

Appendix A

System Design Report


NEPTUNE PROJECT

SYSTEM DESIGN REPORT

PREPARED FOR

NEPTUNE LNG LLC

INTEC PROJECT NUMBER 11185602

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EXECUTIVE SUMMARY

Neptune LNG LLC (the Applicant), a Delaware limited liability company, is filing an application for a license pursuant to the Deepwater Port Act of 1974, as amended (the DWPA), and the United States Coast Guard's (USCG's) January 6, 2004, Temporary Interim Rules to construct, own, and operate a deepwater port. The proposed Neptune deepwater port will be located in the federal waters of the OCS blocks NK 19-04 6525 and NK 19-04 6575, approximately 22 miles northeast of Boston, Massachusetts and in approximately 260 feet water depth. The location is shown on Figure 1, an artist's rendering of the proposed deepwater port is shown on Figure 2, and a site plan of the proposed deepwater port is shown on Figure 3.

It is anticipated that the increased use of clean burning fuel such as natural gas, will drive the need for additional infrastructure to import liquefied natural gas (LNG) from alternative overseas sources. The Applicant has evaluated several approaches for the import of LNG to serve residential, commercial, industrial, and electricity generation consumers primarily in the northeastern United States market. The selected design will receive and vaporize LNG from a purpose-built and dedicated fleet of shuttle regasification vessels (SRVs). These vessels will be equipped with vaporization equipment that will convert the LNG to natural gas. This gas can be transported to shore through conventional subsea pipelines.

During the vaporization of LNG and send out of natural gas to the pipeline, up to two SRVs, each with a capacity of approximately 140,000 cubic meters (m³), will temporarily moor at the proposed deepwater port by means of a submerged unloading buoy system. Each unloading buoy would secure a SRV on location throughout the unloading cycle by means of mooring lines and anchor points located on the seabed. Two unloading buoys allow continuous natural gas flow by having a brief overlap between arriving and departing SRVs. As the first SRV moored at the deepwater port finishes unloading, a second SRV (following its transit from an overseas loading point) will moor at the deepwater port. After vaporization of LNG and send out of natural gas, the first SRV will disconnect from the unloading buoy and proceed to an overseas loading point to reload. Meantime, a third SRV, already in transit to the deepwater port, will repeat the cycle to allow uninterrupted delivery of natural gas. A marine site plan showing the SRV traffic pattern is shown on Figure 4.

The source of LNG delivered to the deepwater port may be from the Applicant's affiliate Suez's global portfolio of LNG supply at locations including the Caribbean, Africa, and the Middle East. SRVs may be loaded at overseas LNG sources and will transport the LNG to the deepwater port. An SRV will typically moor at the deepwater port for between four and eight days depending on SRV size, vaporizer throughput, and send-out rate.

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The SRVs will be equipped to store, transport, and vaporize LNG and to odorize, meter and send out natural gas via the unloading buoys. Each unloading buoy will be connected to a 16-inch flexible riser and 24-inch subsea flowline leading to a 24-inch gas transmission line that connects the deepwater port to the existing 30-inch Algonquin HubLineSM. The HubLineSM, operated by Algonquin Gas Transmission Company, runs below Massachusetts Bay, approximately 9 miles west of the proposed deepwater port location. From there, natural gas would be transported to serve residential, commercial, industrial, and electricity generation consumers, primarily in the northeastern United States. The deepwater port would have a peak capacity of approximately 750 MMscfd (million standard cubic feet per day).

The functions of the proposed deepwater port are to:

- Temporarily moor shuttle regasification vessels;
- Vaporize LNG, odorize and meter natural gas; and
- Send-out natural gas by pipeline.

The major fixed components of the proposed deepwater port are:

- An unloading buoy system located in a water depth of approximately 260 feet with two buoys separated by a distance of approximately 2 nautical miles. Each unloading buoy may have:
 - ◆ Eight mooring lines consisting of wire rope and chain connecting each unloading buoy to anchor points on the seabed;
 - ◆ Eight suction pile anchor points;
 - ◆ One 16-inch inside diameter (ID) flexible pipe riser, and;
 - ◆ One electrohydraulic control umbilical from the unloading buoy to the riser manifold;
- Two riser manifolds with isolation and control valves located on the seabed below and offset approximately 350 feet from each unloading buoy;
- One 24-inch diameter natural gas flowline, with a length of approximately 2.5 miles, connecting each riser manifold;
- One 24-inch gas transmission line, approximately 10.9 miles long;
- One transition manifold with an isolation valve; and
- One hot tap and connecting pipe with a check valve from the transition manifold tying into the existing 30-inch Algonquin HubLineSM.

Figure 5 is a schematic diagram of the pipeline and subsea system. Figure 6 shows an unloading buoy, mooring and riser arrangement.

Each proposed SRV combines the storage and transportation capabilities of a conventional LNG carrier, with dedicated onboard LNG vaporization facilities and offshore offloading capability (a shuttle regasification vessel). The SRVs will have dual fuel diesel electric propulsion systems for transit between an overseas LNG

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loading point and the deepwater port, including thrusters and a dynamic positioning (DP) control system. The DP system will be utilized while approaching and connecting to the unloading buoys. Typically, each SRV would have an LNG storage capacity of approximately 140,000m³ and would be approximately 918 feet long and 141 feet beam, with a normal operating draft of approximately 35 feet.

Natural gas would be discharged via a swivel connected to a turret in the mooring and unloading buoy that, in turn, will be connected to a riser and flowline. Each SRV may feature four membrane-type insulated, cargo tanks, (however, spherical, self-supporting prismatic-shape, or other acceptable containment systems may be used). The complete tanks will be located within the double hull of the SRV. Figure 7 shows a general arrangement of an SRV.

Once connected to a buoy, the vaporization of LNG and send-out of natural gas will begin. LNG from the storage tanks in an SRV will be pumped by means of low-pressure in-tank pumps. The LNG will be boosted to a working pressure of up to 1,740 pounds per square inch (psi) using a high-pressure cryogenic pump.

The onboard vaporization system will have a capacity of approximately 750 MMscfd consisting of three individual vaporization units. The vaporization system will have the capacity to empty a 140,000m³ vessel in approximately four to eight days. The vaporization plant will use a water-glycol heat transfer system. The system is based on evaporation of LNG at high pressure with steam as the heating agent. In order not to use steam from the shuttle regasification vessel's boiler room directly in a heat exchanger against LNG, a closed loop with an intermediate media is used to heat the LNG. This prevents the danger of hydrocarbon gas entering the boiler room in case of internal leakage in LNG /steam heat exchanger. Vaporized LNG shall leave as gas at a minimum of 32°F prior to fiscal metering and pipeline send-out. Fiscal metering can also be accomplished with an LNG tank gauging system typically installed on SRVs. Figure 8 shows the process system schematic. The location and nature of water discharges and air emissions from the SRV while moored at the deepwater port are included in supporting documents [Ref. 23, 24].

Natural gas from the vaporizers will be metered and odorized, then discharged via a trunk in the forward part of the SRV that would house a turret buoy mating cone and swivel system. The swivel system is designed to operate with natural gas at the system send-out working pressure. The SRV is designed for operation in harsh environments and can connect to the unloading buoy in up to 11.5 feet significant wave heights and remain operational in up to 36 feet significant wave heights providing high operational availability.

The main on-vessel components of the unloading system will include a pull-in winch, control system, natural gas piping, a gas swivel, buoy locking mechanism, and receiving cone. All, but the pull-in winch, will be located in the unloading buoy trunk

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within the hull of the SRV. The trunk will be fitted with a protective hatch and provided with a ventilation system.

The unloading buoy will consist of a locking recess ring for secure attachment to the SRV, mooring line connecting links, and a riser connection flange. Radial and axial bearings supporting an integral turret will allow the SRV to passively weathervane while unloading. When not connected to an SRV, the unloading buoy will submerge approximately 125 feet below the sea surface and supported by buoyancy compartments. In this position, the buoy will be held on location by the mooring lines. A marker buoy and retrieval line will be used to locate and recover the buoy as an SRV arrives at the deepwater port. The unloading buoy will be retrieved from its submerged position by means of a winch and recovery line. The unloading buoy will be hoisted up through a moon-pool in the forward part of the SRV where it would be located in a receiving cone within the hull trunk. After the buoy is locked in position, unloading of natural gas could begin.

Construction of the deepwater port components is expected to take 6 months from mid-May 2009 and would be completed by mid-November 2009 including mechanical downtime, weather delays and other contingencies. Start-up of commercial operations is expected in late-2009.

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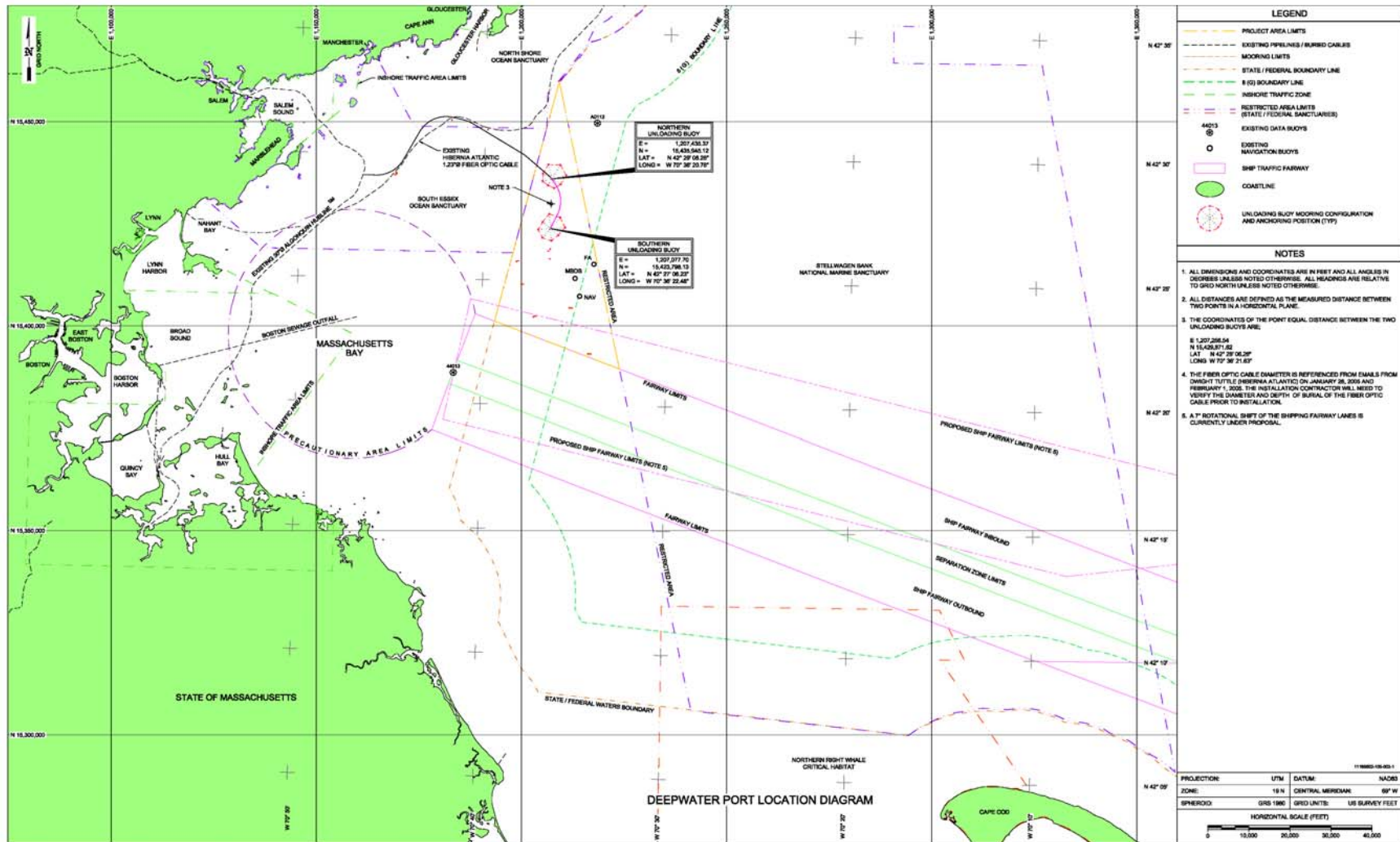


Figure 1: Deepwater Port Location Diagram

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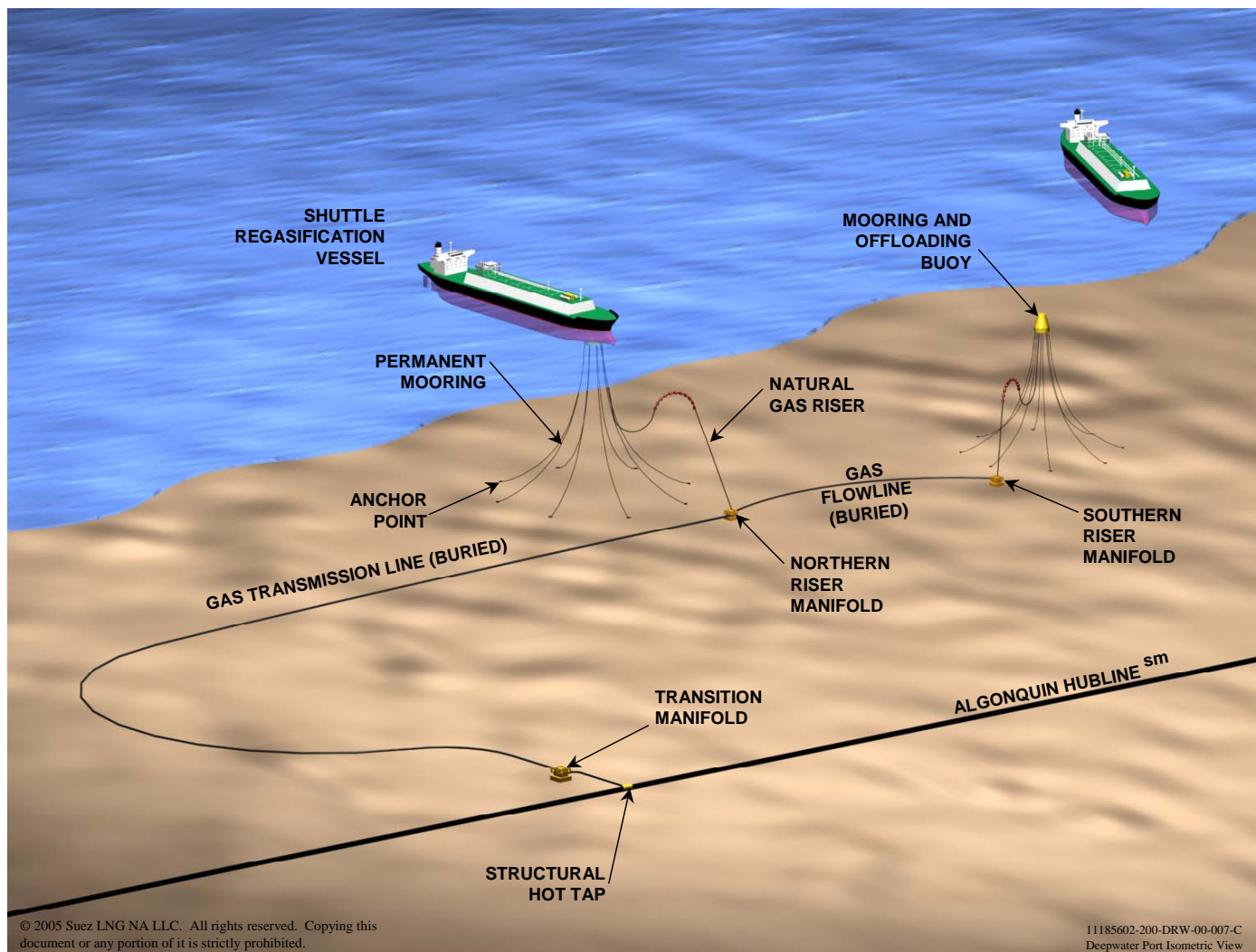


