UTILIZATION OF UNDERGROUND GAS STORAGE (UGS) IN JAPAN

Koji Yoshizaki\(^1\), Noriaki Sato\(^2\), Hiroshi Fukagawa\(^3\), Hiromi Sugiyama\(^3\), Genta Takagi\(^3\) and Takenobu Jono\(^3\)

1. Tokyo Gas Co., Ltd., Japan
2. Japan Natural Gas Association, Japan
3. INPEX Corporation, Japan

Keywords: 1. UGS; 2. JAPAN; 3. Security of supply.

1 Introduction

The share of natural gas in primary energy supply in Japan is increasing from 10.2% in 1990 to 16.3% in 2007 [1] as shown in Figure 1. Since domestic natural gas production is limited, 96.4% of the natural gas used in Japan was imported as Liquefied Natural Gas (LNG) [2] and domestic gas production was 3.7 billion m\(^3\) [3] in 2007. Japan is the largest importer of LNG in the world and its share is 39%. Approximately 3/4 of the imported LNG is from Asia-Pacific countries such as Indonesia, Malaysia and Australia as shown in Figure 2 [4]. 1/3 of the natural gas is used for city gas, and 2/3 is used for generating power. The sales volume of city gas in fiscal year 2007 was 37.4 billion m\(^3\), at the result of consecutive increasing for 30 years [5].

Since the most of the natural gas is imported as LNG, the transmission pipelines have been developed from 27 LNG receiving and re-gasifying terminals located close to the high demand areas along the coast as shown in Figure 3. 7 terminals are under construction or planned.

There are 212 city gas utilities, and the 4 big utilities represent 3/4 of the total sales volume. The utilities are not unbundled. Tokyo Gas, which is the biggest utility in Japan, imports LNG from other countries and re-gasifies it at its three receiving terminals and distributes to 10.2 million customers through its transmission and distribution pipelines. It buys as well domestic gas produced in Niigata prefecture, which is the northern part of the main island, Honshu, and gas dissolved in water produced in Chiba prefecture, which is next to Tokyo Metropolis.

![Figure 1 Primary energy supply in Japan (1990 and 2007)](image1.png)

![Figure 2 LNG import in Japan by supply country (2007)](image2.png)
2 UGS in Japan

There are five Underground Gas Storages (UGSs) in Japan as listed in Table 1 [7]. All of them are located in Niigata prefecture where many oil and gas fields exist as shown in Figure 4 (a). INPEX has been operating one of the largest gas fields in Japan called as Minami-Nagaoka gas field, located 10 km southwest from Nagaoka city in Niigata prefecture. It was discovered in 1979 and the cumulative gas production as is 13 billion m$^3$. Annual production is 1.6 billion m$^3$, which is increasing year by year with the expanding demand for natural gas. Most of the natural gas produced in the Minami-Nagaoka gas field is directly supplied to Tokyo Metropolitan area through its pipeline network. To adjust its calorific value to the specification for the city gas supplied in Tokyo area, 6 mol% of CO2 is removed in the processing facility.

INPEX also has been operating an UGS named “Sekihara” nearby the Minami-Nagaoka gas field. The Sekihara UGS was originally a gas producing reservoir and then converted to an UGS after depletion in 1969. The Sekihara UGS and the Minami-Nagaoka gas field are connected through a pipeline as shown in Figure 4 (b). Most of the stored gas in the Sekihara UGS has been brought from the Minami-Nagaoka gas field. The Sekihara UGS is utilized for the purpose of peak-shaving.

Figure 5 shows the history of P/Z, pressure divided by gas deviation factor, in the Sekihara UGS. As shown in the figure, it is difficult to store the same amount of gas at a certain pressure level of the primary depletion period due to the aquifer encroachment to the reservoir. In the case of the Sekihara UGS, the stored gas volume is 100 million m$^3$ less than the initial gas volume at the initial pressure.

### Table 1 Underground Gas Storages (UGSs) in Japan [7]

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
<th>Working since</th>
<th>Number of wells</th>
<th>Depth of wells (m)</th>
<th>Total gas volume (Bcm)</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nakajo</td>
<td>Japan Energy</td>
<td>1985.1</td>
<td>2</td>
<td>800</td>
<td>0.2</td>
<td>Peak shaving / Emergency stockpile</td>
</tr>
<tr>
<td>Shiunji</td>
<td>JAPEX (Japan Petroleum Exploration)</td>
<td>1989.1</td>
<td>3</td>
<td>900 – 1,100</td>
<td>0.33</td>
<td>Peak shaving</td>
</tr>
<tr>
<td>Sekihara</td>
<td>INPEX</td>
<td>1969.4</td>
<td>13</td>
<td>1,000</td>
<td>0.25</td>
<td>Peak shaving</td>
</tr>
<tr>
<td>Kumoide</td>
<td>JAPEX</td>
<td>1989.1</td>
<td>5</td>
<td>1,700</td>
<td>0.35</td>
<td>Emergency stockpile</td>
</tr>
<tr>
<td>Katakai</td>
<td>JAPEX</td>
<td>1979.5</td>
<td>4</td>
<td>1,000</td>
<td>1.01</td>
<td>Emergency stockpile</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>2.14</strong></td>
<td></td>
</tr>
</tbody>
</table>
3 Utilization of UGS combined with LNG terminals

Although the supply of natural gas from LNG in Japan is secured enough with the various measures such as diversification of supply sources, the long-term contracts, flexibility clause in the contracts and/or utilization of LNG spot market, the combination of UGS and LNG terminals can make the security level even higher. If an UGS is linked with a high demand area with large pipeline capacity (hereafter, “connected area”), the gas stored in the UGS can be available in the case that the amount of LNG supplied to the connected area is reduced due to supply problems such as upstream trouble, as shown in Figure 6 (a). Even the security level of a demand area which is not connected to the UGS (hereafter, “unconnected area”) becomes higher when the gas stored in the UGS is used for the connected area and the LNG cargoes which are going to the connected area supply LNG to the unconnected area. In the case that such LNG cargoes are not able to supply LNG due to the destination clause or inadequate timing, several LNG terminals in Japan can ship LNG in coastal vessels which are actually supplying LNG to satellite terminals, as shown in Figure 6 (b). The scheme utilizing UGS with LNG terminals can be effective for raise the security level of supply when it is realized in the future.
A feasibility study was conducted to evaluate the cost for the case of utilization of UGS combined with LNG terminals (hereafter, "UGS case") and the case of utilization of LNG tanks only (hereafter, "LNG tanks case") for emergency stockpile. There are several depleted gas fields which are considered as good candidates for UGS in Japan. The size of the depleted gas fields varies from 50 million m$^3$ to 15 billion m$^3$. In the case that the volume of working gas is 2.5 billion m$^3$, a simple gas simulation calculated the volume of cushion gas as 5.0 billion m$^3$ when gas booster compressors are not utilized for the production period, as listed in Table 2. The number of the LNG tanks with capacity of 200,000 kl is 22 for the equivalent volume for emergency stockpile to the UGS with working gas volume of 2.5 billion m$^3$.

Figure 7 compares the cumulative cost of the UGS case and that of the LNG only case. The cost is normalized with the initial cost of the UGS case, which includes cushion gas, above-ground facilities, wells, LNG receiving terminal close to the UGS and pipelines connected to the LNG receiving terminal and the high demand area. For the UGS case, the cumulative cost includes the initial cost of UGS listed above and the operating cost for energy cost for injection and withdrawal of natural gas and operating cost including maintenance cost for the LNG receiving terminal and the pipelines. For the LNG tanks case, the initial cost includes the construction cost for 22 LNG tanks, the facility for re-liquefaction of boil-off gas (BOG) and re-gasification facility, and the operating cost includes the energy cost for re-liquefaction of BOG and maintenance. As shown in Figure 7, the cost for the UGS case was much lower than that of the LNG tanks case for the purpose of emergency stockpile.
### Table 2 Specification for UGS and LNG tank

<table>
<thead>
<tr>
<th></th>
<th>UGS</th>
<th>LNG tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working gas volume, bcm</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Cusion gas volume, bcm</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Capacity, kl</td>
<td>200,000</td>
<td></td>
</tr>
<tr>
<td>Number of tanks</td>
<td>22</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7 Comparison in cumulative cost between the “UGS case” and the “LNG tanks case” for emergency stockpile

4 Summary

This paper describes the utilization of UGS in the gas industry in Japan. Since the most of the natural gas is imported as LNG, the transmission pipelines have been developed from 27 LNG receiving and re-gasifying terminals located close to the high demand areas along the coast. There are five UGSs in Japan for the purpose of emergency stockpile and/or peak-shaving.

A feasibility study has been conducted to evaluate the effect of utilization of UGS combined with LNG terminals. A depleted gas field was assumed to be converted to UGS with working gas of 2.5 million m$^3$ and combined with LNG terminal, and compared with 22 LNG storage LNG tanks for the equivalent effect of storage. The result of the study showed that the cost for the case of utilization of UGS combined with LNG terminals wasa much lower than that of the case of utilization of LNG storage tanks only for the purpose of emergency stockpile.

References