

GUIDE FOR

VESSELS INTENDED TO CARRY COMPRESSED NATURAL GASES IN BULK APRIL 2005

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GUIDE FOR

VESSELS INTENDED TO CARRY COMPRESSED NATURAL GASES IN BULK

APRIL 2005 (Updated February 2017 – see next page)

**American Bureau of Shipping
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Foreword

1 Introduction

ABS has been requested by various designers to review their proposed design scenarios for the transportation of compressed natural gas (CNG) by sea. The proposed CNG carrier designs considered thus far are considered somewhat novel in that they differ from any one of the vessels that are currently transporting methane by sea, not only in that the methane will not be transported as a cryogenic liquid, LNG, but also in several key areas, including the following:

- Pressure and temperature of the cargo being carried
- Possible storage of cargo above the main deck
- Proposed method for loading and off-loading the cargo
- Proposed deviations from the IMO Gas Code factors of safety for hoop stress in independent Type B and C tanks.

This Guide provides requirements for design, construction and periodic surveys required for maintenance of classification that would be applicable to CNG carriers, where it is intended to obtain ABS class for the vessels. These requirements may also serve to satisfy Port State and Flag State Regulations as they develop. As these projects are still at the concept stage and various scenarios are being considered at this time, the objective will be to establish an overall philosophy or approach to provide a framework of reference material and cite precedence, where applicable, as to what methodologies followed by designers in similar projects have proven successful in the past.

While it is certainly not the intent of ABS to in any way prevent or stifle creative development of new ideas and concepts, ABS will point out where a proposal appears to go beyond the bounds of what has been accepted practice in the past. In such cases, ABS will provide the designer with a list of steps considered necessary to establish that such a proposal, in fact, does not compromise the level of safety well established in the published Rules of the American Bureau of Shipping and those of applicable national and international Regulatory bodies.

2 Applicability of Existing ABS Rules and Regulatory Requirements for LNG Carriers to CNG Carriers

It is recognized that the ABS “Rule Requirements for Vessels Intended to Carry Liquefied Gases in Bulk” (Part 5C, Chapter 8 of the *ABS Rules for Building and Classing Steel Vessels*), which is in full agreement with the IMO IGC Code, do not envisage the carriage of Compressed Natural Gas (CNG) as compared to LNG. However, it is considered that that these requirements are an excellent starting point for ABS as a Classification Society seeking to establish requirements for the safe transport of CNG by sea. Also, IMO Guidelines for Formal Safety Assessment (FSA) for use in the IMO Rule-Making Process, MSC/Circ. 1023, MEPC/Circ., should be used to qualify such a novel concept.

Some of the hazards applicable to LNG carriers, such as methane vapor release, fire, explosion, toxicity, collision and grounding, would also be applicable to CNG carriers. However, there are a number of additional hazards or possible increased risk from the same hazards due to the differences identified in Paragraph 1 above. These would include the following;

- While there is no cryogenic liquid being transported or handled, the possibility of critical structure being exposed to low temperatures from impingement of auto-cooled escaping gas must be provided for in the design.
- While the existing requirements for LNG carriers establish hazardous areas around potential sources of gas release, it will be required that a gas dispersion analysis be carried out to demonstrate that areas normally considered gas safe will not be engulfed during a venting or blow-down of high pressure gas or during an upset condition. Depending on the results of the gas dispersion analysis, a vessel Emergency Shut-down system may be required to protect against the migration of methane gas into spaces normally containing a source of vapor ignition.

- While a gas detection system in the cargo holds warns of a gas leak, since the gas is stored at high pressure in containers in cargo holds, a rapid gas release due to container or piping system failure could result in an overpressure condition in the cargo hold jeopardizing the integrity of the vessel's hull. Accordingly, overpressure protection for cargo hold spaces should be provided. The relief devices should have sufficient capacity to handle a rupture of the largest cargo tank, assuming rupture at any location. In addition to these relief devices, hatches shall be provided in each hold space cover. Discharge from the hold spaces shall be routed to a safe location.
- While the IMO Gas Code includes requirements for active and passive fire protection systems applicable for liquid methane fires, it does not envisage a high pressure (jet) fire which could result from the ignition of a high pressure gas flow from a ruptured pipe. Accordingly, means to protect against such an occurrence will be required to be demonstrated for CNG carriers.

Regarding the appropriate application of the requirements of Chapters 2 and 3 of the IGC Code to the damage assumptions and segregation of the cargo area, please note that in accordance with Chapter 19 of the IGC Code, a vessel transporting methane is required to comply with the requirements for a type 2G ship, or 2PG if of 150 meters in length or less, as defined in 2.1.2 of the Code. Accordingly, ABS would consider the same to be applicable for the CNG carriers.

3 Flag State Requirements

ABS cannot speculate with regard to the requirements that would be applied to the proposed CNG carrier concept by an Administration. ABS can, however, offer the following insights based on the knowledge of past practices and the workings of the IMO Organization.

- i) Since the IMO IGC Code became effective in 1975, it has been adopted and implemented by almost every maritime nation in the world and since that time virtually all of the LNG and LPG cargos that have been transported have been carried in vessels in full, or at least substantial, agreement with the Code.
- ii) While the transportation of natural gas in a gaseous state rather than a liquid state was never envisaged by the IMO IGC Code, it would be reasonable to assume that any Administration signatory to the IGC Code, such as the United States, would seek to establish some level of compliance with the Code, at least as a starting point or frame of reference.
- iii) The LNG community is a relatively small community that meets in various forums such as SIGTTO (Society of Gas Tanker and Terminal Operators) and exchanges information readily. This community takes great pride in the fact that there has never been a major LNG incident at sea. Owners and operators of gas carriers and terminals can influence their respective Flag States and they should be expected to rightfully demand that there be no reduction in overall safety as a result of this new means of transporting natural gas.
- iv) Reliability-based engineering and other methodologies have not been used heretofore to justify designs in the marine community, so many Administrations may not initially be prepared to consider designs that significantly differ from what has been done in the past on the basis of such studies. Administrations that are "Coastal States" for offshore activities may be more familiar with reliability-based engineering methods.
- v) Paragraph 1.4 of the IGC Code provides for Equivalents, which gives certain latitude toward the acceptance of alternative provisions, procedures or arrangements if such has been determined to be not less effective.



GUIDE FOR

VESSELS INTENDED TO CARRY COMPRESSED NATURAL GASES IN BULK

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CHAPTER 1 Scope and Conditions of Classification (Supplement to the ABS Rules for Conditions of Classification)

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CHAPTER 1 Scope and Conditions of Classification

Foreword (1 January 2008)

For the 2008 edition, Chapter 1, “Scope and Conditions of Classification” was consolidated into a generic booklet, entitled *Rules for Conditions of Classification (Part 1)* for all vessels other than those in offshore service. The purpose of this consolidation was to emphasize the common applicability of the classification requirements in “Chapter 1” to ABS-classed vessels, other marine structures and their associated machinery, and thereby make “Conditions of Classification” more readily a common Rule of the various ABS Rules and Guides, as appropriate.

Thus, Chapter 1 of this Guide specifies only the unique requirements applicable to vessels intended to carry compressed natural gases in bulk. These supplemental requirements are always to be used with the aforementioned *Rules for Conditions of Classification (Part 1)*.



CHAPTER 1 Scope and Conditions of Classification

SECTION 1 Classification *(1 January 2008)*

The requirements for conditions of classification are contained in the separate, generic *ABS Rules for Conditions of Classification (Part 1)*.

Additional requirements specific to vessels intended to carry compressed natural gases in bulk are contained in the following Sections of this Chapter.



CHAPTER 1 Scope and Conditions of Classification

SECTION 2 Classification Symbols and Notations (1 January 2008)

A listing of Classification Symbols and Notations available to the Owners of vessels, offshore drilling and production units and other marine structures and systems, "List of ABS Notations and Symbols" is available from the ABS website "<http://www.eagle.org/absdownloads/index.cfm>".

The following notations are specific to vessels intended to carry compressed natural gases in bulk.

1 Class Notations

In accordance with 1-1-3/3 of the ABS *Rules for Conditions of Classification (Part 1)*, the classification notation **✠ A1 Compressed Natural Gas Carrier** is to be assigned to vessels designed and specifically fitted for the carriage of Gas and built to the requirements of this Guide and other relevant Sections of the Rules.

These requirements are intended to apply to steel vessels with machinery aft regardless of their size, including those of less than 500 tons gross tonnage, engaged in carriage of gas.

The requirements relating to the primary container apply only to Compressed Natural Gas. If the cargo composition carried in primary container has a presence of contaminants, these must be evaluated and additional measures will be required and are not covered in this Guide. When there is a presence of contaminants, the scantlings may need to be suitably increased or an effective method of corrosion control is to be adopted and the design assessed for their effects.