Figure 2: Artist Rendering of the Deepwater Port

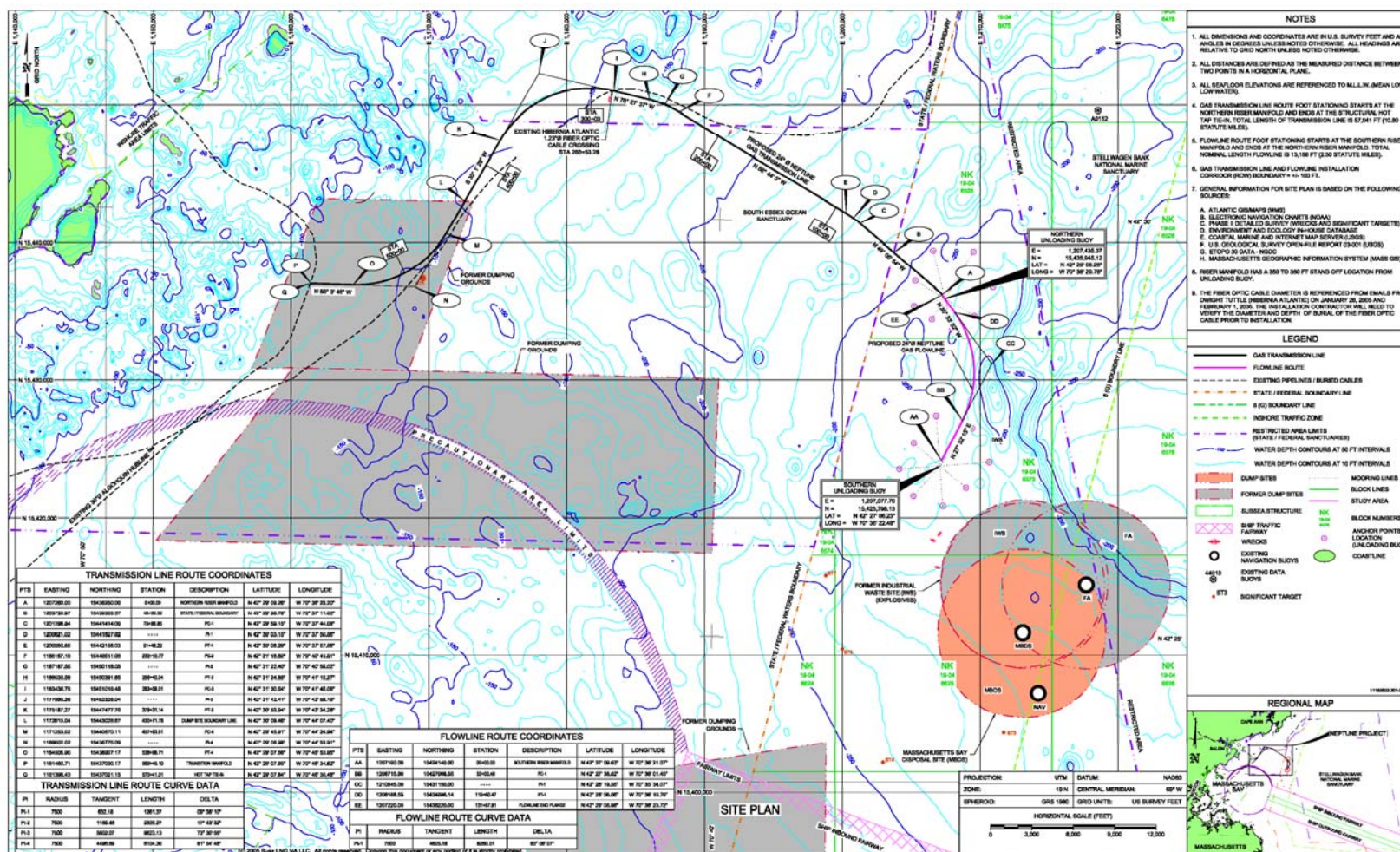


Figure 3: Site Plan

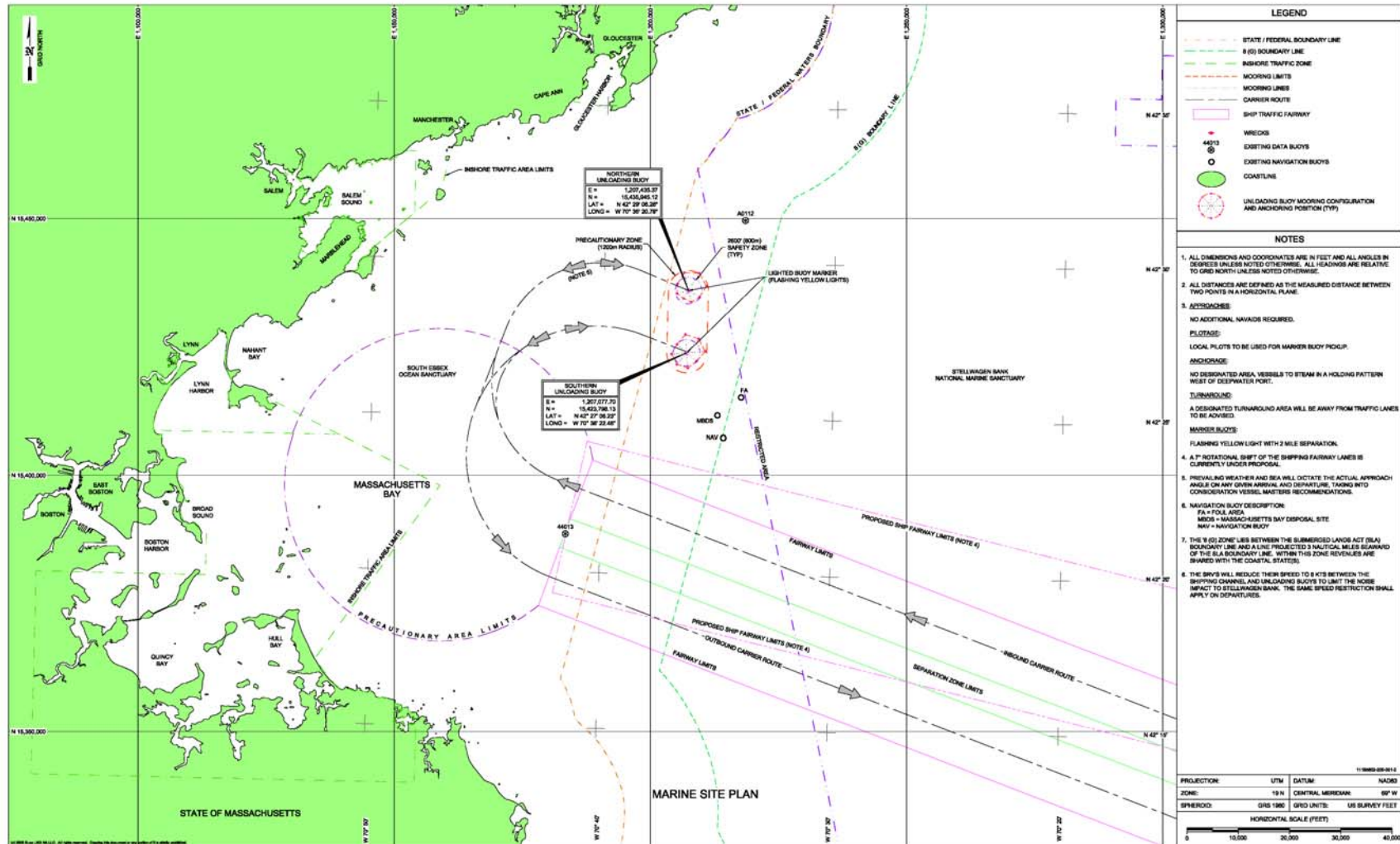


Figure 4: Marine Site Plan

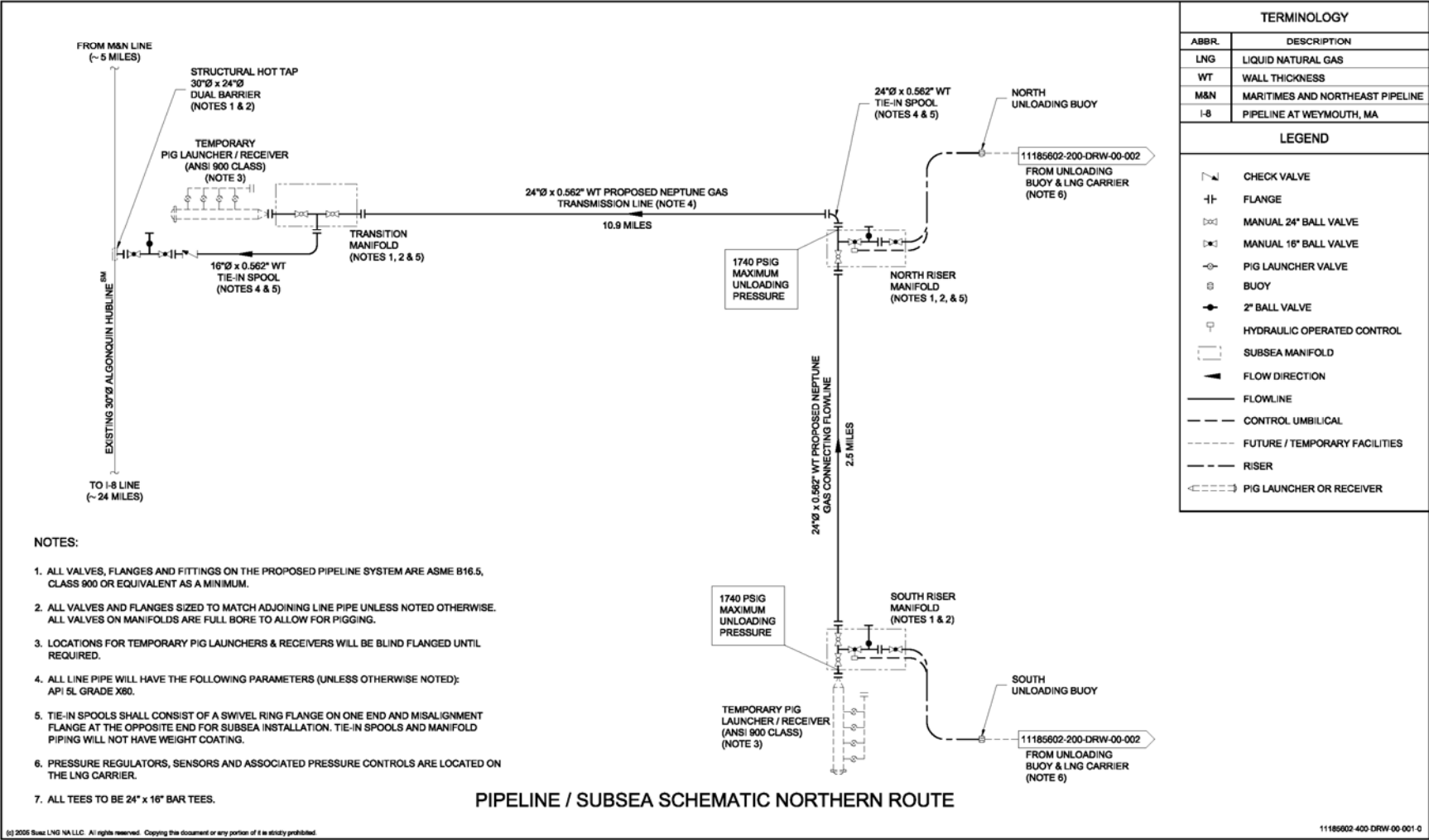


Figure 5: Pipeline and Subsea Schematic

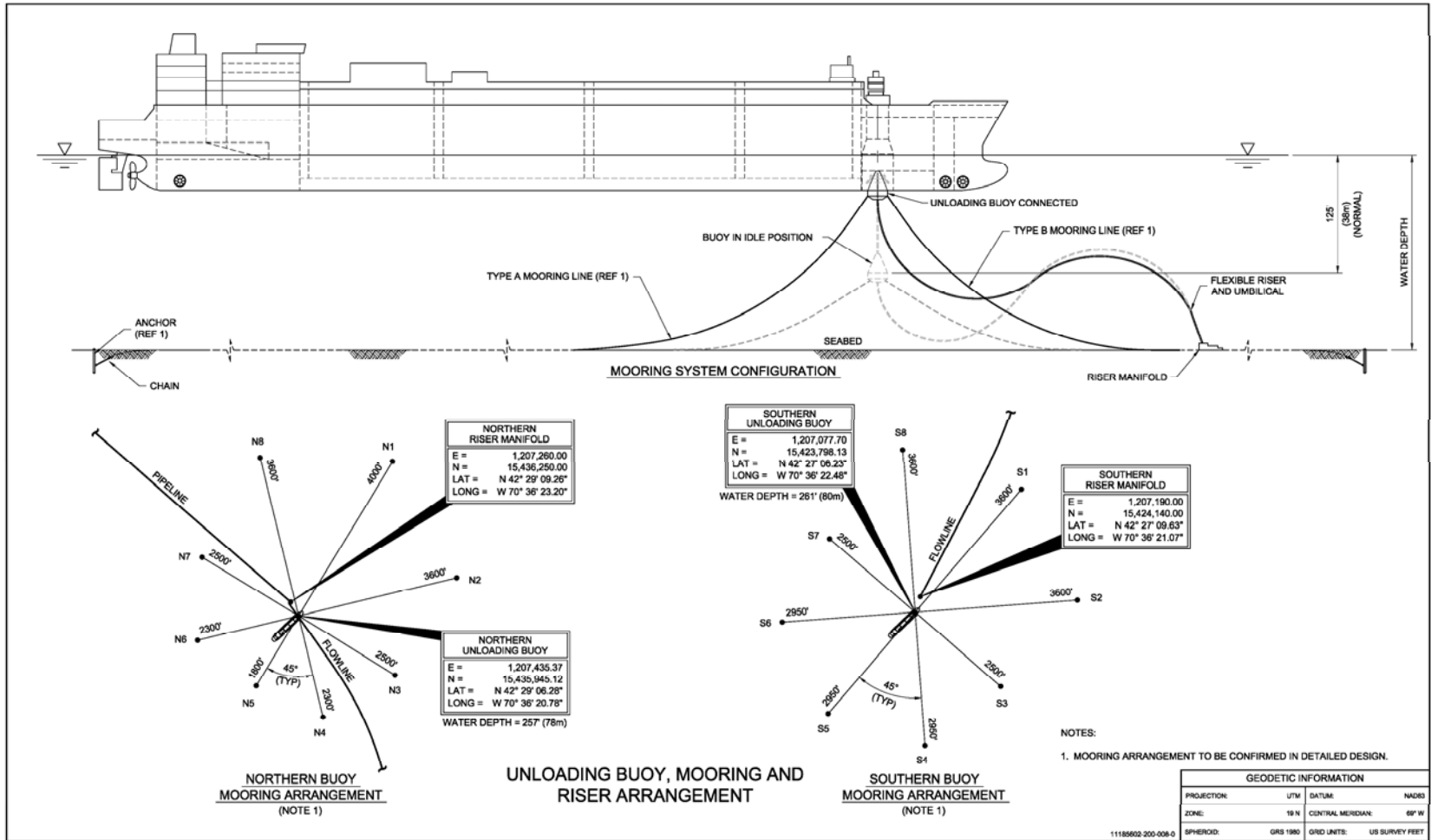
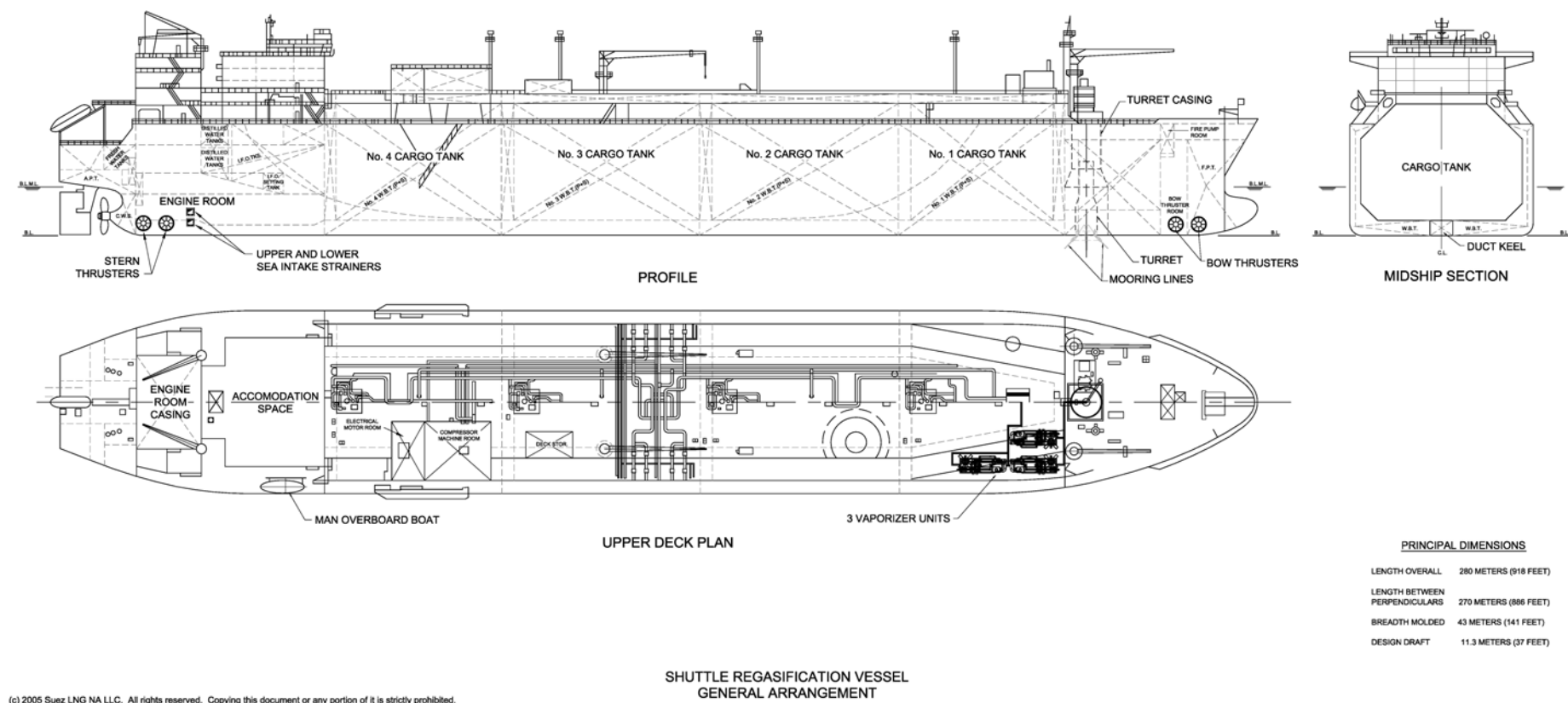


Figure 6: Unloading Buoy, Mooring and Riser Arrangement

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Figure 7: SRV General Arrangement



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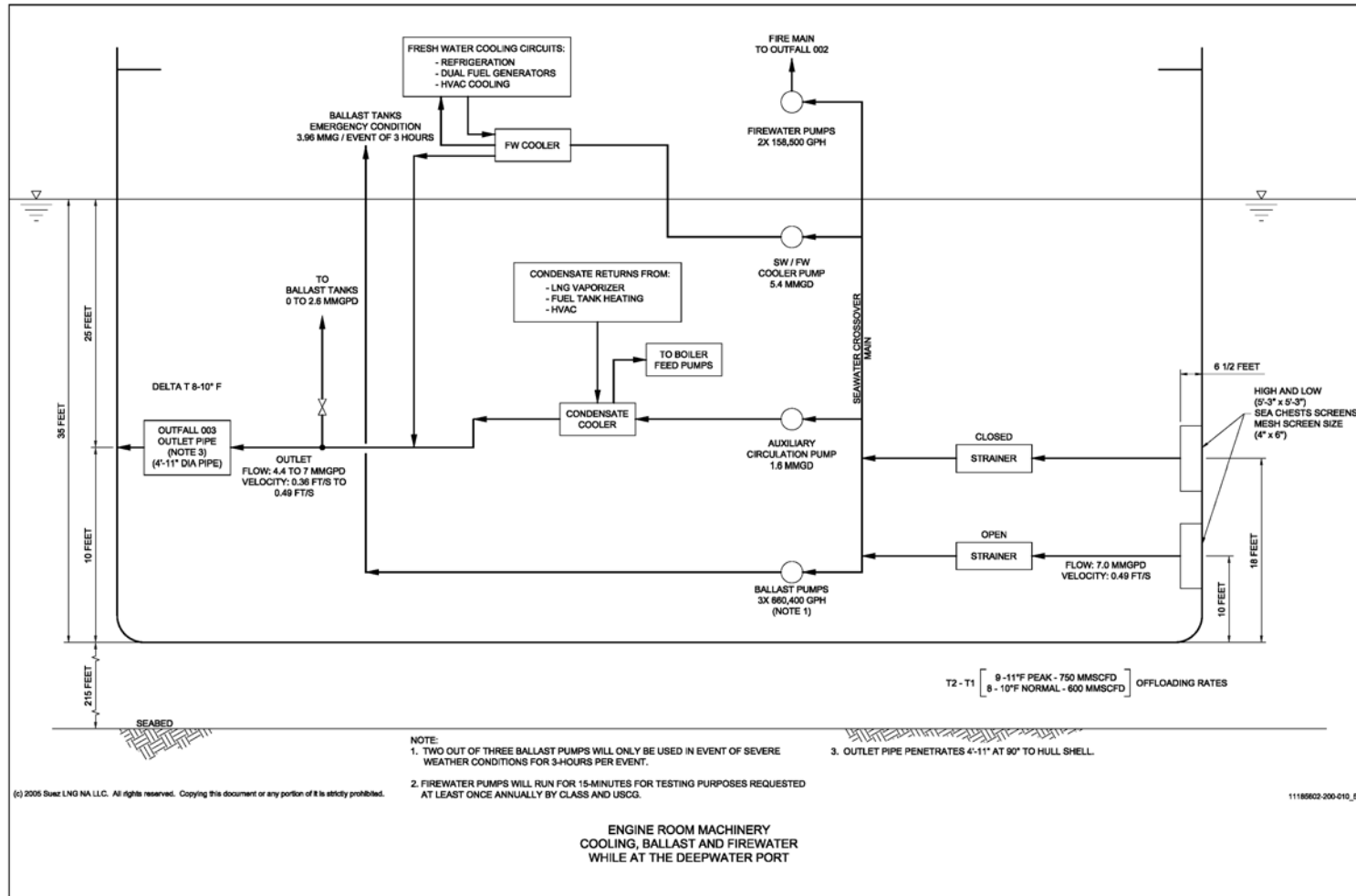


Figure 9: Engine Room Machinery Cooling, Ballast and Firewater

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Acronyms and Abbreviations

ABS	American Bureau of Shipping
API	American Petroleum Institute
APRS	Acoustic Positioning Reference System
ASME	American Society for Mechanical Engineers
CFR	Code of Federal Regulations
CTS	Custody Transfer System
DCS	Distributed Control System
DGPS	Differential Global Positioning System
DNV	Det Norske Veritas
DOI	Department of Interior
DOT	Department of Transportation
DPLA	Deepwater Port License Application
DWP	Deepwater Port
DWPA	Deepwater Port Act
FBE	Fusion Bonded Epoxy
FERC	Federal Energy Regulatory Commission
FSRU	Floating Storage and Regasification Unit
IACS	International Association of Classification Societies
ID	Inside Diameter
ILO	International Labor Organization
IMO	International Maritime Organization
LNG	Liquefied Natural Gas

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MAOP	Maximum Allowable Operating Pressure
MARPOL	International Convention for the Prevention of Pollution From Ships
MLLW	Mean Low Low Water
MMS	U.S. Minerals Management Service
MMscfd	Million Standard Cubic Feet per Day
MSL	Mean Sea Level
NIS	Norwegian International Ship Register
NOAA	National Oceanic and Atmospheric Administration
NOP	Normal Operating Pressure
OCIMF	Oil Companies International Marine Forum
OD	Nominal Outside Diameter
PCHE	Printed Circuit Heat Exchanger
SIGTTO	Society of International Gas Terminal and Tanker Operators
SOLAS	Safety of Lives at Sea
SRV	Shuttle Regasification Vessel
USCG	United States Coast Guard

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1. INTRODUCTION

Neptune LNG LLC (OPERATOR) is filing an application for a license to construct, own, and operate a deepwater port near Boston, Massachusetts. The proposed deepwater port named Neptune will receive and vaporize Liquefied Natural Gas (LNG). It will be located in Federal waters approximately 22 miles to the northeast of Boston in a water depth of approximately 260 feet. The Neptune deepwater port will utilize 140,000 cubic meters (m³) shuttle regasification vessels (SRV). Up to two SRVs would temporarily moor at the proposed deepwater port by means of an unloading buoy system. Two separate buoys would allow natural gas to be delivered in a continuous flow, without interruption, by having brief overlap between arriving and departing SRVs. The throughput will have a peak capacity of approximately 750 million standard cubic feet per day (MMscfd). The SRVs would be equipped to store, transport, vaporize LNG to natural gas, then odorize, meter and send out the natural gas by means of two 16-inch flexible risers connected to a 24-inch subsea flowline. This 2.5-mile flowline connecting the northern and southern riser manifolds connects to a proposed 10.9-mile long 24-inch gas transmission pipeline. The gas transmission pipeline connects the deepwater port via a hot tap tie-in to the existing 30-inch Algonquin HubLineSM, located approximately 9 miles west of the proposed deepwater port location. Construction of the deepwater port components is expected to take 36 months and start-up of commercial operations is expected in late-2009. The deepwater port will be designed, constructed, and operated in accordance with applicable codes and standards and will have an expected operating life of approximately 20 years.

2. LOCATION

The Neptune Deepwater Port (DWP) is located 22 miles to the northeast of Boston Massachusetts in Outer Continental Shelf (OCS) area NK 19-04, lease blocks 6525 and 6575. This places the Neptune DWP just to the west of the Stellwagen Bank National Marine Sanctuary and just east of the state seaward boundary as defined by the Submerged Lands Act.

The coordinates midway between the two unloading buoys are approximately 42° 28'06" N Latitude and 70° 36'22" W Longitude. The location is shown in drawing No. 11185605-200-GIS013, and a site plan of the proposed deepwater port is shown in drawing No. 11185602-200-DRW-00-001.

