GUIDE FOR BUILDING AND CLASSING

GRAVITY-BASED OFFSHORE LNG TERMINALS

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Foreword

This *Guide for Building and Classing Gravity-Based Offshore LNG Terminals* (*GBLNGT Guide*) replaces previous editions of the *Guide for Building and Classing Offshore LNG Terminals*. The *GBLNGT Guide* also describes criteria to be used for gravity based offshore LNG terminals which are to be classed or certified by American Bureau of Shipping (ABS).

ABS is willing to expand the criteria for handling other gaseous materials for gravity based terminals as the industry demand for same increases. ABS recognizes that industry participation is a vital factor due to the rapidly progressing use of offshore gas terminals. To understand and apply this new technology and its standards, ABS, the offshore and onshore community, and regulatory agencies would benefit from having a common understanding of the terms and concepts involved, and an awareness of how these concepts are to be applied to ABS rule-making. This continues to be the driving force for the Guide.

The effective date of this Guide is 1 June 2010. In general, until the effective date, plan approval for designs will follow prior practice unless review under this Guide is specifically requested by the party signatory to the application for classification.

Changes to Conditions of Classification

Chapter 1, Section 1, "Scope and Conditions of Classification" was consolidated into a generic booklet, entitled *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)* for all units, installations, vessels or systems in offshore service. The purpose of this consolidation was to emphasize the common applicability of the classification requirements in "Chapter 1, Section 1" to ABS-classed offshore units, pipelines, risers, and other offshore structures, and thereby make "Conditions of Classification" more readily a common Rule of the various ABS Rules and Guides, as appropriate.

Thus, Chapter 1, Section 1 of this Guide specifies only the unique requirements applicable to gravity-based offshore liquefied gas terminals. These supplemental requirements are always to be used with the aforementioned *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

Reference Note

Reference to a paragraph in the *Steel Vessel Rules*, *MODU Rules* or *FPI Rules* is made in the format 'P-C-S/ss.p' where 'P' is the Part, 'C' is the Chapter, 'S' is the Section, 'ss' is the Subsection and 'p' is the Paragraph.

Reference to a paragraph in this Guide is made in the format 'C-S/ss.p', where 'C' is the Chapter, 'S' is the Section, 'ss' is the Subsection and 'p' is the Paragraph.

Reference to a Figure or Table in this Guide is made, respectively, in the format 'C-S/Figure #', or 'C-S/Table #'.

GUIDE FOR BUILDING AND CLASSING

GRAVITY-BASED OFFSHORE LIQUEFIED GAS TERMINALS

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[See also separately published booklet ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*]

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CHAPTER 1 Conditions of Classification

SECTION 1 Scope and Conditions of Classification (Supplement to the ABS Rules for Conditions of Classification – Offshore Units and Structures)

1 Classification

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

Additional requirements specific to gravity-based offshore LNG terminals are contained in the following Subsections.

3 Purpose

A *Gravity-Based Offshore LNG Terminal* provides LNG storage and receives and/or offloads LNG. There are two major variations of offshore LNG terminal: Load Terminals and Discharge Terminals, with various configurations of each.

A *Load Terminal* receives gas directly from one or more wells or from another offshore facility where it may or may not have been processed. The gas is liquefied in an onboard liquefaction facility and stored for offloading as LNG to a trading LNG carrier. Alternatively, a *Load Terminal* may receive LNG from a liquefaction plant via a pipeline.

A *Discharge Terminal* receives LNG from trading LNG carriers and stores it. In such terminals, the stored LNG is normally vaporized in a re-gasification facility and discharged ashore. However, offloading LNG in a lightering operation is also feasible.

5 Classification Symbols and Notations

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".

The following notations are specific to gravity-based offshore LNG terminals.

5.1 Class Notations

Gravity-based offshore LNG terminals 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 for service for the specified design environmental conditions, may be classed and distinguished in the ABS *Record* by the symbol ✠ **A1**, followed by **Offshore Liquefied Gas Terminal** and the appropriate notation for the intended service listed below.

Class notations were chosen to provide a clear description of the function of each configuration using the following symbols:

- **G** Gravity Based
- **L** Liquefaction Facility
- **O** Transfer of LNG (Offloading/Loading)
- **P** Gas Processing Facility
- **R** Re-Gasification Facility
- **S** Storage Facility
- **T** Terminal with processing facilities that are not classed

A complete description of applicable class notations is provided for gravity-based offshore LNG terminals in 2-1/1.1 of this Guide.

5.3 Geographical Limitations

Gravity-based offshore LNG terminals which have been built to the satisfaction of the ABS Surveyors to special modified requirements for a limited service, where approved by the Committee for that particular service, may be classed and distinguished in the *Record* by suitable symbols or notations, but the symbols or notations will either be followed by or have included in them the appropriate service limitation.

5.5 Terminals Not Built Under Survey

The symbol "✠" (Maltese-Cross) signifies that the system was built, installed and commissioned to the satisfaction of the ABS Surveyors. Gravity-based offshore LNG terminals 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, they may be classed and distinguished in the *Record* by the notation described above, but the symbol "✠" signifying survey during construction will be omitted.

7 Rules for Classification

7.1 Application of Rules

This Guide contains provisions for the classification of gravity-based offshore LNG terminals. This Guide is intended for use in conjunction with the ABS *Rules for Building and Classing Steel Vessels* (*Steel Vessel Rules*), ABS *Rules for Building and Classing Mobile Offshore Drilling Units* (*MODU Rules*), ABS *Rules for Building and Classing Offshore Installations*, ABS *Rules for Building and Classing Floating Production Installations (FPI Rules)* or other applicable ABS Rules and Guides.

7.3 Scope of Class

A description of the parts of a gravity-based offshore LNG terminal included in the ABS classification is provided in 2-1/1 of this Guide.

7.5 Alternatives

Any departure from the requirements of this Guide may be considered by ABS on the basis of an additional risk assessment to that required per 2-2/3 of this Guide, or at least a separate, clearly identified part of the risk assessment. In the 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 are 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 terminal as a whole or to individual systems, subsystems or components. As appropriate, account must be given to remote hazards outside of 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 terminal, verification surveys during construction and surveys for maintenance of class.

Portions of the terminal 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

9 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)

11 Abbreviations and References

11.1 Abbreviations

ABS	American Bureau of Shipping
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
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
CSA	Canadian Standards Association
FIP	Federation Internatioale de la Precontrainte
IMO	International Maritime Organization
NACE	National Association of Corrosion Engineers
NFPA	National Fire Protection Association
PCI	Prestressed Concrete Institute
SIGTTO	Society of International Gas Tanker and Terminal Operators Ltd.

11.3 References

i) *Steel Vessel Rules* – ABS *Rules for Building and Classing Steel Vessels*

ii) *MODU Rules* – ABS *Rules for Building and Classing Mobile Offshore Drilling Units*

iii) *M/W Rules* – ABS *Rules for Materials and Welding – Part 2*

iv) *Offshore Installations Rules* – ABS *Rules for Building and Classing Offshore Installations*

v) *SPM Rules* – ABS *Rules for Building and Classing Single Point Moorings*

vi) *FPI Rules* – ABS *Rules for Building and Classing Floating Production Installations*

vii) *Facilities Rules* – ABS *Rules for Building and Classing Facilities on Offshore Installations*

viii) *LGC Guide* – ABS *Guide for Building and Classing Liquefied Gas Carriers with Independent Tanks*

ix) ABS *Guide for Automatic or Remote Control and Monitoring for Machinery and Systems (other than Propulsion) on Offshore Installations*

x) ABS *Guide for the Fatigue Assessment of Offshore Structures*

xi) ABS *Guide for Nondestructive Inspection of Hull Welds*

xii) ABS *Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries*

xiii) ABS *Guide for Risk Evaluations for the Classification of Marine-Related Facilities*

xiv) ABS *Guidance Notes on Review and Approval of Novel Concepts*

xv) ABS *Guide for Surveys Using Risk Based Inspection for the Offshore Industry*

xvi) ABS *Guide for Surveys Based on Machinery Reliability and Maintenance Techniques*

xvii) ACI 213R Guide for Structural Lightweight Aggregate Concrete

xviii) ACI 301 Specifications for Structural Concrete

xix) ACI 311.4R Guide for Concrete Inspection Programs

xx) ACI 318 Building Code Requirements for Structural Concrete

xxi) ACI 357R-84 Guide for the Design and Construction of Fixed Offshore Concrete Structures

xxii) ACI 357.2R-88 State-of-the-Art Report on Barge-Like Concrete Structures

xxiii) AISC Manual of Steel Construction, ASD

xxiv) API RP 2A, RP 2T, RP 14C, RP 500, RP 521, 620, RP 2003

xxv) ASTM 330 Specification for Lightweight Aggregates for Structural Concrete

xxvi) CSA S474-94 Concrete Structures (Offshore Structures)

xxvii) NACE RP0176-94

xxviii) NFPA 59 A *Standard for Production, Storage and Handling of Liquefied Natural Gas*

Note: The requirements of the IMO "International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk" are incorporated within requirements in Part 5C, Chapter 8 of the ABS *Steel Vessel Rules*.

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

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CHAPTER 2 Requirements for Gravity-Based Offshore LNG Terminals

SECTION 1 Classification of Gravity-Based Offshore LNG Terminals

In addition to all of the requirements contained in the ABS* Rules for Conditions of Classification – Offshore Units and Structures (Part 1) *and Chapter 1 of this Guide, the following requirements are applicable to gravity-based offshore LNG terminals.

1 ABS Class Symbols and Notations

1.1 Class Notations

Gravity-based LNG terminals (GBLNGT) 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 for service for the specified design environmental conditions, may be classed and distinguished in the ABS *Record* by the symbol ✠ **A1**, followed by **Offshore Liquefied Gas Terminal** and the appropriate notation for the intended service listed below:

Class notations were chosen to provide a clear description of the function of each configuration using the following symbols:

- **G** Gravity-Based
- **L** Liquefaction Facility
- **O** Transfer of LNG (Offloading/Loading)
- **P** Gas Processing Facility
- **R** Re-Gasification Facility
- **S** Storage Facility

Where a gravity-based terminal is fitted with processing facilities, but classification of the entire processing facilities is not desired, certain essential safety systems and equipment for the processing facilities as indicated in 2-2/9 of this Guide are to be in compliance with requirements of ABS. The gravity-based terminal will be classed and distinguished in the ABS *Record* by the symbol ✠ **A1** followed by **Offshore Liquefied Gas Terminal** and the notation **T**.

The class notations are:

G(LNG) PLSO – Gravity-Based LNG Terminals with Gas Processing and Production, Liquefaction, Storage and Offloading – The terminal receives well gas, processes it and liquefies the natural gas and condensate for storage and offloading.

G(LNG) ORS – Gravity-Based LNG Storage Terminals with Re-Gasification Facility – The terminal receives LNG from a trading LNG carrier, stores it, re-gasifies and discharges the gas ashore.

G(LNG) SO – Gravity-Based LNG Storage and Offloading Terminals – The terminal receives, stores and offloads LNG in a lightering operation

G(LNG) T – Gravity-Based LNG Terminals with Gas Processing and Production, Liquefaction, Storage and Offloading – The terminal receives well gas, processes it, liquefies the natural gas and condensate for storage and offloading. The gas processing, production and liquefaction facilities are not desired to be within the scope of class. However the essential safety features of these facilities are to comply with ABS requirements.

1.3 ✠ AMCC and ✠ AMCCU Notations

Automatic or remote control and monitoring equipment/machinery that have been constructed and installed to the satisfaction of the ABS Surveyors and to the full requirements of the ABS *Guide for Automatic or Remote Control and Monitoring for Machinery and Systems (other than propulsion) on Offshore Installations*, when found satisfactory after trial and approved by the Committee, may be classed and distinguished in the *Record* by the notation ✠ **AMCC**. Where it is intended that the machinery be controlled and monitored from a remote control and monitoring center located outside the machinery space(s), a Class notation ✠ **AMCCU** will be assigned. It should be noted that the above notations do not cover the instrumentation and control systems for any process systems.

1.5 Application of Class Notations

The class notations described above cover the following components:

i) Gravity-based offshore LNG terminals including the terminal's principal structure, equipment, machinery and all electrical systems under one of the notations in 2-1/1.1 above, subject to the requirements of this Guide.

ii) Foundations in accordance with the requirements of this Guide.

iii) Gas processing, production and liquefaction facilities according to the requirements of this Guide and the applicable sections of the *Facilities Rules*.

iv) LNG storage facilities (Containment Systems) in accordance with the requirements of this Guide and the applicable sections of Part 5C of the *Steel Vessel Rules*.

v) Inlet and outlet facilities in accordance with the requirements of this Guide.

vi) LNG and GNG (Gaseous Natural Gas/LNG vapor) handling systems in accordance with the requirements of this Guide and the applicable sections of Part 5C of the *Steel Vessel Rules*.

vii) Re-gasification facilities in accordance with the requirements of this Guide.

viii) Safety systems in accordance with the requirements of this Guide.

ix) Helicopter landing area in accordance with the requirements of this Guide and the applicable sections of the *Steel Vessel Rules*.

TABLE 1
Terminal Configuration

	Structure	*Storage*	*Gas Processing*	*Liquefaction*	*Gasification*	*Station Keeping Foundation*	*Import and Export Systems*	*Risers and Flow Lines*	*Min. System Compliance Required*
G(LNG)PLSO	X	X	X	X	–	X	X	Optional	X
G(LNG)LSO	X	X	–	X	X	X	X	Optional	X
G(LNG)ORS	X	X	–	–	X	X	X	Optional	X
G(LNG)SO	X	X	–	–	–	X	X	Optional	X
G(LNG)T	X	X	–	–	–	X	X	–	X

Notes:

P = Process
L = Liquefaction
S = Storage
O = Transfer of LNG (Offloading/Loading)
R = Re-gasification
T = Terminal with processing facilities which are not classed

3 Plans and Data to be Submitted

(2011) Plans and data to be submitted for design review shall generally be submitted electronically to ABS. However, hard copies will also be accepted. Proceeding paragraphs of this Subsection "Plans and Data to be Submitted" cover submittals for the full variety of Class Notations. The actual extent of plans and data to be submitted depend upon the equipment, machinery and systems installed on the terminal and requested for Classification by the Owner.

3.1 Design Plans and Data for Structures

Plans showing the scantlings, arrangements and details of the principal parts of the hull structure of each terminal to be built under survey are to be submitted and approved before the work of construction has commenced. These plans are to clearly indicate the scantlings, joint details and welding, or other methods of connection. In general, plans are to be submitted that include the following, where applicable:

- Arrangement plans, elevations and plan views clearly showing in sufficient detail the overall configuration, dimensions and layout of the structure, its facilities and foundation
- Layout plans indicating the locations of equipment and locations of the equipment loads and other design deck loads, fender loads, etc., which are imposed on the structure
- Structural plans indicating the complete structural arrangement, dimensions, member sizes, plating and framing, material properties and details of connections and attachments; for concrete structures, plans indicating general notes about materials and workmanship, arrangements and details of reinforcement, typical details of concrete cover, the location and detail of construction joints, waterstops, etc.
- Pile plans indicating arrangements, nominal sizes, thicknesses and penetration
- Welding details and procedures, and schedule of nondestructive testing
- Corrosion control systems
- Structural plans indicating the complete arrangements of structures, such as helidecks, crane pedestals, equipment foundations and manner of reinforcement, fendering, various houses and other structures which are not normally considered vital to the overall structural integrity of the offshore structure
- Various information in support of novel features utilized in the offshore structure design such as hydrostatic and stability curves, elements of any mooring system, etc.

3.1.1 Site Condition Reports

The site condition reports are to be submitted. For details, refer to 1-1-4/1 of the *Offshore Installations Rules*. The principal purpose of these reports is to demonstrate that site conditions have been evaluated in establishing design criteria. Among the items to be discussed are:

i) Environmental conditions of waves, winds, currents, tides, water depth, air and sea temperature and ice

ii) Seabed topography, stability and pertinent geotechnical data

iii) Seismic conditions

Where appropriate, data established for a previous installation in the vicinity of the installation proposed for classification may be utilized if acceptable in the opinion of ABS.

3.1.2 Design Data and Calculations

Information is to be submitted for the terminal that describes the methods of design and analysis which were employed to establish its design. The estimated design service life of a terminal is also to be stated. Where model testing is used as a basis for a design, the applicability of the test results will depend on the demonstration of the adequacy of the methods employed, including enumeration of possible sources of error, limits of applicability and methods of extrapolation to full-scale data. Preferably, procedures should be reviewed and agreed upon before model testing is done.

As required in subsequent Sections, calculations are to be submitted to demonstrate the sufficiency of the proposed design. Such calculations are to be presented in a logical and well-referenced fashion employing a consistent system of units. Where the calculations are in the form of computer analysis, the submittal is to provide input and output data with computer-generated plots for the structural model. A program description (not listings), user manuals and the results of program verification sample problems may be required to be submitted.

3.1.3 Plans or Specifications

Plans or specifications depicting or describing the arrangements and details of the major items of the terminal are to be submitted for review or approval in a timely manner.

Documentation to facilitate the survey of concrete quality, as applicable to the Quality Control Plan (QCP) (see 2-3/3.5 for details), is to be submitted for approval.

Detailed procedural descriptions and design calculations covering all phases of the construction, transportation and installation of the gravity-based structure are to be submitted prior to the work being done.

Where deemed appropriate, and when requested by the Owner, a schedule for information submittal and plan approval can be jointly established by the Owner and ABS. This schedule, which ABS will adhere to as far as reasonably possible, is to reflect the construction schedule and the complexity of the terminal as it affects the time required for review of the submitted data.

3.1.4 Information Memorandum

An information memorandum on the terminal is to be prepared and submitted to ABS. ABS will review the contents of the memorandum to establish consistency with other data submitted for the purpose of obtaining classification. ABS will not review the contents of the memorandum for their accuracy or the features described in the memorandum for their adequacy.

