General Specification for LNG Carrier (Module A)

Shipping Requirements

Scope

1) This specification is the core document describing the requirements for a liquefied natural gas carrier (LNGC) that is to be suitable for the international transportation of LNG at -163°C and atmospheric pressure.
2) This document shall be used together with the other Module documents provided with the ITT package, in order to propose Carrier(s) that meets the needs of this LNG project.
3) The Builder may offer alternative designs provided these designs are proven and currently in service.
4) A complete technical specification, fully detailing the proposed Carrier, shall accompany each bid in accordance with Instructions to Bidders.

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General Specification - Revision history

Rev.	Description	Date	Prepared By	Reviewed	Approved
0	Final	Feb 14, 2019	RTS	All	PFD

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1. General Requirements

1.1. Introduction

The hull form, together with propulsion and power generation systems, shall be designed for maximum efficiency and fuel economy in both laden and ballast conditions, with minimum impact on the environment.

All materials and workmanship used in the construction of the Carrier shall be of high shipbuilding and marine quality, and shall conform to the requirements of the Classification Society (Class), the applicable regulatory authorities and the cargo containment system licensors.

The Builder shall consider the use of alternative materials and equipment to those listed in this document, provided that such alternatives do not impair the efficiency and reliability of the Carrier or any of its parts. Any such alternatives shall have the Purchaser's approval before being adopted for use.

The Purchaser of the Carrier(s) shall have representatives present at the Builder's facilities to monitor the progress and quality of construction and commissioning of the Carrier(s). The Purchaser shall be entitled to review the shipbuilding plans, drawings, calculations, and equipment specifications of the Carriers.

As specified in **Section 2,** equipment for the ship shall only be sourced from reputable and recognized manufacturers and all sub-contractors and suppliers to them shall be traceable and submitted to the Purchaser for approval. The Builder shall compile a list of all materials and equipment to be used in the Carrier before issuing any purchase orders, including, but not limited to, such items as castings, paint, valves, and pipes, and shall submit this list to the Purchaser for approval. Purchaser shall have the right to inspect and witness the Quality Assurance / Quality Control (QA/QC) taking place in subcontractor facilities.

Where new equipment or designs are introduced, appropriate due diligence and/or technical qualification shall be applied to a degree as agreed with the Purchaser. This action may include, as appropriate, engineering surveillance, construction surveillance, (qualification of component materials, welding methods and procedures, component manufacturing), equipment testing and post-test inspections. The Builder shall identify equipment and Makers where they do not have experience in the proposed equipment size or model. The Qualification programs shall be proposed by Builder and shall be subject to Purchasers' approval.

As specified in **Section 2,** the Builder shall adopt and be responsible for the principle of minimizing the number of Makers so as to reduce the number of interfaces between equipment and subcontractors.

Builders' specifications shall follow the Section organization of this specification. Exceptions shall be kept to a minimum. Purchaser shall be advised on such exceptions.

All machinery, components and equipment located internally within the Carrier shall be capable of operating at temperatures between 0 and 55^{o}C.

1.2. Required References

1) This Section lists the practices, codes, standards, specifications, and publications that shall be used with this document. Unless otherwise specified herein, use the latest edition.
2) The designs of the Carrier shall incorporate, but shall not necessarily be limited to, the various features and equipment described in this General Specification and in the other Modules for size, capacity, propulsion options, and treatment of boil off gas (BOG). These include this module and the following modules for the required options, as appropriate:

Document # TBD	Outline Specification for 172K m3 - 180K m3 LNG Carrier (Module B)
Document # TBD	Specification for Slow Speed Duel Fuel Propulsion ME-GI (Module C1)
Document # TBD	Specification for Slow Speed Duel Fuel Propulsion X-DF (Module C2)
Document # TBD	Specification Requirements for Gas Management System (Module D)

1.3. Definitions and Glossary

Term	Description
ABS	American Bureau of Shipping
ACB	Air Circuit Beaker
AC/h	Air Changes per hour
AIS	Automatic Identification System
BHP	Brake Horse Power (PS)
BMS	Burner Management System
BMT	British Maritime Technology
BOG	Boil-Off Gas
BOR	Boil-Off Rate
BSRA	British Ship Research Association
Builder	Shipyard bidding for contract
Buyer	Buyer of the LNGC (also known as Owner or Purchaser)
CCR	Cargo Control Room
CCTV	Close Circuit Television
CE	Chief Engineer
CIF	Cost Insurance Freight
Class or Classification Society	Nominated classification society
Contract	Ship Building Contract
CPP	Controllable Pitch Propeller
CSP	Chloro-Sulphorated Polyethylene
CTMS	Custody Transfer Measurement System
CTS	Custody Transfer System
IAS	Instrumentation Automation System

Term	Description
DF	Dual Fuel
DFT	Dry Film Thickness
DGV	Diffuser Guide Vane
DGPS	Differential Global Positioning System
DNV-GL	Det Norske Veritas – Germanischer Lloyd
DOF	Degrees Of Freedom
ECDIS	Electronic Chart Display Information System
ECR	Engine Control Room
EG	Emergency Generator
ESB	Emergency Switch Board
EP	Environmental Protection
EPIRB	Emergency Position Indicating Radio Beacon
EPR	Ethylene Propylene Rubber
ERC	Emergency Release Coupling
ERSB	Engine Room Switch Board
ESB	Emergency Switch Board
ESDS	Emergency Shut Down System
EUC	Equipment Under Control
FAT	Factory Acceptance Test
FBOG	Forced Boil Off Gas
FCC	Fire Control Centre
FCS	Fire Control Station
FEA	Finite Element Analysis
Flag State	Country of ship registration
FLAN	Fiber-optic Local Area Network
FMEA	Failure Modes and Effects Analysis
FG	Fuel Gas
FO	Fuel Oil
FRP	Fibre Reinforced Plastics
FRS	Full Reliquefaction System
FW	Fresh Water

Term	Description
GA	General Arrangement
GCU	Gas Combustion Unit
GMDSS	Global Maritime Distress and Safety System
GPS	Global Positioning System
GRP	Glassfiber Reinforced Plastics
GRE	Glassfiber Reinforced Epoxy -- Non-metallic composite material pipe
GTT	GazTransport & Technigaz
HDPE	High Density Polyethylene
HFO	Heavy Fuel Oil
HP	High Pressure
HOFR	Heat, Oil and Flame Retardant
HRSG	Heat Recovery Steam Generators
HT	High Temperature
HV	High Voltage (≥ 1000V)
IAS	Integrated Automation System
ICC	Integrated Computer Control
IGC	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
IGG	Inert Gas Generator
IMO	International Maritime Organization
INS	Integrated Navigation System
IR	Infrared
ISPS	International Code for the Security of Ships and Port Facilities
ITTC	International Towing Tank Conference
KG	Height of Center of Gravity above Base Line
LCV	Lower Calorific Value
LEL	Lower Explosion Limit
LR	Lloyd's Register
LNG	Liquefied Natural Gas
LNGC	Liquefied Natural Gas Carrier
LO	Lubricating Oil
LP	Low Pressure

Term	Description
LSA	Life Saving Appliance
LSMGO	Low Sulfur (<0.1%) Marine Gas Oil
LT	Low Temperature
LV	Low Voltage (<1000V)
Maker	A manufacturer or supplier of equipment (also known as Vendor)
MBL	Minimum Breaking Load
MCR	Maximum Continuous Rating (of engine)
MDO	Marine Diesel Oil
ME	Main Engine
MGO	Marine Gas Oil
Module	Specification section or part
mLC	Meter Liquid Column
MS	Medium Speed
MSB	Main Switch Board
MSR	Maximum Service Rating
mTH	Meter Total Head
NBOG	Natural Boil Off Gas
NBOR	Natural Boil Off Rate
NCR	Normal Continuous Rating (of Engine) (same as NOP)
ND	Nominal Diameter
NDE	Non-Destructive Examination
NDT	Non-Destructive Testing
NPSH	Net Positive Suction Head
NOP	Normal Operating Power (of engine) (same as NCR)
OCIMF	Oil Companies International Marine forum
ODP	Ozone Depleting Potential
OWS	Oily Water Separator
PFE	Purchaser Furnished Equipment
Purchaser	Purchaser of the ship (also known as Buyer or Owner)
PMS	Power Management System
PPM	Parts Per Million

Term	Description
PS	Metric Horse Power
PVC	Polyvinyl Chloride
PWM	Pulse Width Modulated
RH	Relative Humidity
rpm	Revolutions per Minute
QA/QC	Quality Assurance / Quality Control
QCDC	Quick Connect Disconnect Coupling
SAS	Shipboard Administration System
SBTT	Secondary Barrier Tightness Test
SCBA	Self Contained Breathing Apparatus
SDNR	Screw Down Non Return
SECA	Sulfur Emission Control Area
Seller	Seller of the LNG at the loading port (FOB trade)
(S)FOC	Specific Fuel Oil Consumption
SG	Specific Gravity
SIN	Ship Identification Number
SIGTTO	Society of International Gas Tanker and Terminal Operators
SOPEP	Shipboard Oil Pollution Emergency Plan
SPC	Self Polishing Co-polymer
SPOR	Single Point Of Responsibility
SSAS	Ship Security Alert System
SSD	Slow Speed Diesel
SSPC	Steel Structures Painting Council (Society of Protective Coatings)
STBD	Starboard
SUS	Stainless Steel per Japanese Industrial Standard
SW	Sea Water
SWL	Safe Working Load
TEFC	Totally Enclosed Fan Cooled
TFT	Thin Film Transistor
THD	Total Harmonic Distortion
TMCP	Thermo Mechanical Controlled Process (steel)

Term	Description
UMS	Unmanned Machinery Space (used generically in context)
UPS	Uniterruptible Power Supply
UV	Ultraviolet
VDU	Visual Display Unit
Carrier	LNG Vessel or ship
VFD	Variable Frequency Drive
VMD	Video Motion Detection
VR	Vapor Return
WH	Wheelhouse
WHR	Waste Heat Recovery
WHU	Waste Heat recovery Unit

1.4. Classification and Regulations

The Carrier, including its machinery, equipment and outfitting shall be constructed in accordance with the rules and regulations of the Classification Society (Class) of the Purchaser's choice, and under special survey of the Class surveyors. Class notation shall be equivalent to the notations listed below.

Builder to provide all certificates required by Flag State, Classification Society and Port States for the Carrier, its equipment, appurtenances, and sub-components. The list of certificates shall be submitted as an approval drawing.

The pre-approved classification societies are ABS, DNV-GL, and Lloyd's Register.

1.4.1. American Bureau of Shipping (ABS)

Hull:

✠A1 (E) Liquefied Gas Carrier, Ship Type 2G (Membrane tank, Maximum pressure of 0.25/0.35 barg, Minimum temperature -163ºC, Specific gravity 0.5), SH, FL(40), SH-DLA, SFA(40), SLAM-S, RRDA, GP, +APS, DFD, TCM, PMP, R2, CPS, ENVIRO, SHCM, BWT.

Machinery:

✠AMS, ✠ACCU, NIBS

Descriptive Note:

UWILD, PMS, CMS

In addition, F-AMC (without certification)

1.4.2. Det Norske Veritas-Germanischer Lloyd (DNV-GL)

Hull:

+1A1 Tanker for Liquefied Gas, NAUTICUS (newbuilding), PLUS-2, COAT-2, CSA-2, HMON-1, OPP-F, FLS1, RSD

Machinery:

Machinery CMON, EO, NAUT-OC

Descriptive Note:

UWILD, TMON, PMS, ER TIER III , Cyber Security, Torsional Vibration, LCS, VIBR, BWM T

In addition, F-AMC (without certification)

1.4.3. Lloyd's Register (LR)

Hull:

✠100 A1 Liquefied Gas Carrier, Ship Type 2G, ShipRight (SDA, FDA plus (40,NA)), *IWS, LI, +Lloyd's RMC (LG), IGS

Machinery:

✠LMC, UMS, NAV1 - IBS, LFPF(GC)

Descriptive Note:

ShipRight [PCWBT, FDA plus, CM, SEA (Hss - 4L, VDR), ICC, MPMS, MCM, SCM CAC, SERS, VECS, BWMP(T)], ETA.

In addition, F-AMC (without certification)

1.4.4. Rules and Regulations

All rules and regulations of the Flag State (see Modules B), Class, as well as the relevant authorities of the loading and discharging ports known at the time of signing of the Contract are applicable to the Carrier. This shall include those amendments that are being officially declared and published by the concerned authority and which shall be brought into force up to delivery of the Carrier and shall be implemented prior to delivery.

All such rules and regulations shall be interpreted in the English language version and, in case of any conflict between them, the more stringent rules shall be applied, unless the Purchaser approves otherwise. These shall include:

1) International Convention on Load Lines 1966, as modified by the 1988 Protocol, all amendments up to and including the January 2016 Supplement and all later amendments.

   - International Convention for Safety of Life at Sea Consolidated 1997, 2000, 2009 and all later amendments, including the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk 2016 (IGC Code) and all later amendments (MSC.1/Circ.1549 EiF due on 1 January 2020), the International Life-saving Appliances Code (LSA Code), 2010, and the International Ship & Port Facility Security Code (ISPS Code), 2003.

2) International Convention for Prevention of Collision at Sea 1972 and all later amendments, including the International Maritime Organization (IMO) Resolutions A464 (XII), A626(15), A678(16), A736(18) and A.910(22).
3) International Convention for Prevention of Pollution from Ships 1973, (Annex I, IV, V, and VI) as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) and all later amendments.

   International Telecommunications Union radio regulations incorporates the decisions of the World Radiocommunication Conferences of 1995 (WRC-95), 1997 (WRC-97), 2000 (WRC-2000), 2003 (WRC-03), 2007 (WRC-07), 2012 (WRC-12) and 2015 (WRC-15) in addition to SOLAS Chapter IV, as amended
4) International Convention on Tonnage Measurement of Ships 1969 as amended by IMO Resolutions and all later amendments.
5) International Convention on Standards, of Training, Certification, and Watchkeeping (STCW) 1995 and all later amendments.

6) USCG Rules for Foreign Flag LNG Tankers for LNG ship operating in US navigable waters and involves compliance with USCG CFR 33 Parts 155, 156, 159, and 164, and CFR 46 Parts 153 and154 excluding Alaskan waters", with all Carrier requirements for certification included.
7) USCG Rules regarding Oil Pollution (except as required for Alaskan waters), Sanitation, and Navigation Safety.
8) Suez Canal Regulations, including Regulations for the Measurement of Tonnage.
9) Maritime Labour Convention, 2006 (MLC, 2006), as ammended
10) Maritime Labour Convention, 2006 (MLC, 2006), as ammended
11) ILO Recommendation - Crew Accommodation (Noise Control) Recommendation, 1970 (No. 141)
12) ILO Convention 152: concerning occupational safety and health in dock work (1979).
13) ILO Convention 155: concerning occupational safety and health convention (1981).
14) Rules and Regulations of the Country of Registry.
15) Marine rules and regulations of the national governments for ships entering their ports.
16) Statement of compliance with DNV notation F–AMC (without certification) – Additional Fire Protection.
17) IMO Performance Standards for Protective Coatings (PSPC) (IMO MSC 215[82])

1.4.5. Recommendations and Guidelines

The following recommendations and guidelines shall apply:

1) IMO, Iternational Code on Intact Stability 2008, as amended.
2) IMO, MSC.35(63), Guidelines for Emergency Towing Arrangements for Tankers, as amended
3) IMO Resolution A330 (IX) "Safe access to and working in ballast spaces."
4) IMO Resolution A343 (IX) "Recommendations on the method of measuring noise levels at listening posts."
5) IMO Resolution A468 (XII) "Code of noise levels on board ships."
6) IMO Resolution A601 (XV) "Provision and display of maneuvering information onboard ships."
7) IMO Resolution A708 (XVII) "Navigation bridge visibility and functions and SOLAS Chapter V Regulation 22."
8) IMO Resolution A719 (XVII) "Prevention of air pollution on ships" and all subsequent amendments.
9) IMO Resolution A.1021(26), Code on Alerts and Indicators, 2009
10) IMO Resolution A 868 (XX) "Guidelines for the control and management of ship’s ballast water to minimize the transfer of harmful aquatic organisms and pathogens, Plus the International Convention for the control and Management of Ships' Ballast Water and Sediments 2004.
11) IMO, International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001, as amended
12) IMO Resolution MSC 137 (76) "Standards for ship maneuverability."
13) IMO Publication 978 "Performance Standards for Navigational Equipment (latest edition).
14) IMO MSC Circular 982 "Principles relating to Bridge Design (SOLAS Chapter V Regulation 15)" (IACS UI SC 181 "Bridge Design, Equipment Arrangements and Procedures" to be used as guideline)
15) IMO MSC Circular 1053 "Explanatory Notes to the Standards for Ship Maneuverability."

16) IMO MSC Circular 1091, June 2003 "Issues to be considered when introducing new technology on board ships."
17) IMO MSC Circular 1097, June 2003 "Guidance relating to the implementation of SOLAS Chapter XI-2 and the ISPS Code."
18) IMO MSC.1/Circ.1461 - Guidelines for Verification of Damage Stability Requirements for Tankers
19) ILO Guide to Safety and Health in Dock Work 1976, amended in 1979.
20) ILO Recommendation 141: Crew accommodation (noise control) (1970).
21) ExxonMobil Marine Environmental, and Quality Assurance Criteria 2017 Edition.

    Items Marked with "must" or "strongly preferred" shall be applied.
22) The recommendations of the OCIMF Tanker Structures Co-operative Forum shall be used as guidance by the Builder.
23) OCIMF Recommendations on Equipment for the Towing of Disabled Tankers 1981 (see SOLAS/IMO Res. A.535).
24) OCIMF Mooring Equipment Guidelines (MEG4) Fourth Edition 2018.
25) OCIMF Guidelines and Recommendations for the Safe Mooring of Large Ships at Piers and Sea Islands 1994.
26) OCIMF Recommendations for Ships' Fittings for Use with Tugs 2006.
27) OCIMF HSE at Newbuilding and repair shipyards and during factory acceptance testing July 2003.
28) OCIMF Recommendations for Liquefied Gas Carrier Manifolds Second Edition 2018.
29) ICS/OCIMF/SIGTTO Ship-to-Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases 2013.
30) ICS Guide to Helicopter/Ship Operations Fourth Edition 2008.
31) SIGTTO ESD Arrangements & Linked Ship/Shore Systems for Liquefied Gas Carriers 2009 and 2017 addendum.
32) SIGTTO Guidelines for the Alleviation of Excessive Surge Pressures on ESD for Liquefied Gas Transfer Systems 2018.
33) SIGTTO Guidance for LNG Carriers Transiting the Panama Canal 2014.
34) SIGTTO LNG Emergency Release Systems - Recommendations, Guidelines and Best Practices 2017.
35) Witherbys LNG Port Info 2018.
36) SIGTTO The Selection and Testing of Valves for LNG Applications 2008.
37) IEC Publications 60332-1-2:2004+AMD1:2015 CSV "Tests on electric and optical cables under fire conditions"
38) IEC Publications 60331-1:2018 RLV "Tests for Electric Cables under Fire Conditions"
39) IEC Publications 60332-3: 2018 "Tests on electric cables under fire conditions"
40) IEC Publication 60092:2018 SER "Electrical installations in ships."
41) IEC Publication 60533:2015 RLV "Electrical and electronic installations on ships - electromagnetic compatibility."
42) IEC 61363-1:1998 Electrical Installations of Ships and Mobile and Fixed Offshore Units - Part 1 "Procedures for Calculating Short-Circuit Currents
43) ISO 484-1:2015 "Shipbuilding - Ship screw propellers - Manufacturing tolerances - Part 1: Propellers of diameter greater than 2.50m"

44) ISO 2923:1996 plus Cor. 1:1997 "Acoustics - Measurement of noise onboard Vessels."

45) ISO 4406:2017 "Hydraulic fluid power - Fluids - Method for coding the level of contamination by solid particles."

46) ISO 12669:2017 Hydraulic fluid power -- Method for determining the required cleanliness level (RCL) of a system

47) ISO 6954:2000 "Mechanical vibration - Guidelines for the measurement, reporting, and evaluation."

48) ISO 7547:2002 Ships and marine technology -- Air-conditioning and ventilation of accommodation spaces -- Design conditions and basis of calculations

49) ISO 8573-1:2010 "Compressed Air – Part 1: Contaminants and purity classes."

50) ISO 8861:1998 "Engine room ventilation in diesel engined ships -- Design requirements and basis of calculation."

51) ISO 17894:2005 "Computer Applications - General principles for the development and use of programmable electronic systems in marine applications."

52) ISO 10816-3:2009 Mechanical vibration - Evaluation of machine vibration by measurement on non-rotating parts - Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15000 r/min when measured in situ.'

53) ISO 10816-6: 1996/Amd 1:2015 Mechanical vibration - Evaluation of machine vibration by measurement on non-rotating parts - Part 6: Reciprocating machines with power ratings above 100 kW.

54) ISO 3046 - Reciprocating Internal Combustion engines - Performance

55) ISO 15016:2015 Ships and marine technology "Guidelines for the assessment of speed and power performance by analysis of speed trial data".

56) SNAME Technical & Research Bulletin 3-11, "Marine steam power plant heat balance practices."

57) SNAME Technical & Research Bulletin 3-39, "Guide for shop and installation tests."

58) SNAME Technical & Research Bulletin 3-47, "Guide for sea trials."

59) SNAME Technical & Research Bulletin 5-2, "Gas trials guide for LNG Vessels."

60) BS 6883:1999 "Elastomer insulated cables for fixed wiring in ships and on mobile and fixed offshore units. Requirements and test methods"

61) BS 1807-1981, "Surface finish requirements for reduction gears."

62) IMPA Recommendations for Pilot Ladders

63) Council Directive 96/98/EC on Marine Equipment as amended by Commission Directive 2009/26/EC for MED Certification.

64) Council Directive 2005/33/EC as regards the sulfur content of Marine Fuels.

(Initial arrangement only as specified in Group 7)

65) DNV Requirements for F-AMC (without Certification or Inspection).

66) Material Standards - as referenced in various sections of this specification.

67) IACS - S14- Testing Procedures of Watertight Compartments

68) Resolution A.1116(30), Escape Route Signs and Equipment Location Markings

1.5. Speed

Service speed at design fully loaded condition with 21% sea margin shall not be less than 19.5 knots at Normal Operating Power (NOP) with NOP being no greater than 85% of the Derated Maximum Continuous Rating (MCR).

1.6. Model Tests

1.6.1. General Requirements

For existing proven hull forms the Builder may submit existing model testing data in lieu of tests listed within this section and subject to Purchaser's approval. For new hull forms the Builder shall carry out model testing to determine the Carrier's hull form and hydrodynamic design. The tests shall be carried out at both the full-load and ballast drafts (including the sea trial condition), and shall include:

- Initial bare hull resistance tests
- Initial self-propulsion tests
- Flow visualization tests (initial and updated hull design)
- Updated resistance and self-propulsion tests with revised hull form
- Wake survey
- Wind tunnel tests
- Propeller open-water tests
- Sea-keeping tests
- Cavitation tests
- Maneuvering performance tests

The Builder's model test plan shall be submitted to the Purchaser for review and approval.

Preliminary model tests (initial hull form) may be conducted at the Builder's choice of facilities. All other model tests shall be performed with the final hull form at an internationally recognized facility that employs the International Towing Tank Conference's (ITTC) recommended procedures for model testing and data processing. All tests shall be conducted in accordance with ITTC procedures, unless otherwise specified herein.

The following facilities are preferred for tests and computer simulations:

a) SSPA Sweden AB (Gothenburg, Sweden),
b) IMD (St John's, Newfoundland, Canada),
c) SINTEF Ocean (formally Marintek) (Trondheim, Norway),
d) MARIN (Wageningen, The Netherlands).

Subject to the Purchaser's approval, the following may be used:

a) HSVA (Hamburg, Germany),
b) SVA-Potsdam (Potsdam, Germany),
c) KSRC (St. Petersburg, Russia), and
d) Force Technology (DMI) (Lyngby, Denmark)

The hull scale model for the resistance and propulsion tests shall be as large as practicable, but shall have a length of 5 m as a minimum. All models shall be retained by the testing facility for at least five years after delivery of the first Carrier.

The builder shall submit a comprehensive model test plan describing each of the above tests (and the maneuvering simulation), the test schedule and the deliverables and documentation for all tests. Photographs and videos shall be taken to document all of the tests performed. The Purchaser shall be invited to witness the model tests at an appropriate stage of the design development. The builder shall submit copies of all model test results to the Purchaser.

The following additional requirements also apply, unless superseded by the model test plan as approved by the Purchaser.

1.6.2. Initial Bare-Hull Resistance Tests

Bare-hull resistance tests shall be performed at full-load and ballast drafts, for a total of seven speeds over the full speed range, extending beyond the anticipated trial speed.

Additional low-speed tests, to determine the hull form factor per the Prohaska method, shall be performed at both drafts, and Prohaska plots developed and compared to other similar Carriers. No appendages shall be added to the hull.

1.6.3. Initial Self-Propulsion Tests

Self-propulsion tests with a stock propeller shall be performed at the full-load and ballast drafts, for a range of speeds from 13 knots and extending beyond the anticipated trial speed, testing not fewer than seven speeds. These tests may be performed only at the estimated self-propulsion point, compensating for the difference between model and full-scale frictional resistance.

Test results shall include wake fraction, thrust deduction, relative-rotative efficiency, and extrapolation to full-scale propulsion. For a twin-screw Carrier, self-propulsion tests in the full-load and ballast conditions at the design speed shall be performed, to determine the optimum direction of propeller rotation and the optimum zero-setting rudder angles. Single propeller operation shall be tested with the dead propeller locked, in accordance with the propulsion machinery design.

1.6.4. Flow Visualization Tests

Flow visualization tests shall be performed using the paint streak method.

a) For the initial hull configuration, the tests shall enable expert observation of the fore body (including bulb) and the after body, with the aim of improving flow behavior. The tests shall be conducted at both the full-load and ballast drafts.

b) For the updated hull, the tests shall be performed to determine the optimum location and alignment of the bilge keels. The tests shall be conducted at both the full-load and ballast drafts.

For both the initial and updated hulls, the tests shall be with the model in the self-propelled condition and at design speed.

1.6.5. Updated Resistance and Propulsion Tests

Following analysis of initial resistance and propulsion tests, the hull form shall be revised as appropriate. Bare-hull resistance and self-propulsion tests shall be repeated in accordance with a) and b) above. The updated self-propulsion tests shall use a stock propeller, but unlike the initial propulsion tests, shall include conditions other than the self-propulsion point (overload/underload).

For a twin screw Carrier, tests to determine the optimum direction of rotation of the propeller need not be repeated, unless warranted by any change in the after body lines; however, tests to determine the optimum rudder zero setting shall be performed.

1.6.6. Wake Survey

A three-dimensional wake survey of the final hull shall be conducted at both full-load and ballast drafts and at design speed.

1.6.7. Wind Tunnel Tests

Wind tunnel tests shall be conducted of the upper hull and superstructure, to determine aerodynamic forces for Carrier slow-down in weather, and for determining the horizontal plane forces (lift and drag) and yaw moment for use in maneuvering simulations. Relative headings shall include head winds (180°), 150°, 90° and 60°. A range of realistic wind velocities and vertical profiles shall be tested (these shall be described in the model test plan).

A funnel smoke test shall also be performed to ensure that exhaust gas and soot will not descend upon the deck, nor enter the engine room casing or accommodation.

1.6.8. Propeller Design and Open-Water Tests

The final propeller design shall be based on results from the initial and updated resistance and propulsion tests and wake survey. The propeller shall be designed with a margin on RPM as specified in Modules C1 and C2. To confirm the design, open-water tests of the final propeller shall be performed. The final powering predictions shall incorporate the results from the open-water propeller tests.

1.6.9. Sea-keeping Tests

Sea-keeping tests shall be conducted with the final hull form in the free-running, self-propelled condition, fitted with stock propellers, rudders and bilge keels, and at both the full-load and ballast drafts. The model shall be connected to the carriage in such a manner that the model motions are not affected.

Tests for added power in regular waves shall be conducted for both the full-load and ballast drafts, to determine the mean added thrust and mean added power operators. Headings shall include 180°, 150°, 90°, and 60° with three sea states and minimum three speeds for each sea state. The number of regular wave frequencies shall be adequate to determine, for each heading, the added thrust and added power response peaks.

Tests in irregular waves shall be performed to determine general sea keeping performance [e.g., 6 DOF (Degrees Of Freedom) motions and added resistance] and to observe sea-keeping response phenomena (e.g., deck wetness, slamming and propeller emergence). The tests shall focus on the most severe seas, at combinations of heading and speed that approximate to actual operating conditions, including both voluntary and involuntary speed reductions. Measurements shall include the following:

a) 6 DOF motions
b) Linear (surge, sway, heave) accelerations at several locations
c) Relative water motion at several locations, to include FP, AP and 3 to 4 other locations agreed with purchaser
d) Carrier speed and rudder angle
e) Propeller thrust and torque (to determine mean added thrust and power)
f) Slamming pressure on the bottom forward and on the bow flare
g) Slamming pressure on the stern

Response statistics shall be computed for all harmonic phenomena and transient events.

The sea-states to be tested and the characteristics of those sea-states shall be derived from sea-keeping analyses and described in the model test plan. A minimum of 4 sea-states shall be tested for each draft, with minimum three speeds for each sea state. Headings shall include 180°, 150°, 120°, 90°, 60°, 30°, and 0°. Testing shall be performed in short-crested seas. Testing shall be agreed with purchaser.

Upper hull-form modifications shall be performed to reduce slamming, whipping, green-seas on deck and propeller emergence based on the above tests.

1.6.10. Cavitation Tests

Cavitation tests shall be performed with the final design propeller behind the complete Carrier model. Flow visualization over the hull and erosion paint tests on the stock propeller shall be incorporated into the test program. Pressure pulse measurements shall be made at several Purchaser-approved locations at both full load and ballast drafts.

1.6.11. Maneuvering Tests and Simulations

The maneuverability of the Carrier shall be assessed in accordance with the IMO Standards for Ship Maneuverability. During design, this assessment shall be performed with the use of scale model tests and numerical maneuverability simulations. In the case of a twin-screw Carrier, the effect of rudder failure, including one (1) rudder locked hard over, shall be studied with both scale model tests and the mathematical/computer simulations.

1.6.12. Maneuvering Tests

Maneuvering tests shall be performed with a self-propelled, free-running model having an appropriate number of rudders and propellers and bilge keels. The model may be the same as used for the resistance and self-propulsion tests, but will represent the final hull form.

Both free-model tests conducted in an open-water basin or captive model tests (using a rotating arm basin or a planar motion mechanism in a towing tank) are acceptable; however, free-model tests shall be preferred.

If free-model tests are selected, the following shall apply:

a) Compensation for the model's excess frictional drag (versus that of the full-scale Carrier) shall be provided, preferably via the use of an air fan mounted on the model.

b) The model shall be tested at the full-load and ballast drafts.

Free-model tests shall include:

1) Zigzag maneuvers over at least two, and preferably four, cycles
   - 10°/10°
   - 20°/20°
2) Turning circles with pull-out tests (for turning performance and directional stability)
   - 35° rudder
   - 25° rudder
   - 15° rudder (if practicable)
3) Tests, as necessary, to characterize the presence and magnitude of a hysteretic spiral loop, indicating directional instability
   - Direct or indirect spiral tests
   - Modified zigzag tests δ/ψ (rudder angle/ heading change), e.g., (5°/1°)

1.6.13. Maneuvering Simulation

In addition, a mathematical/computer simulation shall be used to predict and evaluate the Carrier's maneuvering performance both in the open ocean and in selected ports. The method and program used shall be of industry standard, and performed by an organization that is internationally recognized for this type of analysis. Such organizations may include those listed above as "preferred" for scale model testing. Other facilities or organizations, including those listed above but not on the "preferred" list, shall be subject to the Purchaser’s approval.

An initial maneuvering simulation shall be performed based on prior experience with Carriers of similar hull form, dimensions and propulsion/steering systems. This simulation shall be used to determine or confirm the initial rudder design and steering response characteristics. The initial simulation shall include open sea maneuvers and port entrance and departure simulations.

A final simulation shall be performed with maneuvering characteristics derived from the maneuvering model tests with the final hull form, as well as the aerodynamic forces and moments from the wind tunnel tests. The final simulation shall include only the stopping test from the open-sea maneuvers, as well as all port entrance and departure simulations.

The open-sea simulations shall reproduce the maneuvering trials required by **Section 1.18,** "Maneuverability," of Module A, specifically:

a) 35° turning test
b) Zigzag tests (10°/10° and 20°/20°)
c) Stopping test

The port simulation study shall be based on port characteristics to be provided by the Purchaser, with the corresponding Carrier draft (full-load or ballast). Approaches from the open sea into port and departures from port into the open sea shall be modeled for combinations of Carrier speed, wind, wave, current and tidal variations, according to a simulation plan approved by the Purchaser. Shallow water and bank effects shall be included.

Documentation of the simulation study shall include all input assumptions, a description of the simulation model and the analysis results, including track plots and time histories.

1.7. Carrier Bunker Tank Capacity and Range

The Carrier bunker tank capacity and range shall be:

- Fuel Oil Tank capacity: 15,000 N.M. + 5 Days
- Loaded Fuel Oil at design draft and service speed of 19.5 knots: 15,000 N.M. + 5 Days without making use of BOG and 50% supplies of other consumables and power generation liquid fuel consumption.

Above with sea margin when burning compliant liquid fuel at the fuel rate calculated from sea trial data, plus a reserve of 5 further days at the same conditions.

Draft assignment shall be agreed with the purchaser.

1.8. Stability and Loading Computer

1.8.1. Stability

Statutory stability requirements shall be met over the full range of operating conditions, including partial cargo filling conditions, full cargo conditions, all load and discharge sequences and exchange of ballast water conditions while on passage (using either sequential ballast exchange or overflow methods) .

The vessel must comply with the Ballast Water Management Convention by use of a Ballast Water Treatment plant.

See Section 3.1.3. The GM shall be positive at all loading conditions.

1.8.2. Loading Computer

The Carrier shall be fitted with an online loading computer capable of verifying all loading cases, load/discharge sequences, ballasting operations, and damage stability (limiting KG not flooding calculations).

Both the hardware and software program in the loading computer shall be approved by the Classification Society. The software program shall be approved from both strength and stability aspects, as a minimum of Type 2 Installation. The software program shall be capable of automatically performing calculations to simulate a full user-specified ballast water exchange sequence using the sequential drain-and-fill method.

1.8.3. Ballast Exchange

The sequential exchange of the full quantity of ballast water within 72 hours shall be specifically demonstrated by calculation. Demonstration is by the provision of loading manual ballast exchange sequences and loading computer displays, both to be approved by the Classification Society.

The sequences need to be for safe sea going conditions including trim and heel. Preliminary ballast exchange sequences to be submitted to Purchaser at early design stage.

Ballast water exchange shall be designed to have a minimum number of steps.

1.9. Accommodation

Accommodation shall be provided for 45 persons, including 8 Suez Canal workers. The final number and configuration shall be subject to Purchaser approval **(see Section 4.1).**

1.10. Noise and Vibration

1.10.1. Noise

Under normal operating power (NOP) noise levels shall not exceed the following limits:

a)	Cabins, hospital, public spaces and offices	55 dB(A)
b)	Galley, pantry	65 dB(A)
c)	Workshops in engine room	75 dB(A)
d)	Workshops in accommodation	65 dB(A)
e)	Engine Room and other machinery spaces	105 dB(A)
f)	Engine Control Room	70 dB(A)
g)	Cargo Control Room	55 dB(A)
h)	Wheelhouse	65 dB(A)
i)	Machinery Spaces Manned	90 dB(A)

All other areas and inter-cabin noise insulation levels shall comply with IMO Resolution A468 (XII) and the rules and regulations of the Flag State.

External noise levels shall not exceed 90 dB(A) at any location approximately 1.0 meter above the deck during cargo and ballast operations with hydraulic machinery in use. Also, external noise levels shall not exceed 90 dB(A) in Navigation bridge deck surrounding wheelhouse during the GCU operation at sea at NOP of the main engines as well as while Carrier is operating in port.

1.10.2. Vibration

Vibration levels in the accommodation and working spaces during normal operating conditions shall be within the range " Values above which adverse comments are probable and Values below which adverse comments are not probable"given by the lower limit in the ISO 6954:2000 guidance.

The Builder shall fully investigate, at the design stage by means of a 3-D finite element vibration analysis, the global and local vibrations of the Carrier, in ballast and loaded conditions, for the complete hull including superstructures. In addition, all major Cargo and Propulsion related piping systems shall be analyzed for acceptable levels of vibration. A mutually agreed independent institute shall verify the results of this analysis.

The following vibration calculations shall also be carried out by the Builder at the design stage and submitted for Purchaser review:

a) Whirling, torsional, and axial vibrations of the propulsion shaft(s).
b) Natural frequencies of each deck in the superstructure.
c) Natural frequencies of local structures, including support structures of main equipment.
d) Vibration response analysis of the entire Carrier by 3-D finite element analysis.

An excitation test shall be performed at the construction stage, to evaluate the natural frequencies of hull, accommodation block, and engine room casing including funnel, to limit vibrations during sea-trials and operations.

Noise and vibration trials shall be carried out during sea trials, as specified in **Section 1.13**, by an independent contractor or Classification Society. Global vibration measurements shall be carried out during sea-trials at MCR, NOP and at 75%, 50%, and 25% MCR.

1.11. Access

All walkways and access areas shall have a minimum height clearance of 2.20 meters and minimum width of 1.30 meters except for specific areas where, subject to Purchaser approval, the minimum height shall not be less than 2 meters and minimum width shall not be less than 0.60 meters.

See also **Section 3.2** for details of tank access.

Handrails should be provided on both sides of the walkway and accommodation stairways. All inclined ladders should be provided with two intermediate rails. Half landings should be provided for staircases where stairs would require in excess of 16 risers. Such landings should be provided at the midway height of the staircase wherever possible, landings should be provided at the top and bottom of every flight, and should be at least as great as the smallest width and depth of the staircase. To afford safe passage, landings should be clear of any permanent obstruction.

The central stairway within the accommodation shall be fitted with handrails on both sides, each of an identical design.

Flights and landings should be guarded at the sides where there is a drop of more than 600 mm. Handrails or the like should be positioned at a minimum height of 900 mm above staircase risers and treads and 1 m above landings.

The steepness of the staircase should normally be between 37.5° and 45°. The riser should not exceed 190 mm and tread 240 mm.

Builders should submit details of any areas were these conditions cannot be met, for review by owner.

All non-flush deck fittings shall in general be minimized and considerately located to eliminate trip hazards. Pipe racks , supports and other fittings shall be arranged to minimise obstructions below 2.2m from walkways and decks.

No tripping hazards or tank openings are to be fitted outside door entry points or at base of any stairway. This includes openings for valves or equipment , in the ER walkway that can be opened for valve access are not to be fitted at the base of stairways.

Requirements around the vessel concerning tie-off points on vertical ladders are to be one common standard – hoops/cages, tie-off are to be of a common standard throughout the vessel.

On vertical ladders an intermediate platform to be provided every 6m.

1.12. Drawings and Operating Manuals

All drawings, specifications and other documents relating to the Carrier shall be written in English. Metric units of measurement shall be adopted for the design and construction of hull, machinery, and equipment. SI units of measurement shall be adopted for the cargo system unless otherwise described in the specification. IMO symbols shall be used for all drawings. All Carrier's plans, manuals and other documents shall be marked with the IMO ship identification number (see MSC Circ. 1142/MEPC Circ. 425 dated 20/12/04 for details).

The Builder shall provide the Purchaser with the following documents in both hard copy and electronic format:

a) Drawings (to include General Arrangement, mid-ship section, engine room arrangement and accommodation arrangement as a minimum), specifications, and documents for approval – minimum of 6 copies (to be agreed during technical negotiations).
b) Finished plans – 6 copies.
c) Makers' instruction books (final) – 3 copies.
d) Copies of all technical correspondence (Purchaser, Builder, Classification Society, etc).
e) Ship computer model used in the build-up of the loading instrument approved by Classification Society

Plan approval arrangements shall be defined within the Contract documents and as agreed during technical negotiations. The Purchaser requires electronic document and data transmission during the plan approval process, backed up by hard copies of drawings and full electronic data on CDROM. Drawings shall generally be transmitted in black and white only.

Instruction manuals provided by equipment Makers shall be available for the Purchaser's review six months before contractual delivery. All equipment instruction manuals shall be bound in a common style binder for easy storage in Carrier's technical libraries.

All of the Carrier's major finished drawings, as well as Maker instruction manuals and Makers drawings for the major machinery and equipment, shall also be supplied in a standard digital electronic format to allow easy uploading into the Carrier's shipboard administration system (SAS). There shall be no restriction on printing hard copies from this digital electronic format

Aluminum metal photo plans for General Arrangement, Capacity Plan, Safety Plan, Ship's Principal Particulars, Maneuvering characteristics, and Fuel Transfer Procedures shall be provided and installed in locations as required by regulations and as agreed with purchaser.

Purchaser's Subcontractor shall be allowed access to the vessel to complete a full 3-D laser scan of all areas including, but not limited to, the Hull, Deck, Accommodation and Machinery spaces.

1.13. Trials and Commissioning

Comprehensive trials of the Carrier, to a program approved in advance by the Purchaser, shall be carried out to verify the performance of the Carrier to the Purchaser's satisfaction. Prior to commencement of commissioning all installations and associated equipment shall be the subject of a formal physical inspection by the Builder's and Purchaser's Representatives. Commissioning of all equipment (including testing of control, alarm and monitoring systems), excluding cargo plant, shall be carried out to the Purchaser's satisfaction prior to sea trials. This shall include a dock trial with the main propulsion plant developing at least 10% MCR. Shop trials shall be carried out in accordance with the SNAME bulletin 3-39 "Guide for Shop and Installation Tests."

The Carrier shall be dry-docked within the 3 weeks prior to the commencement of sea trials. The sea trials shall include speed runs at the ballast draft identical to that used in the model tests (for comparison). The speed runs for the first Carrier shall be carried out at MCR, NOP and 75%, 50%, and 25% MCR, with the fuel consumption rate measured over a 2 hour run A to B and B to A at each power level and for each fuel type, liquid and gas.

Maneuvering trials shall be carried out in accordance with the guidelines in IMO Resolution A751 (XVIII) and MSC Circular 644. The speed runs for subsequent Carriers shall be carried out at MCR, NOP, and 50% MCR. For twin screw Carriers, maneuvering tests shall be carried out in all single and twin screw modes.

The method for calculating corrections to reach the design speed specified in **Section 1.5,** in loaded condition at the design draft and trim, shall be submitted for the Purchaser approval before contract signing. The speed trials shall be conducted in deep water with weather conditions not exceeding Beaufort 3 and tidal stream in the trial area not exceeding 0.5 m/sec. However, if the weather conditions at the time of the speed trials exceed Beaufort 3 and it is forecast that these weather conditions will continue for such a period that an inability to conduct speed trials within the Beaufort 3 criteria will delay the delivery of the Carrier, the speed trials may be conducted in such weather conditions as may be mutually agreed in writing between the Builder and Purchaser.

An endurance run of at least 12 hours shall be undertaken with the main engine(s) at MCR, which shall include at least 8 hours under unmanned engine room conditions (UMS), during which no control adjustments shall be made. In addition, there shall be a UMS period of 2 hours at various maneuvering speeds. Fuel consumption data shall be collected and reported during the endurance run. Noise and vibration measurements shall be carried out in all living and working spaces during the endurance run.

If the propulsion plant has twin screws, in addition to the above, each engine and/or power train in turn shall be run individually with the other locked for 2 hours. These 2-hour running periods shall be at MCR (subject to any torque limitations) for the operating power train. Power output, speed, fuel consumption and other parameters shall be recorded during these periods.

Astern endurance tests shall be conducted for thirty (30) minutes during endurance trial.

Additional trials to cover all operating modes particular to each Carrier e.g., low speed maneuvering, different speeds and maneuvering for each shaft on Carriers as applicable, split engine maneuvering shall be implemented. Split engine operation shall include determination of Carrier maneuvering characteristics with one engine operating ahead and the other engine operating astern at forward speeds up to half ahead. This will then be repeated with the engines operating in the opposite direct. Details shall be agreed with the purchaser.

Capability to switch between the different fuel types (distillate, residual and gas) within the specified time (Modules C1 and C2) shall be verified during sea trials.

Major items of propulsion equipment shall be opened up for inspection on conclusion of the sea trials, in accordance with guidelines and Class requirements. The Builder shall submit a list of inspection items prior to sea trials, which shall be agreed with and approved by the Purchaser.

