Annex 5B

Detailed Operation and Process Description

5B DETAILED OPERATION AND PROCESS DESCRIPTION

This *Annex* presents a detailed description of the process systems and operation of the Project components from the QRA Study point of view as follows:

- ***Section 5B.1*** – LNGC Operation
  - Process and Utility Systems within the LNGC
  - LNGC Approach to the LNG Terminal
  - Key Safety Systems for the LNGC
- ***Section 5B.2*** – FSRU Vessel Operation
  - Process and Utility Systems within the FSRU Vessel
  - Key Safety Systems for the FSRU Vessel
- ***Section 5B.3*** – LNG Terminal Operation
  - LNG Unloading Operation and High Pressure Natural Gas Send-out at the LNG Terminal
  - Key Safety Systems for the LNG Terminal
- ***Section 5B.4*** – Operation of the New GRS at the BPPS
  - Key Safety Systems for the New GRS at the BPPS
- ***Section 5B.5*** – Operation of the New GRS at the LPS
  - Key Safety Systems for the New GRS at the LPS

5B.1 LNGC OPERATION

5B.1.1 Process and Utility Systems within LNGC

The following process and utility systems are typically provided on the LNGC:

- LNG Storage and Unloading System;
- Utility System – Power Generation System;
- Utility System – Diesel Oil Storage System;
- Utility System - Lubricating Oil Storage System;
- Utility System – Nitrogen Generation System;

- Utility System – Seawater System;
- Utility System – Sodium Hypochlorite Package;
- Utility System – Instrument Air System;
- Utility System – Fuel Gas System; and
- Utility System – Fresh Water and Demineralised Water System.

LNG Storage and Unloading System

Two (2) types of LNGC are considered in the QRA Study:

- Small LNGC (170,000 m^3 capacity, with each LNG storage tank capacity of about 34,000 m^3); and
- Large LNGC (270,000 m^3, capacity, with each LNG storage tank capacity of about 54,000 m^3).

Membrane type double containment system for the LNG cargo storage tanks are provided for the LNGC. The containment system will be designed as per international standards including the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)* (1). The containment system will be provided with a full secondary liquid-tight barrier capable of safely containing all potential leakages through the primary barrier and, in conjunction with the thermal insulation system, of preventing lowering of the temperature of the ship structure to an unsafe level.

In-tank LNG storage pumps are submerged in the LNG cargo tanks. During LNG unloading operation at the LNG Terminal, the LNG in the cargo tanks of the LNGC will be pumped through the unloading arms, via the Jetty, to the LNG cargo tanks of the FSRU Vessel. Detailed description of the LNG unloading operation is presented in ***Section 5B.3.1*** below.

Utility System – Power Generation System

The FSRU Vessel is provided with its own dedicated power generation system. The dual fuel type power generators can operate on both boil off gas as fuel gas and diesel oil (HFO). Under normal circumstances power generation will consume Boil-Off Gas (BOG) as fuel gas. However, under start-up or special maintenance repair circumstances as well as under emergency conditions, the fuel gas may not be available and diesel oil will be the fuel supply to the power generator. In addition, a dedicated emergency diesel power generator is also provided on the FSRU Vessel for back-up power generation and black start-up.

(1) *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, Resolution MSC.370 (93)*

Utility System – Diesel Oil Storage System

Diesel oil (HFO) is used for power generation (for both duel fuel main power generator and back-up emergency generator), for supply crane operation, as well as for the diesel driven firewater pumps. Diesel oil storage tanks, settling tank and service tanks are provided for the FSRU Vessel. The maximum capacity of the diesel storage tank was considered as 6,000 m^3 in the QRA Study.

Bunkering of diesel oil will be conducted within reach of the supply crane on the FSRU Vessel to handle bunker hoses. A bunker hose reel will be provided. In the QRA Study, it was conservatively considered that the bunkering operation will be performed three (3) times a year with duration of six (6) hours for each operation.

Utility System – Lubricating Oil Storage System

Lube oil storage and settling tanks are typically provided for the FSRU Vessel. Lube oil is used for the power generation prime movers and for major rotating equipment. The maximum capacity of the lube oil storage tank was considered as 100 m^3.