An information memorandum is to contain, as appropriate to the terminal, the following:

- Site plan indicating the general features at the site and the exact location of the terminal
- Environmental design criteria, including the recurrence interval used to assess environmental phenomena (2-2/1.1)
- Plans showing the general arrangement of the terminal
- Description of the safety and protective systems provided
- The number of personnel to be normally stationed at the terminal
- Listing of governmental authorities having cognizance over the terminal
- Listing of any novel features
- Brief description of any monitoring proposed for use on the terminal
- Description of transportation and installation procedures

3.3 Design Plans for LNG Containment System, LNG and GNG Handling Systems

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 – Offshore Units and Structures (Part 1)*:

- Full particulars of the intended cargo including maximum vapor pressure, minimum and maximum temperature, and loading and storage procedures
- General arrangement plans of the terminal showing the position of the following:
  - *i)* Cargo containment system, cargo tanks, fuel oil, water ballast and other tanks and void spaces
  - *ii)* Manholes and any other opening of the cargo tanks
  - *iii)* Doors and other openings in cargo pump and compressor rooms and other gas-dangerous rooms

iv) Ventilation ducts of cargo compressor rooms and other "gas-dangerous" spaces

v) Door, air-locks, manholes, ducts and other openings for "non-gas-dangerous" spaces which are, however, adjacent to the cargo area

vi) Cargo piping, both liquid and gaseous phases, located under and above deck

vii) Vent piping and gas-freeing piping and protective devices such as flame screens, etc. fitted at the outlet end of the vents etc.

viii) Gas-dangerous spaces

- Plans of the terminal structure in way of the cargo tanks, including the installation of attachments, accessories, internal reinforcements, saddles for support and tie-down devices
- Plans of the structure of the cargo containment system, including the installation of attachments, supports and attachment of accessories. Detailed construction drawings together with design calculations for the pressure boundary, tank support arrangement and analysis for the load distribution. Anti collision, chocking arrangement and design calculations.
- Distribution of the grades and of the types of steel proposed for use in the structures of the terminal together with the calculation of the temperatures on all of the structures which can be affected by the low temperatures of the cargo
- Results of direct calculations of the stresses in the cargo containment system
- Specifications and plans of the insulation system and calculation of the heat balance
- Thermal heat analysis determining the LNG boil-off rate from the storage tanks
- Calculations to show the means provided for handling the boil-off gas from storage tanks without causing overpressurization in the tanks
- Procedures and calculations of the cooling down, loading and unloading operations
- Loading and unloading systems, venting systems and gas-freeing systems, as well as a schematic diagram of the remote controlled valve system
- Details and installation of the safety valves and relevant calculations of their relieving capacity
- Details and installation of the various monitoring and control systems, including the devices for measuring the level of the cargoes in the tanks and the temperatures in the containment system
- Schematic diagram of the ventilation system indicating the vent pipe sizes and height of the openings above the main deck
- Schematic diagram of the refrigeration system together with the calculations concerning the refrigerating capacity for a re-liquefaction plant, if provided
- Details of the electrical equipment installed in the cargo area and of the electrical bonding of the cargo tanks and piping
- 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 of 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)
- Details of testing procedures of cargo tanks and liquid and vapor systems
- Diagram of inert-gas system or hold-space environmental-control system
- Diagram of gas-detection system
- Jettison arrangements, if provided
- Details of all cargo and vapor handling equipment

- Welding procedure for LNG storage tanks and LNG and GNG piping systems
- Emergency shutdown arrangements
- Construction details of cargo and booster pumps and compressors including material specification
- Hazardous areas drawing showing access, openings, vent outlets
- De-watering and ballast arrangement for the cargo area

3.5 Design Plans for Process Facilities, Support and Safety Systems

3.5.1 Process and Re-Gasification Facilities

- The process system description
- Project specification and overall process concept evaluation
- Process flow sheets
- Heat and mass balance
- Equipment layout drawings
- Area classification and ventilation drawings
- Piping and Instrument Diagrams (P&IDs)
- Safety Analysis Function Evaluation (SAFE) charts
- Shut down and emergency shut down system (to include a hazard analysis and Failure Modes and Effects Analysis (FMEA) to identify critical components)
- Pressure relief and depressurization systems
- Flare and vent systems
- Spill containment, closed and open drain systems
- Process equipment documentation including calculations showing suitability of all pressurized components in the system to withstand the maximum design pressure that a specific component is likely to encounter in service
- Process piping systems
- Packaged process units
- The monitoring and control system for the entire system pressure regulation and gas dispersion system (to include calculations for sizing of the venting system and the relief valve) radiant heat analysis to demonstrate that the radiant heat intensity at any deck level or location where normal maintenance or operating activity could take place is not exceeding API RP 521 recommendations.

3.5.2 Process Support and Service Systems

- Piping and Instrument Diagrams (P&IDs) for each system
- Equipment documentation
- Process support piping specifications
- Specifications and data sheets for internal combustion engines and turbines
- Specifications and data sheets for cranes (Optional)
- Marine support systems as required by the ABS Rules applicable to the type of terminal

3.7 Electrical Installations

- Electrical one-line diagrams
- Short-circuit current calculations
- Coordination study
- Specifications and data sheets for generators and motors
- Specifications and data sheets for distribution transformers
- Details of storage batteries
- Details of emergency power source
- Standard details of wiring cable and conduit installation practices
- Switchboards and distribution panel
- Panel board
- Installations in classified areas

3.9 Instrumentation and Control Systems

- General arrangements
- Data sheet
- Schematic drawings – Electrical systems
- Schematic drawings – Hydraulic and pneumatic systems
- Programmable electronic systems

3.11 Fire Protection and Personnel Safety

- Firewater system
- Water spray (Deluge) systems for any deckhouse, superstructure and manifold areas
- Water spray (Deluge) systems for process equipment
- Dry powder system for LNG storage tank area
- Fixed fire extinguishing systems
- Paint lockers and flammable material storerooms
- Emergency control stations
- Portable and semi-portable extinguishers
- Fire and gas detection and alarm systems
- Fire and gas cause and effect chart
- Structural fire protection (which indicates classification of all bulkheads and decks for quarters section, machinery spaces and processing facilities)
- Heating Ventilation and Air Conditioning (HVAC) plan [including Air Handling Unit (AHU)] location, duct layout, duct construction and bulkhead and deck penetration details
- Joiner detail arrangement and structural fire protection material certification
- Guard rails
- Escape routes (may be included on the fire control plan or separate plan)
- Lifesaving appliances and equipment plan (escape routes must be indicated)

- Insulation of hot surfaces
- Fire and explosion hazard analysis
- Due to the varying configurations of the project, some portions of these requirements may not be applicable

3.13 Installation Procedures

- Procedures for loading sections of the terminal structure, deck area, process modules decks and topsides
- Procedures for carrying out all installation work offshore including foundation preparation, platform installation and completion

3.15 Start-up and Commissioning Manual

- Provisions/procedures for start-up
- Manual/procedures for commissioning trials

CHAPTER 2 Requirements for Gravity-Based Offshore LNG Terminals

SECTION 2 Design of Gravity-Based Offshore LNG Terminals

1 Environmental Loading and Design Basis

1.1 Environmental and Related Conditions

1.1.1 General

The minimum recurrence interval used to establish the magnitude of the *Design Environmental Condition* is 100 years, except where the use of a shorter recurrence interval produces higher magnitude load effects. As applicable, when a National Authority having jurisdiction over the LNG terminal specifies the use of a lower return period, this will be specially considered.

1.1.2 Environmental Conditions

The gravity-based terminal is to be designed for the site-specific environmental conditions specified in Part 3 of the *Offshore Installations Rules*. In addition to the *Design Environmental Conditions* mentioned above, the designer is to specify any limiting *Operating Environmental Conditions*. These are sets of characteristic parameters for the environmental factors that need to be limited so that the safe performance of an operation or function is not compromised. Such operations may include, as appropriate, transportation and installation of the gravity-based terminal structure itself and for conditions after the gravity-based terminal structure's installation (berthing and mooring of cargo and supply vessels, cargo transfer, personnel transfer, fuel oil transfer etc.). These sets of conditions are herein referred to as *Operating Environmental Conditions.*

1.1.3 Environmental Factors to be Considered

In general, the design of the gravity-based terminal will require investigation of the following environmental factors, as appropriate to the type of terminal structure and the terminal's installation site:

i) Waves

ii) Wind

iii) Currents

iv) Tides and storm surges

v) Air and sea temperatures

vi) Ice and snow

vii) Marine growth

viii) Seismicity

ix) Sea ice

Other phenomena, such as tsunamis, submarine slides, seiche, abnormal composition of air and water, air humidity, salinity, ice drift, icebergs, ice scouring, etc. may require investigation depending upon the specific installation site.

The required investigation of seabed and soil conditions is described in Section 3-2-5 of the *Offshore Installations Rules*.

1.3 Design Basis

The design of the unit and the facilities on the installation for gas processing, liquefaction, storage, re-gasification including importing of raw gas or LNG and exporting of processed gas or LNG is to be in accordance with the criteria defined in this Guide, including any additional prevention or mitigation safeguards identified in the risk assessment required in 2-2/3 of this Guide.

In addition to the requirements mentioned above, it is also the responsibility of the designer, owner and operator to comply with any additional requirements that may be imposed by the flag state or the coastal state or any other jurisdictions in the intended area of deployment and operation. This would include requirements for importing and exporting pipelines.

The complete basis for the design is to be stated in the operations manual and is to include the intended location, the envelope of environmental operating conditions and the storage capacities and throughputs of the production/re-gasification systems.

3 Risk Assessment

A Risk Assessment shall be carried out to identify significant hazards and accident scenarios that may affect the installation or any part thereof, and to consider the benefit of existing or potential risk control options.

The objective of the risk assessment is to identify areas of the design that may require the implementation of risk control measures to reduce identified risk(s) to an acceptable level. For this purpose, a systematic process is to be applied to identify situations where a combination or sequence of events could lead to undesirable consequences such as property damage, personnel safety and environmental damage.

The risk assessment shall consider, as a minimum, the following events:

i) Damage to the primary structure due to extreme weather, impact/collision, dropped objects, helicopter collision, exposure to unsuitably cold temperatures, exposure to high radiant heat

ii) Fire and explosion

iii) Loss of primary liquid containment (for a duration to be determined based on an approved contingency plan)

iv) LNG leakage

v) Release of flammable or toxic gas to the atmosphere or inside an enclosed space

vi) Roll-over (thermodynamic instability due to LNG stratification)

vii) Loss of ability to offload LNG or discharge gas ashore

viii) Loss of any one critical component in the process system

ix) Loss of electrical power

The identified risk control options (prevention and mitigation measures) deemed necessary to be implemented should be considered part of the design basis of the terminal.

ABS recommends that early in the project a risk assessment plan be developed, documented and submitted to ABS for review prior to conducting the risk assessment. During review of the plan, an agreement will be reached on the extent of ABS participation and/or monitoring of project-related risk studies. ABS's participation in and/or monitoring of key tasks (e.g. Hazard Identification meetings) is necessary in order to establish a minimum level of confidence on the risk assessment results.

5 Structure – Gravity-Based Terminal

This Section defines the general design requirements and load type definitions of steel or concrete gravity-based offshore LNG terminals.

The *Offshore Installations Rules*, directly and by reference to other standards, present the criteria deemed most applicable to the structural design of gravity-based offshore LNG terminals. Major portions of the structural criteria from these ABS standards are excerpted and modified below to reflect envisioned LNG terminal service. This has been done for the convenience of users and to concisely present in this Guide the main structural design and construction features included in the scope of Classification and the criteria to be applied. Reference should be made to the aforementioned *Offshore Installations Rules* for additional background on the referenced criteria.

In the design criteria presented below, it is assumed that the structural elements and the seabed foundation soil that resist the specified loads will not be exposed directly to the LNG and its cryogenic temperature.

5.1 General Design Requirements and Load Type Definitions

5.1.1 Analytical Approaches

5.1.1(a) Format of Design Specifications. The design requirements of this Guide are generally specified in terms of a working stress (also called 'allowable stress') format for steel structures and an ultimate strength format for concrete structures. In addition, this Guide requires that consideration be given to satisfying the serviceability of structure relative to deflection, vibration and, in the case of concrete, cracking.

ABS will give special consideration to the use of alternative specification formats such as those based on probabilistic or semi-probabilistic limit state design concepts.

5.1.1(b) Loading Formats. Either a deterministic or spectral format may be employed to describe various load components. When a static approach is used, it is to be demonstrated, where relevant, that consideration has been given to the general effects of dynamic amplification. The influence of waves, other than the highest waves, is to be investigated for their potential to produce maximum peak stresses due to resonance within the structure.

When considering an earthquake in seismically active areas, a dynamic analysis is to be performed. A dynamic analysis is also to be considered to assess the effects of environmental or other types of loads where dynamic amplification is expected. When a fatigue analysis is performed, a long-term distribution of the stress range with proper consideration of dynamic effects is to be obtained for relevant loadings anticipated during the design life of the terminal [see 2-2/5.3.7 and 2-2/5.5.5(d)].

5.1.1(c) Combinations of Loading Components. Loads imposed during and after installation are to be taken into account. In consideration of the various loads described in 2-2/5.1.4, loads to be considered for design are to be combined consistent with their probability of simultaneous occurrence. However, earthquake loadings may be applied without consideration of other environmental effects unless conditions at the site necessitate their inclusion. If site-specific directional data are not obtained, the direction of applied environmental loads is to be such as to produce the highest possible influence on the terminal.

Loading combinations corresponding to conditions after installation are to reflect both operating and design environmental loadings (2-2/1.1). Reference is to be made to 2-2/5.3, 2-2/5.5 and 2-2/5.7 regarding the minimum load combinations to be considered. The Operator is to specify the operating environmental conditions and the maximum tolerable environmental loads during installation.

5.1.2 Overall Design Considerations

5.1.2(a) Air Gap. An air gap of at least 1.5 m (5 ft) is to be provided between the maximum wave crest elevation and the lowest protuberance of the superstructure for which wave forces have not been included in the design. After accounting for the initial and expected long-term settlements of the structure due to consolidation (and possibly regional subsidence in a hydrocarbon or other reservoir area), the design wave crest elevation is to be superimposed on the still water level and consideration is to be given to wave run-up, tilting of the structure and, where appropriate, tsunamis.

5.1.2(b) Long-Term and Secondary Effects. Consideration is to be given to the following effects, as appropriate, to the planned structure:

i) Local vibration due to machinery, equipment and vortex shedding.

ii) Stress concentrations at critical joints, openings and any location where stress risers may occur due to discontinuities in stress flow (e.g., appurtenance attachments).

iii) Secondary stresses induced by large deflection (P-δ effects).

iv) Cumulative fatigue.

v) Corrosion.

vi) Abrasion due to ice.

vii) Freeze-thaw action on concrete and coatings.

viii) Differential settlement and rocking.

ix) Water migration into void and/or dry ballast areas

5.1.2(c) Reference Marking. For large or complex terminals, consideration should be given to installing permanent reference markings during construction to facilitate future surveys. Where employed, such markings may consist of weld beads, metal or plastic tags or other permanent markings. In the case of a concrete terminal, markings may be provided using suitable coatings or permanent lines molded into the concrete.

5.1.2(d) Zones of Exposure. Measures taken to mitigate the effects of corrosion are to be specified and described in terms of the following definitions for corrosion protection zones.

- *Submerged Zone.* That part of the installation below the splash zone.
- *Splash Zone.* The part of the installation containing the areas above and below the still water level which are regularly subjected to wetting due to wave action. Characteristically, the splash zone is not easily accessible for field painting, nor protected by cathodic protection.
- *Atmospheric Zone.* That part of the installation above the splash zone.

Additionally, for terminals located in areas subject to floating or submerged ice, that portion of the structure which may reasonably be expected to come into contact with floating or submerged ice is to be designed with consideration for such contact.

5.1.2(e) Access for Inspection. In the design of the terminal, consideration should be given to providing access for inspection during construction and, to the extent practicable, for survey after construction.

5.1.3 General Design Considerations for Concrete or Steel Gravity-Based Terminals

5.1.3(a) Positioning. The procedure for transporting and positioning the structure and the accuracy of measuring devices used during these procedures are to be documented.

5.1.3(b) Repeated Loadings. Effects of repeated loadings on soil properties, such as pore pressure, water content, shear strength and stress-strain behavior, are to be investigated.

5.1.3(c) Soil Reactions. Soil reactions against the base of the structure and possible differential settlements during and after installation are to be investigated. Consideration should be given to the occurrence of point loading caused by sea bottom irregularities. Suitable grouting between base slab and sea floor can be employed to reduce concentration of loads.

5.1.3(d) Terminal Operation. The expected loads and other demands that will be acting on the LNG Terminal as a result of the need to berth and moor vessels are to be considered in the design. These may include vessel breasting and mooring loads, the presence of fenders and the additional hydrodynamic and gravity loads that they bring, the need to support bollards and other mooring hardware, etc.

5.1.3(e) Maintenance. The strength and durability of construction materials is to be maintained. Where sulphate attack is anticipated, as from stored oil, adequate mitigation methods are to be employed.

5.1.3(f) Reinforcement Corrosion. Means to minimize reinforcing steel corrosion are to be considered and may include the use of high chromium and low carbon steel.

5.1.3(g) Instability. Instability of structural members due to submersion is to be considered, with due account for second-order effects produced by factors such as geometrical imperfections.

5.1.3(h) Horizontal Sliding. Where necessary, protection against horizontal sliding along the sea floor is to be provided by means of skirts, shear keys or equivalent means.

5.1.3(i) Dynamic Analysis. Where dynamic effects are significant to the structural design, dynamic analysis, including simulation of wave-structure response and soil-structure interaction, should be carried out.

5.1.3(j) Long Term Resistance. The long-term resistance to abrasion, cavitation, freeze-thaw durability and strength retention of the concrete is to be considered.

5.1.3(k) Negative Buoyancy. Provision is to be made to maintain either adequate negative buoyancy or the functional equivalent such as tension piles attached at all times to resist the uplift forces from submergence, waves, currents and overturning moments.

5.1.4 Types of Loads

Loads applied to a gravity-based offshore terminal are, for purposes of this Guide, categorized as follows.

5.1.4(a) Dead Loads. Dead loads are loads that do not change during the mode of operation under consideration. Dead loads include the following:

i) Weight in air of the structure including, as appropriate, the weight of the principal structure (e.g., caissons, gravity foundation, piling), weight of the internal LNG containment structure, grout, module support frame, decks, modules, stiffeners, piping, helicopter deck, skirt, columns and any other fixed structural parts.

ii) Weight of permanent ballast and the weight of permanent machinery.

iii) External hydrostatic pressure and buoyancy calculated on the basis of the still-water level.

iv) Static earth pressure.

5.1.4(b) Live Loads. Live loads associated with the normal operation and uses of the structure are loads which may change during the mode of operation considered. Though environmental loads are live loads, they are categorized separately [see 2-2/5.1.4(d)]. Live loads acting after construction and installation include the following:

i) The weight of temporary equipment which can be removed

ii) The weight of crew and consumable supplies

iii) Fluids in the vessels and pipes during operation

iv) Fluids in the vessels and pipes during testing

v) The weight of fluids in storage and ballast tanks

vi) The forces exerted on the structure due to terminal operations, e.g., LNG cargo vessel berthing and mooring

vii) The forces exerted on the structure during the operation of cranes and vehicles

viii) The forces exerted on the structure by vessels moored to the structure or accidental impact consideration for a typical supply vessel that would normally service the installation

ix) The forces exerted on the structure by helicopters during take-off and landing or while parked on the structure

Where applicable, the dynamic effects on the structure of the listed items are to be taken into account. Where appropriate, some of the items of live load listed above may be adequately accounted for by designing decks, etc. to a maximum, uniform area load as specified by the Operator, or past practice for similar conditions.

Live loads occurring during transportation and installation are to be determined for each specific operation involved, and the dynamic effects of such loads are to be accounted for as necessary.

5.1.4(c) Deformation Loads. Deformation loads are loads due to deformations imposed on the structure. The deformation loads include those due to temperature variations (e.g., hot or cold hydrocarbon or process fluid storage) leading to thermal induced stress in the structure and, where necessary, loads due to soil displacements (e.g., differential settlement or lateral displacement) or due to deformations of adjacent structures. For concrete terminals, deformation loads due to prestress, creep, shrinkage and expansion are to be taken into account.

5.1.4(d) Environmental Loads. Environmental loads are loads due to wind, waves, current, ice, snow, earthquake and other environmental phenomena. The characteristic parameters defining an environmental load are to be appropriate to the installation site and in accordance with the requirements of 2-2/1.1 of this Guide. Operating environmental loads are those loads derived from the parameters characterizing operating environmental conditions. Design environmental loads are those loads derived from the parameters characterizing the design environmental condition.

The combination and severity of design environmental loads are to be in accordance with 2-2/1.1 of this Guide.

Environmental loads are to be applied to the structure from directions producing the most unfavorable effects on the structure, unless site-specific studies provide evidence in support of a less stringent requirement. Directionality may be taken into account in applying the environmental criteria.

Earthquake loads and loads due to accidents or rare occurrence environmental phenomena need not be combined with other environmental loads, unless site-specific conditions indicate that such combinations are appropriate.

5.1.4(e) Other Loads. For deck mounted equipment – for use in the preliminary design of deck transverses and girders that are directly resisting the reaction forces and when ABS permits it in lieu of a more comprehensive method, the approach presented in 5A-3-3/11 and 5A-3-6/3 of the *FPI Rules* may be used.