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3. DESIGN BASIS

Some of the critical aspects included in the design basis are [Ref. 1]:

- Water depth for unloading buoys 260 feet
- Peak unloading rate 750 MMscfd
- Average annual unloading rate 600 MMscfd
- Approximate SRV capacity 140,000 cubic meters
- Quantity of dedicated SRVs At least three
- Quantity of unloading buoys Two
- SRV to remain moored on location through 100-year storm.

4. DEEPWATER PORT COMPONENTS

The three major components of the proposed deepwater port are:

- SRVs
- Mooring System and Unloading Buoys
- Pipelines and Manifolds

All of these components are discussed in detail in the following sections.

5. SHUTTLE REGASIFICATION VESSELS

5.1 Functional Specifications

The SRV will be a standard design for oceangoing LNG carriers, plus the following additional items:

- Trunk and mating cone to receive the unloading buoy
- Gas vaporization system
- Gas metering system
- Gas odorization system

It will include a trunk and mating cone to receive the mooring and unloading buoy.

5.2 Codes and Standards

The SRVs will meet, or exceed all applicable codes and standards associated with LNG carriers, including the special requirements for the mooring and vaporization of the LNG.

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Det Norske Veritas (or equivalent) will class the SRVs for unrestricted service +1A1, Tanker for Liquefied Gas (-163 ° C, 500 kg/m³, 0.25 bar), Ship type 2G, E0, F- AMC, W1- OC, Plus-2, CSA-2, Clean Design. Alternatively, Lloyds Register (or another Classification Society that is a member of IACS with experience with this type of ship) will be considered.

The ship is to be registered under the flag of Norway or equivalent.

The following rules and regulations will be followed as far as relevant for this vessel, (including the latest amendments and protocols that are adopted or in force at the date of the contract):

- National Rules of the Flag of Registry
- International Convention on Load Lines
- International Convention for the Safety of Life at Sea (SOLAS), including International Gas Code
- International Convention for the Prevention of Pollution from Ships (MARPOL)
- International Convention for the Prevention of Collisions at Sea
- International Telecommunication Union Radio Regulations
- International Tonnage Measurement and Certification
- Suez Canal Navigation Rules, including Regulations for Measurement of Tonnage
- Safety and Health Regulations for Longshoring, U.S. Department of Labor
- USCG rules for obtaining certificate of compliance for foreign flag vessels carrying liquefied gases in bulk except requirements for Alaskan waters, and U.S.C.G. rules and regulations for foreign flag vessels operating in the navigable waters of the United States
- ILO, Code practice, Safety and Health in Dock Work, 1977, and Convention concerning Crew Accommodation on Board Ships, no. 92 and no. 133
- U.S. Department of Health Regulations for Foreign Flag Vessels as in "Handbook on Sanitation"

Navigation Rules and Regulations

- IMO Publication no. 978 - Performance Standard for Navigational Equipment
- IMO Resolution A.665 (16) Radio Direction Finding System
- IMO Draft Guidelines of Bridge Visibility
- IMO Resolutions A 468 (XII) "Code on Noise Levels on Board Ships" and A343 "Recommendation on Methods of Measuring Noise Levels at Listening Posts"
- IMO Res. MSC.35(63) Guidelines for Emergency Towing Arrangements on Tankers (SOLAS Conference May 1994)
- ISO 6954 "Guidelines for the Evaluation of Vertical and Horizontal Vibrations in Merchant Ships"

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OCIMF Guidelines

- Recommendations on equipment for The Towing of Disabled Tankers,
- Standardization of Manifolds for Refrigerated Liquefied Gas Carriers and
- Guidelines and Recommendations for the Safe Mooring of Large Ships at Piers and Sea Islands
- Mooring Equipment Guidelines
- Ship-to-Ship Transfer Guide (Liquefied Gas)

SIGTTO

- Recommendations for Emergency Shut- down Systems
- Recommendations for the Installation of Cargo Strainers on SRVs
- Guidelines for Alleviation of Excessive Surge Pressure on ESD

IEC, International Electro-technical Commission

- Certificates pertinent to these rules and regulations, and other usual certificates, will be delivered (including certificate for complying with USCG Rules for foreign flag vessels).