Utility System – Nitrogen Generation System

Membrane type nitrogen generators will be typically provided for the FSRU Vessel to generate nitrogen for the purpose of inert gas purging.

Utility System – Seawater System

Seawater will be used to vaporize LNG in the heat exchanger. The seawater will be filtered by intake screens, chlorinated with sodium hypochlorite solution and pumped by seawater pumps. The seawater used from the LNG vaporisation system will return to the sea via gravity discharge off the FSRU Vessel.

Utility System – Sodium Hypochlorite Package

The Sodium Hypochlorite Package provides the on-board generation of sodium hypochlorite by partial electrolysis of sodium chloride contained in the seawater. The electro-chlorination system produces and feeds sodium hypochlorite solution to the seawater intake system to inhibit the growth of marine organisms, bacterial slime, and algae which would otherwise clog the suction and equipment and affect the surface heat transfer of the vaporisation system.

The produced sodium hypochlorite solution, together with the by-product hydrogen, flows through the outlet header to the Hydrocyclones. Hydrogen degassing happens in the Hydrocyclones, and hydrogen is diluted by an air blower before venting to atmosphere. The generated hypochlorite is then injected into the seawater intake structure. During hypochlorite generation, some cations present in seawater will form hydroxides and carbonates resulting in suspended solids depositing on the electrode surface. Hence an acid cleaning system is provided to periodically clean the electrode surface with diluted hydrochloric acid. The acid used for electrode cleaning will be neutralized with diluted caustic soda solution. The maximum capacity of the acid and caustic soda solution storage age tanks are 20 L.

Utility System – Instrument Air System

Redundant air compressors will be provided to generate the utility and instrument air for the FSRU Vessel. An instrument air receiver will also be provided for a specified hold up volume.

Utility System – Fuel Gas System

The BOG from the LNG storage tanks will be sent to BOG Compressor. Part of the compressed BOG will be used for fuel gas for power generation. In addition, a small LNG vaporisation unit is also provided for forced BOG generation to provide fuel gas for the FSRU Vessel. Under normal circumstances, power generation will consume BOG treated by the fuel gas skid and delivered at approximately 6 barg.

Utility System – Fresh Water and Demineralised Water System

Fresh water generation system and sterilization system for domestic water will be provided for the FSRU Vessel. A demineralised water system will be required for the boilers. Demineralised water generator will be provided to ensure sufficient demineralised water is available for the boilers.

5B.1.2 LNGC Approach to the LNG Terminal

In the final segment of the approach transit, tugboats will assist in controlling the heading and speed of the LNGC while entering into and manoeuvring within the turning area as well as for the final approach towards the LNG Terminal. The tugboats will continue to assist until the mooring operation has been completed. The number and bollard pull of tugboats for such operations will be based on the findings of a simulation study for the safe manoeuvring of the LNGC.

5B.1.3 Key Safety Systems for the LNGC

Navigation System

The LNGC is equipped with advanced navigational systems such as Digital Global Positioning System (DGPS), radar and communication system. The marine traffic is monitored by the Vessel Traffic System (VTS), providing an active monitoring and navigational advice for vessels.

Also, the LNGC's navigation is constantly monitored by well trained and experienced master and the officers to make good use of the navigation system for the LNGC transit to the LNG Terminal.

Double Containment System

The containment system is designed as per international standards including the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)* (1). The containment system is provided with a full secondary liquid-tight barrier capable of safely containing all potential leakages through the primary barrier and, in conjunction with the thermal insulation system, preventing the lowering of ship structure temperature to an unsafe level.

Leak detection system is provided between the primary and secondary containment barriers. In addition, the LNG cargo tanks are provided with pressure relief valves which connect to a designated vent piping system.

Process Control System

Process control valves (e.g. pressure control, temperature control etc.) are provided in the process facility in order to continuously maintain the stability of the overall process operation. Process deviation alarms are also provided to alert the operators to take necessary actions.