5.3 Gravity-Based Steel Terminals

5.3.1 General

5.3.1(a) Materials. The requirements of this Paragraph are intended for terminals constructed of steel, manufactured and having properties as specified in Part 2, Chapter 1 of the *Offshore Installations Rules*. Where it is intended to use steel or other materials having properties differing from those specified in Part 2, Chapter 1 of the *Offshore Installations Rules*, their applicability will be considered subject to a review of the specifications for the alternative materials and the proposed methods of fabrication.

5.3.1(b) Corrosion Protection. Materials are to be protected from the effects of corrosion by the use of a corrosion protection system including the use of coatings. The system is to be effective from the time the terminal is initially placed on site. Where the sea environment contains unusual contaminants, any special corrosive effects of such contaminants are also to be considered. For the design of protection systems, reference is to be made to the National Association of Corrosion Engineers (NACE) publication RP 0176-94, or other appropriate references.

5.3.1(c) Steel-Concrete Hybrid Structures. The steel portions of a steel-concrete hybrid structure are to be designed in accordance with the requirements of 2-2/5.3 of this Guide, and the concrete portions are to be designed as specified in 2-2/5.5. Any effects of the hybrid structure interacting on itself in areas such as corrosion protection should be considered.

5.3.1(d) Steel-Concrete Composite Structures. Steel-Concrete composite structures are to be designed in accordance with 2-2/5.3 of this Guide and the AISC, “Allowable Stress Design”.

5.3.2 General Design Criteria

Steel terminals are to be designed and analyzed for the loads to which they are likely to be exposed during construction, installation and in-service operations. To this end, the effects on the structure of a minimum set of loading conditions, as indicated in 2-2/5.3.3, are to be determined, and the resulting structural responses are not to exceed the safety and serviceability criteria given below.

The use of design methods and associated safety and serviceability criteria other than those specifically covered in this Section is permitted where it can be demonstrated that the use of such alternative methods will result in a structure possessing a level of safety equivalent to or greater than that provided by the direct application of these requirements.

5.3.3 Loading Conditions

Loadings that produce the most unfavorable effects on the terminal during and after construction and installation are to be considered. Loadings to be investigated for conditions after installation are to include at least those relating to both the realistic operating and design environmental conditions combined with other pertinent loads in the following manner.

Operating environmental loading combined with dead and maximum live loads appropriate to the function and operations of the terminal.

Design environmental loading combined with dead and live loads appropriate to the function and operations of the terminal during the design environmental condition.

For terminals located in seismically active areas, earthquake loads are to be combined with dead and live loads appropriate to the operation and function of the terminal which may be occurring at the onset of an earthquake.

5.3.4 Structural Analysis

5.3.4(a) The nature of loads and loading combinations as well as the local environmental conditions are to be taken into consideration in the selection of design methods. Methods of analysis and their associated assumptions are to be compatible with the overall design principles. Linear, elastic methods (working stress methods) can be employed in design and analysis, provided proper measures are taken to prevent general and local buckling failure, and the interaction between soil and structure is adequately treated. When assessing structural instability as a possible mode of failure, the effects of initial stresses and geometric imperfections are to be taken into account. Construction tolerances are to be consistent with those used in the structural stability assessment.

5.3.4(b) Dynamic effects are to be accounted for if the wave energy in the frequency range of the structural natural frequencies is of sufficient magnitude to produce significant (greater than 15% of the static loads) dynamic response in the structure. In assessing the need for dynamic analyses, information regarding the natural frequencies of the structure in its intended position is to be obtained. The determination of dynamic effects is to be accomplished either by computing the dynamic amplification effects in conjunction with a deterministic analysis or by a random dynamic analysis based on a probabilistic formulation. In either case, the analysis is to be accompanied by a statistical description and evaluation of the relevant input parameters.

5.3.5 Allowable Stress Approach

When a design is based on a working stress method [2-2/5.1.1 and 2-2/5.3.4(a)], the safety criteria are to be expressed in terms of appropriate basic allowable stresses in accordance with requirements specified below.

5.3.5(a) Controlling Reference Standards

i) For stiffened and unstiffened flat plate or cylindrical shell structure, the allowable stresses are as specified in the API RP 2T with element strength as defined in the API Bulletins 2V or 2U for flat plate or cylindrical shell structure, respectively.

ii) For tubular elements and their connections (e.g., jacket type construction), the allowable stresses are as specified in the API RP 2A.

iii) For structural members and loadings covered by Part 5 of the American Institute of Steel Construction (AISC) Manual of Steel Construction, ASD, with the exception of earthquake loadings (see 2-2/5.3.5(c) below), the basic allowable stresses of the members are to be obtained using the AISC Specification.

iv) Other applicable recognized industry standards

5.3.5(b) Where stresses in members/components described in 2-2/5.3.5(a) are shown to be due to forces imposed by the design environmental condition acting alone or in combination with dead and live loads, the basic allowable stresses cited in 2-2/5.3.5(a) may be increased by one-third, provided the resulting structural member sizes are not less than those required for the operating environment loading combined with dead and live loads without the one-third increase in allowable stresses.

5.3.5(c) When considering loading combinations which include earthquake loads (2-2/5.3.3) on individual members or on the overall structure, the allowable stress may be set equal to 1.7 times the basic allowable stress of the member.

5.3.5(d) The allowable stresses specified in 2-2/5.3.5(b) are to be regarded as the limits for stresses in all structural parts for the marine operations covered in Section 3-2-6 of the *Offshore Installations Rules*, except for lifting, where the one-third increase in the basic allowable stress is not permitted. The lifting analysis should adequately account for equipment and fabrication weight increase.

5.3.5(e) For any two- or three-dimensional stress field within the scope of the working stress formulation, the equivalent stress (e.g., the vonMises stress intensity) is to be limited by an appropriate allowable stress less than yield stress, with the exception of those stresses of a highly localized nature. In the latter case, local yielding of the structure may be accepted, provided it can be demonstrated that such yielding does not lead to progressive collapse of the overall structure and that the general structural stability is maintained. The allowable vonMises stress of the structure is to be 0.6 of the yield strength for the operational conditions. A one-third increase in the allowable stress (i.e., 0.8 of the yield strength) is allowed for the design conditions.

5.3.5(f) Whenever elastic instability, overall or local, may occur before the stresses reach their basic allowable levels, appropriate allowable buckling stresses govern.

5.3.5(g) Mooring between Terminal and Vessel. The local foundation structure and vessel structure are to be checked for the given mooring loads using an appropriate engineering method such as FEA. The operating mooring load is defined as the maximum load imposed on the mooring lines between the terminal and the maximum size vessel for the operating environmental condition and the terminal, unless a smaller vessel is apt to impose higher mooring loads under the influence of the operating wind, wave, current and tides. Data and calculations are to be submitted to establish the validity of this operating mooring load. Safety factors for the mooring lines between the terminal and vessel are to comply with 3-4-1/11 of the ABS *Rules for Single Point Moorings*.

When a rigid mooring structure is used as the mooring structure between the terminal and vessel, the connecting structures are to comply with 3-2-4/5 of the *Offshore Installations Rules*.

5.3.6 Structural Response to Earthquake Loads

Terminals located in seismically active areas are to be designed to possess adequate strength and stiffness to withstand the effects of a strength level earthquake, as well as sufficient ductility to remain stable during rare motions of greater severity associated with a ductility level earthquake. The sufficiency of the structural strength and ductility is to be demonstrated by strength and, as required, ductility analyses.

For a strength level earthquake, the strength analysis is to demonstrate that the structure is adequately sized for strength and stiffness so as to maintain all nominal stresses within their yield or buckling limits.

In the ductility analysis, it is to be demonstrated that the structure has the capability of absorbing the energy associated with the ductility level earthquake without reaching a state of incremental collapse.

In all seismically active locations around the world, a seismic report should be submitted that presents the seismic design parameters in a manner consistent with the approach taken in the RP 2A for developing site-specific criteria.

5.3.7 Fatigue Assessment

For structural components, members and joints where fatigue is a probable mode of failure, or for which past experience is insufficient to assess possible cumulative fatigue damage, an assessment of fatigue life is to be carried out. Emphasis is to be given to the splash zone, areas that are difficult to inspect and repair once the terminal is in service, and areas susceptible to corrosion-accelerated fatigue.

For structural members and joints which require a detailed assessment of cumulative fatigue damage, the results of the assessment are to indicate a minimum expected fatigue life of a fatigue design factor (safety factor for fatigue design) times the design life of the terminal. The fatigue design factor is a factor that is applied to individual structural details which accounts for: uncertainties in the fatigue assessment process, the consequences of failure (i.e., criticality) and the relative difficulty of inspection and repair. Section 4, Table 1 of the ABS *Guide for the Fatigue Assessment of Offshore Structures* provides specific information on the values of the fatigue design factor. For a terminal located on the outer continental shelf of the United States, an alternative version of Table 1 is presented in Appendix 3 of the same document.

A spectral fatigue analysis technique is recommended to calculate the fatigue life of the terminal. Other rational analysis methods are also acceptable if the forces and member stresses can be properly represented. The dynamic effects should be taken into consideration if they are significant to the structural response.

5.3.8 Stresses in Connections

Connections of structural components and members are to be developed to provide effective load transmission between joined elements to minimize stress concentration and (as applicable) to prevent excessive “punching” shear. Connection details are also to be designed to minimize undue constraints against overall ductile behavior and to minimize the effects of post-weld shrinkage. Undue concentration of welding is to be avoided.

The design of tubular joints may be in accordance with the API RP 2A.

5.3.9 Local Structure

Structures that do not directly contribute to the overall strength of the gravity-based offshore terminal, i.e., their loss or damage would not impair the structural integrity of the offshore terminal, are considered to be local structure.

Local structures are to be adequate for the nature and magnitude of applied loads. Allowable stresses specified in 2-2/5.3.5 are to be used as stress limits, except for those structural parts whose primary function is to absorb energy, in which case, sufficient ductility is to be demonstrated.

5.5 Gravity-Based Concrete Terminals

5.5.1 General

5.5.1(a) Materials. Unless otherwise specified, the requirements of this Paragraph are intended for structures constructed of materials manufactured and having properties as specified in Part 2, Chapter 1 of the *Offshore Installations Rules*. Where it is intended to use materials having properties differing from those specified in Part 2, Chapter 1 of the *Offshore Installations Rules*, the use of such materials will be specially considered. Specifications for alternative materials, details of the proposed methods of manufacture and, where available, evidence of satisfactory previous performance are to be submitted for approval.

Structural lightweight concrete should conform to ACI 213R, “Guide for Structural Lightweight Aggregate Concrete”. Lightweight aggregates should conform to the requirements of ASTM C330, “Specification for Lightweight Aggregates for Structural Concrete”.

5.5.1(b) Durability. Materials, concrete mix proportions, construction procedures and quality control are to be chosen to produce satisfactory durability for structures located in a marine environment. Problems to be specifically addressed include chemical deterioration of concrete, corrosion of the reinforcement and hardware, abrasion of the concrete, freeze-thaw durability and fire hazards as they pertain to the zones of exposure defined in 3-2-4/5.9 of the *Offshore Installations Rules*.

Test mixes should be prepared and tested early in the design phase to verify that proper values of strength, creep, alkali resistance, etc. will be achieved.

5.5.1(c) Concrete-Steel Hybrid Structures. The concrete portions of a hybrid structure are to be designed in accordance with the requirements of this Paragraph and the steel portions in accordance with the requirements of Section 3-2-3 of the *Offshore Installations Rules.* Any effects of the hybrid structure interacting on itself in areas such as corrosion protection should be considered.

5.5.2 Design Method

5.5.2(a) General. The requirements of this Paragraph relate to the ultimate strength method of design employing the Limit State Design [or Load and Resistance Factor Design (LRFD)] format.

5.5.2(b) Load Magnitude. The magnitude of a design load for a given type of loading k is obtained by multiplying the load, F_k, by the appropriate load factor, c_k, i.e., design load = $c_k F_k$.

5.5.2(c) Design Strength. In the analysis of sections, the design strength of a given material is obtained by multiplying the material strength, f_k, by the appropriate strength reduction factor, φ, i.e., design strength = φf_k. The strength reduction factor and material strength of concrete (f_c') and reinforcement steel (f_y) are defined in 2-2/5.5.5(c) and 2-2/5.5.6(b), respectively.

5.5.3 Load Definition

5.5.3(a) Load Categories. The load categories referred to in this Paragraph, i.e., dead loads, live loads, deformation loads and environmental loads are defined in 2-2/5.1.4.

5.5.3(b) Combination Loads. Loads taken in combination for the Operating Environmental Conditions and the Design Environmental Condition are indicated in 2-2/5.5.5(b).

5.5.3(c) Earthquake and Other Loads. Earthquake loads and loads due to environmental phenomena of rare occurrence need not be combined with other environmental loads unless site-specific conditions indicate that such combination is appropriate.

5.5.4 Design Reference

Design considerations for concrete terminals not directly addressed in this Guide are to follow the requirements of the American Concrete Institute (ACI) 318 and ACI 357R, or equivalent.

5.5.5 Design Requirements

5.5.5(a) General. The strength of the LNG terminal structure is to be such that adequate safety exists against failure of the structure or its components. Among the modes of possible failure to be considered are the following:

i) Loss of overall equilibrium

ii) Failure of critical sections

iii) Instability resulting from large deformations

iv) Excessive plastic or creep deformation

The serviceability of the structure is to be assessed. The following items are to be considered in relation to their potential influences on the serviceability of the structure:

i) Cracking and spalling

ii) Deformations

iii) Corrosion of reinforcement or deterioration of concrete

iv) Vibrations

v) Leakage

5.5.5(b) Required Strength (Load Combinations). The required strength (U) of the structure and each member is to be equal to, or greater than, the maximum of the following.

$$U = 1.2(D + T) + 1.6L_{max} + 1.3E_O$$

$$U = 1.2(D + T) + 1.2L_{max} + c_E E_{max}$$

$$U = 0.9(D + T) + 0.9L_{min} + c_E E_{max}$$

in which c_E assumes the following values:

c_E = 1.3 for wave, current, wind or ice load

c_E = 1.4 for earthquake loads

In the preceding equations, the symbols D, T and L represent dead load, deformation load and live load, respectively (see 2-2/5.5.3). The symbol E_O represents operating environmental loads while E_{max} represents design environmental loads. The symbol L_{min} represents minimum expected live loads, while L_{max} represents maximum expected live loads. Each live load is to be established with respect to expected environmental conditions which may limit or preclude the existence of the live load.

For loads of type D, the load factor 1.2 is to be replaced by 1.0 if it leads to a more unfavorable load combination. For loads of type E_O, the load factor 1.3 may be reduced if a more unfavorable load combination results. For strength evaluation, the effects of deformation load may be ignored, provided adequate ductility is demonstrated.

While the critical design loadings will be identified from the load combinations given above, the other simultaneously occurring load combinations during construction and installation phases are to be considered if they can cause critical load effects.

5.5.5(c) Strength Reduction Factors. The strength of a member or a cross section is to be calculated in accordance with the provisions of 2-2/5.5.6 of this Guide and it is to be multiplied by the following strength reduction factor, φ:

i) For flexure without tension, $\varphi = 0.90$

ii) For axial compression or compression combined with flexure.

Reinforced members with spiral reinforcement, $\varphi = 0.70$

Other reinforced members (excluding slabs and shells), $\varphi = 0.65$

The values given above may be increased linearly to 0.90 as φP_n decreases from $0.10 f_c' A_g$ or φP_b, whichever is smaller, to zero.

f_c' = specified compression strength of concrete

A_g = gross area of section

P_n = axial design load in compression member

P_b = axial load capacity assuming simultaneous occurrence of the ultimate strain of concrete and yielding of tension steel

Slabs and shells, $\varphi = 0.70$

iii) For shear and torsion, $\varphi = 0.75$

iv) For bearing on concrete, $\varphi = 0.65$, except for post-tensioning anchorage bearing.

For bearing on concrete in post-tension anchorage, $\varphi = 0.85$.

Alternatively, the expected strength of concrete members can be determined by using idealized stress-strain curves and material factors (c_M) given in ACI 357R. The material factors applied to the stress-strain curves limit the maximum stress to achieve the desired reliability similar to using the strength reduction factors given above. The strength reduction factors (φ) and the material factors (c_M) are not to be used simultaneously.

5.5.5(d) Fatigue. The fatigue strength of the structure will be considered satisfactory if under the unfactored operating loads the following conditions are satisfied:

i) The stress range in reinforcing or prestressing steel does not exceed 138 MPa (20,000 psi), or where reinforcement is bent, welded or spliced, 69 MPa (10,000 psi).

ii) There is no membrane tensile stress in concrete and not more than 1.4 MPa (200 psi) flexural tensile stress in concrete.

iii) The stress range in compression in concrete does not exceed $0.50f_c'$ where f_c' is the specified compressive strength of concrete.

iv) Where maximum shear exceeds the allowable shear of the concrete alone, and where the cyclic range is more than half the maximum allowable shear in the concrete alone, all shear is taken by reinforcement. In determining the allowable shear of the concrete alone, the influence of permanent compressive stress may be taken into account.

v) In situations where fatigue stress ranges allow greater latitude than those under the serviceability requirements given in 2-2/Table 1, the latter condition shall assume precedence.

vi) Bond stress does not exceed 50% of that permitted for static loads. If lap splices of reinforcement or pretensioning anchorage development are subjected to cyclic tensile stresses greater than 50% of the allowable static stress, the lap length or prestressing development length should be increased by 50%.

Where the above nominal values are exceeded, an in-depth fatigue analysis is to be performed. In such an analysis, the possible reduction of material strength is to be taken into account on the basis of appropriate data (S-N curves) corresponding to the 95th percentile of specimen survival. In this regard, consideration is to be given not only to the effects of fatigue induced by normal stresses, but also to fatigue effects due to shear and bond stresses under unfactored load combinations.

Particular attention is to be given to submerged areas subjected to the low-cycle, high-stress components of the loading history.

In prestressed members containing unbonded reinforcement, special attention should be given to the possibility of fatigue in the anchorages or couplers that may be subject to corrosive action.

Where an analysis of the fatigue life is performed, the expected fatigue life of the terminal is to be at least twice the design life. In order to estimate the cumulative fatigue damage under variable amplitude stresses, a recognized cumulative rule is to be used. Miner's rule is an acceptable method for the cumulative fatigue damage analysis.

5.5.5(e) Serviceability Requirements

Serviceability. The serviceability of the structure is to be checked by the use of stress-strain diagrams (2-2/Figure 1 and 2-2/Figure 2) with strength reduction factor, φ = 1.0, and the unfactored load combination:

$$U = D + T + L + E_O$$

Where L is the most unfavorable live load, and all other terms are as previously defined.

Using this method, the reinforcing stresses are to be limited in compliance with 2-2/Table 1. Additionally, for hollow structural cross sections, the maximum permissible membrane strain across the walls should not cause cracking under any combination of D, L, T and E_{max} using load factors taken as 1.0. For structures prestressed in one direction only, tensile stresses in reinforcement transverse to the prestressing steel shall be limited so that the strains at the plane of the prestressing steel do not exceed D_{ps}/E_S where D_{ps} is as defined in 2-2/Table 1 and E_S is the modulus of elasticity of reinforcement [see 2-2/5.5.6(b)].

Alternative criteria such as those which directly limit crack width will also be considered.