This inspection list shall include, but not be limited to, the following: in addition to requirements noted in modules C1, C2, D, and E:

a) Inspection of underwater hull area (to include rudders, sea suctions, anodes, propellers, bilge keels, etc) by divers, to include photographic and video footage of the complete underwater area.
b) Internal inspection of all cargo tanks.
c) Internal inspection of all ballast tanks, including peak tanks.
d) Inspection of all void/cofferdam spaces.
e) Thrust bearings/blocks–upper housings opened up and internals visually inspected as per manufacturer's recommendations.

f) For all dual fuel generators, (one unit per engine) to be overhauled and inspected (one unit per engine), as per manufacturer's instructions, as follows:
   - Piston removed and dismantled
   - Crank bearing and main bearing, dismantled
   - Cylinder liner in the installed condition
   - Cylinder head, valves disassembled

g) For all dual fuel generators–crankcases opened up, internals visually inspected and crankshaft deflections taken.

h) For all dual fuel generators–covers of drive equipment (gears, chains, camshafts, etc) to be opened up and internals visually inspected.

i) For all dual fuel generator turbochargers exhaust blading shall be inspected (fiber optic inspection with video footage is acceptable).

j) Thermographic survey of all switchboards, oil fired boilers, exhaust gas economizers and exhaust uptakes. *

k) Bilge pump and one of each type of air compressor to be overhauled and inspected.

l) Alignment checks for propulsion shafts –Vertical and horizontal deflections as well as bearing load test and strain gauge measurements for shaft bearings, and forward stern tube bush to be carried out by using jack-up method for shaft alignment condition check (in hot condition). Methodology shall be agreed with Purchaser.

m) Auxiliary Oil Fired Boilers–water and gas sides to be opened up, cleaned, and inspected.

n) Exhaust gas economizers–gas side to be opened up, cleaned, and inspected.

o) All filters and strainer to be inspected and, where applicable, cleaned or renewed. Flushing system to required cleanliness if required prior to installation of new filter/strainer.

p) All vibration monitoring equipment data to be analyzed.

q) All oil (lubricating or hydraulic) systems–oil sample to be taken and analyzed.

r) All emissions monitoring equipment readings taken during sea trials/gas trials to be analyzed.

s) GCU shall be tested during gas trials in accordance with Class requirements and manufacturer's recommendations. * *

t) Re-Liquefaction Plant shall be tested during gas trials in accordance with Class requirements and manufacturer's recommendations. * *

* During sea trials

* *During gas trials

1.14. Post Gas Trial Inspections

Major items and propulsion equipment shall be opened up for inspection on conclusion of the gas trials, in accordance with guidelines and Class requirements. A documented record of all inspections shall be made which shall include, as a minimum, a written report with all recordable readings and photographs.

The Builder shall submit a list of inspection items prior to gas trials, which shall be agreed with the Maker and approved by the Purchaser as described in Module A. In addition to the list noted in Module A, the following list shall apply:

a) For one unit on each main engine the following shall be overhauled and inspected:
   - Piston removed and dismantled
   - Crosshead bearing, dismantled
   - Crank bearing and main bearing, dismantled

- Cylinder liner in the installed condition
- Cylinder head, all valves disassembled

b) For both main engines–crankcases opened up, internals visually inspected and crankshaft deflections taken.

c) For each main engine–covers of drive equipment (gears, chains, etc) to be opened up and internals visually inspected.

d) For each main engine–one turbocharger rotating element to be withdrawn and inspected.

e) For all remaining main engine turbochargers–exhaust blading to be inspected (fibre optic inspection with video footage acceptable).

f) For each main engine–exhaust manifold inspection to include visual inspection of all piston ring packs.

g) For each main engine–scavenge space inspection to include visual inspection of all internal fittings.

h) Both shaft locking arrangements – to be overhauled or inspected as per manufacturer's recommendations.

i) Both main engines–foundation bolts and chocks to be checked and readings taken

j) All fuel gas line filters opened for inspection then cleaned

Diesel generator engines : After the gas trial, the overhaul inspection shall be carried out in accordance with the engine manufacturer's standards, and the scope of the overhaul inspection shall be one(1) cylinder unit for each engine.

Boiler and exhaust gas economizers: gas side visual inspection through inspection hole

All filters and strainers for SW, FO, LO systems : opened and cleaned

Air conditioning air handling unit filters.

Any other items where performance during sea/gas trials does not meet the performance criteria in accordance with the Builder’s standards.

Noise measurements shall be taken under sea trial, gas trial, maximum electrical load, and port operating conditions, e.g., cargo pumping, deck machinery running, etc., to establish that the specified limits are not exceeded. In addition, noise measurements as agreed with the Purchaser are to be taken with the GCU in operation. A vibration test shall be carried out during the trials, to establish resonant frequencies and ensure they lie outside the Carriers’ normal operating conditions.

Vibration testing shall be carried out to establish the baseline "vibration signature" for all main rotating equipment. The information shall then be entered into the vibration monitoring system software database.

Torsional vibration shall be measured at the intermediate shaft(s).

The sea trial analysis and correction methods shall be in accordance with agreed international codes, e.g., SNAME bulletin 3-47 "Guide for Sea Trials." Corrections for wave height shall not be applied unless a robust scientific method for measuring wave height is established and confirmed by a mutually accepted authority.

Separate gas trials shall be carried out prior to delivery of the Carrier to prove that the cargo system complies with the requirements of the specification. The Builder shall carry out full commissioning tests and shall provide and load free of extra cost a suitable quantity of LNG prior to the gas trials. Gas trials shall be carried out following the guidelines set out in the SNAME bulletin 5-2 "Gas Trials Guide for LNG Vessels." In the case of Membrane Carriers, the gas levels measured by the gas detection system

when monitoring the inter-barrier space (between primary and secondary barriers) and insulation space (between secondary barrier and hull) shall be continuously monitored and recorded. If gas levels in excess of those set by the membrane designers and the IGC Code are reached in the insulation space during gas trials, then correction work shall be made until the levels are satisfactory within the membrane designers' and IGC Code limits.

Schedule, duration and test sequence of equipment is to be mutually agreed between the Builder and the Purchaser prior to signing of contracts. This shall include testing of the cargo tank and insulation space relief valves. Where cargo handling equipment and associated monitoring systems are normally intended to be operated with the machinery spaces unmanned, 'hands off control' shall be demonstrated during the Gas Trials.

On completion of gas trials, all cargo tanks shall be gas freed, aerated and safe for entry to allow all cargo tanks to be internally inspected for possible damage or contamination prior to Delivery.

1.15. Purchaser Furnished Equipment

The Builder shall be responsible for receiving, storing in good conditions and transporting all Purchaser Furnished Equipment (PFE) within the shipyard as per the Contract. The Builder shall undertake installation and commissioning of the OFE. The expenses relating to receiving, storing, installation and commissioning shall be at the Builder's account. Where provided, Builder will strictly follow the Maker's preservation instructions.

The following items shall be supplied by the Purchaser to the Builder in satisfactory condition ready for installation at the agreed time, to meet the construction schedule of the Carrier:

1) Charts general
2) Electronic charts for ECDIS
3) Charts for lifeboats
4) Flags, signals and nautical equipment other than those mentioned in the Specifications
5) Galley and pantry utensils including pans, glassware, cutlery, crockery, etc.
6) Linen including blankets, bed sheets, towels, table clothes, pillows, etc.
7) Brooms, brushes, vacuum cleaners, waste baskets, etc. for accommodation
8) Stationery including pencils, rulers, papers, etc.
9) Consumables including soaps, toilet papers, foods, etc.
10) Office machines other than those mentioned in the Specifications
11) All medicine and medical equipment
12) Decorations such as paintings, flowers, etc. including frame or box
13) Fitness equipment and game equipment
14) Steel wire and mooring ropes in excess of the Classification's requirements or other than those mentioned in the Specifications
15) Personal computers with peripheral devices for shipboard administration system
16) UHF onboard radio communication (walkie-talkies)
17) Boatswain's and carpenter's tools other than those mentioned in the Specifications
18) Bunker, lubricating oil, consumable stores except those consumed during sea trials
19) Chemical compounds for the treatment of feed water and cooling fresh water
20) Hoses in general
21) Portable gas detectors

22) Loose fittings for cargo handling other than those mentioned in the Specifications
23) Shipboard oil pollution emergency plan (SOPEP) and Ballast Water Management Plan - All relevant technical information shall be supplied by the Builder
24) Such items described as "Purchaser's supply or equivalent" in the Specifications.
25) Purchaser's manuals and paperwork
26) Technical Publications
27) Hobby Equipment in excess of those specified in the specifications
28) Spare parts and tools other than those required by Classification Society or described in the specification
29) Radio receivers, TV sets and general entertainment equipment other than mentioned in **Section 39**
30) Test kits and chemicals for water, fuel oil and lube oil
31) Consumable items for lifeboats
32) Portable fire extinguishers (including spares), portable fire-fighting equipment and a compressor for recharging the breathing apparatus air bottles in accordance with the rule requirements or Purchaser's requirements, whichever is the more onerous
33) MARPOL placard and garbage stowing boxes
34) Material for oil removal specified in SOPEP
35) Personnel protection and safety equipment, in accordance with rule requirements or Purchaser's requirements, whichever is the more onerous
36) Personnel life-saving equipment, in accordance with rule requirements or Purchaser's requirements, whichever is the more onerous
37) Application software for chart management system (electronic chart updating and weather reporting system)
38) Two cellular telephone systems

For the above equipment the Purchaser shall furnish the Builder with necessary specifications, plans, drawings, instruction books, manuals, test reports, certificates, etc., as required by the Builder

1.16. Miscellaneous

The Builder shall supply six (6) Carrier models in display cases for each LNG carrier ordered, two (2) at a scale of 1:200 (each with a cutaway section into one cargo tank and ballast tank showing the key internal structure) and four (4) at a scale of 1:400 without cutaway section.

In addition a series of Aerial Framed Photographs for each vessel in series.Vessel owner to hold Copyright of these photographs (RAW format).

1.17. System Responsibility

The shipboard instrumentation and control system **(**as detailed in **Section 26)** consists of all equipment and its associated control and instrumentation installed throughout the Carrier. There shall be a Single Point Of Responsibility (SPOR) for the integration of the system within the Carrier. This shall include, but not be limited to, the development, design, implementation, installation, commissioning and testing of the complete system and all its components. The SPOR in this case shall be the Builder.

The principle of using a single Maker for all hardware, software, and documentation shall be applied to the major systems as defined by the Purchaser. While the Builder shall be the SPOR for all shipboard systems, it is acceptable that the major equipment Maker shall assume technical responsibility, on behalf

of the Builder, for all integration and compatibility issues between the different subsystems that are contained within a major system.

The shipboard system shall be implemented in compliance with Lloyd's Register Rules Part 6, Chapter 1, with emphasis placed on the requirements for ICC notation (or equivalent).

MSC Circular 1091 (Issues to be considered when introducing new technology on board ship) shall be used as guidance.

1.18. Maneuverability

The Carrier shall meet the recommendations laid out in the IMO document "Standards for Ship Maneuverability" (MSC137 (76)), with additional requirements presented below.

	Purchaser Requirement	**IMO Requirement**
35° Turning Test		
Advance	≤ 3.75 *L_{BP}	≤ 4.5 * L_{BP}
Transfer	≤ 1.7 *L_{BP}	
Tactical Diameter	≤ 4.25 *L_{BP}	≤ 5 * L_{BP}
10°-10° Zigzag Test		
10° heading change	≤ 2 *L_{BP}	≤ 2.5 * L_{BP}
1st overshoot angle	≤ 12°	≤ 20°
2nd overshoot angle	≤ 27°	≤ 40°
(Minus) 2nd -1st		≤ 15°
20°-20° Zigzag Test		
1st overshoot angle	≤ 23°	≤ 25°
Stopping Test		
Track reach		≤ 15 * L_{BP}

Fulfillment of these maneuvering criteria shall be verified by an independent organization during the design stage with scale model testing and mathematical/computer simulations. The conditions under which these tests are carried out shall be as recommended in the IMO "Standards for Ship Maneuverability" (MSC Resolution 137(76)) and "Explanatory Notes to the Standards for Ship Maneuverability" (MSC Circular 1053). For further guidance see the Model Tests **Section 1.6.**

Full scale results need not be the same as the model scale results, but shall meet the criteria specified above.

2. Materials and Standards

2.1. General

All equipment and materials used in the construction of the Carrier shall be of new stock and manufacture and of good shipbuilding and marine engineering quality. Materials shall be tested, inspected, and certified by the Classification Society and other regulatory bodies concerned. Where deficiencies are evident additional testing, as designated by the Purchaser, shall be carried out.

All work, material, and equipment shall be inspected by the Purchaser, who shall reserve the right to reject any work, material or equipment that does not reasonably meet with the Contract and the Contract Specifications.

No asbestos or PCB materials shall be used in the construction and outfitting of this Carrier.

The vessel shall be declared asbestos free following the verification survey by an ISO 17020 accredited company.

2.2. Material Purchase

The Builder shall procure the major materials and equipment from sources specified on the final "Supplier List," as mutually agreed between Builder and Purchaser. Their quality shall be in accordance with the relevant specifications, and the Builder shall not purchase materials of which the production may be discontinued in the foreseeable future.

As part of the ITT the Purchaser shall provide a list of materials and equipment which will, as a minimum, be included in the Builder's Supplier List. The Builder shall assign Makers/Suppliers for each of the equipments listed in the Purchaser provided Template for Supplier's List. Where available there shall be a minimum of three Makers/Suppliers for each listed equipment. This "Suppliers List' shall be provided by the Bidder as part of their bid submission and be reviewed in conjuction with the Purchaser to ensure the assigned Makers/Suppliers meet the Purchasers criteria as listed below. Makers/Suppliers that do not meet this criteria shall be removed from the Suppliers List.

The Builder shall propose materials from those suppliers who are properly equipped to meet the following requirements:

a) Satisfactory performance records (current experience)
b) Satisfactory operational maintenance records
c) Quality assurance system such as ISO 9001:2015
d) International reputation
e) 24/7 technical support
f) World-wide after sales service network
g) Anticipated spares availability for a minimum of 10 years, and
h) Proven successful application onboard in service LNG Carriers.

The Builder's proposed Suppliers List shall be agreed with the Purchaser prior to award of the Contract.

If the Builder subsequently wishes to add to the agreed list, the Purchaser's written permission shall be obtained before going out for enquiries.

For reasons of standardization, the Builder shall select sources for materials in such a manner that the variety of types is minimized as far as possible. The Builder shall aim at selecting a single Maker for similar types of equipment, such as groups of pumps, electrical motors, instruments, control valves, etc., with due regard to the Maker's capacity and extent of exposure. Design selections shall also attempt both

to restrict the number of different sizes and types of pumps, electrical motors and other equipment, and to duplicate these for the various applications.

The Builder shall ensure that the single supplier concept is utilized across all internal departments whenever possible, i.e., the hull and machinery sections shall draw from a common supplier and utilize standard components, as long as they meet specifications for the particular service. For example, items such as lighting, pressure and temperature transducers, valves, fittings, bolting, pump seals, instrumentation, etc.

Materials for piping systems and equipment shall be selected with a view to minimizing in-service maintenance. Unless stated otherwise in this specification, these shall be in accordance with **Table 2-1**. Equivalents may be proposed, but acceptance shall be subject to the Purchaser approval on a case by case basis.

Table 2-1: Material List – Pipelines and Valves

System	Pipeline	Valves
Cargo System	—SUS 316L on the deck —SUS 304L for cargo lines inside tank	Cast stainless steel CF3M or CF8M as appropriate for type of valve.
Cargo System Bolts & studs/nuts	ASTM A320 B8M Class II / ASTM A 194 8M	
Inert gas lines	SUS 316L Sch.10. GRE shall be used for scrubber water overboard line.	Lined cast steel
Water ballast lines	—GRE, conductive, in cargo areas and ballast tanks, including ‘elephant's feet". Penetration pieces shall be in mild steel (Sch. 80) with anti-abrasive coating glass flake or equivalent coating - 2 coats. (shipbuilder shall specify coat thickness) —Mild steel with polyethylene lining in machinery space.	Lined cast steel with Ni-Al bronze disc (BS EN 1982 gr. CC333G or equivalent)
Hydraulic lines	90/10 Cu-Ni or SUS 316L. 90/10 Cu-Ni in Ballast Tanks	SUS 316 L or Ni-Al bronze BS EN 1982 gr. CC333G or equivalent, as applicable
Firemain/Foam	Polyethylene lined steel.	Copper-tin-lead (BS EN 1982 CC491K/CC492K) with Ni-Al

System	Pipeline	Valves
	90-10 Cu-Ni for pipes 100 mm diameter and below	bronze disc BS EN 1982 gr. CC333G or equivalent
Dry powder exposed parts (external)	SUS 316L	
All sea water systems of continuous or intermittent duty	Polyethylene lined steel. Cu-Ni 90-10 for piping below 100 mm diameter.	Cast steel with rubber lining and Ni-Al bronze disc. Valves of less than 200mm will have a bronze body.
Bilge systems	Seamless mild steel pipes, Sch. 80, hot-dip galvanized after fabrication.	Cast bronze SDNR globe with Ni-Al bronze disc/seat , BS EN 1982 gr. CC333G or equivalent & stainless steel spindle
Domestic water system	Seamless copper ASTM B88 type K or L or PVC ASTM D1785 Type I (Accommodation only).	Heavy gauge bronze
Fresh water Deck Service	Steel pipe, galvanized, Schedule 40	
Pipes less than 25 mm diameter (fresh water, compressed air, lube oil)	Seamless Copper or SUS 316 stainless steel to meet system material requirements, pressure rating, location and fire safety requirements	
Scupper pipes	GRP/GRE (preferred if permitted by Rules) or extra heavy gauge galvanized steel, flanged and with stainless steel bolts and lock nuts.	Heavy gauge bronze
Ballast vents	Steel (Sch. 40) galvanized	
Compressed air (starting)	Steel (Sch. 40) galvanized	Cast or forged steel, stainless steel seats
1. Compressed air (general service) - covered spaces 2. Compressed air exposed piping on deck	1. Steel (Sch. 40) galvanized 2. SUS 316L	Cast iron or bronze, bronze seats
Control air	Copper except for lines for fire control equipment (fire dampers, quick closing valves, etc.)	Bronze
Sounding tubes	Steel (Sch. 80) galvanized	

System	Pipeline	Valves
Fuel oil heating coils	Steel (Sch. 80)	
Fresh water cooling	Steel (Sch. 40) with Polyethylene lining	Cast iron or bronze, bronze seats
Lubricating oil	Mild steel	Cast iron or bronze, bronze seats
Soil drains in accommodation	PVC	Cast iron rubber lined or bronze, bronze seats
Soil drains in engine room	Steel galvanized	Cast iron rubber lined or bronze, bronze seats

NOTE 1: Fire safe valve packing shall be used in cargo, liquid and gas fuel, LO, hydraulic, fire and foam systems, as required by Class.

NOTE 2: The above Table is intended to provide guidance to the Builder to ensure that the major piping system materials the Builder proposes are in line with the Purchaser's expectations.

NOTE 3: Hydraulic multicore pipes and tubes shall be accepted provided that individual pipes within the bundle are themselves sheathed in HDPE with an overall outer sheath and suitably sealed at both ends to prevent water ingress.

NOTE 4: In all weather exposed areas, and where appropriate, all bolts and nuts of which the diameter is less than 22 mm shall be of stainless steel, unless otherwise specifically described in the Specification.

NOTE 5: Bolts and studs for manhole covers shall be of stainless steel.

NOTE 6: For hydraulic lines, flangeless brazed or welded joints shall be preferred in the hull part.

Material for all equipment shall be selected with a view to minimizing in-service maintenance and, unless stated otherwise in this specification, shall be as stated in **Table 2-2**.

The use of different metallic materials in direct contact shall be avoided to prevent galvanic corrosion. When galvanically different materials are in contact specific measures, approved by purchaser, shall be implemented to prevent galvanic corrosion.

GRP materials used in cargo or other designated hazardous areas shall be of the conductive type to prevent the build-up of static electricity.

When machinery package units are employed, every effort shall be made to utilize the material specifications as listed here and any deviation from this shall only be allowed with the Purchaser's specific agreement.

Piping exterior coatings shall be to the same standard as the compartment they are located and compatible with fluid temperatures, as required, unless coating is indicated in the specification.

Outside of stainless steel piping, (except insulated piping) shall be solvent cleaned and coated with one coat of epoxy primer 100 µm and top coating 50 µm as agreed with purchaser. Other stainless steel surfaces such as vent masts and drip trays exposed to the weather shall be blasted as per coating manufacturer's recommendations and coated with one coat of epoxy primer 100 µm and top coating 50 µm as agreed with purchaser. Any not coated areas such as cargo valves, bellows, etc. shall be treated by passivation. Details shall be agreed with purchaser.

All galvanized piping shall be by hot dipped method to a thickness of 55 microns to ASTM A 123 or equal standard proposed by builder. Each section length and number of bends shall be limited and spool pieces shall be flanged to allow galvanized surface inspection and subsequent assembly without hot work. Where galvanized piping is damaged by welding and removal is not possible repair will be done with a method subject to approval by Purchaser.

Table 2-2: Material List—Pump Equipment

Equipment	Materials
Sea water pumps	Casing of copper-tin-lead BS EN 1982 CC491K/CC492K or Bronze(Cu 87, Sn 8%, Zn 4% and Pb 1%) with stainless steel (AISI 316 or ASTM A 276, type XM19) shaft and cast nickel aluminum bronze (BS EN 1982:99 gr. CC333G) impellers or stainless steel (AISI 316/SCS 14) impellers and synthetic resin wear rings. Shaft sleeves shall be chrome molybdenum steel ASTM 276, type XM19 or S-Monel QQ-N-288 d and fitted with cartridge-type ceramic-faced mechanical seals. Pumps with stainless steel impellers shall have casings fitted with Zinc anodes
Fresh water pumps	Casing of nodular cast iron (BS EN 1561 GJL-300 or EN-JL-1050) with stainless steel (AISI 316) shaft and aluminum bronze (BS EN 1982 CC331G) or phosphor bronze (JIS PBC2) impellers and wear rings. Shaft sleeves shall be stainless steel AISI A743, gr. CF20 and fitted with cartridge-type ceramic-faced mechanical seals.
Lubricating and fuel oil pumps	Casing of nodular cast iron (BS EN 1561 GJL-300 or EN-JL-1050) with stainless steel (AISI 316) shaft and aluminum bronze (BS EN 1982, gr. CC331G) or phosphor bronze (JIS PBC2) impellers and wear rings.
O-rings for control switches, valves, air relays or similar	For engine room and other high temperature applications, "O" ring material used shall be able to withstand temperatures above 90°C or operating temperature, whichever is greater.

Preference would be for pumps to be fitted with magnetic couplings.

All instrumentation and lighting equipment on deck and in open areas shall be of a suitable material with high resistance to seawater and ambient atmosphere and will be subject to Purchaser approval. The preferred materials shall be stainless steel 316L or marine bronze alloys.

2.3. Hull Material

The structural members of the Carrier shall be of steel approved by the Classification Society.

Hull material shall also comply with the requirements of the IGC Code.

The quality of steel for the part not specified by the Classification Society shall be to a standard agreed between Builder and Purchaser.

Ambient condition around hull surface for determining material grade of the hull structure shall be the following, to meet USCG requirements, excluding Alaska:

Temperature of air -18°C at wind speed 5 knots (Internal contiguous hull structure in cargo hold area)

+5°C still air (External contiguous hull structure in cargo hold area)

Temperature of sea water 0°C

The main hull structure and tank cover plates shall be mild steel throughout except that consideration may be given to the use of higher tensile steel in limited locations at the deck and bottom plating, and associated longitudinals.

Where the use of higher tensile steel is proposed for the Purchaser's approval, a detailed description shall be submitted, to include clear marking on hull drawings of the quantity and the location of any high tensile steel (yield stress 270 kg/mm^2 and above) and/or thermo-mechanical controlled process (TMCP) steel proposed in the design. This proposal shall include the additional steps the Builder proposes to assure that in-service performance is not adversely affected.

TMCP steel shall be avoided if possible and only used if fully coated. If TMCP steel is used, builder shall confirm that thermoforming processes used shall be controlled so that all steel properties are maintained.

All frames, beams, and stiffeners shall be of rolled section, flat bar or built-up section.

Structural steel, stainless steel or aluminum plates, and stiffeners forming the cargo tank boundary shall be ordered without negative rolling tolerances, i.e., the cargo tank boundary plates shall be controlled so that the average thickness of each steel plate is equal or greater than the nominal thickness. All other steel shall satisfy the Class tolerance requirements.

3. Hull and Structure

3.1. General Construction

3.1.1. General

Hull shall be of double bottom, double hull construction, and in accordance with the cargo containment system licensor's standard arrangement.

The Carrier shall be of all welded construction with, principally, a longitudinal framing system and adequate scarfing where transverse framing is used. Continuity of primary longitudinal structure shall be maintained as far aft and as far forward as practicable, into the main machinery space, the superstructure and the spaces forward of the cargo tanks.

The scantling draft shall be the design draft plus one meter or the design draft plus the increase in draft caused by the filling of the ballast spaces and any cofferdams around one cargo tank, whichever is greater. A cargo specific gravity of 0.50 shall be used in determining the scantlings of the hull and cargo containment system.

The "flat of side" at the ballast draft shall be such that the required number of jetty fenders, at the LNG berths specified in Modules B, are fully in contact with the "flat of side" when the Carrier manifolds are correctly aligned with the jetty loading arms.

Adequate railing reinforcement and manifold grating and deck supports shall be provided in gangway landing areas at all positions, considering mooring on both sides of the Carrier. Cargo manifold handrails to be designed to allow laying down to assist in loading arm positioning. Strengthened gangway landing rails to consider full range of terminals. In addition shipyard to consider required clear landing areas on upper deck for those terminals that use deck landing type gangway, for example redesigning or relocating ballast tank accesses.

Particular attention shall be paid to minimize vibration caused by propeller or machinery excitation.

Passageways shall be fitted on membrane Carriers immediately below the weather deck, between the aft and forward areas on the port and starboard sides, for personnel access forward and for protection of piping and cabling.

Steel bulwarks, of about 1.1 m in height, shall be fitted on the upper deck forward, in way of the accommodation deckhouse and around the bridge wings. Breakwaters shall be fitted where necessary. Effective air deflectors are to be fitted at bridge wings, suitable for 2 m clear viewing height.

Continuous bilge keels, correctly aligned with streamline flow, shall be fitted along the parallel mid-body length amidships, as determined by the model tests stated in **Section 1.6**.

Engine room construction shall have be designed and constructed in such way to avoid use of trusses.

3.1.2. Scantling

Scantling calculations shall be provided to the Purchaser for reference, with both the actual scantling and Class requirement. The Classification Society Global Head Office shall perform final approval and review of the main scantling drawings and structural analysis.

For the purpose of longitudinal strength and tank scantling design, a specific gravity of 0.5 shall be used for the cargo. For the purpose of sloshing calculations, a specific gravity of 0.47 shall be used for cargo.

Forward bottom structure reinforcement shall be added as indicated by the slamming study to the highest pressure and the largest coverage area that shall meet the American Bureau of Shipping (ABS), Lloyd's Register (LR), and Det Norske Veritas (DNV) requirements. Similarly, the bow shall be strengthened to resist bow impact loads, as required by class using methodology that meets class requirements as well as to ensure that loads determined by the slamming study are included.

Structural profiles used on deckheads in water ballast spaces shall be of bulb-plate or flat-bar section for corrosion reasons. Symmetrical sections shall be used throughout the bottom shell and at the side shell below 3 m above the scantling waterline.

The penetration connections of transverse webs and longitudinal stiffeners shall be checked for increased strength including fatigue strength to determine the requirement for collar or lug plates. However, for inner hull structures, collar or lug plates shall be fitted.

Longitudinals shall not terminate at bulkheads. All longitudinal stiffening within the cargo tank area shall be continuous. Plate shall be tapered, using classification society approved method, to within +/- 3 mm. Where it is found necessary to fit brackets at the interconnections between longitudinal and transverse structure, these brackets shall be provided with soft toes and heels. Soft toe, soft heel, and equal leg size brackets shall be used throughout.

No reduction in scantlings shall be permitted due to "corrosion control" allowance from the Classification Society.

Five areas of shell shall be reinforced on each side for a four cargo tank Carrier. All such areas shall be marked for tug pushing (marking to be 8 meters wide and extend from the light WL to 3 m above the scantling WL). The pushing force of each tug is expected to be up to 100 metric tons. For the purposes of determining hull scantlings in way of tug push areas and for relevant structural calculations, the aforementioned tug pushing force shall be assumed to be applied 30 metric tons/m^2 anywhere within the area, as a minimum. Area shall be clearly marked with weld beads. Calculations shall be performed by builder and provided to demonstrate compliance with this requirement.

Hull reinforcement for mooring fender loads shall be designed to withstand up to 20 metric tons/m^2 pressure. Mooring fender strengthening shall be provided to cover the entire Flat of Side length and width. Hull reinforcement calculations shall be performed by builder and provided to purchaser to demonstrate compliance with this requirement.

Foundation seats for main and auxiliary machinery shall be of all welded, rigid construction, designed to minimize vibration and to achieve sufficient fatigue life from the foundation structures.

Minimum steel thickness for ballast tank structural steel shall be 11 mm.

For membrane Carriers, the inner hull plating shall have a thickness of minimum 13 mm, in order to prevent damage to the ballast tank coating from the welding of stud bolts.

Hull structure of the proposed Carrier shall be strengthened to allow for a dry-docking condition with 50% bunkers on board. Adequacy of local structure in the docking condition is to be demonstrated as adequate by a full-ship finite element analysis and 1st principle engineering methods. Hull strength, especially at the forward and aft bottom area, for docking load at repair yard to be checked based on docking block data for standard blocks.

Slamming pressures calculated from the sea-keeping tests as required by **Section 1.6.9** shall be used in determining the minimum scantlings for the stern shell plating and associated internal structure.

A two position docking plan shall be provided by Builder for approval by the Purchaser.

3.1.3. Structural Analysis

Hull scantlings shall be adequate to allow any combination of cargo tank or tanks to be empty with the adjacent tank or tanks still full. Water ballast may be used to limit shear forces and bending moments in this case. For design sea-going conditions, the ballast tanks shall be either completely full or empty.

Structural analysis calculations, using finite element analysis methods, shall be carried out for the Carrier's main hull structure, incorporating requirements of the Classification Society. This shall include a Carrier motion analysis, a sloshing analysis, a 3-D full ship Finite Element Analysis (FEA) that includes the accommodation block, local fine mesh FEAs for critical areas and a fatigue analysis.

The following shall be noted:

a) FEA stress levels shall not exceed 90% of yield or that percentage of yield proposed by the Classification Society, whichever is the more onerous.

b) No rounding of analysis results shall be allowed.

c) Fatigue life for the hull structure, tank structure, and equipment foundations shall be sufficient for 40 years (50% in ballast and 50% loaded).

d) Spectral fatigue analysis shall be performed in accordance with the Classification Society's standard procedure.

e) The criteria for the fatigue analysis shall be the worst case of worldwide trading or the intended routes (as per Modules B) for the hull structure. Membrane containment supporting structure (inner hull and attachments) shall be designed for a factor of safety of 2 (Miner's Law fatigue damage factor = 0.5) to the fatigue life using the worst case of worldwide trading or the intended trade route. The purpose of this enhancement is for improved connection and weld details with respect to structural fatigue life and not for global increase in scantlings. This is in line with fatigue criteria in **Section 6.2.2** (Cargo Containment System Structural Integrity).

f) The Builder is to advise the derived North Atlantic fatigue life (UK South West Approaches to Boston U.S.A., great circle route).

g) The outcome of the structural analysis shall be discussed at a joint meeting (including Purchaser) with the relevant Classification Society at their Global Head Office.

The Builder shall conduct a screening analysis based on industry experience, simplified methods, and discussions with the Purchaser, to identify areas with a high probability of fatigue problems. Identified critical areas shall be analyzed in detail by the builder using fine mesh FEA models employing element thicknesses approximately equal to the local plate thickness. Critical areas shall include but not be limited to:

Membrane:

a) lower & upper knuckles in both hopper and upper chamfer,

b) inner bottom to transverse cofferdam bulkhead,

c) stringer connections in way of cofferdam bulkhead,

d) corner of domes, or any other large deck opening.
e) trunk deck scarfing etc, including doors and windows in the stress path.
f) longitudinal frame connections to transverse web frames and bulkheads for the cargo area and forward deep tanks.
g) Tank supports and anti-movement chocks as required.

The critical areas shall be clearly labeled on all structural drawings.

The structural design methodology shall be included in the tender and full details (including modeling, load conditions, boundary conditions, properties and stress and buckling assessment results) of results of the fatigue and strength analysis shall be given to the Purchaser in electronic form for review and approval as well as for reference at the plan approval stage. Structural Modifications resulting from structural analysis shall be to builder's account.

3.1.4. Workmanship

Welding procedure, including edge preparation, shall be executed in accordance with the Builder's current practice, as approved by Class.

The Builder shall submit a quality assurance plan for the Purchaser's review, detailing the practices to be followed in construction of the Carrier, in order to ensure the required high quality of the structures.

All welding shall be continuous double sided welds, except behind linings in dry spaces in the accommodation, which may be intermittent in accordance with Classification Society's rules.

Automatic and semi-automatic welding shall be executed extensively as far as practicable.

Welding joints between castings and plating shall be made as butt joints. Any heat treatment shall be in accordance with the requirements of the Class.

Loose mill scale and excessive rust shall be removed from the steel surface where welding is applied.

3.1.5. Testing and Correction

Radiographic examination of the main hull welding shall be carried out in accordance with Classification Society and Purchaser's requirement. An additional allowance of 20% of the number of radiographic examinations required by Class shall be available for use of the Purchasers who will advise location on a case by case basis.

All welding of stainless steel inserts on deck and double hull plating shall be fully tested by non-destructive method. The Purchaser may call for an increase of up to 20% in testing over that required by Class.

Where defects are found, the Purchaser may increase the scope of additional testing to determine extent on builder's account

Corrective measures for incorrectly cut holes, the lack of alignment of joints, excessive gaps, etc. shall be applied according to the Builder's practice, approved by Class and Purchaser, and shall be specified in the Quality Plan.

Stress relieving of the hull structure shall not be executed except cast steel parts of the stern frame and rudder, which shall be annealed at the casting shop.

All leak testing of hull structures shall be made using air pressure and soapy water. A full stagger test shall be carried out on all ballast tanks for first of class.

3.2. Tank Configuration and Access

All bunker tanks and consumable tanks shall be located aft, above the engine room double bottom level, and shall not overhang any machinery. However, forward bunker tank(s) may be proposed where such an arrangement improves the Carrier design. A double side shell shall be fitted in way of the bunker tanks

and all engine room tanks that may contain oil or oily water (to include the bilge holding tank). Cofferdams and the engine room double bottom shall be dry spaces. Bunker tanks shall comply with the latest IMO regulations regarding maximum size and separation from side shell.

Each ballast and fuel oil tank shall be provided with a hinged and bolted access hatch of sufficient dimensions to allow removal/replacement passage of any part of the piping within that tank (including flanges, valves, etc.).

Suitable arrangements, approved by Purchaser, shall be provided in ballast tanks and void spaces, in way of the cargo tanks, in order to facilitate adequate close up inspection and maintenance of the structure. Ballast tank purging shall be done initially by ballast change, followed by the use of an inert gas fan with temporary connection to the existing ballast pipes.

An acceptable alternative to such an arrangement (e.g., in order to provide access to the knuckle connections within the membrane Carrier hull) is the creation of inspection walkways utilizing the enlarged webs of side shell longitudinals. In such a case, two rows of inspection walkways with handrail shall be provided in each water ballast tank, i.e., one row at under the deckhead and a second row at the hopper area. Vertical ladders shall also be arranged leading down to the top stringer and the tank bottom at the forward, middle and aft of the inspection walkways.

Handrails shall be fitted to all walkways and openings in horizontal structure in ballast, void, peak and hold spaces. All large openings, and those openings through which a person could fall, and the free edges of stringers shall be protected by guardrails or rungs, as appropriate, to ensure safe access for inspections. All ladders shall have handrails on both sides.

Easily accessible clear openings of 800 mm x 600 mm shall be provided throughout double bottom and side-shell structure and arranged with markings for inspection route purposes.

The main access ladders in the water ballast spaces shall be of the inclined type. Walkways and platforms, where fitted, in the water ballast spaces shall utilize GRP gratings in a steel frame. All fastenings and fixings shall be selected to minimize corrosion in service.

The access arrangements within tanks shall be such as to facilitate easy access for the removal of any injured personnel.

Heated settling and service oil tanks shall not be located adjacent to ballast tanks (as such an arrangement can lead to tank coating failures).

3.3. Corrosion Protection

3.3.1. Coating–General

The following outline specification shall be regarded as being the minimum acceptable standard.

Prior to Contract, the Builder shall submit details of the proposed building program and coating plan, with special attention addressed to the application of ballast tank coatings, and to clarify interface priorities with reference to the coating of inner hull areas and block assembly joints on membrane tank designs.

A corrosion protection system of the highest standards appropriate to the value of this type of Carrier and its anticipated service life shall be provided. The finish colors shall be to the Purchaser's approval. Extended written guarantees holding the shipbuilding yard responsible for repairing coating defects and/or failures shall be provided, where appropriate, in particular:

a) at least 5 years for the anti-fouling coating.
b) at least 10 years for the water ballast tank coating.

Minimum first three years shall be Builder's direct guarantee.

Coating failure criteria shall be defined by the Purchaser at the Contract stage and shall be adhered to by all parties when allocating coating failure and restitution responsibilities.

All hull structural members shall be shot blasted to Grade Sa2.5 of the Swedish Standard SIS 05.59.00 with a surface roughness corresponding to that recommended by the paint manufacturer and immediately

primed. Large size outfitting, such as masts, posts, davits, deck machinery foundations and pipes (with nominal diameter 250 mm and above) shall be blasted and coated as specified in the specifications. However, small size outfitting, including pipes (below nominal diameter 250 mm) which are not practical to apply blasting, shall be cleaned by means of pickling in accordance with the Builder's practice. Plates, profiles and fitments, which are subsequently to be coated, shall be primed with a compatible shop primer immediately after shot blasting. No mill scale covered permanent component or fitment, either welded or bolted, shall be fitted in any part of the Carrier.

All free edges (except rolled sections) of structural members and openings in all salt water tanks, ballast spaces, peak tanks and fresh water tanks shall be either treated by means of edge milling or ground 2mm radius finished smooth to touch.

All other free edges of structural openings, stiffening and outfitting, in areas exposed to weather including deck fittings, shall be ground to a one pass grinding radius after construction.

After fabrication of block sections, welded, burnt, and damaged parts of shop-primed surfaces, including construction joints, shall be prepared as follows:

a) Outside shell, weather decks, water ballast tanks (including peak tanks), fresh water tanks, cofferdams, pipe duct inside, side passages and erection damage shall be blasted to Sa 2.5. The remainder of these areas shall be swept blasted to remove at least 70% of the intact shop-primer.

b) Other areas shall be prepared to ST 3. The remainder of the intact shop-primer shall be treated in accordance with the paint manufacturer's recommendation and the approval of the Purchaser's Representative.

Steel grit or mineral abrasives (but not sand) shall be used for blasting these surfaces, and full moisture control and ventilation facilities shall be applied throughout the whole preparation and painting period.

Salt contamination shall be removed by fresh water high pressure cleaning prior to blasting. A chlorides test shall be carried out and recorded to confirm this removal. Blast material shall also be checked for salt contamination prior to blasting (in line with 'immersion surfaces' salt limitations).

For Chloride testing on all immersion surfaces the chloride density shall be less than 30 mg Cl per m^2 and the average density shall be equal to or less than 20 mg Cl per m^2. On all atmospheric surfaces the chloride density shall be less than 40 mg Cl per m^2 and the average density shall be equal to or less than 30 mg Cl per m^2. The method of testing shall be by using a conductivity test for chloride ions. Sampling points and extent of testing shall be agreed with purchaser.

After blasting, blast grit and dust on the block assembly shall be thoroughly removed before shop primer is applied. Regular assessment of the blasting profiles shall be carried out to ensure that they do not deviate from the paint manufacturer's recommendations. The Purchaser's representative shall have the right to carry out cleanliness inspections and reject non-compliance with the quality plan standards.

Blow holes and other weld defects shall be repaired, not filled, prior to surface preparation and painting. Removal of welding spatter shall be performed prior to any coating being applied. Surfaces to be coated shall be randomly checked by the paint manufacturer's supervisor for the presence of salts and other foreign matters, and coating only applied if test results are within the paint manufacturer's recommendation.

Surface preparation for burn-damaged areas, where already shop primed, shall be blasted to Sa2.5. In particular:

a) On Carriers with membrane containment systems special attention shall be given to potential damage to previously coated areas of the inner hull bulkheads within the water ballast spaces.

b) Where studs or connectors are welded after the block coating is applied, a test program shall prove that the coating is not damaged. Any damaged coating shall be removed by blasting to Sa 2.5 and full system repair carried out.

c) Vacuum blasting shall be used to minimize the potential damage to surrounding areas of coating within the water ballast spaces when re-blasting erection joints and any burn-damaged areas.

Where access is restricted then alternate mechanical surface preparation may be applied provided surface profile of 50 microns minimum is achieved.

On the three above-mentioned areas, the adjacent layers of paint coating edges shall be properly feathered after blasting using disc sanders.

Stripe coat shall be applied, after the application of each full coat, at all weld connections with the exception of smooth automatic butt welds, at all free edges (including slots, scallops, drain holes, etc), edges of structural members, external corners, and areas shielded from spray coverage. Stripe coats shall be applied in all water tanks, voids, cofferdams, passageways, duct keels, ventilation duct interiors, external hull, external superstructure, exposed deck fittings and fixtures and all manual welds.

The dry film thickness (DFT) of the paint shall be checked (with calibration checks performed on smooth steel surfaces in accordance with the manufacturer's recommendations) to ensure that at least 90% of the points measured shall have a thickness greater than or equal to the specified DFT. The remaining 10% shall have a DFT greater than 90% of that specified. None shall be below 90% of the specified DFT. Measuring points shall sample the thickness in five locations for each 10 m^2 in ballast tanks and submerged areas and for each 20m^2 in other spaces shall be made according to the recommendation of SSPC (including SSPC PA 2 "Measurement of Dry Coating Thickness with Magnetic Gages"). Particular attention shall be paid to d.f.t measurements of obscured surfaces (i.e., stripe coated areas). The maximum DFT shall be in accordance with the manufacturer's recommendations and shall be agreed by all parties prior to the commencement of any work. In general, the thickness of each coat will be in accordance with manufacturer's recommendation where multiple coats are specified, thicknesses of each coat shall be equal.

All faying surfaces (surfaces in contact) in ballast tanks and submerged surfaces shall be fully coated prior to 'mating'.

All paints and coatings shall be prepared and applied strictly in accordance with the instructions and under the supervision of the paint supplier. The Purchaser's representatives shall be fully integrated into all production and inspection procedures with the Builder and paint supplier, and shall inspect the quality of surface preparation and coating at all stages of application. Over-coating intervals shall be strictly complied with in the construction schedule.

Principal coating systems shall be applied as per **Section 3.3.2** (only tar free paints shall be used).

Final coating applications of topside areas in **Section 3.3.2** shall be performed with due attention paid to the paint manufacturer's recommended over-coating intervals.

3.3.2. Hull External Coating

Flat of Bottom	Two coats of aluminum (minimum 9% by weight) pigmented pure epoxy to total dry film thickness (DFT) 300 µm, plus a suitable tie-coat of epoxy (or equivalent Paint Manufacturer recommended) 75 µm DFT and a Silicon based fouling release system to provide a minimum 5 years protection against marine growth.
Side Shell and rudder (below loaded waterline)	As for flat of bottom plus one extra coat of fouling release system, to provide 5 years protection against marine growth. To also include area 2 metres above waterline at forward end tapering down to waterline at 10 metres from forward end.
Side Shell and rudder (above loaded waterline)	Two coats of aluminum (minimum 9% by weight) pigmented pure epoxy to total 300 µm DFT, plus a suitable tie-coat of epoxy (or equivalent) and two coats of polyurethane finish coat of 50 µm DFT each coat.

Side shell in fender areas from side tangent line to loaded water line.	Three coats of anti abrasive aluminum (minimum 9% by weight) pigmented pure epoxy to total 450 µm DFT, plus a suitable tie-coat of epoxy (or equivalent) and two coats of polyurethane finish coat of 50 µm DFT each coat.

NOTES:

a) When applying fouling release or anti-fouling, appropriate action to be taken to prevent contamination due to painting in adjacent areas. In general, apart from areas in way of supporting blocks, the anti-fouling system shall only be applied in the building dock after completion of all erection joints and final coating of the topside areas, or at final docking stage.

b) Hull roughness of the underwater area shall not exceed 100 µm by using a purchaser approved hull roughness analyzer/method. Limits for silicon-based coatings shall be confirmed by supplier subject to approval by purchaser.

c) Fresh water cleaning to the full antifouling area shall be carried out at the final docking. Salt testing shall additionally be carried out before any additional antifouling application.

d) The base case will be a proven, latest technology, high quality silicon-based fouling release system applied to large LNG Carriers. The Builder may offer an alternative tin-free SPC anti-fouling system fully described and warranted with cost variants to the base case.

e) Propellers shall be coated with a silicon based foul release coating with three coats as follows: 1st Coat 100µm, 2nd Coat 100µm, 3rd Coat 150µm. This coating system to be designed specifically for propeller use. The Builder may offer an alternative fully described and warranted with cost variants to the base case.

f) The stated aluminum pigmented pure epoxy (minimum 9% by weight) is guidance of the performance expectation rather than chemical composition, equivalent proven alternatives may be acceptable subject to approval by Purchaser and demonstrated satisfactory performance and longevity equal to the 9% by weight aluminum pigmented pure epoxy.

g) Sea chests to be coated with suitable anti-fouling taking into account there is no polishing/cleaning effect.

