pipelines;
(6) Tightness testing;
(7) Hot ESD testing;
(8) Pre-cooling of LNG handling or bunkering pipelines;
(9) ERS testing;；
(10) Cold ESD testing;
(11) LNG handling or bunkering process;
(12) Purging and inerting of pipelines;
(13) Disconnection of pipelines.

An evaluation team is established to carry out risk identification, and obtain the risk identification worksheet of LNG handling or bunkering operation (partial), which is shown as following.

Risk identification worksheet **Table 2.3**

Operation step	Hazardous event	Cause	Probability	Consequence	Severity		Risk level		Recommendation
					Personnel	Ship	Personnel	Ship	
LNG handling or bunkering process	LNG leakage	Hose rupture	1	Ship damage; Personnel casualty; Fire/explosion	4	4	5	5	1. Hose inspection; 2. Emergency response plan; 3. Emergency communication between ships
		Flange interface leakage	2	Interruption of operation; Personnel frostbite	2	2	4	4	1. Tightness testing
		Leakage of the instrument pipeline of bunkering ship	2	Interruption of operation; Personnel frostbite; Fire/explosion	3	3	5	5	1. Personnel protection measures 2. Clearly identify safe areas 3. Follow the operating procedure
	Steam reflux - insufficient flow rate	High tank pressure of bunkering ship	2	Decreased bunkering speed	1	1	3	3	1. Control the tank pressure prior to operation
	Steam reflux - excessive flow rate	Depressurization system of bunkering ship malfunction	2	Decreased LNG handling or bunkering speed; Interruption of LNG handling or bunkering	1	1	3	3	1. Strengthen equipment maintenance

2.4 Design casualty scenarios

Based on risk identification, this case uses leakage-based frequency to determine the location and rate of LNG leakage.

LNG leakage scenario **Table 2.4**

No.	Description of scenario	Detection time T_1	Emergency release time T_2	Valve closing time T_3	Safety factor	Duration T	Wide direction
1	Leakage of liquid phase hose, with a leakage aperture of 50mm	35s	5s	20s	1.5	90s	Astern
2	……						

2.5 Quantitative analysis

LNG leakage scenarios is simulated by the three-dimensional computational fluid dynamics software - FLACS. This software can be used to simulate ventilation, toxic gas diffusion, vapor cloud explosion and shock waves in complex buildings and production areas. FLACS has multiple sub-modules including gas diffusion, fire, explosion and ventilation, and has been widely used in risk assessment in the global oil and gas industry.

The three-dimensional model of the ship is shown in the following figure.

Fig. 2.5 CFD calculation model

2.6 Vapor cloud diffusion results

According to calculations, when the wind direction blows along the stern of the ship, the farthest leakage points of the combustible vapor cloud are 28m. Considering that the distance between the manifolds and the front bulkhead of superstructure is about 55m, in the design casualty scenario, combustible gas will not diffuse to the superstructure area in the event of a leakage accident in the manifolds.

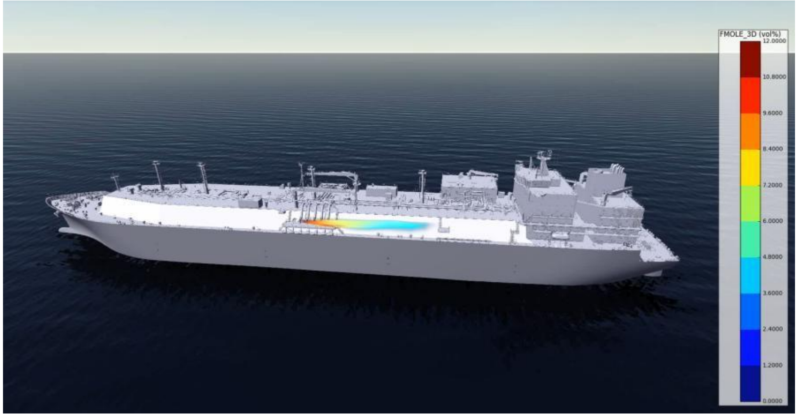


Fig. 2.6-1 Diffusion of vapor cloud after jet leakage

Considering the presence of a certain ignition source within the diffusion range of combustible vapor clouds in the manifolds, LNG leakage jet fire calculation is to be further carried out, as shown in Fig. 2.6-2. The calculation results indicate that the temperature at the front bulkheads of the superstructure is much lower than 60 ℃, and the received thermal radiation intensity is also much lower than 2.5kW/m^2.