Liquid-Containing Structures. The following criteria are to be satisfied for liquid-containing structures to provide adequate design against leakage:

- The reinforcing steel stresses are to be in accordance with 2-2/5.5.5(e) above
- The compression zone is to extend over 25% of the wall thickness, or 205 mm (8 in.), whichever is the lesser
- There is to be no membrane tensile stress unless other construction arrangements are made, such as the use of special barriers to prevent leakage

TABLE 1
Allowable Tensile Stresses for Reinforcing Steel and Prestressing Tendons to Control Cracking

Stage	*Loading*	*Allowable Stress, MPa (ksi)*	
		Reinforcing Steel, f_s	*Prestressing Tendons, D_{ps}*
Construction: where cracking during construction would be detrimental to the completed structure	All loads on the structure during construction	160 (23.0)	130 (18.5)
Construction: where cracking during construction is not detrimental to the completed structure	All loads on the structure during construction	210 (30.0) or 0.6 f_y, whichever is less	130 (18.5)
Transportation and installation	All loads on the structure during transportation and installation	160 (23.0)	130 (18.5)
At offshore site	Dead and live loads plus operating environmental loads	120 (17.0)	75 (11.0)
At offshore site	Dead and live loads plus design environmental loads	0.8 f_y	

f_y = yield stress of the reinforcing steel

f_s = allowable stress in the reinforcing steel

D_{ps} = increase in tensile stress in prestressing steel with reference to the stress at zero strain in the concrete.

5.5.6 Analysis and Design

5.5.6(a) General. Generally, the analysis of structures may be performed under the assumptions of linearly elastic materials and linearly elastic structural behavior, following the requirements of ACI 318 and the additional requirements of this Subsection. The material properties to be used in analysis are to conform to 2-2/5.5.6(b) of this Guide. However, the inelastic behavior of concrete based on the true variation of the modulus of elasticity with stress and the geometric non-linearities, including the effects of initial deviation of the structure from the design geometry, are to be taken into account whenever their effects reduce the strength of the structure. The beneficial effects of the concrete's nonlinear behavior may be accounted for in the analysis and design of the structure to resist dynamic loadings.

When required, the dynamic behavior of concrete structures may be investigated using a linear structural model, but soil-structural impedances are to be taken into account. The analysis of the structure under earthquake conditions may be performed under the assumption of elasto-plastic behavior due to yielding, provided that the requirements of 2-2/5.5.6(g) of this Guide are satisfied.

5.5.6(b) Material Properties for Structural Analysis.

i) *Specified Compressive Strength.* Unless otherwise specified, f_c' is to be based on 28 day tests and performed in accordance with specifications ASTM C172, ASTM C31 and ASTM C39.

ii) *Early Loadings.* For structures which are subjected to loadings before the end of the 28-day hardening period of concrete, the compressive strength of concrete is to be taken at the actual age of concrete at the time of loading, and determined based on field-cured cylinders tested at same age in accordance with the QCP.

iii) *Modulus of Elasticity – Concrete.* For the purposes of structural analyses and deflection checks, the modulus of elasticity of normal weight concrete may be assumed as equal to 4733 $(f_c')^{0.5}$ MPa [57,000 $(f_c')^{0.5}$ psi], or calculated in accordance with ACI 318, or determined from stress-strain curves developed by tests (e.g., 2-2/Figure 1). When the latter method is used, the modulus of elasticity is to be determined using the secant modulus for the stress equal to $0.5f_c'$.

iv) *Uniaxial Compression-Concrete.* In lieu of tests, the stress-strain relation shown in 2-2/Figure 1 may be used for uniaxial compression of concrete.

v) *Poisson Ratio.* The Poisson ratio of concrete may be taken equal to 0.20.

vi) *Modulus of Elasticity – Reinforcement.* The modulus of elasticity, E_S of non-prestressed steel reinforcement is to be taken as 200×10^3 MPa (29×10^6 psi). The modulus of elasticity of prestressing tendons and special deformed steel reinforcing bars are to be determined by tests.

vii) *Uniaxial Tension-Reinforcement.* The stress-strain relation of non-prestressed steel reinforcement in uniaxial tension is to be assumed as shown in 2-2/Figure 2. The stress-strain relation of prestressing tendons and special deformed steel reinforcing bars are to be determined by tests, or taken from the manufacturer's certificate.

viii) *Yield Strength-Reinforcement.* If the specified yield strength, f_y, of non-prestressed reinforcement exceeds 420 MPa (60,000 psi), the value of f_y used in the analysis is to be taken as the stress corresponding to a strain of 0.35%.

FIGURE 1
Idealized Stress-Strain Relation for Concrete in Uniaxial Compression

E_c is defined in 2-2/5.5.6(b).

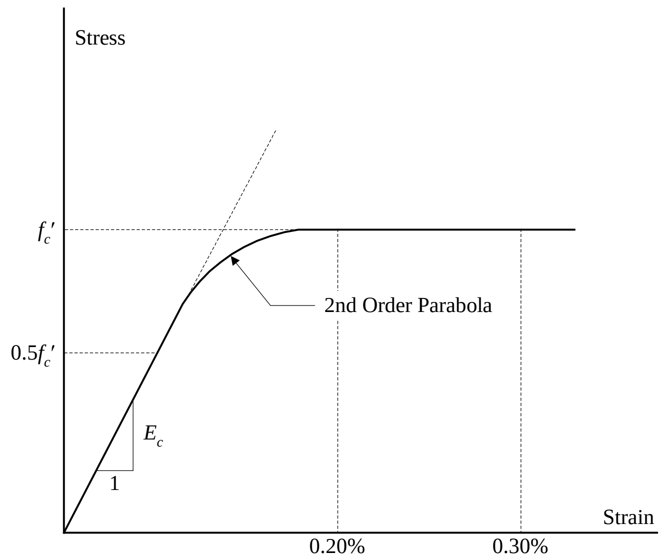
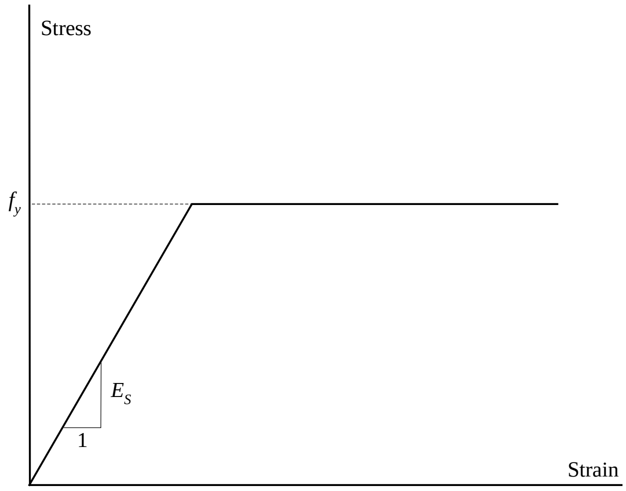


FIGURE 2
Idealized Stress-Strain Relation for Non-Prestressed Steel in Uniaxial Tension

$E_S = 200 \times 10^3$ MPa (29,000 ksi)



5.5.6(c) Analysis of Plates, Shells, and Folded Plates. In all analyses of shell structures, the theory employed in analysis is not to be based solely on membrane or direct stress approaches. The buckling strength of plate and shell structures is to be checked by an analysis that takes into account the geometrical imperfections of the structure, the inelastic behavior of concrete and the creep deformations of concrete under sustained loading. Special attention is to be devoted to structures subjected to external pressure and the possibility of their collapse (implosion) by failure of concrete in compression.

5.5.6(d) Deflection Analysis. Immediate deflections may be determined by the methods of linear structural analysis. For the purposes of deflection analysis, the member stiffnesses are to be computed using the material properties specified in the design and are to take into account the effect of cracks in tension zones of concrete. The effect of creep strain in concrete is to be taken into account in the computations of deflections under sustained loadings.

5.5.6(e) Analysis and Design for Shear and Torsion. The applicable requirements of ACI 318 or their equivalent are to be complied with in the analysis and design of members subject to shear or torsion or to combined shear and torsion.

5.5.6(f) Analysis and Design for Bending and Axial Loads

i) *Assumed Conditions.* The analysis and design of members subjected to bending and axial loads are to be based on the following assumptions:

- The strains in steel and concrete are proportional to the distance from the neutral axis.
- Tensile strength of the concrete is to be neglected, except in pre-stressed concrete members under unfactored loads where the requirements in 2-2/5.5.5(e) apply.
- The stress in steel is to be taken as equal to E_S times the steel strain, but not larger than f_y.
- The stresses in the compression zone of concrete are to be assumed to vary with strain according to the curve given in 2-2/Figure 1 or any other substantiated rule acceptable to ABS. Rectangular distribution of compressive stresses in concrete specified by ACI 318 may be used.
- The maximum strain in concrete at the ultimate state is not to be larger than 0.30%.

ii) *Failure.* The members in bending are to be designed in such a way that yielding of steel occurs prior to compressive failure of concrete.

5.5.6(g) Seismic Analysis

i) *Dynamic Analysis*. For terminals to be located at sites known to be seismically active [see 2-2/5.5.6(h)], dynamic analysis is to be performed to determine the response of the terminal to design earthquake loading. The terminal is to be designed to withstand this loading without damage to the structural integrity. In addition, a ductility check is also to be performed to verify that the structure has sufficient ductility to experience deflections more severe than those resulting from the design earthquake loading without the collapse of the structure or its foundation.

ii) *Design Conditions*. The dynamic analysis for earthquake loadings is to be performed taking into account:

- The interaction of all load bearing or load carrying components of the structure
- The compliance of the soil and the dynamic soil-structure interaction
- The dynamic effects of the ambient and contained fluids

iii) *Method of Analysis*. The dynamic analysis for earthquake loadings may be performed by any recognized method such as determination of time histories of the response by direct integration of the equations of motion or the response spectra method.

iv) *Ductility Check*. In the ductility check, ground motions (e.g., spectral ordinates) at least twice those used for the design earthquake are to be assumed. If the ductility check is performed with the assumption of elasto-plastic behavior of the structure, the selected method of analysis is to be capable of taking into account the non-linearities of the structural model. The possibility of dynamic instability (dynamic buckling) of individual members and of the whole structure should be considered.

5.5.6(h) Seismic Design

i) *Compressive Strains.* Compressive strains in the concrete at critical sections (including plastic hinge locations) are to be limited to 0.3%, except when greater strain may be accommodated by confining steel.

ii) *Flexural Bending or Load Reversals.* For structural members or sections subjected to flexural bending or to load reversals where the percentage of tensile reinforcement exceeds 70% of the reinforcement at which yield stress in the steel is reached simultaneously with compression failure in the concrete, special confining reinforcement (e.g., T-headed bars) and/or compressive reinforcement are to be provided to prevent brittle failure in the compressive zone of concrete.

iii) *Web Reinforcement*. Web reinforcement (stirrups) of flexural members is to be designed for shear forces which develop at full plastic bending capacity of end sections. In addition:

- The diameter of rods used as stirrups is not to be less than 10 mm (#3 bar).
- Only closed stirrups (stirrup ties) are to be used. T-headed bars or other mechanically-headed bars may be used if their effectiveness has been verified.
- The spacing of stirrups is not to exceed the lesser of $d/2$ or 16 bar diameters of compressive reinforcement where d is the distance from the extreme compression fiber to the centroid of tensile reinforcement. Tails of stirrups are to be anchored within a confined zone, i.e., turned inward.

iv) *Splices*. No splices are allowed within a distance d, defined above, from a plastic hinge. Lap splices are to be designed in accordance with ACI 318. Mechanical and welded splices are permitted. Mechanical splices are to be in compliance with ACI 349.

5.5.7 Design Details

5.5.7(a) Concrete Cover

i) *General*. The following minimum concrete cover for reinforcing bars is required:

- Atmospheric zone not subjected to salt spray: 50 mm (2 in.)
- Splash and atmospheric zones subjected to salt spray and exposed to soil: 65 mm (2.5 in.)
- Submerged zone: 50 mm (2 in.)
- Areas not exposed to weather or soil: 40 mm (1.5 in.)
- Cover of stirrups may be 13 mm (0.5 in.) less than covers listed above.

ii) *Tendons and Ducts*. The concrete cover of prestressing tendons and post-tensioning ducts is to be increased by at least 25 mm (1 in.) above the values listed herein.

iii) *Sections Less Than 500 mm (20 in.) Thick*. In sections less than 500 mm (20 in.) thick, the concrete cover of reinforcing bars and stirrups may be reduced below the values listed herein, however, the cover is not to be less than the following:

- 1.5 times the nominal aggregate size
- 1.5 times the maximum diameter of reinforcement, or 19 mm (0.75 in.)
- Tendons and post-tensioning duct covers are to have 12.5 mm (0.5 in.) added to the above.

5.5.7(b) Minimum Reinforcement. The minimum requirements of ACI 318 should be satisfied. In addition, for loadings during all phases of construction, transportation and operation (including design environmental loading) where tensile stresses occur on a face of the structure, the following minimum reinforcement is to be provided.

$$A_S = (f_t/f_y)bd_e$$

where

A_S	=	total cross-section area of reinforcement
f_t	=	mean tensile strength of concrete
f_y	=	yield stress of the reinforcing steel
b	=	width of structural element
d_e	=	effective tension zone, to be taken as $1.5c + 10d_b$
c	=	cover of reinforcement
d_b	=	diameter of reinforcement bar

d_e should be at least 0.2 times the depth of the section, but not greater than 0.5 $(h – x)$, where x is the depth of the compression zone prior to cracking and h is the section thickness.

At intersections between structural elements where transfer of shear forces is essential to the integrity of the structure, adequate transverse reinforcement is to be provided.

5.5.7(c) Reinforcement Details. Generally, lapped joints and mechanical splices should be avoided in structural members subjected to significant fatigue loading. Where lapped splices are used in members subject to fatigue, the development length of reinforcing bars is to be twice that required by ACI 318, and lapped bars are to be tied with tie wire. Where mechanical splices are used in members subject to fatigue, the coupled assembly of reinforcing bars and the mechanical coupler shall demonstrate adequate fatigue resistance by test.

Where lapped bars will be subject to tension during operation, through-slab confinement reinforcement is to be considered at the splices. Where longitudinal bars are subjected to tension during operation, special consideration should be given to the number of reinforcements with splices at a single location.

Reinforcing steel is to comply with the chemical composition specifications of ACI 359 if welded splices are used.

For anchorage of shear and main reinforcement, mechanically-headed bars (T-headed bars) may be used if their effectiveness has been verified by static and dynamic testing. Shear reinforcement should be full length without splices. Entire close-up stirrups should be anchored by hooks or bends of at least 90° followed by a straight leg length of a minimum 12 bar diameters.

5.5.7(d) Post Tensioning Ducts. Ducting for post-tensioning ducts may be rigid steel or plastic (polyethylene or polystyrene). Steel tubing is to have a minimum wall thickness of 1 mm. Plastic tubing is to have a minimum wall thickness of 2 mm. Ducts may also be semi-rigid steel, spirally wrapped, of minimum thickness of 0.75 mm and are to be grout-tight. All splices in steel tubes and semi-rigid duct are to be sleeved and the joints sealed with heat-shrink tape. Joints in plastic duct are to be fused or sleeved and sealed.

The inside diameter of ducts shall be at least 6 mm (0.25 in.) larger than the diameter of the post-tensioning tendon in order to facilitate grout injection.

Flexible ducts are used only in special areas where the rigid or semi-rigid duct is impracticable, such as at sharp bends. A mandrel should be inserted into the ducts to prevent them from dislocation during concreting.

5.5.7(e) Post-Tensioning Anchorages and Couplers. Anchorages for unbonded tendons and couplers are to develop the specified ultimate capacity of the tendons without exceeding anticipated set. Anchorages for bonded tendons are to develop at least 90% of the specified ultimate capacity of the tendons, when tested in an unbonded condition without exceeding anticipated set. However, 100% of the specified ultimate capacity of the tendons is to be developed after the tendons are bonded in the member.

Anchorage and end fittings are to be permanently protected against corrosion. Post-tensioning anchorages shall preferably be recessed in a pocket which is then filled with concrete. The fill should be mechanically tied to the structure by reinforcements as well as bonded by epoxy or polymer.

Anchor fittings for unbonded tendons are to be capable of transferring to the concrete a load equal to the capacity of the tendon under both static and cyclic loading conditions.

5.5.7(f) Embeded Metals in Concrete. Consideration should be given to preventing corrosion of exposed faces of steel embedment. These embedments should be separated from the reinforcing steel. Effects of dimensional changes due to factors such as prestressing, and temperature changes which may result in fractures near embedments may require provisions to prevent deformation.

5.5.8 Construction and Detailing

5.5.8(a) General. Construction methods and workmanship are to follow accepted practices as described in ACI 301, ACI 318, ACI 357 or other relevant standards.

5.5.8(b) Mixing, Placing and Curing of Concrete. Mixing of concrete is to conform to the requirements of ACI 318 and ASTM C94.

In cold weather, concreting in air temperatures below 2°C (35°F) should be carried out only if special precautions are taken to protect the fresh concrete from damage by frost. The temperature of the concrete at the time of placing is to be at least 4°C (40°F) and the concrete is to be maintained at this or a higher temperature until it has reached a strength of at least 5 MPa (700 psi).

Protection and insulation are to be provided to the concrete, where necessary. The aggregates and water used in the mix are to be free from snow, ice and frost. The temperature of the fresh concrete may be raised by heating the mixing water or the aggregates or both. Cement should never be heated nor should it be allowed to come into contact with water at a temperature greater than 60°C (140°F).

During hot weather, proper attention is to be given to ingredients, production methods, handling, placing, protection and curing to prevent excessive concrete temperatures or water evaporation which will impair the required strength or serviceability of the member or structure. The temperature of concrete as placed is not to exceed 30°C (90°F) and the maximum temperature due to heat of hydration is not to exceed 65°C (145°F).

Special attention is to be paid to the curing of concrete to promote maximum durability and to minimize cracking. Concrete should be cured with fresh water, whenever possible, so that the concrete surface is kept wet during hardening. Care should be taken to avoid the rapid lowering of concrete temperatures (thermal shock) caused by applying cold water to hot concrete surfaces.

Sea water is not to be used for curing reinforced or prestressed concrete, although, if demanded by the construction program, "young" concrete may be submerged in sea water, provided it has gained sufficient strength to withstand physical damage. When there is doubt about the ability to keep concrete surfaces permanently wet for the whole of the curing period, a heavy-duty membrane curing compound should be used.

The rise of temperature in the concrete caused by the heat of hydration of the cement is to be controlled to prevent steep temperature stress gradients which could cause cracking of the concrete. Since the heat of hydration may cause significant expansion, members must be free to contract, so as not to induce excessive cracking. In general, when sections thicker than 610 mm (2 ft) are concreted, the temperature gradients between internal concrete and external ambient conditions are to be kept below 20°C (68°F).

Construction joints are to be made and located in such a way as not to impair the strength and crack resistance of the structure. Where a joint is to be made, the surface of the concrete is to be thoroughly cleaned and all laitance and standing water removed. Vertical joints are to be thoroughly wetted and coated with neat cement grout or equivalent enriched cement paste or epoxy coating immediately before placing of new concrete.

Whenever watertight construction joints are required, in addition to the above provisions, the heavy aggregate of the existing concrete is to be exposed and an epoxide-resin bonding compound is to be sprayed on just before concreting. In this case, the neat cement grout can be omitted.

5.5.8(c) Reinforcement. The reinforcement is to be free from loose rust, grease, oil, deposits of salt or any other material likely to affect the durability or bond of the reinforcement. The specified cover to the reinforcement is to be maintained accurately. Special care is to be taken to correctly position and rigidly hold the reinforcement so as to prevent displacement during concreting.

5.5.8(d) Prestressing Tendons, Ducts and Grouting. Further guidance on prestressing steels, sheathing, grouts and procedures to be used when storing, making up, positioning, tensioning and grouting tendons will be found in the relevant sections of ACI 318, Prestressed Concrete Institute (PCI) publications, Federation Internationale de la Precontrainte (FIP) Recommended Practices and the specialist literature.

All steel for prestressing tendons is to be clean and free from grease, insoluble oil, deposits of salt or any other material likely to affect the durability or bond of the tendons.

During storage, prestressing tendons are to be kept clear of the ground and protected from weather, moisture from the ground, sea spray and mist. No welding, flame cutting or similar operations are to be carried out on or adjacent to prestressing tendons under any circumstances where the temperature of the tendons could be raised or weld splash could reach them.