This Guide applies to the cargo containment system and related systems. The remainder of the vessel is to comply with the hull and machinery requirements of the Rules, except as modified in this Guide.

CNG carriers that have been built, installed and commissioned to the satisfaction of the ABS Surveyors to the full requirements of this Guide, where approved by the Committee, will be classed and distinguished in the ABS *Record* by:

✠ A1 Compressed Natural Gas Carrier

2 CNG Carriers not Built Under Survey

The symbol "✠" (Maltese-Cross) signifies that the vessel was built, installed and commissioned to the satisfaction of the ABS Surveyors. CNG carriers and their equipment that have not been built under ABS survey, but which are submitted for classification, will be subjected to special consideration. Where found satisfactory and thereafter approved by the Committee, it will be classed and distinguished in the *Record* by the notation described above, but the symbol "✠" signifying survey during construction will be omitted.



CHAPTER 1 Scope and Conditions of Classification

SECTION 3 Rules for Classification (1 January 2008)

1 Application of Rules

This Guide contains provisions for the classification of CNG carriers. This Guide is intended for use in conjunction with the *Steel Vessel Rules* or other applicable ABS Rules and Guides.

3 Alternatives

The Committee is at all times ready to consider alternative arrangements and designs which can be shown, through either satisfactory service experience or a systematic analysis based on sound engineering principles, to meet the overall safety, serviceability and strength standards of the Rules and Guides. The Committee will consider special arrangements or design for details of CNG carriers and their equipment which can be shown to comply with standards recognized in the country in which the CNG carrier and its equipment are designed or built, provided these are not less effective.

Any departure from the requirements of this Guide may be considered by ABS. In case of such departures, classification is subject to ABS's approval upon a demonstration of fitness for purpose in line with the principles of ABS Guides and Rules, as well as recognized and generally accepted good engineering practice. Risk acceptance criteria are to be developed in line with the principles of the ABS Rules and subject to ABS's approval. The *ABS Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries* contain an overview of risk assessment techniques and additional information.

A risk approach justification of alternatives may be applicable either to the CNG carrier as a whole or to individual systems, subsystems or components. As appropriate, account must be given to remote hazards outside the bounds of the system under consideration. Such account must include incidents relating to remote hazards directly affecting or being influenced by the system under consideration. ABS will consider the application of risk-based techniques in the design of the CNG carrier, verification surveys during construction and surveys for maintenance of class.

Portions of the CNG carrier not included in the risk assessment are to comply with the applicable parts of the ABS Rules.

The following are the responsibility of the Owner/Operator:

- i) Risk acceptance criteria
- ii) Hazard identification
- iii) Risk assessment
- iv) Risk management
- v) Compliance of the system under consideration with the applicable requirements of Flag and Coastal State



CHAPTER 1 Scope and Conditions of Classification

SECTION 4 Submission of Data

The following plans, calculations and information, as appropriate, are to be submitted in addition to those required by Section 1-1-7 of the [ABS Rules for Conditions of Classification \(Part 1\)](#).

- i) Full particulars of the intended cargo or cargoes and their properties, including maximum temperature and loading and carriage procedures.
- ii) General arrangement plans of the vessel showing the position of the following:
 - Cargo containment system, cargo tanks, fuel oil, water ballast and other tanks and void spaces
 - Openings in the cargo tanks and holds.
 - Doors and other openings in spaces containing cargo handling systems and equipment and other gas-dangerous rooms
 - Ventilation ducts of cargo pump and compressor rooms and other “gas-dangerous” spaces
 - Door, air locks, manholes, ducts and other openings for “non-gas-dangerous” spaces which are, however, adjacent to the cargo area, including rooms inside and under the forecastle deck
 - Cargo piping, loading and discharge located under and above deck
 - Vent piping and gas-freeing piping and protective devices such as flame screens, etc. fitted at the outlet end of the vents etc.
 - Gas-dangerous spaces
 - Cargo process area layout
 - Mooring system arrangements
- iii) Plans of the hull structure in way of the cargo tanks, including the installation of attachments, accessories, internal reinforcements, saddles/skirts for support and tie-down devices.
- iv) Plans of the structure of the cargo containment system, including the installation of attachments, supports and attachment of accessories
 - For cargo tanks, the standard or Code adopted for the construction and design is to be identified.
 - Detailed construction drawings together with design calculations for the pressure boundary, tank support arrangement and analysis for the load distribution.
 - Anti collision, anti flotation, chocking arrangement and design calculations.
- v) Distribution of the grades and of the types of steel proposed for the structures of the hull and of the cargo containment system, including attachments, accessories, etc., together with the calculation of the temperatures on all the structures which can be affected by the low temperatures of the cargo and Joules-Thompson effect
- vi) Results of direct calculations of the stresses in the hull and in the cargo containment system
- vii) Specifications and plans of the thermal protection system and calculation of the heat balance
- viii) Procedures and calculations of the cooling-down, warm-up, loading and unloading operations

- ix) Loading and unloading systems, venting systems and gas-freeing systems, as well as a schematic diagram of the remote controlled valve system
- x) Details and installation of the safety valves and relevant calculations of their relieving capacity
- xi) Details and installation of the various monitoring and control systems, including the devices for measuring the level of the cargoes in the tanks (if applicable) and the temperatures/ pressure in the containment system
- xii) Schematic diagram of the ventilation system, indicating the vent pipe sizes and height of the openings above the main deck
- xiii) Schematic diagram of the refrigeration system (if applicable) together with the calculations concerning the refrigerating capacity
- xiv) Details of the electrical equipment installed in the cargo area and of the electrical bonding of the cargo tanks and piping
- xv) Where fitted, plans and specifications relative to the use of the cargo as fuel for boilers and internal combustion engines (general installations; schematic diagram of the fuel-gas lines with the indication of all the valves and safety devices; compressors of the fuel gas and relevant engines; fuel-gas heaters and pressure vessels; installation of the burners of the fuel-gas and of the fuel oil; electrical bonding systems)
- xvi) Details of testing procedures of cargo tanks and process systems
- xvii) Diagram of inert-gas system or hold-space environmental-control system
- xviii) Diagram of gas-detection system
- xix) Blowdown and jettison arrangements, if provided
- xx) Schematic-wiring diagrams
- xxi) Details of all cargo, process and gas handling equipment
- xxii) Details of fire extinguishing systems
- xxiii) Welding procedures
- xxiv) Emergency shutdown provisions and arrangements
- xxv) Construction details of components of cargo handling systems, including material specification.
- xxvi) Hazardous area drawing showing access, openings, vent outlets.
- xxvii) Bilge and ballast arrangement for the cargo area.
- xxviii) Emergency Towing Arrangement.
- xxix) If gas processing is done onboard the vessel, then plans, calculations and information as listed in Chapter 3, Section 2 of the ABS *Rules for Building and Classing Facilities on Offshore Installations* are to be submitted, as appropriate
- xxx) If loading and unloading is done by providing Single Point Mooring system by internal or external turret system, please refer to ABS *Rules for Building and Classing Single Point Moorings* for detailed requirements
- xxxi) **Cargo Containment Survey Plan (see 17-2/1)**



CHAPTER 1 Scope and Conditions of Classification

SECTION 5 Hazards

Hazards considered in this Guide are fire, corrosion, temperature, and pressure.



CHAPTER 1 Scope and Conditions of Classification

SECTION 6 Conditions for Survey After Construction (1 January 2008)

See Sections 7-3-2 and 7-6-2 of the *ABS Rules for Survey After Construction (Part 7)* for survey requirements for vessels in service intended to carry liquefied gases. See also Section 1-1-8 of the *ABS Rules for Conditions of Classification (Part 1)* for requirements for conditions for surveys after construction. The following requirements are specific to vessels carrying compressed natural gases in bulk.

1 Temporary Installation, Maintenance, Modification, Repair or Replacements

ABS is to be notified of the Owner's intention to install temporary equipment or machinery that can affect the safety or intended functioning of the system. Depending on circumstances, ABS may require design review, surveys and individual certification of such equipment or machinery.

Where a major modification or replacement is made to the structure, equipment or machinery of the CNG carrier, ABS is to be notified and the applicable requirements of this Guide are to be met.



CHAPTER 1 Scope and Conditions of Classification

APPENDIX 1 Definitions

Except where expressly provided otherwise, the following definitions apply to this Guide. Additional definitions are given in Chapter 5.

1 Accommodation Spaces

Accommodation Spaces are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, barber shops, pantries containing no cooking appliances and similar spaces. *Public Spaces* are those portions of the accommodation which are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

2 'A' Class Divisions

'A' *Class Divisions* means divisions as defined in regulation II-2/3.3 of the 1983 SOLAS amendments.

