EFFORTS TO MINIMIZE THE ENVIRONMENTAL LOAD AT LNG RECEIVING TERMINALS

Main author

Mitsutaka Kajitani

JAPAN
ABSTRACT

Environmental changes due to global warming have caused various kinds of serious problems on a global scale. From this standpoint, the LNG industry must reduce harmful effects on the environment with the LNG related working chain, which includes mining, liquefaction, transportation of a natural gas and re-gasification.

Tokyo Gas' Ohgishima LNG Terminal started its operation in 1998 as an LNG receiving terminal. At that time, it introduced the most advanced technologies, and since then it has been reducing actively the environmental load up to the present level.

For example, the terminal has achieved the reductions of sea water used in LNG re-gasification, the reduction of electric power used in Boil off Gas (BOG) treatment and LNG pumping, and the reduction of SOx emissions in LNG unloading operation. In reducing the amount of sea water used for LNG re-gasification, we control the rotation speed of the pumps according to the temperature of the sea water, which is the world first technology. The electric power used for the sea water pumps have also been reduced to 70% of previous levels.

In this report we describe several examples of how we minimized the environmental load at Tokyo Gas' Ohgishima LNG Terminal. Outline of the environmental load at LNG receiving terminals and examples of how to minimize the environmental load are introduced in section 1 and section 2. The results of performance of minimizing the environmental load and conclusion are reported in section 3 and section 4.
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1. The Environmental Load At LNG Receiving Terminals

The operation flow of unloading LNG to sending out gas is shown in Figure 1.

In unloading LNG, the cargo pumps are used for transferring LNG from LNG carrier to receiving terminal. The electric power of these pumps is generated by steam-turbine installed in carrier. Heavy oil is used as fuel for power generation, and combustion of heavy oil generate a lot of SOx emissions.

In discharging LNG from the storage tanks, the LNG pumps are used for sending LNG to the vaporizer which re-gasifies LNG. In re-gasification of LNG, the sea water pumps are used for pumping up the sea water used as a heat medium. In treatment of BOG (boil-off gas), the compressors are used for compressing BOG and sending it to BOG re-liquefaction facilities. Since BOG is always generated in storage tanks, compressors are operated continuously.

The LNG pumps, the sea water pumps and the BOG compressors shown above are main equipments which consume much electric power at LNG receiving terminal. And also a lot of SOx is discharged in unloading LNG.

Considering the above situations, we assume that reducing the consumption of electric power in operating these equipments and reducing the emission of SOx leads greatly to the reduction of environmental load.

Figure 1. Main Process Flow of LNG Receiving Terminal
2. Examples of how to minimize the environmental load

2.1 Reduction of sea water used in LNG re-gasification

- An open-rack type vaporizer (where sea water is used as a heat medium) is used for LNG re-gasification. The amount of required sea water depends on the sea water temperature as shown in Figure 2.
- In the previous method, a fixed amount of sea water was sprayed regardless of the sea water temperature.
- In the new method, the amount of sea water can be reduced according to the sea water temperature, and the consumption of electric power to operate the pumps can also be reduced. Sea water is reduced by controlling the rotation speed of the sea water pumps.
- The adoption of a pole-change motor and variable frequency drive make this effect possible.

- In the case of adopting a pole-change motor, the electric power of a sea water pumps were reduced to around 80% in comparison with the previous method. On the other hand, in the case of adopting variable frequency drive, the amount decreased to about 70%.
- In addition, when the amount of sea water is reduced by extracting the outlet valve of a sea water pumps, the effect for reducing the electric power of a sea water pumps cannot be expected so much, because the pressure loss of the piping system increase.
- Although the more sea water temperature rises, the more amount of required sea water of a vaporizer decreases as shown in Figure 2, marine organisms such as shellfish may adhere to heat exchanger tubes of vaporizer. Therefore, when the minimum amount of the required sea water is determined, it is necessary to check the influence on the vaporizer performance.
Figure 2. Reduction of sea water in LNG re-gasification (A principle of pumps power reduction)

- Figure 3 is a graph showing the relation between Q-H characteristic (Quantity of flow – Head pressure) of a pump and pipeline resistance. H1 is a Q-H characteristic curve in the rating speed, and the quantity of flow QA equivalent to point of intersection A with pipeline resistance curve R1 becomes rating capacity.
- When the rotation speed of a pump decreases, Q-H characteristic curve falls from H1 to H2, and the quantity of flow decreases in QB equivalent to point of intersection B with R1. The ejection pressure of a pump falls from HA to HB at the same time, too.
- A reduction part of a pump power becomes a hatching part of figure 3. This area is almost in proportion to square of the rotation speed of pump. Therefore, it will produce a big energy-saving effect of decreasing the amount of sea water to a demanded level.

![Figure 3. Energy saving by decreasing the rotation speed of pump](image)

2.2 Reduction of electric power used in BOG treatment

- Although LNG tanks are enclosed by insulation (PUF), some of the LNG in the tanks continuously
evaporate by heat from the surroundings.