Emergency Shutdown System

ESD System is provided at the LNGC to stop LNG flow in the event of an emergency and to return the system to a safe, static condition so that remedial action can be taken. The ESD system can be activated automatically through various initiators (e.g. power failure, cargo tank overfill etc.) and manually through push buttons.

The ESD system is generally divided into two levels:

- ESD-1: Shuts down the cargo transfer operation in a quick controlled manner by closing the shutdown valves and stopping the transfer pumps and other relevant equipment in ship;

- 2nd stage: Activates the Powered Emergency Release Coupling (PERC) System installed on the unloading arms (ESD-2).

According to the IGC Code requirements (2), the following protection systems are required to be installed in the LNGC:

- Overfill protection in the LNG cargo tanks;

- Vacuum protection in the LNG Cargo tanks; and

- Excess flow protection in the LNG unloading lines and vapour return lines.

(1) *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, Resolution MSC.370 (93)*

(2) *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, Resolution MSC.370 (93)*

Overpressure Protection System

The boil-off vapour in the cargo tanks can be sent to BOG system to maintain the vapour pressure inside the cargo tanks. Pressure relief system is also provided for the LNG cargo tanks. The cargo tank and interbarrier space are fitted with pressure relief valve(s) which connect to a venting system. The setting of the pressure relief valves will be lower than the vapour pressure adopted in the design of the cargo tanks.

Emergency Flare System

The LNGC is equipped with an emergency flare stack that is use only for the release of vaporized LNG in the event of an emergency.

Custody Transfer Measurement System

The LNGC is provided with an automatic system for the calculation of LNG and gas volumes in each cargo tank. The use of such system, commonly referred to as the ship's custody transfer measurement system (CTMS) will facilitate the process of determining quantities transferred during loading and unloading. The CTMS processes data from tank level, temperature, pressure sensors, etc. in real time, taking into account the required corrections and certified gauge table, to produce a calculation of volumes before, during and after LNG transfer operation.

Fire Detection and Protection System

Flammable gas and fire detectors are provided at the LNGC to detect leakage of natural gas and fire events respectively. The detectors will be positioned at strategic locations to provide adequate detection coverage for the facility.

Typically the following fire-fighting systems are provided in the LNGC:

- Deluge/water spray system;
- Dry chemical power system; and
- Foam system to cover deck.

5B.2 FSRU VESSEL OPERATION

The schematic diagram for the LNG Terminal, including FSRU Vessel, LNGC is depicted in ***Figure 5B.1***.

5B.2.1 Process and Utility Systems within the FSRU Vessel

The LNG cargo tanks, process and utility systems described in ***Section 5B.1*** for the Large LNGC are applicable to the FSRU Vessel as well. The following additional process systems are provided for the FSRU Vessel:

- LNG Send-out Booster Pump System;

- LNG Regasification System; and
- BOG Handling and Recovery System.

LNG Booster Pump System

The LNG from the discharge of the In-Tank LNG Storage Pump is pumped at 5 barg to the LNG Booster Pump Suction Drum which acts as a buffer volume. The LNG inside the Suction Drum is then pumped via the LNG Booster Pumps, at a capacity of 250 m^3 for each Booster pump, to the Regasification System at 90 barg.

LNG Regasification System

Regasification trains are provided at the Regasification Module of the FSRU Vessel, with a maximum installed capacity of 1,000 mmscfd.

The LNG from the discharge of the LNG Booster Pumps is re-gasified and superheated to the required send-out temperature of 5 °C. The LNG is re-gasified by a simple heat exchange process using seawater. Common types of vaporizers for an FSRU Vessel include generic Intermediate Fluid Vaporizer (IFV) and Shell & Tube Vaporisers (STV) which are both compatible with wave motions experienced by the FSRU Vessel.

BOG Handling and Recovery System

The FSRU Vessel is equipped with a BOG Recovery System to handle the BOG generated by heat ingress during normal operations as well as BOG generated during unloading and reloading operations. Typically the BOG Recovery System consists of the following equipment items:

- BOG Compressor Suction Drum;
- BOG Compressors; and
- BOG Recondenser.

During LNGC unloading, the displacement vapour from the FSRU Vessel LNG storage tanks flows back to the LNGC via the vapour return loading arm to replace the displaced LNG volume in the LNGC storage tanks. Excess displacement vapour flows to the BOG Compressor (2 x 100%) where it is compressed and sent to the BOG Recondenser at 6 barg. The LNG cargo tank boil off rate is selected as 0.13 vol% per day in the QRA Study. A BOG Compressor Suction Drum is provided to prevent any liquid entering the BOG Compressors.

The BOG Recondenser has two primary functions: the top section of the BOG Recondenser houses a packed bed in which BOG is contacted with sub-cooled LNG for liquefying the BOG; and the lower section of the BOG Recondenser serves as a liquid holdup drum for the LNG Booster Pumps.

Sub-cooled LNG for recondensing BOG is taken from the LNG send-out line and the operating pressure of the BOG Recondenser ensures that LNG remains at sub-cooled conditions. LNG in excess of the recondensation requirements is routed through the BOG Recondenser bypass line and mixed with the LNG stream leaving the bottom of the BOG Recondenser. This mixed stream of LNG is then routed to the LNG Booster Pumps.

When the FSRU Vessel is not connected to the double berth jetty (e.g. during adverse weather conditions), BOG which cannot be held in the FSRU Vessel LNG storage tanks and is not required for power generation (i.e. excess BOG) will be routed to an oxidizer. The BOG will then undergo combustion before being vented to the atmosphere via the FSRU Vessel cold vent.

5B.2.2 Key Safety Systems for the FSRU Vessel

The safety systems described above for the LNGC are also applicable for the FSRU Vessel.

5B.3 LNG TERMINAL OPERATION

5B.3.1 LNG Unloading Operation and High Pressure Natural Gas Send-out at the LNG Terminal

The maximum LNG unloading rate of 12,000 m^3/hr was conservatively considered in the QRA Study. The LNG unloading time from Small LNGC (170,000 m^3) to FSRU Vessel is a maximum of 24 hours, and the LNG unloading time from Large LNGC (270,000 m^3) to FSRU Vessel is a maximum of 36 hours.

The LNG from LNGC is unloaded via four (4) standard 16 inch loading arms on the jetty head (2 for LNG unloading; 1 for vapour return; 1 hybrid for spare). During cargo discharge the vapour pressure in the LNGC cargo tanks will be maintained by returning vapour from the FSRU Vessel. With this balanced system, under normal circumstances, no hydrocarbons will be released to the atmosphere from ship.

At the end of unloading, pressurised nitrogen gas will be used to purge the unloading arms of LNG before disconnecting.

Ballasting operations (i.e. taking on seawater to compensate for the unloaded mass of LNG) will be concurrent with the LNG unloading. The maximum LNGC staying time at the LNG Terminal is 48 hours after arrival. This includes allowances for the pre-cooling operations, arrival cargo measurements, unloading operations, cargo measurements on completion of discharge and nitrogen displacement of unloading arms prior to disconnection.

Once the LNG in the FSRU Vessel is re-gasified, the send-out high pressure natural gas is delivered to the LNG Terminal via three (3) standard 12 inch loading arms on the jetty head (2 working and 1 spare).

The LNG Terminal will operate in two main modes of operation:

- **Unloading Mode –** The unloading mode is the period when an LNGC is moored on the double berth jetty and is connected to the FSRU Vessel storage tank by means of unloading and loading arms on the jetty platform. The pumps on the LNGC will transfer the LNG in both the unloading and the re-circulation lines to the FSRU Vessel storage tanks. At the end of unloading, pressurised nitrogen gas will be used to purge the arms of LNG before disconnecting.

- **Holding Mode –** The holding mode is the period when no unloading takes place, while send-out to the subsea gas pipelines continues. The purpose of the holding mode is to allow cryogenic conditions to be maintained in the unloading and circulation system. In order to maintain these conditions LNG will be circulated via the unloading line to the double berth jetty head and back to the FSRU Vessel storage tanks or the send-out system via the re-circulation line.

5B.3.2 Key Safety Systems for the LNG Terminal

Jetty monitoring and management system is provided at the LNG terminal, which serves to closely monitor the mooring line tension and vessel motion. Excessive mooring line tension and vessel motion will activate alarm and subsequent ESD system to shutdown the LNG cargo transfer operation.

5B.4 OPERATION OF GRS AT THE BPPS

The schematic diagram for the GRS facilities at the BPPS is depicted in ***Figure 5B.2***.

The maximum flow rate at the new GRS at the BPPS is 700 mmscfd. The inlet emergency shutdown valve (ESDV) defines the transition between the 30" BPPS Pipeline and the new GRS at the BPPS. A pig receiver receives maintenance and inspection pigs from the BPPS Pipeline connecting to the LNG Terminal.

The high pressure natural gas at 88 barg and 20 °C first enters the Gas Filter Skid (3 operational filters and 1 spare filter) to remove traces of liquid mist and solid particles in the incoming gas. The filtered gas then flows through the Gas Metering Skid (3 operational meters and 1 spare meter). Flow signals are transmitted to the control room at the BPPS. A composite sampler is provided to gather samples for gas chromatography testing.

The gas is then heated in the Pipeline Gas Heaters (1 operational heater and 1 spare heater) to 60 °C, before entering the Pressure Control Skid. The Pressure Control Skid consists of three (3) parallel pressure reduction stations and one (1) standby pressure reduction station, in order to adjust the delivery sales gas pressure to 38 barg.

The natural gas at 38 barg and 20 °C then flows through the HIPPS Skid and mixes with the sales gas from the existing BPPS GRS at the existing Mixing Station, before entering the BPPS power generation facilities.

5B.4.1 *Key Safety Systems for the New GRS at the BPPS*

Process Control System

Process control valves (e.g. pressure control, temperature control etc.) are provided in the new GRS area in order to continuously maintain the stability of the overall process operation. Process deviation alarms are also provided to alert the operators to take necessary actions.

Emergency Shutdown System

ESD system is provided at the new GRS area in the event of an emergency and to return the system to a safe, static condition so that any remedial action can be taken. The ESD system can be activated automatically through various process initiators and manually through push buttons.

ESDV are provided in the new GRS to isolate the inventory in the event of emergency situation as such the leakage of the hazardous material can be controlled and minimized.

Overpressure and Blowdown System

Pressure control valves are provided at the new GRS area to maintain the pressure of natural gas in the process system. However, in the event of overpressure, the blowdown system is designed to vent automatically from a point downstream of the pressure reduction station to a vent stack. A CO_2 snuffing system is installed to extinguish the vent if the gas is ignited by lightning or other causes.

Fire and Gas Detection System

Fire and flammable gas detectors are provided at the new GRS area to detect events of fire and flammable gas leakage.

Fire Protection System

Firewater ring main system, firewater monitors, fire hydrants and hose reels are provided at the new GRS area.

5B.5 *OPERATION OF THE NEW GRS AT THE LPS*

The schematic diagram for the GRS facilities at the LPS is depicted in ***Figure 5B.3***.

Four (4) trains of gas receiving units are provided at the new GRS at the LPS. Four (4) natural gas conditioning trains are provided at the GRS, with maximum flow rate of 63.5 mmscfd for each train. The total maximum flow rate for the new GRS is approximately 254 mmscfd. Each train is dedicated to one CCGT unit.

The inlet emergency shutdown valve (ESDV) defines the transition between the 20" LPS Pipeline and the new GRS at the LPS. A pig receiver receives maintenance and inspection pigs from the LPS Pipeline connecting to the LNG Terminal.

The high pressure natural gas at 82 barg and 6 °C flows through the common header of the incoming gas, which connects to four (4) trains of gas receiving systems. In each of the gas receiving trains, there is a Gas Filter Skid (1 operational filter and 1 spare filter) to remove traces of liquid mist and solid particles in the incoming gas. Then the filtered gas flows through the Gas Metering Skid (1 operational meter and no spare). Flow signals are transmitted to the control room at the LPS. A composite sampler is provided to gather samples for gas chromatography testing.

In addition, part of the natural gas from the existing pipeline for the existing GRS is diverted to the proposed GRS at the LPS. A dedicated Gas Filter Skid (1 operational filter and 1 spare filter) and Gas Metering Skid (1 operational meter and no spare) are provided in each of the proposed GRS Trains to receive the natural gas from the existing natural gas subsea pipeline.

The natural gas from the outlet of the two metering skids in each GRS train is then mixed at the Mixer (1 operational meter and no spare) and then enters the Water Bath Heater (1 operational meter and no spare) to heat up the gas to 51 °C. The heated gas then flows through the Pressure Reduction Skid, in order to adjust the delivery sales gas pressure to 41 barg. The natural gas at 41 barg and 20 °C is then sent to the CCGT facilities at the LPS.

5B.5.1 Key Safety Systems for the Proposed GRS at the LPS

Major safety systems described above for the proposed GRS at the BPPS are also applicable for the proposed GRS at the LPS.

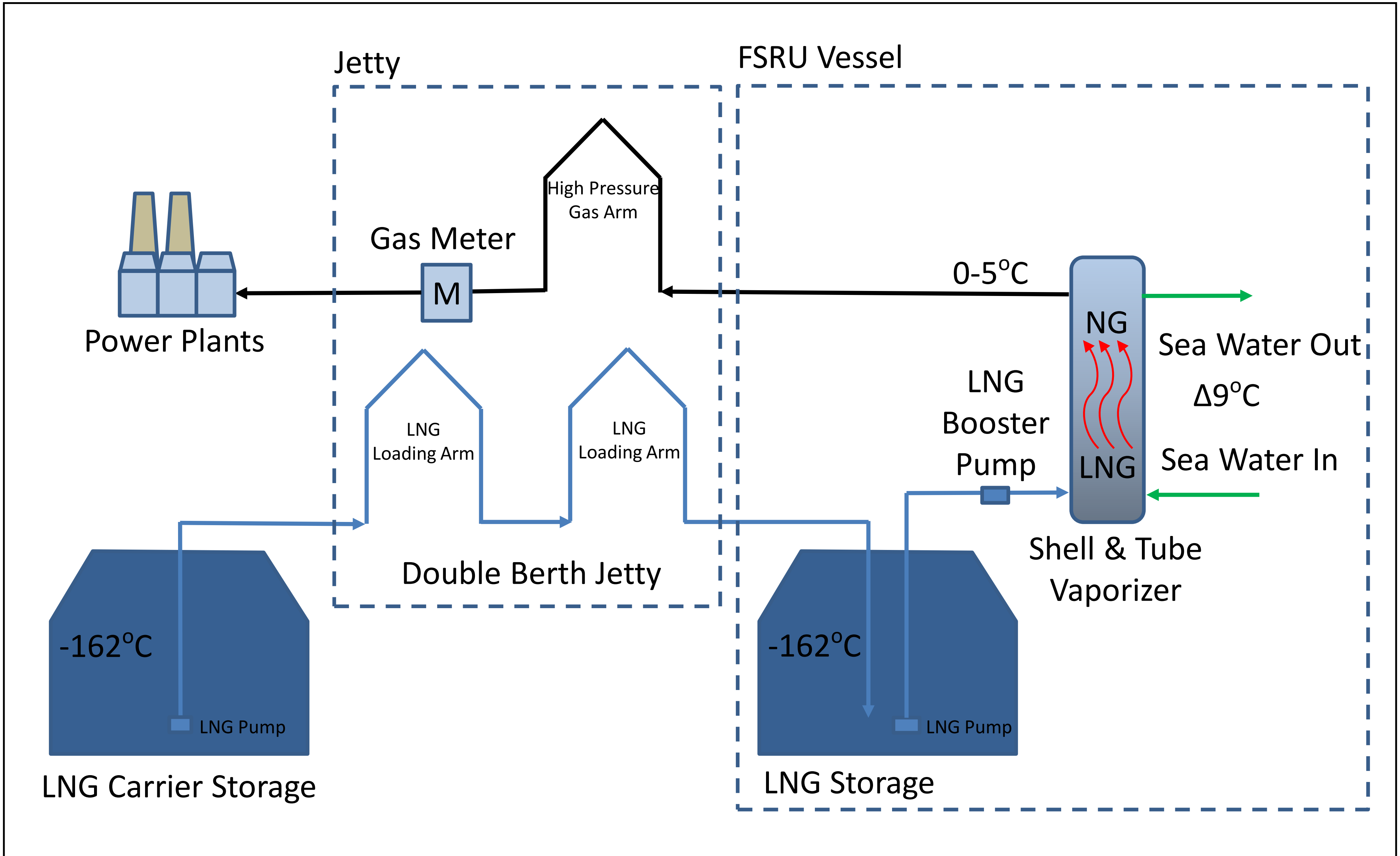

Figure 5B.1

Schematic Diagram for the LNG Terminal

Environmental Resources Management

ERM

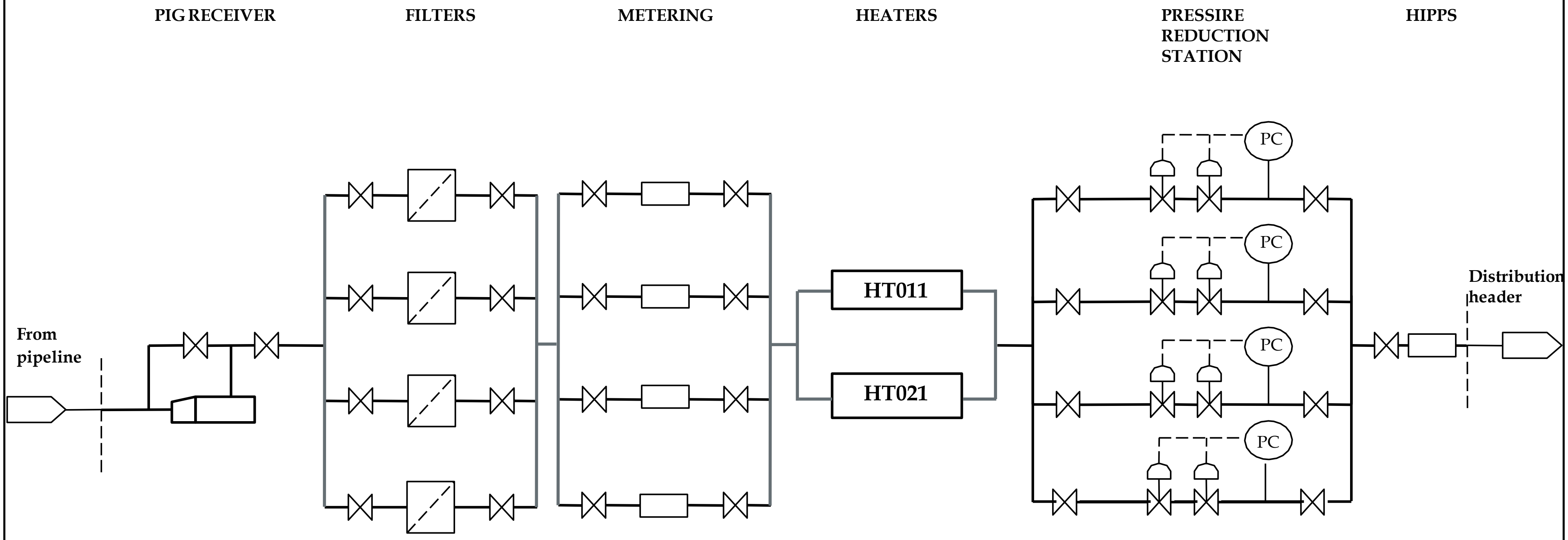

Figure 5B.2

Schematic Diagram for GRS facilities at the BPPS

Environmental Resources Management

ERM

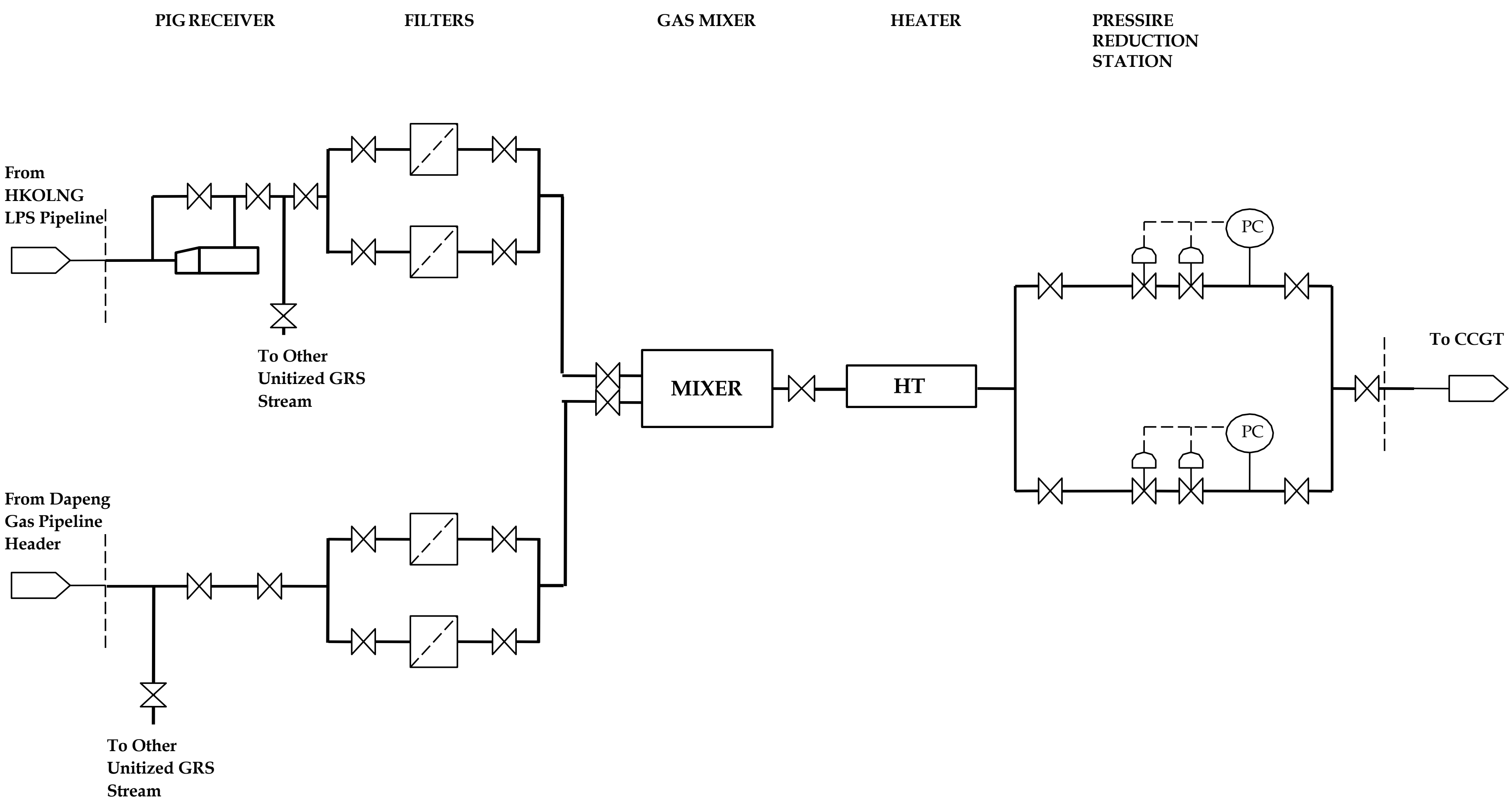

Figure 5B.3

Schematic Diagram for GRS facilities at the LPS

Environmental Resources Management

ERM