3 Administration

Administration means the Government of the State whose flag the ship is entitled to fly.

4 Port Administration

Port Administration means the appropriate authority of the country in the port of which the ship is loading or unloading.

5 Blow Down

Blow Down is depressurizing or disposal of a pressurized cargo inventory from a cargo tank, process vessels, cargo and process piping in a controlled manner via the vent system.

6 Boiling Point

Boiling Point is the temperature at which a product exhibits a vapor pressure equal to the atmospheric pressure.

7 Breadth

Breadth (B) means the maximum breadth of the ship, measured amidships to the molded line of the frame in a ship with a metal shell and to the outer surface of the hull in a ship with a shell of any other material. The breadth (*B*) is to be measured in meters.

8 Cargo Area

Cargo Area is that part of the ship which contains the cargo containment system and cargo handling systems and equipment and includes deck areas over the full length and breadth of the part of the ship over the above-mentioned spaces. Where fitted, the cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space are excluded from the cargo area.

9 Cargo Containment System

Cargo Containment System is the arrangement for containment of cargo including, where fitted, thermal protection, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements.

9.1 Containment System Component

Containment System Component is the CNG Cargo Tank (see 1-A1/13) and its support. This includes individual cargo cylinders, associated manifold piping up to first stop valve and support.

10 Cargo Control Room

Cargo Control Room is a space used in the control of cargo handling operations and complying with the requirements of Chapter 4, Section 4.

11 Cargo – Compressed Natural Gas

Compressed Natural Gas constituents are Methane, Natural Gas Liquids (ethane, propane, butane, pentane, etc), water, carbon dioxide, nitrogen and other non-hydrocarbon contaminants. CNG that is transported is to have the water, carbon dioxide, nitrogen and other contaminants removed and are pipeline quality where no additional treatment is done prior to delivery to the pipeline. *Cargo* is the various compositions of natural gas that will be carried.

12 Cargo Service Spaces

Cargo Service Spaces are spaces within the cargo area used for workshops, lockers and storerooms of more than 2 m² in area, used for cargo handling equipment.

13 Cargo Tank

A *Cargo Tank* is all pressurized equipment up to the cargo tank first stop valve of a cargo containment system that stores compressed gas within cargo holds. *Cargo Tank* includes the storage container and associated manifold piping up to first stop valve. Cargo tanks can be either coiled type or multiple cylinder type, as defined below:

- i) *Coiled Cargo Tank* is a long continuous coiled pipe inside the cargo hold supported independently up to first stop valve.
- ii) *Cylindrical Cargo Tank* is an assembly of multiple individual cargo cylinders connected by a common manifold and supported individually inside the cargo hold up to first stop valve.

13.1 Cargo Cylinder

Cargo Cylinder is an individual pressure vessel for storage of CNG.

13.2 Cargo Tank Piping

Cargo Tank Piping is the piping manifolds connecting main pressurized components of the cargo tank and the cargo tank first stop valve, i.e., headers connecting the cargo cylinder, coselle, etc. Cargo tank piping is within the cargo hold and there should be no valve or flow-restricting devices.

13.3 Cargo Tank First Stop Valve

Cargo Tank First Stop Valve isolates the cargo tank from the cargo piping.

14 Cofferdam

Cofferdam is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

15 Contiguous Hull Structure

Contiguous Hull Structure means hull structure that includes the inner deck, the inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffeners.

16 Control Stations

Control Stations are those spaces in which ships' radio or main navigating equipment or the emergency source of power is located or where the fire-recording or fire-control equipment is centralized. This does not include special fire-control equipment which can be most practically located in the cargo area.

17 Design Temperature

Design Temperature. See 5-2/5.

18 Design Pressure

Design Vapor Pressure. See 5-2/2.

19 Flammability Limits

Flammability Limits are the conditions defining the state of fuel-oxidant mixture at which application of an adequately strong external ignition source is only just capable of producing flammability in a given test apparatus.

20 Flammable Range

Flammable Range means the range between the minimum and maximum concentrations of vapor in air which form a flammable mixture.

21 Compressed Gas Carrier

Compressed Gas Carrier is a cargo ship constructed or adapted and used for the carriage in bulk of compressed natural gas.

22 Gas-dangerous Space or Zone

Gas-dangerous Space or Zone is:

- i) A space in the cargo area which is not arranged or equipped in an approved manner to ensure that its atmosphere is at all times maintained in a gas-safe condition;
- ii) An enclosed space outside the cargo area through which any cargo piping liquid or gaseous process passes, or within which such piping terminates, unless approved arrangements are installed to prevent any escape of product vapor into the atmosphere of that space;
- iii) A cargo containment system and cargo piping;
- iv) A hold space where cargo is carried;
- v) A space separated from a hold space by a single gastight steel boundary;
- vi) A room containing cargo handling systems and equipment;
- vii) A zone on the open deck, or semi-enclosed space on the open deck, within 3 m of any cargo tank outlet, gas or vapor outlet, cargo pipe flange or cargo valve or of entrances and ventilation openings to rooms containing cargo handling systems and equipment;
- viii) The open deck over the cargo area and 3 m forward and aft of the cargo area on the open deck with no limit on height;

- ix) A zone within 2.4 m of the outer surface of a cargo containment system where such surface is exposed to the weather;
- x) An enclosed or semi-enclosed space in which pipes containing products are located;
- xi) A compartment for cargo hoses; or
- xii) An enclosed or semi-enclosed space having a direct opening into any gas-dangerous space or zone.

23 Gas-safe Space

Gas-safe Space is a space other than a gas-dangerous space.

24 Heat Affected Zone (HAZ)

Heat Affected Zone in a weldment is considered to be a part of the base material of the weldment, where deterioration in mechanical properties is expected due to weld heat input and certain metallurgical changes occurring in the material.

25 Hold Space

Hold Space is the space enclosed by the ship's structure in which a cargo containment system is situated.

25.1 Hold Space Cover

Hold Space Cover is the enclosure of hold space above main deck protecting cargo tanks and providing controlled environmental conditions within hold space and is gastight.

26 IMO

IMO means International Maritime Organization

27 Independent

Independent means that a piping or venting system, for example, is in no way connected to another system and there are no provisions available for the potential connection to other systems.

28 Insulation Space

Insulation Space is the space, outside a cargo bottle, occupied wholly or in part by insulation.

29 Length

Length (L) means 96% of the total length on a waterline at 85% of the least molded depth measured from the top of the keel, or the length from the foreside of the stem to the axis of the rudder stock on that waterline, if that be greater. In ships designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline. The length (*L*) is to be measured in meters.

30 Machinery Spaces of Category A

Machinery Spaces of Category A are those spaces and trunks to such spaces which contain:

- i) Internal combustion machinery used for main propulsion; or
- ii) Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
- iii) Any oil-fired boiler or oil fuel unit.

31 Machinery Spaces

Machinery Spaces are all machinery spaces of category A and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces; and trunks to such spaces.

32 MARVS

MARVS is the maximum allowable relief valve setting of a cargo tank.

33 Nondestructive Testing (NDT)

Nondestructive Testing (NDT) is any test conducted on materials and products without altering their product usefulness or end use.

34 Oil Fuel Unit

Oil Fuel Unit is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1.8 bar gauge.

35 Organization

Organization is the International Maritime Organization (IMO).

36 Permeability

Permeability of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.

37 Process Pressure Vessel

Process pressure vessel means a pressure vessel that is used in a reliquefaction system, cargo heating/cooling system, cargo processing/cleaning system or other system that processes cargo onboard.

38 Relative Density

Relative Density is the ratio of the mass of a volume of a product to the mass of an equal volume of fresh water.

39 Separate

Separate means that a cargo piping system or cargo vent system, for example, is not connected to another cargo piping or cargo vent system. This separation may be achieved by the use of design or operational methods. Operational methods are not to be used within a cargo tank and are to consist of one of the following types:

- i) Removing spool pieces or valves and blanking the pipe ends.
- ii) Arrangement of two spectacle flanges in series with provisions for detecting leakage into the pipe between the two spectacle flanges.

40 Service Spaces

Service Spaces are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, storerooms, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

The *service spaces* refer to normal stores for hotel services and other similar spaces. Boatswain stores, lamp lockers and carpenter shops would not be considered “service spaces”.

41 Shut-off Valve

Shut-off valve means a valve in a cargo liquid or vapor line that fully closes a pipeline and provides nominal metal-to-metal contact between the valve operating parts, including the disc and gate, and the valve body.

42 1974 SOLAS Convention

1974 SOLAS Convention means the International Convention for the Safety of Life at Sea, 1974.

43 1983 SOLAS Amendments

1983 SOLAS amendments means amendments to the 1974 SOLAS Convention adopted by the Maritime Safety Committee of the Organization at its forty-eighth session on 17 June 1983 by resolution MSC.6(48).