Where protective wrappings or coatings are used on prestressing tendons, they are to be chemically neutral so as not to produce chemical or electrochemical corrosive attack on the tendons.

All ducts are to be watertight and all splices carefully taped to prevent the ingress of water, grout or concrete. During construction, the ends of ducts are to be capped and sealed to prevent the entry of sea water. Ducts may be protected from excessive rust by the use of chemically neutral protective agents such as vapor phase inhibitor powder.

Where ducts are to be grouted, all oil or similar material used for internal protection of the sheathing is to be removed before grouting. However, water-soluble oil used internally in the ducts or on the tendons may be left on, to be removed by the initial portion of the grout.

Air vents are to be provided at all crests in the duct profile. Threaded grout entries which permit the use of a screwed connector from the grout pump may be used with advantage.

For long vertical tendons, the grout mixes, admixtures and grouting procedures are to be checked to verify that no water is trapped at the upper end of the tendon due to excessive bleeding or other causes. Suitable admixtures known to have no injurious effects on the metal or concrete may be used for grouting to increase workability and to reduce bleeding and shrinkage. Temperature of members must be maintained above 10°C (50°F) for at least 48 hours after grouting. General guidance on grouting will be found in the specialist literature. Holes left by unused ducts or by climbing rods of slipforms are to be grouted in the same manner as described above.

5.7 Foundation Design

For the foundation design, a site investigation should be carried out in accordance with 3-2-5/3 of the *Offshore Installations Rules*. Soil data should be taken in the vicinity of, and preferably within, the terminal base area. For gravity-based terminals, the borings are to be taken to a minimum depth of the larger horizontal dimension or three times the smaller dimension of the base, whichever is greater. If piles are used, the depth of the boring should be in accordance with 3-2-5/3 of the *Offshore Installations Rules.*

5.7.1 Foundation Design Requirements

5.7.1(a) General. The loadings used in the analysis of the safety of the foundation are to include those defined in 2-2/5.7.1(g) and those experienced by the foundation during installation. Foundation displacements are to be evaluated to the extent necessary to verify that they are within limits that do not impair the intended function and safety of the structure.

The soil and the structure are to be considered as an interactive system, and the results of analyses, as required in subsequent paragraphs, are to be evaluated from this point of view.

5.7.1(b) Cyclic Loading Effects. The influence of cyclic loading on soil properties is to be considered. For gravity-based terminals in particular, possible reduction of soil strength is to be investigated and employed in design. Where appropriate, the following conditions are to be considered:

i) Design storm during the initial consolidation phase

ii) Short-term effects of the design storm

iii) Long-term cumulative effects of several storms, including the design storm

iv) Reduced soil strength characteristics resulting from these conditions are to be employed in design.

v) In seismically active zones, similar deteriorating effects due to repeated loadings are to be considered.

vi) Other possible effects resulting from cyclic loading, such as induced cyclic loading effects on soils from resonant breaking of impinging ice sheets, such as changes in load-deflection characteristics, effect of rocking inducing high pore pressures, liquefaction potential and slope stability are also to be considered, and these effects should be accounted for when they could affect the design.

5.7.1(c) Scour. Where scour is expected to occur, either effective protection is to be furnished soon after the installation of the terminal, or the depth and lateral extent of scouring, as evaluated in the site investigation program, is to be accounted for in design.

5.7.1(d) Deflections and Rotations. Tolerable limits of deflections and rotations are to be established based on the type and function of the LNG terminal's structure, and the effects of those movements on other structural elements that interact with the terminal's structure. Maximum allowable values of structural movements, as limited by these interactive considerations or overall structural stability, are to be considered in the design.

5.7.1(e) Soil Strength. The ultimate strength or stability of soil is to be determined using test results which are compatible with the method selected. In a total stress approach, the total shear strength of the soil obtained from simple tests is used. A total stress approach largely ignores changes in the soil's pore water pressure under varying loads and the drainage conditions at the site. When an effective stress approach is used, effective soil strength parameters and pore water pressures are determined from tests that attempt to predict in-situ total stresses and pore pressures.

5.7.1(f) Dynamic and Impact Considerations. For dynamic and impact loading conditions, a realistic and compatible treatment is to be given to the interactive effects between the soil and structure. When analysis is required, it may be accomplished by lumped parameter, foundation impedance functions or by continuum approaches including the use of finite element methods. Such models are to include consideration of internal and radiational damping provided by the soil and the effects of soil layering.

Studies of the dynamic response of the structure are to include, where applicable, consideration of the nonlinear and inelastic characteristics of the soil, the possibilities of deteriorating strength and increased or decreased damping due to cyclic soil loading and the added mass of soil subject to acceleration. Where applicable, the influence of nearby structures is to be included in the analysis.

5.7.1(g) Loading Conditions. Loading scenarios due to various installations and operating conditions shall be evaluated and conditions exerting the highest loadings on the foundation are to be taken into account. Post installation loadings to be checked are to include at least those relating to both the operating and design environmental conditions combined in the following manner:

i) Operating environmental loading combined with dead and maximum live loads appropriate to the function and operations of the structure

ii) Design environmental loading combined with dead and live loads appropriate to the function and operations of the structure during the design environmental condition

iii) Design environmental loading combined with dead load and minimum live loads appropriate to the function and operations of the structure during the design environmental conditions

For areas with potential seismic activity, the foundation is to be designed for sufficient strength to sustain seismic loads. The designer should take measures to prevent frost heave such as by adding a heating system, and should also determine the risk of liquefaction of granular soil.

5.7.2 Gravity-Based Terminal Foundations

5.7.2(a) General. The stability of the foundation with regard to bearing and sliding failure modes is to be investigated, employing the soil shear strengths determined in accordance with 3-2-5/3 of the *Offshore Installations Rules* (that concern the investigation of seabed soil conditions) and 2-2/5.7.1(b). The effects of adjacent structures and the variation of soil properties in the horizontal direction are to be considered, where relevant.

Where leveling of the site is not carried out or any other measures are not taken to reduce tilt, the predicted tilt of the overall structure is to be based on the average bottom slope of the sea floor and the tolerance of the elevation measuring device used in the site investigation program. Differential settlement is also to be calculated, and the tilting of the structure caused by this settlement is to be combined with the predicted structural tilt. Any increased loading effects caused by the tilting of the structure are to be considered in the foundation stability requirements of 2-2/5.7.2(b).

When an underpressure or overpressure is experienced by the sea floor under the structure, provision is to be made to prevent piping which could impair the integrity of the foundation. The influence of hydraulic and slope instability, if any, is to be determined for the structural loading cases *ii)* and *iii)* of 2-2/5.7.1(g).

Initial consolidation and secondary settlements, as well as permanent horizontal displacements, are to be calculated.

5.7.2(b) Stability. The bearing capacity and lateral resistance are to be calculated under the most unfavorable combination of loads. Possible long-term redistribution of bearing pressures under the base slab is to be considered so that the maximum edge pressures are used in the design of the perimeter of the base.

The lateral resistance of the platform is to be investigated with respect to various potential shearing planes. Special consideration is to be given to any layers of soft soil.

Calculations for overturning moment and vertical forces induced by the passage of a wave are to include the vertical pressure distribution across the top of the foundation and along the sea floor.

The capacity of the foundation to resist a deep-seated bearing failure is to be analyzed. In lieu of a more rigorous analysis where uniform soil conditions are present or where conservatively chosen soil properties are used to approximate a non-uniform soil condition, and where a trapezoidal distribution of soil pressure is a reasonable expectation, the capacity of the foundation to resist a deep-seated bearing failure can be calculated by standard bearing capacity formulas applicable to eccentrically loaded shallow foundations. Alternatively, slip-surface methods covering a range of kinematically feasible deep rupture surfaces can be employed in the bearing capacity calculations.

The maximum allowable shear strength of the soil is to be determined by dividing the ultimate shear strength of the soil by the minimum safety factors given below.

When the ultimate soil strength is determined by an effective stress method, the safety factor is to be applied to both the cohesive and frictional terms. If a total stress method is used, the safety factor is to be applied to the undrained shear strength. Any degradation due to cyclic effects is to be considered. The minimum safety factors to be obtained when employing a standard bearing capacity formulation and various trial sliding failure planes with the loading conditions of 2-2/5.7.1(g) are 2.0 for loading case *i)* and 1.5 for loading cases *ii)* and *iii)*. The safety factors to be obtained when considering the Design Earthquake will be specially considered.

Where present, the additional effects of penetrating walls or skirts that transfer vertical and lateral loads to the soil are to be investigated as to their contribution to bearing capacity and lateral resistance.

5.7.2(c) Soil Reaction on the Structure. For conditions during and after installation, the reaction of the soil against all structural members seated on or penetrating into the sea floor is to be determined and accounted for in the design of these members. The distribution of soil reactions is to be based on the results of the site-investigation specified in 3-2-5/3 of the *Offshore Installations Rules*. Calculations of soil reactions are to account for any deviation from a plane surface, the load-deflection characteristics of the soil and the geometry of the base of the structure.

Where applicable, effects of local soil stiffening, nonhomogeneous soil properties, as well as the presence of boulders and other obstructions are to be accounted for in design. During installation, consideration is to be given to the possibility of local contact pressures due to irregular contact between the base and the sea floor. These pressures are additive to the hydrostatic pressure.

An analysis of the penetration resistance of structural elements projecting into the sea floor below the foundation structure is to be performed. The design of the ballasting system is to reflect uncertainties associated with achieving the required penetration of the structure. Since the achievement of the required penetration of the platform and its skirts is of critical importance, the highest expected values of soil strength are to be used in the calculation of penetration.

5.7.2(d) Pile Foundations. Pile foundations are to be capable of withstanding axial, bending and lateral forces at the same time. Analysis of the pile as a beam column on an elastic foundation is to be submitted to ABS for review. The analyses of different kinds of soil using representative soil resistance and deflection (*p-y*) curves are described in the *Offshore Installations Rules* and API RP2A, as applicable.

7 Containment Systems

The LNG containment system is a mandatory part of ABS classification of the terminal's structure. The LNG containment system is to be in accordance with the requirements of Section 5C-8-4 of the *Steel Vessel Rules* or NFPA 59A.

Alternative arrangements for the LNG containment system such as the use of properly designed prestressed concrete structure as a secondary cryogenic barrier, application of membrane lining/barrier systems into concrete containment components, etc., may be given special consideration.

7.1 Design Features

Unless considered otherwise, the design of the containment system should incorporate the following features to satisfy the intent of these Rules and Standard:

i) A secondary containment system such that if there is a failure in the primary system, the secondary system is to be capable of containing the leaked liquid contents for an agreed period of time consistent with the approved scenarios for the safe disposal of same

ii) There is to be a minimum of two independent means of determining the liquid level in the LNG storage tanks.

iii) Means to fill the tank from various elevations within the tank to avoid stratification

iv) Independent high and high-high level alarms

v) At least one pressure gauge connected to the vapor space

vi) Two independent overpressure protection devices

vii) Devices for measuring the liquid temperature at the top, middle and bottom of tank

viii) A gas detection system which will alarm high gas concentrations in the space between the primary and the secondary barrier

7.3 Design Loads

Tanks together with their supports and fixtures are to be designed with consideration of proper combinations of the following loads:

i) Internal Pressure

ii) External Pressure

iii) Seismic loads

iv) Thermal loads

v) Tank and cargo weight with the corresponding reactions in way of the supports

vi) Insulation weight

vii) Loads in way of towers and other attachments

7.5 Steel Terminals

In the case of gravity-based steel offshore LNG terminals, the requirements of Section 5C-8-4 of the *Steel Vessel Rules* are considered applicable.

7.7 Concrete Terminals

On gravity-based concrete offshore LNG terminals, the outer containment system may be constructed of concrete in accordance with the requirements of Section 4.3 of NFPA 59A.

7.9 Condensate Storage

Condensate storage tanks integral with the terminal's hull are to be in compliance with the requirements of Section 5C-1-7 of the *Steel Vessel Rules* and 3-5/5.9 of the *Facilities Rules*.

Condensate storage in tanks adjacent to LNG storage tanks will be considered acceptable, provided it can be shown that loss of primary LNG containment would not cause an underpressure situation or the ingress of air into the condensate tank.

9 Process Facilities

Where process facilities are requested to be within the scope of Class, the facilities installed onboard the terminal for processing raw gas from the well(s) or bringing partially processed gas from another installation, LNG production or liquefaction or re-gasification system for converting LNG into vapor for shipment ashore, the entire installation including the import and export system are subject to requirements of this Guide.

For Classification purposes, whichever of the process systems are employed, the facilities are to be in place so that the entire operation can be carried out safely. Accordingly, in order to carry out an assessment of the system, the plans and calculations listed in 2-1/3.5 of this Guide are required to be submitted:

ABS may require additional information depending on the systems used and their configuration.

Where processing facilities are not within the scope of Class, requirements contained in this Guide relating to the safety of the terminal will be considered within the scope of Class. For example, the following systems will be subject to approval by ABS:

i) Interface to the Fire Extinguishing system

ii) Hazardous areas

iii) Gas disposal system (venting and relief)

9.1 Process Safety Criterion

The design of the onboard process facilities described above is to include an overall evaluation of the proposed concept with a view toward reducing the likelihood of the occurrence of the undesirable events identified in 2-2/3 of this Guide.

ABS evaluation will include a systematic consideration of arrangements, layouts, process systems, process support systems, process controls and safety systems as well as a review of fitness for purpose of all safety critical equipment. The term “safety critical” is meant to include all equipment whose reliable performance is essential to maintaining a safe facility as well as equipment whose failure in and of itself could lead to an unsafe occurrence.

While the design of the terminal arrangements, safety systems and systems for handling LNG and LNG vapor on a terminal may rely primarily on the proven practices employed on LNG carriers, it must be recognized that on an LNG carrier, except during cargo loading and discharge operations, there is very little hydrocarbon outside of the containment system. Accordingly, additional provisions may be required depending on the process system installed on the terminal. This may include such items as an extension of the hazardous areas, the need for a gas dispersion analysis and the provision of a means to de-energize electrical systems in the event of a major release of high-pressure gas.

Due to the varying quantity and means of handling and storage of the hydrocarbon refrigerants, it must also be recognized that the level of risk associated with natural gas liquefaction is dependent on the liquefaction process selected. Accordingly, wherever possible, the location of these systems should be on open deck.

Similarly, while some LNG carriers are arranged for bow or stern loading and unloading in accordance with the provisions of 5C-8-3/8 and 5C-8-5/10.1 of the *Steel Vessel Rules*, it must be recognized that the existing requirements for LNG carriers do not envisage the increased risk of an LNG or LNG vapor release from the systems and equipment that may be employed in the import and export systems covered under 2-2/9.9 and 2-2/9.11 of this Guide. Accordingly, drip trays are to be provided as necessary and components such as cryogenic hoses and gas swivels that may be susceptible to leakage should be located on the open deck. Furthermore the means to provide reliable, adequate ventilation in any enclosed spaces containing portions of the gas transfer system and provisions for gas detection are to be considered and included in the overall risk analysis required in 2-2/3 of this Guide.

The safe disposal by flaring of hydrocarbon gas released due to an overpressure or other upset condition should be taken into consideration in the design of the system. However, the process systems are to be closed systems. Accordingly, continuous flaring is not an acceptable design premise.

The process safety overall criterion is that systems and equipment on an offshore LNG terminal be designed to minimize the risk of hazards to personnel, property and environment. Implementation of this criterion to gas processing, liquefaction or re-gasification facilities and the associated support facilities is intended to:

i) Prevent an abnormal condition from causing an upset condition

ii) Prevent an upset condition from causing a release of hydrocarbons or cryogenic fluids

iii) Safely collect and dispose of hydrocarbon or cryogenic fluids released

iv) Prevent formation of explosive mixtures

v) Prevent ignition of flammable liquids or gases and vapors released

vi) Limit exposure of personnel to fire hazards

9.1.1 System Requirements

The design of process systems and process control systems described above, along with process support systems, depressurization and vent systems, flares and drain systems, is to comply with the requirements of Chapter 4, Section 3 of the *Facilities Rules*. In addition, systems that are in direct contact with LNG or LNG vapor are to be designed for compliance with the requirements of Part 5C, Chapter 8 of the *Steel Vessel Rules* and the applicable requirements of NFPA 59 A *Standard for the Production, Storage and Handling of Liquefied Natural Gas (LNG)* 2001. Where there is a conflict between various referenced requirements, ABS is to be consulted for clarification.

The systems and equipment for ship-to-terminal LNG loading or LNG discharge such as special loading arms and/or cryogenic hose, hose cranes, primary emergency release couplings (PERCs), relative motion sensors, emergency shutdown systems and other special arrangements will be considered in each case based on the submitted design justification. The design justification is to include an envelope of limiting operational environments, including sea states, wind, current and visibility.

9.1.2 Component Requirements

It is envisaged that a list of major components present on an LNG terminal includes but is not limited to: loading arms, cryogenic hoses, pig receivers, separators, knock-out drums, heat exchangers, packed columns, absorbers, plate fin type heat exchangers, spiral (spool) wound heat exchangers, tube and shell heat exchangers, pumps, and compressors with either gas turbine or electric drivers, direct and indirect heaters and vaporizers. These process system components and the associated piping systems that carry hydrocarbon liquids and vapors will be subject to ABS review.

The design, manufacture, testing, certification and installation of process components are to be in compliance with the requirements of 3-3/17 of the *Facilities Rules*. The selection of material of components subject to temperatures below –18°C (0°F) is to comply with the requirements of Section 5C-8-6 of the *Steel Vessel Rules*. Conformance to standards or codes different from those listed therein will be considered, where applicable. Components not covered in the referenced ABS Guide will be considered on the basis of compliance with applicable acceptable industry standards and the manufacturer’s design justification and proof testing. Design justification based on stress analysis should comply with the requirements of the ASME Boiler and Pressure Vessel Code Section VIII Division 2.

9.3 Gas Processing

For the purposes of this Guide, the gas processing facilities are considered to include all systems and components for the reception of raw gas from the well(s) or partially processed gas from another installation on the platform facilities for such processes such as acid gas removal, dehydration and mercury removal.

9.5 Liquefaction

For the purpose of this Guide, the Liquefaction Facilities are considered to include all systems and components for pre-cooling, fractionation, main cryogenic refrigeration and storage. There are a number of proven proprietary liquefaction methodologies available. Whichever of these systems is used, details, as mentioned in 2-2/9.1, are to be submitted.

The subsystems and major items of equipment can vary significantly depending on which liquefaction methodology is employed. Accordingly, a description of the system and an operational philosophy adopted is to be submitted in order to evaluate the safety of the entire system.

However, the following is given as a reference to define the scope of classification:

i) It is envisaged that the pre-cooling may be done in a propane, nitrogen or mixed refrigerant heat exchanger with the associated refrigerant refrigeration cycle: compressor, condenser, coolers and accumulators. The pre-cooling heat exchanger may be of the spiral wound or plate fin type.

ii) It is envisaged that the fractionation includes subsystems or plants called de-ethanizers, de-propanizers and de-butanizers. Each plant is comprised of a vertical column type separator, pumps, heat exchangers and accumulators.

iii) The main cryogenic refrigeration is normally done in either a multi-stage spiral wound heat exchanger or in an assembly of plate fin type heat exchangers called a cold box. In most LNG liquefaction processes, a mixture of hydrocarbons is used as the primary refrigerant and these processes are called MR Processes. However, in the cascade system, propane, ethane, methane and ethylene are each used at consecutive stages of refrigeration. In the nitrogen system, nitrogen is used as the refrigerant in a compression and expansion process.

iv) The storage includes both LNG storage and storage of condensate produced from the liquefaction process.

9.7 Re-gasification

For the purposes of this Guide, Re-gasification Facilities are considered to include all systems and components for removing LNG from the storage tanks, pressurizing, heating and vaporizing LNG and, in some cases, odorizing the LNG vapor and discharge ashore of vaporized gas through an off-loading system. If there are compressors in the discharge system, they would be considered part of the Re-gasification Facility.