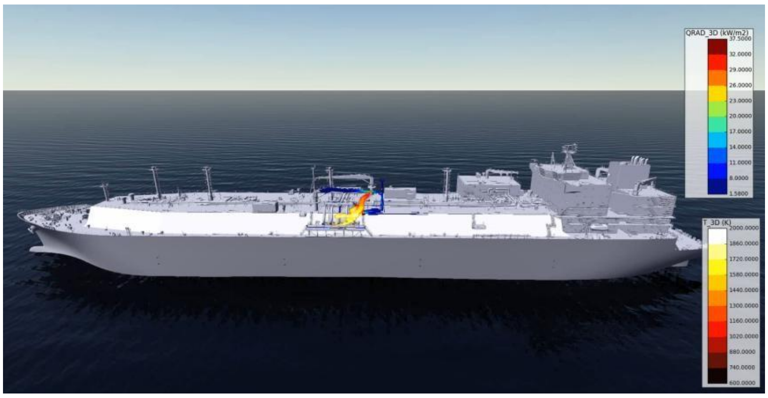


Fig. 2.6-2 Fire diffusion after jet leakage

2.7 Conclusions

This case takes a certain LNG carrier as the research object, analyzing the impact of the design and arrangement of the manifolds on the superstructure. In qualitative analysis, risk identification is carried out on the design and arrangement of the manifolds, and LNG leakage is identified as the maximum risk source for the ship. A representative liquid-phase hose leakage (with a leakage aperture of 50mm) is selected as the design casualty scenario. In quantitative analysis, the LNG leakage accident in the manifolds is quantitatively calculated, and the diffusion of LNG vapor cloud and fire hazards after the leakage are analyzed. The results show that under the design casualty scenario, the combustible gas in the manifolds will not diffuse to the superstructure in the event of a leakage accident, and the temperature at the front bulkheads of the structure is much lower than 60 ℃, and the received heat radiation intensity is also much lower than 2.5kW/m^2, which meets the relevant requirements of performance criteria, so that the arrangement of the manifolds meets the corresponding safety objectives.

ANNEX 1 APPLICATION FORM OF ALTERNATIVE DESIGN

Ship’s Particulars	Name of ship: Principal dimension: Hull structure: Main equipment: Navigation area:
Related background and necessity	
Scope of application	
Applicable prescriptive requirements	
Attachment	

Note: If the relevant content is not sufficient to fill in, please attach another page.

Submitter: ________ （Signature/stamp）

_________(YY)_______(MM)_______(DD)

ANNEX 2 APPROVAL FORM OF ALTERNATIVE DESIGN

THE APPROVAL OF ALTERNATIVE DESIGN AND ARRANGEMENTS FOR

..

Issued in accordance with provisions of.., under the authority of the Maritime Safety Administration of the People's Republic of China by ………..……………………………….……….

Name of ship: __________________________

Port of registry: ___________________________

Type of ship: ___________________________

IMO No.: ___________________________

(1) Scope of the analysis or design, including the critical design assumptions and critical design features;

(2) Description of the alternative design and arrangement;

(3) Approval conditions, if any:

(4) List of convention regulations affected;

(5) Summary of the engineering analysis results and approval basis, including performance criteria and design casualty scenario;

(6) Test, inspection and maintenance requirements;

(7) Drawings and specifications of alternative design and arrangement.

Issued at .... on ....

....

(Signature of authorized official issuing the certificate)

(Seal or stamp of issuing authority, as appropriate)