44 Thermo-Mechanically Controlled Processing/Processed (TMCP)

Thermo-Mechanically Controlled Processing/Processed is a specialized controlled material processing method/technique in which mechanical deformation and heat treatment are combined together to achieve very fine-grained microstructure with improved mechanical, impact and fracture toughness properties in the material. Reheating TMCP materials to above certain critical levels would result in loss of these properties due to coarsening of grains in the material, and therefore, post-thermal treatments on TMCP materials are generally prohibited.

45 Vapor Pressure

Vapor pressure is the equilibrium pressure of the saturated vapor above the liquid expressed in bars absolute at a specified temperature.

46 Void Space

A *Void Space* is an enclosed space in the cargo area external to a cargo containment system, other than a hold space, ballast space, fuel oil tank, cargo pump or compressor room, or any space in normal use by personnel.

47 Units

This Guide is written in three systems of units, viz., SI units, MKS units and US customary units. Each system is to be used independently of any other system.

Unless indicated otherwise, the format of presentation in this Guide of the three systems of units is as follows:

SI units (MKS units, US customary units)



CHAPTER 1 Scope and Conditions of Classification

APPENDIX 2 Abbreviations and References

1 Abbreviations

ABS	American Bureau of Shipping
ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ASME	American Society of Mechanical Engineers
AWS	American Welding Society
IMO	International Maritime Organization
NFPA	National Fire Protection Association
SIGTTO	Society of International Gas Tanker and Terminal Operators Ltd.
LBF	Leak Before Failure
JT	Joule Thompson Effect
CVN	Charpy V-Notch
Q	Qualification Testing
P	Production Testing
M	Manufacturers' Data
QA	Quality Assurance
CTOD	Crack Tip Opening Displacement
CNG	Compressed Natural Gas
SPM	Single Point Mooring

2 References

- i) *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*
- ii) *ABS Rules for Materials and Welding (Part 2)*
- iii) *ABS Rules for Building and Classing Single Point Moorings*
- iv) *ABS [Rules](#) for Building and Classing Facilities on Offshore Installations*
- v) *ABS Guide for Automatic or Remote Control and Monitoring for Machinery and Systems (other than Propulsion) on Offshore Installations*

- vi) *ABS Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries*
- vii) *ABS Guide for Risk Evaluations for the Classification of Marine-Related Facilities*
- viii) *ABS Guidance Notes on Review and Approval of Novel Concepts*
- ix) *ABS Guide for Surveys Using Risk Based Inspection for the Offshore Industry*
- x) *ABS Guide for Surveys Based on Reliability-Centered Maintenance*

ABS is prepared to consider other appropriate alternative methods and recognized codes of practice.



CHAPTER 2 Risk Assessment and Special Studies

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CHAPTER 2 Risk Assessment and Special Studies

SECTION 1 General

Risk methods are increasingly being used for Rule-making, particularly when the Rules pertain to novel systems or to systems for which there is limited experience, such as those inherent in the design and construction of a CNG carrier. This Chapter provides general guidance on the risk assessments that will normally be required as part of the overall CNG carrier design approval. The methods outlined in this Chapter generally follow the guidelines published in IMO Guidelines for Formal Safety Assessment (FSA) for use in the IMO Rule-Making Process, MSC/Circ. 1023 and MEPC/Circ. 392 and are considered an integral part of the design development process.

The requirements detailed herein are a reflection of the novelty of significant parts of CNG marine transportation systems and as such tend to parallel the approaches described in the *ABS Guidance Notes on Review and Approval of Novel Concepts*. The risk assessments are intended to compliment the engineering and testing regime, from the initial FEED (front end engineering and development) up to detailed design, with the ultimate objective of ensuring all aspects of the CNG carrier are fit-for-purpose for the specific operations. In order to do this, both qualitative and quantitative risk methods are required. Note that as knowledge and experience are gained from the design, fabrication and actual operation of the CNG carriers, the requirements outlined in this Chapter may be reduced.

In addition to the risk assessments, the novel aspects of the CNG carrier will require certain special studies be conducted which will feed the engineering, testing and risk assessment process. Special studies generally include consequence analysis (e.g., gas dispersion, fire analysis, etc.), as well as special operability, engineering assessment, prototype testing or other studies (e.g., cargo tank inspectibility assessment, fracture mechanics evaluations, etc.) which are not normally required for typical class approval.

This Chapter is intended to provide a general understanding of the class requirements as they relate to risk as well as special studies required to address the novel aspects of the CNG carrier.

The risk assessments and special studies described in this Chapter will be required regardless of whether the containment system is designed using design codes or limit state design methods of Chapter 5 of this Guide. Furthermore, this Chapter describes the minimum risk assessments and special studies requirements for class approval. Other studies, in addition to those described in this Chapter, may be required by class depending on the features inherent in the proposed CNG carrier system.



CHAPTER 2 Risk Assessment and Special Studies

SECTION 2 Requirements

1 Risk Assessment Plan

As part of the CNG carrier design development, an overall risk assessment plan is required to be developed by the client that identifies the specific assessment techniques and systems that will be evaluated during the course of the project. This plan should be submitted to ABS for review during the early stages of the design development outlining the particular risk assessment methods and estimated time when the various assessments, in relation with the design development, will be conducted. The risk assessment plan services multiple objectives including:

- Provides a clear road map on how each aspect of the system will be addressed with regard to risk.
- Initiates the process of identifying and describing the novel aspects of the system as well as the associated interfaces with other conventional aspects of the ship.
- Provides the framework for ensuring all hazards and failure modes are identified and adequately addressed during the design development.

1.1 Risk Plan Submittal

In order to review the proposed risk assessments plan, the plan submittals are required to include design basis documents as well as available preliminary design documents. These documents are necessary to understand of the overall system and how the proposed risk assessments are to be incorporated to address the various aspects of the design. The risk assessment plan submittal must contain the following items:

Engineering/Design Documents

- Design basis documents that include the “operating envelope”, working environment, design life, etc.
- Functional description to include descriptions of all of the key systems (containment, marine, structural, propulsion, cargo handling, etc.) and general outline of the interfaces between the systems.
- Preliminary general arrangements/layout drawings
- Other relevant preliminary drawings related to the containment and cargo handling systems (e.g., piping, safety systems, etc.)

Risk Assessment and Special Study Plan

- Description of proposed risk assessments to be conducted over the course of the design development. The descriptions must include:
 - Proposed method or methods to be used and when (e.g., HAZID, HAZOP, QRA, etc.)
 - Proposed scope of the risk assessment (i.e., covering what system and/or systems, operating conditions, etc.)
 - Objectives of the assessment and how the results will be used in the overall design development
- Management and organization of hazard register. Note that a master hazard register will be required to document all major hazards and mitigation and/or actions required during the design development. The risk assessment plan must clearly state what will be contained in the register and how it will be managed and updated over the course of the design development.

- Proposed risk acceptance criteria. For qualitative risk assessments, a risk ranking methodology or risk matrix must be provided. The use of the organization's risk matrix may be acceptable provided it is in general compliance with ABS's safety, environmental and operability philosophies. For quantitative risk assessments, proposed risk criteria should be provided. ABS will review and verify that the criteria are generally in line with similar applications. Note that it is envisioned that these criteria would be related to total risk and be applicable when comparing calculated overall health and safety risks as they relate to the entire CNG ship system. In cases where quantitative risk assessments are used for subsystems of the CNG ship, adjustments to the total risk criteria may be warranted such that it is representative of the fractional contribution to the total risk.
- Description of proposed special studies to be conducted over the course of the design development. The descriptions must include:
 - Proposed analysis methods (e.g., dispersion analysis, jet fire analysis, etc.)
 - Proposed scope of the study (i.e., covering what system and/or systems, operating conditions, etc.)
 - Objectives of the assessment and how the results will be used in the overall design development as well as the risk assessment defined above

The plan submittals must show a holistic approach to risk assessment for all stages of the project with the understanding that as knowledge is gained from the pre-FEED/FEED engineering and testing as well as in the initial risk assessments, adjustments to this plan may be warranted. Any adjustments to the risk assessment plan will be submitted to ABS for review and approval.