9.9 Import Systems

For the purposes of this Guide, Import Systems on load terminals are considered to include the entire gas swivel on turret-moored units and the first onboard flange for units maintained on station through a spread mooring system, plus all onboard gas flow lines up to the gas processing facility.

In the case of discharge terminals, the Import Systems would include the liquid and vapor loading arms and the cryogenic hoses or the cargo manifold, depending on the LNG ship to terminal transfer configuration employed, plus all on deck valves and piping up to the liquid and vapor inlet flanges on the cargo tank domes.

9.11 Export Systems

For the purpose of this Guide, Export Systems on load terminals are considered to include the cargo pumps, stripping pumps, high duty gas compressors, LNG vaporizers and all valves and piping in the liquid discharge and vapor return systems up to and including the cargo manifold, loading arms or cryogenic hoses, depending on the LNG-terminal-to-ship transfer configuration employed.

In the case of discharge terminals, the Export Systems would include the gas flow lines from the re-gasification facility up to and including the last onboard flange.

9.13 Risers and Flow Lines

Rigid and flexible risers, connecting flow lines and submerged jumpers are not considered to be within the scope of classification of the terminal. However, at the Owner's request, the Owner import or export risers starting from but not including the Pipe Line End Manifold (PLEM) may be included in the scope of classification, provided they are found to be in compliance with the requirements of Part 4, Chapter 2 of the *FPI Rules*.

11 Arrangements

11.1 Referenced Rules, Guides and Documents

Refer to 1-1/11 of this Guide.

11.3 General Arrangement

Machinery and equipment are to be arranged in groups or areas in accordance with API RP14J. Equipment items that could become fuel sources in the event of a fire are to be separated from potential ignition sources by space separation, firewalls or protective walls.

Typical fuel sources may be as listed below:

i) Gas inlet and departing flow lines
ii) Process and Hydrocarbon Refrigerant Piping
iii) Risers and Pipelines
iv) Vents
v) Pig Launchers and Receivers
vi) Drains
vii) Portable Fuel Tanks
viii) Chemical Storage Tanks
ix) Laboratory Gas Bottles
x) Sample Pots
xi) LNG manifolds or loading arms
xii) Separators and Scrubbers
xiii) Coalescers
xiv) Gas Compressors
xv) Liquid Hydrocarbon Pumps
xvi) Heat Exchangers
xvii) Hydrocarbon Refrigerant Storage Tanks
xviii) Gas Metering Equipment
xix) Oil Treaters (unfired vessels)
xx) Swivels

Typical ignition sources may be as listed below:

i) Fired Vessels
ii) Combustion Engines & Gas Turbines
iii) Living Quarters
iv) Flares
v) Welding Machines
vi) Grinding Machines
vii) Cutting Machinery or Torches
viii) Static Electricity
ix) Ships
x) Electrical Equipment
xi) Waste Heat Recovery Equipment
xii) Mobile phones
xiii) Lightning
xiv) Spark Producing Hand Tools
xv) Portable Computers
xvi) Cameras
xvii) Non-Intrinsically Safe Flashlights
xviii) Helicopters

In case of a fire, the means of escape is to permit the safe evacuation of all occupants to a safe area, even when the structure they occupy can be considered lost in a conflagration. With safety spacing, protective firewalls and equipment groupings, a possible fire from a classified location is not to impede the safe exit of personnel from the danger source to the lifeboat embarkation zone or any place of refuge.

11.5 Storage Tank Locations

The location of storage tanks with respect to the outer boundaries of the structure is to be consistent with the extent of damage assumed in 2-2/3i) of this Guide, unless it can be shown that other arrangements will be not less effective at protecting the storage tanks.

11.7 Bow or Stern Loading

The requirements of 5C-8-3/8 and 5C-8-5/10.1 of the *Steel Vessel Rules* for bow or stern loading arrangements will be considered applicable to import or export systems that are routed in the vicinity of accommodations or other sources of vapor ignition.

11.9 Location and Insulation of Accommodation Spaces and Living Quarters

Accommodation spaces or living quarters are to be located outside of hazardous areas and may not be located above or below LNG or condensate storage tanks or process areas. "H-60" bulkhead requirements of 4-8/9 of the *Facilities Rules* will be applied. If such bulkhead is more than 33 m (100 ft) from this source, then this can be relaxed to an "H-0" rating. As is explained in Chapter 3, Section 8 of the *Facilities Rules*, "A-60" and "A" rated bulkheads, respectively, may be utilized, provided that a risk analysis or fire load analysis was satisfactorily reviewed by ABS, indicating that lower bulkhead fire ratings are acceptable.

13 Hazardous Areas

The delineation of hazardous areas or gas-dangerous spaces on an offshore LNG terminal is to be consistent with the following general guidelines. Where there is overlapping, in general, the higher (more conservative) delineation should be applied.

The delineation of gas-dangerous spaces in 5C-8-1/2.24 of the *Steel Vessel Rules* and Chapter 7, Section 7.6 of NFPA 59A, as applicable, will be considered applicable to LNG storage and LNG and LNG vapor piping systems associated with LNG storage, loading and discharge.

The delineation of gas-dangerous spaces associated with process facilities is to be consistent with the requirements of 3-6/15 of the *Facilities Rules*, which is consistent with API RP 500 series.

The delineation of hazardous areas associated with the below deck storage of condensate and other hydrocarbon liquids with a flash point of less than 60°C (140°F) is to be consistent with the requirements of 5C-1-7/31.5 of the *Steel Vessel Rules*.

15 Process Support and Service Systems

This Subsection presents criteria for the design and installation of process support and service systems on offshore LNG terminals. General arrangement of these systems is to comply with API RP 14J, or other applicable standards. Process support systems are utility and auxiliary systems that complement the process systems covered in 2-2/11 of this Guide.

Process support systems include, but are not limited to, the following:

i) Utility/Instrument Air System

ii) Fuel/Instrument Gas System

iii) Use of Produced Gas as Fuel

iv) Purging System

v) Inert Gas System

vi) Nitrogen System

vii) Fuel Oil System

viii) Hydraulic System

ix) Lubricating Oil System

x) Chemical Injection System

xi) Heating and Cooling System

These systems are to be in compliance with the requirements of Chapter 4, Section 4 of the *Facilities Rules* and Part 5C, Chapter 8 of the *Steel Vessel Rules*, as applicable.

Depending on the type of structure, support systems and components may include, but are not limited to, the following:

i) Boilers and Pressure Vessels

ii) Turbines and Gears

iii) Internal-Combustion Engines

iv) Pumps and Piping Systems (i.e., Fuel Oil, Lube Oil, Fresh Water, De-watering, Inert Gas, etc.)

These systems are to be in compliance with the requirements of Chapter 3, Section 5 of the *Facilities Rules* and the applicable sections of the *Steel Vessel Rules* and the *MODU Rules*.

17 Electrical Systems and Installations

Electrical systems used solely for the process facilities described in 2-2/11 of this Guide are to meet the requirements of Chapter 4, Section 6 of the *Facilities Rules*. Where electrical systems or equipment are used to supply services other than these process facilities, the equipment is to comply with the requirements of a recognized code for electrical installations acceptable to ABS.

Electrical installations are to comply with the above referenced requirements and with API RP 14F. Consideration will be given to the use of other recognized national or international standards, such as IEC, provided they are no less effective and the entire system is designed to such standards. For installations classified by class and zone, the requirements of API RP 14FZ (when approved) may be used in lieu of API 14F.

Where sections of API RP 14F are called out in the following text, the intent is solely to help identify relevant clauses. The designer is not relieved from full compliance with all of the recommended practices contained in API RP 14F. The references to IEC standards are intended solely as minimum requirements when standards other that API RP 14F are applied.

Where conflicts exist between various referenced standards, ABS is to be consulted to provide required clarification.

19 Instrumentation and Control Systems

The control and instrumentation systems are to provide an effective means for monitoring and controlling pressures, temperatures, flow rates, liquid levels and other process variables for the safe and continuous operation of the process and storage facilities. Where control over the electrical power generation and distribution is required for the operation of the facilities, then the control system should also be arranged to cover this. Control and instrumentation systems for process, process support, utility and electrical systems are to be suitable for the intended application. All control and safety shutdown systems are to be designed for safe operation of the equipment during start-up, shutdown and normal operational conditions.

Instrumentation and control systems serving the process facilities described in 2-2/11 of this Guide are to be in compliance with Chapter 4, Section 7 of the *Facilities Rules*, which is based on API RP 14C and other applicable standards.

Instrumentation and control systems serving the LNG storage and transfer of LNG and LNG vapor on and off the unit are to be in compliance with the requirements of Section 5C-8-13 of the *Steel Vessel Rules*.

Where there is a conflict between overlapping referenced requirements, ABS is to be consulted for required clarification.

21 Safety Systems

21.1 General

21.1.1 Approach

The safety systems referred to in this Subsection are intended to protect life, property and the environment and are applicable to the entire installation, including the loading and off-loading arrangements for gas, LNG and LNG vapor. The overall safety system should be comprised of subsystems providing two levels of protection: the primary system which is to provide protection against the risk of fire or explosion; and the secondary system which is intended to reduce the consequence of fire by affording protection to the people and the facility and reducing the risk of fire spread. The primary and secondary safety measures required consist of both active and passive systems as described in this Subsection. However, in all cases, the effectiveness of these systems should be established by conducting a fire and explosion hazard analysis.

Each space considered a fire risk, such as the process equipment, cargo deck area, spaces containing gas processing equipment such as compressors, heaters, etc. and machinery spaces containing any oil-fired unit or internal combustion machinery with an aggregate power of not less than 375 kW (500 hp), is to be fitted with an approved gas detection, fire detection and fire extinguishing system complying with the requirements of this Subsection.

21.1.2 Governmental Authority

In addition to the ABS Class requirements of this Subsection, depending on the flag of registry of the terminal or area of operation, the flag or coastal State may have additional requirements or regulations which may need to be complied with. Therefore, the appropriate governmental authorities should be consulted for each installation.

21.1.3 Primary Systems

Many of the products being handled onboard an offshore LNG terminal are highly flammable, and therefore, examples of some of the measures that may be necessary to protect against fire or explosion risk are as follows:

i) Avoid the possibility of liquid or gas escaping in locations where there is a source of vapor ignition. A typical example of this will be to isolate the vent and relief valve outlets from storage tanks and process systems in relation to the air intakes and openings.

ii) Provide fixed gas detection systems comprised of two different types of elements which will activate an audible alarm at a manned control station to alert of a gas release before the gas can migrate to an unclassified area.

iii) A low temperature detection system in and around the LNG storage facility to sound an alarm at a normally manned station to alert in the event of a liquid or vapor leak.

iv) A multi-tiered Emergency Shutdown system capable of isolating an upset condition with local system or single train shutdowns before the condition requires a complete platform shutdown.

v) Maintain integrity of the containment boundary at all times to reduce the possibility of an uncontrolled discharge of LNG or LNG vapor. Where it is possible for LNG to leak in the event of a failure, such as at a joint, valve or similar connection, a spill tray immediately underneath these components should be provided.

vi) Maintain a positive separation between process areas, cargo storage, cargo handling area and areas containing source of vapor ignition. A typical example of this is electrically driven cargo or process compressors.

vii) Eliminate direct access from the space containing process equipment to spaces containing machinery such as electrical equipment, fired equipment or other similar equipment which may be considered an ignition source.

21.1.4 Secondary System

The secondary systems are systems which are employed to prevent the spread of fire and may be categorized as follows:

i) Fire detection system

ii) Fire extinguishing systems

iii) Water deluge system

iv) Personnel protection and life saving appliances

v) Structural fire protection

21.3 Gas Detection Systems

21.3.1

The fixed gas detection system is to comply with requirements of Chapter 4, Section 8 of the *Facilities Rules*.

21.3.2

The requirements of NFPA 59A Chapter 9 will be considered to be applicable in the LNG processing areas. In such areas where there is a potential for gas concentrations to accumulate, the gas detection sensors should activate an audible and visual alarm at not more than 25% of the lower flammable limit of the gas or vapor being monitored.

21.3.3

The gas detection system is to be of an approved type and the installation arrangements such that loss of single detector(s) over a specific area will not render the entire system ineffective.

21.3.4

The gas detection system should be provided with an alternative source of power such that in the event of failure of the main power source the alternative power supply will commence automatically.

21.5 Fire Detection Systems

The fire detection system protecting the LNG Storage and LNG and LNG vapor handling systems is to be in accordance with the requirements of Chapter 4, Section 8 of the *Facilities Rules*. The requirements of NFPA 59A Chapter 9 are also considered applicable.

21.7 Fire Extinguishing and Water Spray (Deluge) Systems

NFPA 59A Chapter 9 is considered applicable to offshore LNG terminals, and as is required therein, the extent of fire protection required shall be determined by an evaluation based on sound fire protection engineering principles, analysis of local conditions, hazards within the facility and exposure to or from other sources of fire such as the attending vessels.

Fire water systems, water spray systems, dry powder, foam and carbon dioxide systems are to be provided as required by Section 5C-8-11 of the *Steel Vessel Rules* and Chapter 4, Section 8 of the *Facilities Rules*.

21.9 Structural Fire Protection

The term "structural fire protection" refers to the passive method of providing fire protection to the spaces/compartments of the unit through the usage of fire divisions and the limitation of combustibles in the construction materials. Maintaining the adequacy of the fire division includes proper protection of penetrations in those divisions, which includes electrical, piping or ventilation system penetrations.

The requirements of 4-8/9 of the *Facilities Rules* will be applied. In applying these requirements, the gas inlet and LNG vapor outlet system are to be treated as wellhead areas.

21.11 Personnel Protection and Life Saving Appliances

Compliance with Chapter 4, Section 8 of the *Facilities Rules* is required.

Personnel involved in emergency activities shall be equipped with the necessary protective clothing and equipment qualified in accordance with 5C-8-11/6 of the *Steel Vessel Rules* and NFPA 600 *Standard on Industrial Fire Brigades.*

Written practices and procedures shall be developed to protect personnel from identified hazards such as entry into confined or hazardous spaces.

21.13 Means of Escape

At least two means of escape are to be provided for all continuously manned areas and areas that are used on a regular working basis. The two means of escape must be through routes that minimize the possibility of having both routes blocked in an emergency situation. Escape routes are to have a minimum width of 0.71 m (28 in.). Dead-end corridors exceeding 7 m (23 ft) in length are not permitted. Dead-end corridors are defined as a pathway which (when used during an escape) has no exit.

Escape route paths are to be properly identified and provided with adequate lighting. An escape route plan is to be prominently displayed at various points in/of the facility. Alternatively, this information may be included in the Fire Control or Fire/Safety Plan.

21.15 Emergency Shutdown Systems

21.15.1 Process Emergency Shutdown (ESD)

An emergency shutdown (ESD) system with manual stations is to be provided, in accordance with Appendix C of API RP14 and Section 9.2 of NFPA 59A, to shut down the flow of hydrocarbon gas on to the platform and to terminate all gas processing and liquefaction process on the facility.

In addition, for the LNG loading and discharge systems and the LNG storage systems, Emergency Shutdown Valves are to be provided along with means for control, in accordance with 5C-8-5/5 of the *Steel Vessel Rules*.

The emergency shutdown system is to be automatically activated by:

i) The detection of an abnormal operating condition by pressure sensors in the inlet and outlet systems or in the process systems

ii) The detection of fire on the terminal

iii) The detection of combustible gas at a 60% level of the lower explosive limit

iv) The detection of hydrogen sulfide (H_2S) gas at a level of 50 ppm

Emergency shutdown stations are to be provided for manual activation of the Process Safety Shutdown system for shutdown of all pumping and process systems. These manual activation stations are to be protected against accidental activation, and conveniently located at the primary evacuation points (i.e., boat landing, helicopter deck, etc.) and the emergency control stations.

For design guidance, the following additional locations may be considered appropriate for emergency shutdown stations:

i) Exit stairway at each deck level

ii) Main exits of living quarters

iii) Main exits of production (process) facility deck

CHAPTER 2 Requirements for Gravity-Based Offshore LNG Terminals

SECTION 3 Surveys During Construction, Installation and Commissioning

1 General

This Section pertains to surveys and inspections during construction, installation and commissioning of a gravity-based offshore LNG terminal. The documentation requirements for review are given in 2-1/3 of this Guide. A general quality plan highlighting required surveys together with ABS hold points is to be determined by the builder and agreed upon by the attending Surveyor.

3 Construction Surveys

3.1 General

During construction of equipment components for an offshore LNG terminal, the attending Surveyor is to have access to vendors' facilities to witness construction and/or testing, as required by this Guide. The vendor is to contact the attending Surveyor to make necessary arrangements. If the attending Surveyor finds reason to recommend repairs or additional surveys, notice will be immediately given to the Owner or Owner's Representative so that appropriate action may be taken. Coordination of the vendors' certification program is carried out through ABS' Vendor Coordinators.

3.3 Survey at Vendor's Shop

Survey requirements for equipment components and packaged units at the vendor's shop are summarized in relevant sections of applicable ABS Rules/Guides. Each vendor is required to have an effective quality system which is to be verified by the attending Surveyor.

3.5 Structure Construction/Fabrication Surveys

A Quality Control Program (QCP) compatible with the type, size and intended service of the terminal is to be developed and submitted to ABS for approval. Required hold points on the QCP that is to form the basis for future ABS surveys at the fabrication yard shall be agreed upon by the attending Surveyor. As a minimum, all of the items enumerated in the following applicable Subsections are to be covered by the QCP. ABS shall verify that all tests and inspections specified in the QCP are satisfactorily carried out by a competent person, and ABS surveys shall be considered to supplement and not replace inspections that should be carried out by the fabricator or operator.

The fabricator is to maintain a system of material traceability to the satisfaction of the attending Surveyor. Data as to place of origin and results of tests for materials shall be retained and are to be readily available to ABS upon request.

Where equipment and components are assembled in blocks or modules, the Surveyor is to inspect the fit-up, piping and electrical connections, and to witness the required tests on the completed assembly in guidance with QCP and in accordance with the approved plans and Rule/Guide requirements. The progress and suitability of structural fit-up and joining of constructed/fabricated blocks/modules are to be to the satisfaction of the attending Surveyor. All erection joints are to be subjected to visual examination, proven tight, and the extent of Non-Destructive Examination (NDE) carried out is to be to the satisfaction of the attending Surveyor.

3.5.1 Surveys on Steel Structures

3.5.1(a) Quality Control Program (QCP). The quality control program for the construction of a steel terminal is to include the following items, as appropriate:

- Material quality and traceability
- Steel Forming
- Welder qualification and records
- Welding procedure specifications and qualifications
- Weld inspection
- Tolerances alignments and compartment testing
- Corrosion control systems
- Tightness and hydrostatic testing procedures
- Nondestructive testing
- Installation of main structure

The items which are to be considered for each of the topics, mentioned above are indicated in 2-3/3.5.1(b) through 2-3/3.5.1(j).

3.5.1(b) Material Quality and Traceability. The properties of the material are to be in accordance with Part 2, Chapter 1 of the *Offshore Installations Rules*. Manufacturer's certificates are to be supplied with the material. Verification of the material's quality is to be done by the Surveyor at the plant of manufacture, in accordance with ABS *Rules for Materials and Welding (Part 2)*. Alternatively, material manufactured to recognized standards may be accepted in lieu of the above steel requirements provided the substitution of such materials is approved by ABS. Materials used are to be in accordance with those specified in the approved design and all materials required for classification purposes are to be tested in the presence of an ABS Surveyor. The Constructor is to maintain a material traceability system for all the primary and special application structures.

3.5.1(c) Steel Forming. When forming changes base plate properties beyond acceptable limits, appropriate heat treatments are to be carried out to reestablish required properties. Unless approved otherwise, the acceptable limits of the reestablished properties should meet the minimums specified for the original material before forming. ABS will survey formed members for their compliance with the forming dimensional tolerances required by the design.

3.5.1(d) Welder Qualification and Records. Welders who are to work on the structure are to be qualified in accordance with the welder qualification tests specified in a recognized code or, as applicable, ABS *Rules for Materials and Welding (Part 2)* to the satisfaction of the attending Surveyor. Certificates of qualification are to be prepared to record evidence of the qualification of each welder qualified by an approved standard/code, and such certificates are to be available for the use of the Surveyors. In the event that welders have been previously tested in accordance with the requirements of a recognized code and provided that the period of effectiveness of the previous testing has not lapsed, these welder qualification tests may be accepted.

3.5.1(e) Welding Procedure Specifications and Qualifications. Welding procedures are to be approved in accordance with ABS *Rules for Materials and Welding (Part 2)*. Welding procedures conforming to the provisions of a recognized code may, at the Surveyor's discretion, be accepted. A written description of all procedures previously qualified may be employed in the structure's construction provided it is included in the quality control program and made available to the Surveyors. When it is necessary to qualify a welding procedure, this is to be accomplished by employing the methods specified in the recognized code, and in the presence of the Surveyor.

3.5.1(f) Weld Inspection. As part of the overall quality control program, a detailed plan for the inspection and testing of welds is to be prepared and this plan is to include the applicable provisions of the *Offshore Installations Rules*.

3.5.1(g) Tolerances and Alignments. The overall structural tolerances, forming tolerances, and local alignment tolerances are to be commensurate with those considered in developing the structural design. Inspections are to be carried out to verify that the dimensional tolerance criteria are being met. Particular attention is to be paid to the out-of-roundness of members for which buckling is an anticipated mode of failure. Structural alignment and fit-up prior to welding shall be monitored to promote consistent production of quality welds.

3.5.1(h) Corrosion Control Systems. The details of any corrosion control systems employed for the structure are to be submitted for review. Installation and testing of the corrosion control systems are to be carried out to the satisfaction of the attending Surveyor in accordance with the approved plans.

3.5.1(i) Tightness and Hydrostatic Testing Procedures. Compartments which are designed to be permanently watertight or to be maintained watertight during installation are to be tested by a procedure approved by the attending Surveyor. The testing is also to be witnessed by the attending Surveyor.

3.5.1(j) Nondestructive Testing. A system of nondestructive testing is to be included in the fabrication specification of the structures. The minimum extent of nondestructive testing shall be in accordance with the *Offshore Installations Rules* or recognized design Code. All nondestructive testing records are to be reviewed and approved by the attending Surveyor. Additional nondestructive testing may be requested by the attending Surveyor if the quality of fabrication is not in accordance with industry standards.

3.5.2 Surveys on Concrete Structures

3.5.2(a) Quality Control Program (QCP). For concrete structures, the QCP mentioned above is to cover the following items, as appropriate:

- Survey prior to concreting
- Survey during batching, mixing and placing concrete
- Survey of joints, prestressing and grouting
- Survey of form removal and concrete curing
- Survey of finished concrete
- Installation survey of main structure
- Tightness and Hydrostatic testing, as applicable (See 5-1-2/17 of the *Offshore Installations Rules*)

The items which are to be considered for each of the topics mentioned above are indicated in 2-3/3.5.2(b) through 2-3/3.5.2(h) of this Guide.

3.5.2(b) Surveys Prior to Concreting. Prior to their use in construction, the manufacturers of cement, reinforcing rods, prestressing tendons and appliances are to provide documentation of the pertinent physical properties. These data are to be made available to the attending Surveyor who will check conformity with the properties specified in the approved design.

As applicable, at the construction site, the Surveyor is to be satisfied that proper consideration is being given to: the support of the structure during construction; the storage of cement and prestressing tendons in weathertight areas; the storage of admixtures; adhesives and coating materials to manufacturer's specifications; and the storage of aggregates to limit segregation, contamination by deleterious substances and moisture variations within the stock pile.

The quality, cleanliness, dimension and alignment of the forms and shores supporting the forms are to be to the satisfaction of the attending Surveyor. The measurements are to be within the allowable finished dimensional tolerances specified in the approved design.

Reinforcing steel, prestressing tendons, post-tensioning ducts, anchorages and any included steel are to be checked, as appropriate to the planned structure, for size, bending, spacing, location, firmness of installation, surface condition, vent locations, proper duct coupling and duct capping.

3.5.2(c) Surveys during Batching, Mixing and Placing Concrete. The production and placing of the concrete are to employ procedures which will provide a well mixed and well compacted concrete. Such procedures are also to limit segregation, loss of material, contamination and premature initial set during all operations.

Field-testing of aggregate gradation, cleanliness, moisture content and unit weight is to be performed by the constructor following standards and schedules specified in the QCP. The frequency of testing is to be determined taking into account the uniformity of the supply source, volume of concreting and variations of atmospheric conditions. Mix water is to be tested for purity following methods and schedules specified in the QCP.

Mix components of each batch of concrete are to be measured by a method specified in the quality control program. The designer is to specify the allowable variation of mix component proportions, and the constructor is to record the actual proportions of each batch.

Sampling and testing of concrete are to be carried out following the procedures specified in the QCP. As a minimum, the following concrete qualities are to be measured by the Constructor:

i) Consistency

ii) Workability

iii) Air content

iv) Unit Weight

v) Strength

To minimize macro and micro cracking due to heat of hydration during concreting and curing, the temperature rise and thermal gradients are to be monitored, controlled and recorded to the satisfaction of the attending Surveyor.

3.5.2(d) Survey of Joints. All construction joints are to be to the satisfaction of the attending Surveyor. Where required, leak testing of construction joints is to be carried out using procedures specified in the QCP. When deciding which joints are to be inspected, consideration is to be given to the hydrostatic head on the subject joint during normal operation, the consequence of a leak at the subject joint and the ease of repair once the platform is in service.

3.5.2(e) Surveys of Prestressing and Grouting. A schedule indicating the sequence and anticipated elongation and stress accompanying the tensioning of tendons is to be prepared. Any failures to achieve proper tensioning are to be immediately reported to the designer to obtain guidance as to needed remedial actions.

Pre- or post-tensioning loads are to be determined by measuring both tendon elongation and tendon stress. These measurements are to be compared, and should the variation of measurements exceed the specified amount, the cause of the variation is to be determined and any necessary corrective actions are to be accomplished.

The grout mix is to conform to that specified in the design. The constructor is to keep records of the mix proportions and ambient conditions during grout mixing. Tests for grout viscosity, expansion and bleeding, compressive strength and setting time are to be made by the constructor using methods and schedules specified in the QCP. Procedures are to be employed so that ducts are completely filled.

Anchorages are to be inspected to verify that they are located and sized as specified in the design. Anchorages are also to be inspected to verify that they will be provided with adequate cover to mitigate the effects of corrosion.

3.5.2(f) Surveys of Form Removal and Concrete Curing. The structure is to have sufficient strength to bear its own weight, construction loads and the anticipated environmental loads without undue deformations before forms and form supports are removed. The schedule of form removal is to be specified in the QCP, giving due account to the loads and the anticipated strength.

Curing procedures for use on the structure are to be specified in the QCP. When conditions at the construction site cause a deviation from these procedures, justification for these deviations is to be fully documented and included in the construction records.

Where the construction procedures require the submergence of recently placed concrete, special methods for protecting the concrete from the effects of salt water are to be specified in the QCP. Age of concrete at submergence in sea water is to be specified in the QCP (see also 3-2-4/11.3.5 of the *Offshore Installations Rules*). Unless otherwise noted, concrete should not be submerged until 28 days after placing. Any deviation from the QCP should be justified, fully documented and submitted to ABS for approval.

3.5.2(g) Survey of Finished Concrete. The surface of the hardened concrete is to be inspected for cracks, honeycombing, pop-outs, spalling and other surface imperfections. When such defects are found, their extent is to be reported to the Surveyor and to the designer for guidance on any necessary repairs.

The structure is to be examined using an appropriate NDE method such as calibrated rebound hammer or similar device. Refer to ACI "Guide for Concrete Inspection Programs" ACI 311.4R for guidance on additional requirements. Where the results of surface inspection, cylinder strength tests or nondestructive testing do not meet the design criteria, the designer is to be consulted regarding remedial actions which are to be taken.

The completed sections of the structure are to be checked for compliance with specified design tolerances for thickness, alignment, etc., and to the extent practicable, the location of reinforcing and prestressing steel and post-tensioning ducts. Variations from the tolerance limits are to be reported to the designer for evaluation and guidance as to any necessary remedial actions.

3.5.2(h) Records. Reference is to be made to 5-1-2/23 of the *Offshore Installations Rules* regarding the need to compile construction records. For a concrete structure, the construction records are to include, as applicable, all material certificates and test reports, tensioning and grouting records, concrete records including weight, moisture content and mix proportions, a listing of test methods and results, ambient conditions during the pours (temperature rise and thermal gradients), calibration data for test equipment, towing records, data on initial structural settlements and the inspector's logs. These records are to be retained by the Operator.

3.7 LNG Containment and Handling Systems

3.7.1 LNG Storage Tank, LNG and GNG Piping System Fabrication

All LNG storage tanks or storage systems and LNG and GNG piping systems are to be fabricated in accordance with approved plans to the satisfaction of the Surveyor and in compliance with the manufacturer's approved quality assurance program and fabrication procedures. The ABS Surveyor will verify the use of ABS-certified materials for the tank shell and/or membranes, piping components and insulation systems. Welders, weld procedures, nondestructive examination procedures, equipment and personnel will all be qualified by the Surveyor who will monitor the phases of LNG tank construction and review fabrication reports and NDE records. The ABS Surveyor will attend and report on all pressure testing and tightness testing during the entire fabrication period.

3.7.2 LNG Systems Operations Manual

The LNG systems operation/handling manual should be available onboard to all persons concerned, outlining necessary data for the safe storage and handling of LNG. Description contained in the manual is to include, but is not limited to the following:

i) Outline feature of LNG and GNG systems such as:

- Principal particulars
- Properties and characteristics of the LNG (range of density and composition)
- Storage tanks, piping, LNG/GNG handling equipment
- Control system and instrumentation

ii) Safety systems such as:

- Fire protection, ventilation, fire detection, fire-fighting equipment
- Personnel protection, safety precautions, equipment
- Communications

iii) Normal operating procedures or cargo handling guidance such as:

- Inerting, gasing, cooling down, loading, discharging, warming up, aeration

iv) An envelope of limiting environmental conditions for carrying out safe operations.

v) Emergency operations such as:

- Cargo leakage or spillage
- Jettisoning (if applicable)
- Accepting LNG from a disabled LNG carrier at a load terminal
- Lightering at a discharge terminal that normally only discharges vapor

3.9 Process Systems

Process pressure vessels, refrigerant storage tanks, heat exchangers piping system components, compressors, pumps and other mechanical equipment and electrical and control systems and equipment that is part of a classed process system will be surveyed during fabrication, installation and testing to the same extent that LNG storage and handling systems are reviewed, in accordance with 2-3/3.7 above.

3.11 Piping

All piping installation/testing is to be in accordance with ABS-approved drawings and procedures. Welds are to be visually inspected and nondestructively tested, as required and to the satisfaction of the attending Surveyor. Upon completion of satisfactory installation, the piping system is to be proven tight by hydrostatic testing to the required pressure, but not less than its normal working pressure. Where sections of pipes are hydrostatically tested at the fabrication shops, an onboard test is to be conducted to confirm proper installation and tightness of the flanged and/or welded connections.

3.13 Electrical

All electrical wiring, equipment and systems are to be installed/tested in accordance with ABS-approved drawings and procedures. Proper support for all cables and suitable sealing of cable entries to equipment are to be verified. Upon completion of wire connections, the affected sections of the equipment and cabling are to be insulation-tested and proven in order. All grounding is also to be verified in order.

3.15 Instrumentation

All instrumentation installation/testing is to be in accordance with ABS-approved drawings and procedures. All supports are to be verified. Upon completion, all systems are to be functionally tested and proven in order.

3.17 Mechanical

All mechanical equipment installation/testing is to be in accordance with ABS-approved drawings and procedures, including the grounding of the equipment. Upon completion, all equipment is to be functionally tested and proven in order.

5 Installation, Hook-up and Commissioning Surveys

Surveys during installation are to be carried out in accordance with approved plans and procedures.

5.1 Installation Surveys

The effects which may be induced in the structure during the marine operations required for the transportation and installation of the structure and equipment are to be accounted for. The emphasis of this Subsection is on the influence which these operations may have on the safety and integrity of the structure.

Upon completion of fabrication and when the structure is to be transported to site for installation, the installation procedures are to be to the satisfaction of the attending Surveyor. Procedures for the below-mentioned operations are to be submitted to ABS for review and approval. In order to verify that installation has been accomplished in a manner conforming to the approved plans or drawings covering these procedures, the attending Surveyor is to witness these operations, as applicable. The extent of the Surveyor's attendance may vary depending on whether the terminal is steel or concrete.

For steel gravity-based terminals, installation surveys shall typically include:

- Load-out and tie-down for systems/components applicable or floating and towing operations for self-floating systems/components that are towed to site
- Launching, floating, lifting and/or upending for dry tow items or submergence operations for self-floating items
- Positioning at site and leveling, which may include penetration of internal skirt
- Installation of decks and modules
- Piling and grouting as applicable
- Welding and NDE
- Final field erection and leveling
- Pre-tensioning

For concrete gravity-based terminals, installation surveys shall typically include:

- Load-out and tie-down for systems/components applicable or floating and towing operations for self-floating systems/components that are towed to site
- Towing arrangements
- Positioning at site and leveling, which may include penetration of internal skirt
- Installation – topside and equipment
- Installation – gravity-based structure
- Touch-down procedure
- Skirt penetration
- Verticality of structure
- Pre-tensioning

Significant deviations from approved procedures may require re-submittal of supporting documentation to provide an assessment of the significance of the deviation and the remedial actions to be taken.

To verify that overstressing of the structure during transportation has not occurred, ABS is to have access to towing records to ascertain if conditions during the towing operations exceeded those employed in the analyses required in Section 3-2-6 of the *Offshore Installations Rules*. Results are to be submitted to demonstrate compliance with the reviewed design analysis.

5.3 Commissioning Surveys

The commissioning date will be the date on which a Surveyor issues the Interim Classification Certificate for the offshore LNG terminal. Commissioning of all Rule-required systems is to be verified by the attending ABS Surveyor. The commissioning is to be in accordance with the approved step-by-step commissioning procedures. The Surveyor is to be permitted access to critical/hold points to verify that the procedures are satisfactorily accomplished. The Surveyor is to observe the terminal operating under various capacities and conditions.

Approved LNG and GNG transfer operations including emergency procedures are to be verified to the extent deemed necessary by the attending Surveyor. The overall performance of the LNG containment system should be verified for compliance with the design parameters during the initial cool-down, loading and discharge operations. Records of all of these performances should be maintained and are to be made available to ABS.

Similarly, the safe and satisfactory performance of all process systems covered under the terminal's classification will be verified by the Surveyor as part of the commissioning survey.

5.5 Personnel Safety

Personnel safety precautions, which should include checks of operational readiness of all lifesaving, fire and gas detection and fire fighting equipment, ESD systems, unobstructed escape routes and establishment of communication procedures, are to be taken during commissioning and are required to be verified by the attending Surveyor. All such emergency procedures should be capable of dealing with any contingencies such as spillage, fire and other hazards.

CHAPTER 2 Requirements for Gravity-Based Offshore LNG Terminals

SECTION 4 Surveys After Construction and Maintenance of Class

1 General

This Section pertains to periodical surveys after construction for the maintenance of classification for gravity-based offshore LNG terminals.

3 Surveys

3.1 Annual Survey

An Annual Survey is to be carried out within three (3) months before or after each annual anniversary date of the crediting of the previous Special Periodical Survey or original construction date.

For terminals on Continuous Survey, all Continuous Survey requirements for those parts (items) due are generally to be completed each year. The Annual Survey will not be credited and the Certificate of Classification will not be endorsed unless Continuous Survey items which are due or overdue at the time of the Annual Survey are either completed or granted an extension.

3.3 Intermediate Survey

Intermediate Survey of gravity-based terminals is not required.

3.5 Special Periodical Survey

A Special Periodical Survey is to be carried out within five (5) years of the initial Classification Survey, and at five-year intervals thereafter.

Special Periodical Survey may be commenced at the fourth Annual Survey and be continued with completion by the fifth anniversary date. Where the Special Periodical Survey is commenced prior to the fourth Annual Survey, the entire survey is to be completed within 15 months if such work is to be credited to the Special Periodical Survey.

A Special Periodical Survey will be credited as of the completion date of the survey but not later than five (5) years from date of build or from the date recorded for the previous Special Periodical Survey. If the Special Periodical Survey is completed within three (3) months prior to the due date, the Special Periodical Survey will be credited to agree with the effective due date.

Special consideration may be given to Special Periodical Survey requirements in unusual cases. Consideration may be given for extensions of Rule-required Special Periodical Surveys under extreme circumstances.

3.7 Continuous Survey Program

At request of the Owner, and upon approval of the proposed arrangements, a system of Continuous Surveys may be undertaken, whereby the Special Periodical Survey requirements are carried out in regular rotation to complete all of the requirements of the particular Special Periodical Survey within a five-year period. The proposed arrangements are to provide for survey of approximately 20% of the total number of survey items during each year of the five-year period. Reasonable alternate arrangements may be considered.

Each part (item) surveyed becomes due again for survey approximately five (5) years from the date of the survey and the due parts (items) are generally to be completed each year. For Continuous Surveys, a suitable notation will be entered in the *Record* and the date of the completion of the cycle published.

ABS may withdraw its approval for Continuous Survey if the Surveyor's recommendations are not complied with.

3.9 Survey Based on Preventative Maintenance Techniques

A properly conducted preventative maintenance/condition-monitoring plan may be credited as satisfying the requirements of Special Continuous Survey. This plan must be in accordance with Appendix 7-A-14, "Surveys Based on Preventative Maintenance Techniques" of the ABS *Rules for Survey After Construction (Part 7)*.

3.11 In-line Surveys and Timing of Surveys

All items required to undergo Special Periodical Surveys are to be carried out at the same time and interval in order that they are recorded with the same crediting date. In cases where damage has involved extensive repairs and examination, the survey thereon may, where approved by the Committee, be accepted as equivalent to Special Periodical Survey.

Surveys are to be completed within three (3) months of their due dates, unless extended by agreement with ABS. Surveys carried out within this three-month window period will be credited and due at the same anniversary date in subsequent cycle. When so desired by the Operator/Owner, any part of the terminal installation may be offered for survey prior to the three-month window and the survey will be credited as of the date it has been surveyed.

3.13 UWILD Surveys

UWILD Surveys are to be carried out by competent diver(s) or other approved means once in any five-year period and in association with Special Periodical Survey, with an interval not exceeding five (5) years. Consideration may be given for extensions of the Under Water survey In Lieu of Drydocking (UWILD) due dates under special circumstances.

3.15 Boiler Surveys

Waste-heat or fired auxiliary boilers intended for working pressures above 3.4 bar (3.5 kgf/cm^2, 50 psi), are to be surveyed two times in any five-year period, with an interval not exceeding three (3) years between Boiler surveys. Consideration may be given for extensions of Rule-required Boiler Surveys. The extension may be granted by the Surveyor, provided a survey is carried out in accordance with 7-7-1/7 of the ABS *Rules for Survey After Construction (Part 7)*.

5 Maintenance Records

Maintenance records are to be kept and made available for review by the attending Surveyor. The maintenance records will be reviewed to establish the scope and content of the required Annual and Special Periodical Surveys which are to be carried out by a Surveyor. During the service life of the unit, maintenance records are to be updated on a continuing basis. The operator is to inform ABS of any changes to the maintenance procedures and their frequencies as may be caused, for example, by changes or additions to the original equipment. The Surveyor may determine during his periodic survey if the changes are sufficient to warrant review by the ABS Engineering staff.

5.1 Annual Survey

At each Annual Survey, in addition to a general review of the maintenance records and where applicable and required for Classification of the terminal, the Surveyor is to verify the effectiveness of the following items by visual examination and operational testing, as appropriate:

5.1.1 Hull Structure

i) Visual examination of the terminal's structure above water to be carried out as far as accessible/possible while paying special attention to splash zones for possible damage or deterioration from corrosion.

ii) Any novel features incorporated in the design of the terminal in accordance with procedures agreed to by ABS during design review.

iii) Particular attention is to be given to significant modifications or repairs made as a result of findings at time of previous survey.

5.1.2 Equipment and Machinery

i) Equipment/machinery with their associated pumps, piping, electrical installations are to be generally examined as accessible.

ii) Machinery and boiler space(s), bilge pumping system including bilge wells and associated alarms are to be generally examined and bilge alarms to be tested.

iii) Boilers and pressure vessels and their external appurtenances including safety devices, foundations, controls, relieving gear, high pressure and escape steam piping, insulation and gauges are to be examined.

5.1.3 Electrical, Instrumentation and Control Systems

i) Electrical installation, emergency sources of power, switch gears and other electrical equipment. The operation of the emergency sources of electrical power and their automatic operation are to be confirmed as far as practicable.

ii) Precautions against electric shocks, fire and other hazards of electrical origin are to be generally examined.

iii) Electrical equipment installed in hazardous or gas dangerous spaces delineated in the ABS-approved plan are to be generally examined as accessible.

iv) Instrumentation and control equipment with their associated electrical cabling are to be generally examined.

5.1.4 Containment Systems

i) Survey of the containment system is to be carried out in line with the applicable requirements of ABS' Annual Survey for liquefied gas carriers. (Refer to 7-3-2/1.13.8 of the ABS *Rules for Survey After Construction (Part 7)* for details)

ii) Inerting system installed in accordance with Section 5C-8-9 of the *Steel Vessel Rules* is to be examined and tested in accordance with 7-6-2/3.1.1 of the ABS *Rules for Survey After Construction (Part 7)*.

5.1.5 Safety Systems

i) General examination of the safety systems are to be carried out as far as practicable. These systems include are but not limited to: gas detection, fire detection, fire extinguishing, structural fire protection and emergency shutdown systems.

ii) Personnel protection and life saving appliances, and means of escape are to be examined as far as practicable.

iii) Fire-extinguishing equipment required for classification purposes, as outlined in the *Steel Vessel Rules*, are to be examined, including examination and/or test of the following:

a. Fire main system including isolating valves and hydrants

b. Fire/emergency fire pumps

c. Fire hoses, nozzles, applicators and spanners

d. Semi-portable and portable fire extinguishers

e. Fire Control Plans, where required

f. International Shore Connection

g. Fixed fire-fighting system controls, piping, instructions and marking

h. Remote controls for stopping fans/machinery and shutting off fuel supplies in machinery spaces

i. Fireman's outfits

j. Closing arrangements of funnel annular spaces, skylights, doorways, tunnels, and machinery ventilation system

iv) Access doors and ventilation systems serving the hazardous or gas-dangerous spaces, and associated alarms.

v) Where areas of the terminal are designated for helicopter operations and where fitted, the following are to be generally examined:

a. Access arrangements, ventilation, and electrical equipment

b. Fuel storage and refueling system including tank, pumps, piping, valves, vent, sounding, overflow, spill containment and remote shutdowns

5.1.6 Additional Requirements

i) Where the terminal's process and/or support system is classed with ABS, the survey of the systems is to be carried out considering the extent of classification defined within the Class Notation assigned to the terminal, and in line with the applicable requirements of ABS' Annual Survey for facilities on offshore installations. (Refer to Paragraph 5-2/7.1 of the *Facilities Rules* for details)

ii) Where the terminal's automatic and remote control and monitoring system is approved for **AMCC** or **AMCCU** Class Notation, the system is to be generally examined while the terminal's service generators are in operation and control systems are energized. For further details, refer to Section 7-8-1 of the ABS *Rules for Survey After Construction (Part 7)*.

iii) Where the terminal's import and export system is classed with ABS, the survey of the system is to be carried out in accordance with the requirements of Section 7-7-1 of the *FPI Rules*.

iv) Where parts (items) of the terminal are approved for "Surveys based on Preventive Maintenance Techniques", each such part due or overdue at the time of the Annual Survey is to be examined/tested as required by the Surveyor.

v) Where parts (items) of the terminal are approved for "Continuous Surveys", each such part due or overdue at the time of this Annual Survey is to be examined/tested as required by the Surveyor.

vi) Where parts (items) of the terminal are approved for "Risk-Based Inspection" (RBI), each such part due or overdue at the time of this Annual Survey is to be examined/ tested in accordance with the ABS approved RBI Plan.

Because of the varied nature and purposes of offshore LNG terminals, the above requirements are to be considered as the general scope of required surveys. Additional surveys defined in the ABS-approved "Inspection Plan" (See 2-4/7 of this Guide) are to be carried out to confirm the fitness of the terminal for satisfactory continuous operation.

5.3 Special Periodical Survey

The Special Periodical Survey is to include all items listed under the Annual Survey with more comprehensive examination and testing of the terminal's structure, machinery, equipment, fire protection/fighting/extinguishing systems, cargo containment and transfer systems. The Special Periodical Survey is to be carried out in conjunction with the fifth year UWILD Survey.

At each Special Periodical Survey, in addition to a general review of the maintenance records and where applicable and required for Classification of the terminal, the Surveyor is to verify the effectiveness of the following items by visual examination and operational testing, as appropriate:

5.3.1 Hull Structure

i) Underwater inspection of selected areas of the terminal.

ii) Nondestructive Examination (NDE) is to be carried out on representative joints of the structure and if found necessary, structural supports of conductors and risers. The extent and method to be employed in the cleaning, inspection and NDE process are to be in accordance with an approved Inspection Plan.

iii) Corrosion protection system.

iv) Degree of scouring in way of terminal support structure, tilt and subsidence of the terminal are to be checked and witnessed by the attending Surveyor.

v) Hull thickness measurements (gaugings). The extent and method to be employed in gauging process is to be in accordance with an approved Inspection Plan.

5.3.2 Equipment and Machinery

i) All openings to the sea, including sanitary and other overboard discharges together with the valves connected therewith, are to be examined internally and externally.

ii) The emergency fire pump nonreturn valve (if fitted) is to be examined internally and externally.

iii) Pumps and pumping arrangements, including valves, cocks, pipes, strainers and nonmetallic flexible expansion pieces in the main circulating system are to be examined.

iv) Operation of the bilge/dewatering system. Other systems are to be tested as considered necessary.

v) The foundations of main and auxiliary machinery are to be examined.

vi) Heat exchangers and other unfired pressure vessels with design pressures over 6.9 bar (7 kgf/cm^2, 100 psi) are to be examined, opened out and pressure tested as deemed necessary, and associated relief valves proven operable. Evaporators that operate with a vacuum on the shell need not be opened, but may be accepted on basis of satisfactory external examination and operational test or review of operating records.

vii) Air compressors, air reservoirs and associated piping are to be examined. If air reservoirs cannot be examined internally, they are to be hydrostatically tested. All relief valves and safety devices are to be proven operable.

viii) Where provided, steam reciprocating engines are to be opened and examined including cylinders, pistons, valves, valve gear, crossheads, crankpins, main journals and thrust bearing.

ix) Where provided, main and auxiliary steam condensers are to be opened, examined and leak tested as deemed necessary by the Surveyor.

x) Where provided, main steam piping is to be examined. Where deemed necessary by the Surveyor, the thickness is to be ascertained by NDE. Alternatively, for installation operating at temperatures not exceeding 427°C (800°F), hydrostatic tests to 1.25 times the working pressure may be accepted.

xi) For operational testing of main and auxiliary machinery, see appropriate sections of the ABS *Rules for Survey After Construction (Part 7)*, as applicable.

xii) Where provided, auxiliary internal combustion engines are to be opened, examined and measured as applicable, in accordance with 7-6-2/3.1.2 of the ABS *Rules for Survey After Construction (Part 7)*.

Parts which have been examined within 15 months need not be examined again, except in special circumstances. Special consideration as to the requirements for Special Periodical Surveys may be given for main engines with bores 300 mm (11.8 inches) or under, provided the engine is maintained under a manufacturer's scheduled maintenance program. The records of the program, including lubrication servicing, are to be made available to the Surveyor. Periodical overhauls, required by the manufacturer's scheduled maintenance program, are to be witnessed by the Surveyor and will be accepted for completion of the cycle.

5.3.3 Electrical, Instrumentation and Control Systems

i) Fittings and connections on main switchboards and distribution panels.

ii) Electric cables, as far as practicable.

iii) Generators, including emergency generator, are to be run under load. Where the generators are arranged to operate in parallel, satisfactory load sharing and operation of the circuit breakers, including the reverse power trip, is to be demonstrated.

iv) The insulation resistance of the circuits is to be measured between conductors and between conductors and earth and these values compared with those previously measured.

v) Where electrical auxiliaries are used for vital purposes, the generators and motors are to be examined and their prime movers opened for examination. The insulation resistance of each generator and motor is to be measured with all circuits of different voltages above earth being tested separately and in accordance with 7-6-2/3.1.2 of the ABS *Rules for Survey After Construction (Part 7)*.

vi) On the occasion of major repairs, the coils repaired or renewed are to be subjected to a dielectric strain test, as specified under the applicable parts of 4-8-3/3.15 of the *Steel Vessel Rules*. In addition, the circuits containing the repairs or renewals and coils which have been disturbed during repairs are to be subjected to dielectric strain tests for one minute by application of a potential of 125% of the maximum operating voltage of the circuits to which it is applied. The DC fields of generators and motors are to be subjected for one minute to a test potential equal to 50% of the value specified under the applicable parts of 4-8-3/3.15 of the *Steel Vessel Rules*, and the whole apparatus operated under full-load conditions.

5.3.4 Containment Systems

i) Survey of the containment system is to be carried out in line with the applicable requirements of ABS' Special Survey for liquefied gas carriers. (Refer to 7-3-2/5.11 of the ABS *Rules for Survey After Construction (Part 7)* for details)

ii) The inerting system installed in accordance with Section 5C-8-9 of the *Steel Vessel Rules* is to be examined and tested in accordance with 7-6-2/1.1.11 of the ABS *Rules for Survey After Construction (Part 7)*.

5.3.5 Additional Requirements

i) Where the terminal's process and/or support system is classed with ABS, the survey of the system is to be carried out considering the extent of classification defined within the Class Notation assigned to the terminal, and in line with the applicable requirements of ABS' Special Periodical Survey for facilities on offshore installations. (Refer to 5-2/7.3 of the *Facilities Rules* for details) *ii)* Where the terminal's automatic and remote control and monitoring system is approved for **AMCC** or **AMCCU** Class Notation, in addition to the applicable requirements of the Annual Survey [refer to 2-4/5.1.6ii) above], all mechanical, hydraulic and pneumatic control actuators and their power systems are to be examined and tested, insulation resistance readings are to be taken, automatic controls are to be tested, and the entire control system is to be subjected to a trial at reduced power to ascertain proper performance of the automatic functions, alarms and safety systems. For further details, refer to Section 7-8-2 of the ABS *Rules for Survey After Construction (Part 7).*

iii) Where the terminal's import and export system is classed with ABS, the survey of the system is to be carried out in accordance with the requirements of Section 7-7-2 of the *FPI Rules*.

Because of the varied nature and purposes of offshore LNG terminals, the above requirements are to be considered as the general scope of required surveys. Therefore, additional surveys defined in the ABS approved "Inspection Plan" (See 2-4/7 of this Guide) are to be carried out to confirm the terminal remains in compliance with the applicable Rule requirements and other relevant standards.

5.5 UWILD Survey

The UWILD is to be carried out in accordance with documented procedures that have been submitted for review and approved by ABS in advance of the survey. The approved procedure is to be made available onboard the terminal for the Surveyor's reference. The UWILD Survey is to include the following:

i) The UWILD procedure is to contain the following:

- Procedure for divers to identify the exact location at which they are conducting their inspection
- Procedure for cleaning the marine growth for inspection purposes that is to include the extent and location of the underwater cleaning
- Procedure and extent for measuring the cathodic potential readings in way of the structures
- Procedure and extent for taking thickness gaugings of the structures and NDT of critical joints
- Qualifications of all divers conducting the inspection, NDT and thickness gaugings
- Type of underwater video and photography, including means of communication, monitoring and recording

ii) All Special Periodical Survey items related to the underwater portion of the hull or structure, including the gauging requirements are to be dealt with during the underwater survey.

5.7 Boiler Survey

Boiler surveys are to comply with the requirements stated in Section 7-7-1 of the ABS *Rules for Survey After Construction (Part 7).*

7 Inspection Plan

The requirements of 2-4/5.1 and 2-4/5.3 above are intended to define the general scope of required surveys. Because of the varied nature and purposes of offshore terminals, it is not considered practicable to establish a firm schedule of requirements. The periodical surveys are to be carried out in accordance with the reviewed inspection plan to confirm the terminal remains in compliance with the applicable Rule requirements and other relevant standards. The Inspection Plan should cover all surveys for the design life of the terminal.

9 Modifications

When it is intended to carry out any modifications to the LNG containment systems, process systems, machinery, piping, equipment, etc., which may affect classification, the details of such modifications are to be submitted for review. If ABS determines that the modification will affect classification, the terminal to be modified will be subject to the review, testing and inspection requirements of this Guide.

11 Damage and Repairs

11.1

If an offshore LNG terminal that has been classed suffers any damage to the terminal structure, LNG containment system, process systems, machinery, piping, equipment, etc., which may affect classification, ABS is to be notified and the damage examined by a Surveyor. Details of intended repairs are to be submitted for approval, and the work is to be carried out to the satisfaction of the attending Surveyor.

11.3

When a piece of machinery, piping or process equipment suffers a premature or unexpected failure, and is subsequently repaired or replaced without Surveyor attendance, details of the failure, including damaged parts, where practicable, are to be retained onboard for examination by the Surveyor during the next scheduled visit. Alternatively, the part or parts may be landed ashore for further examination and testing, as required.

11.5

If failures noted in 2-4/11.3 above are deemed to be a result of inadequate or inappropriate maintenance, the maintenance and inspection plan is to be amended and resubmitted for approval.

13 Certification on Behalf of Coastal and Flag States

When ABS is authorized to perform surveys on behalf of a governmental authority, and when requested by the Owner, items as specified by the governmental authority or Owner will be surveyed. Reports indicating the results of such surveys will be issued, accordingly. Where the periodicity and types of surveys on behalf of a governmental authority differ from those required by the applicable portions of this Section, the flag State, coastal State or other governmental authority's requirements take precedence.

CHAPTER 2 Requirements for Gravity-Based Offshore LNG Terminals

SECTION 5 Risk-based Surveys for Maintenance of Class

1 General

The provisions of this Section contain survey requirements specific to the maintenance of classification for gravity-based offshore LNG terminals for which inspection plans have been developed using risk-based techniques as an equivalent alternative to prescriptive requirements, as defined in Chapter 2, Section 4 of this Guide.

1.1 Applicability

While this Section provides risk-based survey requirements as an alternative for maintenance of Class, the Sections on the classification process contained in this Guide are still applicable. Where no specific references or guidance are given in this Section, the relevant requirements of conventional Rules/Guides remain valid.

1.3 Survey Periods

Because of the diverse nature and purposes of offshore LNG terminals and the varied contents of inspection plans likely to be developed as part of an Owner's risk-based approach to Classification, it is not considered practicable to establish a firm schedule of survey requirements in this Section for maintenance of Class.

3 Requirements for Risk-Based Survey

3.1 General

Where the risk-based approach is to be adopted, the Owner's proposed maintenance and inspection plans, including details of frequency and extent of activities, are to be submitted for review. Where these plans deviate from the conventional survey requirements described in this Guide, the risk assessment methodology is to specifically address these deviations, which are not to result in an unacceptable level of safety or integrity of the terminal. In addition to the maintenance and inspection plans noted above, the following documentation is to be submitted to ABS at least six months before the plan is to be put into effect. This documentation is to establish, at a minimum:

i) The basis and methodology employed in the risk-based techniques

ii) The means by which the technique is used to establish maintenance plans

iii) The means by which the technique is used to update and modify maintenance and inspection plans

iv) The means by which the following items are to be controlled:

- Accident and Non-Conformity Reporting
- Overdue Inspections/Surveys
- Internal Audits and Management Reviews
- Control, Storage and Retention of Documents and Data
- Change Procedures for ABS-approved plans

3.3 Site-Specific Risk Assessment

Where the risk-based approach is to be adopted on offshore LNG terminals, the risk assessment on which the inspection and maintenance plan is based is to be site-specific.

5 Surveys

5.1 General

5.1.1 Special Periodical Survey

To credit a Special Periodical Survey based on risk-based inspection techniques, the terminal is to be subject to a continuous survey program, whereby the survey of all applicable items is to be carried out on a continuous basis over the five-year Special Survey cycle. If this program includes a preventative maintenance/condition monitoring plan, this plan is to be in accordance with Appendix 7-A-14, "Surveys Based on Preventative Maintenance Techniques", of the ABS *Rules for Survey After Construction (Part 7).*

5.1.2 Inspection Plan

The inspection plan detailing the timing and extent of activities will be reviewed to establish the scope and content of the Annual and Special Periodical Surveys which are required to be carried out by a Surveyor, who will also monitor the Owner's in-house quality management system required by this Guide. During the service life of the terminal, maintenance and inspection records are to be updated on a continuing basis and are to be available for reference by the attending Surveyor. The operator is to inform ABS of any changes to the maintenance procedures and their frequencies, as may be caused, for example, by changes, additions or deletions to the original equipment.

5.3 Initial Survey

An Initial Survey is to be carried out to confirm that systems and required plans have been properly implemented. The survey is to be carried out a minimum of three (3) months after the date of implementation of the approved plans, but no later than concurrently with the next due Annual Survey.

5.5 Annual Survey

An Annual Survey is to be carried out by a Surveyor within three (3) months before or after each anniversary date of the initial/renewal Classification Survey. The survey is to be carried out in accordance with the approved risk-based inspection plan to confirm the terminal remains in compliance with the applicable Rule requirements and other relevant standards. Where the inspection plan specifically applies ABS Rules, the applicable items are to be complied with.

5.7 Special Periodical Survey

A Special Periodical Survey of the facilities is to be carried out within five (5) years of the initial Classification Survey and at five-year intervals thereafter. The survey is to include all items in the approved risk-based inspection plan listed under the Annual Survey, confirmation of the completion of the continuous survey program, and where the inspection plan specifically applies ABS Rules, the applicable items are to be complied with.

7 Modifications

When modifications to the terminal that may affect classification are to be carried out after the issuance of the Classification Certificate, the details of such modifications are to be submitted for review. If ABS determines that the modification will affect classification, the terminal to be modified will be subject to the review, testing and inspection requirements of this Guide. All documentation requirements for review and the design documentation described in Chapter 2, Section 1 of this Guide is to be available to the attending Surveyor at the time of the modifications.

9 Damage and Repairs

The requirements stated in 2-4/11 of this Guide shall apply.

11 Certification on Behalf of Coastal and Flag States

Only when the coastal and/or flag States and/or other governmental authority accept and authorize ABS for Certification based on risk-based inspection techniques, ABS will carry out surveys as authorized. If the coastal and/or flag States and/or other governmental authority do not accept the risk-based approach, surveys will be carried in conventional, prescriptive manner.