5.3 Status of Design and Construction

LNG carriers are normally designed and constructed based on functional specifications prepared by the prospective owner. A functional specification has been prepared [Ref. 20] along with information for the installation of the trunk, mating cone and associated shipboard equipment needed to receive the unloading buoy [Ref. 16, 17, 18]. Final design and construction of the SRVs will be performed by a reputable international shipyard experienced in the design and construction of SRVs.

5.4 Hull

5.4.1 General

The SRV will have a flush deck without forecastle and have a bulbous bow and transom stern. The engine room, crew accommodation and bridge normally will be located aft. Two bow thrusters and two stern thrusters will be provided to improve maneuvering of the SRV when approaching the loading or unloading locations.

A trunk and mating cone will be constructed in the forward part of the SRV to allow the SRV to moor to the unloading buoy at the proposed deepwater port.

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5.4.2 Double Hull

The SRV will have an inner hull to accommodate the membrane-type cargo tanks. Double bottoms and double sides will be utilized for seawater ballast. Double bottoms will be arranged in the cargo area and below the engine room, and double sides shall be arranged in the cargo area.

A conventional cargo manifold amidships will be provided for loading and unloading of the LNG at an LNG terminal.

5.4.3 Principal Capacities and Dimensions

Cargo tank total capacity at 100 % full at -163 ° C (-261° F) will be approximately 140,000 cubic meters.

The ballast tank capacity shall be sufficient to limit the draft variations when loading and discharging the cargo. The SRV and the cargo containment and handling systems will be suitable for cargoes of specific gravities up to 0.50. The approximate dimensions of the SRVs will be:

Length overall	280 meters (918 feet)
Length between perpendiculars	270 meters (886 feet)
Breadth molded	43 meters (141 feet)
Design Draft	11.3 meters (37 feet)

The vessel will be designed to be capable of entering the Boston/Everett LNG receiving terminal with full cargo.

The various tanks will have approximately the following capacities:

Marine diesel oil tanks (M.D.O.)	6,000 cubic meters (37,700 barrels)
Gas oil tanks (G.O.)	240 cubic meters (1,500 barrels)
Distilled water (feed water) tanks	280 cubic meters (1,760 barrels)
Fresh water tanks	250 cubic meters (1,570 barrels)
Potable water tanks	250 cubic meters (1,570 barrels)

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5.5 Propulsion

Electrical power and propulsion shall use four dual fuel (DF) diesel engines, two @ 5.7 MW and two @ 11.4 MW as an alternative to traditional steam turbine for propulsion and electrical power generation. This is based on the DF-electric power plant principle and propulsion is arranged with a single-screw driven by twin electric motors.

The smaller generators will be used while the SRV is on the buoy discharging cargo, the two larger generators will be operated when propulsion is required.

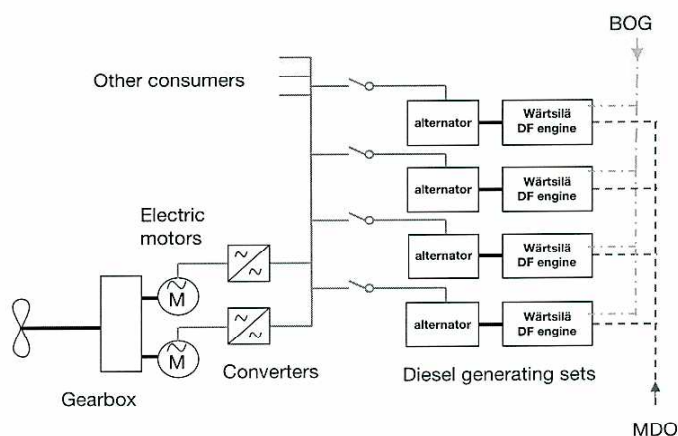


Figure 5-1: Propulsion System

The DF engines will burn 99% natural gas (a combination of 67% boil-off gas from the cargo tanks, 33% vaporized LNG), and 1% marine diesel (MDO) as pilot fuel.

Marine diesel serves as back up fuel.

The DF-electric machinery concept combines multiple DF engines with an electric propulsion system, and will offer a significant improvement in terms of operating economy, exhaust gas emissions and redundancy. At the same time, standards of safety, reliability and maintainability will be kept at appropriate levels. The increased economy over conventional steam plants is due to the higher efficiency of DF engines.

The steam plant will be optimized to two low-pressure marine auxiliary boilers, each rated at about 278 MM BTU/hr, which are being designed to operate on cargo boil-off gas and vaporized LNG. The steam will be supplied to the cargo vaporization units and not to the power generation and propulsion systems.

The SRVs will have a single highlift rudder of the Schilling or Becker type. The steering machinery will be rotary vane, electro-hydraulically driven.

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5.6 Dynamic Positioning

The SRVs will have two tunnel thrusters forward and two tunnel thrusters aft. Each thruster will have a controllable pitch propeller, with joystick control at the bridge house and bridge wings.

The dynamic positioning (DP) system will be used while retrieving the submerged unloading buoy handling line and moving on to the buoy. The system normally will not be utilized while the SRV is moored to the unloading buoy. The SRVs will be rated Class 1 DP, as defined by the International Marine Contractors Association (IMCA).

The main position reference system on the SRVs will be a Differential Global Positioning System (DGPS). The Acoustic Positioning Reference System (APRS) system will be used for monitoring the unloading buoy draft and its position before and during connection and disconnection to the unloading buoy. The bottom of the unloading buoy will be fitted with six transponders, equally spaced around the circumference of the lower part of the buoy. The APRS system will automatically search for the strongest return signal from the buoy. Because of their spacing at the bottom of the buoy, two of the transponders will always receive a signal from the ship's transceiver.

5.7 SRV Mooring System

The SRVs will be equipped with conventional LNG carrier mooring equipment to include forward port and starboard anchors, and mooring winches fore and aft for handling head, breast and spring lines. Additional equipment for each SRV will be provided for retrieving and securing the submerged combination mooring/unloading buoy.

5.8 LNG Containment System

Two main options for LNG systems are suitable for SRVs. One is the self-supporting Type B, and the other is a membrane tank system. Within the Type B option, there are two approved systems, the Moss spherical tank system, and the IHI Self supporting Prismatic Type B tank system, as shown in Figure 5-2.

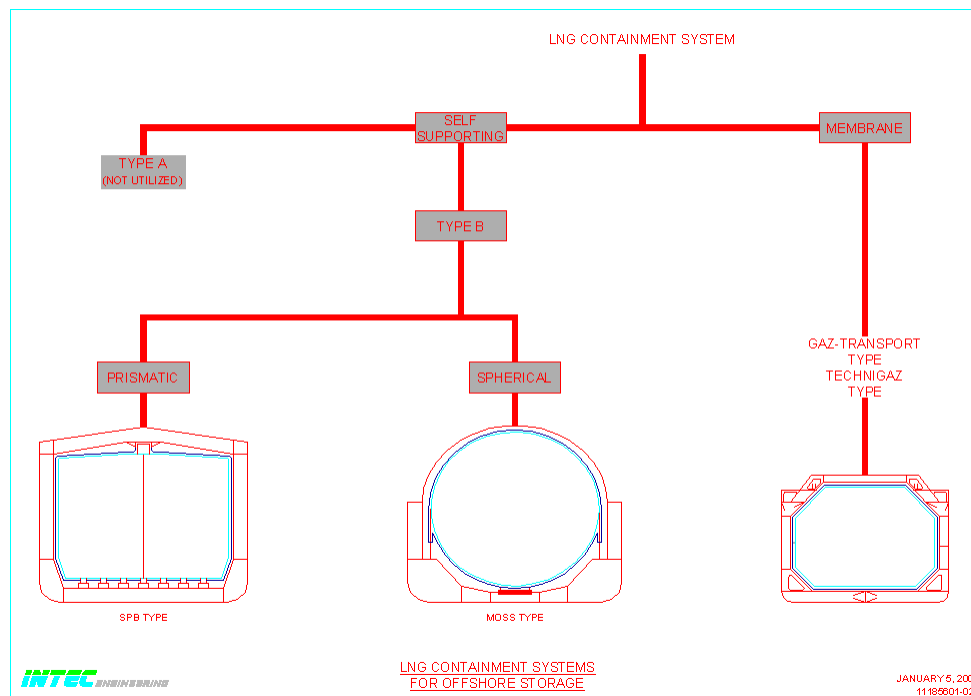


Figure 5-2: LNG Containment System

The containment system considered for the Neptune Project will utilize a membrane tank. Two variations of membrane tanks systems are available

- Gaz-Transport No. 96.
- Technigaz Mk III

The Gaz-Transport system (No. 96) has two identical and independent metallic membranes. The one in contact with the cargo being the 'primary membrane' and the second one the 'secondary membrane'. The metallic membranes are made of Invar Strakes, a 36% nickel-steel alloy with an extremely low thermal contraction coefficient, measuring 0.7mm thick and 500 mm wide.

These membranes act as dual barriers protecting the hull from exposure to the low-temperature cargo. The insulation space is filled with expanded silicone-treated perlite, and is internally strengthened to withstand high-impact pressures and to absorb the energy from the liquid motions and pressure head. The insulation spaces are inerted with nitrogen and equipped with detectors for permanent monitoring of the insulation spaces in order to detect possible gas leaks.

Technigaz Mk III is the latest version of the original Technigaz Mk I patent. In this system the insulation is effected by two layers of high-density polyurethane panels separated from each other by a membrane of triplex, a material composed of fiberglass

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and aluminum. This triplex would constitute the secondary barrier, while the primary barrier with the cargo would be a corrugated stainless steel membrane.

The design chosen will comply with all IMO requirements in accordance with a forty-year North Atlantic operational lifespan. The builder of the SRVs will provide detailed sloshing analysis for partially filled tanks (to any cargo loading level) to demonstrate that the membrane will not be damaged during voyage or while discharging at the Deepwater Port.

The proposed cargo system will have four membrane type tanks. The LNG with a specific gravity of approximately 0.45 will be stored at -163°C (-261°F). The maximum daily boil-off rate will be 0.15% of the cargo capacity.

Figure 5-3 illustrates a cross section of the hull and membrane tank for the SRV.

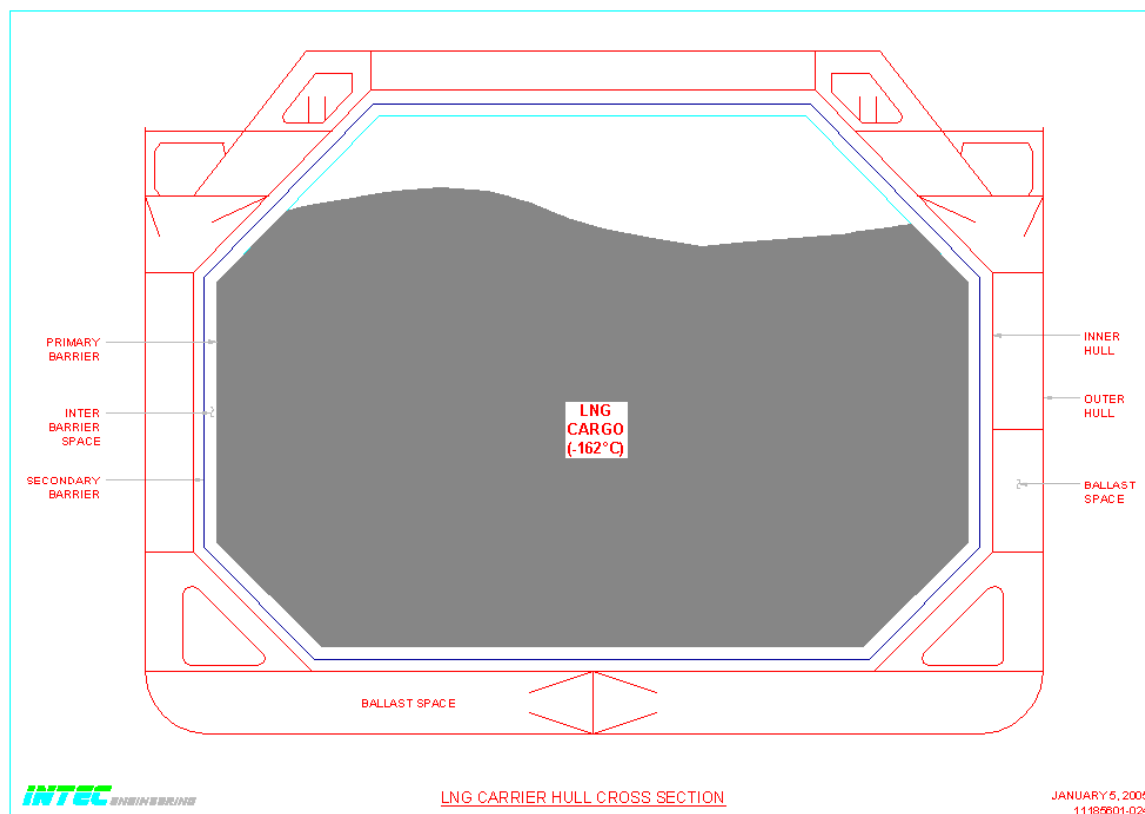


Figure 5-3: Hull and Membrane Tank

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5.9 Vaporization and Process Facilities

5.9.1 Vaporization System Description

The simple water-glycol heat transfer system is based on evaporation of LNG at high pressure with steam as the heating agent. In order not to use steam from the SRV's boiler room directly in a heat exchanger against LNG, a closed loop with an intermediate media is used to heat the LNG. This prevents the danger of hydrocarbon gas entering the boiler room in case of internal leakage in LNG/steam heat exchanger.

This change from the engine propane system will eliminate onboard propane inventories. The new design still maintains its status as "closed loop" where seawater plays no role in the re-gasification of LNG.

Each SRV would be equipped with three vaporization units, each with a capacity to vaporize 250 MMscfd (about 210 metric tons per hour [mt/hr]). Under normal operation, two units would be in service, with a combined maximum send-out capacity of 500 MMscfd. The average annual send-out capacity is expected to be 400 MMscfd. The third vaporization unit is intended to be on standby, but the vessel is designed for all units to be operational simultaneously at a maximum send-out capacity of 750 MMscfd. Each unit has turn-down capability of 100 to 20%.