1.2 Minimum Requirements

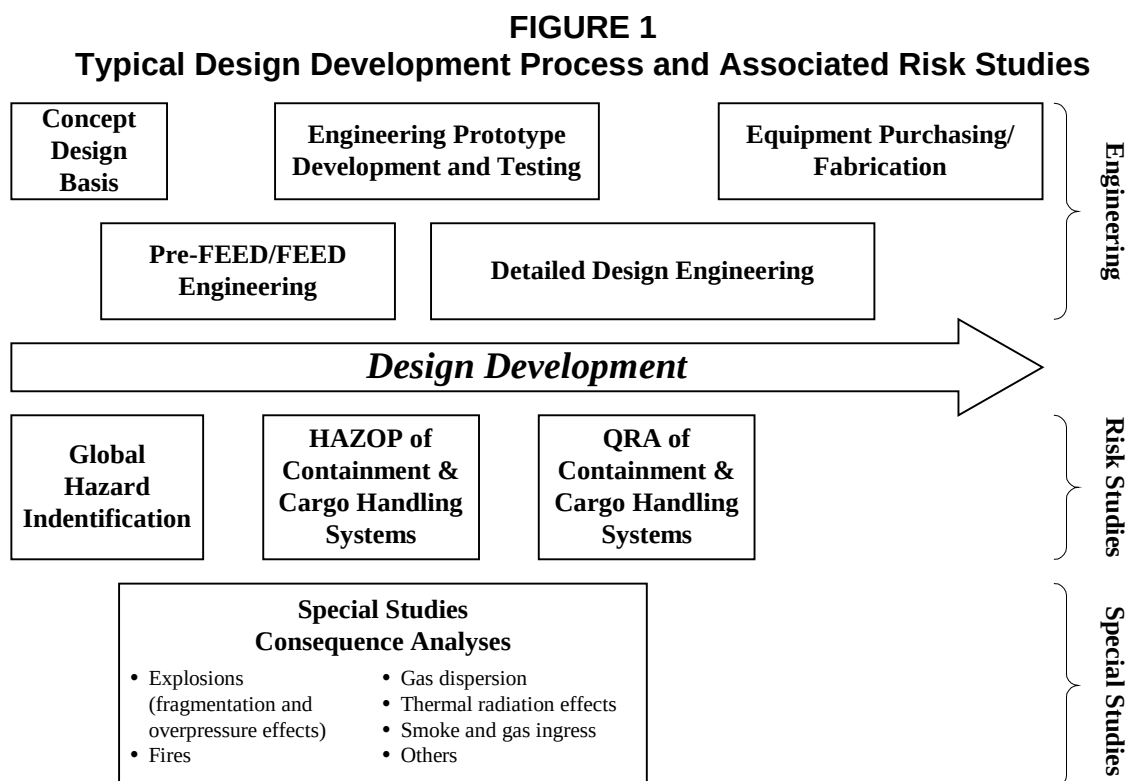
ABS will require specific qualitative and quantitative risk assessments as well as consequence studies to be conducted in order to obtain class approval. Specifically, the submitted risk assessment plan must as a minimum contain the following studies:

- *Hazard Identification (HAZID)* – A global HAZID which will include the major systems (i.e., containment, offloading, structural, propulsion, etc.) must be conducted. The HAZID needs to cover the various operating conditions (i.e., loading, discharging, transit, drydock, containment system start-up and shut-down) that the vessel will experience over the service life.
- *Containment and Cargo Handling System Hazard and Operability Study (HAZOP)* – The HAZOP must assess in detail the various containment and cargo handling control systems required in the operation of a CNG carrier. Key interfaces between these systems and other systems, such as marine, propulsion, etc., must be included in this assessment.
- *Quantitative Risk Assessment (QRA) of CNG Carrier Critical Systems* – The QRA must analyze the containment system and loading and cargo handling systems as a minimum. Additional systems may be included in the QRA as deemed appropriate based on the findings from the HAZID, HAZOP or other risk and engineering studies.

In addition to the risk assessments, special studies related to potential failure consequences of the containment system and the system for loading and discharging the cargo will be required. Specific consequence studies required as part of the design approval process are described in 2/2.3.

2-2/Figure 1 contains a general chart showing the typical design development stages of a project. Included in the figure are some of the key risk assessments and special studies described above that are considered to be minimum requirements for class approval. The placement of the risk assessment and special studies boxes on the figure generally indicates when during the design development these studies would typically be conducted. The later Sections of this Chapter provide further detail on these required studies as well as submittal requirements.

If the concept has obtained Approval-in-Principle (AIP) in accordance with the ABS *Guidance Notes on Review and Approval of Novel Concepts* and no major modifications to the concept have occurred since the AIP approval, the risk assessment plan, as described above, will have already been developed and approved by ABS as part of the AIP process. Furthermore, some of the risk assessment requirements (e.g., HAZID, HAZOP, etc.) described in this Chapter may have already been completed for the AIP approval process. In this case, ABS may accept these evaluations in lieu of the one described in this Chapter provided no major design evolution or changes have taken place since the studies were carried out. If the above is not true, then a revision to these studies may be warranted.



2 Approach

As described in 2-2/1, specific risk assessment and special studies are required to obtain class approval for the design. The overall requirements to conduct these assessments and studies are described in this Section. The assessment types are broken into two types of assessments which relate to the engineering design development; Pre-FEED/FEED Risk Assessments and Detailed Design Risk Assessments. Generally, the pre-FEED assessments relate to qualitative or high-level risk assessments. The primary objective of these assessments is to identify critical elements of the CNG carrier that warrant more detailed risk assessment treatment, elements that are considered novel, and elements that have the greatest degree of uncertainty. The detailed design assessments tend to be more focused, covering the system of interest in more detail in an effort to understand the sensitivities and reduce the overall uncertainty of the system.

The procedures and methods described in the *ABS Guidance Notes on the Review and Approval of Novel Concepts* and the *ABS Guide for Risk Evaluations for the Classification of Marine-Related Facilities* compliment the approach described in this Section and can be referred to for additional detail.

2.1 Pre-FEED/FEED Risk Assessments

During the Pre-FEED/FEED stage of development, the initial concept is further refined. The engineering evaluations at this stage generally are used to verify that the design is feasible with respect to the intent and overall level of safety required by Rules, Guides and statutory requirements in all phases of operation. Generally, preliminary design drawings are being produced for the key CNG carrier systems and structures.

Similar to the engineering, the risk assessments conducted at this stage of the development are also used to verify the feasibility of the system and lay the ground work for further more detailed risk analysis or special studies. At this stage in the design, qualitative risk assessments tend to be more applicable due to the level of detail of the design (i.e., still in the concept or development stages). As described in 2/1.2, as a minimum of two qualitative risk assessments are required as part of the design development. These are a HAZID covering the main systems of the CNG carrier and a HAZOP covering the containment system as well as the gas loading and discharge systems.

2.1.1 HAZID

For the HAZID exercise, the objective is to identify all major hazards associated with the CNG carrier and prioritize them based on perceived risk. The HAZID exercise is used to ensure there are no “showstoppers” early in the design process and to identify areas requiring further testing, analysis, in-service monitoring or design enhancements and, if necessary, additional risk mitigation measure requirements for safe operation of the systems. The exercise will also identify key interfaces and novel features of the design.

Another important feature of the exercise is that it initiates the development of a master hazard register which is used to track identified issues through the resolution process and eventually to closure. This document is updated throughout the design process up until final class approval of the vessel. Submittal of this document will be part of the class approval process.

The HAZID scope must cover all the major CNG carrier systems and interfaces to include as a minimum;

- Ship arrangement
- Containment system
- Cargo handling systems
- Safety systems
- Power systems
- Marine systems
 - Structural
 - Propulsion
 - Steering

The evaluation of these systems must address the various operating conditions (i.e., loading, discharging, transit, drydock, containment system start-up and shut-down) that the vessel will experience over the service life.

2.1.2 HAZOP

For the HAZOP exercise, the objective is to identify the hazards and potential operating problems of the gas containment system and cargo handling systems. Generally, this exercise is conducted near the end of the FEED phase or at the beginning of detailed engineering since by this time the initial concept is beginning to form and many of the aspects of the design are well-defined. A HAZOP evaluation requires well-defined systems and procedures related to the operations in order for it to be useful. The exercise is used to ensure all relevant safety and operability aspects of the system are being addressed in the design and is a further refinement on the HAZID defined above with respect to the containment and cargo handling systems.

The HAZOP scope must cover the following CNG carrier systems and interfaces:

- Containment system, including
 - Systems to handle inadvertent gas releases
 - Monitoring and inspection systems
- System for loading and discharging gas
- Systems for station-keeping while at an offshore discharge buoy, as applicable
- Safety systems, including means or features that aid in escape and evacuation

The findings of the HAZOP will be logged in the master hazard register and addressed via further engineering/testing or risk studies or modifications to the design. The HAZOP also provides a framework for quantitative risk assessment of the above systems by identifying operation hazards, failure modes and potential consequences as well as active and passive safeguards.

Both the HAZID and HAZOP evaluations provide valuable input to the design to ensure all aspects, particularly those that are considered novel, are adequately addressed. Additionally the evaluations involve team brainstorming sessions that provide a unique forum for designers and operational and safety personnel, as well as ABS representatives, to discuss the concept in a structured manner. ABS does not mandate that ABS personnel be part of the risk assessment team. However, benefits can be derived by the participation of an ABS representative that will be directly involved in the reviewing the risk assessment to support the approval process.