3.3.3. Superstructure and Deck Coatings

External structure vertical surfaces, bulkheads, etc. *	Minimum two coat of aluminum pigmented pure epoxy and two coats of polyurethane acrylic to a total DFT of 300 µm.
Exposed decks, deck fittings & machinery	Minimum two coat of aluminum pigmented pure epoxy and two coats of pure epoxy finish to a minimum of DFT of 350 µm and two stripe coats. Finish coat on deck in way of walkways and passageways shall be non-slip.

	Monkey Island deck to be painted white to minimize heat ingress to internal bridge space.
Internal Deckhouse	All coatings to be tested and approved in accordance with the SOLAS requirements
NOTE: • To include angled sides from main to trunk deck levels	

3.3.4. Tanks and Other Spaces Coating

Tanks and Other Spaces	**Coating Type**
Water ballast tanks Sequence – full coat, stripe, full coat and stripe	Two full coats of light-colored aluminum (minimum 9% by weight) pigmented pure epoxy to a minimum total DFT 350 µm and two stripe coats. Extra erosion protection (e.g., glass flake) shall be applied beneath suction bells.
Void spaces, peak tanks, under-deck pipe passages & double bottom pipe passage Sequence - full coat, stripe, full coat and stripe	Two full coats of light colored aluminum (minimum 9% by weight) pigmented pure epoxy to minimum total DFT 250 µm and two stripe coats. Particular attention shall be paid to the paint adherence in the horizontal deck trunk void spaces due to the moisture and temperature in this area.
Cargo hold spaces (independent tank designs) Sequence - full coat, stripe, full coat	Two full coats of light colored aluminum (minimum 9% by weight) pigmented pure epoxy to minimum total DFT 250 µm and one stripe coat.
Cargo hold spaces (membrane)	Special Primer 1 coat 50 µm approved by containment system manufacturer.
Machinery spaces, including steering gear room and compressor room Sequence – full coat, stripe, full coat	Two coat fire retardant paint system (fire retardancy to be agreed with purchaser) with white gloss finish (d.f.t 120 µm). Two full coats and one stripe coat of light colored epoxy mastic under engine room floor and on tank tops to total DFT 250 µm.
Store rooms	Two coat fire retardant paints system with white gloss finish (d.f.t 120 µm).
Fuel Oil Tanks	Rust inhibitive oil. Fwd F O tanks coating of under-surface of upper deck down to 1 m below underdeck passage level, as applicable - 1 coat pure epoxy 40 µm. Provision of coating subject to agreement with purchaser. Potential restrictions in presence of zinc primers in fuel tanks for some propulsion options to be discussed with purchaser.

Tanks and Other Spaces	Coating Type
Lubricating oil tanks	Two full coats and one stripe coat of pure epoxy to total DFT 250 µm.
Hydraulic oil tanks	Two full coats and one stripe coat of pure epoxy to total DFT 250 µm.
Distilled water tanks	One coat pure epoxy primer d.f.t 50 µm Two full coats and one stripe coat of pure epoxy to total DFT 250 µm. Coatings manufacturer to confirm suitability for distilled water application.
Domestic fresh water tanks Sequence – full coat, stripe, full coat, stripe	Two full coats and two stripe coats of light color solvent free epoxy of total 300 µm. Solvent based primer or stripe coat may not be applied (to be compatible with health regulations - Coatings manufacturer to confirm suitability - confirmation by third-party (external) institution)
Bilge holding tank(s) Sequence – full coat, stripe, full coat, stripe	Two full coats and two stripe coats of pure epoxy to total DFT 300 µm.
Soot collecting tank(s)	Glass flake coated.
NOTES: a) The staged aluminum pigmented pure epoxy (minimum 9% by weight) is based on the performance expectation rather than a set chemical composition. Proven equivalent alternatives may be proposed for consideration by purchaser. These shall be subject to approval by Purchaser after demonstrated satisfactory performance and longevity equal to the 9% by weight aluminum pigmented pure epoxy.	

3.3.5. Cathodic Protection

External Hull

The external hull shall be protected by a thyristor controlled impressed current system consisting of two independent suitably rated systems, one forward and one aft, with titanium or equivalent anodes. Mean current density shall be 40 mA/m^2 (120 mA/m^2 for rudder outside and 600 mA/m^2 for propeller area).

The system shall be capable of maintaining a current density range of 700 to 1000 mA/m^2 with a voltage range determined by the Manufacturer and dependent on the type of reference cells proposed. The system shall be capable of effective operation at all Carrier speeds and in all water conditions.

Full status and performance monitoring for both systems shall be provided within the ECR and data regarding the performance of the systems shall be fed directly into the IAS. The systems shall be suitable for a five year docking cycle.

Zinc anodes having an expected life of at least 5 years with mean current density of 40 mA/m^2 shall protect sea chests and inlet grids.

Temporary sacrificial aluminum anodes shall be provided for protection of underwater hull, rudder, and propeller during outfitting and installation of the cargo containment system.

Inner Hull

The ballast tanks shall be protected by zinc anodes rated for a 10 year life at a mean current density of 5 mA/m^2 and ballast residence time of 50%. Additional "pitguard" type anodes shall be installed to protect those areas close to ballast suctions. All anodes shall be located so as to afford maximum protection. Anodes shall be fixed by means of bolted clamps, with pointed stainless steel screws to ensure good electrical contact with the exposed steel.

3.4. Anchoring and Mooring Equipment

All mooring equipment and fittings shall be designed, constructed, and fitted in accordance with ISO standards and to OCIMF recommendations for LNG Carriers. The mooring system shall incorporate high modulus polyethylene mooring lines and universal roller fairleads shall be installed in line with main mooring winch drums. Closed chock fairleads shall be installed in line with main winch warping heads and others. Equipment and arrangements will comply with MEG4.

Two high holding power stockless anchors shall be provided to Classification Society requirements (no on board spare is to be carried). Special quality steel chain cables shall be made up in interchangeable lengths of 27.5 m, each exclusively composed of identical stud links with Kenter joining shackles. All anchors and cables shall be one rank above the grade given by the calculated equipment number. A swivel piece with pennant shall be fitted by Kenter shackle at the outboard end of each anchor chain to allow for shifting of the outboard chain link in drydock.

Mooring winches and windlasses shall be self-contained electro-hydraulic or low-pressure (max. 70 kgf/cm^2) hydraulic type with double split drums, with rendering but without self-tensioning capability. They shall be arranged for efficient manning during mooring operations, with both local and remote control from suitable centralized locations at the Carrier's side. Gear cases containing lubricating oil shall be of the closed type and split horizontally to facilitate maintenance. Split drum arrangement and capacity shall accommodate synthetic ropes. To avoid chafing in the transfer section between the storage drum and the split drum the profile of the fairing edge shall be beaded and have an edge with radius 40 to 50 mm or as per OCIMF recommendations.

Each windlass shall have an independent hydraulic power pack unit with provisions for interconnection and be capable of lifting the anchor and four lengths of cable at an average speed of not less than 12 m /min using one power pack unit only. A cable counter and fail-safe payout speed limiting devices shall be fitted to the Cable lifter, with hydraulically operated brakes able to be remotely controlled from the Carrier's side. For the first Carrier in the series a scale model of the anchor deployment and stowage system shall be built to demonstrate anchor storage and lead of chain.

Brake drums for windlass and winches shall be of stainless steel or stainless steel lined, with brake linings of approved and recognized make. All winch brakes shall have the facility to test their holding power by the connection of portable hydraulic test equipment. The deck shall be suitably reinforced in the area where the test equipment is placed. The safe working load of all mooring equipment and fittings, with appropriate safety factors, shall be based upon the minimum breaking load of the mooring ropes and shall be marked on all items of equipment by means of bead welding.

The motive power system shall be arranged so that any of the mooring winches can be operated either independently from each other or simultaneously, even when operating at different speeds or pulls. Separate hydraulic power packs, with their associated hydraulic oil storage tanks, shall be fitted at the forward and aft ends of the Carrier. The hydraulic oil pumps and electric motors for forward and aft power packs shall be interchangeable (identical pumps and motors).

Savealls, to contain any oil leakage, shall be fitted around mooring winches, windlass positions and all other hydraulic equipment above and below deck.

Each system shall be fitted with a holding tank with sufficient size to retain 110% of the working oil capacity of the system. There shall be an emergency top up tank, 15% of working oil capacity of system, which shall be able to gravity fill the working system.

Emergency stops for each power pack shall be located at the remote control stations forward and aft and be clearly marked.

ISO standards 4406:2017 and 12669:2017 shall be followed when commissioning the hydraulic system(s), particularly with regard to electronic particle counting. Cleanliness shall be to ISO 4406:2017 or the Maker's standard, whichever is the more onerous. Electronic particle filtration shall be used during commissioning. Suitable connections shall be provided to allow for cleaning the hydraulic system without removal of sections of pipeline. Power packs and other components not included in the flushing process shall be flushed at the manufacturer's works to the standard specified, and then shall be properly protected during transportation and installation. Initial and subsequent filling of all hydraulic systems shall be accomplished using permanently installed filters.

Full calculations of the mooring arrangement for each of the berths listed in Modules B shall be submitted for Purchaser approval. The mooring arrangement shall generally consist of at least three head lines, three stern lines, four spring lines and eight breast lines per side, in accordance with the latest OCIMF Mooring Equipment Guidelines. Mooring arrangements should not allow for any mooring lines to cross. (See Modules B for any special requirements.) A Ship/Shore interface plan shall be provided to indicate all interface points of the Carrier and dock as well as Carrier and tug covering all operations. The plan shall include type, number, size, and rating of all equipment and interface points on the Carrier. Bow mooring arrangements shall provide for symmetrical mooring bollards and chocks to allow tug line to be made up through chocks fwd. on port, center, or starboard.

A spare mooring line shall be provided both forward and aft. Both shall be stowed on power-assisted drums below deck.

The mooring arrangement in this instance shall be as stated above using high-modulus polyethylene fiber ropes with a diameter of approximately 44 or 48 mm and a length of 275m. Rated minimum strength shall be 138 or 165 metric tons. The Carrier size and the number of lines shall determine required rope diameters and corresponding rated strengths. Reference shall be made to the OCIMF publication MEG4 on the use of high-modulus synthetic fiber ropes as mooring lines on large tankers. One nylon tail rope 11 m with MBL at least 140% of mooring rope MBL shall be fitted on each mooring rope with stainless steel shackle.

Provision shall be made for accepting 4 shore ropes (2 forward and 2 aft) at both port and starboard shoulders and quarters.

Special provision shall be made for allowing the mooring of two Carriers together in case of ship-to-ship transfer of cargo. Drawings and diagrams which demonstrate the appropriate location of mooring fittings for STS Transfer operations shall be provided for purchaser's approval. These drawings/diagrams shall indicate the arrangement of the Carrier and the lightering ship performing emergency STS transfer operations and the mooring arrangement used. These drawings are also to be used to confirm compliance with **Section 9**, "Ship-to-Ship Transfer." Various sizes of lightering Carrier shall be considered to demonstrate applicability.

To assist the safe handling of the Carrier in port and the securing of tug lines, approximately 16 to 20 sunken bits (in total, depending on Carrier size, each 150 ton SWL capacity) shall be fitted on the side shell at suitable heights and positions for loaded and ballast conditions and to be compatible with loading and offloading terminals as specified in Module B, and shall be able to handle 80 mm towing hawser.

The Carrier shall also be fitted with 200 ton rated bits and fairleads or in accordance with OCIMF publication MEG4, for bow and stern escort tug handling. Bollard arrangement shall be such to facilitate minimum friction of the messenger line around the bollards as the line is heaved-up.

See **Section 5.10** for fire wires and emergency towing requirements.

3.5. Hull Outfit

3.5.1. Walkways and Access

Safe access forward shall be provided in compliance with SOLAS Chapter II-I, Part A-1, Regulation 3-3.

All exposed piping, fittings and controls shall be of corrosion resistant material.

Two aluminum accommodation ladders of self-stowing, fixed rail type with lower platform, shall be fitted within the parallel mid-body, leading aft. The handling mechanism shall be electric or pneumatic powered (to Class requirements) and capable of one-man operation. The length of each ladder shall be sufficient to reach one meter above the lightest ballast waterline at a maximum inclination angle of 55 degrees.

Where fitted, all air driven machines on deck shall be connected to the deck air system by means of standardized hoses of the same diameter and quick connectors.

Recessed side shell cleats, shall be provided to secure accommodation ladders at various heights at ballast, loaded and light ship conditions.

Masts and posts, for navigation equipment and lights, deck floodlights and communications equipment, shall be self-supporting and constructed of steel, without stays.

Suitable access for operation and maintenance shall be provided to all pipe and cable runs, to all valves, to all ventilation screens & dampers and to wheelhouse windows. Access platforms around all deck equipment and working areas shall be, as far as practicable, of GRP construction. Exposed vertical ladders (only to be used where inclined ladders with handrails are impractical) shall have safety hoops or, if over 4 m high, protective cages. Stainless steel wire for use with fall arrest equipment shall be provided in way of all vertical ladders more than 2 m high, and in way of accommodation ladders. All outfitting on outside decks shall be welded onto reinforced plates.

Handrails (1.06 m high and with 2 intermediate rails) and stanchions shall be provided inboard of the gunwale radius and outboard trunk deck edges to an approved design. External storm rails shall be fitted on the outside of all deckhouses.

Walkways, platforms, and steps for ladders on the weather decks shall be grating type with non-slip surfaces. As far as practicable and acceptable to Class, the gratings shall be of GRP, held in place by SUS 316 stainless steel fastenings, with steel frame construction. The supports shall be of box girder or tube type, to facilitate maintenance. Mild steel, welded assemblies shall be hot dip galvanized after completion of fabrication. Walkways and Platforms shall be designed for ice loads.

Fittings shall be made of corrosion resistant materials, designed for long life. External nuts and bolts and those used in ballast tanks shall be of SUS 316 stainless steel or non-ferrous material, dependent on the application. Toggles and hinges for doors and hatches shall be of stainless steel or brass.

At least 2 hatches or manholes shall be fitted for each tank (ballast, lubricating oil, or fuel), void spaces, cofferdam, double bottom passage, trunk deck passage, steering gear room, and other compartments.

Access arrangements in all tanks, void spaces, and cofferdams shall be such as to facilitate easy removal of injured personnel (complete with breathing apparatus) from the tanks. For this purpose a small portable davit shall be provided and web frame numbers shall be marked by paint at all access routes in passageways, ballast tanks, and voids, etc. in the double hull.

Adequately sized maintenance hatches shall be provided for the cargo machinery room, cargo electrical room, engine room and other machinery spaces. All large hatch covers shall be hinged and fitted with counter balance arrangements (not spring type).

Machinery and motor rooms shall be fitted with lifting eyes to facilitate the overhaul and moving of all heavy equipment and spare parts. Special attention shall be given to the handling of heavy electric motors located in the engine room. All lifting eyes shall be tested and marked with capacity (using bead weld) and shall be fitted above equipment items in excess of 20 kg in weight.

External hull markings shall be provided as follows:

a) Carrier's name, port of registry, IMO number, draft and freeboard marks, and funnel emblem, shall be marked with welding bead and painted.

b) Tank and compartment names, tug push marks and related hull reinforced area boundary, bulbous bow symbols, manifold location, winching area marks, paint separation marks, etc on the hull shall be bead welded and painted. The LNG side mark shall be bead welded but shall not be painted other than defined in **Section 3.3.2.**

c) To meet statutory requirements.

d) Frame numbers shall be bead welded and painted on deck. Two pilot boarding doors, one port and

3.5.2. Bilge System (Hull)

Bilge eductors and high level alarms for each bilge well shall be installed to service the following spaces (where applicable to design):

a) Bosun's store

b) Forward pump room

c) Passageway P/S (2 or more sets each side - forward and aft)

d) Bottom pipe duct (forward and aft)

e) Cargo tank hold spaces, if applicable

f) Cargo space cofferdams

g) Emergency fire pump space

h) Chain locker

A flooding alarm system, with alarms for each bilge well shall be installed in those spaces with water draining facilities, as below.

Means shall be provided for draining of:

a) the steering gear room and rope storage areas

b) the cargo compressor and cargo machinery room, and

c) the trunk deck void spaces (where applicable)

Valves for bilge suctions in pipe duct in double bottom space and for cargo space cofferdams shall be remotely hydraulically operated from the CCR.

3.5.3. Steam and Exhaust Piping (Hull)

Where fitted, this system shall be supplied from the engine room, and shall be used for fuel tank heating, cargo heaters, vaporizers, steam tracing, cofferdam heating and other applicable steam heated services.

3.5.4. Deck Drain and Scupper (Hull)

Drain from upper deck shall be discharged overboard through scuppers led to side shell. Scuppers shall not interfere with fender deployment and shall be flush with hull in areas where fender deployment is expected. All overboard scuppers shall be fitted with a stainless steel insert to accommodate expandable spindle operated scupper plugs. Deck stores not connected to a scupper shall be fitted with drain and brass drain plug. Details shall be agreed with purchaser.

Deck drains shall be provided in all wet spaces in the accommodation, e.g., galley, pantry, laundry, private shower/toilet, etc. Waste (grey water) from living quarters (except hospital) shall be collected in scupper main and led overboard through storm valve, and shall not pass over/through spaces used for food preparation or electrical equipment.

Deckhouse drains shall be arranged to drain efficiently to decks below through pipes. All scupper, condensate, and grey water drains from the accommodation spaces shall be fitted with effective and easily accessible water seals to prevent spread of smells, etc.

Galley and provision store drains shall have separate overboard discharges. Grease trap shall be fitted to galley drain.

A drain sump with grating over and scupper pipe drain shall be fitted in front of each wheelhouse entrance from exterior, doors in galley and dry provision space.

The garbage room shall be fitted with a drainpipe with effective and easily accessible water seal.

3.5.5. Deck Inventory

List of 'Deck' related equipment to include, but not be limited to, nautical instruments, signal flags, tools, etc., shall be submitted by the Builder with the Carrier specification.

3.6. Deck Cranes

Two hydraulic slewing and luffing cranes of sufficient capacities (minimum 10 metric tons) shall be fitted in way of the amidships manifolds. Each crane shall be able to achieve its safe working load when plumbing any point within the area of the manifold and, as a minimum, up to 3 meters from the Carrier's side, over the full length of the cargo, bunkering, and service manifolds. They shall be able to lift and safely handle Suez Canal boats, and land them on a designated area adjacent to the manifold port and starboard. They shall also be rated to allow for handling equipment required for Emergency Ship to Ship transfer.

Two electro-hydraulic pedestal cranes of sufficient capacities, with one-man control and hydraulic operation, shall be fitted aft. They shall be suitable for handling the largest spare part component and shall be able to plumb the provision stores hatch, the machinery maintenance hatches, and a point 4 meters beyond the line of the Carrier's parallel body. Flush-mounted container lashing sockets shall be provided at the crane landing areas at aft upper deck port and starboard within the crane's working radius to allow lashing of storage containers. Container number and location shall be as agreed with purchaser.

Facility to be available and clear access routes provided for easy transport of provisions, stores, and spare parts loaded amidships (either side port or starboard) to the engine room and storerooms aft, including on pallets.

At least one of the aft cranes shall be able to plumb the poop deck, and the access hatch to the Steering Flat.

The cranes shall be located with due regard to the necessity to handle stores from a barge (or, if facilities are available), directly from stores platforms at each of the port berths listed in Modules B, if such arrangements are provided. Additional cranes of at least 3-ton capacity shall be installed where necessary.

Suitable means that include a hydraulic crane minimum 5-ton capacity or to accommodate the heaviest equipment, whichever is greater, shall be provided to lift all components requiring maintenance located within the cargo machinery room and electrical room and to enable these items to be transferred onto or off the Carrier to a point at least 4 m clear of the Carrier side.

The cranes shall be fitted with hydraulic luffing, stainless steel anti-twist wires and shall be capable of "inching" control. Crane hydraulic systems shall be completely independent from each other and any other onboard hydraulic system.

Sufficient portable davits shall also be provided for easy storing and handling of equipment on board, such as emergency cargo pumps and cargo pumps, manifold blanks and reducers, manholes injured persons lifting and the Suez Canal searchlight. The locations shall include, but not be limited to, the Bosun's store, steering gear room and cargo tank domes. A portable davit shall be provided for the lifting of windlass and winch motors, where applicable. Arrangements shall be made for hose handling, lifting

equipment, saddles etc. to facilitate fueling HFO and MGO as well as lube oil receipt at stations located at the house front port and starboard. The Suez Canal searchlight to be provided with a permanent structure.

All lifting and mechanical handling equipment shall be load tested at 1.5 times the safe working load and furnished with a test certificate provided by the Classification Society.

3.7. Requirements for Low Maintenance

Hull outfit design and selection of materials shall be such as to require minimum maintenance. This can be achieved by allowing adequate clearance between and beneath fittings to permit coating maintenance of all surfaces, use of suitable materials to avoid corrosion of fasteners, pipe clamps, supports, and brackets.

So far as possible, pipelines, cables and fittings shall be installed below the upper deck or trunk deck, in under-deck pipe passages, inside deckhouses and similar protected spaces in order to minimize exposed steelwork. This requirement shall include, but not limited to:

a) Electric cables
b) Pneumatic pipe work
c) Fire lines
d) Hydraulic pipelines
e) Nitrogen distribution pipe work
f) Signal lines (except those carrying gas under high pressure)
g) Sampling lines
h) Control and instrumentation
i) Dry-powder houses and similar structures

The underside of the bridge wings shall be "boxed in" and provided with suitable drainage facilities.Cables to bridge wing equipment shall be routed through the resulting void as far as practical. Recessed manhole covers will be fitted on bridge wings to allow access to these void spaces. Where possible, provision of open structures having similar access problems shall be avoided.

All foundations for external auxiliary and ancillary equipment should be enclosed. All pipe supports and cable racks should be closed section pipe/tube or solid round bar. In particular areas of high maintenance where access is limited or at height.

All sounding points on the vessel should incorporate a striking plate beneath the sounding pipe for any wet or dry tank.

3.8. Rudder(s)

Streamlined, semi-balanced, or high lift section rudder(s) shall be designed based on the speed at MCR in the summer draft condition, and shall have a working angle of 35 degrees either side of the centerline. The effective rudder area shall be verified from simulation and extensive model tests in order to ensure that the Purchaser maneuvering criteria is met.

Rudder(s) shall be coated internally by volatile corrosion inhibitor.

The rudderstock(s) shall be one piece of forged steel, with a shrunk-on welded stainless steel sleeve in way of the carrier bearing. The diameter of the stock(s) shall be increased in way of the carrier. Rudder pintles, of forged steel, bearing sleeves shall be of stainless steel and the bushes shall be made of bronze or an Purchaser approved synthetic material, with easy access for inspection.

The location of the rudder(s) shall allow it (them) to be readily removed from the stock. In the case of a twin screw, twin rudder Carrier, the rudders' transverse location and working angle will be determined during the model tests.

The rudders shall have sufficient bottom-clearance for safe dry-docking, but shall not be less than the propellers projection.

Any change of thickness of the rudder shell shall occur on the inside to keep the surface smooth. The rudder surface shall be smooth and fair throughout with no exposed recesses, grooves, or projections that might result in localized turbulence and erosion. The entire rudder shall be made watertight by welding.

Jump stoppers shall be installed to prevent the rudder from undue lifting, and to prevent damage to the steering gear.

Physical rudder stops shall be installed port and starboard to safeguard the steering gears and rudderstocks. The stops and their supporting structure shall be stronger than the rudderstocks.

Stainless steel drain plugs shall be fitted, one (1) at top and one (1) at bottom. Sufficient ventilation ports shall be installed to allow draining and testing during dry-docking.

Rudder shall be fabricated from rolled steel plate and weldable cast steel for securing the pintle and rudder foot. Rudderstock(s) shall be of the straight type.

Pintle and both ends of the rudderstock shall be fitted with key-less conical couplings with oil injection system and hydraulic nuts. The nuts shall have saw-type threads, in accordance with DIN 2781. Minimum contact area between key-less fittings shall be 80%. The tapered surface of the pintle boss shall be sealed at both ends.

Stock and pintle shall be pushed-up at least twice in the workshop, to verify the difference in total distances between two successive push-ups is less than 5%. If the difference in total push-up distance is more than 5% between successive push-ups the push-up process shall be repeated until the difference is 5%, or less.

Cast steel carriers with bronze (or Purchaser approved synthetic material) bush and bronze disc, shall be provided.

Steel seat shall be used for the installation of the rudder carrier in the steering gear flat and the rudder trunk is to be constructed as a void space. All exposed areas of the rudderstock and pintles shall be fitted with stainless steel sleeves.

The Purchaser shall approve rudder carrier bearing design and lubrication arrangement.

4. Accommodation

4.1. General

Accommodation, with necessary facilities for both male and female crew, domestic systems, heating, ventilation, air conditioning systems, and stores shall be provided for 45 persons, including Suez Canal workers, according to the Purchaser’s standard and in accordance with the requirements of the relevant Rules and Regulations.

The general block layout shall reflect modern day concerns with security, by locating all the public spaces required for access during in port periods on one level, with access to that level restricted by design. Careful attention shall be given to keeping the accommodation and enclosed working areas (machinery rooms, etc.) secure.

Layout and security aspects of the accommodation arrangement shall be designed in accordance with the guidelines in the ISPS Code, and in conjunction with the Purchaser. See **Section 5.12** for details concerning the ship security systems and security of the accommodation.

An approved and reliable system shall be used to prevent unauthorized entry into the accommodation, with emergency exits located at the end of all internal corridors to allow evacuation of the accommodation block in case of fire. The Suez Canal Workers' cabin shall be located outside the accommodation citadel area.

Clear height in the accommodation shall be 2300 mm, except in areas such as the gymnasium where the clear height above the tread mill, etc., shall be a minimum 2400 mm. All fittings in accommodation ceilings, such as light fittings, ventilation fittings, etc., shall be flush mounted. Living spaces shall consist of, but not necessarily be limited to, the following:

a) 2 Senior Officer cabins for Master and Chief Engineer with bedroom, dayroom, lobby, and bath with shower/WC.
b) 2 Purchaser cabins with bedroom, dayroom, lobby, and bath/WC.
c) 2 Senior Officer cabins with bedroom, dayroom, lobby, and bath/WC.
d) 10 Junior Officer cabins with combined dayroom/bedroom and shower/WC.
e) 2 spare Junior Officer cabins with combined dayroom/bedroom and shower/WC.
f) 1 Pilot cabin with combined dayroom/bedroom and shower/WC (Junior Officer class).
g) 16 Crew cabins with shower/WC.
h) 2 Suez Canal worker cabins each with four berths and shower/WC.
i) General office.
j) Conference room.
k) Training room.
l) Officers' mess room and pantry.
m) Crew's mess room and pantry.
n) Officers' duty mess room.
o) Crew's duty mess room.
p) Officers' recreation room.
q) Officers' TV room.
r) Crew's recreation room.
s) Crew's TV room.
t) Games room.
u) Gymnasium.
v) Hospital room with separate bathroom.
w) Treatment and dispensary room.
x) Prayer room

In general all living spaces shall be fully carpeted. All living space and W.C. doors shall be fitted with an emergency escape hatch incorporating adjustable ventilation louvers.

A dedicated smokeroom with separate ventilation/air conditioning shall be provided.

Soft furnishings (carpet, chair and sofa cover, mattresses and curtains) shall be fire retardant (low flame spread characteristics where appropriate) and with low toxic smoke emissions, to meet European Union standards with certificates for the Purchaser's retention. In addition, soft furnishings shall also be in accordance with Annex 1, Parts 2, 7, 8, & 9 of the IMO Fire Test Procedures Code.

Material designs and colors shall be approved by the Purchaser. All carpets shall be a minimum of 80% coated with scotchguard or similar and the designs approved by the Purchaser. All fabrics for curtains, sofa coverings, etc shall be of natural materials, the Purchaser shall approve designs and colors.

Functional spaces shall consist of, but not necessarily be limited to, the following:

a) Common W.C. on each accommodation level.

b) External W.C. on upper deck.
c) Hospital bath room.
d) Officers' laundry with drying room.
e) Crew's laundry with drying room.
f) Ship's laundry with drying room.
g) Officers' changing room.
h) Crew's changing room.
i) Galley.
j) Officers' night pantry.
k) Wheelhouse with chart and radio spaces.
l) Cargo control room (location to take into account security issues).
m) Electric equipment room.
n) Cargo switchboard room.
o) Fire control station (location to take into account security issues).
p) Hydraulic pump unit room.
q) Air handling unit room.
r) Emergency generator and switchboard room.
s) Incinerator room.
t) Fixed fire-fighting equipment room(s).
u) Dry provision and soft drink store.
v) Refrigerated provision stores.
w) Bonded store.
x) Safety equipment lockers.
y) Gas bottle store (O_2 and acetylene).
z) Paint store of sufficient size to store 300 x 25 liter tins of paint with emergency shower (engine casing side).
aa) Oil and grease store (engine casing side).
bb) Chemical store with save-all and emergency shower (engine casing side).
cc) Waste management room (to allow segregation, storage, and processing of waste).
dd) Deck store.
ee) Clean gear locker.
ff) Deck workshop.
gg) Linen lockers – both clean and dirty.
hh) Emergency equipment room.
ii) Other sundry store and lockers.

The large central office space, combining several desks, computer desks, filing cabinets and cupboards, and including drawing stowage facility and a drawing table, shall serve as the combined centralized office and be arranged next to the cargo control room. Specific dedicated areas within this office (complete with desks) shall be allocated for the Captain and Chief Engineer. A conference room/administration office shall be arranged adjacent to this office space, as well as a technical reference library.

The forward facing windows and all the accommodation side windows, shall be fitted with A-60 non-gel type glass. For wheelhouse windows detail see **Section 37.10**.

All glass used within the accommodation shall be of the hardened safety type. All windows shall have a clear size of 500 mm by 800 mm, except in the wheelhouse where the clear area shall be a minimum of 2000 mm by 1000 mm.

The hospital shall have two single gimballed beds and a bathtub/shower/WC, and shall have direct access to the outside deck. A dispensary/medical treatment room shall be located in an adjacent space.

Both dispensary and hospital shall be provided with telephones.

The fully equipped stainless steel lined galley shall be provided including as a minimum: cooking range, baker's oven, salamander grill, griddle, rice cooker, two twin fry-fry, separate hot and cold press for officers and crew and equipment suitable for all nationalities. Provision room wall panels shall likewise be stainless steel and designed to achieve good standards of hygiene.

If the provisions store and cold rooms are not on the same level as the galley then a 'dumb waiter' stores elevator is to be fitted to carry provisions etc from the stores to the galley.

Internal stairwell(s) shall be fitted with twin stainless steel handrails.

The fully equipped gymnasium shall be large enough to accommodate a table tennis table, as well as the fitness equipment.

The sanitary system shall use fresh water.

Drinking water fountains shall be provided on each deck of the accommodation and at three levels in the engine room. All taps (faucets) shall be the single lever type and all showers shall have thermostatic mixing valves.

The officers' laundry and crews' laundry shall each be equipped with 2 sets of washing machines, tumble dryers, irons, and ironing boards. A separate ship's laundry shall be equipped with sufficient industrial standard washing, drying and ironing machines to handle all the ship's linens.

Washing machines and tumble dryers to be separate units, i.e. not combined washer/dryers.

To minimize the transmission of vibration, the machinery casing shall not be integrated into the accommodation deckhouse.

A cargo control room (CCR) shall be provided within the accommodation house at a suitable level to give simple and direct access to the cargo tanks and deck. Its location shall also take into account security and access concerns (as provided for in the ISPS Code). The control room shall be provided with large windows overlooking the main deck and cargo areas. If practicable, the fire control station shall be located next to the CCR.

There shall be at least two means of access to each control room. For the machinery control room at least one means of access should be provided that does not pass through the open engine room. Large viewing windows should be provided

Working and living spaces within the accommodation shall be kept separate as far as is practicable.

Hinged access panels shall be provided for access to all the overhead spaces in the accommodation, including public spaces and passageways.

File cabinets shall be made of wood. Top surfaces of desks, tables, chest of drawers, sideboards, etc., shall be covered with light colored, wear resistant, laminated hard plastic. Beds, desks, tables, chest of drawers, sideboards, etc. shall have hardwood edges.

The mess rooms, galley, provisions stores, and garbage handling area shall, as far as practicable, be arranged on the same deck level. An electrically powered garbage compactor shall be installed in a waste management room and sized for the number of persons and the trade route used. The waste management room shall be located in the same vicinity as the galley/storerooms and adjacent to the incinerator room. Galley and serving areas shall be arranged to save transportation of food between spaces (e.g., with serving hatches).

A 6-person elevator shall be fitted to serve all levels from the deck below the wheelhouse down to the lowest practicable level in the engine room or as agreed with the purchaser. Elevator controls shall be programmable and provided with features to take into lines the security issues regarding restricted access to accommodation levels and machinery spaces.

Deck coverings in control rooms and wheelhouse shall be oil resistant stud-type non-slip rubber tiles.

All sanitary, catering and provision spaces shall have floor coverings of self-levelling epoxy.

An adequately sized library shall be arranged adjacent to the recreation areas, suitable for the storage of entertainment material.

4.2. Heating, Ventilation and Air Conditioning

All living, public, sanitary, working spaces, galley, pantries, changing room, dry provision stores, wheelhouse, electrical equipment rooms, switchboard room(s), control rooms, and other spaces in the accommodation shall be air conditioned by main system.

Dedicated extraction ventilation fans shall be provided, but not be limited to, the following:

a) Public living spaces
b) Toilets
c) Galley & laundries
d) Lockers & equipment rooms
e) Storage spaces
f) Function rooms

The main accommodation ventilation system shall be designed to operate at constant pressure, irrespective of the operation of individual ventilation controls. Special attention shall be paid to minimizing noise from ventilation outlets. CO_2 monitoring shall be provided for the re-circulated air circuit.

The air conditioning system shall consist of two cross-connected central units, each of 100% capacity, and refrigeration plant incorporating two rotary screw compressors, each of 100% capacity. The system shall be capable of maintaining a temperature of 27°C dry bulb at an average relative humidity of 50%, when the outside conditions are 45°C dry bulb and 80% relative humidity. The fresh air intake shall be adjustable up to 50%. Suitable filtration systems shall be provided with easy access for cleaning or replacement.

The heating system shall be steam and/or electric, and fitted with a humidifier, and shall be capable of maintaining a temperature of 22°C and 50% relative humidity, with an outside air temperature of -10°C and a seawater temperature of 5°C.

Any humidifiers fitted to air handling units must be guided by UK MCA MGN 38 to avoid the risk of legionella bacteria forming in the units. Water spray type humidifiers shall not be used; instead steam type shall be fitted.

Fail-safe automatic dampers shall be fitted to each ventilation fan, which shall close when the fan stops. Remote control for all dampers shall be located adjacent to the fire smothering controls at the fire control station and shall be of the self-contained pneumatic type. Bearings and bushes shall be provided with easily accessible grease fittings.

The central duct shall have dampers fitted at all levels, complete with automatic means of closure in the event of fire.

All intake and exhaust louvers shall be positioned in easily accessible locations, constructed of stainless steel or GRP (or a similar non-metallic material), and shall be easily accessible for cleaning and replacement. All fresh air inlets shall be fitted with efficient water de-misters, to minimize the ingress of

driven water into the ductwork. The fresh air intakes shall be provided with closing devices which are capable of being operated from inside the space.

All ventilators in the accommodation and the storeroom spaces throughout the Carrier shall have stainless steel mosquito screens fitted.

All fresh air inlets shall be provided with sand filters. Metallic construction filters shall be stainless steel.

An independent self-contained air conditioning system shall be provided as a back up to the main system in each of the following areas in the accommodation to maintain the temperature and humidity conditions as specified above:

a) Main electric equipment rooms
b) Cargo control room
c) Cargo Switchboard rooms
d) Wheelhouse (including electrical/navigation equipment rooms)
e) IAS I/O Cabinet Room

These units are not to form part of the capacity required for the normal cooling of the spaces

Independent self-contained package type air conditioning systems shall be provided in each of the following areas:

a) E. R. Switchboard rooms - two (2) units
b) Engine control room - two (2) units

Workshops shall have single self-contained air conditioning systems.

All self-contained air conditioning units shall be fresh water cooled type except the wheelhouse that may be air cooled type.

4.3. Refrigerated Stores and Other Stores

The following cold rooms shall be provided, capable of holding 4 months provisions for a full complement of crew:

a) Meat rooms	-25°C	30 m^3
b) Deep freeze room	-25°C	20 m^3
c) Vegetable room	+2°C	40 m^3
d) Dairy room	+2°C	20 m^3
e) Handling space	+4°C	10 m^3
f) Dry Provisions	+18C	120 m^3

The temperatures shall be automatically maintained and recorded, using one rotary screw compressor running not more than 16 hours per day in tropical conditions, with one additional identical compressor as a stand-by. A fresh water cooling temperature of +37°C shall be used when sizing equipment. High temperature alarms for the cold stores shall be incorporated in the IAS (see **Section 26**).

One cooling fan unit externally mounted with an electric defrosting system shall be fitted for each cold room. The temperature difference between the inlet and outlet shall be no greater than 6°C. The temperature in the dry provision store shall not exceed +18°C.

Cold rooms, dry provision, and bonded stores shall be arranged with easy access from the galley and the loading area, on the same level as the latter.

Condensate drains shall be provided in each space, independent from the ship's sanitary drain system. All drains from the evaporator drip trays in the meat and deep freeze rooms shall be provided with electric resistance heating tracer lines to prevent freezing. All drains, cooling piping and fittings shall be insulated so as to minimize ice formation. Easy access shall be provided for cleaning.

A hot potable water connection and ozone generator shall be provided in the vegetable room.

Two central general stores (to be designated the Spare Gear Store and General Store), one of which shall be air-conditioned, shall be arranged at the upper levels of the engine room, with suitable shelving and good lockable access from deck, for loading stores and spares, with good lockable access to the engine room(s), motor rooms, etc. for transporting heavy units (see also **Section 19**). Upper shelving levels shall be provided with safe and easy access.

A chemical locker shall be provided, with saveall and emergency shower. A large paint store, a deck store, and a separate emergency equipment store shall be provided in the after part.All air conditioning and refrigeration cycles on board shall use the same refrigerant gas based on R407C refrigerant. Use of alternatives shall be subject to approval by purchaser. A portable "pump down" unit shall be supplied, with suitable and sufficient cylinders, for emptying and holding the largest system working gas volume. LR EP notation or equivalent class designation shall be applied for AC and refrigeration systems.

5. Fire, Safety and Security Systems

5.1. General

This Section covers the requirements for fire-fighting, fire protection and life-saving appliances (LSA), as well as the design of Carrier systems to comply with the guidelines in the ISPS Code. The Carrier shall comply with the requirements of DNV notation F-AMC (without certification) - see **Section 1.4.2.** Fire protection and extinction requirements shall comply with Chapter 11 of the IGC Code and the requirements indicated below.

The design of fire protection, detection, and extinguishing systems will depend, to an extent, on the choice of propulsion system. This is described in Modules C and may affect the separation and isolation of machinery and electrical equipment spaces, as well as the selection of detection and extinguishing methods for different propulsion solutions.

5.2. Structural Fire Protection

All accommodation bulkheads, ceilings, and partitions shall be made from non-combustible material, such as calcium silicate board or TNF type panels.

A-60 class insulation shall be fitted on deckheads between control rooms, machinery spaces or switchboard rooms and the accommodation, and on the house front. The forward facing windows and all the accommodation side windows, shall be fitted with A-60 non-gel type glass. All bridge and accommodation windows shall be fitted internally with 3M blast-proof film or proven equivalent with Purchaser’s approval. Cable spaces and/or ventilation duct spaces that travel continuously the full length of the accommodation block shall be fully A-60. Staircase for the engine control room shall have A-60 fire insulation.

A designated fire control station, with direct access to the deck as well as from the accommodation, shall be incorporated in the accommodation block and separated from the engine room by (as minimum) a cofferdam. Fire control station location shall be agreed with the purchaser. The boundaries of the space shall be protected to A-60 standard. The fire control station shall contain remote controls for all fire fighting and safety equipment, fuel oil shut off valves, pumps, and ventilation fan stops. It shall be provided with fan damper closures and direct voice communication to the wheelhouse.

5.3. Fire Detection

The fire detection equipment and associated equipment shall be a fully addressable intelligent analogue system. The system shall feature intelligent detectors. Alarm processing and decision making shall be made in the detector head itself. If a "true" alarm condition is activated by the detectors then the alarm

shall sound on all panels. If no attention is given within two minutes an audible alarm shall be sounded throughout the Carrier.

A fire detection and alarm system shall be fitted throughout the Carrier to cover all accommodation (including cable/pipe duct) and control rooms, store-rooms, working and machinery spaces, including the forward enclosed areas and the cargo machinery spaces. The main panel shall be located in the wheelhouse, a second panel, with the same functionality as the main panel, shall be provided in the CCR and shall provide fire detection alarm management when the vessel is in port, with repeaters in the engine control room and the designated fire control station.

All spaces that contain machinery and/or electrical equipment shall have detectors fitted.

Equipment in hazardous areas, including cargo machinery spaces, paint stores and forward spaces, shall be of the intrinsically safe, or alternatively of a certified safe, type.

The detectors shall be of optical, thermal or flame type dependent on location. Dual function detectors (smoke & heat) shall be used throughout the Carrier.

Areas in which hydrocarbon processing or internal combustion machinery is located (e.g., boilers, generators, IG plant, incinerator, gas compressors etc.) shall be provided with flame detectors and smoke detectors.

All detectors shall be easily accessed for the purposes of testing and maintenance.

The fire detection system shall be tied into the CCTV system and automatically switch to the area indicated on the fire alarm panel in the event of a fire alarm in the engine room.

The fire detection system shall have a separate event recorder located within the wheelhouse. The information indicated on the fire control panels is to be repeated on the IAS in a graphical display format that reflects the Carrier layout, showing all the detectors and actuators. The operator shall be able to determine from these displays the exact location and real time status of all detectors and actuators associated with the fire detection system.

Within all machinery spaces fire detector head tag numbers are to be marked on the deck directly beneath each detector.

An automatic door closure system shall be fitted to all doors on the central stairway and centerline of each accommodation deck, linked into the detection system with both auto initiation and manual activation from the wheelhouse and fire control station. Individual door local manual activation to be included.

An automatic door closure system shall be fitted to all doors leading to the galley from officers and crews messrooms to enable doors to be open during meal service times.

5.4. Fire Water System

Two electrically driven fire, bilge and general service pumps and one fire pump shall be located in the engine room. All pumps shall be self-priming. The emergency fire pump shall be located aft. Access shall be available to fire pumps at all times.

All the fire pumps shall be capable of supplying the fire main, which shall be pressurized at all times. Pressurization shall be achieved by using either an auto-start auxiliary jockey pump or a continuously operated engine room seawater pump. In the event of a fire main pressure drop, a main fire pump shall automatically start to supply the fire main while it initiates an alarm.

The fire main for the cargo area shall be a pressurized ring main located in the under deck passages with spurs to the fire hydrants on the open deck and supply other systems, e.g., bilge eductors, anchor chain wash, etc. In the case of exposed spherical cargo tanks being adopted, pressure control valves shall be installed in the lower fire hydrants.

Except for first-aid hoses, all other hydrants shall be 65 mm diameter, with BS336 or equivalent instantaneous couplings and provided with a 15 m hose. Fresh water first aid hoses shall be installed in

recessed hose boxes to reach all parts of the accommodation. Accommodation shall have 20 m hose lengths.

Attention shall be paid to the type of flange provided to the copper-nickel piping branches to ensure that the pressure rating is compatible with the fire pump pressure, including the hydrostatic head imposed in hydrants at the lower engine room level.

A fixed water spray system shall be supplied by a dedicated pump to protect the cargo tank domes, cargo liquid and vapor discharge and loading manifolds and their control valve area which shall be at least equal to the drip tray area provided, compressor houses, lifeboat embarkation areas, access to the lifeboats and the forward bulkheads of the accommodation block.

The fixed water spray system shall be fitted with a facility for fresh water flushing and draining cocks at lowest points.

A crossover shall be provided to allow the water spray system to be fed from the fire main.

The fire water spray system shall be instantly available, and shall be started locally as well as remotely from the wheelhouse, fire control station, and CCR.

Fresh water and seawater hydrants shall be provided at the vicinity of each cargo liquid dome or cover, as well as on each manifold, to supply sufficient flow of water for operational purposes.

5.5. Fire Extinguishing Systems

5.5.1. Fixed Fire Extinguishing Systems

A high expansion foam fire extinguishing shall be provided for the engine room(s), purifier/fuel oil room, incinerator room and steering gear room. The system shall be operable in the event of a dead ship condition. Water shall normally be supplied from fresh water storage tanks using a dedicated pump with the fire-main as a secondary source of water. The system shall be zoned to allow selective release.

Gas based fixed local application fire-extinguishing systems shall be provided for individual compartments, such as the engine control room, switchboard rooms, emergency generator room, cargo compressor room, cargo motor room and paint store. Builder is requested to quote for CO2 as the basecase and may also propose an alterative fire extinguishing medium. Gas based fire extinguishing systems are to comply with MSC.1/Circ.1387.

The design is to allow a simultaneous discharge of both the high expansion foam system and the gas-based systems into all covered spaces or for a partial discharge into only those spaces affected by fire.

Automatic local protection fresh water "fog" systems shall be used to protect local high risk zones such as (where applicable) boiler firing platforms, fuel oil rooms, incinerator spaces, and around main diesel engines, diesel generators, inert gas generators and gas combustion units.

Automatic local protection systems are to comply with MSC/Circ.913 and should be termed "Fixed local application fire-extinguishing systems" (SOLAS II-2 Para. 10.5.6).

A summary of the fire-fighting system requirements for different compartments (dependent on the general arrangement) can be found in the following table:

High Expansion Foam	Water Based Fog (Local System)	Gas Extinguishing—CO2 or alternative (as approved by Purchaser) (Local Systems as follows) (1)
Engine Room(s)	Prime Movers	ECR
Purifier/Treatment Rooms	Boilers	Main Switchboard Room
		Emergency Switchboard Room
Incinerator Room	Incinerator	Cargo Switchboard Rooms
Steering Gear Room	Purifiers	Electrical Equipment Rooms
		Cargo Transformer room
Paint Store	IGG	Fwd Pump Room
Cleaning Chemical Store	GCU	Emergency Generator Room
Treatment Chemical Store	Purifier/Treatment Rooms	Galley Exhaust Uptake
Elevator Motor Room	Fwd Pump Room	Cargo Compressor Room
	Emergency Fire Pump Space	Cargo Compressor Motor Room GCU/Hood Room Oil/Grease store
(1) Appropriate air locks and independent ventilation shall be provided to EERs and other spaces, as required, to allow flexibility of operation without affecting other compartments.		

A dry powder system shall be fitted to protect the main deck and cargo manifold areas, with two fixed monitors at each manifold and hand nozzles or monitors for the other areas. The dry powder installations, including the activating gas cylinders, shall be located in the under deck passage spaces, with spurs to the cargo deck areas. Valves shall be provided to isolate hose stations when a single unit is piped to multiple areas. Remote actuation shall be provided from the cargo deck, the cargo control room, and the fire control station. The gas cylinder pressure shall be permanently verifiable in situ. Dry powder systems require 100% backup.

5.5.2. Portable Fire Extinguishing and Fire Fighting Equipment

The Purchaser, in accordance with the requirements of the relevant rules and regulations, shall provide portable fire extinguishers and fire-fighting equipment, including spare parts.

These will include fireman outfits and a compressor Self Contained Breathing Apparatus (SCBA) for recharging the breathing apparatus air bottles.

The Builder shall provide all stowage requirements.

Fire control plans (using IMO symbols) shall be provided for internal display and external emergency use.

5.5.3. Safety and Personal Protection Equipment

Personal protection and safety equipment, e.g., helmet, goggles, BA set, stretchers, survival suits, etc shall be provided by the Purchaser in accordance with the relevant rules and regulations.

The Builder shall provide all stowage requirements.

5.6. Lifesaving Appliances

5.6.1. Lifeboats

Two totally enclosed, fire-protected lifeboats, with self-contained air support systems and powered by fresh water cooled, electrically started diesel engines (there shall be two electrical start systems, each engine shall have an alternative starting mechanism, for example: the stored-energy type. Direct hand cranking of the engine is not an acceptable starting method), shall be fitted with gravity fall davits, with manual lowering capability. Each lifeboat shall have sufficient capacity to accommodate the maximum complement, including supernumeraries and Suez Canal workers, or fifty persons, whichever is greater. Same maker shall be used for lifeboat and davits.

An electric motor driven winch, capable of lifting fully loaded lifeboat to deck level, shall be provided for each lifeboat. The falls shall comprise non-rotating wire rope, with bushes of synthetic material and all pins and sliding surfaces, which are subject to corrosion, shall be of stainless steel. Bowsing lines and harbor pins for davit maintenance shall be provided. An "on load" release testing mechanism shall be provided for all lifeboats.

Lifeboat release hook mechanisms makers shall be included in the maker's list. A single vendor shall be selected for all components of the lifeboat , launch and release equipment

Lifeboat davit motors shall have emergency stops which enable the motor to be stopped in case of contactor seizure. An emergency stop shall be provided at each motor operation positionRecovery time from the water to the stowed position shall be less than 2 minutes. Provision shall be provided for testing the release hook and mechanism while the boat remains secured by alternative mea

2 sets of custom made steel wire strops of adequate SWL will be provided as Fall Prevention Devices. Strops will be fully load tested and certificated.

Lifeboats shall be provided with heavy weather recovery systems.

The option for a free-fall lifeboat of the same capacity shall be considered.

Suitable connections to the SCBA air compressor shall be provided for easy charging of the self-contained air support systems.

Where the lifeboat air cylinders working pressure differs from that of the SCBA sets, each system is to be protected from over pressure by means of dedicated pressure relief valves, interlocked to prevent incorrect usage on the wrong system. The lifeboat air bottles should have convex bases, and be specifically designed to be stored in the flat position lay down ie with slightly strengthened sidewalls, and allowance for some internal corrosion.

5.6.2. Life Rafts

Four inflatable life rafts stowed in reinforced fiber glass container (throw overboard type) two each side shall be located aft, port, and starboard side and shall be fitted in cradles with hydrostatic releases. Each pair of life rafts shall have the capacity to take the entire Carrier's complement. They shall have an effective term of at least nine months after delivery of Carrier.

Embarkation ladders for roll overboard type life rafts are to be provided adjacent to the life rafts.

One off six-person life raft with manual release shall be located forward. A rope ladder shall be provided.

5.6.3. Personal Survival Equipment

Personal life saving equipment shall be provided by the Purchaser in accordance with the relevant rules and regulations. Installation and storage facilities, as appropriate, shall be provided by the Builder.

Storage boxes for life jackets shall be provided by the Builder at each embarkation area.

5.7. Atmospheric Oil Mist Detection System

All machinery spaces where pressurized fuel, hydraulic or lubricating oil are present shall be monitored by an atmospheric oil mist detection system. Detectors shall be fitted in such a way as to detect leakage from pump seals, fuel injectors, pipes, joints and other potential sources of leakage as early as possible, before a fire can start. The system used shall meet the requirements of the Code of Practice for Atmospheric Oil Mist Detectors (MSC/Circ.1086 or latest revision).

The location of the detectors shall be determined and demonstrated with all ventilation systems and machinery running in the normal full away condition. The system shall initiate an alarm when 0.2 ppm of oil is detected in the atmosphere.

5.8. Gas Detection Systems

Two systems of gas detection shall be installed:

a) A system based on infra-red gas analyzers drawing samples from the cargo tank area and (where space permits) the installation of dedicated IS type detectors in spaces which shall include, but not be limited to, hold spaces, insulation spaces and cargo compressor room. All sampling lines shall be 316L stainless steel at a minimum and fitted with welded or brazed joints.

b) A system based on independent infra red type detectors for continuous monitoring of accommodation, machinery spaces, cargo motor room, inert gas line, ventilation ducts, etc. Certain detectors shall be duplicated to provide shutdown gas burning system capability in the event of gas being detected in gas hoods or engine room.

c) The main control panel shall be fitted on the Bridge. A second panel, with the same functionality as the main panel, shall be provided in the CCR and shall provide gas detection alarm management when the vessel is in port.

d) The main control panel shall be interfaced to the IAS using redundant serial links.

The Purchaser shall supply portable instruments as follows:

Instrument	**Quantity**
Detector 100% LEL/100% Volume Hydrocarbon Gases	2
Detector 100% LEL Hydrocarbon Gas	4
Pump for Chemical Detector Tubes	2
Chemical Detector Tubes for Carbon Monoxide (50 ppm)	100
Chemical Detector Tubes for Carbon Dioxide (5000 ppm)	100
Methane in Nitrogen Meter	2
Oxygen Meter with 1%, 5%, 10%, 25% Scales	2
CO_2 Meter	4
Dew Point Meter (For Dew Point between 0 and -80°C)	2
Personal Oxygen Meter	5

5.9. Emergency Stopping Devices

All emergency-stopping functions shall be individually cabled and switched. They shall not operate shunt trips. Emergency stop facilities shall be provided in accordance with statutory regulations and shall include the trip of all workshop machinery. Duplicated units shall not be allocated to the same switch. The number of switches provided, and the allocation of equipment among the switches, shall be adequate to permit testing of the system without disruption to the Carrier's normal operations.

The emergency shut off valves on all the fuel tanks shall be controlled from the fire control station (see **Section 5.2**).

5.10. Emergency Towing Arrangements and Fire Wires

A quick acting emergency towing bracket shall be fitted forward with a central Panama fairlead and with stowage and deployment facilities for a foredeck chafing chain capable of handling a 10 inch towing hawser.

An emergency towing system complying with the latest IMO requirements for "Emergency Towing Requirements for Tankers" shall be fitted aft, "working strength" of 2,000 KN (204 tons). Towing hawser shall be installed below decks and shall have easy access.

Two set (2) fire-wires, 90 m each, stowed on suitable fixed air motor driven reels for easy deployment and recovery, shall be fitted below the mooring decks forward and aft. "Builder shall investigate latest technology on synthetic fire wires."

5.11. General Alarm Systems

This alarm shall be produced by the Public Address (PA) system (**see Section 38.2).**

5.12. Carrier Security Systems

The Builder shall provide a suitable design for the Carrier to meet the guidance given in the International Code for the Protection of Ships and Port Facilities and the U.S. MTSA (Maritime Transportation Security Act) requirements.

Measures shall be installed to provide early detection of intruders, restrict unauthorized access to the Carrier, and secure the protection of personnel on board. In particular, the accommodation block shall be designed so that access within the secure areas is not necessary for non-ship's personnel during port visits.

Specific Carrier design issues should include:

1) **Accommodation Arrangement (designated restricted areas)**

   Creation of secure working area within the accommodation block shall be provided, which would allow normal Carrier operations to continue in port, with minimum disturbance. This area, as a minimum, shall contain the following:-

   - Cargo Control room
   - Toilet/ shower room
   - Rest Area
   - Duty Mess-room/Pantry area
   - Entrance/reception area
   - Meeting room
   - Public Communication room
   - Carriers office with restricted access

- Internal doors and elevator with restricted access.

2) **Access Security Systems**

The Carrier is to made secure from external access by means of a centralized electro-mechanical locking system with automatic and local internal release of all external doors that allow access to the Carriers spaces (accommodation, engine room, etc)

As the machinery spaces could be an indirect means of entry into the accommodation, the electro-mechanical locking system shall cover the machinery spaces in way of outside entrances, emergency exits, lobby doors such as steering gear entrance and engine casing doors. The emergency generator room shall also be included from a security of power supply point of view.

Selective locking shall be provided for these areas to allow various configurations relative to the Carriers operating mode, i.e.,, at sea all locked, for in-port operation cargo deck free access, remainder locked.

Alarm shall be given when the Carrier is not secure.

3) **Personnel Protection**

A safety citadel shall with all steel A-60 bulkheads shall be created within the accommodation block into which all personnel can be accommodated should the security measures be breached, this should provide at a minimum:-

- Secure communications
- Bathroom/toilet facilities
- Mechanical/forced ventilation with gas detection
- Storage facilities for provisions and water, life-saving equipment (lifejackets, etc.) and pyrotechnics
- Medical facilities
- Secure power supply
- Advanced protection doors and windows
- CCTV monitor and control position
- Two secure exits

The Carrier's office and other spaces for cargo handling and stores receipt shall be outside the "citadel." Provisions shall be made for controlled access to the rest of the accommodation from these areas. Alternative citadel concepts/locations may be considered.

4) **Increased Detection Capabilities**

Radars, cameras, lighting, intrusion/detection equipment etc. shall be provided to facilitate the monitoring of decks and areas surrounding the Carrier.

The design of the superstructure should be such as to reduce "blind spots" when viewing from the bridge and CCTV system.

Lighting arrangements on deck shall be arranged with safety and security in mind.

These increased detection measures shall include:

- Aft scanning system to provide 360 degrees vision where existing arrangement does not cover 360 degrees vision.
- External working deck coverage by thermal type cameras for night time detection
- Sweep type searchlights.

5) **Secure Communication Facilities (diversification, etc.)**

Additional external communication links within the Carrier from the Engine Control room, Citadel, Fire control centre shall be provided.

Antenna diversification:-

- Standard practice to locate all antennae in one place to be revised.
- Antenna cable protection and/or separation.

6) **Further ISPS Requirements**

- Provision of Automatic Identification Systems (AIS)
- Provision of Ship Identification Number (SIN) both internally and externally to the Carrier
- Provision of a ship security alert system (SSAS)

Refer also to other sections of this specification for further details. All of the above measures are considered to be for the purpose of guidance only; further enhancements and details can be produced during the Carrier's detailed design phase.

The ship is to have full Global Security arrangements in compliance with BMP 4 which will include the installation of a stern radar.

6. Cargo and Ballast Systems

6.1. General

The Carrier shall be designed, constructed, and equipped to carry liquefied natural gas (LNG) of a minimum temperature of -163°C and maximum density of 500 kg/m^3 at near atmospheric pressure.

The cargo containment system shall be to an approved and tested design of one of the following (subject to the requirements of Module B):

Membrane systems of GazTransport & Technigaz (GTT) design No. 96 or Mk III. Only variations that are currently proven in service at the time of ITT submission will be considered, for example No. 96(GW) or Mk III Flex.

In the event that the proposed containment system is significantly different from the licensor's current design, test reports, calculations, conclusions, and reports on experience shall be submitted to the Purchaser proving the ability of the respective system.

Cargo handling shall be by means of liquid and vapor pipeline systems above the deck. Manifolds for the cargo shall conform to Category C of the latest edition of OCIMF/SIGTTO Recommendations for Liquefied Gas Carrier Manifolds Second Edition 2018.

Two identical submerged electric cargo pumps in each cargo tank shall perform cargo discharge.

Vapor compressors, warm-up heaters, and vaporizers shall be installed in a cargo compressor room.

If cofferdam heating is required by the containment system design, the system shall employ a glycol water mixture circulating system.

An inert gas generator and two equally sized 100% capacity nitrogen generators shall be provided in a separate compartment within the engine room.

A custody transfer system shall be installed and shall meet the needs of the buyers and sellers of the LNG as well as the fiscal authorities of the countries exporting and importing the cargo (**see Section 31.3**). The cargo tanks shall be calibrated and the custody transfer system shall be approved by an independent sworn measurer, who shall be nominated by the Purchaser, and approved by the appropriate Customs and Excise

Authorities having jurisdiction over each of the terminals (listed in the Outline Specification Modules B as appropriate).

Filling Levels:

Maximum filling levels in cargo tanks are not to exceed the following amounts, in accordance with the IGC Code and based upon flat ceiling areas:

Containment System	Filling Level by volume at reference temperature excluding the dome volume
GTT Mark III	98.5%
GTT NO96	98.5%

The cargo tanks and associated piping shall be designed to eliminate vapor pockets in the gas space for static trim up to 15° and static list up to 15°.

For design purposes membrane type systems, the acceptable liquid levels in cargo tanks shall be for low filling minimum 10% of cargo tank height and for high filling over 70% of cargo tank height. The pump tower shall be designed as a minimum to allow for all fill levels above 50% height and below 10% of length, expressed as a height.

As far as possible, all instrumentation lines, hydraulic lines, and electric cables shall be run below the upper deck (**see Section 24.12**). Where this is not practical, they shall be run in strong, self-draining, electrically conductive, GRP ducts, with top access and raised at least 300 mm above the deck. Mild steel cable trays and conduits shall not be fitted.

The Builder can propose an alternative cableway or covered cable tray made of SUS 316L. Supports of this alternative cableway or cable tray shall be of SUS 316L and the height above deck shall be at least 300 mm. The design shall be such as to provide adequate access for maintenance and subject to approval by the Purchaser.

6.2. Design Conditions

6.2.1. Cargo Containment Criteria

The cargo containment and handling system shall be designed to the following criteria:

Minimum design temperature:	–163°C
Cargo density range:	424–500 kg/m^3
Operating pressure range:	Membrane 1030 - 1300 mbar absolute

The insulation system shall be designed so that the laden boil-off rate (BOR) is not greater than:

- NO96 - 0.125% of gross cargo volume per day
- MKIII – 0.085% of gross cargo volume per day

at sea temperature of 32°C and air temperature of 45°C (as defined by GTT).

Where spray pumps are proposed for use as fuel pumps then the Builder is to calculate the heat ingress to the cargo due to LNG recirculation.

The Carrier shall be able to load the full cargo (excluding slow starting and topping off) through three (3) liquid manifolds at the rate or time specified in Modules B with a pressure of 240 kPa (gauge) at the Carrier's presentation flange.

The Carrier shall be able to automatically discharge the full cargo through three (3) liquid manifolds (with standard 60 mesh strainers installed) at the rate or time specified in Modules B against a manifold back pressure after the strainers of 400 kPa (gauge). Bulk discharge time shall exclude the build-up period for starting pumps and slow down or stripping at the end of discharge. Shipbuilder shall confirm flow rate and available pressure at the manifold.

The operations to bring the Carrier into service, from fully gas free to cooled down ready to load, shall be performed within periods not greater than the time indicated in Table 6-1.

Table 6-1: Maximum Time to Place Carrier in Service

Operation	GTT MK III	GTT NO96 GW
Inerting	20 h	20 h
Gassing up	20 h	20 h
Cooling down	15 h	12 h
Notes: GTT containment system cool-down is between +20°C to –130°C (average bottom temperature).		

The operations to take the Carrier out of service, from completion of discharge to fully gas free, shall be performed within periods not greater than the time indicated in Table 6-2.

Table 6-2: Maximum Time to Take Carrier Out of Service

Operation	NO96 GW	MK III Flex
Evaporating un-pumpables and warming up	48 h	61 h
Inerting	20 h	20 h
Aerating	20 h	20 h

The cargo system shall be designed such that gas freeing, and purging procedures can be carried out with all gases displaced from the cargo system being passed through the Gas Combustion Unit (GCU). Any increase in the time (indicated in **Table 6-1** & **Table 6-2**, above) required to carry out these procedures in this manner shall be noted in the Bid package. This facility shall be in addition to the emergency operating procedures involving venting of gases via a riser.

During each cargo operation the condition of cargo containment and handling system shall be controlled automatically or remotely and continuously monitored from the CCR and shall be provided with safety features for safe and reliable operation all the time.

6.2.2. Cargo Containment System Structural Integrity

The following calculations shall be performed by the shipyard to verify the safety of the system for a design life of 40 year service life based on North Atlantic wave data, to a fatigue factor of 0.5 according to Miner's law; against a design S-N curve at 2 standard deviations from the mean curve**.**

a) Thermal stress analysis for the cargo containment system and each tank size, including the cargo piping system, taking into account expansion, contraction, and Carrier flexing. Such analysis shall include transient conditions.
b) Dynamic cargo pressure calculations based on hull accelerations at sea, indicating local maximum forces.
c) Fatigue stress analysis due to thermal stress and forces created by dynamic cargo pressures and induced forces from the hull.
d) Transverse, longitudinal, torsional, and local hull deflection analysis indicating stress levels.
e) Local stress analysis for tank domes and their pipe penetrations as well as pipe supports inside the tank and on the deck.

Any filling restrictions, in any or all of the cargo tanks, shall be clearly stated by the Builder. Studies indicated above shall be submitted to the purchaser.

6.3. Cargo Handling Equipment

6.3.1. General

All cargo machinery and equipment shall be tested at the manufacturer's shop to a test procedure approved by the Purchaser(s).

Performance curves for pumps and compressors and shop test results for all equipment shall be incorporated in the relevant drawings.

6.3.2. Cargo Pumps

Each cargo tank shall include two (or more) equally sized submerged electric cargo pumps. The pumps shall meet the performance requirements set out in **section 6.2.1.** Pumps in all cargo tanks shall be identical in manufacturer, model, and capacity.

The pumps shall be designed with inducers and bell mouths to give maximize NPSH and shall be hydraulically thrust balanced in normal service over a wide capacity range (i.e., the pump thrust bearings shall carry no thrust during steady state operation). Each suction bell mouth shall be fitted with a strainer.

All cargo pumps and stripping/spray pumps shall be tested with LNG or equivalent at Maker's shop. Performance curves shall be drawn up showing discharge head, NPSH, pump down, current, and power versus liquid flow rate. Motors shall be tested. The pump performance shall be tested by eight data points spread across the full range. The pump performance of subsequent sister Carriers shall be tested over three data points spread across the full range.

The cargo pumps, pipeline system, non-return valves, and starters shall be designed to minimize liquid hammer during starting. Soft starting methods shall be used allowing the pump to be started both with a full or empty tank.

Each pump shall be provided with a low power trip to protect against dry running – NOT a low level trip, which is not acceptable (tank low level shall be incorporated as a start inhibit interlock).

6.3.3. Spray Pumps

A spray pump shall be installed in each cargo tank. All spray pumps shall be identical. They shall be of the same design and from the same manufacturer as the cargo pumps. The spray pumps shall be installed as low as possible, consistent with maintaining prime so that they may be used for stripping.

The capacity and head of each pump shall be determined by the containment design to meet the highest of the following requirements:

a) spray cooling all cargo tanks

b) pre-cooling of the liquid lines (if appropriate)
c) stripping main cargo pump un-pumpables within three hours
d) full forced vaporizing at 100% fuel gas burning at MCR

6.3.4. Alternative Discharge System

In event of a failure of all the cargo pumps in any tank, alternative means shall be available to discharge the contents. For membrane tanks, any portable emergency pump shall be able to be left in place until a permanent cargo pump repair can be carried out. The normal arrangement is to use the emergency pump to empty the cargo tank.

6.3.5. High Duty (Vapor Return) Compressors

Two equally sized electric motor driven centrifugal compressors shall be installed in the cargo compressor room.

Each compressor shall have a capacity designed to meet the the performance requirements stipulated in section 6.3.5 with an excess of 10%. at a minimum temperature of -140°C and a discharge pressure of 200 kPa absolute.

The compressors shall be suitable for vapor return duties and for warming up duties and shall be able to handle LNG vapor and inert gas and mixtures of both.

The compressors shall be of radial flow type with integral gearbox unit. Capacity control shall be by means of inlet guide vane (IGV) control. Each compressor shall have an independent and automatic anti-surge control and safety system, suitably sized to take the full discharge of the compressor.

The water-cooled motor shall be installed in the adjacent motor room and shall drive the compressor via an intermediate shaft, which penetrates the bulkhead through a gas-tight gland. The gland shall be nitrogen sealed. The motor, gearbox, and compressor shall be mounted on a common bedplate incorporating the gas-tight gland and partial bulkhead, the whole installation being designed to minimize vibration. Shaft vibration monitoring, alarm, and trip shall be fitted.

Each compressor shall be tested with air before delivery and performance curves shall be established for each compressor corrected for methane at the designed conditions.

Each compressor will then be spin-tested at cryogenic temperatures to verify performance and then dismantled for examination.

6.3.6. Low Duty (BOG) Compressors

Two equally sized low duty (BOG) compressors shall be installed in the cargo compressor room. The compressors shall each be designed to deliver the guaranteed design NBOG to the engine-room, re-liquefaction plant or GCU (as applicable), and shall be controlled to maintain a constant absolute cargo tank pressure. If required by Modules C, arrangements shall also be made to handle the additional FBOG required for fuel at MCR. If used as main propulsion fuel source then each LD/BOG compressor system shall be designed to handle the balance of FBOG, as required to run all available prime movers at their combined MCR power, being supplied via the vaporizer to the fuel gas line downstream of the compressor.

They should be capable of operating with gas inlet temperatures in the range +35°C to -140°C, such that inlet gas does not require pre cooling.

If compression of gas is necessary to the propulsion system, a suitable heat exchanger shall be provided (see Modules C for details).

The compressors shall be of radial flow with an integral gearbox unit. Capacity control shall be appropriate for the duty intended, with stable operation at the minimum flow rate of approximately 7% maximum discharge. Each compressor shall have an independent automatic anti-surge control and safety system, suitably sized to take the full discharge of the compressor.

Each compressor shall be tested with air before delivery and performance curves shall be established for each compressor corrected for methane at the designed conditions.

Each compressor will then be spin-tested at cryogenic temperatures to verify performance and then dismantled for examination.

Provision shall be made to allow free-flow of boil-off gas to the GCU, if the duty compressor fails. Piping and equipment shall be sized to maintain flow through the fuel gas heat exchanger in this condition.

Shaft vibration monitoring, alarm, and trip shall be fitted.

For additional duties, e.g. when reliquefaction plant is fitted, see Module D.

6.3.7. Gas Heaters

Two gas heaters shall be installed in the cargo compressor room and be capable of performing the following duties as and when required. These heaters shall be cross-connected to allow for flexibility.

a) Designed to raise the temperature of gas discharged from both high duty compressors operating in parallel to +80°C so as to provide the heating requirement to warm up the cargo tanks within the time specified in **Section 6.2**

b) Designed to raise the temperature of gas discharged from one of the low duty/BOG compressors to +30°C at the rated compressor capacity.

The gas heaters may be of the direct steam heated type, with automatic temperature control utilizing gas bypass control valves. In this case an automatic protection shall be provided to prevent freezing of the steam side of the heaters. An alternative heating medium can be proposed, but shall be subject to approval by the Purchaser.

Starting and stopping of the heaters shall be under local manual control.

6.3.8. LNG Vaporizer

A direct steam (or alternative medium) heated LNG vaporizer shall be installed in the cargo compressor room for the following purposes:

a) Gassing up the cargo tanks (inert gas purging) within the time specified in **Section 6.2**. This requirement shall govern the design capacity of the vaporizer. The design outlet temperature shall be +20°C for this operation.

b) Maintaining cargo tank pressure within design limits whilst discharging cargo at full rate specified in **Section 6.2** in the absence of vapor return from shore. For this purpose, a spray pump shall supply the LNG and the outlet temperature shall not exceed -130°C.

c) Pressurizing the cargo tanks for emergency discharge (if appropriate).

The vaporizer shall be started and stopped under local manual control and operate under suitable automatic control for each of the required modes of operation with monitoring facilities in the cargo control room. Suitable means shall be provided to ensure accurate outlet temperature, pressure and flow measurement. The LNG flow to the vaporizer shall be automatically stopped in event of high condensate level or low condensate temperature. A high outlet temperature alarm shall also be installed.

To avoid the possibility of liquid droplet carry-over into the compressor, a knockout drum (with internal demister) shall be interposed between vaporizer outlet and compressor suction.

6.3.9. Forcing Vaporizer

If required by the selected propulsion option, a forcing vaporizer shall be installed in the cargo compressor room to vaporize LNG supplied by the designated LNG fuel pumps via the cargo spray header. It should be noted that some cargo tanks could become empty during the ballast voyage and that

the quantity of NBOG can reduce significantly. Therefore, if required by Modules C, the capacity of the forcing vaporizer shall be sufficient to produce the full quantity of gas as FBOG to achieve MCR, with the Carrier in gas burning mode only, in accordance with the requirements of Modules C.

The forcing vaporizer shall achieve an outlet temperature of -40°C and be started and stopped under local manual control. It shall have automatic capacity control from 20% to 100% and be integrated with the main propulsion plant control system.

Appropriate monitoring facilities shall be provided in the cargo and machinery control rooms to ensure accurate outlet temperature, pressure and flow measurement. A high outlet temperature alarm shall be provided. The LNG inlet flow to the unit shall be automatically stopped in the event of high condensate level or low condensate temperature.

To avoid the possibility of liquid droplets carry-over into the fuel compressor, the same knockout drum referred to above shall be installed between the vaporizer outlet and the fuel gas compressor suction.

6.3.10. Cargo and Compressor Room

A separate cargo machinery room and motor room shall be provided for installation of the required cargo handling equipment. A removable connection from the inert gas system shall be provided outside the cargo compressor room.

The motor room shall be separated from the cargo machinery room by a gas tight steel bulkhead. All electric motors for cargo handling machinery shall be installed in the motor room. Motor room ventilation design shall take into consideration increased equipment vent needs for some propulsion option, such as the additional ventilation required for the reliquefaction units, where applicable. Adequate vent branches shall be provided for equipment cooling. The air velocity at the equipment shall be such to allow equipment operation at all ambient conditions without overheating. Air flow velocity at equipment shall be at 5 m/sec or as agreed during plan review.

The entrance to the motor room shall be located in a gas safe space. Compressor motor room shall be located aft of cargo compressor room.

A wind deflector shall be provided when the motor room entrance is facing forward.

Special attention shall be given to emergency escape ways for both the machinery room and motor room.

Vibration and temperature monitoring of bulkhead seals shall be provided.

The design of the room shall incorporate such details as are necessary to deal with the considerable condensation that will be present whenever the Carrier is operational. Savealls to contain oil leaks (e.g., from gas compressor gearboxes) shall be installed and shall be constructed so that condensation from pipes and compressor casings does not run into them.

Cargo compressor room shall be fitted with 2 x 100% capacity ventilation fans with auto-changeover facilities in the event one fan fails.

Lifting, access, transporting, and offloading facilities, as required for handling the largest equipment and for the overhaul of large items, such as exchangers or electric motors, and their transport out of the compressor room or electric motor room shall be supplied and demonstrated to be working satisfactorily with due regard to crew safety.

Cargo compressor - motor room choice location to be made with due regard and consideration to proximity with officer's living quarters.

6.4. Cargo System Piping

6.4.1. General

The cryogenic cargo piping system shall be constructed from austenitic stainless steel as per **Section 2.2**, **Table 2-1**. Stress corrosion cracking shall be avoided by adopting the following measures:

a) Solvent cleaning and coating with epoxy primer and finish coat with a process approved by Purchaser as per **Section 2.2**
b) Ensure proper weld bead shape
c) Avoid expansion on insulation connections
d) Avoid using moisture absorbent tape

Adequate expansion loops shall be provided in the liquid and vapor piping systems to allow for thermal expansion and contraction of the pipes, and for the flexing of the Carrier. Expansion bellows shall not be used for liquid lines unless expansion bends cannot be accommodated. Any such bellows shall be subject to specific approval by the Purchaser.

Any bellows used in the cargo system shall be of the multi-wall type, with Inconel 625 or equivalent flexible elements in the outer layer.

Pipe joints shall be kept to a minimum. The system, including any bellows, shall be welded as far as practical but with sufficient flanges to allow maintenance and removal of equipment. The pressure rating for liquid and vapor piping systems shall be the same.

Fluid velocity in the Carrier's pipelines (other than at manifold connections) in normal service shall not exceed 7 m/s for liquid and 40 m/s for vapor.

A small drip tray and upper spray shield of SUS 316L shall be provided under all flange connections in cargo liquid lines, which shall be raised to a suitable height above the deck in order to allow easy maintenance access to all supports and fittings.

Means of efficient drainage and purging of the loading arms and manifolds shall be provided. The main liquid lines shall be designed to enable self-draining.

The piping system shall be designed to permit warm-up, inerting, purging, cool-down etc of a single cargo tank with the remaining cargo tanks containing cargo or cargo vapor and without interrupting gas burning. Adequate segregation between tanks in this condition shall be demonstrated.

The relief valves fitted to liquid cargo pipelines shall discharge independently to either of two cargo tanks, not to the cargo vent mast. Relief valves shall also be provided for the ends of the cargo liquid manifolds outboard of the Carrier's manifold valves. All safety valves in the cargo pipeline system shall be supplied by one manufacturer and shall be provided with means of manual operation.

6.4.2. Piping Insulation

The cryogenic piping system outside the cargo tanks shall be insulated with rigid, self-extinguishing polyurethane foam or equivalent, suitable for temperatures up to +80°C. The insulation shall be covered with a tough water and vapor tight barrier, preferably of fiberglass or equivalent construction. Heat ingress calculations shall be performed to confirm that the thickness of insulation is sufficient for the satisfactory performance of the cargo handling and management systems. Particular attention shall be given to thermal expansion and contraction arrangements to prevent ingress of moisture.

6.4.3. Cargo Manifolds

The cargo manifolds shall comply with the OCIMF/SIGTTO Recommendations for Liquefied Gas Carrier Manifolds Second Edition 2018. The connections on each side shall be arranged L-L-V-L-L.

Manifolds will be of Category B type consisting of 16" connections.

No hand valves, gauges or other items requiring local manual intervention during bulk load/discharge shall be fitted to the manifold. Where reasonably practical local instrumentation will be extended to trunk deck safe location

Eight manifold strainers with a mesh size of ASTM 60, four for loading and four for discharging shall be provided in accordance with the SIGTTO "Recommendations for the Installation of Cargo Strainers on

LNG Carrier." The strainers shall be designed with sufficient area to minimize loss of head. The Builder, subject to the Purchaser's approval, may propose bi-directional strainers.

Two sets (five per set) of adaptors/reducers (16 in to 20 in) shall be provided suitable for connecting the Carrier's manifold to the shore arm hydraulically operated quick connect/disconnect couplers (QCDC).

Surface roughness of the sealing faces to be no greater than 0.2Ra.

Manifold area will have fresh water supply to facilitate with de-icing operations.
Manifold area will have Nitrogen and General Service air connections with snap fittings.
Manifold area will have sufficient storage lockers to accommodate safe stowage of conical filters

The adaptors/reducers shall be stowed in a protected location. Short spool pieces are not required in this case.

Three portable reducer pieces having end flanges (20 in x 3 in, 3 in x 2.5 in and 3 in x 2 in) shall be provided for connection with any of cargo liquid manifolds for supply of liquid nitrogen to LNG vaporizer during the initial gas filling of the insulation spaces.

A water curtain shall be provided at the manifolds Port and Starboard to protect the ship's side during both normal cargo transfer and emergency cargo jettisoning.

Two sets (five per set) of blank flanges 16 in. (and handling arrangements for the same) shall be provided.

A portable nozzle for emergency liquid cargo jettisoning shall be supplied and stowed in the forward store area. The nozzle shall be capable of mounting on any liquid manifold, project 3 m over the Carrier's side and provide an outlet velocity of 40 m/s when supplied by two cargo pumps at rated capacity. The nozzle and its supports shall be designed to minimize vibration of the nozzle when in use.

6.4.4. Pipe Supports

Pipe line anchor points shall be designed to take the thermal and dynamic loading, including surge pressures, which may be induced in the Carrier's piping. Fixed pipeline anchors shall be designed to avoid point loading and for this reason, pads shall be interposed between the anchors and pipeline. Alternatively, suitably shaped sections of pipeline with increased wall thickness may be employed. "U" bolts and nuts shall be of stainless steel.

In general, all pipelines on deck and in the compressor room shall be installed such that the insertion of suitable pads, chocks or sleeves of PTFE or similar material avoid metal-to-metal contact between the pipe and the Carrier's structure. The supports shall be designed to allow maintenance of the pads in service without hot work.

All pipelines on deck shall be installed to allow safe access and maintenance.

If sliding piping supports are provided, the sliding area shall not be affected by corrosion. Maintenance of pads and sliding soles shall be possible in service without hot work. All pipe movement shall be possible without damage to the insulation.

Use of mild steel angle bar supports for pipelines on deck is not acceptable, cylindrical supports are required.

Calculations shall be submitted which demonstrate the suitability of the design with respect to strength of the supports and stresses in the pipelines under all conditions of operation including transient loads during cool-down. Details of each type and size of pipeline support shall be subject to approval.

6.4.5. Pipe Testing

All pipe welds shall be 100% tested by radiographic inspection or by an equivalent method approved by the Purchasers.

Pipe pressure testing shall be by water in the shop and by dry air or nitrogen on the Carrier.

After fabrication and testing, the pipes shall be internally dried, cleaned, and sealed before installation on the Carrier.

After the pipelines have been installed, all liquid, vapor, nitrogen distribution, and inert gas pipelines shall be blown through with dry air and the main systems shall be internally inspected by remote controlled TV camera and cleaned to Purchaser's satisfaction.

Cold testing shall be carried out by the use of gaseous / liquid nitrogen before the vessel undertakes Gas Trials.

6.5. Cryogenic Valves

Valves for cryogenic service shall have extended bonnets to avoid freezing of the moving parts and shall be installed in the vertical position with the gland up. Liquid service valves shall have means to relieve pressure caused by liquid trapped in the body. Valves shall be "fire safe" to a recognized standard. Non-throttling valves shall be suitable for bi-directional flow.

For large diameter valves, special attention shall be given to the design of the top flange. Special tightness testing under transient cooling and flow conditions shall be conducted.

Valve materials shall be as listed in **Section 2.2 Table 2-1** and based on the following guidelines (alternatives on materials and types may be considered by the Purchasers):

a) Bore > 100 mm: Stainless steel butterfly valve with extended bonnet and stem. Valves shall be side entry, butt welded (where possible) type with replaceable metallic seats (capable of being overhauled in situ). For controllable position valves, actuators shall be double acting with a facility for adjusting the valves manually, without the requirement of accumulators. For ESD valves, hydraulic actuators shall be single acting type with a nitrogen cartridge (or similar) ESD/fail-safe closing device. Stainless steel pressure sensors shall be provided and alarm via the IAS to monitor low pressure in the nitrogen cartridge for each valve in the cargo control room. Spring powered ESD/closing devices are not acceptable.

b) Bore < 100 mm: Stainless steel ball valve or equivalent with extended bonnet and stem

c) Liquid throttling: Stainless steel globe valve with extended bonnet and stem

The cargo pump discharge valves and the designated ESD manifold valves shall all have linear flow characteristics.

Valve actuators, manual or powered, and hydraulic control systems shall be provided by the valve manufacturer and the whole assembly tested before dispatch from the factory.

All hydraulically actuated valves shall be of the high pressure type (low pressure is not acceptable), and shall be capable of local manual operation. Hydraulic lines shall be fitted with facilities for isolating and bypassing hydraulic actuators.

Sampling, vent and drain lines on all liquid and vapor lines, which open to atmosphere, shall be fitted with double isolating valves.

Hydraulic actuators shall be of suitable material for marine use and not be made from aluminum alloy. All actuators shall have local valve position indicators.

Materials for hand wheels, levers, and fittings for all valves and actuators shall be SUS 316L.

6.6. Cargo Tank and Insulation Space Relief Valves

Each tank and insulation space shall be equipped with two diaphragm relief valves of the pilot operated type. Each relief valve shall be provided with a means of manual operation. In the case of spherical cargo tanks, if the chosen means of emergency cargo discharge is by pressurization of the tank, then the relief valves shall be provided with a means to allow re-setting or to otherwise achieve the emergency pressurized discharge required in **Section 6.3.4.**

6.7 Inert Gas/Dry Air Plant

An integrated inert gas generator/dry air production unit shall be provided for inerting and aeration of the cargo system within the time specified in **Section 6.2.1**. The plant shall be located within the machinery casing, in a segregated space having direct access to the machinery space and to the deck Two identical blowers shall be fitted, each capable of handling 50% of the capacity of the inert gas/dry air plant. Blower controls shall be designed to avoid surging during two-blower operation. Vibration monitoring in three directions, alarm and trip limits shall be provided. Blower impellers shall be designed and tested at 115% overspeed. Impeller design and welding shall avoid high stress concentrations. A Finite Element Analysis (FEA) shall be performed for the impeller design by third party. Component materials, welding methods, materials, and procedures shall be subject to purchasers review and approval. Certified welders shall be used. A commissioning and testing program for the system shall be provided. Program shall include endurance runs 6 hours on air and 12 hours on inert gas per fan in full automatic mode and operation. Pressure drop calculations shall be provided. Impellers shall be visually inspected after endurance run. Performance and endurance testing shall be included a makers facility.

Distillate fuel for the production of inert gas shall be as specified in **Section 11.1.**

Inert gas produced by the unit shall meet the specification of the containment system designer but, in any case, shall meet the following minimum quality requirements:

O_2	≤	0.5 % Maximum (by volume)
CO	≤	100 ppm
SO_2	≤	10 ppm
NO_x	≤	100 ppm
Soot	=	0 Bacharach
CO_2 & N_2		Balance
Dew Point	≤	-45°C

No refractory linings shall be used in the inert gas generator. The dew point of dry air produced by the unit shall be equal to that specified for the inert gas. Fresh water from the engine room central cooling system shall be provided for dryer cooling requirements. In addition, fresh water rinsing shall be arranged for the generator.

The plant shall be arranged for fully automatic operation. Starting shall be performed under local control and equipment shall be provided to allow remote monitoring from the IAS.

Where regenerative dryers are installed, facilities shall be provided to allow the unit to produce dry air in the event of the Carrier being laid up.

Provison to be made for a through pipe sight glass (as big as practically possible)and back lighting. Sight glass to be fitted in the gas main down stream of the refrigerant drier and before the deck IG main pressure control valve.

Provison to be made for a gas quality opacity meter and associated alarm DCS interface. Opacity meter to be installed at inert gas outlet from scrubber and before dessicant drier

Provison to me made for a low FLOW and low PRESSURE alarm/TRIP to monitor scrubber tower and jacket cooling water supply

6.8 Nitrogen Generator

Two equally sized nitrogen generator plants of the membrane permeation type shall be installed within the Inert Gas Room and shall serve any propulsion plant requirements as well as the cargo system requirements.

The capacity shall be such that one unit shall satisfy all normal service requirements, including normal loading and cool-down with a 20% margin. Two units operating in parallel shall satisfy periods of exceptionally high demand, such as the initial cool down of the cargo system from ambient conditions. The plant shall be provided with a buffer tank of sufficient capacity to ensure that the plant shall not start more than once per two-hour period in normal operation at sea.

In the case of fully automatic feed air capacity regulation, a low FLOW alarm will be incorporated into the oxygen analyser sampling flow meter.

Two dedicated equally sized rotary screw compressors (same supplier/design to those used for the control air and general service air) shall supply air to the plant. Oil removal/filtration system shall be provided by compressor manufacturer and quality of air in compliance with nitrogen generator/membrane manufacturer. One compressor running with 90% loading ratio shall be able to supply the full capacity of one unit. The compressors shall be cross connected with those described in **Chapter 7.12.**

Nitrogen produced by the unit shall meet the specification of the containment system designer and shall be dust and oil free and shall meet the following minimum quality requirements:

N_2	$\geq$	97% volume
Dew Point	$\leq$	-65°C at atmospheric pressure

The plant shall operate fully automatically and shall be arranged for remote monitoring from the IAS. Discharge flow shall be diverted if the oxygen content exceeds 3% by volume.

7. Ballast System

The ballast system shall consist of a ring main located in the duct keel, with two equally sized spurs and two valves of equal size to each tank. Surge protection devices shall be fitted to prevent excessive movement or rupture of the GRP piping. The surge protection shall consist of water detection probes installed in the ballast ring, forward and aft, port and starboard that will inhibit ballast operations until the ring main is completely flooded. A minimum of three identical capacity electric driven ballast pumps (of which a minimum of two shall be self-priming) shall be located in the engine room. Each pump shall be sized such that with any two running the ballast tanks can be filled or emptied within 12 hours. Two equally sized water driven eductors shall be installed for stripping the ballast tanks via the ballast main, without a separate stripping main.

Ballast line materials shall be as shown in **Table 2-1** of **Section 2.2.** GRP systems shall employ double ring bell and socket joints. Where bell and socket joints cannot be used (because of physical constraints), GRP couplings shall be employed. The GRP piping system shall extend fully from the forepeak ballast tank suction to the engine room bulkhead. The Aft peak shall be connected to the ballast line in the engine room but the Aft Peak is not to be used as a ballast tank at any time. Every low point shall be able to be stripped. The ballast system shall have suction and discharge connections at Carrier port and starboard side.

GRP piping Maker shall provide piping arrangement drawing showing supports and pipe joints, carry out stress analysis, and provide technical support and training as necessary. Monitoring of GRP piping installation by Maker's representative shall be to the Purchaser's satisfaction. Supports shall be designed to best engineering practice and approved by Purchaser. All pipes shall be completely pre-fabricated and tested at the Maker's production facility.

Valves shall be fully lined butterfly types, fitted with direct-coupled hydraulic actuators. Materials are shown in **Table 2-1 of Section 2.2**. The flow rate of water in the ballast system shall not exceed the figure recommended by ballast valve maker. Valve opening/closing times shall be adequate to prevent shock loading to the ballast system.

The ballast valve system shall be fully remote controlled, with remote indication of tank level, draft, ballast pump motor current and suction, discharge and main line pressures. Full integration into the IAS system shall be provided.

The system shall be designed to achieve the complete exchange of ballast water at sea, within seventy-two (72) hours while maintaining the service speed and without exceeding the allowed hull stress limits and bending moment. The sequential procedure shall be fully programmable and shall be capable of running automatically from start to finish and shall be capable of running manually in case of emergency. Overflow procedure shall be possible and Builder shall supply all fittings. The ballast tank vent system shall be sized to accommodate maximum flow encountered during any ballast/deballast operation, in automatic or manual mode, without exceeding the test head of the ballast tanks.

Ballast capacity and distribution shall be sufficient to allow the Carrier to achieve an even keel arrival with any quantity of bunkers at each of the listed LNG terminals (to suit the loading and discharging arms' envelope and the gangway envelope, with the required amounts of heel in the cargo tanks, and with consumables at 50% maximum capacity). The designated ballast spaces may include the peak tanks but only if these peak tanks are either maintained completely empty or completely full in all ballast conditions.