The three vaporization system units would be installed on the forward main deck. Each unit would be independent and could be disconnected from the main deck for transportation to shore for maintenance.

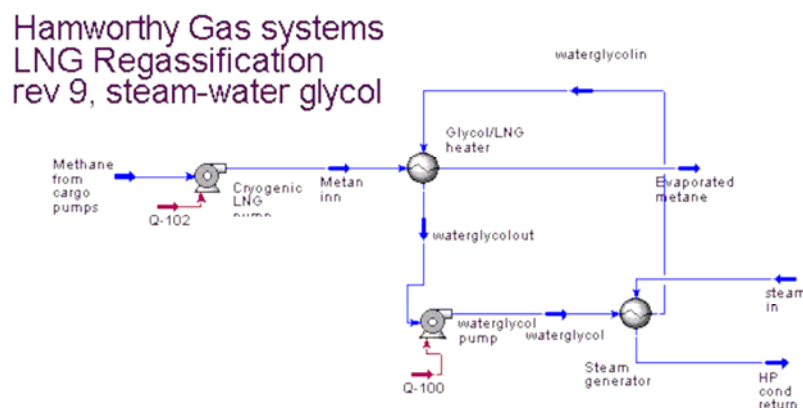


Figure 5-4: Regassification System

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LNG at minus 261° F and approximately 72 psi is pressurized in multi stage centrifugal pump(s) to 1740 psi. The LNG is then evaporated and heated as gas ranging in temperature between 32° to 50°F. Heating is accomplished in a shell and tube heat exchanger, where LNG is evaporated/heated in the tubes by water/glycol in the shell.

The water/glycol is circulated in a closed loop through the following steps:

- Water/glycol enters the LNG heat exchanger at 190°F and leaves at 68°F.
- Water/glycol is pumped with sufficient head to drive it through the closed loop.
- Water/glycol is heated in the steam /water/glycol heat exchanger to 190°F.
- Water/glycol enters the LNG heat exchanger again.

The steam heat exchanger is of the printed circuit type.

The heating media for the three units is steam produced by the auxiliary boilers. Steam is piped from the engine room to the water/glycol steam heat exchangers, and condensed steam from the heat exchangers is returned to the boiler feed water tanks at about 212°F. A control valve regulated by the temperature of the vaporized LNG adjusts steam supply.

The vaporization system would consist of three units on each SRV. Each unit would include the following components:

- One or possibly two high-pressure LNG pump(s);
- One heating water glycol circulation pump;
- One steam/water glycol heat exchanger
- One wateryglycol/LNG heat exchanger;
- One control module.

In addition to the three LNG re-vaporization units a Forcing Vaporizer shall be installed in the cargo compressor room to vaporize LNG, from the spray pumps in the cargo tanks to supply fuel gas to the DF engines. The capacity of the forcing vaporizer shall be sufficient to produce the full quantity of fuel gas as forced boil-off to achieve 100% gas demand from the two DF engines at maximum generated output.

Reference should be made to drawing titled “Process Flow Diagram – Closed Loop LNG Vaporizer” 11185602-200-DRAW-00-001 and Appendix A “Hamworthy Gasification Units For Steam Heating of LNG” [Ref. 21].

5.10 Seawater System Design and Flow Rates

5.10.1 Cooling Seawater

Seven MGD shall be pumped through the engine room machinery cooling plant to satisfy all cooling demand required by the DF diesel generators and LNG vaporization

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auxiliary boilers. Seawater intake will be through one of two chests, upper or lower. The sea chests shall be open to the sea through lattice screens measuring 5'3" x5'3". The water velocity through the lattice screens at the hull side shall not exceed 0.49 ft/s at a flow rate of 1,100 cubic meters per hour (7 MGD).

5.10.2 Intake and Discharge Locations

The two seawater intakes are located 100 feet forward of the aft perpendicular at 10 and 18 feet elevations from base line. The overboard discharge is located 100 feet forward of the aft perpendicular and at elevation 15 feet above the base line.

Reference should be made to drawings:

- 11185602-200-DRW-00-010 Engine Room Machinery Cooling, Ballast and Firewater
- 11185602-200-DRW-00-013 Sea Chest Arrangement

5.10.3 Produced Discharges

The SRVs will have two production discharges while at the buoy: seawater through process cooling and stack gases (emissions) from the two auxiliary boilers and two DF engines. The new design will bring about overall increased machinery plant efficiency with consequent reductions in seawater discharge and stack emissions.

Seawater outfall shall be further reduced to 700 cubic meters per hour from the 1,100 cubic meters per hour at the intake by diverting 400 cubic meters per hour to the ballast tanks. The resulting daily outfall will now be reduced to 4.4 MMGPD. However, the temperature change of 11°F between the inlet and outlet at maximum cargo vaporization rate will remain unchanged.

Emission sources during discharge include two gas-fired marine auxiliary boilers, each with a rated heat input of about 278 mmBtu/hr, and two of the DF engines, rated at 5.7 MW, with a rated heat input of about 40 mmBtu/hr.

The two larger 11.4 MW DF engines, used by the SRV under way, will not be in operation during cargo discharge.

The boilers will have low-NO_x burners with flue gas recirculation (FG). Flue gas recirculation significantly reduces nitrogen oxides (NO_x) emissions (up to 60 percent) in marine boilers by re-circulating a portion of the boiler flue gas (up to 20 percent) into the main combustion chamber. This process reduces the peak combustion temperature and lowers the percentage of oxygen in the combustion air/flue gas mixture; thus retarding the formation of NO_x caused by high flame temperatures (thermal NO_x).

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The two smaller DF engines will have SCR (Selective Catalytic Reduction) units to reduce NO_x emissions by 85% to very low levels, 0.2 g/khr or 0.15 g/bhp-hr. The larger DF engine may be provided with SCR as these engines will be used only when the SRV is under way. The SCR system will use urea as the catalyst agent to reduce NO_x formation. Presently SCR is not achievable for marine boilers.

5.11 Gas Metering System

A gas metering system will be located on the forward part of the main deck, between the vaporization units and the unloading buoy trunk, and will include the following main items (or similar equipment):

- **Ultrasonic Gas Metering System**
 - ◆ Two Ultrasonic Gas Flow Meters
 - ◆ Two Pressure Transmitters
 - ◆ Two Temperature Transmitters
- **Gas Analyser System**
 - ◆ Sample Probe
 - ◆ Two Gas Chromatographs
 - ◆ Pressure Reduction Cabinet
 - ◆ Analyser Cabinet
- **Metering Control System**
 - ◆ Metering Cabinet
 - ◆ Two Flow Computers
 - ◆ Terminal Flow Computers and Gas Chromatographs
 - ◆ Supervisory Computer & Operator Station
 - ◆ LAN Switch
- **Odorization System**
 - ◆ Natural gas will be odorized on board the SRV by connecting injection equipment for the odorization agent (mercaptan) to the suction drum for the high-pressure LNG pumps (or other suitable connecting points). The odorizing agent will be supplied in containers supplied from shore. Provisions for safe storage of the containers will be arranged.

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5.12 Unloading Rates

Each SRV will have the capability to unload at a maximum rate of 750 MMscfd at each buoy. Simultaneous unloading of two SRVs will also be possible at a combined maximum rate of 750 MMscfd. The initial average unloading rate will be approximately 400 MMscfd increasing to 600 MMscfd soon after the deepwater port is commissioned.

5.13 Discharge Pressure & Flow Control

The SRV will have High Pressure LNG Pumps rated at 120 bar (1740 psig) at the discharge side of the pump. Pump speed control will be included so that the maximum allowable operating pressure of the Algonquin HubLineSM will not be exceeded. The shuttle regasification vessels will control the gas delivery rates to the HubLineSM.

5.14 Shipboard Systems

This section describes the standard equipment included on a conventional SRV.

5.14.1 Main Power Generation

Electrical power generation shall use four dual fuel (DF) engines two @ 5.7 MW and two @ 11.1 MW as an alternative to traditional steam turbine for propulsion and electrical power generation. This is based on the DF-electric power plant principle and propulsion is arranged with a single-screw driven by twin electric motors.

The smaller generators will be used while the shuttle regasification vessel is on the buoy discharging cargo, the two larger generators will be operated when propulsion is required.

The DF engines will burn 99% natural gas (a combination of 67% boil-off gas from the cargo tanks, 33% vaporized LNG), and 1% marine diesel (MDO) as pilot fuel. Marine diesel serves as back up fuel.

The DF-electric machinery concept combines multiple DF engines with an electric propulsion system, and will offer a significant improvement in terms of operating economy, exhaust gas emissions and redundancy.

5.14.2 Other Shipboard Systems

The SRV will be equipped with all normal shipboard systems, such as bilge and ballast system, safety equipment, life saving equipment, fire fighting equipment, deck lighting, navigation aids, and all other equipment needed for compliance with the applicable codes, standards, and regulations.

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5.14.3 Cargo and Ballast System

The cargo and ballast system will include the necessary pumps and control systems for monitoring and control of all liquids such as LNG storage, ballast, fuel oil, and other liquids. The onboard load and stability calculator will assure that liquids are properly distributed to minimize the stresses in the vessel hull. The operator will be able to monitor the cargo fluid levels, temperatures and processes within each tank, and control the valves for filling, emptying and stripping the tanks. The operator also can monitor and control the auxiliary equipment associated with the cargo pumps.

The LNG compressor room, situated amidships on the main deck, houses the following major items of equipment:

- **Compressors**
 - ◆ Low Duty (LD) gas compressor, used to provide boil-off gas for the auxiliary boilers and D.F. engines.
 - ◆ High Duty (HD) gas compressors, used to return LNG vapor ashore during loading operations; return gas/vapor ashore during gassing-up and initial cool-down operations; and circulate heated cargo vapor through the cargo tank system during warm-up operations.
- **Cargo Heaters**
 - ◆ Two steam heated, horizontal shell-and-tube type heaters, used to supply warm gas to the boilers and D.F. engines for burning as fuel and to supply gas to the cargo tanks during warm-up operations prior to inerting, aeration and entry.
 - ◆ Two steam heated, horizontal shell-and-tube vaporizers, used to produce gas to purge the inert gas from the cargo tanks prior to cool-down; and produce gas to maintain tank pressure when unloading (if shore return gas is not available).
- **Cargo Pumps**
 - ◆ Capacity: Rated at 1750 cubic meters per hour (typical)
 - ◆ No. of sets: eight (2 per cargo tank)
 - ◆ Operating temperature: -163°C
 - ◆ Rated head: 155 meters (typical)
 - ◆ Power: 275 BHP (typical)
 - ◆ Speed: 1,780 rpm

Each LNG tank will be outfitted with two cargo discharge pumps. These pumps will be single stage, centrifugal pumps with one inducer stage. The single stage helps to obtain a very low Net Positive Suction Head.

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The pumps will be of the submerged motor type, with the motor windings cooled by the pumped LNG. The LNG also lubricates and cools the pump and motor bearings.

When all cargo pumps are in operation, a full cargo of LNG can be unloaded in approximately 12 hours at a conventional discharge port.

5.14.4 Nitrogen Generators

Two nitrogen generators will be installed to provide nitrogen for the following purposes:

- Cargo vapor-compressor gland sealing
- Cargo tank insulation space and inter-barrier space inerting and purging
- Cargo line purging
- Auxiliary boiler and DF engine fuel gas line purging

5.14.5 LNG Custody Transfer System

An LNG Custody Transfer System will be provided to enable accurate LNG quantity measurement when loading or unloading LNG. The system will measure liquid levels, liquid and vapor temperatures and vapor pressure within each LNG tank. This data, together with the tank calibration tables, will automatically calculate the LNG quantities before and after the transfer of the LNG.

A gas metering system also will be provided to satisfy the operating requirements of the Algonquin HubLineSM (see section 5.11).

5.15 SRV Operations

5.15.1 Loading

LNG will be transferred from shore side LNG piers to the SRVs. The loading operations typically will require approximately one day for berthing the SRV, loading the LNG, and preparation for departure from the LNG pier at the supply location. Normal security and safety policies will be followed and comply with all applicable rules and regulations.

5.15.2 Transit

The SRVs will transport the LNG at speeds up to 19.5 knots, and comply with all MARPOL, SOLAS, and other applicable international rules.

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5.15.3 Connection of SRV to Unloading Buoy

When an SRV is not moored to the unloading buoy, the buoy will be submerged approximately 125 feet below the ocean surface, and the riser and control umbilical will remain attached. The valves at the top of the buoy and at the riser manifold will be closed. A pendant line will go from the top of the unloading buoy to a marker buoy that is equipped with the required navigation lights.

When the SRV approaches, the SRV will retrieve the unloading buoy with special shipboard equipment, connect the buoy to the mating cone in the hull of the SRV, and prepares for vaporization and unloading of the LNG.

Additional information can be found in Reference 18.

5.15.4 Vaporization and Unloading of Natural Gas

The Vaporization and Process Facilities were described above in Section 5.9.

Two unloading buoys will be utilized so that natural gas can be delivered in a continuous flow without interruption by having brief overlap between arriving and departing SRVs. As the first SRV moored at the deepwater port is emptied, a second SRV moors up at the deepwater port.

5.15.5 Disconnection from Unloading Buoy

Prior to departure of the SRV, the unloading buoy will be disconnected and lowered to a neutrally buoyant location below the ocean surface.

5.15.6 Manning and Crew Change

The SRVs will have accommodations for as many as 42 persons. Normal crew size will be approximately 30 persons. All critical functions will be manned 24 hours per day. Other functions will be accomplished on a regular, scheduled basis.

Crew changes may occur at the LNG loading terminal, or may take place at the planned deepwater port using the service vessel.

5.16 Safety Features

5.16.1 LNG Leak Detection

Volume III of the SOLAS International Code governs the construction of gas carriers for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (usually referred to as 'The Gas Code').

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The basis of the philosophy is the ‘leak before failure’ concept. This presumes that the primary barrier will fail progressively, not suddenly and catastrophically. In order to meet these requirements certain conditions must be satisfied. These include:

- Stress levels, fatigue life and crack propagation characteristics of the tanks must be determined using finite element model tests and refined analysis methods.
- A partial ‘secondary barrier’ must be capable of containing any envisioned leakage from the ‘primary barrier’ for a period of 15 days and must prevent the temperature of the ship’s structure from falling to an unsafe level. The failure of the primary barrier must not cause the failure of the secondary barrier, and vice versa.

In the exceptional, unusual case of a crack occurring in the primary barrier membrane, a small leakage of LNG within the inter-barrier space will be detected at an early stage by the gas detection system. If the leakage increases the LNG will be restrained from coming in contact with the inner hull by the secondary barrier membrane.

5.16.2 Emergency Shut Down System

The Emergency Shut Down System will be designed to ensure a controlled shutdown of LNG equipment to avoid any unsafe conditions. It is essential that the machinery be stopped and valves closed in the correct order to avoid any pressure surges.