2.1.3 Other Risk Assessments

Note that the aforementioned risk assessments represent the minimum risk assessment requirements to be conducted early in the design development. Other risk assessment methods and/or work scope expansions may be required as part of the overall risk assessment plan described in Subsection 2/1 depending on the proposed CNG carrier design. Furthermore, additional risk assessments may be necessary to address the risk assessment findings.

2.1.4 Submittal Requirements

Documentation supporting the qualitative risk assessment must be submitted for review and approval. The minimum submittal requirements are as follows:

- Identified hazards related to the evaluated system and its potential impact on other systems
- Assessed risks associated with the system (i.e., perceive likelihood, consequence and risk ranking)
- Risk matrix
- Recommended mitigation strategies or safeguards not currently in the design intended to improve safety or operability of the system (as applicable)
- Identified inspectibility/operability issues that may impact maintenance of class requirements or operations (as applicable)
- Identified issues related to the system that warrants further analysis, testing and/or risk evaluations (as applicable).
- Initial and/or updated master hazard register containing results of risk assessment.

2.2 Detailed Design Risk Assessments

The engineering evaluations and testing are used to confirm that all aspects of the design are feasible and fit-for-purpose for the intended service. Aspects related to the manufacturing of special components and ship construction, as well as the detailed design of the various systems that make up the CNG carrier, are carried out during this stage. The additional information generated as part of the engineering and testing effort enable more detailed and system-focused risk assessments to be conducted.

The same as the engineering and testing, the risk assessments conducted at this stage are also used to confirm that all aspects of the design are being addressed such that they provide acceptable levels of risk. As described in 2/1.2, as a minimum, a quantitative risk assessment will be required as part of the design approval process until such time as sufficient experience has been obtained with CNG transportation.

2.2.1 Quantitative Risk Assessment

For the QRA, the primary objectives are to refine the understanding and quantify identified failure modes as they relate to the CNG carrier containment system and loading and discharging systems. The QRA is used to determine the failure probabilities associated with different failure modes and potential consequences by modeling in detail the designed system, associated interfaces and safeguards. The assessment enables interactions and sensitivities to be calculated to assist in prioritizing system hazards and preventative barriers.

As a minimum, the QRA scope must cover the following CNG carrier systems and interfaces;

- Containment system, including
 - Systems to handle inadvertent gas releases
 - Monitoring and inspection systems
- System for loading and discharging gas

Note that depending on the CNG carrier features and intended service, other systems may require a QRA. For example, if the carrier is to load or discharge from offshore buoys, it is likely that a QRA will be required on the loading and discharging system, as well as the station-keeping systems. Systems requiring QRAs will be identified and included as part of the risk assessment plan.

The QRA results will be compared to the approved acceptance criteria. Key findings, sensitivities and associated recommendations should be summarized, and logged in the master hazard register to be subsequently addressed through further engineering/testing, risk studies or modifications to the design.

2.2.2 Other Risk Assessments

Note that the aforementioned QRA represents the minimum risk assessment requirements to be conducted during the detailed design development stage. Other risk assessment methods and/or work scope expansions may be required as part of the overall risk assessment plan described in 2-2/1, depending on the proposed CNG carrier design. Furthermore, additional risk assessments may be necessary to address the risk assessment findings.

2.2.3 Submittal Requirements

Documentation supporting the quantitative risk assessment must be submitted for review and approval. The minimum submittal requirements are as follows:

- System description and risk assessment scope.
- Risk assessment assumptions and data references.
- Description and demonstration of calibration of quantitative method. This is a very important step to ensure that consistent results are obtained using the method. The calibration step also increases the confidence of the quantitative risk analysis.
- Description of uncertainties and sensitivities of risk assessment.
- Risk assessment worksheets, fault trees, event trees and supporting calculations.
- Conclusions, which summarize the results and clearly indicate the risks relative to the risk acceptance criteria.
- Identified areas or issues related to the system that may warrant further analysis, testing or risk evaluations (if applicable).
- Identified potential mitigation strategies or safeguards not currently in the design that could improve the safety, or operability of the concept (if applicable).
- Identified potential inspectability/operability/accessability issues related to the design that might impact requirements for the maintenance of class or operations (if applicable).

2.3 Special Studies (Consequence Modeling)

Consequence modeling provides valuable input into the design and risk analyses in understanding the potential effects of specific failures. Consequence modeling helps identify potential escalation scenarios related to the design, as well as assisting in verifying appropriate layout of equipment, normally manned locations and emergency escape routes. Additionally, if limit state methods are being used in the containment system design, consequence modeling results are required to assist in determining the appropriate acceptance criteria (i.e., maximum allowable failure probabilities permissible for the containment system). How the risk assessments and consequence analyses are used in conjunction with limit state design are discussed later in [Chapter 2, Section 4](#). Also more information on limit state design and the associated requirements is contained in Chapter 5, Appendix 1.

The results of the analyses also feed directly into the aforementioned risk analyses (e.g., HAZOP, QRA, etc.), allowing a more definitive understanding of the potential health and safety, environmental and economic implications of the failure.

As a minimum, ABS requires the following consequence modeling as it relates to the containment, loading and discharging systems to be conducted as part of the overall CNG carrier design development:

- *Gas dispersion* – Of particular interest are the dispersion characteristics and the potential for explosive fuel air mixtures covering both “normal” and inadvertent release scenarios.
- *Smoke and gas ingress* – Of particular interest is the potential impact on accommodations or other normally-manned spaces.
- *Explosions* (fragmentation and overpressure effects, as applicable).
- *Jet fires* – Particular focus should be placed on flame impingement on containment system components and ship structure which may result in escalation as applicable.
- *Thermal radiation effects* – Of particular interest is the potential impact on normally-manned spaces, such as the accommodations, emergency routes and muster areas, as well as the potential impact on adjacent gas-retaining components and tank and structure which may result in escalation.

Additionally, other consequence modeling or special studies may be required as part of the class approval process. The requirement of these analyses will be contingent on the specific features of the CNG carrier design. The need for additional studies may be identified early in the design development and included in the risk assessment plan, or in other cases, the results of the risk analyses may indicate that further analyses are required to understand the implications of particular risk scenarios. For example, risks associated with grounding, collision or dropped objects may warrant special studies to evaluate not only the consequences but also the susceptibility of the design to these events. This may entail the use of specialty structural analysis to evaluate the resistance characteristics of the design to these types of accident scenarios.

2.3.1 Submittal Requirements

Documentation supporting the consequence modeling or special studies must be submitted for review and approval. The minimum submittal requirements are as follows:

- Description of the modeling or study scope. This must clearly describe the modeling/load cases and the basis for the selection of these cases.
- Description of the analysis methods and tools (e.g., computational fluid dynamics, finite element analysis, etc.)
- Analysis assumptions, limitations and data references.
- Supporting calculations and analysis results and conclusions.
- Identified areas or issues related to the system that may warrant further analysis, testing or risk evaluations (if applicable).
- Identified potential mitigation strategies or safeguards not currently in the design that could improve the safety, or operability of the concept (if applicable).



CHAPTER 2 Risk Assessment and Special Studies

SECTION 3 Acceptance Criteria

The designer is responsible for setting the acceptance criteria to be applied to risk assessments required by this Guide. These criteria should be consistent with the principles described in this Chapter. ABS will consider the proposed acceptance criteria within the context of the evaluation of the novelty of the overall CNG transportation concept and would either approve the criteria or recommend changes to render the criteria acceptable.

The broad objective is to ensure that the CNG transportation systems assessed according to the requirements of this Guide yield designs that have safety levels comparable to those of other similar systems, such as LNG transportation systems. The assessment must take due regard of the higher uncertainties associated in evaluating CNG transportation system.

As noted elsewhere in this Chapter, the range of risk assessment methodologies available is broad and ranges from simple qualitative methods to highly quantitative detailed techniques. The acceptance criteria that are appropriate to each methodology will similarly vary.

General guidance on establishing acceptance criteria for novel systems can be found in the *ABS Guidance Notes on the Review and Approval of Novel Concepts*.