List due to designed concentration of weight on one side of the Carrier resulting from features such as Deck Machinery House, and compressor rooms shall be compensated for with other design features such as bunker, fuel, or lube tanks and the use of ballast to correct list in this situation shall be avoided.

Facilities shall be provided for easy sampling of water ballast tank content at any level.

The ballast system shall be designed to allow concurrent de-ballasting during cargo loading or ballasting during cargo discharge without at any time exceeding the maximum and minimum draft limits.

The ballast system valves shall be located in the dry duct keel, instead of in the adjacent ballast tanks.

The ballast piping system shall be designed and equipped to enable it to be used for ventilation of the ballast tanks for inspection and maintenance.

Remote ballast tank level gauging shall be provided as described in **Section 31.2.** This shall also include the draft gauging system. Tank sounding pipes shall also be provided.

Builder shall design the ballast system and tanks so as to minimize the accumulation of mud/silt.

Ballast treatment systems as required by IMO regulations shall be implemented. Builder's proposal shall include consideration of such arrangements and potential alternatives. Ballast treatment system shall be agreed with the purchaser.

7.1. Ballast Water Treatment System

The Ballast Water Treatment System (BWTS) shall meet with the requirements of USCG and IMO type approval.

A suitable Ballast Water Treatment System shall be agreed with the Buyer based on a side stream electro-chlorination design.

Alternatives might be proposed by the builder subject to buyers review and approval.

The particulars of BWTS shall be as follows:

- The fully automatic BWTS shall be designed to have the capacity required for simultaneous operation of two (2) ballast pumps.
- There shall be no limitation on water temperature, salinity or holding time.

- The system shall incorporate a 40 micron full flow filtration system with in-service suction type cleaning arrangement.
- The main components and injector with associated accessories shall be installed in a separate space within the Engine Room.
- The BWTS shall be operated at only ballasting, however, neutralization unit may be operated at de-ballasting depending on the TRO (Total Residual Oxidant) concentration level automatically.
- The Testing Organization (TO) and the Verification Organization (VO) shall be approved by the USCG
- System shall be capable of gravity ballasting.
- Testing and commissioning of the system shall be undertaken during sea trials or onboard testing in accordance with vendor's recommendation, and the vendor shall issue a report stating the achieved performance of the system, compliance with AMS-D2 type approval requirements, as well as the Ballast Water Treatment Systems settings and operation at the time of the test.
- Total two (2) independent hydrogen (H) detectors shall be provided in ballast water treatment room.
- Ballast water treatment system shall be compatible with the selected coating system of water ballast tank.
- The A.P. tank shall be treated from the system installed on upper deck with any additional equipment such as filter in engine room as required.
- The ballast water treatment system shall be automatically controlled as well as locally and remotely controlled at control space.
- Control panel of the system shall be provided in both the ballast water treatment room and cargo control room
- The efficiency of the electrodes shall be maintained without the need for physical cleaning.
- The size of the neutralizing agent tank shall be sufficient for five (5) ballasting operations. Consideration to the placement of the tank to allow for frequent filling.

8. Cargo and Ballast Valve Hydraulic System

A valve control system shall be installed to allow all normal cargo handling and ballasting operations to be controlled from the cargo control room. The valves shall be provided with hydraulic actuators powered from a fully redundant centralized power pack and controlled by electro-hydraulic control valves.

Two 100% identical hydraulic power packs, each comprising two electric motor driven main pumps, one small pump (designed to maintain pressure in low load conditions), accumulators with filters, gauges, etc., shall be installed; one for the cargo valve system, one for the ballast valve system. Each power pack shall have its own independent oil tank and oil circuit. The two power packs shall be able to be interconnected and shall be fitted within an enclosed room having leakage detection, atmospheric oil mist detection, and all statutory fire control measures.

Each main pump shall be capable of the most onerous of the following duties:

a) simultaneous operation of the two largest valves in the cargo system,
b) operation of all the manifold valves on one side of the Carrier within thirty seconds.

Suitable connections shall be provided to allow for flushing and filtering the hydraulic systems without removal of sections of pipeline.

All valve actuators shall be directly mounted on the valve and a local indication of the valve position shall be available. Means shall be provided to allow all hydraulic valves to be operated locally by means of a plug-in portable hand pump. All valve actuators shall be fitted with isolating and by-pass valves for hydraulic lines.

Effective means shall be provided to allow closing of the manifold ESD valves and the fuel gas master valve(s), if applicable, in the event of a loss of hydraulic motive power.

The hydraulic control valves shall be located in groups and in protected spaces such as the under deck pipe passage. Where this is impractical the control valves shall be grouped in watertight boxes on deck. The lines to the actuators shall be run below the deck as far as possible.

All hydraulically operated cargo and ballast valves shall be capable of remote and local operation. In addition, they shall be individually capable of local operation by connecting an emergency manual hydraulic pump.

The actuators and hydraulic control system for the cargo tank filling valves, cargo pump discharge valves and manifold valves shall contain automatic pressure and temperature compensated flow control to ensure consistent speed of operation.

The hydraulic system pressure used shall be dictated by the valve supplier and shall be the system pressure delivered to the actuator.

ISO standards 4406:2017 and 12669:2017 shall be followed when commissioning the hydraulic system(s), particularly with regard to electronic particle counting. Cleanliness shall be to ISO 4406:2017 18/16/13 or the Maker's standard, whichever is the more onerous. Electronic particle filtration shall be used during commissioning.

9. Ship-to-Ship Transfer

The Carrier shall be able, to transfer cargo and electric power to, or receive from, another ship. Such cargo transfer shall be carried out in accordance with the ICS/OCIMF/SIGTTO Ship-to-Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases 2013 or latest revision and the Carrier shall be suitably arranged for this operation on delivery.

A comprehensive Ship-to-Ship Transfer Manual shall be prepared subject to purchasers review and approval as detailed separately in this module.

10. Machinery Systems

10.1. General

All machinery and equipment shall be to the highest marine standards and shall have been well proven, suitable for use onboard Carriers and for unrestricted service.

The design of the propulsion plant and auxiliary systems shall achieve a high fuel and propulsion efficiency at all loads and conditions. The propulsion system shall be capable of burning fuels as specified in Modules C1 and C2.

Main propulsion machinery shall be located in the aft machinery space and shall be one of the options specified in Modules C1 and C2. Details given in the following section shall be modified according to the specification in the applicable Modules C1 and C2.

Design, type, and arrangement of generators for the electric power plant shall be as stated in **Section 24**. One emergency diesel generator shall be provided to meet electrical requirements as stated in **Section 24.**

Automatic controls, alarms and safety devices shall be fitted to permit the engine room to operate with unattended machinery spaces and control room under all operating modes i.e., sea passage, maneuvering, port idle and cargo handling, including ballasting and de-ballasting. The machinery plant shall be operated from the engine control room (ECR).

Duplication/redundancy of equipment shall be of a level to ensure that no single equipment failure, failure of power supply or system malfunction will jeopardize the Carrier's effective automatic unattended plant operation or the overall safety and control of the Carrier.

All machinery and equipment located in machinery spaces shall be designed to operate at ambient air temperatures between 0°C and 45°C with relative humidity of 60%. On deck machinery and equipment shall be designed to operate between -25°C and 55°C. All machinery and equipment shall be designed to operate at a sea temperature of 32°C and an ambient air temperature of 45°C with a relative humidity of 60% while operating at Maximum Continuous Rating (MCR).

In addition, the machinery and equipment in ER shall be able to operate at ER air temperature of 50 oC and a SW temperature of 35 oC with a relative humidity of 80% when operating at Normal Operating Power (NOP). However, the output or performance of the machinery and equipment shall be reduced or limited to the certain level according to relevant manufacturer's recommendations.

All electrical and electronic components shall be designed to operate reliably at temperatures up to 55°C at all times.

The propulsion system shall be designed so that critical torsional vibration and other undue vibration shall not occur throughout the anticipated plant operating range, except at designated critical speeds that shall be minimized in number, precisely identified and shall only occur outside of the normal maneuvering ranges ahead and astern.

All duplicated pumps shall be arranged for automatic starting of the standby pumps on failure of a running pump or on low system pressure.

Main and essential auxiliary machinery is to operate satisfactorily under static and dynamic angles of inclination as specified in the Classification Rules.

Carrier shall be provided emission control equipment for the dual fuel main engines, dual fuel generators and boilers to meet rule requirements as of the expected day of delivery as agreed with purchaser. Further details on emission control equipment requirements for main engines and gererators can be found in Modules C1 and C2.

Space shall be allocated for equipment related to any known future requirements.

10.2. Shafting and Propellers

10.2.1. Shafting

Twin shafts and propellers shall be installed for this Carrier.

The shafting shall be as simple as possible, e.g., consisting of an intermediate shaft and a propeller shaft both made of forged steel.

The section of the propeller shafts in way of the forward bush journal shall be increased by 2 mm in diameter and the section of the intermediate shaft in way of the bearings by 5 mm diameter, both by comparison with the nominal Class requirements for shaft diameters.

The tail-shaft arrangement shall be designed such that the period between tail-shaft withdrawals shall be maximized as applicable to Class Rules, e.g., five to ten years.

The shafting shall be connected by integral flanges coupled by radial fit hydraulically tightened cylindrical forged steel bolts. A set of removal/fitting tools shall be provided. The outside diameter of the flanges shall be not less than the coupling bolt pitch circle diameter plus two coupling bolt diameters. Spot facing of coupling bolt holes shall not cut into the flange fillet radius.

Any flanged couplings for propulsion shaft exposed above floor grating shall be fitted with enclosed guards. The guards and their supports shall be assembled with bolted connections to allow dismantling without the need for hot work. Any necessary lifting arrangements shall be provided.

The intermediate bearings shall be forced lubricated white metal type and shall have the lubricating oil (LO) supplied from the main engine lubricating oil system. The shaft bearing seating shall be designed to accommodate weighing devices for measuring the bearing loads. Bearings shall be provided with sight glass, local pressure and temperature indication and remote indication and alarms for both.

A shaft earthing device with two(2) silver alloy slip rings and a milli-voltmeter shall be provided for each shafting in order to reduce voltage difference between the shaft and hull, and a failure alarm of shaft earthing device shall be displayed in IAS. One (1) set of spare brushes and springs shall be provided.

A torsion meter with power, torque and rpm readouts in the ECR shall be also installed **(**see **Section 28.1)** in each shaft line and shall also form part of the Carrier's performance monitoring system.

When under power, the propellers shall be arranged to counter rotate (port CW and Starboard ACW when view from aft to forward), in order to enhance hull and propulsive efficiency.

A mechanical locking arrangement shall also be provided on each shaft. The locking arrangement shall be engaged by one person and be arranged with suitable interlock to prevent starting of the engine and ME turning gear when the device is in locked position. Shaft locking device shall be fitted which can sustain the forces while the Carrier is sailing with one (1) main engine at MCR.

Thrust bearing assembly will be contained within each main engine casing.

The intermediate bearings shall be forced lubricated white metal type. The shaft bearing seating shall be designed to accommodate weighing devices for measuring the bearing loads. Bearings shall be provided with sight glass, local pressure and temperature indication and remote indication and alarm.

The installation shall be designed to have no barred (critical) speeds. If this is unavoidable (detailed study to be provided to support this position) then there shall be no barred speed between maneuvering full astern and maneuvering full ahead. An automatically programmed quick bypass arrangement shall be provided for any barred speed band outside this range.

Special studies shall be conducted by an approved specialist contractor to determine aft shaft bearing slop requirements and whether a double slope is needed. Methodology shall be agreed with the Purchaser.

For this propulsion arrangement the propeller margin shall be a minimum of 5%.

The stern tube bearing shall be two cast iron bearing bushes lined with white metal bearing material, oil lubricated with a forced circulating system, and fitted with leak detection and drain tank for the inboard and outboard ends. The stern tube bearing shall be installed by means of push up force with appropriate interference as per Class rules. Epoxy resin shall not be used.

The stern tube seal shall be air seal type Air Guard 3 or equal type, as approved by purchaser. Stern tube shall be provided with an additional gravity head tank. The tank shall cover the normal operational draft range, which allows an optional low head to be set to prevent external contamination when operating in ports and coastal waters. The seal casing shall be designed to allow replacement of the sealing rings without disconnecting the shafting or propeller. The seal rings shall be of Viton material. Compact, high integrity, leak proof oil face seals suitable for use with bio-degradable oils shall be selected based upon shaft diameter and surface speed and assuming a 5 year dry-docking cycle. The stern tube seal shall comply with VGP requirement.

The bio-degradable oil approved by VGP shall be used in accordance with the seal manufacture's recommendation, and the material of seal rings shall be compatible with the bio-degradable oil.

Rope cutter, net protector and propeller anodes shall be provided.

The proposed shafting alignment, including proposals for position of intermediate bearings and boring of stern tube lining shall be submitted for Purchaser approval.

Shaft alignment calculations vertical and horizontal shall be performed for the following conditions:-

a) Dry dock,
b) 50% propeller immersion,
c) Loaded/ballast condition,
d) With aft peak full and empty.

Calculations shall be performed at both cold static and hot dynamic conditions where appropriate, taking into account the usual effects of thermal displacements, buoyancy, hull deformations, gear forces, modes of operation, propeller offset thrust, bearing wear down, etc., as applicable. Measurements shall be taken and submitted to Purchaser in order that the calculations may be verified.

Dynamic bearing load simulation shall be performed on the line shafting on the 'first of class' Carrier. An independent Contractor shall be appointed by the Builder and approved by the Purchaser.

10.2.2. Propellers

Each shaft shall be fitted with a fixed pitch, (highly skewed where necessary), nickel aluminum bronze propeller which will be inward turning as seen from aft when going ahead. It shall be a wet-fit keyless type. The manufacturing tolerances shall be in accordance with class I of ISO 484/1, "Ship screw propellers - Manufacturing tolerances". Also, static balancing and the surface finish shall be in accordance with class S of ISO 484/1. The dimensional checks (radius, pitch, thickness, rake, chord length, etc.) shall be witnessed by Buyer's representative to ensure that they are within the manufacturer's tolerance and a copy of the results provided to the Buyer.

Propeller type and blade number shall be subject to approval by purchaser. Propeller type and number of blades shall be included in builder's initial specification.

The propeller fitting/removal tool of hand operated oil injector shall be supplied.

The propeller withdrawal shall be possible without removal of the rudder or propeller shaft.

Hydraulic equipment, fittings and accessories shall be supplied for mounting and dismounting of the propeller. This equipment shall be provided with a pressure test certificate from the maker.

Propeller withdrawal shall be possible without removal of the rudder or propeller shaft.

Steel rope guards shall be provided around the propeller shafts, between the stern frame boss and the propeller hub, and shall be welded to the stern frame boss.

10.3. Main and Emergency Generators

(See Modules C1 and C2 for details of the main engines and their associated auxiliary plant).

10.3.1. Dual Fuel Generators

The main generator sets shall be of 4-stroke, trunk piston, in-line, dual fuel type, turbo-charged engines with air start and operating at 720 rpm. There shall be a minimum of four (4) generators. Builder may propose up to two (2) different capacities, however the engine make, type, cylinder bore and design must be identical with only difference being the number of cylinders. Each shall be directly coupled to its generator and shall have the capability to be operated on either BOG, MDO/MGO, ultra-low sulfur fuels as well as the same HFO grade as the main engines.

The dual fuel generator engine shall be directly coupled with the alternator on a common bed-rail and the bed-rail shall be resiliently mounted to the Carrier's structure. If a flexible coupling between alternator and diesel generator engine is fitted, torsional vibration calculations (TVCs) shall be undertaken by the engine manufacturer. Torsional vibration calculations (if needed) and resilient mount natural frequency calculations shall be submitted to Purchaser for approval.

Crankcase vents shall be fitted with methane detectors with capability for variable alarm settings linked to the IAS.

Power requirements for all operating modes shall be met with three of the four generators in operation with a load no exceeding 85% and with the largest sized prime mover not in operation.

Each generator engine shall have a self-contained jacket cooling system and lubricating oil cooling system with each system being cooled by the engine room centralized fresh water cooling system (low temperature) as outlined in Module A.

The lubricating oil and jacket cooling pumps shall be directly coupled to the engine. The diesel generators shall be installed in rooms that are suitably insulated and well ventilated, not more than two engines (50% of the total power generation capacity) to a room.

A continuously rated, electric drive lubricating oil pump shall be supplied to provide bearing protection. A failure of the electric oil pump shall not inhibit the immediate operation of any automatic starting requirement. In an emergency situation, providing there is sufficient starting air, it shall be possible to start any generator locally. The dual fuel generator engine oil mist detector shall be of the same make and type as the main engine units.

Two lubricating oil filters of the disposable cartridge type shall be fitted and sized to pass the full output of the lubricating oil pump. The maximum particle size shall be in accordance with the diesel manufacturer’s standard.

The dual fuel generators shall be able to operate at full load on a continuous basis and be capable of unrestricted periods of low load running down to 20% of maximum rated power while burning gas or liquid fuel. The MGO shall be supplied by gravity from a minimum of two MGO service tanks, having sufficient capacity for 36 hours operation at Carrier's maximum load, via a duplex filter. The generators shall always be ready for immediate use, with continuously heated jacket water and pre-lubricated.

The engine output shall be based on the methane number of fuel gas at 80 and above in accordance with the engine manufacturer’s standards.

The generator engines shall start/stop directly on HFO or MGO and running on FG according to the engine manufacturer's recommendation.

Builder to provide pilot liquid fuel consumption over the full power range.

The generator engines shall be provided with electronic governor meeting class requirements for steady state and transient response. Diesel generator engines shall be capable of isochronous load sharing or controlled by PMS.

The construction and materials of the diesel generator engine shall be according to the engine manufacturer's standards in compliance with the requirements of the Classification Society.

Pipes, valves, gauges etc. fitted on the engine by the engine manufacturer shall be in accordance with the engine manufacturer's standards.

For dual fuel generators the Builder shall calculate and provide to the Purchaser emissions data for burning HFO at 0.5% sulfur content, complete with certification for all HFO and MDO/MGO burning equipment. Emission data shall include Sulphur Oxides (SOx), Carbon Monoxide (CO), Carbon Dioxide (CO2) Nitrogen Oxide (NOx), Particulates 10 microns or less (PM10). The above shall be provided for power range points 15%, 25%, 50%, 75%, 85% and 100% MCR.

In addition Builder shall calculate and provide to the Purchaser 'Methane Slip' (all methane losses from the point of gas entry to the engine fuel gas system) emissions data over the full power range when burning Fuel Gas. These calculations shall include losses from the combustion space via the exhaust uptakes and well as via the crankcase vent to atmosphere.

Dual fuel generator engine shall comply with Marpol 73/78 Annex VI Regulation 13 (NOx emissions) and IMO NOx Tier III in fuel gas and liquid fuel mode.

Each dual fuel generator shall be delivered with a NOx technical file and EIAPP certificate in compliance with Tier III NOx emissions levels in gas mode and liquid fuel mode as per IMO's Rules and Regulations.

Onboard verification of NOx emissions from the dual fuel generator engines shall be carried out by means of engine parameter check method, if modification of the engine components affecting NOx emissions is made on board.

A provision (blind flange) for future measuring of the NOx emissions from the diesel generator engines shall be fitted at each GE exhaust gas system, and the measuring equipment shall be provided by the Owner, if required.

10.3.2. Emergency Generator

The emergency diesel generator set shall be of sufficient size to meet the duties stated in **Section 24.3** and to allow the engine room and necessary machinery to be started up from dead ship condition. The cooling and lubricating systems shall be completely self-contained. The jackets shall be provided with thermostatically controlled electric heaters to ensure that the engine is capable of immediately delivering load.

Two independent Purchaser-approved starting devices, for example, powered by air and hydraulics, shall be provided. Both systems shall be capable of full operation independent of the provision of main and emergency power sources.

The emergency diesel generator shall operate on the same fuel that is provided for the back up fuel supply to the main generator prime movers, which will allow the fuel to be transferred from the fuel storage tank to the emergency diesel generator fuel service tank. The emergency diesel generator fuel service tank shall be of sufficient size to run the engine on full load for 24 hours.

10.4. Fresh Water Systems

10.4.1. Distilled and Domestic Water Systems

Water from the fresh water generators shall be piped separately to domestic fresh water tank(s) and service fresh water tank(s). An appropriate (silver ion exchange type) sterilizer system shall be provided in the line to the domestic water tanks and a mineral injection system shall also be provided. In addition a UV steriliser is to be fitted on the outlet from the hydrophore tank. A crossover, with a removable spool piece, shall be provided between the domestic water and service water tanks. Non-return valves and suitable isolation arrangements shall prevent transfer of water from the service tanks to the domestic tanks. If necessary, a fresh water transfer pump shall be installed.

A combined sanitary and fresh water supply system shall be provided. Water services shall be divided into the necessary sections to suit the accommodation arrangement. All domestic fresh water piping services shall be provided in copper or an Purchaser approved non-metallic material suitable for this service. Sufficient fresh water connections shall be provided on cargo machinery room, trunk deck at approx 40 m interval, underdeck passageway, upper deck sunken deck, cargo manifold steering gear room and around the accommodation block for maintenance purposes and filling of lifeboat freshwater tanks, etc. Quick coupler valves shall be of the standard stainless steel snap-on connector type.

The hot water system, which shall be a circulation loop, shall have two 100% capacity calorifiers (heaters) each with two sets of electric heating element together with the provision of steam heating.

Two hot water circulating pumps, each 100% of the required capacity, shall be fitted in the return line of the loop which shall be designed to allow maintenance of the non running pump.

The fresh water generating plant shall consist of two plate type fresh water generators each of minimum capacity 40 tonnes per day. The fresh water generators shall be capable of producing their rated capacity at a sea temperature of 32°C. Under these conditions the distillate shall not contain more than 1.5 ppm sodium chloride. A probe type salinity detector shall control a valve, which shall automatically dump the output to the bilge holding tank. Chemical dosage equipment shall be fitted to both units. Each fresh water generator shall use water from one of the main engine jacket cooling water systems as a heating medium, and the distilled water shall be cooled from the low temperature fresh water cooling system. In addition, one fresh water generator will be fitted with a steam heating system.

10.4.2. Fresh Water Cooling System

A fresh water cooling system shall be provided for machinery and cargo related machinery.

The cylinder jackets of each main engine shall be fresh water cooled by separate high temperature systems; each with two 100% HT/LT coolers and two 100% duty circulating pumps. Temperature control valves shall be provided to maintain the jacket temperature in each system.

Each high temperature system shall be cooled, via the LT coolers, by its own low temperature fresh water cooling system, each with two 100% duty circulating pumps.

Jacket water heaters shall be provided where recommended by the engine Maker.

For each main engine there shall be a jacket cooling water drain tank and pump sized to hold the contents of an isolated unit when carrying out maintenance.

The two low temperature fresh water cooling systems shall cool the self contained jacket cooling water circuits of the dual fuel generator engines. The arrangement shall be such as to ensure no complete loss of cooling to the generators in the event that one of the systems has to be shut down.

An electric pre-heating unit, with pump, shall be provided to maintain the jacket temperature of standby engines (as recommended by the engine manufacturer).

A centralized fresh water cooling system to serve other fresh water cooled consumers shall be located in the engine room and shall consist of two plate coolers, two 100% fresh water pumps, and temperature control valves.

The stern tube lubricating oil shall be cooled by the LT fresh water cooling system.

A dedicated centralized fresh water cooling system shall be installed to serve the gas recovery system as specified in Module D.

In general, the system shall comply with the following requirements.

The fresh water cooling system shall be designed with strategic isolation valves so that leaks can be corrected or maintenance performed without having to shut down the whole system thereby losing all power and/or propulsion.

The plate coolers shall be sized such that one shall have sufficient capacity to handle the maximum cooling requirements at 32°C seawater temperature, with a 15% fouling margin. It shall be possible to backflush the seawater side of the plate coolers.

All seawater plate coolers shall have titanium plates and titanium lined nozzles with end covers and frames of epoxy coated mild steel. Gaskets shall be to the accepted standard for the mediums being used.

A water sampling and chemical injection arrangement shall be provided in each fresh water circuit.

Plate coolers for fresh water and lubricating oil handling shall have stainless steel (SUS316) plates and stainless steel (SUS316) lined nozzles with end covers and frames of epoxy coated mild steel. Gaskets shall be to the accepted standard for the media being used.

Plate coolers shall have a minimum plate thickness of 0.6 mm.

The pumps shall be top entry well types with stool mounted vertical motor and removable spool in drive shaft to allow rotating element to be lifted complete for servicing. The pump speed shall not exceed 1,800 rpm.

10.5. Sewage Collection and Treatment

The sewage system, supplied with fresh water, shall be provided with a holding tank of at least 20 days capacity at maximum designed manning level, or 45 cubic meters, whichever is greater. Grey water shall be directed and disinfected through the sewage plant. The biological sewage treatment plant shall have capacity sufficient for the total crew of the Carrier.

To enable compliance in zero discharge areas, a combined treated sewage/grey water holding tank will be incorporated with at least ten days capacity at maximum designed manning level, or 45 cubic meters, whichever is greater; this is in addition to the sewage holding tank.

The sewage treatment plant (STP) shall be approved to meet USCG requirements. Each sewage treatment plant shall have two air compressors, one operating and one standby and two discharge pumps, one operating and one standby.

10.6. Sea Water Systems

10.6.1. General

The sea water system in the engine room shall consist of main and auxiliary systems, which shall have the capability of being cross connected. The main sea water cooling system shall be divided into two independent systems, each serving one main engine. Cross over connections (normally shut) shall be provided between the two systems, though the design shall be such that no single failure can cause loss of cooling to both main engines. Each system shall consist of three 50% main sea water cooling pumps to provide redundancy and shall serve the fresh water coolers of its respective main engine LT system.

The auxiliary sea water cooling system shall consist of two 100% auxiliary sea water cooling pumps to provide redundancy and shall serve the freshwater generators and other sea water consumers.

The main and auxiliary sea water pumps shall be of the same make and design.

Seachests, high and low, shall be provided on each side of the Carrier.

In general, the system shall comply with the following requirements.

Sea water systems shall be designed such as to minimize the quantity of sea water circulating within the engine room. They shall be protected against marine growth by an anti-fouling system of the Electro-Chlorination type with direct injection into the sea chests. Electrolyzer elements shall have a service life in excess of five years. The ability to back flush sea chests and central coolers shall be provided.

All valves throughout the sea water systems, including sea suctions and overboard discharges, shall be of the flanged butterfly type where practicable. The main sea water inlet and discharge valves shall be power operated with automatic and remote control from the IAS. All remotely controlled valves shall also be capable of local manual control.

The seawater pumps shall draw from a common seawater crossover pipe connected to two inlet boxes, one port, and one starboard. The two inlet boxes (each having high and low suctions) shall be located at a height and position which allows good suction in all possible conditions of trim with the Carrier moored either side to. The manifold shall be of steel and lined with polyethylene. Hydraulic sea valves shall be located port and starboard.

Auxiliary sea water cooling pumps shall draw through strainers, which shall be welded steel construction lined with hard rubber and fitted with stainless steel (316L) perforated basket of suitable area. The top cover shall be bolted and fitted with a test cock and vent. Air vents shall reach well above loaded draft line. The strainer body shall be fitted with a drain valve.

Shipside valves shall be made of hard rubber lined cast steel flanged or lug wafer to allow removal of inboard piping with valve closed while in water and the butterfly disc shall be made of nickel aluminum bronze. The spindle and spindle pins shall be made of stainless steel (SS316) and duplex stainless steel (SS2205), respectively. Other seawater system valves shall have a similar grade of materials but with hard rubber lined cast steel bodies.

To enable blanking of sea chest by divers when the ship is afloat, Class approved and certified neutral buoyancy blanks, and the means to safely handle them, shall be supplied for all the Carrier's sea chests and stored in a suitable location, e.g., within the engine room or steering gear room. The deployment and fitting of these blanks shall be demonstrated to the satisfaction of the Purchaser's representative.

Emergency bilge suction shall be arranged to suit propulsion option and class requirements. Pumps connected to the emergency connection shall be provided with self-priming devices.

10.6.2. Sea Water Pumps

Materials for the sea water pumps are as per **Table 2-2** in **Section 2.2**. The electric motor driven pumps shall have vertical stool mounted electric motors. Pump speeds shall not exceed 1800 rpm.

10.7. Lubricating Oil Systems

10.7.1. General

The lubricating oil systems and equipment shall be provided as below.

10.7.2. Main Engines

Each main propulsion slow speed duel fuel engine shall be provided with two 100% duty electrically driven centrifugal lubricating oil pumps per engine, one running and one on standby.Pump, piping and cooler materials, as well as storage facilities, shall be provided as specified in **Section 2**.

All pumps shall have mechanical seals and be arranged for automatic starting of the standby pumps on failure of a running pump or on low system oil pressure.

Two 100% duty lubricating oil coolers shall be provided for each main diesel engine with the lubricating oil for each engine being cooled by its respective low temperature fresh water cooling system. Each

cooler shall be sized such that the heat transfer from lubricating oil to freshwater is sufficient to maintain the lubricating oil at the desired temperature when the main engines are at MCR and the sea temperature is at 32º C, and when taking into account a fouling margin of 15%.

Each dual fuel engine lubricating oil system shall be provided with one self-cleaning and discharge strainer with by-pass filter, with filter mesh sized for particles of 20 µm or greater.

All filters shall be provided with differential pressure gauges and differential pressure alarms.

10.7.3. Purification and Filtration

10.7.3.1. Main Engines

A minimum of two (2) identical, automatic self-cleaning lubricating oil purifiers (of the partial discharge type) shall be provided each with sufficient throughput to effectively treat the oil from and to a main engine renovation tank or direct from and to the main engine sump when engine is in service.

Builder shall install each purifier on a modular base unit, which incorporates the heater and controls, as supplied from Maker.

Two (2) purified feed pumps shall be provided. The purifier feed pump shall take suction from the main engine sumps, lubricating oil tanks and deliver to the purifier via a heater in the purifier room. Two (2) purifier heaters shall be provided. The purifier heaters shall be electric or steam heated.

10.7.3.2. Generator engines

Generator engines lubricating oil shall be purified directly between engine lubricating oil sump and purifier. One (1) automatic, self-cleaning, total discharge type purifier with pump and heater shall be provided for **each** auxiliary generator engine. Builder shall install each purifier on a modular base unit, which incorporates the heater, pump, controls, etc as supplied from the Maker. Appropriate isolation valves and cross connection points shall allow the dedicated purifier from one generator engine to purify oil from another generator engine sump tank for each two generators with appropriate safeguards, such as two-valve isolation with locking arrangements and/or spectacle flange combinations at each cross connection to preclude inadvertent cross-flow. The purifiers shall also provide batch purification to the generator engine lube oil tanks, purification, and settling tanks. The purifier heater shall be electric or steam heated. A common purification system shall not be acceptable.

Provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engines.

Fully automatic lubricating oil purifiers shall be provided and arranged for continuous and batch operation, as outlined in the Modules C1 and C2. The purifiers shall have an electric heater capable of maintaining the temperature of 95°C at optimum throughput and be fitted with sterilizers to kill micro-organisms. Each prime mover will have a lubricating oil purifier with segregation from the other prime mover oil systems. Valve arrangement will

Stern tube lubricating oil shall be capable of being transferred to the main lubricating oil settling tank by the lubricating oil transfer pump and processed by the lubricating oil purifier system.

10.7.4. Lubricating Oil Tanks

Lubricating oil storage tanks shall be provided, with a transfer facility from storage tank to corresponding machinery, for each grade of oil where there are more than 200 liters in service (in all onboard equipment). Any tank with a capacity in excess of 1,000 liters shall have separate filling arrangements from main deck level. All storage tanks shall be equipped with a manhole allowing internal inspection

and cleaning. All lubricating oil storage tanks shall be clean and if not coated shall be oiled after construction.

Associated lubricating oil storage shall include the tanks listed below and those in the relevant sections in Modules C:

a) Main L.O. storage tanks (2 off)
b) Main L.O. settling tanks (2 off)
c) Main Cylinder Oil storage tanks (2 off)
d) Stern tube L.O. drain tank
e) L.O. renovating tank
f) L.O. daily use tanks
g) L.O. drain tank
h) L.O. purifier sludge tank
i) Hydraulic oil storage tanks (Provision to be made for the storage of hydraulic fluids in sealed drums.)

The renovating tank shall be sized for one main engine complete charge plus 10%. It shall be provided with aluminum brass heating coils and circulated with a temperature controlled heating media.

NOTE: As a minimum, tanks shall be supplied with sufficient capacity of consumable oils (e.g. main engine cylinder oil, lube oil, etc.) for a 15,000 N.M. + 5 Days voyage in designed loaded condition at NOP plus a 5 day reserve. Builder shall provide a tank capacities table and basis for deriving proposed quantities.

Local and remote reading L.O. tank contents measurement shall be provided for all tanks indicated in this section as specified in **Section 31.2**.

10.7.5. Lubricating Oil Piping

All lubricating oil piping shall be steel with welded steel flanges. The design of the system shall be such that during cleaning, parts are completely flushed without "dead" pockets and ends. All pipes shall be acid cleaned and passivated after fabrication. Pipes shall be protected and sealed during storage prior to fitting. Pipes penetrating tank tops shall be heavy schedule for protection against mechanical damage.

11. Liquid Fuel Systems

11.1. General

One grade of light fuel oil is preferred for back-up or pilot fuel for the main engines and all other consumers, provided it meets all requirements and manufacturer recommendations. The dual fuel generators, incinerator, GCU, emergency diesel air compressor, lifeboat engines and emergency diesel generator shall operate on the same grade of distillate fuel, as specified in ISO 8217:2017, DMA. The inert gas generator shall also operate on marine gas oil (MGO).

All fuel oil piping shall be fully welded solid drawn seamless steel. There shall be sufficient flanged sections to allow for the removal of, and access to, pumps, heaters (where fitted), valves and other components in the system. Flanged connections on all pipelines containing pressurized and/or heated fuel oils shall be provided with spray shields.

All fuel oil pumps, filters and other components shall be located, where practicable, in a totally enclosed fuel oil room, which shall be fitted with fire detection and a fixed fire-fighting installation.

Fuel oil filters shall be fitted with differential pressure gauges and with alarms to indicate high differential pressure. They shall be designed so they cannot be opened when on line. Drain and vent lines from filters and strainers shall be piped to a drain tank.

Neither the fuel system, nor any equipment in it shall contain copper, zinc, or copper/zinc bearing alloys.

Individual fuel oil flow meters, each with a remote output signal to the IAS, shall be provided for all consumers to enable accurate calculations to be made of the fuel consumption of each prime mover in the power plant system. (See **section 10.3**).

11.2. Main Engines, Dual Fuel Generators and Boilers

Applicable fuel for main engines and dual fuel generators shall be:

- MGO (ISO 8217, DMA) as pilot & back-up fuel
- HFO (ISO 8217, RMK700) as back-up fuel

Applicable fuel for boilers shall be:

- MGO (ISO 8217, DMA)
- HFO (ISO 8217, RMK700)

Each main engine shall be supplied by an independent backup Fuel Oil (maximum 0.5% Sulfur HFO and maximum 0.1% Sulfur MGO as required) service system with all fuel oil heaters, fuel pumps, and treatment plant for each engine located in a separate well ventilated fuel room (total of two fuel rooms).

Each fuel oil system shall also be capable of providing fuel for the dual fuel generators and boilers. Cross over connections (normally shut) shall be provided between the two systems, though the design of the fuel system shall be such that no single failure can cause loss of fuel to both main engines and all dual fuel generators.

The main engines, dual fuel generator engines, boilers and fuel oil transfer and treatment systems shall be designed to operate on liquid fuels as specified in the engine maker's operation manuals.

Each main engine and auxiliary dual fuel generator engine fuel system shall be of the pressurized closed loop type, having circulating fuel pumps (screw type), drawing from the clean oil service tank via duplex basket filters, and discharging to a buffer tank. Suction from the buffer tank shall be by high pressure fuel oil booster pumps (screw type) discharging through fuel oil heaters and hot filters to the main engine and auxiliary generators. The fuel pumps, filters, and heaters shall be duplicated and rated at 100% duty, with one running and one on standby. Each fuel pump shall be capable of pumping either heated residual or distillate fuel.

The main fuel oil heaters shall be capable of maintaining the fuel temperature in the circulating main at a maximum of 150ºC, with a minimum supply temperature of 60ºC under all operating conditions. Any one heater shall be capable of meeting the required performance with a fouling factor allowance of 15%.

All heated fuel system pipes and fittings shall be thermally insulated and fitted with electrical trace heating or steam trace heating.

HFO viscosity for the main engines and diesel generators shall be controlled by electronic type viscosity control units. The steam input valve for the main fuel oil heaters shall be regulated by temperature controllers in the IAS, the set points of which shall be determined by the electronic viscometers. The steam control valves shall be fitted with a positive valve positioner. Hot and cold oil filters shall be fitted with alarms to indicate abnormal differential pressure.

Fuel pumps, filters and heaters shall be installed on a module (to contain possible fuel leakage), with effective drainage. All equipment shall be sited with due regard to maintenance access.

The main engines and dual fuel generator engines shall each be provided with positive displacement fuel oil meters, having local and remote readout. The fuel meters shall be arranged to give actual fuel consumption, including pilot liquid fuel when operating in gas fuel burning mode. Pulse output for

remote reading shall be sufficient to provide accurate data for input into the ship performance monitoring system.

It shall be possible to change over from Gas Fuel to HFO to MGO and MGO to HFO to Gas Fuel without affecting the operation of any of the main engines or dual fuel generators. HFO/MGO changeover valves shall be capable of local and remote operation from the ECR.

11.3. Fuel Tanks

The MGO bunker capacity shall have sufficient capacity for 5 days with all prime movers (main engines and dual fuel generators) operating at MCR. In addition to the two HFO service and two HFO settling tanks, there shall be a minimum of two MDO/MGO storage tanks, two MGO settling tanks and two MGO service tanks. Each settling and service tank capacity shall be not less than 75 m^3.

There shall be sufficient MGO for the inert gas generator to inert the entire cargo tank capacity twice.

The residual fuel oil tanks shall be able to handle fuel with a viscosity of 700 cSt at 50°C and a SG of 1.010 at 15°C. They shall be fitted with heating coils having the capacity to heat to and maintain a temperature of 50°C in the storage or bunker tanks and 60°C in the settling tank with a minimum air temperature of –10°C. and a sea temperature of 0°C.

All bunker tank capacities shall be based on 95% full and 2% unpumpables.

The changeover arrangement (required in coastal and restricted waters) shall not interrupt the fuel supply, shall ensure safe operation, and shall prevent cross contamination of the different fuel grades. The changeover arrangement shall be designed to allow for switch over to 100% low sulfur HFO within 24 hours of initiation.

Where possible, all HFO shall be stored in the after end of the Carrier. Where the design precludes this, fore-deep bunker tank(s) may be proposed and if so shall be provided with local and remote tank content indication, tank heating, two transfer pumps, trace heating, etc. Tank maximum size and arrangement shall comply with the IMO requirements. There shall be cofferdams, voids, or ballast tanks between the fuel tanks and the hull side. The maximum capacity of any fuel tank shall not exceed 2500 m3. Forward fuel tank capacity shall be carried in two or more fuel tanks so that the maximum capacity of any individual tank indicated above is not exceeded.

Tank boundary distance from hull side and the fuel piping shall meet IMO MARPOL Annex I Regulation 12A requirements.

A means shall be provided for cleaning all HFO storage tanks using portable tank washing machines.

In any design involving forward bunker tank(s), adequate provision shall be made for bunker heating. Systems such as indirect electric heating, extensions to the cargo glycol-water systems or steam heating shall be considered. If bunker steam heating is used, steam piping shall be located in the lateral passageway. Bunker transfer facilities shall include two x 100% required capacity hydraulic fuel oil transfer pumps powered by an independent two-pump power pack each with 100% required capacity.

The capacity of the incinerator MGO tank shall be sufficient for a minimum of two days continuous 100% operation.

Tank arrangement, fuel transfer and service system shall be designed to provide flexibility in fuel storage and use with regard to handling of various fuels to meet international and local air pollution regulations.

Local and remote reading tank contents measuring facilities shall be provided, as specified in **Section 31.2.**

No pipelines shall pass through the bunker tanks.

Provision of associated system ancillary tanks shall be as needed, e.g., fuel oil overflow tanks, fuel oil drain tank, sludge tank, etc. Oil overflow lines shall be led to a chamber equipped with an alarm for monitoring from the ECR.

Separate overflow tanks are to be fitted for HFO and MGO.

All fuel tanks shall have means to manually gauge the level.

The emergency shut off valves on all the fuel tanks shall be controlled from the Fire Control Station.

11.4. Bunker Connections

Bunker connections (HFO and MGO) shall be located forward and aft at the amidships manifolds, port and starboard as well as additional connections shall be provided at the side of the accommodation port and starboard.

Each grade of fuel shall have its own connection with a facility for collecting fuel samples using the "drip sampling" method. The manifold connections shall comply with the latest edition of "OCIMF Recommendations for Liquefied Gas Carrier Manifolds."

The sampling point for all HFO & MGO loading lines is to be located away from the manifold area to allow sampling during simultaneous cargo and bunkering operations

The bunker-loading rate shall be such that the loaded fuel oil amount at Td (for each propulsion option) shall be loaded in no more than 10 hours with a maximum pipeline velocity of 4m/s. So far as is possible, long radius bends shall be used in this system.

11.5. Fuel Oil Transfer

Two (2) residual fuel oil transfer pumps shall be supplied with a minimum capacity of 30 tonne per hour each, able to handle fuel with a viscosity of 700 cSt at 50°C and a SG of 1.010 at 15°C.

Two (2) MGO transfer pumps shall be supplied.

The transfer pumps shall be connected so that fuel can be transferred to and from any fuel tank (without use of the main deck bunkering lines unless transferring from or to forward bunker tank(s) if fitted) and from these tanks to the Carrier's manifold amidships. A simplex strainer shall be fitted in each pump suction line. Suitable methods of preventing overflow shall be fitted to each storage, settling and service tank and overflow catchment arrangements shall be required in compliance with U.S. Coast Guard requirements. F. O. overflow tanks shall be provided and fitted with 25% capacity alarms as well as high level alarms.

The level of the fuel oil settling tanks shall be controlled automatically; between high and low level, by the fuel oil transfer pump.

Fuel oil filling and transfer lines, valves and pumps shall be remotely operated via the IAS from the engine control room and locally.

11.6. Purifiers

Four (4) identical self cleaning purifiers (partial discharge type) shall be provided, capable of handling fuels as detailed previously and each having a nominal throughput equal to the total fuel consumption at MCR for both one main engine and two dual fuel generators. At least two of the purifiers shall be capable of treating MGO. Post purification F. O. cooler shall be provided to cool the fuel prior to delivery to tank. Water and sludge from the purifier shall be led to the sludge tank. Sludge tank capacity shall be minimum 14 m^3 or as agreed with Purchaser.

There shall be two separate purification systems with crossovers. Each system shall serve one main engine and two dual fuel generators.

Purifiers shall be provided with a complete set of Maker's maintenance tools.

Each of the four purifiers shall be mounted on a skid and will incorporate a steam or electric fuel oil heaters, screw type FO feed pump, other equipment and all purifier controls (all shall be purifier Maker supplied) at the rated capacity as advised by purifier Maker. Heaters shall be sized with 15% fouling margin.

12. Engine Room Bilge Management System

All manifolds, cocks, and valves in connection with the bilge pumping arrangements shall be in positions which are accessible at all times under ordinary circumstances.

Suction for bilge drainage in machinery spaces other than emergency suctions, shall be led from easily accessible mud boxes, each fitted with straight tail pipes, to the bilge well and having covers secured in such a manner as to permit their being expeditiously opened or closed.

All drains directed to the tank tops shall be piped directly into the bilge wells.

The system shall contain a primary dirty bilge tank, a pre-treatment tank before the oily water separator (OWS), a clean bilge tank after the OWS and a waste oil tank.

Selected clean drains such as turbocharger air cooler drains and air conditioning unit drains shall be led to a dedicated clean drains tank and a dedicated discharge pump avoiding the OWS.

Engine room bilge in the bilge wells shall be transferred to the primary dirty bilge tank by the engine room bilge pump that shall be stopped and started automatically. The pump shall also be fitted with a long run alarm.

The pre-treatment (de-oiler) tank shall be installed prior to the OWS and fitted with a weir and heating coils. This shall be of a size to allow sufficient dwell time to effect separation.

The OWS fitted shall be of an approved type that is capable of meeting IMO guidelines MEPC 60 (33) and/or MEPC.107 (49), as amended. It shall be capable of treating emulsified bilge water with chemicals in holding tanks and shall automatically separate the resultant waste and water. The water shall be further filtered and polished and discharged via a PPM meter capable of meeting IMO Guidelines MEPC.107 (49), as amended. The degree of purity to be achieved shall be a maximum of 5 ppm.

The OWS shall discharge to the clean bilge tank, which shall have sufficient capacity to allow the Carrier to operate for 72 hours without discharging overboard.

The clean bilge tank shall be discharged overboard via a tamper proof MARPOL compliant monitor, with a flow meter and recording device for time, position, and PPM. This shall be fitted with a re-circulation valve to the dirty bilge tank in event of the alarm sounding.

An easily removable section (length 1m max.) of pipe is to be installed between the 3 way valve and ship's side discharge valve to enable internal inspection for USCG compliance purposes. The pipe is to be secured with tamper proof fixings.

The overboard discharge pump shall have an isolation switch on the bridge to prevent unauthorized operation without the bridge being informed. This shall incorporate indication of running status.

All tanks associated with bilges and the bilge management system shall be fitted with local and remote tank contents gauges and alarms.

A positive displacement waste oil transfer pump shall be provided to discharge waste oil ashore or to the incinerator waste oil storage tank, at a minimum rate of 10 m^3/h against a 30m head.

12.1. Sludge System

An automatic sludge de-watering unit shall be fitted as applicable to each propulsion option, drawing from the sludge tank to reduce the volume for disposal. The separated water shall be pumped to the primary bilge tank and the oil to the waste oil tank.

The waste oil tanks shall be able to be pumped to shore facilities and to the incinerator waste storage tank.

All sludge and waste oil lines shall be steam or electric trace heated.

12.2. Bilge, Ballast, Fire and Deck Wash System

Bilge, fire, and general service pumps, which can be interconnected with the bilge system, shall be fitted with a Class approved interlocking device to prevent the bilge main discharging into the fire main.

Where acceptable to Class or Flag State regulations, one ballast pump shall have a connection to the inert gas generator (IGG) cooling water system, to provide redundancy.

The system design shall include, but not limited to, the following:

a) Ballast pump (3 off) [2 pumps shall be self priming]
b) Bilge fire & general service (2 off) [both self priming]
c) Fire pump (1 off) [self priming]
d) Emergency fire pump (1 off) [self priming]
e) Fire line 'jockey pump' (1 off) [with accumulator tank]
f) Bilge separator pump (1 off)
g) Sludge/Waste oil pump (1 off)
h) Salt water spray pump (1 off)
i) E/R bilge pump (1 off)

12.3. Incinerator

The incinerator shall be of the continuous feed type, of multi-chamber design and having a sluice system and shall be capable of disposing of all domestic and engine room solid waste (including plastics). The incinerator shall meet MARPOL 73/78/97-MEP C76 (46) and IMO-Resolution MEPC. 244 (66).

Shall be capable of sludge oil disposal (based on a maximum running time of 10 hours a day) equal to or greater than 1% of total fuel oil consumed at MCR of all fuel oil consumers for Propulsion Options C1 or C2. Incinerator waste oil tank shall be minimum 3.5 m^3 or as agreed with purchaser.

The incinerator shall be capable of disposal of a minimum of 100 kg/hour of solid waste class 2 for Module C1 or C2. Incinerator shall be capable of continuous operation and re-charged with waste while in operation.

Combustion chamber design shall give low particulate emissions.

It shall have separate burners for MGO and waste oils and sludge.

A waste stowage area with compacting/shredding and bagging facilities shall be provided adjacent to, but not in the same space as, the incinerator. An ash reception and storage facility shall also be provided.

The incinerator shall be sited within its own designated room, adjacent to the machinery spaces but with easy access provided for the supply of solid and liquid waste and for the disposal of solid ash. The room shall be provided with controlled ventilation and all required services, including smoke and fire detection, fire extinguishing, etc., as required by Class for an oil fired unit.

13. Compressed Air Systems

13.1. Control and General Service Air Systems

The control air and general service air systems shall each be provided with two equally sized electric driven rotary screw air compressors (4 in total) and two air receivers (1 for each system).

One receiver shall be used for control air and the other receiver for general service. Air receivers shall be fitted with automatic drain and blow down assemblies. Cross connection shall be provided between the two systems.

The control air compressors shall deliver oil free air.

All air compressors shall be fully automatic.

One compressor, running with a 60% to 70% loading ratio, shall be able to supply all control or general service air demands.

The general service air compressors shall be able to be interconnected with those serving nitrogen generators.

The control air shall be oil free, filtered and dried to a dew point of -40°C and shall supply the automation control devices. Control air shall comply with the IS0 standard 8573-1. Two 100% capacity refrigerant-type control air dryers shall be provided.

The general service air shall provide, as required, all other service requirements including maintenance air tools, pilot hoists and accommodation ladders (as applicable). The general service air shall be distributed with the necessary locally installed oiling facilities for the operation of all air driven equipment. Sufficient compressed air connections, of the standard stainless steel snap-on connector type, shall be provided to allow easy maintenance of ships fabric using air power driven tools.

13.2. Starting Air Systems

At least two main engine starting air compressors shall be installed in the engine room and shall be driven by electric motors not exceeding 1,800 rpm. Each compressor and motor shall be mounted on a common bedplate that shall be installed on resilient mounts.

Compressed air shall be led to the main air reservoirs through oil/water separators. Two main air receivers shall be fitted for air start of the main engines. Air start pressure shall be 30 bars. The total capacity of the main engine air reservoirs (charged by the main air compressors within one hour) shall be capable of providing 12 consecutive starts of each main engine without further replenishment. The main air reservoirs shall have automatic drain and blow down facilities.

An electric driven air compressor shall be fitted for the topping up of the dual fuel generator air receivers.

Construction, materials, and accessories of air compressors and reservoirs shall be in accordance with manufacturer's standard, Module A**, Section 2,** and shall meet Class requirements.

Automatic stop/starting of the compressors with lead-lag control shall be provided, as well as automatic draining of high pressure air upon stopping and unloading on starting.

The main air reservoirs shall have the capability to supply air to the general service and control air systems through pressure reducing valves (one working and one standby).

Two 100% capacity, electric driven, air cooled, starting air compressors and receivers shall be provided for starting the dual fuel generators and emergency generator as applicable. Two air receivers, one located in each generator room, shall be fitted for air start of the main dual fuel generators.

Diesel driven emergency air compressor with air receiver shall also be provided in the emergency generator room to allow cold start of the dual fuel generators and the emergency diesel generator. The emergency compressor is to be fitted with both manual and electric start.As an alternative to the compressed air systems outlined above, and subject to the Purchaser's agreement, the Builder may propose a compressed air management system if this is more cost and effective and energy efficient.

14. Machinery Space Ventilation

Mechanical supply and exhaust ventilation shall be provided and designed in accordance with international standards **(see Section 1.4.5**) and to meet the needs of the propulsion options described in Modules C1 and C2.

The supply fans and exhaust fans shall be of the axial type, driven by totally enclosed motors, located in fan rooms, which shall be completely lined with a suitable sound absorbent material to achieve maximum

sound attenuation. The fan inlet shall be fitted with stainless steel or GRP mesh screens, which shall be removable for cleaning purposes. All inlets shall be fitted with effective water de-misting arrangements to minimize carry-over of driven water.

All fan room inlets should be provided with filters capable of removing sand / dust from the atmosphere. These should be provided with a suitable means of removal and be easily cleaned

Capacity of the supply fans shall be determined by carrying out an air balance study. This study to be issued as a drawing for Purchaser Approval. The total air requirement shall be as calculated plus 10%.

Fan motors shall be fitted with sealed bearings requiring no external lubrication. The air distribution trunking shall be coated galvanized steel. Where the Carrier's structure forms part of the trunking, it shall be coated to at least the same standard as the hull void spaces. Adequate access shall be provided for the repair of any damaged paintwork caused during the erection of the trunk and for ongoing maintenance.

All ducts and inlets shall be fitted with remote and local control fire dampers. Simple access to all dampers shall be provided for ease of maintenance. Adequate vent branches shall be provided for equipment cooling. The ventilation system drawing to be matched with the equipment layout to ensure correct cooling and distribution.

The air velocity at the equipment shall be such to allow equipment operation at all ambient conditions without overheating. Air flow velocity at equipment shall be at 5 m /sec or as agreed during plan review.

Other engine room spaces requiring ventilation (to atmosphere) shall include, but may not be limited to, the following:

a) engine room workshop welding bays – exhaust fans,
b) any ducted gas space - exhaust fan,
c) fuel oil room – exhaust fan,
d) chemical store - exhaust fan,
e) incinerator room-supply fan,
f) purifier room - exhaust fans,
g) GCU room.

Section 4.2 specifies the requirements for air conditioning of specific engine room spaces, e.g., ECR, switchboard rooms, and E/R workshop.

15. Exhaust Gas Piping

The exhaust gas piping shall be arranged for the following:

a) Auxiliary boilers.
b) Main and auxiliary dual fuel engines.
c) Incinerator.
d) Emergency generator engine (with independent silencer).
e) Steam system relief valve waste pipes.
f) Emergency air compressor.
g) Gas combustion unit.
h) High pressure air relief arrangements.
i) Any other item(s) requiring this provision.

The upper exhaust system for the main engines shall be designed such that no WHU wash water can flow to the main engine via the turbocharger.

Details of any emission reduction equipment contained in the exhaust gas piping shall be found in Modules C1 and C2.

Design proposals shall be given by the Builder during the bid process stage.

The main engine uptakes shall incorporate silencers.

The main engine uptakes design shall be reviewed and approved by engine and turbocharger makers.

Piping shall be arranged to keep back pressure to a minimum and be within Engine Maker's recommended back pressure limits. Calculations for exhaust gas piping arrangements are to be approved by Engine Maker and Purchaser.

Spark suppressors, expansion joint bellows, and drain pots (at lowest point) shall be installed in exhaust piping as necessary.

The outlet from any rupture discs fitted in the exhaust gas piping is to be led outside the machinery spaces to a safe area.

All exhaust uptakes shall be constructed from weathering steel to grade ASTM A588.

Boiler uptakes shall have large bore drain lines, fitted with ball valves, to enable use of compressed air and fresh water for cleaning purposes.

15.1. Funnel/Exhaust Uptake Fittings

The funnel shall be curved at the forward side (semi-circle) and square at the aft side.

The funnel top shall be provided with camber or sheer.

A rain protecting plate shall be provided near the top of the funnel, with a drain connection (which shall be led to deck) and necessary openings for the passage of pipes, a small hatch cover, and a fire damper.

Uptakes shall be supported by the Carrier's structure. Access from the machinery spaces to funnel top shall be provided via a series of inclined ladders. An access door shall be provided at the funnel base.

A raked aerodynamic fairing approximately 1.1m in height shall be provided, according to the result of the wind tunnel test, at the forward end of the wheelhouse top. The fairing size, shape and rake angle shall be optimised during model wind tunnel tests to optimise air flow to the funnel top.

15.2. Waste Heat Recovery

In order to maximize thermal efficiency, a waste heat recovery system shall be installed to provide heating for, but not limited to, bunker tanks, fuel heaters, lubricating oil tanks, fresh water generators, cargo systems, cofferdam spaces and domestic purposes. Steam boilers and exhaust gas waste heat recovery units are specified below. However, alternative methods of waste heat recovery for both main and supplementary heating may be proposed, subject to the Purchaser's approval.

16. Steam Boilers and Waste Heat Recovery Units

Low pressure steam for cargo, hotel and engine room services shall be generated by two x 60% oil fired steam boilers (based on 100% being the Builder's maximum calculated steam demand) and two main engine exhaust gas Waste Heat recovery Units (WHU) of the smoke tube type design with special consideration to the avoidance of soot deposits and shall have a maker's fouling margin of at least 10%. Particular attention is to be given to good design of the exhaust gas uptakes allowing for effective gas flow and adequate feed water through the waste heat units.

The boilers shall be controlled from the ECR, but also have a local control facility for emergency operation at the firing platform. For remote operation see, **Section 26**. Steam pressure control of the boilers shall be modulated, not on/off control. The water level in the boilers shall be automatically controlled by a feed water control valve.

The steam space of the boilers shall be arranged as the steam separator for the exhaust gas waste heat recovery units. At main engine NOP the steam space for one boiler shall be sufficiently sized to handle the output from both exhaust gas Waste Heat recovery Units.

Boilers and exhaust gas waste heat recovery units shall be fitted with power operated soot blowers as determined by Maker.

The main isolating valves for the steam and feed water connections to the boilers and exhaust gas waste heat recovery units shall be paired, as primary and secondary block valves for securing the boiler, as shall other essential valves such as the shipside overboard blow down valves.

The WHUs shall be capable of providing in excess 110% of the total heating requirements with the main engines running at NOP, without excessive soot fouling or power cooling of exhaust gases. The exhaust gas waste heat recovery units shall be capable of withstanding dry firing at any engine load. All heating surfaces shall have inspection facilities.

The boilers shall be provided with rotary cup burners.

Water and steam cleaning systems shall be provided for heating surfaces. The water washing soot-collecting tank for the WHUs shall be of sufficient size to accommodate two complete water washes of both WHUs. The soot collecting tank shall have a weir separating arrangement. Drain from the main engine exhaust gas pipe shall be led to the bilge water holding tank through a soot collecting tank, and drains from other exhaust gas pipes shall be led to the bilge through the water seal at the near scupper.

Innovative proposals from the shipyard to maximise waste heat recovery and efficiency will be considered.

17. Steering Gear

Steering gear of the four-cylinder, two ram, electro-hydraulic type shall be provided as indicated below.

The Carrier shall be fitted with twin rudders, each rudder shall be provided with two separate hydraulic circuits integrated and having isolation valves. Each of the two separate hydraulic circuits shall have one 100% pump unit, consisting of a variable displacement hydraulic oil pump and a single speed totally enclosed fan cooled motor (IP 44). One 100% unit shall be operating while the other 100% unit will be standby. The system shall be arrange so that in the event of loss of hydraulic fluid from one power hydraulic system the loss shall be detected that the defective system shall be automatically isolated so that the other system remains operational.

Each circuit shall be capable of moving the rudder from 35 degrees on one side to 30 degrees on the other side in 28 seconds with the Carrier at maximum speed and design draft. Maneuvering at low speeds shall be enhanced by either an increased rudder angle or use of a high lift rudder cross-section.

One set of steering gear controls shall be supplied from the emergency switchboard. In the event of a twin screw arrangement (see Modules C1 and C2), the two steering gear controls shall be linked for normal operation. The relevant angle of the two rudders shall be adjustable from the steering control panel on the wheelhouse. Also, the controls shall allow for independent operation in the event of one screw being out of service.

Suitable arrangements shall be provided to ensure good working access to the steering machinery and controls. These arrangements shall include raised walkways with handrails and open GRP gratings, including access from engine room to steering gear.

Hydraulic storage tanks shall be provided with suitable filling connections from the main deck area and be fitted with a simplex filter of suitable mesh size.

A telephone booth shall be installed adjacent to the emergency steering control stand. A hands free head set (telephone set) with extended cable to be provided for communication with bridge when operating emergency steering

ISO 4406:2017 "Hydraulic fluid power - Fluids - Method for coding the level of contamination by solid particles."

ISO 12669:2017 Hydraulic fluid power -- Method for determining the required cleanliness level (RCL) of a system

ISO standard 4406:2017 shall be followed when commissioning the hydraulic system(s), particularly with regard to electronic particle counting.

Cleanliness shall be to ISO 12669:2017 or the Maker's standard, whichever is the more onerous. Electronic particle filtration shall be used during commissioning.

18. Workshop and Stores

The workshop areas shall be air conditioned and soundproofed. The main workshop shall be equipped with:

a) One lathe, length between centers 2,000 mm and height of centre 400 mm with all necessary cutting tools, including a 4-jaws chuck, face plate, free end steady. Lathe is to be fitted with a chuck guard that prevent access to the chuck and workpiece when in position. When the guard is lifted the electrical interlock switch is activated preventing operation of the lathe.

b) Combination multi-purpose boring, milling machine with all necessary accessories and cutting tools. Suitable guard preventing access to all rotating parts to be fitted.

c) Shaping machine with 600 mm ram stroke.

d) Pedestal drilling machine with the necessary chucks and drill up to 38 mm. Robust telescopic type guard to be fitted to all drilling machines. 'Dead Man' footswitch and DC injection braking system to be fitted.

e) 16 mm bench drilling machine with the necessary chucks and drills up to the maximum size. Robust telescopic type guard to be fitted to all drilling machines. 'Dead Man' footswitch and DC injection braking system to be fitted.

f) Pipe threading machine with all accessories.

g) Pipe bending machine for pipes of 100 mm diameter or less.

h) Sawing machine with 150 mm stroke capable of cutting 200 mm diameter round bar and 200 mm x 200 mm square bar. Spare blades shall be supplied.

i) Pedestal grinder to take 300 mm diameter wheels with a spare set of grinding wheels and one 200 mm pedestal grinder for tool use, with spare wheels.

j) An abrasive wheel-cutting machine with spare abrasive wheels.

k) Oxy-acetylene (bottles outside the engine room) welding equipment with all accessories, cabinet of welding tools and spare gas bottles.

l) Two welding bays (one for stainless steel and one for other welding) with fire proof curtain, extraction/exhaust fan, and bench shall be provided. The welding bays shall be protected by a fire detector that can be isolated by a bulkhead mounted timer switch. High capacity exhaust fans shall be fitted for the welding bay. Capacity should be such as to ensure 1m/s air velocity in any part of the welding area. Noise levels shall be assessed with fan running. No electric cables or combustible material shall be installed directly below this hot work space.

m) Plasma arc cutting set for up to 12 mm plate thickness.

n) Laboratory for water analysis fully equipped for 6 months operation.

o) Benches with three 150 mm and two 100 mm vices, racking systems for tools, cupboards, and drawers for ready use materials.

p) Consumable stores and high quality tools for 6 months period. Full inventory shall be supplied.

q) Fuel valve test station and disassembly facilities with all necessary tools, oil catchment and drainage requirements, suitable for work on both main engine and generator fuel valves – applicable for both gas and liquid fuel equipment. A separate fuel test room shall be provided as part of the workshop facilities. The fuel room shall be connected to the workshop spot cooling air conditioning system with adequate air circulation.

r) Working area equipped with all necessary stands/supports and lifting facilities required for the overhaul and assembly of all normally maintained engine components from both main engines and dual fuel generators.

s) Induction type bearing heater.

t) Manual Metal ARC electric welding sets

Traveling hoists (with brakes and locking arrangements) and rail systems shall be provided which are specifically arranged for the handling, turning and stowing of all major items of main engine and dual fuel generators.

In designing the working areas and the facilities to be provided, full allowance is to be made for very low manning levels and the essential provision of simple handling facilities and good ergonomic arrangement. These shall be subjected to Purchaser approval.

All machines shall be fitted with adjustable guards of substantial construction (and the required safety interlocks) to protect personnel from cutting tools and rotating parts. An emergency stop dead man foot switch shall be fitted to each machine and a general trip system for all machines shall be installed with push buttons at three strategic locations in the workshop including at each entrance door. .

A workshop, separate from the main workshop, shall be provided for electrical work. Within this workshop a separate area shall be provided for instrumentation and electronic maintenance and testing which shall be fully equipped with all necessary equipment, including electrical test panel and the calibration units used for all the instrumentation on board. Space shall be provided for the holding of electrical/electronic spare parts, in suitable secure storage units.

Electric Arc welding machine(s) The welding unit shall incorporate direct current facilities only, with an open circuit current limiter (less than 42V) and shall be supplied with at least one ten-metre long ‘earth’ cable.

A welding ring main, supplying socket outlets in the machinery space and in the workshop, shall be permanently connected to the output side of a fixed welding unit by lead and return cables.

Special ventilated stores shall be provided for paint, boiler treatment and cleaning chemicals, and lubricating oils and greases. Where appropriate, a dedicated laboratory shall be provided for isolation of toxic chemicals used in fluid analysis.

Lock-up storage spaces shall be provided for spare gear and stores, to prevent unauthorized access during port and repair yard visits. Stores shall be mechanically ventilated and provided with suitable shelves, racks, and cupboards in sufficient quantity to provide secure covered storage for all spare gear on board at time of delivery to Purchaser. Safe and easy access to all spare parts shall be provided.

Access to and handling arrangements inside all storage areas shall be adequate and approved by Purchaser.

19. Lifting Equipment

Engine room cranes are to be provided for overhaul of the main engines. The engine room cranes shall be able to plumb the storage area for heavy spare parts as well as the main engine.

The engine room cranes shall be provided with a clear route to reach the lowest floor plates.

Suitable lifting arrangements shall be provided to enable the main engine pistons to be safely turned and dismantled for maintenance purposes.

Auxiliary machinery trolley beams shall also be provided for the main engine turbochargers (where not serviced by the engine room crane(s).

All main and auxiliary machinery, including electric motors, pumps and steering machinery shall be served by a comprehensive lifting rail system, which shall allow the items of machinery to be removed from the machinery spaces, transported to the workshop, and taken off the Carrier. These arrangements shall be demonstrated to the Purchaser. Where it is necessary to transfer an item of machinery from one rail system to another, adjacent walkway shall be designed to support the weight of the relevant item of machinery. Suitably rated, marked, tested, and certified lifting eyes (for equipment 20 kg and over) shall be fitted (welded) above all major machinery, including heat exchangers, to allow overhaul and lifting.

Auxiliary machinery trolley beams shall include, but not be limited to, the following:

a) Purifier room
b) Main and auxiliary machinery rooms (main engines, generators, etc.)
c) IGG fans
d) GCU fans
e) Sea water pumps and suction manifold
f) Fresh water pumps
g) Over intermediate shafts

Suitable chain blocks shall be provided with trolley ways, brakes, and/or locking-off arrangements.

A number of lightweight chain blocks shall be provided for general lift use.

All lifting lugs, trolley beams shall be load tested, certified and marked by a specialist firm (to be selected by the Builder and approved by the Purchaser) for inclusion in the Carrier's 'Register of Lifting Equipment' which must be up-to date prior to Carrier acceptance.

Arrangements shall be provided to allow removal of the diesel generator engine.

Arrangements shall be provided to allow removal of the diesel generator alternator.

20. Floors, Gratings and Ladders

Open gratings shall be provided on lower floor level, around boilers and in funnel casing, as appropriate to propulsion requirements. Solid high grip profiled plate shall be provided at, e.g., boiler firing platforms, around diesel engines and other regular maintenance areas.

Vertical ladders shall only be used where it is difficult to arrange inclined ladder, with inclination approximately 55 degrees and of sufficient width. Ladders shall have dust guard, non-slip steps, and side plates.

Hand rails with necessary stanchions and fastenings shall be provided for ladders and platforms around machinery and where required for safety. Where required for maintenance, handrails shall be removable, but firmly secured. Coamings on decks with solid floors shall not be cut, but shall have a step over, to maintain integrity of the coaming.

21. Stores

Lock-up storage spaces shall be provided for spare gear and stores, to prevent unauthorized access during port and repair yard visits. Stores shall be mechanically ventilated and provided with suitable shelves, racks cupboards in sufficient quantity.

Sufficient floor space, racks and securing arrangements are to be provided for main engine spare parts, e.g., cylinder heads, exhaust valves, liners, pistons, etc., and maintenance tools.

22. Spare Parts

22.1. Onboard Spares

As a minimum, spare parts (for a twenty four month operational period assuming 17,500 running hours for every piece of equipment) and tools shall be provided in accordance with the recommendations of the Makers. The spares from each Supplier shall be complete and matched against the maintainance requirements within the Supplier's documentation. 'Starter' or Commissioning' spares will not be acceptable.

In addition, the spare parts and tools listed below and those specific to the propulsion system and listed in Modules C1 and C2 shall be provided.

Depot spares shall be as listed separately in the Appendix A attached to this Module.

The Carrier shall be delivered with a full inventory of "onboard" spares . The Builder shall provide a record of and replace all spares used during periods prior to the delivery.

"Spare Parts List" shall be submitted for approval with the relevant drawings, and shall include spare parts covering all areas of the ship, including the engine room, deck, cargo and accommodation. Upon Carrier delivery, a current version shall be provided on a discipline basis in PDF format. These Spare Parts Lists shall include spares from all makers, whether or not they are included on other plan approval submissions or final drawings.

Spares parts (including depot) requiring Classification Society certification shall be supplied with the appropriate certification.

Hydraulic tools shall conform to the European Pressure Equipment Directive and shall be supplied directly from the Original Equipment Manufacturer (OEM).

All hydraulic tools shall be provided with a test certificate which clearly states the maximum working pressure of the assembled tool system.

The Builder and Makers shall provide equipment manuals and spare part lists in electronic format to facilitate uploading of this information by either the Builder or the Purchaser into the Carrier's Shipboard Administration System (SAS) (refer to **Section 34).** Spares lists shall be incorporated in the planned maintenance program and in a computerized stock control program.

The onboard spares shall be delivered and arranged onboard before the Carrier's delivery, using the stowing facilities provided by the shipyard, and following a stowage plan agreed by the Purchasers. The spare parts shall be stored in an enclosed area on shelves, or racks, allowing storage of parts in boxes or drawers. Spare parts for instrumentation and electronic equipment shall be stored in a special, air-conditioned storage area.

All parts shall be packed individually, or by small groups of similar parts in airtight sealed packing including desiccant for long term protection and with the identification tag attached.

Special tools for equipment such as main engines, generator engines and purifiers shall be provided as listed in the Suppliers documentation and mounted on Builder provided shadow boards or, where not practical, alternative mounting supports.

Upon completion of final commissioning, all final issues of software for each system (application and system) complete with installation documentation are to be copied and stored onboard the Carrier in a suitable secure fireproof location. Installed software shall meet ISO/IEC 25010:2011.

22.1.1. Hull Spares

Windlass (for 2 sets):

2 - Sets bearing metal for each size

Mooring Winches:

1 - Set bearing metal of each size

25% working O-ring seals for each type

Life Boat Davits and Winches:

1 - Set bearing for winch for each type

1 - Set bearing for motor for each type

1 - Set fall wires

Mooring Ropes:

2 - Mooring ropes (275 m length)

4 - Mooring Tails (11 m length)

Anchor Cable:

2 - Kenter shackles

1 - Taper pin for anchor shackle

5 - Taper pins for kenter shackles

1 - Fore runner, complete

1 - Shackle punch

1 - Pin Punch

4 - Chain hook

2 - Anchor hammer

1 - Disengaging tool for kenter shackle

Manifold/Provisions/Engine Parts Cranes:

10% Bearings including sleeves

1 - Spare hoist wire per crane type

1 - Spare set of hydraulic hoses with fittings for each type

22.1.2. Cargo Spares

Cargo Pump:

1 - Set impeller and inducer

2 - Sets bearings

Spray Pump:

1 - Set impeller and inducer

1 - Set bearings

Fuel Pump (where applicable):

1 - Set impellers and inducer

1 - Set bearings

High Duty/VR Compressor:

1 - Set bearings and shaft seal assemblies

Low Duty/BOG Compressor:

1 - Set bearings and shaft seal assemblies

Safety Valve:

1 - Overhauling kit for each type and size

Cargo System Butterfly Valves:

3 - Metallic seals for each size of valve

3 - Hydraulic actuators

3 - Machinery Part Spares (sealing gasket, shaft sealing kit, and disc)

22.1.3. Shafting and Propeller Spares

Main Shafting:

1 - Set of O-rings and packing for the stern tube sealing

1 - Set per shaft of main thrust bearing pads (if not included in the specific propulsion option)

1 - Intermediate shaft bearing shell set

Propeller:

1 - Propeller Packing

22.1.4. Auxiliary Equipment Spares

Auxiliary Machinery and Equipment:

Spare parts for the following machinery and equipment shall be supplied as per the Maker's standard:

Steering gear

Life boat engine

Refrigerating plant for ref. provision store - over those specified for refrigeration and AC compressors

Refrigerating plant for air conditioning system - over those specified for refrigeration and AC compressors

Hydraulic oil pump unit for forward F.O. pump (where applicable)

Accommodation ladder winch

Sewage treatment unit

Ventilation fan

Lift

Hydraulic oil pump unit for deck machinery

Other:

1 - Complete spare unit (excluding motor) for each type of pump of 1.5 kW & below.

1 - set of each kind and size strainer filter for L.O. system

1 - Spare actuator for each size of main engine room valve

Dual Fuel Generator Engine:

Crankshaft:

2 - Main bearing shells for each kind

2 - Sets of bolts and nuts for one main bearing cover

Cylinder cover and valves:

4 – Complete set of assembled cylinder covers, valves, and injectors

½ - Complete set of fuel injectors

4 - Sets of intake valves complete, spindles and springs for one cylinder

4 - Sets of exhaust valves complete, spindles and springs for one cylinder

1 - Set of indicator valves with cylinder safety valves for one cylinder

2 - Sets of starting valve springs for one cylinder

2 - Sets of starting valves complete for one cylinder

2 - Sets of indicator valve springs for one cylinder

Cylinder liner and piston:

2 – cylinder liner with set of seals

2 – pistons

4 - Set of piston rings for one cylinder

4 - Set of oil ring for one cylinder

2 - Set of piston pin for one piston with retaining clips

Connecting rod:

2 - Sets of crank pin metal with bolts and nuts for one cylinder

Fuel injection pump:

2 - Sets of liquid fuel injection pump complete

Liquid fuel injector:

4 – Injectors complete

Gas admission valve:

4 – valves complete

Electronic Governor:

1 – Complete spare

1 - Set of maker's standard spare parts for one governor

Turbocharger:

1 – Turbocharger complete (assembled or in parts as per Maker’s standard)

1 - Complete bearing set for one dual fuel generator

3 - Sets of labyrinth packing bush for one turbocharger

Others:

1 - Complete set of fuel oil and fuel gas high pressure pipes with joints for one cylinder

1 - Set of complete lubricating oil adjusting and pressure relief valve

1 - Thermometer of each kind
2 - Complete sets of oil seals and mechanical seals for one engine
1 - Set of ball or roller bearings of each size (excluding those specified above)
2 - Sets of O rings and springs of each size for one engine (excluding those specified above)
1 - Set of special packing and gasket of each size for one engine (excluding those specified above)
10 - Bolts and nuts of each size (excluding those specified above)

Steam Generating Plant:

Oil Fired Boiler:

1 - Spring for each type of safety valve
1 - Set of main feed water check valve discs
4 - Gauge sets of glass for glass water gauge
4 -G sets of gland packing for glass water gauge
10% of handhold plugs for one boiler
100% of handhold gaskets for one boiler
100% of manhole gaskets for one boiler
5% total number of generating and wall tubes for one boiler
10% total number of each size inspection hole cover with fitting
200% of gaskets for valve for one boiler
100% of peep hole glasses
40 kg castable refractory
40 kg plastic refractory

Burner:

2 - Bodies (without atomiser and cap nut) per burner fitted
200% of working number of atomisers and cap nuts for normal use
4 - Atomizers and cap nuts for cold start use
2 - Flame scanner's elements

Soot blower:

1 - Nozzle and lance tube for long blower
1 - Each size multi nozzle elements for long and rotary blower
1 - Set of cam follower for rotary blower

Combustion control:

1 - Pressure gauge for each type
2 - Sets of spares for drive unit including packing, gasket and O ring1 - Printed circuit board for each type

Feed water regulator:

1 - Set of spares for each feed water control valve including diaphragm, spring, packing and gasket

Remote level indicator:

1 - Printed circuit board for each type
1 - Push button switch with lamp
2 - Sets of lamps

Exhaust Gas Economizers (EGE):

100% of gaskets for manhole

1 - Relief valve spring and disc

2% of generating tubes for each size (dependent on Maker)

Emergency Diesel Generator Engine:

1 - complete set of O-ring seals

1 - connecting rod bearing

1 - thrust race

1 - oil pan gasket

1 - main bearing

1 - set of piston rings for one cylinder

1 - sleeve bearing bush

½ - set of fuel injectors for one engine

1 - set of fuel pumps for one cylinder

1 - set of main bearing shells for each kind

Control, Ship Service, and Starting Air Compressors and Dryers:

For each type of reciprocating compressor:

1 - Crank shaft bearing

1 - Set of crank pin bearing metal for one cylinder

1 - Set of piston pin bearing metal for one bearing

1 - Set of piston rings for one cylinder

1 - Set of bolts and nuts for one cylinder cover

1 - Set of suction valves and discharge valves assembly for each compressor, all cylinders

1 - Spring of each size (including safety valves)

1 - Packing of each size and type

1 - Glass of each size and type

1 - Set V belt for starting air compressor

For each type of screw compressor:

1 - Set V belt

1 - Seal kit for each type of valve

O-rings

Membranes for control valves

1 - Each type solenoid valve

1 - Temperature sensor

1 - Pressure sensor

1 - Vacuum switch

Elastic ring for coupling

1 - Set of shaft seals

1 - Each type of thermostat element

Dryers:

1 - Set of spares for each type of air dryer as recommended by the manufacturers

Refrigerating and Air Conditioning Compressors:

Piston Type: 1 Set of bearings, seals valves, pistons, piston rings and liners for each size.

Screw Type: 1 set of bearings, seals, and valves for each size

Additional items below as applicable:

1 - Set V belt
1 - Seal kit for each type of valve
O-rings
Membranes for control valves
1 - Each type solenoid valve
1 - Temperature sensor
1 - Pressure sensor
1 - Vacuum switch
Elastic ring for coupling
1 - Set of shaft seals
1 - Each type of thermostat element

Emergency Air Compressor:

Compressor:

1 - Crank shaft bearing
1 - Set of bearing shells
1 - Set of piston rings
1 - Set of bolts and nuts for cylinder cover
1 - Set of suction valves and discharge valves assembly
1 - Spring of safety valve
1 - Packing of each size and type
1 - Set V belt

Engine:

1 - Bearing shell
1 - Set of piston rings
1 - Set of inlet valve and exhaust valve assembly
1 - Spring of each size and type
1 - Packing of each size and type
1 - Set of fuel injector, injection nozzle, and high pressure pipe

Ballast Water Treatment Plant:

Centrifugal pumps:

1 – set of impeller per type

1 – set of bearings per type

1 – set mechanical seal

Cell:

1 – Spare cell complete

Rotating Pumps (1.5 kW & over):

Centrifugal pumps:

For each type and size of pump:

1 - Impeller shaft complete with impeller but excluding coupling and bearing

1 - Set of bearings for one pump

1 - Set of casing ring for one pump

1 - Set of coupling bolts, nuts, and rings for one pump

1 - Set of shaft seal for one pump

1 - Rotor shaft complete with rotor but excluding driving face for vacuum pump, if fitted

1 - Liner for vacuum pump (if fitted)

1 - Hot water circulating pump complete with motor

1 - Set of each kind of spring (if fitted)

Screw pumps:

For each type of pump:

1 - Set of rotors for one pump

1 - Set of bearings for one pump

1 - Spring for relief valve

1 - Set of shaft seals for one pump

1 - Set of coupling bolts, nuts, and rings for one pump

Gear pumps:

For each type of pump:

1 - Set of shafts & gears for one pump

1 - Set of bearings for one pump

1 - Spring for relief valve

1 - Set of shaft seals for one pump

1 - Set of coupling bolts, nuts, and rings for one pump

Snake pumps:

For each type pump:

1 - Stator
1 - Set of bearings for one pump
1 - Set of shaft seals for one pump
1 - Set of V belts for one pump
1 - Spring for relief valve

Rotary vane pumps:

For each type and size of pump:

1 - Set of manufacturers' recommended spares

Reciprocating Pumps:

For each type and size of pump:

1 - Set of bucket ring for one pump
1 - Set of suction and discharge valve for one pump
1 - Relief valve spring for one pump
1 - Set of crank pin shells and bolts for one pump
1 - Set of bearing for one pump
1 - Set of gland packing/seal for one pump
1 - Set of liners (if applicable)

Oil Purifiers:

For each type and capacity of purifier:

Bowl:

1 - Main seal ring
1 - Disc
1 - Set of O-rings for each type

Frame:

1 - Brake lining
1 - Set of set screw

Cover:

1 - Set of O-rings for each type

Shaft:

1 - Set of ball bearings for each type
1 - Set of friction block

Others:

As recommended by the manufacturer

Fans:

Engine room ventilating and exhaust fans:

1 - Set of bearings for each size of motor

Fuel gas piping duct exhaust fans (as applicable for the selected propulsion option):

1 - Grid-member for fork coupling
2 - ball bearings
1 - Set of packing for stuffing box
1 - Set of bearings for each size of motor

Heat Exchangers:

Shell and tube type heat exchangers:
For each heat exchanger:

2% of total number of cooling or heating tubes
1 - Set of water chamber packing for feed heater (as applicable)
1 - Set of gasket and packing
1 - Spring of relief valve for each type
1 - Set of water level gauge glass

Plate type heat exchangers:

4 - Spare plates of each type and size, with gasket

Oil heaters:

1 - Set of gasket
1 - Spring for relief valve

Distilling Plants:

For each plant:

4 - Spare plates of each type and size with gaskets
1 - Set of level gauge glasses complete with packing for one plant

(For pumps, see centrifugal pumps section).

Piping:

Reducing and control valves:

1 - Set of diaphragms and bellows for each size and type

1 - Set of springs and piston rings for each size and type

1 - Set of special packing and gaskets for each size and type

Relief valves:

1 - Set of springs for each size and type

Filters and strainers:

1 - Set of elements for each size and type

1 - Set of cover gaskets for each size and type

Others:

1 - Set of principal springs for each size of part, not mentioned above

1 - Packing for each 10 packings

1 - Set of spare actuators for each size of remote operating valves in engine room

22.1.5. Electrical Part Spares

Alternator:

The following list shall be based on the total equipment of each type and size supplied by each Maker per Carrier.

1 - Bearing lining for each 4 or less

1 - Bearing lubricant seals for each 4 or less

1 - Space heater element for each 10 or less

1 - Rotating rectifier generator complete for each set type

1 - Resister for exciter for each 4 or less

1 -Automatic voltage regulator for each size of generator installed

Switchboard and Distribution Board:

1 - Main contact and arcing for each size installed
contact - corresponding to 10 sets of each type breaker or contactor

1 - Auxiliary contact set for 10 sets or less

1 - Attachment of auxiliary set for 10 sets or less contact

Fuse element (non-renewable) - Same as use (1 for 1)

1 - Molded case circuit for each 10 or less (max. 5) breaker

1 - Operating and shunt coil for each 6 or less

1 - Resister element for each 10 or less (max. 4)

Bulb for indicating lamp - Same as use (1 for 1)

1 - Globe for indicating lamp for each 10 or less

5 - Fuse remover

1 - Auxiliary relay for each 10 or less

1 - Operating switch for each 10 or less

1 - Timer relay for each 10 or less, up to 4 a maximum
1 - Transformer for control for each type circuits
1 - Protection relay for each 10 or less
1 - Electronic module/PCB for each type (2 for more than 5 of same type)

HV Switchboard:

1 - Circuit Breaker of each size fitted
1 - CT transducer of each size fitted
3 – Fuses of each size fitted
4 - Auxiliary contactors
4 - Auxiliary relays
4 - Auxiliary Timer relays
1 - MCCB complete for each type fitted
3 – Spring Charge Motor
12 – Signal lamp for each type fitted

Electric Motor:

Spare electric motors – 1 for each size/type of electric motor up to 30kW
Bearing sets - 1 for each 4 of same size or less

Group & Individual Starter:

1 - Main contactor set for each 6 contactor or less
1 - Auxiliary Contactor for each 6 contactor or less
1 - (Aux. relay) 10 contactor or less
1 - MCCB for each 10 or less
1 - Coil for MCCB (shunt trip for each 10 or less or under voltage)
Fuse element (non-renewable) - Same as use (1 for 1)
Bulb for indicating lamp - Same as use (1 for 1)
1 - Globe for indicating lamp for each 10 or less
1 - Thermal type over load for each type relay
1 - Timer relay for each 6
1 - PCB/electronic module for each 10 or less
1 - Control Transformer for motor for each type/size control circuit
1 - Current limiting fuse circuit unit for each 3 circuit units or less
1 - Resister element for each 10 or less (max. 4)
1 - Spring for each 4 or less

Lighting Fixture:

1 - Fluorescent tube for each 10 or less

1 - Glow lamp (Starter) for each 10 or less
1 - Incandescent lamp bulb for each 10 or less
1 - Floodlight lamp bulb for each 10 or less
1 - Plastic globe for each 20 or less (max. 10)
1 - Glass globe for each 10 or less (max. 10)
1 - Socket for fluorescent for each 20 or less (max. 10) and incandescent lamp
1 - Switch (non water-proof type) for each 20 or less (max. 5) type
1 - Switch (water-proof type) for each 20 or less (max. 5)
1 - Receptacle (non water-proof type) for each 20 or less (max. 5)
1 - Receptacle (water-proof type) for each 20 or less (max. 5)
1 - Plug (non water-proof type) for each 2
1 - Plug (water-proof type) for each 5 or less (max. 5)
1 - Ballast for fluorescent for each 20 or less
1 - Bulb for navigation lamp - Twice for use (2 for 1)
1 - Socket for navigation lamp for each type
Bulb for indicating lamp - Twice for use (2 for 1)
1 - Globe for indicating lamp for each 10 or less
1 - Socket for indicating lamp for each 20 or less
1 - Relay for each 10 or less
1 - Switch for navigation for each type lamp circuit
Fuse element (non-renewable) - Same as use (1 for 1)
Bulb for day signal lamp - Twice for use (2 for 1)
1 - Globe of Carrier signal lamp for each type and color

<u>Internal Communications:</u>

1 - Spare circuit board of each type fitted to the automatic telephone exchange
1 - Spare circuit board of each type fitted to the intrinsically safe telephone system
1 - Spare circuit board of each type fitted to the ship/shore communication system
Standard Spares of Maker's for each item of equipment

<u>External Communications:</u>

1 - Spare circuit board of each type fitted to the MF/HF radio installation
1 - Spares of maker's standard for each equipment

<u>Navigation Equipment:</u>

1 - Spare circuit board of each type fitted to the radar installation
1 - Spare TFT screen of each type fitted to the radar installation
1 - Spare TX/RX unit for each radar
1 - Spare magnetron of each type fitted
1 - Spare circuit board of each type fitted to the Doppler log

1 - Spare circuit card of each type fitted to the echo sounder
1 - Spares of Maker's standard set for each equipment

Storage Battery:

1 - Connection bar for each 10 or less
1 - Fixture of connection bar for each 10 or less
1 – UPS unit for each type fitted

IAS:

2 years operational spares as recommended by the Maker but shall include, as a minimum, the following:
1 - Power Supply Unit for each size fitted
2 - Analogue Input card (Current)
2 - Analogue input card (temperature)
2 - Analogue Output card (current)
2 - Digital I/O card for each type fitted
1 - Operator station keyboard
1 - Operator station display
1 - Multiport fibre optic converter
1 - Single point fibre optic Converter
1 - Watch Cabin Unit
2 - Serial isolated adapters
1 - Relay (ordinary type) for each 10 or less (max. 20)
1 - Relay (non contact type) for each 10 or less (max. 5)
1 - Socket for relay for each 20 or less (max. 5)
1 - Switch for each 10 or less
1 - Push button switch for each 10 or less
2 - Bulb for indicating lamp (max. 100)
2 - Globe for indicating lamp for each 10 or less (max. 10)
2 - Socket for indicating lamp for each 10 or less (max. 10)
Fuse element - Same as use (non-renewable)

Controls and Instrumentation Equipment:

Instrumentation:

1 - Instrument equipment for each 10 or less outside cargo tank (temperature, level, pressure, and etc.)
1 - Electronic box for radar set type level gauge

Electronic Systems:

1 - Spare circuit board for each type (2 for more than 5 of same type)

Control Valves (including cargo, ballast and bunkering valves):

Plug, seats, gasket, spindle - 1 for each size
Gland packing, diaphragm, nuts, bolts, and actuator components

Flow Meters:

Flow meter - 1 for each type/size

23. Machinery Part Special Tools

23.1. Shafting and Propeller

1 - Set of spanner for propeller nut
1 - Set spanner for coupling nut of each kind
1 - Set of Maker's standard special tools for the stern tube sealing

23.2. Dual Fuel Generator Tools

The following maintenance equipment shall be included but not limited to:

a) A complete set of maintenance tools as per manufacturer's standard.
b) An exhaust valve grinding machine for re-facing of the generator engine valve and valve seat.
c) Test pumps for generator engine liquid and gas fuel valves.
d) All special tools/handling devices as listed in the manufacturer's maintenance manuals (any special hydraulic power devices and attachments to be supplied in duplicate).

Additionally, the following items to be supplied where they are not listed as manufacturer's standard:

1 - Polishing tool for intake and exhaust valves
1 - Nozzle cleaning tool
1 - Nozzle test pump
1 - Deflection gauge
1 - Thickness gauge
1 - Cylinder bore gauge (inside micrometer)
1 - Cylinder liner position gauge
1 - Micro meter for crankshaft
1 - Maximum pressure indicator
1 - Set of special tools for turbocharger
1 - Set of cleaning tool for blower of turbocharger
1 - Set of blanking pipes for turbocharger
2 - Sets of hydraulic oil pumps (two sizes)

1 - Set of high pressure hoses
1 - Set of oil pressure ram assembly
1 - Set of hydraulic oil jack cylinders

23.3. Emergency Diesel Generator Engine

1 - Polishing tool for intake and exhaust valves
1 - Nozzle cleaning tool
1 - Nozzle test pump
1 - Deflection gauge
1 - Thickness gauge
1 - Cylinder bore gauge (inside micrometer)
1 - Cylinder liner position gauge
1 - Bridge gauge for crank shaft
1 - Maximum pressure indicator
1 - Set of special tools for turbocharger
1 - Set of cleaning tool for blower of turbocharger
1 - Set of blanking pipes for turbocharger

23.4. Steam Generating Plant

Auxiliary Boiler (for one Carrier)
1 - Set of spanners each for glass water gauge, manhole, handhole and safety valve
1 - Set of tube plugs, repair and renewal tools with hammer
24 - for each kind of tube plugs
100% of safety valve gags per boiler
1 - Set of lapping tools for valves
1 - Set of tools for cleaning of tube external and drum internal surface
1 - electric portable igniter
1 - Set of tools for burners (cleaning base, vice and burner wrench)
1 - Set for of removal tools for economiser welding part
1 - Set of tools for soot blowers
1 - standard pressure gauge
1 - Set of repairing tools for refractory
1- set of portable washing device with hose and cable

23.5. Auxiliary Machinery and Equipment

<u>Control, Ship Service, and Starting Air Compressors:</u>
For each type of reciprocating compressor:
1 - Piston set nut removing tool for control air compressor
1 - Piston rod cap for control air compressor
1 - Piston removing tool for control air compressor
For each type of rotary compressor:

1 - Set of Maker's standard special tools

For each type Purifier:

1 - Dismantling stand

1 - Bowl nut spanner

1 - Disc nut spanner

1 - Cap nut spanner

1 - Lifting tool for vertical shaft

1 - Lifting tool for bowl body

1 - Set of other overhauling tools including jacks, push bolts, etc.

Heat Exchanger:

Shell and tube type cooler, heater and distilling plant:

1 - Set of tube expander for each tube size

1 - Set of cleaning tool for each tube size

1 - Set of overhauling tool for each tube size

Other Auxiliary Machines and Equipment:

Special tools - According to Maker's standard.

23.6. Machinery Part General Tools and Outfits

Tools and outfits for required for general repair and maintenance and services of machinery and equipment, such as mechanical, electrical/electronic measuring instruments, working tools, general tools shall be supplied and packed in steel boxes and stowed in engineer's workshop. Lists for such equipment as well as repair consumables and other required materials shall be included in the ship Specification.

24. Electrical Systems

24.1. General

In addition to compliance with the standards specified in Section 1, and in IEC publications 60092:2018 and 60533:2015 RLV, all materials and equipment shall be of good quality and shall have been proven suitable for marine application on board LNG Carriers for unrestricted worldwide service. In addition, all equipment shall comply with a recognized national or international standard, revised to comply with IEC 60092- 101 5th Edition 2018 for ambient conditions.

All skid-mounted or packaged equipment that does not fully comply with this specification shall be subject to Purchaser's approval on a case to case basis.

The electrical equipment shall be sited so as to obtain maximum protection from accidental damage, consistent with accessibility for servicing and safety of operation. Sufficient space shall be allowed for opening doors, removing covers and, where applicable, withdrawing equipment from its housing. There shall be sufficient room for personnel to work on the equipment in situ.

The electrical equipment shall also be sited so as to reduce to a minimum the risk of damage due to excessive heat or leakages of oil, water, steam, gases, etc, from pipes, equipment, and containers, within the same or adjacent compartments. No piping shall be routed through dedicated electrical equipment spaces.

Electrical equipment location and all cable routing shall be installed in such a way that an explosion or fire in any switchboard, or electrical equipment room shall not prevent the Carrier from carrying out its normal operations, including cargo handling.

The hazardous areas on the Carrier shall be zoned in accordance with the requirements of the applicable IMO IGC regulations. Alternatively, IEC 60092-502 may be applied (subject to Class and Flag agreement and the Purchaser's approval) if sufficient advantages (to the Purchaser) can be shown from making the change.

All intrinsically safe, flameproof, increased safety and other safe type equipment shall be certified as such by an approved testing authority, coded, and tagged. All certified equipment shall be listed in a register. Certification details for all certified safe-type equipment (e.g., shunt diode safety barriers) shall be recorded by the Builder in a format agreed by the Purchaser.

Comprehensive control facilities and status information of the total supply and distribution network throughout the Carrier shall be presented within the IAS.

Within the Type Approval testing of the main switchboards and generators, a full sized sample, representative of each separate design assembly, shall have been subjected to a short circuit test at normal operating voltage by an approved testing authority to prove the design capability. Oscillograms and all relevant data shall be recorded and issued with the certificates.

The Builder shall submit to the Purchaser, for approval, details of load scheduling, selectivity calculations and short circuit fault calculations (in accordance with IEC 61363-1:1998 or latest version). These calculations shall be used to substantiate the rating and trip setting of generators, transformers, distribution cabling and switchgear and to show that the main electrical generation and distribution system is capable of providing and maintaining a high level of supply integrity under all conditions of operation. The ultimate responsibility for the correct sizing of equipment and cabling shall rest with the Builder.

All control circuits, including components such as relays, timers, and electronic control units shall be fail safe. No single fault shall result in complete loss of electrical power or loss of propulsion, steering, navigation, communication, or cargo discharge capability.

Except where approved otherwise, the supplies to all equipment and control circuits shall be switched and protected in each insulated pole.

The electrical installation shall be designed to minimize the effects of electromagnetic and supply interference. Sensitive equipment, which may be susceptible to interference, shall be designed to operate in the electromagnetic environment on the Carrier without degradation or limit on performance. Due attention shall be paid to harmonics generated in the electrical system when frequency conversion equipment is used. The builder shall submit a statement on the measures to be taken to fulfill these requirements, prior to design work being started. In addition, the builder shall demonstrate that the Total Harmonic Distortion (THD) is within the Class limits.

24.2. Electrical Power Generation

The electrical generating plant shall consist of a minimum of four (4) inline, four-stroke, trunk, dual fuel engine driven generators.

With the largest dual fuel engine driven generator not in service, the remaining dual fuel generators shall be capable of providing power for all of the Carrier's normal operations when both at sea and in port and in addition to meet port-in loaded and port-out loaded conditions with a load factor not greater than 85%. The port-in loaded and port-out loaded conditions, in addition to the reliquefaction options, the electric load shall include (a) the main engine aux blowers, (b) the GCU combustion air fans, (c) the hydraulic pumps for mooring and anchoring equipment forward and mooring equipment aft units and (d) the extra steering gear pumps.

The Electric Load Analysis (ELA) shall be provided for Purchaser's approval and shall, as a minimum, include the following conditions:

- Seagoing loaded
- Seagoing Loaded with excess BOG
- Seagoing Loaded one tank inspection
- Seagoing ballast
- Seagoing Ballast - Cool-down
- Seagoing Ballast - 1 Tank inspection
- Port-in Loaded (to include use of winches and windlasses)
- Port-out Loaded (and excessive BOG, as applicable)
- Cargo Loading
- Cargo Unloading
- Port Idle (both with and without cargo)
- At anchor - without cargo and with cargo and reliquefaction plant (partial or full as fitted) operating at 100% capacity

Note: to include use of Gas Delivery, Gas Disposal and Gas Recovery Systems when in loaded and, as applicable, ballast conditions

For Emergency Generator:

- Emergency Black out
- Fire
- Engine room Loss

Equipment listed shall be clearly marked as either continuous or intermittent load.

Detailed list of equipment (Maker, type, capacity, etc) used in calculating the ELA shall be provided to Purchaser with the ELA.

The following shall be submitted for Purchaser's review as part of the bid submission and thereafter for approval before detailed design work is started:

- An Electrical Load Analysis (ELA) covering all the identifiable operating modes, including:
  - Laden (including use of the GCU as part of the tank pressure control system)
  - ballast
  - port-in (to include use of winches and windlasses)
  - port-out (and excessive BOG, as applicable)
  - anchor
  - Loading
  - Discharging

Note: to include use of Gas Delivery, Gas Disposal and Gas Recovery Systems when in loaded and, as applicable, ballast conditions

- A capacitive fault current analysis.
- A one-line diagram of the system.

The Builder shall maintain a running record of all load changes and shall issue revised schedules and analyses if significant changes take place during the design, construction and commissioning of the Carrier.

24.3. Supply Systems

The main electric power generation and distribution system shall have sufficient capacity to meet all the Carrier's requirements in any operating mode, including/laden port-in, port-out (and excessive BOG, as applicable) conditions, with the largest capacity generator out of service and operating at a maximum load of 85%.

Where Carrier operating modes require two or more generators in parallel, it is to be ensured that with the loss of the largest single online generator, the sizing and loading of the generators is sufficient to prevent any overloading on the remaining generator(s) or loss of power.

The distribution network shall be designed and configured so as to ensure that the failure of a single supply and/or cable shall not prevent any of the Carrier's normal operations.

The electrical system in the main shall be of the insulated three phase, three wire and single phase, two wire, as appropriate. The yard shall carry out detailed capacitive fault current calculations for the proposed system. Should the level of fault current during normal operating modes exceed 5A, an earthed neutral HV distribution system (or alternative) shall be provided to limit earth fault current levels to below this value.

All galley and laundry equipment shall be supplied via an earthed neutral distribution system supplied via suitable isolating transformers.

All circuit breakers and switches on proprietary equipment for example socket outlets, light switches and protective devices intended for disconnection of electrical supplies, shall interrupt all poles (on insulated neutral systems only).

The following definitions apply:

a) All generators shall be considered as a source of power supply.
b) A supply is a feed from either the main or emergency power source.
c) Main (normal) supply is a feed which is connected direct to the Main Switch Board (MSB) or via the main distribution supply network.
d) Emergency (standby) supply is a feed that is connected directly to the Emergency Switch Board (ESB) or via the emergency distribution supply network.
e) Where equipment, etc is fed from multiple supplies then normal operational duty shall be considered to be from the main supply
f) Voltage levels over 1,000V are to be referred to as High Voltage (HV)

The electrical supply and distribution system shall incorporate the following:

a) HV electrical generators in the main machinery space shall be connected to two main switchboards (HVMSB) connected by bus-tie circuit breakers, each HVMSB installed in dedicated adjacent switchboard rooms, having an A60 fireproof bulkhead separating them.
b) The main switchboards shall provide power directly to cargo switchboards and large machinery consumers such as seawater circulating pumps, ballast pumps, etc. In the case of odd numbers of

generators being provided then one generator shall be capable of being connected to both switchboards.

c) Split Cargo Switch Boards (HVCSB) (each one installed in a dedicated adjacent switchboard room, having an A60 bulkhead separating them) connected by bus-tie circuit breakers shall be fed by the main HVMSB system and provide power directly to cargo consumers. Such as cargo pumps and gas compressors, water spray pumps, etc. For 440v consumers, further split switchboards (CSB) installed in their own enclosed spaces connected by bus-tie circuit breakers shall be fed from HVCSB via dedicated transformers.

d) Split 440V Engine Room Switch Boards (ERSB) installed in their own enclosed spaces connected by bus-tie circuit breakers shall be fed directly from the HV system via step down transformers and provide power to other 440V consumers.

e) Services shall be distributed between the duplicated sections of the MSB, HVCSB, CSB & ERSB so as to ensure continued operation of the propulsion plant and the cargo and ballast systems in the event that one section of a switchboard is de-energized.

f) The emergency generator shall be started automatically by detecting no-voltage of the emergency switchboard bus bar, and its air circuit breaker shall be connected automatically after confirming the continuation of no-voltage conditions. The generator shall be of the constant voltage self-excited type, compounded, self-regulating, rated for continuous operation and be capable of performing the most onerous of the following:

1. Starting the plant from cold (dead ship) condition,
2. Discharge of cargo by a main cargo pump from a dead ship condition,
3. Starting and running the deck water spray pump.

Provision for feedback to the ERSB & CSB from the ESB shall be incorporated.

g) The distribution and supply system shall be so designed that, following the loss of the ESB, the Carrier shall still be capable of maintaining all normal operations (cargo, propulsion, power generation, steering, etc) for an indefinite period.

h) Instrumentation/control system, radio/navigation equipment supplies, where these systems require duplicated supplies as per rules and regulations and extra items subject to Purchaser approval (i.e., consoles, etc.) they shall be provided with a main supply and emergency supply. Failure of the main supply shall automatically initiate bumpless transfer to the standby supply, and failure of either supply shall initiate an alarm. 24V DC shall be provided as and when necessary as a backup supply.

i) Where equipment or systems are required to be operable under blackout conditions, or when the nature of the equipment is such that it may be damaged by supply interruptions or spikes, etc., they shall be supplied by a dedicated UPS. Each UPS shall be fed from both main and emergency supplies, capable of meeting the full load requirements of the system concerned for 30 minutes, and capable of being bypassed for maintenance.

24.4. Electric Generating Sets

All generators shall be capable of continuous parallel running. The emergency generator shall be capable of providing short term parallel operation with main generators, within the guidelines as laid down by the regulatory authorities.

5 The design of the main generators and large motors shall be such that during the most onerous motor starting condition, the transient voltage drop shall not exceed 15%; recovering to and staying within ±2.5 % within 1.5 seconds.

Generator winding insulation shall be to Class F with Class B temperature rise.

Generators shall be of the brushless self-excited type with enclosures to at least IP44 standard and terminal box enclosures to IP55 standard. Terminals within the box shall be arranged so that star connection of the stator winding can be made within the box. Separate terminal boxes shall be fitted for auxiliary devices including heaters.

All generators (except the emergency set) shall be fresh water-cooled, with double walled coolers with copper fins, temperature monitoring and leakage alarms.

During intermittent 10% overload operation, there shall be no restriction on temperature rise nor shall there be any temporary or permanent injurious effects on either the generator or its associated equipment. Generator capacity to be based on 85% of actual full load condition. Each generator shall be capable of providing 80% of its nominal load with its cooler out of service but with air flaps open. The emergency generator shall be cooled via air-to-air heat exchangers.

Winding temperature monitoring shall be provided on all generator windings using six Pt 100 temperature sensors, 3 in use and 3 spare.

Generator shall be supported by two oil lubricated bearings of the pedestal type, and only one bearing on each generator shall be insulated to prevent the circulation of harmful currents between shaft and bearings.

Space heaters shall be fitted in all generators in order to eliminate condensation and prevent insulation resistance falling to low values when the generators are not running.

Basic electrical protection shall include but not necessarily be limited to the following:

a) Reverse power
b) Differential
c) Under/over excitation
d) Out of synch
e) Short circuit and overload.

All devices shall be of manual reset type.

Each generator shall be fitted with an automatic voltage regulator (AVR) and an hour meter located inside the switchboard. In addition, an alternative means of excitation, isolated from the AVR and fitted with manual control, shall be provided for each machine.

24.5. Control Philosophy

In general, full comprehensive control of the electrical system shall normally be carried out from a IAS operator station within the ECR. Should a catastrophic failure occur that prevents IAS operation, then full manual control of generators and distribution network shall be made available at both of the main switchboard rooms.

Control of the emergency diesel generator shall be from a dedicated control panel located adjacent to the unit, with remote control capability and monitoring to be provided within the emergency switchboard. Remote monitoring of emergency generation and distribution system status shall be provided within IAS and HVMSBs.

A power management system shall be incorporated within the IAS to provide the following minimum facilities:

a) Automatic starting, synchronization, and connection of the standby generator set in response to duty generator failure. These shall include, but not be limited to, the following, engine fault, low frequency, low voltage, over-current and upon manual initiation.
b) Two level fault control shall be applied, the first level to allow close transition changeover of main generators, the second level being the more onerous to provide blackout changeover.

c) Automatic load control shall be provided in order to automatically start, synchronize, load share, and shut down according to pre-defined conditions of load demand in order to optimize the connected sets for the most efficient service.

d) Automatic restoration of supplies and restart of services after a "blackout."

e) With more than one generator online and under shutdown of one unit, due to fault conditions and/or operator action, load shedding shall be applied to prevent overloading of the remaining generator set(s).

f) Start inhibit of all heavy consumers in the event of insufficient on-line capacity.

In the event of a blackout the feed between ESB and ERSB shall be maintained, the emergency generator shall start and continue running off line but fully excited. If the standby duty generator set has not restored power to the ERSB and ESB within 30 seconds, then the emergency generator shall trip the ERSB link and close the emergency generator ACB, to supply the ESB. Recovery from blackout conditions shall allow synchronization of the main and emergency supplies, to allow transfer of power without incurring a blackout.

24.6. Switchboards

All switchboards shall be of the self-supporting deck mounted cubicle type with rear access for maintenance and shall be installed in air-conditioned rooms. Handrails and rubber mats shall be provided at front and rear of each section of switchboard, and all doors and boards shall be grounded.

All switchboards located within accommodation dry spaces shall be IP22 protection rating. Other switchboards shall be rated for IP23. High voltage switchboards shall be rated IP33. All switchboards shall be subjected to a thermal imagery survey under loaded conditions during the Carrier's sea trial and gas trials and the results of this survey presented to the Purchaser for approval.

The use of common boards for duplicated units shall not be allowed.

All interlocks within the distribution network shall be hardwired only, with status information relayed to the IAS.

Earth fault monitoring with alarms shall be provided for switchboards/ distribution systems (as applicable) and at all voltage levels.

HV switchboards shall utilize withdrawal type vacuum or SF6 circuit breakers or contactors, as relevant. 440V switchboards shall utilize air circuit breakers (withdrawal type) for bus tie breakers, main incoming and outgoing feeders and protection of generator circuits, and molded case circuit breakers (plug-in type) for protection of feeder circuits.

All circuit breakers shall be easily removable and replaceable and shall be standardized as far as practicable.

Two (2) spare feeder breakers shall be installed in each ERSB and one (1) spare breaker shall be installed in each CSB and ESB (size to be agreed with Purchaser).

Busbars shall be made from hard drawn, high conductivity copper and shall be rated to carry the maximum currents that shall be imposed by the electrical system. Busbars shall be insulated. They shall be designed so that all main generators may be run permanently in parallel without restriction and without use of special fault current limiting devices.

The busbar system shall be of a type that has been type tested in accordance with an appropriate standard to prove their capability to withstand the effects of the maximum short circuit current. They shall be secured with hard -lock bolts and braced to withstand, without damage, fault currents that are at least equal to the fault current ratings of the main circuit breakers.

For HV switchboards, busbar earthing facilities shall be provided for each switchboard section and be arranged to prevent inadvertent operation. An earthing system shall be fitted to switchgear to ensure safe

earthing on all circuits, components, or facilities during inspection or maintenance. Switches or devices used for this purpose shall have proven rating capacity.

Individual check synchronization equipment with manual reset shall be provided for each circuit breaker where relevant. The check synchronizer shall not execute closure of a circuit breaker. Facilities shall be provided to enable a generator circuit breaker to be connected to de-energized bus bars.

ESB shall be constructed whereby the emergency generator ACB and consumers can be isolated (off load) via a busbar switch from the shore connection and bus tie ACBs

Where appropriate, facilities shall be provided to isolate and bypass damaged switchboard sections.

24.6.1. Section and Distribution Boards

Section and distribution boards shall be of dead front type housed in lockable, sheet steel enclosures. Enclosure standards shall be as follows:

Drip Proof - IP 22	Inside Control Room and accommodation
Drip Proof - IP 23	Switchboard Room, outside accommodation dry places
Splash proof - IP 44	Inside Engine Room, Steering Gear Room, and other enclosed machinery spaces
Water Tight - IP 55	Galley and Laundry
Water Tight - IP 56	Weather Exposed areas

Final distribution circuits at 220V and lower voltages shall be protected by miniature circuit breakers. Galley and laundry equipment shall be supplied through residual current circuit breakers.

Two spare feeders of each size installed shall be provided in each board.

24.7. Battery Systems

Maintenance free battery systems shall be valve regulated, sealed batteries complete with chargers. They shall be provided for both general use and radio services, in full compliance with the requirements of SOLAS. Particular care shall be taken to ensure that a ‘single fault’ condition will not, under any circumstances, result in the failure of supply.

Batteries shall be capable of being changed without disruption of supply to consumers. They shall be installed within suitably constructed dedicated spaces with access from the open deck. All equipment located within these spaces shall be suitable for the application and its environment.

24.8. Distribution Transformers

Every transformer shall be matched to the total kVA of the most onerous operational loads connected to its related switchboard, plus a 10% margin and shall be of cast resin type with class ‘B’ insulation.

The capacity of the transformers shall be selected by the Builder in accordance with the final power distribution and actual consumers.

Failure of a single transformer shall not have any effect on the operational performance of the Carrier.

Each transformer (unless specified elsewhere) shall comprise three single-phase transformers, connected delta/delta, and enclosures shall be a minimum of IP23 when in dry spaces and IP55 for other locations.

Two HV/440V transformers of equal size shall be provided for Machinery duty. In addition, at least two HV/440V transformers of equal size shall be provided for Cargo duty. Each transformer shall be capable

of maintaining full normal Carrier operations upon the loss of one unit. The LV/HV windings shall be segregated by an earthed screen. They shall be air cooled.

Two 440V/220V transformers of equal size shall be provided for normal lighting and small appliances. For normal lighting transformers, one single-phase dry unit shall be supplied as a spare and fitted in one of the banks, ready for connection.

Two 440V/220V transformers of equal size shall be provided for the control and instrumentation distribution network with auto-changeover on failure of normal (main) supply. One unit designated "main" shall have dual supplies with manual changeover from either of the MSB, the second unit shall be supplied from the ESB.

One 440V/220V transformer bank shall be provided, comprising four single phase transformers of equal size, three in service with one on standby for emergency lighting and small appliances, located near to the emergency switchboard.

One 440/440V and one 440/220V isolating transformer, as appropriate, shall be provided for galley equipment. One 440/440V and one 440/220V isolating transformer, as appropriate, shall be provided for laundry services. Each shall consist of three single phase transformers and shall serve an earthed distribution system.

One 440/220V isolating transformer shall be provided for portable equipment. It shall be supplied from the ESB and consist of three single phase transformers serving an earthed distribution system.

24.9. Starters

24.9.1. Construction

Motor starters other than HV shall be arranged into two Main Group Starter Panels (MGSP) linked to each ERSB. As far as practicable, essential motors for propulsion plant and other duplicated equipment starters shall be split between each MGSP.

Where starter panels are required at locations throughout the Carrier they can be of individual starter design, for isolated cases, or grouped into a Local Group Starter Panel (LGSP).

Where duplicated units are located on the same LGSP they shall be totally segregated from each other, which includes bus bar systems and cable entries.

Starter panel enclosures shall comply with following:

a) IP56: Weather deck installations
b) IP44: In the spaces where moisture is present i.e., machinery, galley, laundry, etc.
c) IP23: In enclosed space free from moisture

The starter for each motor shall be installed within an enclosed metal cubicle complete with hinged door, constructed so as to provide the following:

a) Safe and easy access for maintenance without affecting adjacent starters.
b) Any faults within the cubicle shall not propagate to adjacent starters.
c) Upon removal no live terminals shall be left exposed.

Group starter boards shall be fitted with starters of the ‘swing out’ or ‘draw out’ type. Alternatively, Purchaser may approve fixed type starters if it can be demonstrated that suitable benefits can be achieved without compromising safety.

One spare starter enclosure of each rating shall be provided in each board.

The safety interlocking of door and isolating switch shall be provided for the starters.

Starters shall have provision for testing and fault finding.

Control voltage of starters shall be AC 220V derived from individual control transformer in each starter with a fuse in all legs. In general, control circuits shall be insulated from earth.

With the exception of any essential interlocking connections, each starter control circuit shall be completely independent.

Vacuum type contactors or SF6 break circuit breakers shall be used for circuits operating at voltages higher than 440V.

Overload protection shall be provided by thermal element, with an element in each phase, Single-phase protection shall be provided in all three phases

Ammeters, marked with the maximum current rating, and running hours meters (interfaced with IAS) shall be provided for all motors of 5 kW and above. Instrumentation class 2.5 shall be used.

24.9.2. Control

Motors that were selected for duty before blackout shall automatically return to duty after recovery from the blackout, with due attention being given to the sequential starting in order to prevent generator overloading. Similarly, motors selected for standby shall automatically return to standby.

All motor controls shall meet the following minimum requirements:

a) IAS control functions: Manual start/stop operation, Process auto selection, Auto Standby/Manual selection
b) MGSP & LGSP control functions: Manual start/stop operation & control position selection
c) Local control function (adjacent to motor): Manual start/stop operation with a Lock stop
d) All stop buttons shall be operable at all times.

Starters shall be of the direct-on-line starting type except where excessively high starting currents are expected or experienced. In this case alternative methods shall be used subject to the Purchaser's approval.

24.10. Motors

Motors shall be of the totally enclosed, fan cooled (TEFC) squirrel cage induction type and shall be continuously rated for 110% of their normal load duty. Sizes and mountings shall be standardized and from one manufacturer as far as possible.

The enclosures for all motors shall be at least to IP54 standard, with or without fan cooling. Terminal box enclosures shall be to IP55 standard in all instances. Motors exposed to the weather shall be IP56.

For all motors of 10 kW and above, both ends of each phase shall be brought out to the terminal box.

Insulation shall generally be Class "F" with Class "B" temperature rise, based on an ambient temperature of 45°C. HV Motors shall be Class "F" with Class "F" temperature rise.

Motors of 160 kW and above shall be fitted with six platinum resistance type winding temperature sensors (two per phase, one working, one spare) for tripping and remote temperature indication purposes.

Motor heating shall be of the low voltage injection into stator windings for all motors of 20 kW and above, as well as for all motors located on the weather deck, forward space, cargo motor room, steering gear spaces and any spaces that have direct access to the weather deck.

Motor speeds shall not exceed 1,800 rpm, unless specifically agreed by the Purchaser, and substantially lower speeds shall be used for large motors, such as those for the main circulating pumps, forced draft fans, etc.

Generally, all motors shall be fitted with pre-lubricated sealed type ball bearings, except on larger machines, where force lubricated sleeve bearings shall be employed, designed to inhibit shaft circulating currents.

Two-speed motors shall employ a separate winding for each speed.

Submerged cargo pump motors shall be manufactured to a proven design with a proven service record and supplied by the cargo pump maker.

All motors of 5 kW and above shall be permanently marked for vibration monitoring measurement points. Motors without free and safe access, such as ventilation fan motors, shall be provided with a remotely located connection point to enable safe collection of data.

24.11. Shore Power Connection

A shore power connection shall be provided within the construction of the emergency switchboard, and it shall be of sufficient capacity to support the most onerous of the following:

a) All the necessary hotel services to allow full occupation of a Carrier in dry dock, plus sufficient spare capacity to recover the Carrier from cold start.
b) Starting and full operation of a single main cargo pump during ship to ship transfer operations

Comprehensive instrumentation shall be provided for safe operation, and a kW hr meter shall be fitted.

Arrangements are to be made whereby cable entry to the Carrier can be made from either side of the Carrier, the shore cable is to be fully supported and protected throughout its length.

24.12. Cables & Installation

24.12.1. General

Wherever possible, cables supplied by manufacturers with their electric equipment shall be in accordance with the specification. Any exceptions to this shall be subject to the Purchaser's approval.

Current rating of cables shall be at least 125% of the maximum current carried under normal circumstances.

Permissible voltage drops, as defined by the rules and regulations, shall be applied to all voltage levels.

The conductors supplying a group of two (2) or more loads shall have a current carrying capacity calculated by the application of a demand factor and/or diversity factor to the connected loads.

The end of cable conductors, in general, shall be connected to the terminal block by solderless type terminal lugs, pin type terminals, or sleeve type terminals, depending upon the type of terminal block. Cap type spring connectors shall not be used.

All cable installation shall be subject to inspection by purchaser prior to connection of any cable. HV cables shall be subjected to a potential test after installation is complete but before final termination.

24.12.2. Construction

Detailed specifications shall be submitted for Purchaser's approval covering the construction, installation and termination methods of all cables carrying voltages above 1 kV and all cables intended for cryogenic service.

Blue-sheathed cables shall be used for intrinsically safe circuits. They shall be twisted pairs with individual screens.

Cables shall not be painted. HV cables shall have a red outer sheath, while all general instrumentation and control cables shall have an orange colored outer sheath. Bus bars and connections shall be clearly marked on all equipment with color scheme as follows, or as approved by purchaser.

AC System	Phase 1	Red	L1	R	U
	Phase 2	White	L2	S	V
	Phase 3	Blue	L3	T	W
DC System	+ (or P)	Red			

	- (or N)	Blue			

Cable circuit number tags and terminal number tags shall be provided for all equipment with details as agreed with purchaser.

Unless specified elsewhere, all cables shall be heat, oil, and flame retardant (HOFR) cables, ethylene propylene rubber (EPR) insulated, chlorosulphorated polyethylene (CSP) sheathed, with galvanized steel wire or bronze wire braid armoring, and the whole sheathed in CSP. (Alternative elastomeric compounds if proposed will be considered). Bedding shall be applied to the inner CSP sheath.

Cables shall have multi-stranded conductors and conform to BS 6883 latest revision and IEC 60332-1 + AMD1:2015 CSV & 60332:2018 SER Category "C" with low toxic gas emission type approved by Class.

Cables within hot locations over 60° C shall be of a high temperature type, silicon rubber or equivalent (lead covered is not acceptable).

Cables for safety systems, that are required to maintain service during the incidence of fire, shall be of a fire resistant type in accordance with IEC 60331 latest revision and Class. This includes, but is not necessarily limited to, fire detection, emergency stops, PA system, telephone systems, fire-fighting systems, and E/R and other CCTV systems, UPS.

Single and multi-core instrumentation cables shall be twisted pairs, with individual screens. Minimum of one spare set of twisted pairs shall be provided within each multi core cable.

The use of multi-core cables for motor control shall be minimized.

24.12.3. Installation

All cables routed externally and within wet spaces, such as cold rooms, galleys, and laundries shall be armored with an outer CSP sheath.

Cables entering equipment located on weather deck or in damp spaces shall do so via a suitable individual cable gland approved by the Purchaser. These shall be made of salt water / weather corrosion resistant material.

All cable routes shall be carefully selected in order to minimize the adverse effects of heat and moisture and those exposed to mechanical damage shall be suitably protected. Cables on the open deck or passing through cofferdams shall be installed in a cableway or covered cable tray made of SUS 316L or alternative Purchaser approved material. Supports of this cable way or cable tray shall be of SUS 316L or equivalent and the height above deck shall be minimum 300 mm.

Cables shall be fully supported by means of straps throughout their full length both vertically and horizontally.

Cables shall, in general, be secured with galvanized steel bands, but 316L stainless steel band shall be used where exposed to weather or subject to high condensation, e.g., cold spaces, galleys, etc.

Non-metallic cable ties may be used, subject to the Purchaser’s approval, provided that the cables remain substantially in their location both during and following the effects of fire. Non-metallic cable tie material shall not be affected by UV radiation.

Cables, where run in groups, shall be supported on metal hangers or a cable tray arranged to permit painting of the surrounding structure, except that branch cables may be installed directly on beams, behind the linings or on wooden walls

All transits between gas hazardous and safe areas shall be via Roxtec type multi cable transits (MCT), configured for back to back installation, complete with inner space test facility. Metal parts of MCTs exposed to the weather shall be made of non-ferrous and corrosion resistant materials. Water based sealing compounds shall not be used. .

Other penetrations of watertight deck or bulkhead shall be carried out with a single Roxtec MCT. Where cables penetrate a non-watertight deck, bulkhead, frame, beam or girder, suitable bushing or coaming shall be fitted.

Where cables penetrate internal fire protection divisions, the Builder's standard method, using sealing materials and methods approved by Class and the Purchaser shall be applied.

HV cables shall be segregated from other cables.

Other power and instrumentation cables shall be run separately from HV cables. Minimum 50 mm separation shall be maintained between power and instrumentation/control cabling on the same routes.

Cable ducts, carriers and trays should have 15% spare capacity.

IS cables shall be installed separately from other general circuits in order to protect against interference from electro-magnetic induction between cables, by means of separating the cable ways (minimum 100 mm), penetrations, banks or cable pipes. IS and non-IS earthing shall be segregated.

Cables for duplicated equipment shall not share the same multi core cable or terminate in the same box.

Cable routes for all duplicated equipment shall be carefully chosen so as not to compromise the integrity of duplicated equipment. Cable runs to and from the emergency switchboard shall avoid the main machinery spaces.

Cables shall be installed in continuous lengths between electric equipment. Junction boxes shall only be used where absolutely necessary and subject to Purchaser’s approval.

Steel wire braid of cable and metallic enclosure of electric equipment shall be earthed in accordance with Rule requirements and Builder's practice, subject to the Purchaser’s approval**.**

A grounding connection shall be provided between Carrier and quay, to permit grounding of the Carrier at the loading and unloading terminals.

Cargo and ballast piping shall be electrically connected to the hull. All flanges shall be bridged with solid stainless steel straps (50 spares to be provided) and welded to the steel hull at each end.

24.13. Lighting

In general, fluorescent discharge lamps shall be used for internal and external areas. Deck lighting shall be a LED type internally in machinery spaces and all areas where floodlights are used (on emergency supply). Over-side and over-bow illumination shall be provided by searchlights.

Floodlights (LED type) for deck illumination shall be controlled from the wheelhouse or a place as agreed with purchaser. Forward facing deck lights shall be switched separately from aft facing deck lights.

High quality manufacturer shall provide lighting of proven and durable design to marine standard, and the installation shall ensure that adequate levels of illumination are provided throughout the Carrier.

At least two separate lighting systems shall be provided throughout all working, living, and access areas, the electrical supplies being drawn from main and emergency power systems. About one third of the Carrier’s total lighting system shall be supplied from the emergency supply. Lighting in the machinery workshop shall be from two different phases to prevent any strobe effect.

Attention shall be given to the design escape route emergency lighting on exposed decks which shall be provided to purchaser's satisfaction.

Any space with two fittings or more shall be fed from a minimum of two circuits, one of which, with a minimum of 30% of space lighting shall be fed from the emergency supply.

Illumination of 300 lux shall be provided in ECR, CCR, workshop, working position in galley, desk space and chart table. An average 200 lux shall be provided in switchboard rooms, offices, wheelhouse, galley, pantry, mess rooms. An average of 100 lux shall be provided in cabins, laundry, recreation room, hospital, gymnasium. A minimum illumination of 100 lux shall be maintained in all the machinery spaces and 200 lux at designated high activity/observation areas within the same machinery spaces. In way of deck machinery and cargo manifolds, the level of illumination shall be greater than 55 lux and shall

comply with USCG and flag state requirements. Other deck areas shall be no lower than 25 lux. Other areas such as pipe duct, electric equipment room, air conditioning room, provision rooms and others shall have minimum illumination levels 100 lux or as agreed with purchaser.

Lighting equipment on deck and open areas shall be of strong material and of high resistance to seawater, ambient atmosphere, and of preferably stainless steel 316 or copper alloys, but not aluminum alloy.

All deck lighting fittings shall be suitable for the zone in which they are located, and of an approved type and watertight.

Approved and watertight type fluorescent lighting fittings of quick start type shall illuminate the cargo compressor room and motor room.

A 24V DC system for emergency transitional lighting shall be provided for all escape routes, throughout all the accommodation and machinery spaces as indicated below, including the lift shaft and lift cage. This system shall provide illumination automatically upon Carrier black out.

220V emergency lighting shall be provided in every cabin, dayroom, office, radio space, public rooms, galley, passages, workshop, ECR, CCR, ER, emergency generator room, steering gear room, emergency escape trunk, stairways, and all other working and escape areas. Bed lights shall be supplied from the emergency source. All emergency lights shall be identifiable.

Use of low energy longlife LED lamps should be utilized as much as possible.

CCR and ECR lights shall be provided with non-reflective diffusers to prevent reflection in consoles / panels.

Wheelhouse red lights shall be provided with dimmer switches.

24.14. Socket Outlets

Double pole switched socket outlets shall be fitted throughout the Carrier except on the open deck or in areas designated hazardous. Socket type required by Purchaser will be advised during bid evaluation phase. Consideration shall be given to the need for facilities for cleaning, occasional lighting, computers, radios, portable chargers for personal use, personal televisions and similar needs when providing socket outlets in the accommodation. Sockets in the alleyway are to be provided with covers and located approximately 15 cm from the deck level.

Power supplies to socket outlets in laundries, machinery spaces, fan rooms, elect equipment rooms, and similar spaces shall be provided by a dedicated earthed distribution system via an isolating transformer and protected by RCCBs.

24.15. Welding Equipment

A 440V 3-phase ring main shall be provided and supply five socket outlets in the main machinery space, one in the workshop welding bay and one in the forward spaces. Each socket shall be capable of supplying a 300A electric portable welding unit.

Three solid state units are to be supplied (one to be suitable for TIG welding) complete with all necessary leads, mask and electrode holders, etc., to carry out all normal welding operations. If units provided do not provide electrical isolation from the distribution network than a dedicated transformer supplying the ring main shall be provided.

One high capacity exhaust fan shall be fitted for the welding bay.

25. Instrumentation and Control

25.1. Shipboard System

Shipboard System shall be considered "a system of systems," which in this section is applicable to three major systems of Machinery, Cargo, and Navigation

Design and engineering of these systems shall follow the guidance in ISO document 17894:2005 or latest revision, Computer Applications - General principles for the development and use of programmable electronic systems in marine applications. Builder shall comply with all requirements or identify any exceptions prior to contract award for purchaser approval.

The Purchaser shall be kept informed of progress throughout all stages of the system development, and all formal testing shall be witnessed by the Purchaser's representative.

The systems shall be so designed and implemented as to ensure a high level of fault tolerance such that the single failure of any component, power supply, or device shall not prevent normal system operation, nor compromise the integrity of the system. This shall be confirmed by the application of recognized methodologies (Hazid, Hazop, risk mitigation, FMEA, etc.), as referenced within the above ISO document.

Modeling and simulation testing of software throughout the development period shall provide key validation evidence of the software's capabilities, integrity, and its ability to meet the user requirements. The software quality plan shall be based on ISO and Classification Society requirements, and be submitted to the Purchaser for approval.

Each main system shall consist of a number of subsystems, the nature of the subsystems being determined by the Equipment Under Control (EUC) and the functional requirements it has to meet as determined by its duty. The boundaries of the system shall include documentation, software, hardware, human element, and EUC.

25.2. General

This specification for instrumentation and control equipment shall apply equally to machinery, cargo, and navigation systems. All materials and equipment throughout shall be of the highest quality and shall have been proven suitable for marine application on board Carriers for unrestricted worldwide service. In addition, they shall comply with a recognized national or international standard, revised where necessary for ambient conditions.

25.3. Instrumentation Standards

All instrumentation and control systems shall be built from standard electronic modules, type approved by the Classification Society, and use the minimum number of different module types. Standard modules of one manufacturer shall be employed to the greatest possible extent. Where machinery package units are employed, every effort shall be made to utilize these standard modules and any deviation from this shall only be made with the Purchaser's specific agreement.

Particular care shall be taken to ensure that the materials and equipment, including casings, supports and fixing arrangements, are resistant to corrosion. They shall also comply with all relevant details given in the various sections of this specification. Electronic instruments must conform to the IEC 80005-1:2012 recommendations and to classification requirements. Particular attention shall be paid to IEC publication 60533:2015 on electromagnetic compatibility of electrical and electronic installations, with regard to guidance on immunity from noise, and installation details.

All equipment shall be designed for ease of testing and repair by Carrier staff, with full isolation facilities at both root and instrument/gauge/transducer positions. Function test facilities and equipment

(intrinsically safe, where applicable) shall be provided and a list of such equipment shall be supplied for approval by the Purchasers. Where appropriate, facilities shall be provided for field testing of devices, such as float switches, pressure switches, etc., without removal from the process loop.

The minimum instrument accuracy requirements (unless otherwise specified) shall be:

a) Pressure ± 0.5% of reading
b) Temperature (thermocouple) ± 0.5% of reading
c) Temperature (RTD) ± 2% of reading
d) Level ± 25 mm
e) Flow ± 0.25% of range
f) Controller/receivers ± 2% of set point

25.4. Machinery and Cargo Control Rooms

The machinery or engine control room (ECR) and the cargo control room (CCR) shall contain all facilities to permit centralized operation of the plant and equipment and shall allow unattended operation of the machinery plant under all operating modes.

The ergonomic design and layout of these consoles shall be subject to Purchaser's approval.

The ECR shall have a console whereby the operator shall be facing forward. The ECR controls shall be arranged so that they allow a single engineer to operate, monitor and adjust equipment during periods of manned operation. There shall be direct access from the accommodation via the elevator. The ECR shall be provided with two doors as far apart as practicable.

The introduction of process fluids into control rooms shall not be permitted, with the exception of clean control air at a pressure not exceeding 7 bar and gas detection samples from the cargo area. The latter shall be installed in accordance with the IGC Code.

The CCR shall have a console facing forward at a deck level that is appropriate for cargo operations and shall give a free uninterrupted view of the cargo deck. Access to the deck, main stairwell, and lift from the CCR shall be as direct as possible.

The control consoles within each space shall form part of the IAS. They shall be of a similar design and shall incorporate suitable displays and controls for all shipboard operations. The arrangement and all information presented shall be such as to permit one man to control all operations. Provision shall also be made to allow the simultaneous dual control (i.e., cargo and ballast) operations within the same console by two operators.

26. IAS (Instrumentation Automation System)

26.1. General

The Machinery and Cargo systems shall form the Carrier's IAS (also known as the Distributed Alarm and Control System (DACS)). The interface between the IAS and Integrated Navigation system (INS) shall be for information exchange only.

Preference would be for a fully integrated IAS incorporating Bridge, Machinery and Cargo Systems.

The system design shall integrate as much of the Carrier's systems and operations into the IAS as is practicable, subject to the applicable Rules and regulations, Purchaser's approval, and within the following guidelines.

The IAS shall be provided with a facility for remote maintenance by the manufacturer (via a secure modem link) using the ship's satellite communications system. This is to be incorporated in to the workstation installed in the Chief Engineers office.

IAS control and monitoring shall apply to, but not necessarily be limited to, the following subsystems**:**

System	Integration Level
LD/BOG compressor	PARTIAL
HD/VR compressor	FULL
Gas heaters	FULL
Vaporizers	FULL
Reliquefaction plant (where fitted)	FULL
GCU	PARTIAL
Cargo discharge	FULL
IG generator	INFO
N_2 generator	INFO
ESD	PARTIAL
Ballast system	FULL
Ballast Water Treatment System	FULL
I.B.S.	INFO
Fire and gas	PARTIAL OR INFO
CTS primary	FULL OR INFO
CTS secondary	INFO
Loading computer	INFO
Hull stress monitor	INFO
Auxiliary Boiler ACC & BMS	PARTIAL
Propulsion system	PARTIAL
P.M.S.	FULL
Generator prime mover	PARTIAL
L.O. system	FULL
Fuel Oil system	FULL
Fuel Gas system	FULL
Central cooling systems	FULL
Pump control	FULL
I.C.C.P.	INFO
Steering system	INFO
Purifiers	INFO
Shipboard LAN system	INFO

System	Integration Level
Emergency generator	INFO
F.O. & F.W. Tank Levels	FULL
CCTV	FULL
Auxiliary Boiler	PARTIAL

FULL: Requires the full integration of the equipment under control (EUC) and its controllers, both hardware and software, within the IAS, with a back up stand alone capability within the IAS environment.

PARTIAL: Under normal conditions, the IAS has full information and simple control capabilities of the EUC, but the subsystem and its equipment are stand-alone units (Hardware & Software) capable of fully functioning outside of the IAS environment.

INFO: The communication link between the IAS and this equipment or system is for full information only no control facilities are provided.

The final integration level of these systems shall be determined during detailed design.

The system shall be based on a fully distributed redundant microprocessor-based integrated control, alarm and monitoring system.

The alarm system shall form part of the IAS and meet the requirements of IMO Resolution A.1021(26), Code on alerts and indicators, 2009.

26.2. Hardware

The system shall use minimum 23-inch high definition (minimum 1080P) visual display units for the presentation of information and shall utilize graphical displays to allow ease of use. They shall not be of the touch sensitive or electrostatic type.

A minimum 55-inch display high definition (minimum 1080P) shall be included in the CCR for the cargo system.

Memory retention by the system, in case of total power outage, shall not rely on the use of embedded batteries.

All data shall be archived on removable solid state disk (SSD) storage medium.IAS workstations shall be installed as follows:-

LOCATION	
ECR	Four (4) VDUs, two(2) keyboards for monitoring and control of machinery system One (1) VDUs, one (1) keyboard for the monitoring only of cargo and machinery systems One (1) Color alarm printer One (1) Dual function full color printer capable of log and screen graphics printing
CCR	Four (4) VDUs, two(2) keyboards for monitoring and control of cargo and ballast system One (1) VDUs, one(1) keyboard for the monitoring only of cargo and machinery systems One (1) Overview display One (1) Color alarm printer One (1) Color data logging/report printer One (1) Color inkjet printer for screen graphics One (1) dedicated operator work station with color inkjet printer dedicated for CTMS duty
WHEELHOUSE	One(1) VDU, one(1) keyboard for monitoring of machinery and cargo systems in the wheelhouse

As far as is possible, all printers shall be of the same make, model and type.

Signal columns shall be provided in prominent locations, as agreed with purchaser, in the machinery rooms and cargo machinery spaces. The alarm column shall have different alarm signals and lights and mimic for each individual function. As a minimum requirement they shall indicate the following:

a) Machinery alarm
b) Machinery critical alarm
c) Machinery room(s) gas alarm
d) Machinery room(s) fire alarm
e) Accommodation fire/general alarm
f) Engineers' call/patrolman alarm
g) Fire extinguishing medium pre-release alarm
h) Telephone

26.3. Configuration

The two main control stations shall operate independently from their respective spaces, with monitoring capabilities available from the other station. It shall be possible, in an emergency, to transfer control and operate cargo systems from the ECR, and machinery systems from the CCR.

The power supply system for the IAS shall be treated as an integral part of the system and shall be designed to achieve the same levels of integrity and redundancy as the system itself.

Each dedicated process area shall be able to operate independently in the event of a total loss of communications and, if necessary, shall be accessible locally using a portable terminal.

Data logging facilities shall monitor, on a continuous basis, all data necessary for safe and efficient operation of the cargo and machinery systems, and print it out in selectable specified log formats.

The system shall be able to display and print both (real time and historical) data, as well as event trends with analysis over selectable time scales. System capacity shall allow for the storage of all data, related to all tag numbers, for one year without resort to archiving.

There shall be no ready access to removable media, e.g., SSD's etc., within the workstations after the Carrier has been commissioned.

I shall be possible to lock out the use of any installed USB ports.

All communication buses and controllers shall be duplexed, including any communications with other control systems, e.g., CTS, loading computer, INS and SMS. Redundant communications buses shall take independent routes.

The IAS design shall incorporate segregated autonomous process areas, with dedicated process controllers connected via redundant communications buses.

Manual local operation of critical equipment shall be possible in the event of a catastrophic IAS failure. This applies to, but is not necessarily limited to, propulsion, navigation, and power generation. IAS failure modes shall be thoroughly tested during commissioning.

All major components of the IAS shall be duplicated, including but not limited to processors, SSD's, power supplies, node controllers, etc.

IAS or network fault alarms shall form a normal part of the alarm recording.

Attention shall be given to ensuring protection from all types of software viruses.

Re-loading of the application software in the event of a cold start must be simple and require only basic computer skills.

Acceptance of alarms shall be possible only at the main control room associated with the alarm.

26.4. Design

Control loops shall be capable of being controlled in both automatic and manual control modes from the IAS.

The status of manually operated valves shall be indicated within the graphic displays. Change of status shall be initiated by operator action within the IAS.

The overview display for the cargo section shall be capable of displaying all graphical displays contained within the IAS system. In addition, the specific overview cargo display shall include, but not necessarily be limited to, the following:

a) Status and running current of cargo pumps
b) Cargo pumps discharge pressure
c) Cargo valves status and intermediate position (where applicable)
d) HD/VR and LD/BOG compressors and main parameters
e) LNG vaporizers and gas heaters
f) Tanks temperature, pressure and level
g) Manifold pressures and temperatures
h) Vapor header pressure and temperatures
i) Complete cargo system layout and piping diagram
j) Reliquefaction plant
k) BOG Disposal System (GCU)
l) Nitrogen generator
m) I.G. Generator

n) BOG Recovery System
o) Fuel Gas Supply System (FGSS)

The display shall be controlled by the information station located within the same console, but each shall be capable of independent display.

The color coding used for the graphic displays shall be, as far as practicable, the same as that used for the actual engine room and cargo system piping systems.

In UMS mode any alarm shall immediately activate the duty engineer's alarm (see **Section 27**), and trigger the Engineers' alarm (see **Section 27.4**) if unacknowledged within the ECR after a specified time, irrespective of the Carrier's operating mode, i.e., in both UMS and non-UMS conditions.

Running hours counting software shall be provided for all machinery monitored by the IAS, and the data shall be transferable to the SAS for condition monitoring and preventive maintenance purposes. Transfer from the IAS to the SAS shall be by an independent communication, complete with a provision to prevent the introduction of computer viruses and unauthorized access.

Alarm sensors and processing cards shall be independent of those used for process control.

Cabling is to be minimized by the utilization of remote I/O capability of the system, thereby maximizing use of data networks.

The capacity of the system in terms of input/outputs, memory, and cabling shall provide 10% spare capacity of each type upon final commissioning.

The IAS shall indicate the true status of both the cargo and machinery systems at all times, irrespective of the Carrier's condition, e.g., including during a blackout.

Alarms shall be inhibited on systems intentionally shut down and shall remain inhibited in the event of a blackout.

Equipment shut down systems (e.g., main engine L.O. pressure low low, etc.) shall be independent of both control and alarm systems and shall be hardwired to the shutdown actuators. Where these circuits are required to be of the energized type for activation, continuous fault monitoring of the circuit shall be carried out to ensure system integrity.

Each component of the shut down system shall be designed in such a way that any fault will result in a "fail safe" condition for the system and the Carrier.

26.5. Process Loops

Control valves shall each be equipped with a local manual control. Control valves shall not be used as emergency shut off valves.

All control loops shall have a fail-safe configuration.

All instruments and related measuring elements shall be installed such that they are easily accessible from decks, platforms, or walkways and are not subject to excessive vibration.

All transducers shall be capable of easy removal without recourse to shutting down the affected or any other process.

Pressure transducers shall be fitted with block and bleed valves to allow in-situ calibration and testing.

26.6. Development and Testing

Full simulation facilities of the IAS graphical user interface shall be made available for Purchaser's comments and approval throughout the detailed design approval stage.

The system shall be capable of supporting online diagnostic fault location down to the single component or transducer level, and the graphical interface shall present full information on faults to allow the operator to carry out a quick and easy fix.

27. Machinery Systems Extension Alarm System

The extension alarm system required for UMS operation shall be incorporated into the main monitoring system, and shall include alarm grouping as required by IMO Resolution A.1021(26), section 27 and elsewhere in this specification. LCD extension display units shall be fitted in all engineer officers' cabins and public rooms, including the central office administration area. In the case of the senior engineer officers, who have more than one room, the panel shall be located within the bedroom with an extension buzzer in the dayroom and/or office.

27.1. Cargo Machinery Extension Alarm System

The audible alarm for the cargo machinery system shall be different in tone from that used for the machinery systems, and shall be extended to the administration area and wheelhouse.

Cargo alarms shall be repeated in the central office, but may only be acknowledged at the main cargo console.

For periods on voyage, and when the cargo control room is unattended, provision shall be made for cargo alarms to be repeated in the wheelhouse, first officer's quarters, chief engineer's bedroom, cargo engineer's quarters, and public rooms.

27.2. Wheelhouse Alarms

Arrangements shall be made either to inhibit alarms in the wheelhouse whilst the Carrier is in port, or to redirect them to the cargo control console.

27.3. Patrolman Alarm

A patrolman alarm system shall be provided for both the machinery rooms and cargo machinery spaces, in accordance with the requirements of IMO Resolution A.1021(26).

27.4. Engineers' Alarm

The engineers' alarm shall comply with IMO Resolution A.1021(26) and be actuated from addressable pushbuttons located in the machinery space(s) and the ECR (and any subsidiary control station located in the machinery rooms). Cancellation of the alarm shall be possible only from the ECR.

The power supply to the engineers' alarm shall be provided from an uninterruptible source.

27.5. General Emergency Alarm System

The "strategic points" referred to in IMO Resolution MSC 48 (66) shall include the cargo control console and the fire control station.

The general alarm system shall be part of the public address (PA) system and use the same sound system.

The power supply to the general alarm shall be provided from an uninterruptible source.

28. Main Propulsion Control

The following sections describe the basic control systems for the propulsion system and further details applicable to the different propulsion options can be found in the appropriate Module C. In addition to the Classification Society's requirements, the following shall apply:

a) Main propulsion control and monitoring shall be in accordance with the prime mover manufacturer's recommendations. The speed of the propellers shall be capable of being controlled independently and together.

b) The main propulsion system shall have the following modes of control:

- Automatic control from the bridge

- Automatic control from the ECR
- Remote manual control from the ECR
- Local manual control

c) Full and comprehensive information and propulsion alarms and shutdowns shall be extended to the IAS via a duplex communication bus.

28.1. Shaft and Bearing Monitoring

An optical shaft power thrust meter measuring system, with accuracy better than ±0.15% of rated output, shall measure and display main propeller shaft(s) power, thrust, torque, and revolutions. System shall be linked into the AIS for information only. A totalizer shall be incorporated in the power meter for recording the total shaft kW hr.

All stern tube bearing temperature sensors shall be duplicated and shall provide analogue indications at the IAS together with alarms, slowdowns, and shutdown. One temperature sensor shall indicate the lubricating oil temperature.

28.2. Machinery Vibration Condition Monitoring

A fixed vibration monitoring system providing full information to the IAS shall be provided for all main and major auxiliary rotating machinery, to an extent agreed with the Purchaser, which shall continuously monitor overall vibration levels for indication, alarm and, where required, tripping.

For other equipment, the condition diagnosis and survey of 5 kW equipment and above the Builder shall provide equipment for periodic plug-in measurement and recording of vibration frequencies and amplitudes. Electric motors enclosed in packaged machinery shall have external measuring points. Any motors agreed by the Purchaser as being for occasional use only may be excluded. The portable measuring equipment shall be certified as intrinsically safe.

Comprehensive computer analysis facilities shall be provided in the SAS. The vibration monitoring system software supplier shall be responsible for a first full survey and baseline analysis during commissioning.

29. Ship Performance Monitoring System

A microprocessor based ship performance monitor shall be provided for the purpose of optimizing the Carrier's thermodynamic and propulsive efficiencies and subject to the approval of the Purchaser.

This system shall support the Ship Energy Efficiency Monitoring Plan (SEEMP) and the Energy Efficiency Design Index (EEDI).

Additionally, this system shall support IMO DCS and EU-MRV reporting requirements.

The system will comprehensively cover, as a minimum, the following areas:

- Fuel Performance Monitoring
- Engine Performance Monitoring
- Energy Management
- Trim Optimisation

The computer, appropriate software and dedicated plant and process transducers shall provide a continuous on-line analysis of up to 60 measured variables and up to 36 calculated parameters, including but not limited to,:

- Carrier positioning

- Duration and distance travelled
- speed
- draft
- trim and list
- weather
- shaft power, thrust, torque, and revolutions measurement
- fuel consumption for each prime mover
- hull efficiency
- engine efficiency for each prime mover
- NOx, SOx and CO2

The system shall be capable of generating detailed reports incorporating the above parameters.
Digital display units shall be provided in the CCR, ECR and Bridge.

It shall be possible to allow, through a portal, on-shore reporting, monitoring as well as sister ship and fleet comparisons.
To enable realtime access to data a Plant Information Management System (PIMS) is to be fitted. This should supply continuous data from the IAS, VDR system, Condition Monitoring, Performance Monitoring and Emission Monitoring systems to the Owner's office via the ships internet connection. The system should allow archiving, trend analysis etc of the data by the owners office.

The parameters shall be agreed with the Purchaser and shall, as a minimum, have accuracy better than ±0.25%, with a resolution within 0.1% of scale. Full information to be provided within the IAS.

30. Hull Stress Monitoring System

This system shall be microprocessor based using the latest fiber optic technology. It shall provide a hull surveillance system that monitors the ship's hull girder stresses and motions, and warns the operator when these stress levels or the frequency and the magnitude of slamming motions are approaching a level where corrective action is advisable.
It shall be installed to Class requirements, and shall be interfaced with the IAS and other ship equipment, i.e., ballast management system, loading computer, VDR, etc.
For any initial membrane Carrier (first of class), subject to full agreement with GTT and Classification Societies, cargo tank sloshing impact pressures shall be monitored in the fore and aft and port and starboard chamfers in order to monitor sloshing loading. Duplicate sloshing pressure sensors shall be fitted.

31. Cargo Instrumentation

31.1. General

All cargo operations, including cargo loading and discharging, inerting, aerating, warming up and cooling down of the cargo system, atmosphere control in the insulation spaces, and ballast handling, shall be carried out and monitored from the cargo control consoles located in the cargo control room.
The installation, automatic control and monitoring of the Ballast Water Treatment System (BWTS). Attention shall also be given to automatic sequential renewal of the ballast water by the IAS, to allow the complete change-out of ballast water prior to entering special areas. Input from the Carrier stress

monitoring system shall be provided and shall raise an alarm in the event of stress levels exceeding normal Carrier parameters.

Temperature Monitoring of Inner Hull and Barrier Space (applicable to membrane systems only):

Temperature measurement of the inner hull for each cargo tank shall be monitored by a minimum of fifty sensors distributed between the cofferdam, duct keel and trunk deck. Cofferdam sensors shall be used to control the cofferdam heating system.

Cargo Barrier Space:

Temperature measurement of the cargo tank barrier space for each cargo tank shall be monitored by a minimum of 20 sensors (one working and one spare at each measurement point - minimum of 40 sensors) distributed throughout to provide overall coverage of the space concerned.

31.2. Remote Level and Draft Gauging System

A remote level measuring system (not resistance tape method) shall be provided within the IAS for remote level reading of the following (as appropriate):

- Water ballast tanks
- Peak tanks
- Liquid fuel bunker tanks
- Liquid fuel settling tanks
- Liquid fuel storage tanks
- Liquid fuel service tanks
- Liquid fuel overflow tank
- Gas fuel buffer/system tank (where fitted)
- Main L.O. storage tanks
- Cylinder oil storage tanks
- Main L.O. settling tank
- Main L.O. sump tanks
- L.O. gravity tanks
- Fresh water header tanks
- Domestic water tanks
- Distilled water tanks
- Etc.

Control operations associated with these tanks shall be provided within the IAS.

High and low alarms shall be provided for water ballast tanks and fuel oil tanks.

Four (4) sets of radar type draft sensors shall be provided for remote reading of the Carrier's draft at forward, mid (P and S) and aft positions.

The level and draft indicators shall have an accuracy better than ± 5 mm from bottom to 10 m and ± 7.5 mm or better from 10 to 35 m level.

The draft indicator shall be calibrated in the same units as the draft marks.

The draft gauging system shall have automatic correction for trim and list.

31.3. Custody Transfer System

An approved Custody Transfer System (CTS) shall be provided to measure cargo volume, temperature, and pressure according to the requirements of cargo sellers, buyers and the fiscal authorities in exporting and importing countries. The CTS shall comply with the relevant regulations for the trading routes specified.

An independent sworn measurer, approved by the Purchaser, shall certify the entire system, including the calibration of the tanks.

Two self calibrating independent tank radar level measuring systems, primary and secondary, shall be installed in each tank.

Each cargo tank shall be provided with a minimum of six temperature sensors, for the purpose of determining cargo temperature for the CTS, with the readout in increments of 0.01 deg. The distribution of the sensors shall be subject to Purchaser approval. A complete backup temperature measuring system shall also be installed.

Each cargo tank shall be provided with pressure measurement for CTS purposes, displayed in increments of 0.1 kPa.

The CTS shall take signals from the primary level gauges and shall automatically and continuously calculate cargo volumes, corrected for trim and list, from signals taken from a sealed trim and list sensor located on the centre line. Alternatively, signals taken from suitably certified draft sensors would be acceptable, based on the certified tank tables. The CTS shall also process the cargo temperature and pressure signals from the sensors in each tank and produce reports of cargo loaded or discharged, to suit the commercial requirements of the Purchasers. The system shall allow draft, ullage, trim and list readings to be input manually.

Two outputs for cargo tank levels shall be provided from CTS to IAS: one shall indicate 'raw tank level' and the other 'corrected tank level' with operator's choice as to which one shall be used for the cargo tank level indications on the IAS displays.

Fore and aft drafts (port and starboard) shall be displayed independently on the cargo control console. An inclinometer, with accuracy better than ±0.025º for list and ±0.01º for trim, shall be installed within the CCR.

The primary CTS system (with its own dedicated printer) shall be fully integrated within the IAS. The secondary system shall have a stand-alone capability with information transfer to the IAS only.

The accuracy of the system shall be equal to or better than the following:

Level (primary system) better than	± 5 mm over full tank height
Level (secondary system) better than	± 5 mm over full tank height
Temperature better than	± 0.1°C over the range -165°C to -145°C
	± 1.0°C above -145°C
Pressure better than	± 1% of span over the range 800 ~ 1400 mbar

The primary level gauging system shall use the latest proven technology and provide adjustable alarm level signals for low level and normal filling level.

The secondary level gauging system shall

- Activate an alarm at a level slightly above normal filling level, and provide a signal to close the filling valve,
- activate an alarm at 99% of tank volume, or higher if allowed by Rules, that shall provide a signal to the emergency shut down system.

If this system allows isolation of the secondary level gauging system then this shall only be possible if this is directly linked to the isolation of the cargo stripping and main pumps.

Tank levels and low, high and high high alarms shall be separately displayed on an individual module clearly visible from a distance of 5m. Status of alarm and override functions shall be visible at all times.

31.4. Gas Flow Meters

Gas flow meters of the Coriolis type with accuracy of at least 0.1% shall be provided for the following applications:

a) Vapor to and from the shore
b) Vapor from the LNG & forcing vaporizer discharges
c) BOG to each propulsion engine
d) BOG to each power generating engine
e) BOG to the GCU
f) BOG to the reliquefaction system(s)
g) Nitrogen generator discharge and major consumers

Sampling equipment shall be provided, in order to monitor methane content of BOG prior to LD/BOG Compressor suction.

32. Cargo Emergency Shutdown System

The cargo emergency shutdown system (ESDS), required by the IGC Code, may be based on independent programmable logic control, or alternatively may be part of the IAS provided that complete independence and redundancy is maintained. It is preferable that the supplier of the ESDS be the same as the supplier of the ship/shore link system.

The fusible links in the cargo area shall be of the electric thermal fuse type.

The types of ship/shore link system shall include but may not be limited to:

a) An optical fiber link system (based on the SeaTechnik system) and incorporating ESD, telephone functions and data transfer modem (for MLM).
b) An electric link system, utilizing Pyle-National connectors (with Miyaki adapter) and incorporating ESD.
c) Provision for the connection of a pneumatic hose as ESD back up system including the necessary electro-pneumatic valves.
d) Telephone functions.
e) Transmission of data for mooring tensioning system.
f) Ability to transmit additional data streams.

Details of required communication and information systems can be found in **Section 41**.

33. Tank Pressure Control System

The Carrier design shall incorporate gas disposal/consumption/recovery to control the tank pressure in all Carrier operating modes. Redundancy shall be built into the system to allow for the handling of excess gas, without venting any gas to atmosphere. The tanks shall be fitted with safety relief valves.

The tank pressure control system shall have the facility to manually control the vent valve position and override IAS control from the Bridge and CCR in an emergency. Bilge Monitoring System

The Carrier shall be fitted with the necessary monitoring and control equipment to conform to Marpol 73/78, Annex I, Regulation 16, with the addition of a record being provided for concentration of oil discharged, either on the IAS or with a separate recording device.

34. Shipboard Administration System (SAS)

A personal computer based shipboard administration system with central file server and workstations shall be provided for handling of spare parts inventories, planned maintenance, accounts, and work processing. Data links shall be provided to the Satcom system for data transmission/reception. It shall also interface to the IAS (cargo and machinery), the custody transfer system (CTS), the ship performance monitoring system, the integrated navigation system (INS), and the loading computer.

The computer network shall be a fiber-optic local area network (FLAN) comprising of multiple workstations, printers, and data links installed in locations to suit the Carrier operator. There shall be one connection point in all cabins, the central store, conference room, training room, and both control rooms, 2 connection points within the wheelhouse and one connection at each desk within the main ship's office. Network cabling shall be multimode fiber-optic cable with a redundant cable fitted and terminated behind each point. The Purchaser shall supply the complete system, with the exception of the fiber-optic cables and connectors.

Server and units installed in wheelhouse, control rooms, and main ship's office shall be supplied by UPS units to give protection against supply spikes and interruptions).

The Builder shall be responsible for installation and commissioning of the hardware and for the provision of the spare parts inventory in a form suitable for direct electronic merging to the Carrier operator's database. The Purchaser will be responsible for providing, installing and commissioning the software.

35. Mooring Line Tension Monitoring System

One(1) mooring line tension monitoring system with a color VDU and keyboard shall be provided for all mooring lines at loading and discharging terminals according to shore terminal information.

A 19" high resolution (minimum 1080P) color monitor and keyboard shall be provided in CCR for mooring wire load at moored condition and show date, time, ship name, and graphic display of all mooring lines and tensions. Trend and data monitoring shall also be provided. System shall generate alarms when tensions exceed preset values.

The system shall be compatible with the fiber optic communication link which is used in related loading and discharging terminals.

The system shall also be interfaced to the IAS with a mimic displaying mooring tension.

36. Navigation and Communications

36.1. Navigation/Communication System

An integrated bridge design philosophy shall be adopted, with all sensor information, alarm information and primary controls brought together in a central wheelhouse area. The extent and layout of navigation and communication equipment shall be suitable for one-man bridge operations without loss of flexibility and safety for conventional bridge manning operations and be approved by the Purchaser and classification society. The bridge wings shall extend outward to allow visibility along the widest part of the Carrier's parallel body

The principle of using a single Maker for all hardware, software, and documentation shall be applied. While the Builder shall be the SPOR for the shipboard system, it is acceptable that the Maker would assume technical responsibility for all integration and compatibility issues between the different subsystems.

The Builder/Maker shall provide a comprehensive integrated Bridge Operation Manual (three copies) incorporating all the navigation and communication equipment on the bridge.

The Navigation/Communication system shall be designed and implemented as described in **section 36**

Power supplies for this equipment shall meet class and regulatory requirements and at a minimum meet the requirements of **Section 24.3** (h) and (i).

37. Bridge Equipment

37.1. General

All equipment provided shall be type approved. It shall reflect the latest proven electronic design and recognize current and future technical developments. Equipment shall be selected on the basis of reliability and flexibility.

Radio and navigation equipment shall be provided with dual supplies (see **Section 24.3**). Failure of the normal supply shall not cause loss of data, and full functionality shall be promptly restored with minimal operator intervention.

A comprehensive internal communications system shall be provided comprising an integrated system of automatic telephones, intercom telephones, mobile communications, and talk-back facilities to allow normal and emergency communications from point to point throughout the ship.

All alarms shall be gathered within a central alarm management system. The audible and visual alarm annunciation for this system shall differentiate between critical and non-critical alarms.

37.2. Layout

The bridge shall be designed (in accordance with ISO 8468:2007 or latest edition) to enable safe control and command of the ship from one central operating area on the bridge and provide workstations for the various functions to be carried out on the bridge.

The configuration of the wheelhouse, workstations, and consoles or the location of other constructions outside the bridge area shall not obstruct the field of view required for maintaining a proper lookout for traffic surveillance from the main workstation and other workstations to be used during transit.

Workstations for the primary and secondary bridge functions shall be provided as specified below:

a) Combined central workstation for navigation, traffic surveillance and maneuvering, and Carrier information centre
b) Workstation for route planning and chart corrections
c) Workstation for manual steering
d) Combined workstation for radio communication functions, Global Maritime Distress and Safety System (GMDSS) and safety operations
e) Bridge wing information station

The design and layout of the bridge shall take account of the requirements for pilot access to Carrier/navigational information. A dedicated position shall be provided along the forward bulkhead of the wheelhouse, on both port and starboard sides complete with all the necessary facilities to carry out this duty. They shall include AIS pilot point and necessary sockets to support a portable conning/docking display.

Bridge wing information stations on each bridge wing shall include high brightness high resolution (minimum 1080P) 26 inch displays interfaced with INS, capable of displaying both conning and docking

displays. They shall be located within SUS 316L (or equivalent) enclosures with an IP56 rating complete with anti condensation heaters.

37.3. Central Workstation

A combined central control console shall be "T" shaped and shall include the following minimum 26-inch TFT high-resolution (minimum 1080P) displays:

a) 2 x Radar display units
b) 2 x ECDIS display units
c) 1 x Central conning displays

All the main four display units shall have multi-function capabilities and display both Radar and ECDIS screens.

In addition to all the necessary communications and controls that are required in order to carry out the specified duties from this position, provision shall be made to incorporate:

a) Central CCTV station
b) IAS information station
c) Central alarm management system

The information on the console shall be presented in such a way that it can be easily viewed at up to a distance of 2m. The displays shall be arranged within the console, which shall be ergonomically designed in line with relevant regulations, (subject to the Purchaser approval) to allow for a primary operator position and secondary operator position both seated. The seats shall be adjustable in all three axes.

All necessary equipment and information shall be readily available to hand in order for the primary operator to perform the designated duties without leaving his seated position.

A lamp or screen dimming facility is critical for maintaining night vision and shall be provided for all equipment, controllable from the primary operator's position.

Quite often the same information is presented many times in different formats, which can lead to information overload. The information presented in the central console shall be provided in such a way as to avoid this.

Provision shall be made on first of class Carriers for the construction of a full size wooden replica of the central console complete with indicative displays and realistic controls for the Purchaser's approval of layout, as part of the detailed design approval procedure.

37.4. Navigation Equipment

The equipment for navigation shall include, but not necessarily be limited to, the following, which shall be supplied, as far as practicable, by a single supplier to satisfy the design philosophy stated previously.

37.5. Main Information systems

One Integrated Navigation System shall be provided and comply with the latest revisions of IEC 61924. This shall include a voyage management station with two approved ECDIS main units with electronic chart display capable of supporting both ENC and ARCS format charts and a digitizing chart table interfaced with position fixing equipment, radars, adaptive autopilot, logs, gyro compasses, satellite navigation equipment, echo sounder, anemometer, rudder angle indicator, shaft revolution indicator, etc.

Bridge overhead display on the bridge front is to provide information on Carrier performance, its condition, and environmental conditions in a form that can be easily read from all points of the wheelhouse. The information will include, but not necessarily be limited to, the following:

a) Wind speed and direction (analogue)
b) Ships heading (digital)

c) Rate of turn (analogue)
d) Rudder angle (analogue)
e) Ships speed(digital)
f) Water depth (digital)
g) Main engine rpm and direction (analogue)

37.6. Position/Heading Systems

Position and heading systems shall be provided as follows:

a) Two fiber optic maintenance free master gyrocompasses, with automatic and manual speed and latitude compensation and alarms.
b) Gyro repeaters, with pedestal, located on each bridge wing and on the wheelhouse front wall, and fitted with illumination and dimmer switch.
c) Repeaters provided in the overhead instrument panel (digital) in wheelhouse, manual steering stand and at emergency steering position.
d) Azimuth circles provided as required.
e) One transmitting and reflector type magnetic compass with illumination, dimmer switch, independent ‘off course’ alarm, azimuth circle and one spare compass bowl.
f) Two sets of minimum 26-inch high-resolution (minimum 1080P) ARPA units with full inter-switching facilities. ARPA shall be integrated with the INS.
g) "S" band and "X" band radar units with performance monitoring. Transceivers shall be installed in the navigation locker.
h) Two steering gear electric control systems of the "follow-up, gyro, non-follow up" type, each capable of operating with either main steering gear system.
i) Two automatic pilots ("auto-helm" systems), one of the ‘adaptive’ type with an "off course" alarm and compass repeater shall be provided. The autopilots shall be capable of follow-up, non-follow up, INS and heading control, from either the gyrocompass or magnetic compass.
j) Two DGPS satellite navigation systems (supporting Russian, European and US satellite systems).
k) Automatic Ship Identification System (AIS).

Chart management shall be an integrated service for both digital and paper formats, providing a unified inventory, updating, cataloguing and purchase system, to co-ordinate the upkeep of all onboard charts. Facilities shall be provided to receive and print onboard paper charts from their digital formats as well as material such as notices to mariners, chart corrections, electronic navigation chart updates and weather forecasting. Builder to supply and install purchaser selected hardware.

37.7. Carrier Information

Carrier information systems shall be provided as follows:

a) A rudder angle indicator system shall be provided with watertight repeaters on the bulkhead above both bridge-wing doors with illumination and dimmer switches. A three-face repeater shall be located beneath the wheelhouse front deckhead with dimmer switches on console. Repeaters shall be provided on manual steering stand, steering gear room, ECR console, captain’s dayroom, and wheelhouse overhead display.
b) Course/rudder angle recorder.
c) Propeller rpm and direction indication system with illumination on wheelhouse front and dimmer switch on central console. Watertight indicators with illumination and dimmer switch over both bridge wing doors. Indicator and counter on the console in ECR. Indicators in emergency engine operating location, captain’s office, and CCR console.

d) Rate of turn indicator, on wheelhouse front wall and over both bridge wing doors (P and S).
e) Doppler log providing the real time fore and aft speeds (both bottom track and water track) and athwart speed of the ship. One digital repeater in wheelhouse and interfaced with INS.
f) Drafts, list and trim indication.
g) One telegraph logger to record and print out all relevant information relating to main engine commands and movements complete with time and date.

37.8. Environmental Equipment

Environmental equipment shall be provided as follows:

a) Echo sounder combined with Doppler suitable for shallow and deep-water use, with a digital repeater and recorder in the wheelhouse.
b) Wind speed and direction monitoring equipment with repeater on the bridge overhead display and in the cargo control room.
c) Weather facsimile receiver, with DGPS time signal input, with programmable time and frequency control and at least 10" paper width.

37.9. Signal equipment

Signal equipment shall be provided as follows:

a) One set fog bell and gong signal system.
b) One set whistle including air horn on radar mast and electric horn with heater on the foremast. Control panel shall control both whistles and signal lamp, with pushbuttons on central console, front of wheelhouse and each bridge wing.
c) One blue heading indicator light LED located on the foremast.
d) One complete set of navigation lights (LED type) with control panel, configured and supplied to meet all the necessary flag and regulatory requirements.
e) One green ‘flashing’ light LED (plus 1 spare) in compliance with Japanese Maritime Safety Regulations.
f) One red ‘flashing’ light LED (plus 1 spare) in accordance with Japanese port regulations
g) RAM (restricted ability to maneuver) lights LED.
h) Suez Canal signal lights LED.
i) Suez Canal Bow Mounted Light LED on/off control.
j) Two sets of NUC lights LED one supplied for emergency AC supply the other from 24V DC General service batteries

37.10. Miscellaneous

Miscellaneous navigation equipment shall be provided as follows:

a) Window wipers of parallel type at all windows in protruding part of the wheelhouse front and in compliance with ISO 17899
b) Bridge watch monitoring system, that monitors operator fitness and equipment failures etc
c) Sound reception system
d) One sweep type searchlight (1 kW) on each bridge wing controlled manually.
e) To meet ISPS requirements a 180 degree horizontal sweep searchlight shall be installed to overlook the Carrier's stern. The travel shall be continuously automatic with unit being initiated from the wheelhouse.

f) Depending on how the X-band and S-band radars are arranged and subject to detail design, if there is a blind sector aft, a radar system shall be fitted aft to cover the blind sector as part of the ISPS measures.

g) The bridge front windows shall be fitted with electric heating devices and a washing system. All bridge windows shall be provided with roller sun shields. All bridge windows shall be fitted internally with 3M Ultra-600 anti-ballistic film or equivalent (subject to approved by Purchaser), subject to class approval for visibility.

h) Voyage Data Recorder (VDR) to IMO performance standards. Additionally, this unit will be capable of complying with BOQA (Bridge Operating Quality Assurance) and connecting to a remote access and analysis system as determined by the Purchaser and shall include audio inputs from bridge (three locations), each bridge wing station, cargo control room and engine control room.

i) Other navigation equipment will include:
   - 1 x Marine chronometer
   - 1 x Sextant
   - 1 x Daylight Signal Light, complete with battery (fixed daylight signaling light power supply receptacle required in wheelhouse and on bridge wings)
   - 2 x pairs of Binoculars
   - 1 x Loud hailer

38. Communication Equipment

38.1. Internal Telephony

The following internal telephony systems shall be provided:

a) Automatic telephone system with central exchange of the solid state type, capable of providing telephone communications in every cabin and working space, and having the following facilities:
   - Connection to Carriers satellite communications system shall be provided
   - selected telephones shall be used for announcement through PA system
   - telephones in the engine room shall be connected to the light signal columns and acoustic signal
   - telephones in the workshop, engine room and one of the telephones in the ECR shall be connected to a common circuit and have a common number
   - two separate lines shall be provided within the wheelhouse and ECR
   - telephones in the switchboard rooms shall have the same calling number
   - telephones in noisy areas shall have headsets
   - intrinsically safe telephones shall be installed in hazardous areas.
   - telephone headset for use in steering gear gear room/emergency steering position shall have a suitably long lead.

b) A telephone system certified as intrinsically safe (not sound powered) and connecting the bunker stations to the ECR.

c) A 24V DC telephone system shall be provided serving the wheelhouse, ECR, CCR, FCC, steering flat, C/E and Captain cabins and M/E maneuvering station, powered from the general use batteries (**see Section 24.7**).

38.2. Internal Broadcast and General Alarm

The following internal broadcast systems shall be provided:

a) Ship wide public address system, which shall include loudhailer for the cargo deck. Duplicated amplifier, master station in the navigation locker with monitor speaker, SW/AM/FM radio, CD player, and USB input. Control panel with microphone and monitor speaker on navigation console, ECR and CCR. Telephone announcements to speakers in selected groups from selected auto telephones. Dual AC power supplies with DC backup. Public address announcements to selected groups as follows: deck, accommodation, machinery, all/emergency. Priorities shall include: 1 emergency speech, 2 normal speech, 3 auto-telephone paging & 4 broadcast and 1 wheelhouse, 2 CCR & 3 ECR. Cabin and passage speakers shall have a volume control that is bypassed when in emergency speech. The public address system shall be used for general and fire alarm distribution.

b) Talkback systems for:

- mooring purposes, with portable microphones for bridge wings.
- machinery spaces and fire control station.
- between wheelhouse and each bridge wing.

39. Entertainment

The following entertainment systems shall be provided by the Builder:

a) Communal aerial system (radio and television) shall be provided in all cabins and public rooms with a radio outlet only in the galley and control rooms.

b) Dual band satellite TV system shall be provided suitable for the intended trading route with ten receivers, some for individual locations (TV rooms), and some fed through the communal aerial system.

c) Eight multi system color televisions high resolution (minimum 1080P), with HDMI and USB capability, shall be provided in the master's and chief engineer's dayroom, in public recreation areas, the main conference room, and the ship's office. Two of the eight televisions in the TV rooms shall be 55-65 inch, the other six televisions shall be 40-50 inch.

d) Stereo audio set with minimum CD player, USB input and SW/AM/FM radio in master's day room, and chief engineer's day room. Larger sets to the same minimum specification shall be fitted in the officers' and crew lounges.

39.1. Miscellaneous

The following miscellaneous communications systems shall be provided by the Builder except where specifically stated otherwise:

a) A multi-channel, intrinsically safe, UHF internal ship communication system with stations in ECR, CCR and Wheelhouse, 25 IS mobile handsets (including three headsets for hands free operation) with leather case/belt and clip microphone and fixed charging facilities in ECR, CCR, Wheelhouse and senior officer cabins, having a minimum of six duplex channels and the facility to reduce the power output of the base station to 1 watt for port use. They shall be equipped with programmable frequencies for use in conjunction with LNG terminal private frequency systems. The Purchaser shall provide the above equipment.

   The Builder shall install the necessary infrastructure to support the above system, including aerials and leaky feeders as required, to provide comprehensive coverage throughout the Carrier, including machinery spaces, duct keels, forward spaces, etc. Master units shall be located in WH, CCR, and ECR.

b) Refrigeration chamber alarm system.

c) Hospital alarm system.

40. External Communications

40.1. Radio Plant and Satellite Communication System

An external communications system shall be fitted, incorporating all equipment necessary to meet the current and known future requirements at the time of contract, for operation on the Global Maritime Distress and Safety System (GMDSS) in areas A1, A2, and A3. The system shall be provided with shore-based maintenance and duplication of equipment using 500W MF/HF radio and Satcom C system.

40.2. Commercial

The following systems shall be provided:

a) Radio Plant- To include, as a minimum, MF/HF transmitter with semi-duplex operation, MF/HF receiver, DSC terminal, DSC watch receiver, battery charging system, set of aerials, spare antenna, portable battery charger, battery charger and battery with low voltage alarm indication, set of accessories. Equipment shall be fed from AC 220 V and DC 24 V.

b) INMARSAT standard Fleet broadband 500 type satellite communications system. Main unit, including display, printer, and telephone shall be in the main ship's office. G3 Facsimile with 2nd ID shall be in the ship's central office. The distress alarm unit shall be in the wheelhouse. The message indicators shall be in the wheelhouse, CCR and master's dayroom. Remote telephones shall be in the captain's dayroom, wheelhouse, and CCR. Data interface shall be provided to the SAS. Facilities shall be fitted to prevent unauthorized telephone calls. It shall be provided with a dual power supply, with battery backup.

c) INMARSAT – C – Two sets to be provided with EGC reception, located in wheelhouse. One set will include Long Range identification in accordance with IMO Resolution MSC.210(81).

d) Set of VSAT Internet Network System, with all necessary hardware, shall be provided by the Purchaser and installed by the Builder. Purchaser to arrange commissioning. The system shall be interfaced with the Carriers's SMS, CCTV System and auto telephone exchange system.

e) INMARSAT Fleet Broadband communications system for voice communication to be provided with electronic unit in the Captain's Cabin, a telephone in a separate small room in the accommodation (equipped with a chair, small desk, and crew card phone) and an antenna unit suitably located in the accommodation block.

f) One Non-DCS VHF set with controller in CCR, with the facility to reduce the output to 1W. and the capability to program for private LNG terminal channels.

g) As part of ISPS requirements one non-DSC VHF shall be provided with Transceiver control unit (57 channels) installed within Safety Citadel and repeater stations in ECR and FCC.

40.3. Safety Systems

A VHF system forming part of the GMDSS requirements shall be provided consisting of two transceiver control units, each with a handset in the wheelhouse, a built in DSC watchkeeping receiver and a DSC printer. One system shall provide a receptacle for a portable handset at each bridge wing.

A self-contained automatic Carrier tracking system and ship security alert system shall be provided which continuously monitors the exact location of the Carrier anywhere in the world and which, in case of an alert, provides information simultaneously to a competent authority, as well as to the ship purchaser. It shall continue to operate even after the ship's communication equipment and main power supply have been disabled. Two alert buttons shall be installed as suggested by Builder and agreed by Purchaser.

The following additional safety equipment shall also be provided:-

a) Navtex receiver

b) Dual Frequency float flee type Satellite EPIRB
c) Helicopter homing beacon
d) Portable VHF transceivers (for lifeboats)
e) Two sets of 9 GHz search and rescue radar transponders (SART)
f) Three separate sets of VHF Radio Telephones, two of which will incorporate a DSC control unit and also interface with VDR. One set will also incorportate extension units on bridge wings and the DSC watch receiver.

41. Ship/Shore Communications for Cargo Terminals

The following facilities shall be provided for use when the Carrier is alongside LNG terminals, using the ship/shore links provided as per **section 41:-**

a) A 'hotline' call telephone installed on the cargo control console, providing voice communications with shore control room – preferably incorporated within ship/shore link system.
b) An analogue pushbutton telephone installed in the cargo control room, providing communications to the terminal's internal telephone network - preferably incorporated within ship/shore link system.
c) An analogue pushbutton telephone of universal international standards installed on or near the CCR console, providing communications to the shore public telephone network.
d) A telephone socket for fax communications installed in the cargo control room area and connected to shore public telephone network.
e) Mooring line tension monitor.

42. Closed Circuit Television System (CCTV)

42.1. General

The wired IP based digital CCTV system shall be fully integrated with the IAS. All control and set-up functions shall be provided within the IAS environment, with the exception of dual independent monitors being provided at each control point and the Wheelhouse control position, where an independent control station (monitor, keyboard, etc) shall be provided.

The system shall have four control positions, each with its own 27-inch high resolution (minimum 1080P) color monitors (2 per station). Monitors shall be available for console mounting and also ceiling mounted, using suitably constructed hangers. It shall be possible to view and operate any of the Carrier's cameras from each position.

The remote control positions will be located in the WH, CCR, ECR and personnel Safety Citadel and be linked via the IAS to a central video and data distribution unit. All cameras shall be available at each control position. The central distribution unit shall be configured for up to 24 cameras, 8 monitors, and 4 keyboards.

A video quad unit shall also be included, allowing the user to see up to four camera pictures per screen at the same time. It shall also be possible to program an individual camera sequence into the video quad, for at least one of the four split screen pictures.

Dual powers inlet for UPS and normal feeds. Separate network/sub net to be used.

System will be capable of automatically digitally recording onto data storage, e.g. solid state drives (SSD), with a minimum 7 day storage capability at normal viewing resolution. The system will be capable of automatically re-writing to a duplicated data storage unit/system after 7 days.

CCTV system shall be capable of being integrated to the Fire and Gas Alarm Systems. When an alarm sounds the CCTV displays shall automatically switch to the camera output nearest the alarm point.

Video Motion Detection (VMD) system shall be capable of supporting user-defined configurations to meet the Carrier's different operational modes (i.e., in port, anchor duties, etc). Any transgression of the monitored areas shall be presented to the operator in a timely manner. Each control station shall be capable of being selected as the lead monitoring station.

All camera housings shall be minimum IP56 rated and constructed from maintenance free electro-polished stainless steel with integral junction boxes to eliminate flying leads.

42.2. Wheelhouse System Equipment

A CCTV system, covering the deck areas, shall be provided as follows:

a) One dual lens type thermal camera (minimum 720P) with zoom, pan/tilt, and wash/wiper facilities at forward mooring deck.
b) One dual lens type thermal camera (minimum 720P) with zoom, pan/tilt and wash/wiper facilities at aft of mooring deck.
c) One thermal camera (minimum 720P) with zoom, pan/tilt and wash/wiper facilities at wheelhouse top.
d) Two dual lens type thermal cameras (minimum 720P) with wash/wiper facilities, located to provide coverage of deck areas either side of accommodation.

These cameras shall be linked into the VMD (video motion detection) system for day and night supervision.

Control functions to be provided via dedicated keyboard/joystick on central workstation.

42.3. CCR System Equipment

A second CCTV system, similar to the above, covering the following areas, shall be provided as follows:

a) Two Ex cameras (minimum 720P) with zoom, pan/tilt and wash/wiper facilities, one at port and the other at starboard cargo manifold area.
b) Two Ex cameras (minimum 720P) with zoom and pan/tilt facilities, in the compressor room.

42.4. ECR System Equipment

A third CCTV system with auto switching, covering the high-risk areas of the machinery space(s) shall be provided. The cameras (minimum 720P) listed below shall be located within areas where gas or oil-burning equipment is fitted, including the incinerator room and steering flat.

a) Machinery room(s) (safe areas): Ten camera stations, fixed type with microphone.
b) Steering flat (safe area): One dome camera station.

These cameras shall be mechanically protected, complete with zoom and pan/ tilt facilities, the steering gear camera shall be linked into the VMD system.

CCTV system shall be interfaced with the fire detection system to perform automatic switching to the fire detected area in the engine room.

43. Electric Clock System

A marine use, quartz controlled electric master clock system shall be provided with a minimum of 40 slave clocks in all living areas, public rooms, wheelhouse, control rooms, offices, and similar areas. A watertight slave clock shall be provided in the galley.

Master clock with slave clock control device shall be provided in the wheelhouse (with illumination and dimmer switch).

Three hand slave clocks shall be provided in the radio space, CCR and ECR.
A clock signal shall be provided for the telegraph logger, INS, CTS and IAS, using an automatic time signal from the GPS.

Appendix A: Depot Spares

The Builder shall provide individual costs for each of the following depot spares to the Purchaser's approval.

1) Hull Spares

a) Windlass (for 2 sets)
   1 - Hydraulic motors (per class of ship)

b) Mooring Winches
   1 - Hydraulic motors (per class of ship)

c) Manifold Cranes
   1 - Hydraulic motor for manifold crane (per class of ship)

d) Ballast system valves
   2 - Branch line valves (per class of ship)
   2 - Hydraulic actuators (per class of ship)

e) A/C and Auxiliary A/C system
   1 - Motor for A/C compressor (per class of ship).

2) Cargo Spares

f) Cargo pump
   2 - Complete pump with electric motor (per class of ship)
   (to be reviewed depending on number of ships per class)

g) Spray pump
   2 - Complete pump with electric motor (per class of ship)

(to be reviewed depending on number of ships per class)

h) High duty/VR compressor

1 - Set of rotor for high duty compressor (per class of ship)

i) Low Duty/BOG compressor

1 - Set of rotor for low duty compressor (per class of ship)

j) Safety Valve

1 - Complete of each size (per class of ship)

k) Cargo System

1 - Actuator for each valve type and size (incl. globe valve, seals, and seats)

1 - Pressure relief valve of each size

Expansion Bellows

1 - Complete for each size (per class of ship)

3) Machinery Part Spares

l) Main Slow Speed Dual Fuel Engines (2 off)

1 - Turbocharger casing complete (per class of ship)

1 - Complete conrod (per class of ship)

1 – Cylinder Gas Block complete (per class of ship)

m) Shafting and Propeller

Main Shafting:

1 - Set of metal for intermediate shaft bearing (per class of ship)

1 - Complete tailshaft (per class of ship). Shaft thread for propeller shall not be cut.

Propeller:

2 - Complete propellers (1 set) (per class of ship)

n) Emergency Diesel Generator Engine

1 - Set governor complete with motor (per class of ship)

4) Controls and Instrumentation Equipment

o) Instrumentation

Instrument equipment inside cargo tank ballast and void spaces:

1 - Each for 10 or less (temperature, level, pressure, etc) transmitters and transducers (per class of ship)

Record of Change

Location	Action	Description	Date: