Development and Application of New Heat Supplying Systems Utilizing Hot Spring Water in the Northern Island of Japan

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Outline

■ Introduction Hokkaido, the Northern Island of Japan and the motivation of this research (Energy self-sufficiency and CO$_2$ emission in Hokkaido)
■ Evaluation of utilizable energy of hot spring water in Hokkaido as a heat source for 4GDH
■ A Newly developed palisaded heat exchanger combined with plastic pipes to collect heat from hot spring water
■ A heat energy network system among several facilities using hot spring water and the heat exchanger
Where is Hokkaido? The Northern Island of Japan

Location of Hokkaido  Ski resort in Hokkaido  Radiation panels for heating

- About 8000km away from CPH
- Annual average temp. of prefectural capital (Sapporo): 8.9°C (CPH: 8.4°C), snowy and cold climate
Motivation of this research

Import rate in Hokkaido
※ (Total amounts: 906 billion yen, Exports: 371)
Source: Hakodate Customs (2017)

- Low energy self-sufficiency rate: only 7%
- Renewable energy sources and their suitable systems are required.

CO₂ emission in Hokkaido
※ 13.0 t-CO₂/person (10.4 t-CO₂ in Japan)
Source: Hokkaido local government (2018)
Hot springs in Hokkaido

- Sites: 245, Number 2225
- The total emission amount: 2,110 m³/min
- About 59% more than 315K (42°C)

Source: Environment ministry of Japan (2015)

Hot springs as heat sources

- Hot springs like lakes
- Unutilized hot springs
- Waste hot water from spa facilities
Utilizable energy of hot spring water as a heat source for 4GDH

Maps of the utilizable energy of hot springs in Hokkaido

Calculated from more than 333K(60°C)  Calculated from more than 313K(40°C)

Estimated more than 1MW

- 40 already used sites, 11 unused sites (more than 60°C)
- 6 added for already used, 1 added for unused (more than 40°C)
- Concentrated in the eastern area or the western area

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Problems of metal heat exchangers for heat collected from hot spring water
A new type of palisaded heat exchanger for hot spring water

Appearance of palisaded heat exchanger (prototype: 893 × 1023 × 560 mm)

- A palisaded heat exchanger combined with pipes formed by thermal fusion bonding
- Corrosion resistance
- Ease of cleaning

Sites of thermal fusion bonding

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Cleaning of heat exchangers

Cleaning of heat exchanger using water or dissolution of scale by hydrochloric acid.

Before cleaning → Cleaning → After cleaning
Hot water pre heat system

Outline of hot water pre heat system (indirect heat exchange method)
Scale riched hot spring

Raw hot spring water tank

Sulfurous, heavily acidic hot spring

Wasted hot spring water tank

Heat exchanger

Heat exchanger

Sulfurous heavily acidic hot spring
## Energy conservation and cost at system-installed facilities

<table>
<thead>
<tr>
<th>Entry</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Location of facilities</td>
<td>Kamoenai village</td>
<td>Ishikari city</td>
<td>Noboribetsu city</td>
</tr>
<tr>
<td></td>
<td>Characteristics of hot spring</td>
<td>Scale rich</td>
<td>mild</td>
<td>Sulfurous, heavily acidic</td>
</tr>
<tr>
<td></td>
<td>Heat source</td>
<td>Raw hot spring</td>
<td>Wasted hot spring</td>
<td>Wasted hot spring</td>
</tr>
<tr>
<td></td>
<td>Number of prototype heat exchanger</td>
<td>2 sets</td>
<td>2 sets</td>
<td>2 sets</td>
</tr>
<tr>
<td></td>
<td>Amounts of average heat collect [kWh/day]</td>
<td>576.9</td>
<td>110.2</td>
<td>314.9</td>
</tr>
<tr>
<td></td>
<td>Energy contribution of the system [%] (boiler efficiency 90%)</td>
<td>49.8</td>
<td>33.9</td>
<td>44.0</td>
</tr>
<tr>
<td></td>
<td>Temperature of the hot water tank[℃]</td>
<td>65</td>
<td>70</td>
<td>41</td>
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<tr>
<td></td>
<td>Payback time [year]</td>
<td>5.6</td>
<td>5.6</td>
<td>7.6</td>
</tr>
</tbody>
</table>
Heat energy network systems among several facilities using hot spring water

A schematic diagram of the system
Conclusion

- Already used in 46 sites, and Not used in 12 sites of the hot springs in Hokkaido, (the northern most island of Japan,) were shown as the sites that more than 1MW of the utilizable energy existed.

- A palisaded heat exchanger combined with plastic pipes for preventing corrosion and clogging was newly developed and applied for heat recovery systems from the hot springs.

- We are trying to design an energy network system to install hot spring water. The heat exchanger is one of the solutions to deal with hot spring problems such as corrosion and clogging.
Appendix
Evaluation of utilizable energy of hot spring water as a heat source for 4DH

\[ Q = \frac{1}{1000} \times C_p \times \rho \times F \times 60 \times (T_{out} - 313) \cdots \quad (1) \]

- **Q**: Amount of the utilizable energy [MW]
- **Cp**: Specific heat of hot spring water \( \cong 4.2\, \text{[kJ/kg} \cdot \text{K]} \)
- **\( \rho \)**: Density of hot spring water \( \cong 1.0\, \text{[kJ/kg} \cdot \text{K]} \)
- **F**: Flow rate of hot spring water [L/min]
- **\( T_{out} \)**: Discharge temperature of hot spring water [K]
- **313**: Temperature for heating [K] (40°C)
Heat exchange capability

\[ Q = C_p \times \rho \times F \times (T_2 - T_1) \text{[W]} \quad (1) \]

\[ Q = K \times A \times \Delta T_m \text{[W]} \quad (2) \]

\( Q \): Heat exchange capability [W], \( C_p \): specific heat of water [J/(g·K)], \( \rho \): density of water [g/L], \( F \): flow rate inside heat exchanger [L/s], \( K \): the overall heat transmission coefficient of the heat exchanger [W/(m²·K)], \( A \): heat transfer area of the heat exchanger [m²], \( \Delta T_m = (\Delta T_{\text{inlet}} - \Delta T_{\text{outlet}}) / \ln(\Delta T_{\text{inlet}} / \Delta T_{\text{outlet}}) \)
Heat exchange capability test apparatus

Heat exchange capability of the heat exchanger to flow rate of the water

- Temperature difference of the inlet: 20K → the maximum heat recovery: about 20kW
- The maximum temperature rise: 18K

![Graph showing heat exchange capability and temperature rise vs water flow rate.](image-url)
Overall heat transmission coefficient

- Low overall heat transmission coefficient
- Enough to deal with the hot spring and wasted water that are corrosive or have a lot of suspended solids
**Example of operation data**

Heat collect data of the scale riched hot spring  
(December 23 2018, Indirect heat exchange method)

- Cold water is warmed from 12～15℃ to about 35℃.
Material endurance

Test pieces set in the hot springs

- Test pieces had **endurance** in the early periods.
- The heat exchangers installed at location A has worked well for **more than 4 years**.

### Tensile yield strength of test pieces of the heat exchanger

<table>
<thead>
<tr>
<th>Location</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water temperature [°C]</strong></td>
<td>60.2</td>
<td>58.8</td>
<td>72.5</td>
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<tr>
<td><strong>Quality</strong></td>
<td>Sulfurous spring pH=2.3</td>
<td>Sulfurous spring pH=1.6</td>
<td>High temperature spring</td>
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<tr>
<td>Before soaking [MPa]</td>
<td>22.5</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>1 time [MPa]</td>
<td>23.4</td>
<td>23.1</td>
<td>23.1</td>
</tr>
<tr>
<td>2 times [MPa]</td>
<td>23.5</td>
<td>23.5</td>
<td>23.6</td>
</tr>
<tr>
<td>3 times [MPa]</td>
<td>23.2</td>
<td>23.6</td>
<td>22.3</td>
</tr>
<tr>
<td>4 times [MPa]</td>
<td>23.6</td>
<td>23.6</td>
<td>22.6</td>
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</tbody>
</table>
Effect of cleaning for heat collect

(Sulfurous, heavily acidic hot spring 2015)