CHAPTER 2 Risk Assessment and Special Studies

SECTION 4 Limit State Design Interaction

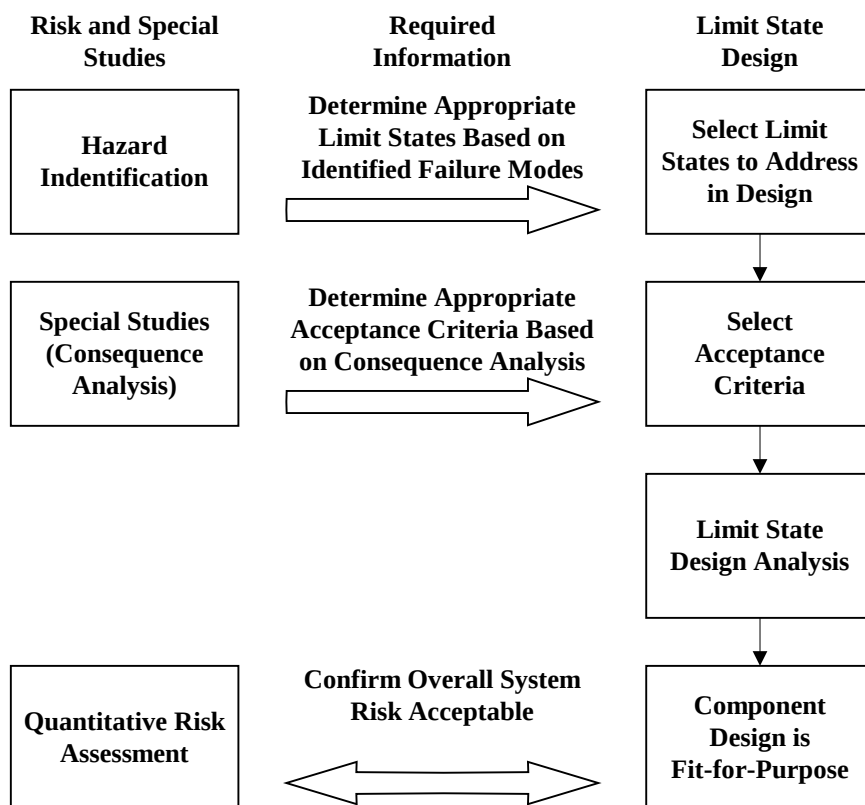
As described in Chapter 5, the designer can choose to design the containment system by complying with recognized pressure vessel codes (i.e., code-based design) or applying probabilistic limit state design principles. As described in 2/1.2, the risk assessment requirements described in this Chapter will apply to both containment system design methods. However, in the case of the limit design approach, it is important to highlight the interactions between the risk and special studies described in this chapter and the limit state design described in Chapter 5, Appendix 1.

Limit states are conditions in which the structural system or component fails to meet its performance requirements. The performance requirements may be related to ultimate strength or fatigue or some other serviceability or accidental parameter required by the system component to ensure it is fit-for-purpose. In general, the limit state design approach entails evaluating load and resistance variables associated with the system or component to determine the probability that the design fails to meet a specific performance requirement. To determine if the design is acceptable, the probability of failure is compared to an acceptance criterion for the particular failure mode in question. In order to conduct this design process, there are three important steps which require input from risk assessments and consequence analysis.

- i) The initial steps of the limit state design approach are the identification and definition of the key limit states that must be addressed in the design. The specific limit states that must be evaluated are driven by the potential failure modes associated with the system or concept. To identify these potential failure modes, a qualitative risk assessment (e.g., HAZID) must be conducted on the system of interest. In the case of the CNG carrier, the system of interest is generally the containment system and cargo handling systems and associated interfaces. The risk assessment provides the necessary input for the selection of the appropriate limit states that must be addressed in the design. 2-4/Figure 1 provides a schematic of key interactions between the risk and special studies and the limit state design.
- ii) Another important interface point for the limit state design is the selection of acceptance criteria. In general, the acceptance criteria are related to the criticality of the component (i.e., the potential consequences related to the failure of the component). For example, a component that is considered safety-critical (i.e., failure may result in severe consequences) would require more stringent acceptance criteria (i.e., lower failure probabilities) than for a component determined to have minimal consequence as a result of failure. Therefore, to assist in determining the appropriate acceptance criteria, consequence modeling results and detailed understanding of the applicable failure modes related to the system are required as part of the limit state design process. More information on consequence categories and associated acceptance criteria are contained in Chapter 5, Appendix 1.
- iii) One other important interaction is between the quantitative risk assessment and the limit state design. As defined in this Guide, the limit state design option generally relates to component design and not to the overall system evaluation. In this regard, the acceptance criteria in Chapter 5, Appendix 1 relate only to a defined containment component and are intended to be used for the express purpose of evaluating the compliance of an individual component using limit state design.

The overall system failure probability is an important aspect that must also be addressed. However, it is considered more appropriate to address the overall system performance in the context of risk rather than setting specific system failure probability targets. To evaluate the system and better understand the system performance, a QRA is conducted. This assessment complements the limit state design conducted on the components. The limit state calculations provide important information on the structural and pressure retaining capability associated hazards of the cargo tanks which is one contributor to the many potential hazards that influence the overall risk to the containment system. Other hazards, such as accidental loading or human error, as well as other system failures (electrical, mechanical, process control, instrumentation failure, etc.), also contribute to the overall risk and are addressed in the QRA.

FIGURE 1
Key Interaction between Risk Studies and Limit State Design





CHAPTER 3 Ship Survival Capability and Location of Cargo Tanks

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CHAPTER 3 Ship Survival Capability and Location of Cargo Tanks

SECTION 1 General

1

Vessels subject to the Guide requirements are to survive the normal effects of flooding following assumed hull damage caused by some external force. In addition, to safeguard the vessel and the environment, the cargo tanks are to be protected from penetration in the case of minor damage to the vessel (resulting, for example, from contact with a jetty or tug) and given a measure of protection from damage in the case of collision or stranding by locating them at specified minimum distances inboard from the vessel's shell plating.

2

Vessels subject to this Guide are compressed natural gas carriers intended to transport CNG that require significant preventive measures to preclude the escape of the cargo.



CHAPTER 3 Ship Survival Capability and Location of Cargo Tanks

SECTION 2 Freeboard and Intact Stability

1

Vessels subject to the Guide may be assigned the minimum freeboard permitted by the International Convention on Load Lines in force. However, the draft associated with the assignment is not to be greater than the maximum draft otherwise permitted by this Guide.

2

The stability of the ship in all seagoing conditions and during loading and unloading cargo is to be to a standard which is acceptable to ABS.

3

When calculating the effect of free surfaces of consumable liquids for loading conditions, it is to be assumed that, for each type of liquid, at least one transverse pair or a single center tank has a free surface and the tank or combination of tanks to be taken into account is to be those where the effect of free surfaces is the greatest. The free surface effect in undamaged compartments is to be calculated by a method acceptable to ABS.

4

Solid ballast is not normally to be used in double bottom spaces in the cargo area. Where, however, because of stability considerations, the fitting of solid ballast in such spaces becomes unavoidable, then its disposition is to be governed by the need to ensure that the impact loads resulting from bottom damage are not directly transmitted to the cargo tank structure.

5

A Loading and Stability Information booklet is required to be submitted for review. This booklet is to contain details of typical service conditions, loading, unloading and ballasting operations, provisions for evaluating other conditions of loading and a summary of the ship's survival capabilities. In addition, the booklet is to contain sufficient information to enable the master to load and operate the ship in a safe and seaworthy manner.

When a CNG Carrier is designed to operate for certain sea state conditions due to design restrictions, all necessary information for safe operation such as loading, unloading, processing, etc., is to be included in the booklet.

6 Onboard Computers for Stability Calculations (1 July 2007)

The use of onboard computers for stability calculations is not a requirement of class. However, if stability software is installed onboard vessels contracted on or after 1 July 2005, it should cover all stability requirements applicable to the vessel and is to be approved by ABS for compliance with the requirements of Appendix 3-A1, "Onboard Computers for Stability Calculations".



CHAPTER 3 Ship Survival Capability and Location of Cargo Tanks

SECTION 3 Shiplside Discharges Below the Freeboard Deck

1

The provision and control of valves fitted to discharges led through the shell from spaces below the freeboard deck or from within the superstructures and deckhouses on the freeboard deck fitted with weathertight doors are to comply with the requirements of the relevant regulation of the International Convention on Load Lines in force, except that the choice of valves is to be limited to:

- i) One automatic non-return valve with a positive means of closing from above the freeboard deck; or
- ii) Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds $0.01L$, two automatic non-return valves without positive means of closing, provided that the inboard valve is always accessible for examination under service conditions.

2

For the purpose of this Guide, “summer load waterline” and “freeboard deck” have the meanings defined in the International Convention on Load Lines in force.

3

The automatic non-return valves referred to in 3-3/1i) and 3-3/1ii) are to be of a type acceptable to ABS and are to be fully effective in preventing admission of water into the ship, taking into account the sinkage, trim and heel in survival requirements in Chapter 3, Section 9.



CHAPTER 3 Ship Survival Capability and Location of Cargo Tanks

SECTION 4 Conditions of Loading

Damage survival capability is to be investigated on the basis of loading information submitted to ABS for all anticipated conditions of loading and variations in draft and trim. The survival requirements need not be applied to the ship when in the ballast condition*, provided that any cargo retained onboard is solely used for cooling, circulation or fueling purposes.

- * The cargo content of small independent purge tanks on deck need not be taken into account when assessing the ballast condition.



CHAPTER 3 Ship Survival Capability and Location of Cargo Tanks

SECTION 5 Damage Assumptions for Stability Assessment

1 Assumed Maximum Extent of Damage

ABS is prepared to consider a probabilistic approach to determining the effects of a collision or grounding.

Where probabilistic damage assessment has not been done, the assumed maximum extent of damage to be used in the stability assessment is to be:

1.1 Side Damage

1.1.1 Longitudinal Extent

$(1/3)L^{2/3}$ or 14.5 m (47.57 ft), whichever is less

1.1.2 Transverse Extent

Measured inboard from the ship's side at right angles to the centerline at the level of the summer load line: $B/5$ or 11.5 m (37.73 ft), whichever is less.

1.1.3 Vertical Extent

From the molded line of the bottom shell plating at centerline: Upwards without limit.

1.2 Bottom Damage

1.2.1 Longitudinal Extent

For $0.3L$ from the forward perpendicular of the ship: $(1/3)L^{2/3}$ or 14.5 m (47.57 ft), whichever is less

Any other part of the ship: $(1/3)L^{2/3}$ or 5 m (16.4 ft), whichever is less

1.2.2 Transverse Extent

For $0.3L$ from the forward perpendicular of the ship: $B/6$ or 10 m (32.8 ft), whichever is less

Any other part of the ship: $B/6$ or 5 m (16.4 ft), whichever is less

1.2.3 Vertical Extent

For $0.3L$ from the forward perpendicular of the ship: $B/15$ or 2 m (6.56 ft), whichever is less, measured from the molded line of the bottom shell plating at centerline (see 3-6/2).

Any other part of the ship: $B/15$ or 2 m (6.56 ft), whichever is less, measured from the molded line of the bottom shell plating at centerline (see 3-6/2).

2 Other Damage

2.1

If any damage of a lesser extent than the maximum damage specified in 3-5/1 would result in a more severe condition, such damage is to be assumed.

2.2

Local side damage anywhere in the cargo area extending inboard 760 mm (30 in.) measured normal to the hull shell is to be considered, and transverse bulkheads are to be assumed damaged when also required by the applicable paragraphs of 3-8/1.



CHAPTER 3 Ship Survival Capability and Location of Cargo Tanks

SECTION 6 Location of Cargo Tanks

1

The cargo containment system is to be located at the following distances inboard:

- i) *Bottom Shell.* From the bottom shell plating at centerline, not less than the vertical extent of damage specified in 3-5/1.2.3 or as otherwise justified on the basis of a probabilistic damage assessment
- ii) *Side Shell.* From the side shell, nowhere less than 760 mm (30 in.).

2

For the purpose of the cargo containment system, the vertical extent of bottom damage is to be measured to the bottom of the cargo tanks. The transverse extent of side damage is to be measured to the side of the cargo tanks (see 3-7/Figure 1).

Where the cargo tanks are located within the extent of damage assumed in Chapter 3, Section 5, the stability is to be investigated assuming the cargo tanks are damaged and also with the cargo tanks undamaged (3-5/2). Deck cargo tanks are to be located not less than 760 mm (30 in.) inboard from the side shell.

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CHAPTER 3 Ship Survival Capability and Location of Cargo Tanks

SECTION 7 Flooding Assumptions

1

The requirements of Chapter 3, Section 9 are to be confirmed by calculations which take into consideration the design characteristics of the ship; the arrangements, configuration and contents of the damaged compartments; the distribution, relative densities and the free surface effects of liquids; and the draft and trim for all conditions of loading.

2

Where direct calculations are not submitted, the permeabilities of spaces assumed to be damaged are to be as follows:

<i>Spaces</i>	<i>Permeabilities</i>
Appropriated to stores	0.60
Occupied by accommodation	0.95
Occupied by machinery	0.85
Voids	0.95
Intended for consumable liquids	0 to 0.95*
Intended for other liquids	0 to 0.95*

* The permeability of partially filled compartments is to be consistent with the amount of liquid carried in the compartment.

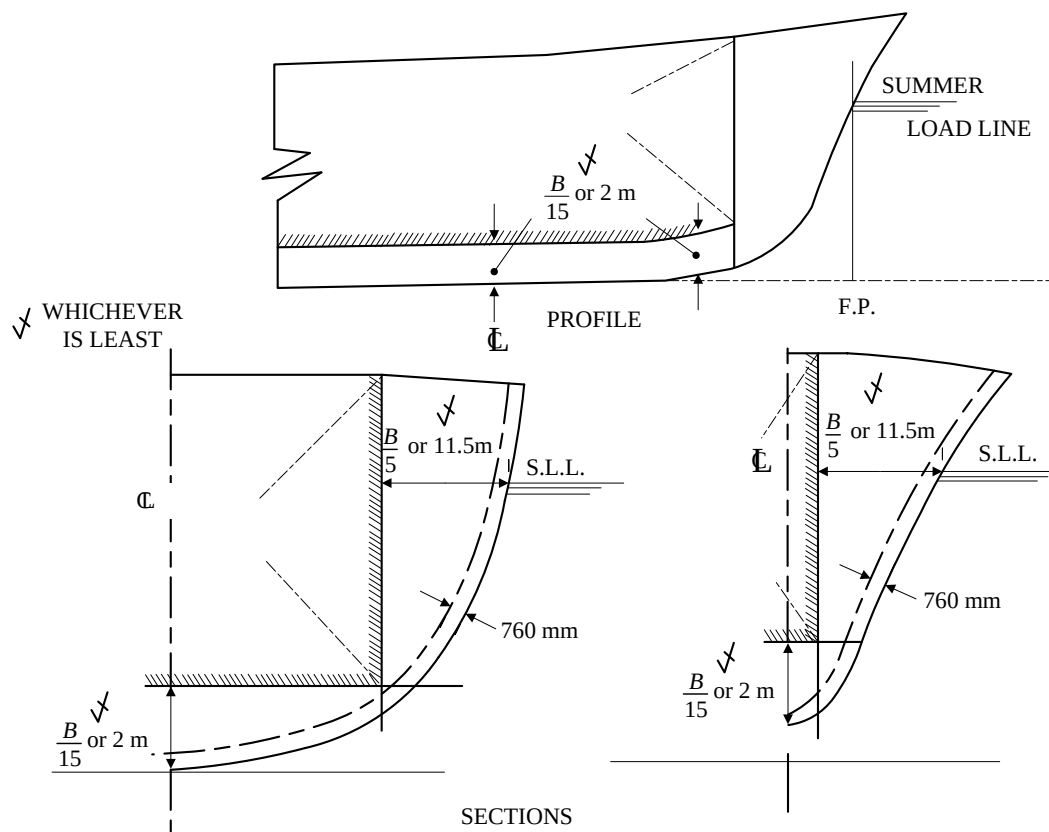
3

Wherever damage penetrates a tank containing gas/liquids, it is to be assumed that the contents are completely lost from that compartment and replaced by salt water up to the level of the final plane of equilibrium.

4

Where the damage between transverse watertight bulkheads is envisaged as specified in 3-8/1.3, transverse bulkheads are to be spaced at least at a distance equal to the longitudinal extent of damage specified in 3-5/1.1.1 in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads within such extent of damage is to be assumed as non-existent for the purpose of determining flooded compartments. Further, any portion of a transverse bulkhead bounding side compartments or double bottom compartments is to be assumed damaged if the watertight bulkhead boundaries are within the extent of vertical or horizontal penetration required by Chapter 3, Section 5. Also, any transverse bulkhead is to be assumed damaged if it contains a step or recess of more than 3 m (9 ft-10 in.) in length located within the extent of penetration of assumed damage. The step formed by the after peak bulkhead and after peak tank top is not to be regarded as a step for the purpose of this Subsection.

FIGURE 1
Tank Location Requirements as Set Out in Chapter 3, Section 6



5

The ship is to be so designed as to keep unsymmetrical flooding to the minimum consistent with efficient arrangements.

6

Equalization arrangements requiring mechanical aids such as valves or cross-leveling pipes, if fitted, are not to be considered for the purpose of reducing an angle of heel or attaining the minimum range of residual stability to meet the requirements of 3-9/1, and sufficient residual stability is to be maintained during all stages where equalization is used. Spaces which are linked by ducts of large cross-sectional area may be considered to be common.

7

If pipes, ducts, trunks or tunnels are situated within the assumed extent of damage penetration, as defined in Chapter 3, Section 5, arrangements are to be such that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage.