Chiyoda's Experience in LNG / LPG Receiving Terminals
Introduction

Chiyoda has been engaged in the engineering and construction of LPG/LNG receiving terminals, utilizing the technology and experience not only in cryogenic engineering but also in petroleum refining, gas processing, chemical, petrochemical, and other related industries.

To construct economical and reliable LPG/LNG receiving terminals and gasification plants for our clients, Chiyoda organizes a project team on a task force basis. This is to handle every aspect of the project systematically and smoothly, from initial planning to basic design, engineering, fabrication, procurement, construction, and commissioning, all under single responsibility.

With its expertise in cryogenic technology and its engineering capabilities, Chiyoda implements the project by mobilizing its corps of qualified and experienced engineers and specialists, all dedicated to providing an economical and reliable plant to meet the client’s needs.

LPG / LNG Receiving Terminals

LPG Receiving Terminal

As far terminals for delivering imported LPG, Chiyoda has engineered and constructed the largest number of such terminals, over twenty facilities until now, with more under construction or in the planning stage. The imported LPG is loaded into tankers and coastal tankers, fed to power stations after vaporization by heating, or put in cylinders for use as industrial and domestic fuel.

LNG Receiving Terminal

In 1969, Chiyoda constructed the first terminal for receiving LNG in Japan at the Negishi Works of the Tokyo Gas Co., Ltd. Since then, many more LNG receiving terminals have been constructed in Japan. This is in line with the Japanese policy of increasing the calorific value of city gas, and also of changing the feedstock for thermal power plants to pollution-free LNG. Because LNG itself is mainly consumed as a source of energy for city gas and electric power, the essentials for everyday life, naturally a very high level of reliability is required for LNG receiving terminals. Chiyoda which enjoys a reputation in meeting the severe standards required, is playing a major role in the planning, design and construction of such receiving terminals.
Features for LPG / LNG Receiving Terminals

The following presents a part of Chiyoda’s capability in the technology related to LPG / LNG receiving terminals.

Storage Tanks

Design and Construction

LPG/LNG storage tanks are subject to extremely low temperatures. To ensure safe storage of the liquefied gas, the project begins with careful selection of the material and structural design based on in-depth analyses. At the construction site, the tanks are subjected to exacting construction standards and careful inspection at each stage of the work.

Chiyoda’s more than 40 years of experience in the engineering and construction of cryogenic storage tanks, and 60 years of experience in the petroleum refining, gas processing, chemical, petrochemical and other related industries permits its dedicated engineers to construct these tanks to the most stringent specifications of the client.

Seismic Analysis and Structural Analysis

LPG and LNG stored in tanks are extremely volatile, therefore, even the slightest accident cannot be allowed to occur. This requires careful seismic analysis, as well as analyses of various types of stresses, by considering the foundation and the tank as an integral whole.

Chiyoda’s group of specialists has developed one of the world’s most extensive setups of analytical procedures and computer programs in seismic and structural analyses. These procedures and programs have already been used in designing storage tanks, pressure vessels, piping systems, and other facilities. Furthermore, the Chiyoda-developed lever-and-pendulum earthquake isolating device has made it possible to construct spherical tanks and other similar structures highly resistant to earthquakes.

LPG Shipping System

Coastal shipments are benefiting from a high level of automation. After the loading arm is connected, the amount of delivery and the blend ratio are set on a control panel, and the system starts.

The heater and the blende, as well as the flow rate, are automatically controlled according to preset values. When the specified amount of LPG cargo has been loaded, the operation stops automatically and the system returns to stand-by mode.

Propane Heater

Seawater is the most economical heat source for propane heaters. There are several types of propane heaters which utilize seawater. Even with its increased capacity, the propane heater developed by Chiyoda is compactly designed and does not require an especially large space for installation. This feature lowers construction cost and ease of operation and maintenance.

LPG Shipping Facility

Return Gas Condensation System

Low-temperature propane is pressure-boasted as it is pumped from the cryogenic tank and sent to a heater where it is warmed to ambient temperature and then loaded into a coastal tanker for shipping. Normally, low-temperature butane is pressure-boasted as it is pumped from the cryogenic tank and loaded directly into a coastal tanker. Propane and butane can be blended in-line at highly accurate mixing ratios. This permits the shipment of the propane and butane mixture to be loaded directly from tank to ship while being blended.

Chiyoda’s proprietary process has been adopted, where, return gas from the coastal tanker during cargo loading is condensed by using the cold energy of the LPG being shipped, and the condensate is shipped together with the LPG.

LPG cavern storage system

LPG cavern storage system, in which underground water pressure around cavern is made over LPG vapor pressure, is the most economical and safe system for huge volume LPG storage.

The design for safety in cavern LPG storage system is excellent, because the installation depth of cavern is very deep, such as App. 200m for propane, App. 90m for butane, and also emergency shut-off valve installed in cavern prevents to leak LPG, and the shelter above piping shaft protects piping.

For LPG user, another merit is in being able to construct cavern storage system in a small area, at such sites where it is not able to construct aboveground cryogenic tanks system. Safety space between other facilities can be minimized in cavern storage system.

From economical viewpoint, construction cost and operation cost for liquefying boil-off gas for aboveground cryogenic tanks, are not needed for LPG cavern storage system. Therefore LPG cavern storage system is the most economical and safe system for huge LPG storage.

On-board boil-off gas reliquefaction plant for LNG carrier

Boil-off gas (BOG) generated in the LNG ship cargo during its voyage is burned in the boiler on conventional LNG carriers. On-board BOG reliquefaction plant had been studied for over a decade, because it is a key technology for LNG carriers in order to employ a new and more efficient propulsion system in the future.

LNG carrier, “LNG JAMALI,” owned by Osaka Gas International Transports, Inc. (OGIT), Nippon Yusen Kabushiki Kaisha (NYK Line), Mitsuji O.S.K Lines., Ltd. and Kawasaki Kisen Kaisha, Ltd., has become the world’s first ship equipped with on-board BOG reliquefaction plant. The achievement has been made jointly by Osaka Gas Co., Ltd., OGIT, NYK Line, Mitsubishi Heavy Industries, Ltd., and Chiyoda Corporation.

Chiyoda was responsible for the basic design of the reliquefaction plant. Refrigeration cycle, employing the Brayton cycle with nitrogen coolant, was designed to liquefy all the BOG generated during the voyage to return to cargo tanks. Chiyoda optimized the system to fit the limited on-board space and to achieve the efficiency required for the economic operation. Central schemes are crucial to the reliable and safe operation since BOG generation rate is likely to change during the voyage. Chiyoda established the reliquefaction control system through the verification with dynamic simulation.

The plant has demonstrated its performance and effectiveness successfully in the voyage between Oman and Osaka, Japan starting from November 2000.

Overview of the BOG Reliquefaction Plant

![Diagram of BOG Reliquefaction Plant]
Chiyoda has developed LNG BOG re-condensing process with Tokyo Electric Power Co., Inc. which is named as "Hot Gas Bypass Control". Conventionally, BOG is compressed to send-out pressure by a high-pressure compressor in order to maintain a tank pressure of several LPa and is sent out along with LNG vaporized by a LNG vaporizer. In the newly developed system, however, BOG is re-condensed at about 0.5MPa in the plate-fin heat exchanger by utilizing cryogenic energy of LNG which is supplied to LNG Vaporizer, and is sent back to LNG tank. This process unit enables us to keep BOG compressor discharge pressure constant without controlling both LNG and BOG flow rate. This process unit can also maintain a constant LNG composition in LNG Tank without concentration over the long period. This BOG re-condensing process is economical compared with conventional system, when gas send-out pressure from the LNG terminal is over 2.0MPa.

LPG/LNG stored in low-temperature storage tanks, is vaporized by heating and then sent to the power plant as fuel or to the utility company to make city gas. LPG/LNG is also used in steel plants which consume considerable amounts of fuel. Accordingly, a very high level of reliability is required for the LPG/LNG vaporization unit. Vaporizers are classified into the kettle type, the vertical thermosiphon type, the horizontal thermosiphon type for LPG, and the open rack, submerged combustion and steam ejector types for LNG. Chiyoda has designed and supplied various types of vaporizers, choosing the one most suited for each case. Electric power companies require LPG/LNG vaporization units having a quick response to the rapid fluctuations in load of the generators. To meet this requirement, Chiyoda has designed and constructed fully automated vaporization units which have met with full satisfaction of the clients.

The calorific value of vaporized natural gas is maintained within a specified narrow range when it is used as city gas, and essentially adjusted by adding LPG (Propane or Butane), since LNG calorific value is normally less than the required range. In general, required LPG flow rate is calculated based on the flow rate of natural gas, calorific value of natural gas, LPG and target product gas.

Several methods of adding LPG have been developed as follows,

- **Liquid / Gas calorific value adjustment**
  Natural gas and LPG are mixed by spraying LPG inside of a venturi type mixer or a drum. A natural gas heater needs to be installed at upstream of the mixer or the drum to completely vaporize LPG.

- **Gas / Gas calorific value adjustment**
  LPG is vaporized before it is added to send out gas. An LPG vaporizer is necessary.

- **Liquid / Liquid calorific value adjustment**
  Both LNG and LPG are mixed in the liquid phase. LNG is vaporized after calorific value adjustment. Optimum method is selected through the consideration of LPG composition, availability of the heat source, such as steam or hot water, plant plan and facility investment costs.
The operation and maintenance training simulator for LNG receiving terminals was designed and constructed by Chiyoda at the Shigakawa Training Center of Tokyo Electric Power Co., Inc. in 1987 to improve operating techniques and to provide training in the appropriate actions to be taken in emergency situations. The simulator was developed based on the identical DCS control system and actual equipment configuration with the two existing terminals. The capabilities of the simulator include the following:

1. Training for start-up, normal-shutdown operation for each operation mode such as unloading, sending out to vaporizer, and loading operations.
2. Training for cooldown and heat-up operation.
3. Training for shift operation of LNG between tanks and reliever phenomena.
4. Training for emergency operation at the failure of major equipment such as LNG pumps, BOG compressors and LNG vaporizers.
5. Training for Safety equipment.

The operating phenomena in the above operations are simulated by a computer program based on the actual composition of receiving LNG. This Simulator was replaced recently by Chiyoda as seen in the pictures.
**Experience at a Glance**

**LNG RECEIVING TERMINAL**
1. Sendai City Gas Bureau
2. Nihonkai LNG Co., Ltd.
3. Tokyo Gas Co., Ltd.
4. Tokyo Electric Power Co., Inc.
5. Tokyo Electric Power Co., Inc.
7. Tokyo Gas Co., Ltd.
8. Tokyo Gas Co., Ltd.
9. Tokyo Gas Co., Ltd.
10. Tohoku Gas Co., Ltd.
11. Tokyo Electric Power Co., Inc.
12. Tokyo Electric Power Co., Inc.
15. Tokyo Electric Power Co., Inc.
17. Tokyo Electric Power Co., Inc.
18. Tokyo Electric Power Co., Inc.
20. Tokyo Electric Power Co., Inc.

**LPG RECEIVING TERMINAL**
1. Tohoku Oil Co., Ltd.
2. Kashima Oil Co., Ltd.
4. Tokyo Electric Power Co., Inc.
5. Tokyo Gas Co., Ltd.
6. Japan Energy Corp.
7. Tokyo Gas Co., Ltd.
8. Toho Gas Co., Ltd.
9. Mizushima LNG Co., Ltd.
10. Continental Grain Co./Shanghai Petrochemical Co., Ltd.
11. BP Ningbo Huadong LPG Co., Ltd.

**LPG STORAGE TERMINAL**
2. Japan O&G and Metals National Corporation
3. Oita LPG Joint Stockholding Co., Ltd.
4. Japan O&G and Metals National Corporation
5. Japan O&G and Metals National Corporation
6. Japan O&G and Metals National Corporation
7. Japan O&G and Metals National Corporation

*Basic Design/FEED*
### LNG Receiving Terminal Projects

<table>
<thead>
<tr>
<th>LNG Gas Co., Ltd.</th>
<th>Storage Capacity (kL)</th>
<th>Project</th>
<th>Location</th>
<th>Year of Completion</th>
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<td>Tokyo Electric Power Co., Inc.</td>
<td>160,000</td>
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### LPG Receiving Terminal Projects

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<tr>
<th>Client</th>
<th>Storage Capacity (m³)</th>
<th>Project</th>
<th>Location</th>
<th>Year of Completion</th>
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<tr>
<td>Mitsubishi LNG Co., Ltd.</td>
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<td>Chubu Electric Power Co. Inc.</td>
<td>-</td>
<td>Grass-Roos</td>
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<td>Inpex Corporation</td>
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<td>Grass-Roos</td>
<td>Chugoku</td>
<td>2013</td>
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<td>Hibiya LNG Co., Ltd.</td>
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<td>Tokyo Gas Co., Ltd.</td>
<td>-</td>
<td>Grass-Roos</td>
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### LNG/LPG Receiving Terminal Projects

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<th>Project</th>
<th>Location</th>
<th>Year of Completion</th>
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<tr>
<td>Nippon Mining Co., Ltd.</td>
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<td>Mitsubishi Crystal</td>
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<td>Kyodo Oil Co., Ltd.</td>
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<td>Maruzen Oil Co., Ltd.</td>
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<td>Grass-Roos</td>
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<td>Idemitsu Kosan Co., Ltd.</td>
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<td>General Gas Co., Ltd.</td>
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<td>Expansion</td>
<td>Mizushima</td>
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<td>Grass-Roos</td>
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<td>Kobe Steel, Ltd.</td>
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<td>Sumolime Metal Industries, Ltd.</td>
<td>48,000</td>
<td>Grass-Roos</td>
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<td>Grass-Roos &amp; Vaporization Plant</td>
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<td>Sumolime Metal Industries, Ltd.</td>
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<td>Vaporization Plant (expansion)</td>
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<td>Iwami &amp; Co., Ltd.</td>
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<td>Kyodo Petroleum Industries, Ltd.</td>
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<td>Chugoku Electric Power Co., Inc.</td>
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<td>Inoue</td>
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<td>Tohoku Electric Power Co., Inc.</td>
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<td>Vaporization Plant</td>
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<td>Zen-nin Energy Terminal Corp.</td>
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<td>Shanghui Petrochemical Co., Ltd.</td>
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<td>Grass-Roos</td>
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<td>BP Ningbo Huadong LPG Co., Ltd.</td>
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### LPG Storage Terminal

<table>
<thead>
<tr>
<th>Client</th>
<th>Storage Capacity (m³)</th>
<th>Project</th>
<th>Location</th>
<th>Year of Completion</th>
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<tr>
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<td>Osaka Gas and Metals National Corporation</td>
<td>420,000</td>
<td>Grass-Roos</td>
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<td>Kashima LPG joint Stockholding Co., Ltd.</td>
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<td>Grass-Roos</td>
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<td>Osaka Gas and Metals National Corporation</td>
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