5.16.3 Ship-to-Shore Link

Linked ship-to-shore emergency shutdown systems are required by SIGTTO for loading LNG and discharge at shore side LNG piers. They minimize the consequences of an accident or, if abnormal conditions arise, they allow the process to be shut down with minimum spillage of liquid. This will avoid:

- Excessive surge pressure on the loading arm connection (the upstream valve is closed first)
- Overfilling the cargo tanks
- Risk of damage or spillage due to excessive movement of the SRV with respect to the shore side berth

During vaporization of LNG and unloading natural gas at the planned deepwater port, ship-to-shore communications will be achieved by radio or satellite links.

5.16.4 LNG Tank High Level Shut-off System

Each LNG tank will have an independent high-level alarm and shut-off function, which work independently of each other. The shut-off function will be connected to the high-level alarm system. A pre-warning alarm will be sounded when the tank volume reaches 95%. This will activate an alarm in the Cargo Control Room (CCR)

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and an alarm horn with a different tone from above will sound on deck, accompanied by an orange flashing warning light. When the liquid level in the tank reaches a position equal to 99.2% full by volume, a signal will be sent to the tank loading valve remote control system to close the valve automatically. When this valve is activated, red warning lights will flash and an alarm horn will sound on deck.

5.16.5 LNG Tank Relief Valves

Each LNG tank will have two pressure / vacuum relief valves as required by the IMO code. The relief valves will be of the PORV (Pilot Operated Relief Valve) type. An LNG tank pressure sensing line relays the pressure directly to the pilot-operating valve. This assures that relatively low pressure is maintained inside the tank.

5.16.6 Accommodation and Machinery Spaces Gas Detection System

This gas detection system monitors the accommodation and machinery space areas of the ship. The system uses infrared gas analysis to measure air samples for methane content (typically at twelve or more locations). The system also uses contact combustion methods to test for the presence of combustible gases in nine or more other locations. Alarm indication will be shown locally and in the CCR. The infrared system analyzers will automatically (or manually) switch between the locations. The range of measurement is from 0-100% LEL (Lower Explosion Limit). The system normally will scan the locations continuously and sequentially for 24 hours per day, seven days per week.

5.16.7 Cargo Areas Gas Detection System

A separate gas detection system covers the LNG insulation spaces and miscellaneous areas housing any part of the LNG handling systems including the three vaporization units and turret trunking. The control unit is similar in operation to the accommodation and machinery spaces gas detection system.

5.16.8 Fire Detection System

The fire detection system will be computerized, with fully addressable digital fire alarm system and discreet detectors. The central control unit with back-up battery, operating panel and power supply will be contained in a central cabinet on the bridge. There will be a repeater panel in the fire control headquarters. This system, by code, must be a triple redundant, stand-alone, PLC based system.

The system will be interfaced to the Distributed Control System (DCS) via a converter and RS232 serial interface. The DCS will indicate loop status and can control the fire pumps. The operator will also access deck plans indicating the exact location of individual detectors. The system uses a wide range of detectors and sensors to suit different needs and conditions. It will include detectors with different alarm parameters

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(for example ion and optical smoke detectors, heat and flame detectors, manual call points, short circuit isolators and timers where required). The detectors will be wired in a loop configuration with four loops in total. A fault in the system or a false alarm will be detected immediately since the function of the detectors and other installed loop units will be tested automatically and continuously.

5.16.9 Fire Water System

The following pumps will supply the fire water system:

- Main Fire Pumps
 - ◆ Capacity: 600 cubic meters per hour at 120 MWG (typical)
 - ◆ Speed: 3,500 rpm
 - ◆ No. of sets: 2
- Emergency (Forward Pump Room) Fire Pump
 - ◆ Type: Hydraulic, electric motor driven from emergency switch board
 - ◆ Capacity: 50 cubic meters per hour at 90 MWG (typical)
 - ◆ No. of sets: 1

The fire main system will be supplied from the engine room by two fire pumps. The pumps will be single speed centrifugal pumps, with a combined delivery capacity of 1,200 cubic meters per hour.

The electrically driven pumps shall be started from their main switchboard starters in the ECR, the emergency fire headquarters or via the DCS (ECR, CCR or LCCR).

The system can also be supplied from the emergency fire pump. This pump will be located in its own compartment aft of the forepeak. The pump will be a self-priming centrifugal pump with its own direct sea suction. The pump will be rated at 50 cubic meters per hour and will be powered by an electric motor. The deck fire ring has a main isolator valve, fitted before the port and starboard feeder. The ring main will be fitted with further section isolator valves to allow any part of the system to be supplied from either side of the SRV. This set up will allow a section of the fire main to be isolated for maintenance purposes, while the rest of the fire main remains in service.

5.17 Special Features

In addition to the above safety features that are inherent for a conventional LNG carrier, the SRVs that will unload at the deepwater port will have extensive safety features associated with the mooring and unloading buoys, the flexible pipe risers, and the subsea pipelines, as discussed in the other sections of this report.

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5.18 SRV Decommissioning

The SRV can be decommissioned simply by disconnecting from the unloading buoy, and transporting the SRV to a suitable facility for removal of equipment that will be further utilized.

6. MOORING AND UNLOADING BUOYS

6.1 Status of Design and Construction

The design of the mooring and unloading buoys will be based on the proven technology that was developed by Advanced Production and Loading AS, and utilized successfully for more than a decade in hostile locations such as the North Sea, and in environmentally sensitive areas. The unloading buoy will have the same dimensions as prior projects to allow SRVs to moor to the unloading buoy although newly built SRVs are presently planned. The size and length of the mooring lines, risers, and control umbilicals will be custom designed for the site-specific conditions for the planned deepwater port facility during the detailed design and construction phase of the project.

6.2 Codes and Standards

The design and construction of the mooring and unloading buoys will be based on the latest edition of the following codes and standards:

AISC	Manual of Steel Construction
API RP 17B	Recommended Practice for Flexible Pipe
API RP 17J	Specification for Unbounded Flexible Pipe
AWS D1.1-82	Structural Welding Code
API RP 2SK	Design and Analysis of Station Keeping System for Floating Structures
API RP2F	Specification for Mooring Chain
API RP 2FP1	Recommended Practice for Design, Analysis, and Maintenance of Mooring for Floating Production Systems
API RP 9A	Specification for Wire Rope
API RP 1104	Standard for Welding Pipelines and Related Facilities
ASME V	Non-Destructive Examinations
ASTM A 106-A	Standard Specification for Seamless Carbon Steel Pipe for High Temperature Service
ASTM A 182-A	Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service
ASTM A 234-A	Standard Specification for Piping Fittings of Wrought Carbon Steel for Moderate and High Temperature Service

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ASTM A 609-A	Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Steel, Ultrasonic Examination Thereof
ASTM A 488-A	Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
ASTM A 370	Standard Test Methods for Mechanical Testing of Steel Products
ANSI B-31.3	Chemical Plant and Petroleum Refinery Piping
ANSI / ASME M 45.2-1977	Quality Assurance Program Requirements for Nuclear Feasibility
ISO/R 1101	Tolerances of Form and Position
I.E.C.	Electrical Recommendations

6.3 Functional Specifications

The mooring and unloading buoys will be designed for the SRV to remain moored on location during the 100-year storm conditions, and to survive the 100-year storm conditions when the unloading buoy is idle and submerged below the ocean surface.

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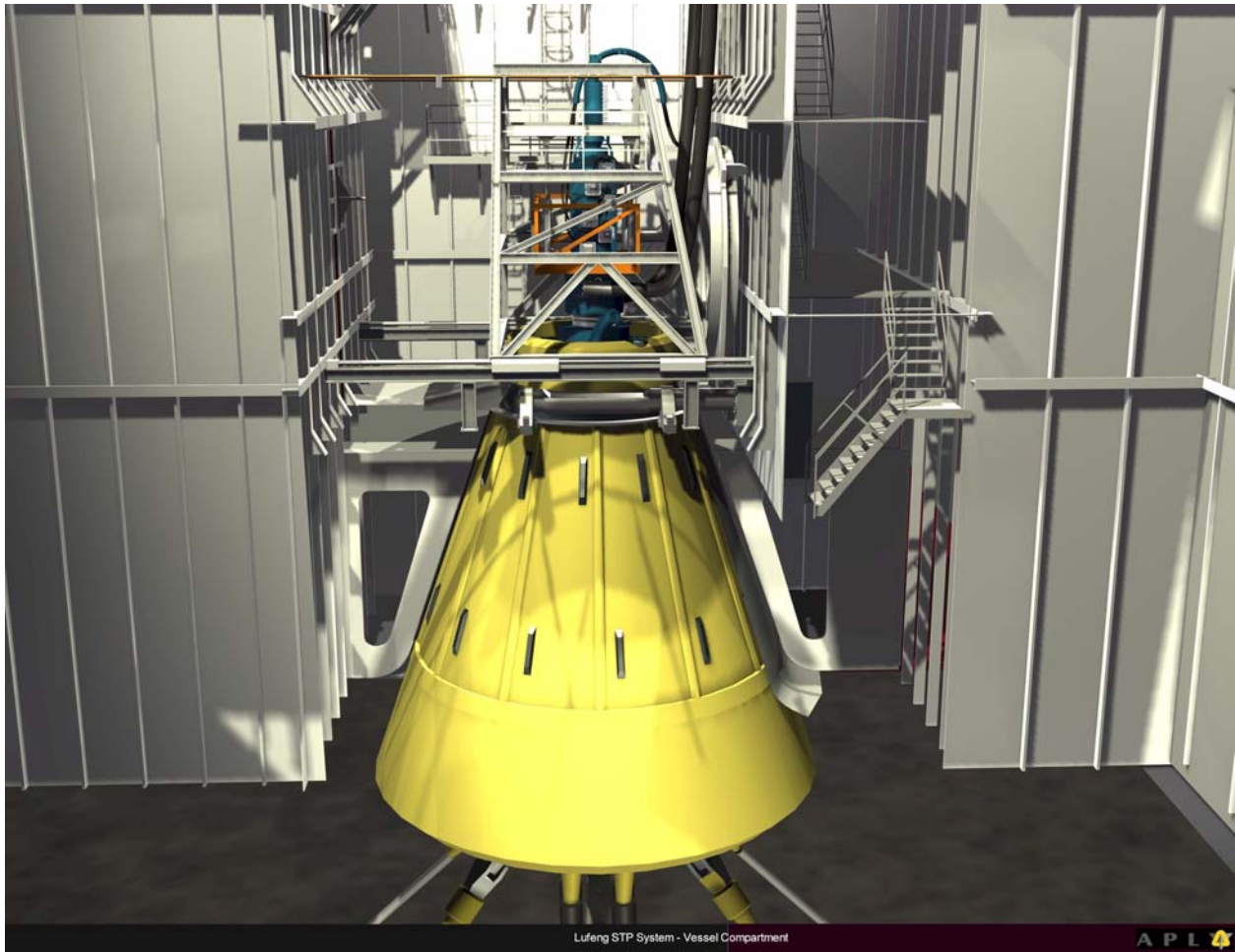


Figure 6-1: Unloading Buoy and Hull Mating Cone

6.4 Unloading Buoys

The major components of the mooring system and unloading buoys at the deepwater port are:

- Two unloading buoy systems located in a water depth of approximately 260 feet and separated by a distance of approximately 2 nautical miles for safe navigation of the SRVs. Each unloading buoy consists of:
 - ◆ Buoyancy Cone.
 - ◆ Eight mooring lines consisting of wire rope and chain connecting each unloading buoy to mooring points on the ocean floor.
 - ◆ Eight anchor points consisting of suction piles, driven and drag anchors are secondary options.
 - ◆ Turret Structure, that allows the SRV to weathervane about the unloading buoy as the wind, waves, and current change directions.

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- ◆ Marker buoys and navigation aids for the submerged buoy (when an SRV is not moored to the unloading buoy).
- ◆ Buoy retrieval bridle.
- ◆ One 16-inch inside diameter flexible pipe riser.
- ◆ One electro hydraulic control umbilical from each unloading buoy to the riser manifold.
- Two riser manifolds (discussed in Section 7 with the pipelines)

These major items are described in the following sections. Further information also can be found in Reference 16.

6.4.1 Buoyancy Cone

The buoyancy cone is a welded conical steel structure, which provides the required buoyancy and ensures smooth transfer of mooring, riser/umbilical and reaction forces to the vessel hull. The Buoyancy Cone is stationary to the vessel when the unloading buoy is connected.

The outer shell is designed to withstand expected impact loads during hook-up and disconnection, in addition to hydrostatic pressure in the submerged position. Physical contact with the vessel is limited to the upper and lower mating rings, which requires strict interface tolerances.

A vertical support structure is located on top of the buoyancy cone. The top is also made as a protection structure for the buoy mounted valves and the male part of the mechanical connector, such that these will not suffer any damage during a connection and disconnection. Lifting and pull-in pad-eyes are also integrated in the top structure.

6.4.2 Turret

6.4.2.1 Turret Structure

The integrated turret is the fixed portion of the unloading buoy, and consists of a shaft and a lower section with mooring connections (pad-eyes). Mooring line tensions are transferred into the turret through the turret pad-eyes. These forces are further transferred via the bearings and into the buoy and vessel structure.

Preliminary estimates of weight and buoyancy are given below of buoyancy cone and integrated turret.

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	Weight (tonnes)	Displacement (tonnes)	Net Buoyancy (tonnes)
Buoyancy Cone	102	203	101
Turret	40	30	-10
Valves, anodes, etc.	10	5	-5
Total	152	238	86

Preliminary overall dimension of buoyancy cone: height 30 feet, diameter 27 feet

The buoyant turret is divided into separate watertight compartments to contribute redundancy and to reduce thrust forces on the axial bearing during operation.

The turret is equipped with integrated guide-tubes allowing the riser and umbilical to be pulled all the way through the turret for final suspension at the turret top plate. Alternatively, the riser will be connected below the buoy to a Connecting Pipe running through an I-tube in the turret.

6.4.2.2 *Riser Hang-off*

The riser hang-off is located at the top plate of the turret. The riser will probably be located in the center of the turret, with the umbilical located eccentrically.

6.4.2.3 *Bend Stiffener Connection*

The sliding type bend stiffener is connected (locked) to the bottom end of the J-tubes. The bend stiffener is extended with a strong tubular collar that will have a tight fit with the mating receptacle in the bottom of the J-tube. Bending moments and shear-forces from the riser are thus transferred to the turret structure via the collar/receptacle, while the tension load is taken at the top of the turret.

Alternatively, the riser will be connected below the buoy to the Connecting Pipe running through an I-tube in the turret.

6.4.2.4 *Mooring Connection*

Each mooring line is connected to the lower turret section at a double lug integrated with the turret internal structure. A connecting link element is fitted between the lugs and the mooring wire socket in order to allow free pivoting about both axes. Self-lubricating bushings are fitted for both pins.

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6.4.3 Turret Bearings

The main purpose of the three turret bearings shown below is to ensure load transfer from the turret structure to the buoyancy cone and allow free and unrestricted rotation.

- Upper axial bearing
- Upper radial bearing
- Lower radial bearing

The upper axial bearing supports all the vertical loads from mooring, riser/umbilical and valve/connector/swivel assembly. This bearing will be exposed to the highest continuous loading. A summary of other functional requirements are listed below:

- The turret bearings will be capable of transferring all loads from the turret structure into the buoyancy cone.
- The turret bearings will allow the vessel to fully weathervane, with no restrictions regarding weather conditions or vessel operation.
- No planned maintenance will be required.
- Although not a planned operation, it will be possible to change the upper turret bearings.