- When handling BOG, it is compressed and re-liquefied by using LNG cold energy. Re-liquefied BOG is sent out to the LNG vaporizers with the booster pumps.

- In order to reduce the electric power used by the BOG compressors, the pressure in the LNG tanks (inlet side of compressors) is heightened to the operational maximum, and the rate of compression of the compressors are reduced.

- During daytime when an electric bill is high, the BOG compressors load is decreased and the pressure in the LNG tanks is heightened. When the tanks internal pressure become high, BOG compressors load is raised and low power operating can be performed.

- An another measure to reduce the electric power used by the BOG compressors is to lower down the BOG pressure in the outlet of BOG compressors. Since compressed BOG is re-liquefied by using LNG cold energy, increasing LNG for cooling enables to reduce the BOG pressure.

### 2.3 Reduction of electric power used in LNG pumping

- The number of operating LNG pumps and vaporizers is automatically controlled according to the amount of send-out gas from the LNG terminal.

- Electric power used for pumping LNG is significantly reduced in the following way.

  a. Reduction of the number of operating pumps used for each LNG vaporizer loading

     After evaluating the influence at each pump trip, we reduce the number of the pumps operating at the LNG vaporizer rating from 3 to 2 as shown in Figure 4.

     The operation point shown in Figure 4 is the rated point of one LNG vaporizer, and the period of operation here is the longest. For this reason, reducing the number of the pumps operating here contributes to electric power reduction greatly.
Figure 4. Energy saving by reducing the number of the pumps

( The influence of the LNG pump accident )

- When one of the pumps trips, another pump starts operating immediately and the amount of LNG flow of a vaporizer increases temporarily. If LNG flows beyond a regulation value, the heat exchanger tubes of a vaporizer freeze, and evaporability of the LNG vaporizer may fall.
- In the above-mentioned measure, the upper limit value is set with the open degree of FCV (Flow Control Valve) by which the amount of LNG flow of a vaporizer is controlled currently.

However, if the upper limit value set is low, the amount of LNG flow of a vaporizer becomes below the LNG vapor rating.

b. Reduction of LNG pumps capability

By considering the send-out gas pressure demands, we cut down the number of pump impeller stages to reduce the electric power.

2.4 Reduction of SOx emissions in LNG unloading operations

- The electric power used in LNG unloading operations is supplied from the steam-turbine generator.

In the previous method, only heavy oil was used for the boiler-fuel during berthing of LNG carriers.

- We use BOG with heavy oil as the boiler-fuel during unloading operations of Tokyo Gas managed LNG carriers for the first time (dual burning). As BOG does not include sulfur content, we have achieved great reductions in SOx emissions from LNG carriers during unloading operations by minimizing the consumption of heavy oil.

- During unloading of LNG, the shipside tanks and shore side receiving tanks are connected with liquid pipelines and additional pipelines for the gas, to build a closed system for a safe transfer of LNG and its boil-off-gas as shown in Figure.5.

- The consumption of BOG in LNG Carrier is changed according to the boiler-load. If the amount of return BOG is required more, we increase BOG using Return Gas Blower.
Now, this operation of reducing SOx emissions is applied only to the management carriers of Tokyo gas company, not to the LNG project carriers.

![Flow Chart of Fuel Consumption and Operation](image)

**Figure 5. The Flow Chart of Fuel Consumption and Operation**

### 3. RESULTS

1. **Reduction of the electric power consumption**
   
   Using various methods, we have reduced the electric power consumption to about 47% of the levels of the starting time of operations.

2. **Reduction of CO$_2$ and SOx emissions**
   
   As mentioned above, we were able to reduce CO$_2$ and SOx emissions significantly as shown in Table 1.

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<th>Amount of reduction</th>
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<td></td>
<td>Reduction of sea water used in LNG re-gasification</td>
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<tr>
<td></td>
<td>Reduction of electric power used in BOG treatment</td>
<td>▲5%</td>
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<tr>
<td></td>
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<table>
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<th>SOx</th>
<th>Method</th>
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<tbody>
<tr>
<td></td>
<td>Reduction of SOx emissions in LNG unloading operation</td>
<td>▲70%</td>
</tr>
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</table>

※ Emission Coefficient : 0.438 t CO$_2$/MWh
4. **Conclusion**

At the Ohgishima LNG receiving terminal, Tokyo Gas has used various methods to reduce the environmental load, and, as a result, electric power consumption rates and CO₂ / SOx emissions have been reduced significantly.

We will continue to search for new ways to reduce the environmental load and increase our competitive advantage as LNG receiving terminal. That is why we expect our customers to continue to choose Tokyo Gas in this era of intense competition in the energy industry.

5. **LIST OF TABLES**

Table1: Reduction of CO₂ and SOx emissions

6. **LIST OF FIGURES**

Figure1: Main Process Flow of LNG Receiving Terminal

Figure2: Reduction of sea water in LNG re-gasification

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Figure4: Energy saving by reducing the number of the pumps

Figure5: The Flow Chart of Fuel Consumption and Operation