Evolution of an LNG Terminal:
Senboku Terminal of Osaka Gas

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Senboku LNG Terminal

Commissioned in 1977
Senboku 2

Commissioned in 1971
Senboku 1

North area  South area
Evolution into multi-energy terminal

LNG terminal in operation for over 30 years

(1) How to address the aging of facilities
(4) Human resources development

(2) Power generation business

(3) Cryogenic business

Multi-energy terminal

City gas business
There is the fear of hidden deterioration advancing (machine facilities and concrete structures)

Current maintenance cycle

Establishment → Operation → Daily inspection → Periodic Maintenance (maintain reliability) → Deterioration → Repair: Part replace (Recover reliability) → Visible Deterioration → The large-scale replace → Trouble

10 years [↓] 20 years [↓] 30 years [↓]

Now
We are digging up and assessing items of uncontrolled, invisible deterioration

**LNG Tank**
- Fatigue degree of inner tank
- Corrosion of drain nozzle

**Boil-off gas compressor**
- Heat fatigue of impeller
- Fatigue of crank
- **Insulation-deterioration of electric motor**

**Open rack type vaporizer**
- Heat fatigue of inside surface of tube
- Corrosion and SCC of header of sea water line

**Normal temperature piping**
- Corrosion of piping support
- Corrosion of pipe under hot or noise insulation

**LNG, BOG piping**
- SCC (Stress corrosion crack) of pipe under cold insulation
- Degradation of urethane support

**LNG pump**
- Fatigue degree of shaft and keyway
- Strain of shaft and casing

**Concrete structure**
- Chloride attack and neutralization
- Alkali-aggregate reaction
Evaluation of the insulation-deterioration with electric motor

Degree of deterioration which is found from $\tan\delta$

Decline degrees to the break-down voltage with electric motor immediately after manufacturing

Lower limit which can be safely operated

Estimated lifetime

Period of operation

Years

%
Maintenance of the electricity and instrumentation facilities

The electric and the instrumentation facilities need to be updated in the period between 15 and 20 years for the following reasons.

1) Application limits of the parts
2) Parts supply termination
3) Expiration of the maintenance contract

Renewal timings of operation control systems

<table>
<thead>
<tr>
<th>Site</th>
<th>Installation</th>
<th>The 1st update</th>
<th>The 2nd update</th>
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</thead>
<tbody>
<tr>
<td>Senboku 1</td>
<td>1971</td>
<td>1987</td>
<td>2002</td>
</tr>
<tr>
<td>North area of Senboku 2</td>
<td>1976</td>
<td>1994</td>
<td>2006</td>
</tr>
<tr>
<td>South area of Senboku 2</td>
<td>1988</td>
<td>2007</td>
<td></td>
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</tbody>
</table>
# Power generating plants of Osaka Gas

<table>
<thead>
<tr>
<th>Site</th>
<th>Power generation method</th>
<th>Output</th>
<th>Start of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senboku 1</td>
<td>gas turbine combined cycle</td>
<td>18MW (9 MW x 2 units)</td>
<td>July 2002</td>
</tr>
<tr>
<td>Himeji Terminal</td>
<td>gas turbine combined cycle</td>
<td>50 MW</td>
<td>June 2004</td>
</tr>
<tr>
<td>Senboku 1 &amp; 2</td>
<td>gas turbine combined cycle</td>
<td>1,100 MW (270 MW x 4 units)</td>
<td>November 2009</td>
</tr>
</tbody>
</table>
Power generating plants of Osaka Gas

Power generation plant at Senboku 1

<table>
<thead>
<tr>
<th>Type of power generation</th>
<th>Single-shaft gas turbine combined cycle (combined heat and power)</th>
</tr>
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<tbody>
<tr>
<td>Power output</td>
<td>18,000kW (16°C)</td>
</tr>
<tr>
<td>Gross thermal efficiency</td>
<td>44% [LHV]</td>
</tr>
<tr>
<td>Main equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gas turbine (6,600kW X 2 lines)</td>
</tr>
<tr>
<td></td>
<td>Steam turbine (2,400kW X 2 lines)</td>
</tr>
<tr>
<td></td>
<td>Heat recovery steam generator (12MW X 2 lines)</td>
</tr>
</tbody>
</table>

NOx

- below 30ppm (Oxy 0% conversion)
- Type of gas turbine combustion: low NOx combustor
- Type of NOx removal: urea

110MW Power generation plant

Senboku 1

NO.1,2

NO.3

NO.4
History of LNG Cold Use at Senboku LNG Terminal

‘70s  ‘77 : Air Separation (Cold Air Products #1) 
          ‘79 : Cryogenic Power Generation 
                (Propane Rankine Cycle)
‘80s  ‘80 : Carbon Dioxide Liquefaction
          ‘82 : Cryogenic Power Generation 
                (Propane Rankine+Direct Expansion)
          ‘83 : Air Separation (Cold Air Products #2)
                ‘87 : Cold Source for the Chemical Industry
‘90s  ‘93 : Air Separation (Cryo Air)
          ‘97 : Boil Off Gas Liquefaction
‘00s  ‘04 : **Cascade LNG Cold Energy** 
          **in an Industrial Complex**
Major cryogenic applications in the past

Cryogenic power generator

Air separation

Boil-off gas liquefaction system
LNG cryogenic energy cascade process
Policy on human resources development

We have developed the simulator equipment which can reproduce the dynamics of the operational process with high precision.

By using the simulator, we can train operators under contingency situation that are difficult to experience in normal operations.
Conclusion

City gas business

Power generation business

Cryogenic business

LNG underwater pipeline