All turret bearings are made in segments, self-lubricating sliding bearing materials. The upper bearing segments (both axial and radial) are fitted into a housing in the locking recess ring of the buoyancy cone. The lower bearing segments are fitted into a housing in the lower ring of the buoyancy cone. The bearings can operate properly even when submerged in nearly stagnant seawater.

The turret bearings are designed to operate without additional lubrication. However, grease ports are included for the upper bearings, allowing manual lubrication, although this is neither a planned nor a required operation.

6.4.4 Pick-Up Line System

To pull in the unloading buoy for mating to the SRVs, a pick-up assembly is connected to the top of the unloading buoy.

Main components are:

- Three leg lifting bridle
- Messenger line with spring buoys. The spring buoys are attached to the messenger line in order to obtain extra buoyancy
- Marker buoys

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6.4.5 Coating Systems

High quality, corrosion resistant coating systems will be used for the unloading buoys.

6.4.6 Buoy Hull

All plating and profiles used for the construction of the buoy hull are made from low alloy carbon steel with a yield limit of approximately 350 MPa (51 psi), typically NV E36. Cast parts are made of low alloy steel with a yield limit of approximately 410 MPa (60 psi), typically CSN 4000+ (by River Don Castings) or similar.

All steel surfaces facing open seawater are corrosion protected with sacrificial anodes in combination with a high-quality coating system. This corrosion protection system should supply a tough and abrasive resistant surface with good long-term corrosion resistance and anti-fouling properties.

Steel surfaces within the centre opening of the buoy, facing the turret shaft, are exposed to enclosed seawater and should be coated accordingly.

6.4.7 Turret Structure

All plating and profiles used for the construction of the turret are made from low alloy carbon steel with a yield limit of approximately 350 MPa (51 psi), typically NV E36.

6.5 Mooring Lines

Each unloading buoy will have eight mooring lines designed so that the SRV can remain moored in the 100-year storm conditions. It is anticipated that the mooring lines will range in length from 1,800 feet to 4,000 feet depending on orientation and as found soil conditions, and consist of 134 mm (5.25-inch) Grade R4 chain and 125 mm (4.92-inch) spiral strand wire rope. During the detailed design phase, the mooring arrangement will be optimized for the metoceanographic conditions and as found soil conditions.

6.6 Anchors

It is anticipated that each unloading buoy will have eight suction piles that are 5 m diameter, with a length of approximately 12 m. The final size and length of the piles will be determined after data from soil borings in the vicinity are available.

6.7 Flexible Risers

The riser system consists of one 16-inch ID flexible riser in a Steep-Wave configuration. The riser will be directed between two of the mooring lines. A typical flexible riser construction will consist of several layers. The different layers will consist of the following, starting with the innermost layer.

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6.7.1 Carcass

The carcass forms the body of the flexible pipe and is essentially a corrugated metallic tube. The primary function of the carcass is to prevent the polymer inner liner from collapsing due to possible external pressure or rapid decompression.

6.7.2 Pressure Sheath

Inner liner that is highly resistant to hydrolysis and virtually any chemicals used in the offshore industry.

6.7.3 Pressure Armor

Pressure armoring layer consists of C-shaped profiles.

6.7.4 Tensile Armor

Two cross-wound layers of rectangular carbon steel wires providing the strength of the flexible riser in respect of axial forces, which are induced by the internal working pressure, weight of the flexible pipe and external loads (e.g. tension loads during installation or dynamic loads).

6.7.5 Insulation Layer

Insulation layer applied before the extrusion of the outer sheath.

6.7.6 Outer Sheath

The function of the outer sheath is to protect the steel armor layers against mechanical damage and exposure to seawater, thus providing corrosion protection of the steel strands in both the pressure and the tensile armor.

At each end, there will be an end termination, which also provides a gas relief system as well as the termination flange. In addition, the upper end will be fitted with a bend stiffener, which is pulled into the lower part of the J-tube in the unloading buoy.

6.8 Control Umbilicals

The control umbilical connects the riser manifold controls to the control system onboard the SRV. The umbilical will have sufficient hydraulic lines to open and close valves, and sufficient signal lines to transmit required information.

The upper end of the umbilical will be fitted with a bend stiffener, which is pulled into the lower part of the I-tube in the unloading Buoy. The umbilical is further fitted with an end termination and hang-off arrangement at the upper turret plate. The hydraulic and signal lines are routed from the end termination to wet matable connectors.

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At the manifold end, the umbilical is fitted with an end termination, which most likely will be bolted to the manifold. The hydraulic and signal lines must have wet matable connectors.

The umbilical will be fitted with distributed buoyancy and configured the same way as the flexible riser (either as stand-alone or strapped to the flexible riser).

6.9 Offshore Installation

A derrick/lay barge will be utilized to install the suction piles, with the lower portion of the mooring chain attached. The unloading buoys will be transported to the operating site, unloaded from the transport barge, and anchor-handling tugs or the derrick/lay barge will connect the mooring lines to each unloading buoy. The risers will be connected between the unloading buoys and the riser manifolds after the manifolds have been installed and tested. Additional information can be found in Section 8 of this report.

6.10 Operations

When an SRV is not moored to the unloading buoy, the buoy will be submerged approximately 125 feet below the ocean surface, and the riser and control umbilical will remain attached. The valves at the top of the buoy and at the riser manifold will be closed. A pennant line will go from the top of the unloading buoy to a marker buoy that is equipped with the required navigation lights.

When the SRV approaches, the SRV will retrieve the unloading buoy, connect the buoy to the mating cone in the hull of the SRV, and prepare for vaporization and unloading of the LNG. Those operations are described in Section 5 of this report. Prior to departure of the SRV, the unloading buoy will be disconnected and lowered to a neutrally buoyant location below the ocean surface.

6.11 Safety Features

The mooring and unloading buoys will have a design life of at least 20 years. The mooring lines will be inspected periodically, as required by the Classification Society and the regulatory agencies. The total system has sufficient redundancy that the SRV can remain on station even if one of the eight mooring lines fails. The valves are fail-safe, so that the system is closed in the event of unexpected problems and the risers and control umbilicals can be isolated and replaced if there is unexpected damage to them. The SRV includes pressure control valves so that the pipelines will not be over-pressured, and the riser manifolds are equipped with an Emergency Shut Down (ESD) system that is activated through the control umbilicals. The control umbilicals have electronic signal circuits and hydraulic fluid that close and open the subsea valves.

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6.12 Mooring Buoy Decommissioning

At the end of the economic life of the deepwater port, the subsea valves will be closed, the risers and control umbilicals will be disconnected from the riser manifolds, the mooring lines will be disconnected from the unloading buoys and from the anchor points, and those major components will be removed from the deepwater port site.

In the event that the piles cannot be removed, they will be cut 15 feet below the mudline and the top section removed.

7. PIPELINES AND MANIFOLDS

7.1 Overall Configuration

The Neptune Deepwater Port (DWP) is located 22 miles to the northeast of Boston Massachusetts. The DWP site is positioned in Outer Continental Shelf (OCS) blocks NK 19-04 6525 and NK 19-04 6575. This places the Neptune DWP just to the west of the Stellwagen Bank Marine Sanctuary and just east of the state seaward boundary as defined by the Submerged Lands Act.

The Neptune pipeline system consists of a flowline approximately 2.5 miles, a 24-inch gas transmission line approximately 10.9 miles long that carries the gas from the Unloading Buoys to the existing 30-inch Algonquin HubLineSM. Integral to the Neptune pipeline system are:

- Two Riser Manifolds connecting the flexible risers to the flowline
- Transition Manifold and Hot Tap that connect the Neptune gas transmission line to the existing Algonquin HubLineSM.

The Neptune gas transmission line departs from the northern riser manifold and traverses eleven statute miles to the Algonquin HubLineSM. The area over which the pipeline is routed is relatively flat, only changing in elevation by 125 feet over the route. The soil composition is variable along the route ranging from clayey silt at the planned deepwater port to sands near the tie in to the Algonquin HubLineSM. The route traverses a disused spoil dumpsite on the approach to the HubLineSM tie-in. A number of shipwrecks are in the general area of the proposed gas transmission line route and terminal. The pipeline route and terminal location have been developed based on detailed site survey [Ref. 3 and 4].

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7.2 Codes and Standards

The design and construction of the pipelines will be based on the following codes and standards:

API SPEC 5L	Specification for Line Pipe
API SPEC 6H	Specification on End Closures, Connectors and Swivels
API SPEC 6D	Pipeline Values
API RP 1111	Design, Construction, Operation and Maintenance of Offshore Hydrocarbon Pipeline and Risers.
API RP 2A	Recommended Practice for Planning, Designing, and Constructing Offshore Platforms.
ASME B31.8	Gas Transmission and Distribution Piping Systems
CFR 30 Part 250, Subpart J	Pipelines and Pipeline Right of Ways
CFR 33 Part 148	Navigation and Navigable Waters: Coast Guard, Department of Homeland Security
CFR 49 Part 192	Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards
DNV RP B401, 1993	Rules For Submarine Pipelines: Cathodic Protection Design

7.3 Engineering and Design

All pipeline design activities will be done in accordance with the following codes:

- ASME B31.8
- 30 CFR 250
- 49 CFR 192
- API RP 1111.

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7.4 Marine Pipeline Survey and Route Design

The Neptune pipeline system begins at the Neptune deepwater port and proceeds westward to a subsea tie-in at the Algonquin HubLineSM.

The Site Plan (Drawing 11185602-301-DRW-00-003) and the Pipeline/Subsea Schematic Northern Route (Drawing 11185602-400-DRW-00-001) illustrate the placement and configuration of each of the manifolds within the pipeline system.

Table 7-1 shows approximate locations for the major components of the deepwater port and the connecting flowlines and gas transmission line.

Table 7-1: Pipeline Route Definition

ID	Easting (ft)	Northing (ft)	Station (ft)
Center of North Unloading Buoy	1207435	15435945	NA
Center of South Unloading Buoy	1207078	15423798	NA
North Riser Manifold	1207260	15436250	0
Transition Manifold	1161460	15437030	569+45
Hot Tap Tie-in	1161396	15437021	570+41

The geophysical and geotechnical surveys for the Neptune deepwater port were conducted in two phases as follows:

- Phase I geophysical and geotechnical survey investigated the Northern Terminal Area and Direct pipeline route corridor to the proposed HubLineSM tie-in location (for details see Phase I Seabed Facies Distribution 11185602-301-GIS007). This survey campaign was conducted by Alpine Ocean Seismic Survey, Inc, between February and April 2005, Ref 3;
- Phase II geophysical and geotechnical survey [Ref. 38] investigated the Central and Southern Terminal Areas and the Northern Pipeline Route corridor to the proposed HubLineSM tie-in location (for details see the Phase II Seabed Facies Distribution Overview 11185602-301-GIS015). This survey campaign was conducted by Seaforth Engineering, between June and August 2005, Ref 4.

The survey results are presented in United States Department of Interior Minerals Management Service (MMS) Notice-to-Lessees (NTL 98-20 and 2002-G01) compliant reports. The results are summarized in the project design basis, Ref 1.

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7.5 Riser Manifolds

There are two riser manifolds in the system, each located within a 350-360-foot offset from the proposed northern and southern buoy location. The purpose of the Riser Manifold is to provide an interface between the pipeline system and the flexible riser; isolation of the riser between gas unloading operations; and for the future attachment of a temporary subsea pig launcher or receiver. The riser manifolds will include:

- Flange connection for attaching the subsea pig launcher/receiver (southern riser manifold)
- Full-bore 16-inch ANSI 900 class subsea hydraulic control valve and electrohydraulic umbilical termination assembly (with allowance for ROV and diver control)
- Full-bore 24-inch ANSI 900 class subsea manual isolation valve (with allowance for ROV and diver control). Two valves on the southern manifold with a single valve on the northern riser manifold.
- Small diameter flushing and pressure equalization spool, as shown on the Piping Arrangement Drawings (Drawing 11185602-501-DRW-00-001 and Drawing 11185602-501-DRW-00-002).
- Mud mat foundation that provides a stable base for bearing, as well as resist the sliding and overturning forces. The mud mat for each riser manifold will be approximately 15 feet wide and 25 feet long.
- Protection from marine components.

The riser manifold features the subsea hydraulic control valve in tandem with a manual isolation valve to provide a “double block” for the unloading system. The Manifold Arrangement (Drawings 11185602-501-DRW-00-001 and 11185602-501-DRW-00-002) provides a configuration layout for each of the Riser Manifolds.

7.6 Flowline

The North and South Riser Manifolds are connected to the Flowline. The properties of the flowline is listed on Table 7-2.

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Table 7-2: Properties of Flowlines

Parameter	Size
Nominal OD (Inches)	24
Nominal Wall Thickness (Inches)	0.562
Fusion Bonded Epoxy Coating Thickness (Inches)	0.016
Concrete Weight Coating Thickness (Inches)	3.0
Length of Continuous Flowline (feet)	13,187
Maximum Allowable Operating Pressure (psig)	1740 psig
Throughput Range (MMscfd)	400 to 750
Trench Depth (from mudline to top of pipe)	0 ft (flush with seabed)

7.7 Gas Transmission Pipeline

The planned gas transmission line will extend approximately 10.9 miles from the Northern Riser Manifold to the Algonquin HubLineSM and have the properties shown on Table 7-3.

Table 7-3: Properties of Gas transmission line

Parameter	Size
Nominal OD (Inches)	24
Nominal Wall Thickness (Inches)	0.562
Length	56,945
Fusion Bonded Epoxy Coating Thickness (Inches)	0.016
Concrete Weight Coating Thickness (Inches)	3.0
Maximum Allowable Operating Pressure (psig)	1740 psig
Throughput Range (MMscfd)	400 to 750
Trench Depth (measure from mudline to top of pipe)	3 feet

The applicable rules state that the pipeline must be buried to 3 feet over the top of pipe in water depths less than 200 feet. However, to maintain the same level of protection over the entire length of pipeline, it will be trenched to 3 feet. The flowline, which is within the terminal area, will be buried flush with the seabed.

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7.8 Transition Manifold and Hot Tap Configuration

The Transition Manifold is located at the end of the gas transmission line and is attached to the spool piece connecting the hot tap to the existing Algonquin HubLineSM. The Transition Manifold provides an interface between the gas transmission line and the HubLineSM; for isolation of the proposed gas transmission line when required; and for the temporary attachment of a pig launcher or receiver for the gas transmission line. The hot tap assembly provides access to the HubLineSM as well as isolation of the HubLineSM from the proposed gas transmission line when required.

The Transition Manifold and Hot Tap assembly include:

- Two full-bore 24-inch ANSI 900 class subsea manual isolation valves on the manifold (with allowance for ROV and diver control)
- Two full-bore 16-inch ANSI 900 class subsea manual isolation valves on the hot tap spool as a dual barrier system (with allowance for ROV and diver control)
- One 16-inch ANSI 900 class check valve in the tie-in spool
- Welded tees on the planned gas transmission line (with a flange on the tee stub for attaching the tie-in spool) and cross bars to prevent trapping of pig
- Flange connection at the end of the gas transmission line for attaching a temporary subsea pig launcher/receiver
- Tie-in spool with a 90-degree elbow and misalignment flange at one end and a check valve and swivel ring flange on the other end
- Small diameter flushing and pressure equalization spool on the manifold as shown on Drawing 11185602-501-DRW-00-003.

The mud mat for the Transition Manifold will be approximately 15 feet wide and 25 feet long, provides a stable base and resists the sliding and overturning forces.

The Transition Manifold Arrangement (Drawing 11185602-501-DRW-00-003) and the Hot Tap Arrangement (Drawing 11185602-407-DRW-00-002) provide the configuration layout for the total assembly.

7.9 Offshore Pipeline Construction Methodology

The offshore construction of the pipelines will include the following effort:

- Mobilize appropriate installation vessels and workboats to the deepwater port site.
- Place pre-lay mattresses at the crossing location.
- Install the flowline and pipeline.
- Install the Hot Tap and protect with concrete mats.
- Install the two riser manifolds and transition manifold.
- Install tie-in spools.

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- Trench and backfill the pipeline and flowline.
- Place post lay mattresses at crossing and transition locations.
- Flood, clean, test, dewater and dry the flowline and gas transmission line (pipeline system).
- Install buoy and mooring system.
- Demobilize the offshore construction equipment.

7.10 Pipeline and Cable Crossings

A pipeline route survey has been completed to identify any underwater hazards along the pipeline routes and to locate the exact location of existing subsea pipelines or cables that may be crossed. Currently, one (1) cable is known to cross the proposed gas transmission line route. The Hibernia Atlantic fiber optic cable is located in state waters in approximate 160 feet water depth. Refer to the Site Plan, Drawing No. 11185602-301-DRW-00-003, for location details.

Divers and/or remotely operated vehicles (ROVs) will be used to locate and prepare the crossings, monitor the crossings during pipeline construction, and finalize the crossings after the pipeline has been installed, all in accordance with pre-approved and agreed procedures.

The pipelines will be constructed in accordance with the requirements of 49 CFR 192.325, which mandates “at least 18 inches (450 millimeters) of clearance from any other underground structure”. Concrete mats will be used to ensure a minimum 18 inches of separation between the proposed pipeline and the existing pipeline cable as mandated by 30 CFR 250.1003(a)(3). In the event that the installation results in less than 3 feet of cover for portions of the new pipeline in water depths less than 200 feet as mandated by 30 CFR 250.1003(a)(1), concrete mats will be used to provide an equivalent degree of protection. All crossings will be coordinated with the relevant pipeline or cable owners and operators and the applicable regulatory agencies. A Typical Pipeline/Cable Crossing is shown in Drawing No. 11185602-404-DRW-00-001.

7.11 Pipeline Operations and Maintenance

The SRVs will control the normal pipeline system operations with onboard control and monitoring systems, unloading buoy valves, and the hydraulic control valve on the riser manifolds. Intervention and/or maintenance work may require divers or an ROV to open or close pipeline system valves.

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The pipeline system has been designed to accommodate subsea pigging operations, including passage of instrumented internal inspection devices (intelligent pigs). Additionally, flanged connections and tie-in spools can be leak-tested subsea without having to pressure-test the entire system. Pig launchers and receivers will be installed at the southern riser and transition manifolds for pigging the flowlines and the planned gas transmission line.

In accordance with 30 CFR 250.1005, the pipeline routes will be inspected at the time intervals and methods prescribed by the Minerals Management Service (MMS) Regional Supervisor for indication of pipeline leakage. The results of these inspections will be retained for at least 2 years and be made available to the MMS Regional Supervisor upon request. Currently, there is no MMS requirement to perform periodic internal inspection of the pipelines.

7.12 Safety Features and Protection

The control and safety systems onboard the SRVs will control pipeline pressures and flow rates.

The hot tap tie-in spool will have a flow safety valve (check valve) to prevent gas from the Algonquin HubLineSM flowing back into the proposed gas transmission line, as required by 30 CFR 250.1004(6).

All flow paths are designed with double block valves to minimize potential leaks from the system and allow the risers, flowlines, or transmission pipeline to be isolated from each other or from the Algonquin HubLineSM.

The pipelines are coated with approximately 3 inches of high-density (190 lb/ft³) concrete. The pipeline will be buried and have at least 3 feet of cover, and mattresses and / or grout bags may be used to protect the manifolds, tie-in spools, hot tap and trench transitions. The flowline will be covered to the top of the pipe. These design considerations minimize the potential for third party damage to the pipeline system.

7.13 Decommissioning of Pipelines

The pipeline and flowline will be decommissioned in place. Typically, the owner of the pipelines will submit a pipeline decommissioning application in triplicate to the MMS Regional Supervisor in accordance with 30 CFR 250.1750 through 250.1754. For this deepwater port, the US Coast Guard, in consultation with the MMS Regional Supervisor, will determine whether the pipelines constitute a hazard (obstruction) to navigation and commercial fishing operations, unduly interfere with other uses of the Outer Continental Shelf (OCS), or have adverse environmental effects.

Decommissioning will include the following:

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- Closing hot tap valves and plugging the end
- Pigging and flushing the pipelines
- Filling the pipelines with seawater
- Removing the manifolds and tie-in spools
- Cutting and plugging each end of the pipelines
- Burying each end of the pipelines at least 3 feet below the seafloor or cover each end with protective concrete mats, if required.
- Removal of the unloading buoys, mooring lines and anchors.
- If the anchors cannot be removed, they will be cut 15 feet below the mudline and the top section removed. The remainder will be left in place.

8. CONSTRUCTION PLAN

Refer to: Construction Plan (11185602-200-PRC-001), Construction Contingency Plan (11185602-102-PRC-001) and Construction Schedule (11185602-102-SCD-001).

9. OVERALL PROJECT SCHEDULE

Figure 9-1 presents the summary of the overall project schedule for development of the planned deepwater port, including approval of the Deepwater Permit Application, construction of three custom designed SRVs, and the offshore construction effort. A detailed project schedule is included in Reference 11.

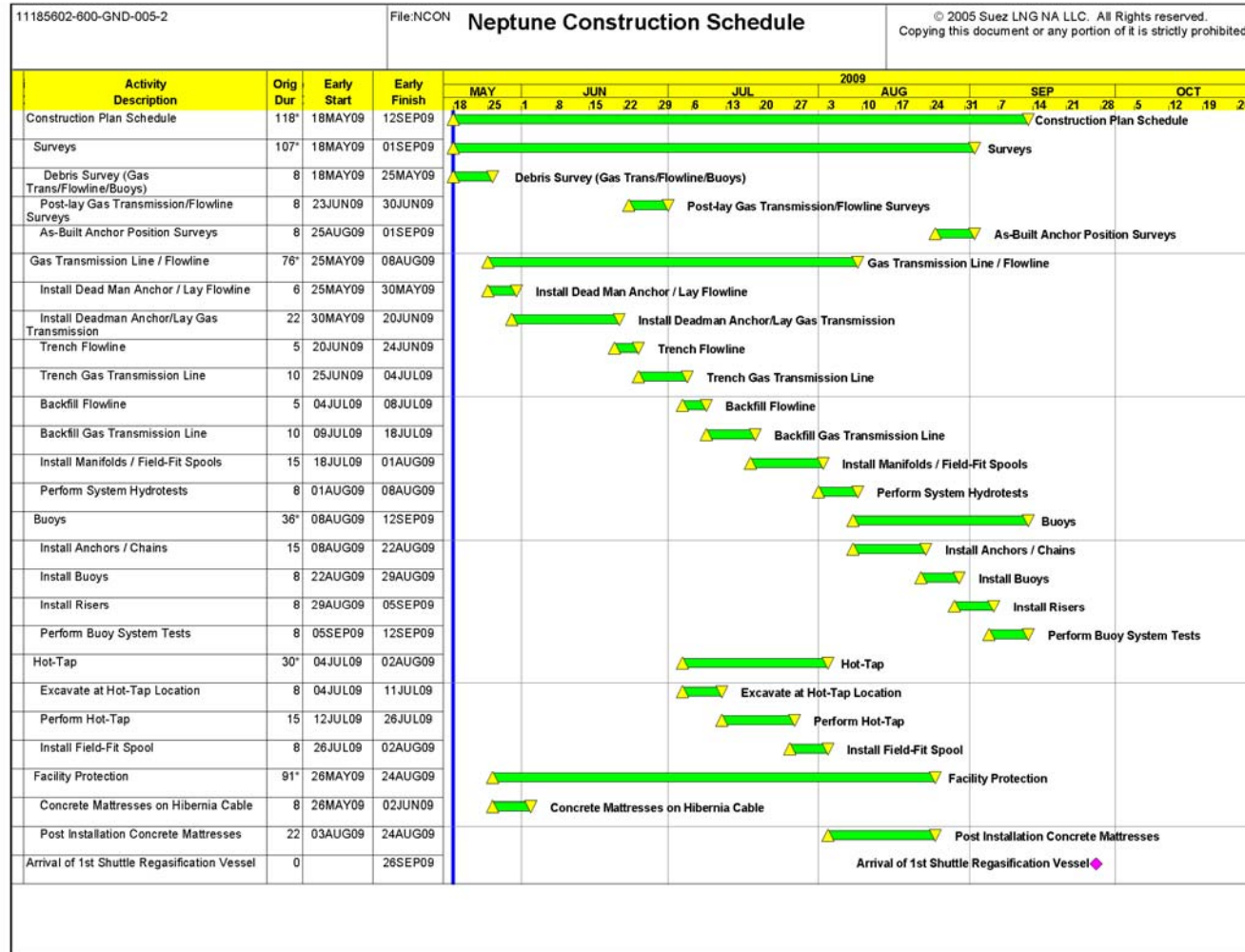


Figure 9-1: Construction Schedule

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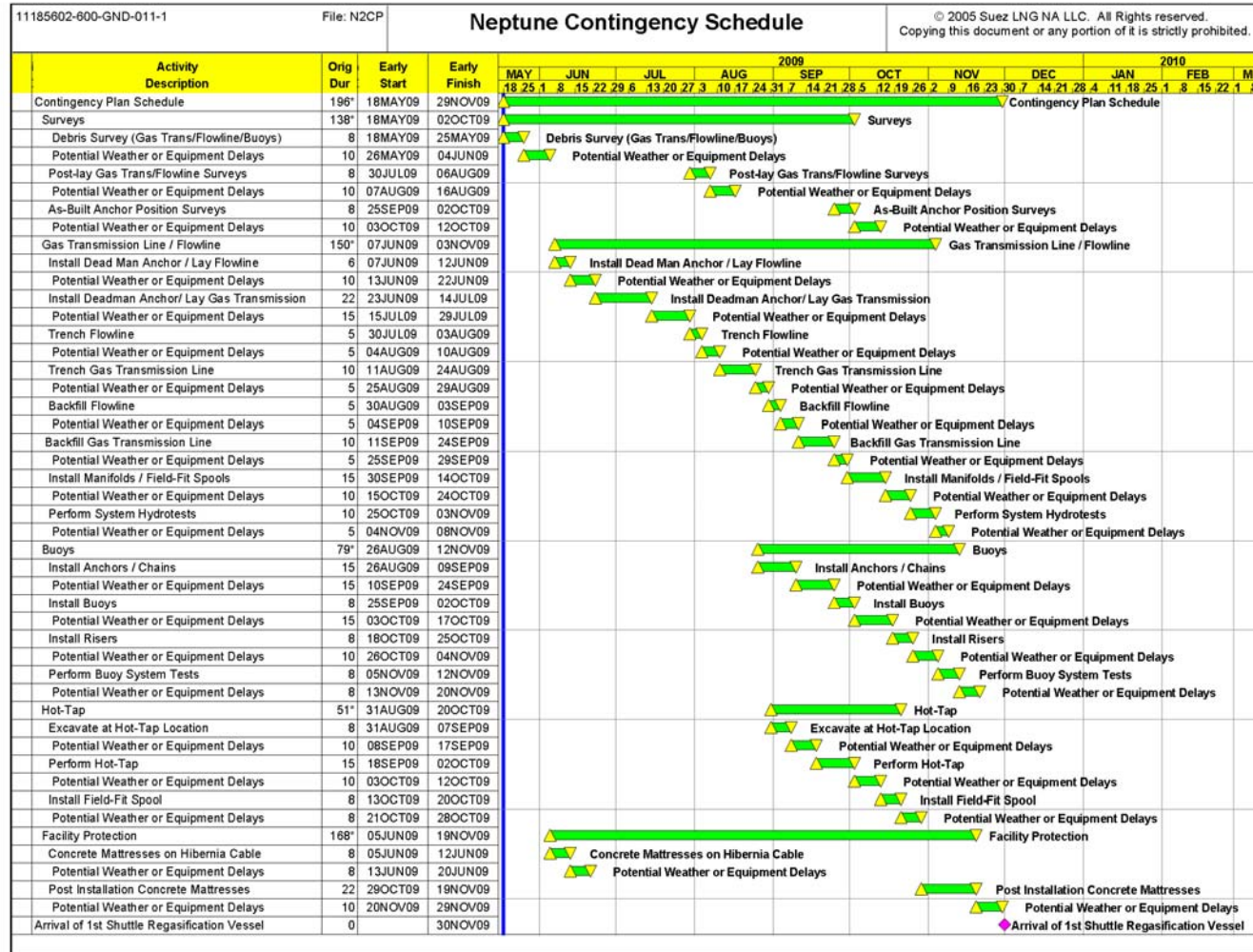


Figure 9-2: Construction Contingency Schedule

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Major events and tentative milestone dates follow:

Approximate Dates	Event
18 November 2005	Submittal of DWP Application
Early 2006 to Mid 2007	Design, Engineering, and Contract Negotiations for SRVs, Unloading Buoys, and Offshore Pipelines Site specific deep geotechnical survey
Mid November 2006	USCG Record of Decision Issued
Late 2006 to Early 2010	Construct, Test, and Commission Three SRVs at an International Shipyard (Three Years for each SRV)
Mid May to Mid November 2009	Offshore Construction at Deepwater Port
Late 2009	Initial Offloading from SRV # 1

The approximate dates are tentative, and represent best estimates for the duration and sequences for approximately 200 activities.

It should be noted that there is only one planned period for offshore construction activity at the deepwater port. There will be very minimal impact on the seabed during the final hookup phase, both because of the type of required construction activity and because of the brief duration of effort. At the conclusion of construction, side scan sonar will be used to survey the construction area and any construction debris will be removed from the ocean floor.

At an appropriate time Neptune will coordinate the actual offshore construction schedule with the appropriate groups, including the United States Coast Guard (USCG), the Massachusetts Department of Environmental Protection (DEP), the Division of Marine Fisheries (DMF), the Environmental Protection Agency (EPA), and the National Marine Fisheries Services (NMFS) to determine the two most favorable Time of Year (TOY) work windows.

In summary, it is anticipated that delivery of natural gas from the SRVs will commence in late 2009. The actual schedule will be controlled by the time required for approval of the DWP application and the time required to construct the three SRVs. Other activities are not on the critical path schedule.

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