HOT WATER SUPPLY TEST USING GEOTHERMAL HEAT PUMP SYSTEMS AT PETROPAVLOVSK-KAMCHATSKY, THE CAPITAL OF KAMCHATKA, RUSSIA

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ABSTRACT

"Fundamental investigation of the promotion of a joint implementation for the fiscal year 1998 - The fundamental investigation related to local heating utilizing geothermal in Kamchatka, Russia" was carried out with the support of the New Energy and Industrial Technology Development Organization (NEDO). It was carried out as a feasibility study and to implement the "joint implementation."

As the results, it was verified that heating by geothermal heat pump (GHP) can be used instead of the existing boiler heating in the severe climate condition in Kamchatka. In this report, the results of the GHP test as a part of this feasibility study is summarized.

INTRODUCTION

The third conference (COP3) of the parties for the United Nations Framework Convention on Climate Change was held in Kyoto in December, 1997. In order to prevent the global warming by the effects of greenhouse gases such as carbon dioxide, the protocol in Kyoto adopted reduced targets for the quantity of greenhouse gas exhausted in developed countries. Further, in the protocol in Kyoto, the methods of achieving the targets were made flexible, such as by "joint implementation," among developed countries.

With this background, "The fundamental investigation related to local heating utilizing geothermal in Kamchatka, Russia" was carried out. The region selected for this project was Petropavlovsk-Kamchatsky, the capital of Kamchatka (hereinafter called "P-K city") and its environs (Figure 1). P-K city faces the Bay of Avanchiskaya located a little to the south of the center of the east Pacific coast. Three hundred thousand of the state's total population of about 350,000 live in the city and it is the center of administration and industry of the Peninsula. It is located 30 km from the Erizoho airport, the gateway to Kamchatka.

There is a district heating system using hot water in P-K city. This includes two systems for the supply of hot water from exhaust heat of the power plant and the supply of hot water furnished by heavy oil combustion. Sixty five percent of local heating in P-K city is supplied by hot water from heavy oil combustion through a pipeline.

The purpose of this test was to verify that the heating can be carried out adequately by GHP instead of the boiler heating in Kamchatka, a severe cold district.

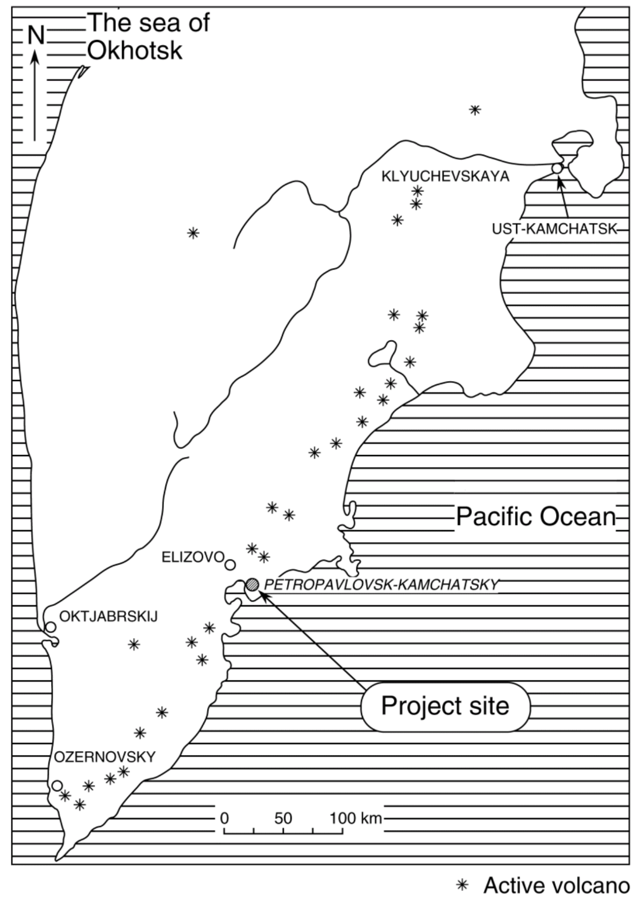

Figure 1. Southern part of Kamchatka peninsula.

GEOTHERMAL HEAT PUMP TEST PROGRAM

Selection of Test Site

The GHP test began by selecting the test site. As the conditions of the test site, the vertical ground heat exchanger type heat pump system was adopted. Because the site area was comparatively unrestricted for the location of the heat pump test, it was possible to drill boreholes. Accordingly, as the result of the proposal by Russia and the preliminary discussion, four locations were selected as the proposed test sites. Then the on–site investigation of these proposed test sites were carried out, taking the following into consideration:

1. Geographical position,
2. Geological conditions,
3. Existing heating system,
4. Social importance of installation site,
5. Reliability of electric power supply to the installations, and
6. Issue of ownership and the of approval of the test.

As the result of the comparison and investigation of the four proposed sites, the sanatorium of Kamchatka Energo Company (electric power company) in Aginuk region was selected as the test site. This sanatorium is located in the Paratunsky hot spring area 60 km from P-K city.

This sanatorium is the property of Kamchatka Energo Company, used as a children training camp in summer and as the lodging facility for the employees and their families of Kamchatka Energo Company in winter. The facility consists of two hotel-type residential buildings, an administration building, a pool and auxiliary buildings. The area was most suitable for the GHP test site as a well can be drilled anywhere. Electricity is supplied by independent power generation for twenty-four hours. The heating of all buildings is centralized in a heavy oil boiler system. The temperature is controlled by the outdoor temperature and is operated manually. There were no problem in use or that could occur in the drilling and approval. The room selected for the test has the advantage in being easily compared with the adjacent room in which the existing equipment is used. Further, there is no problem in opening to the public or for advertisement because it is a public building and the facility is suitable for PR, such as observation.

It was expected that the underground water level existed at a depth of about 3 m. The static formation temperature is 7-8ºC at a depth of approximate 90 m, measured in an existing borehole.

This potential test facility consisted of the administration building in the sanatorium and the lodging building. The administration building was under construction and thus, the piping work and the observation of the heating conditions was made easy. Further, a half of the administration building was not scheduled for use. From these points of view, the administration building was adopted as the test house. The plan also considered setting the GHP system in a separate house and putting it on the side of the administration building.

Trial Design of Heat Pump Test

Since the sanatorium of Kamchatka Energo Company in Aginuk region was selected as the test facility, the project was designed to take the site conditions into consideration. Half of the rooms of the administration building were assigned to be observation rooms in which the test was carried out; that is, five rooms were to be heated by GHP. The observation rooms were selected by locating the heating pipes coming into the administration building so that the supplied hot water only entered approximately half of the heating pipes. To heat the half of the administration building of double windows with walls made of concrete, 5.7 kW or more of GHP capacity was enough. Therefore, the capacity of GHP was set to 6.7 kW using a ready-made article, providing a margin of safety. In Switzerland, the peak heat output to be recovered from the heat exchanging well in the

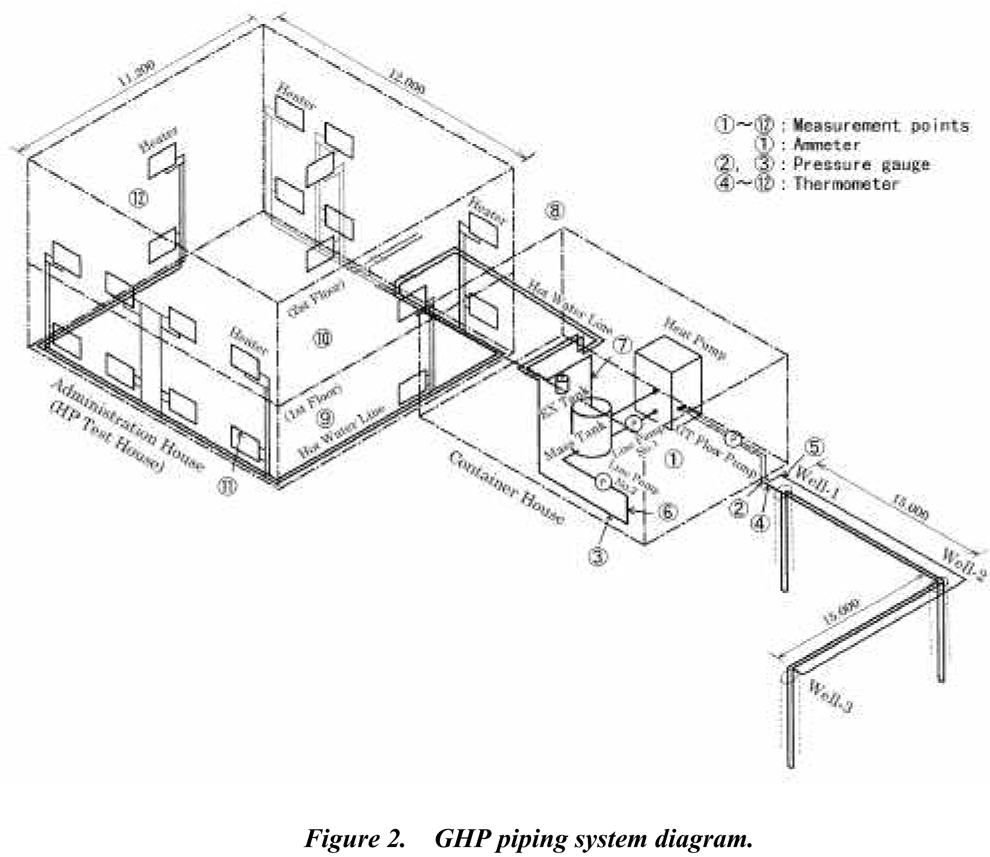

Figure 2. GHP piping system diagram.

GHP system is 45 W/m (Rybach and Eugster, 1997), so the peak output of 4.5 kW can be obtained in the case of the well of 100 m depth. The formation temperature is low in the severe cold district such as Kamchatka; thus, the COP would be poorer than in a warmer district and the heat output from the well was thought to be less. Since the capacity of the GHP used in this test was 6.7 kW, 2.2 wells of depth 100 m were required. It was estimated that 3 kW could be obtained from a well of depth 100 m. Therefore, three wells of depth 100 m were drilled in this test. The system diagram is shown in Figure 2.

GEOTHERMAL HEAT PUMP TEST

Purpose of Investigation

When we visited the Kamchatka Energo Company's sanatorium in the Aginuk region, the existing heating was controlled by a supply temperature of 50°C (0.4 MPag) from the supplied hot water and 40°C (0.16 MPag) return temperature. This facility is also utilized as a sanatorium in winter by using this heating system. Therefore, the purpose of this test using this sanatorium was to prepare the hot water for heating of at least 50°C or more by GHP and to verify that the heating can be carried out sufficiently by GHP instead of the boiler heating in Kamchatka, a severe cold district.

Result of Investigation

Temperature Measurement of Heat Exchange Borehole

The temperature in the well measured on April 17, 1999 is shown in Table 1. These values were measured in Well-2 (standing time was one month or more) which was finished first with water level at a depth of 20 m. These values were measured separately by using a maximum temperature thermometer (max.100°C). The maximum temperature in Well-2 was 13°C at a depth of 100 m and it was a little higher than the estimated value (7 to 8°C at a depth of 90 m).

Table 1. Results of Well-2 Temperature Measurement (measured on April 17, 1999).

Depth	Temperature
20 m	10°C
50 m	10°C
100 m	13°C

Conditions of GHP Installation

The drilling was carried out using a truck mounted rig. The polyethylene U-shape tubes, with outside diameter of 33.4 mm, were inserted just after completion of drilling to be used as the heat exchanger (Oklahoma State University, 1997), and a casing was set for the reason of timing problems in the installation. The space between the casing and the U-shape tubes were back-filled with pure bentonite. After that, glass wool insulation was wound around the surface piping. The house for the heat pump system was installed in the space between the administration building and the wells. The heat pump and the observation unit were placed in this building.

Result of GHP Test

The piping system diagram of the GHP test is shown in Figure 2 and the results of the observations are shown in Table 2. The test was started at the end of April and the observation period of the test was 18 days. Half of the rooms in the administration building were scheduled to be heated by GHP according to the initial plan, but as shown in Figure 2, a system to heat the whole administration building was adopted because of a problem in welding the piping at the site. Therefore, the head of the circulating pump of the initial plan was not adequate and a sufficient quantity of hot water could not be circulated in the entire administration building. The positions of the respective measurement channels (ch.) in Table 2 are shown in Figure 2. Since May 2-4, during the measurement period, was a public holiday in Russia, data were not obtained. Further, channel 11 which measured the temperature of the face of the heating pipe, did not measure the temperature from May 5 to May 10 because of a faulty sensor. After May 11, since air entered into the heater, the hot water could not be circulated around the temperature sensor and thus, heating was insufficient. Therefore, channel 11 values are small.

As shown in Table 2, the outdoor temperature was about 5°C and the room temperature was kept at 18-20°C. This temperature was sufficient in the heating condition of the periphery of P-K city. Further, in this GHP test, as shown in Figure 2, the system with the buffer tank (called the mass tank) was provided to store the hot water created by the GHP. The stored hot water in the tank was then circulated. As shown in Table 2, the temperature of the hot water delivered from the mass tank was about 44°C to 46°C and the return temperature was about 41°C to 43°C, resulting in the supply of heat equivalent to about 3°C.

The temperature difference between the delivered hot water and the return hot water was maintained about 3°C. The room temperatures of channels 9, 10 and 12 were kept at 18-20°C; while, the output temperature of the hot water on channel 6 decreased daily. This means that the capacity of the GHP is not enough for all rooms of the administration building.

On the other hand, the reason that the hot water could not be circulated around channel 11 temperature sensor was that the circulated pump capacity was not enough due to heating twice of the number of test rooms as planned.

Because of the above-mentioned reasons, we could not circulate enough hot water. However, the test room could be heated adequately in the environment where the outdoor temperature was close to 0°C (sometimes, below-zero at night).

From these tests, it was verified that heating by GHP can be used instead of the existing equipment in the severe climate condition in Kamchatka. Moreover, it is possible to decrease the discharge of carbon dioxide with the local GHP heating system.

CONCLUSIONS

Summarizing the GHP test: the proposed test sites were selected first, the final test site was then decided between

Table 2. Result of GHP Test Observation.

Date \ Measurement item	No.1ch (Amp)	No.2ch (MPaG)	No.3ch (MPaG)	No.4ch (°C)	No.5ch (°C)	No.6ch (°C)	No.7ch (°C)	No.8ch (°C)	No.9ch (°C)	No.10ch (°C)	No.11ch (°C)	No.12ch (°C)
4/30/1999	8.0	0.06	0.06	0.6	3.0	41	37	7	22	21	35	19
5/1	7.6	0.06	0.06	0.5	2.7	43	40	6	18	20	31	18
2												
3												
4												
5	7.5	0.06	0.06	0.3	2.2	46	43	3	19	17	--	19
6	7.5	0.06	0.06	0.3	2.3	46	43	4	20	17	--	19
7	7.6	0.06	0.06	0.3	2.4	46	43	5	20	18	--	20
8	7.6	0.06	0.06	0.3	2.5	47	43	6	20	18	--	20
9	7.6	0.06	0.06	0.4	2.6	47	44	7	20	18	--	20
10	7.7	0.06	0.06	0.5	2.7	47	44	9	21	18	--	21
11	7.7	0.06	0.06	0.5	2.6	47	44	10	21	18	22	21
12	7.7	0.06	0.06	0.6	2.5	47	44	9	21	18	22	21
13	7.7	0.06	0.06	0.6	2.4	46	43	8	21	19	23	21
14	7.8	0.06	0.06	0.6	2.3	44	41	7	21	18	23	20
15	7.8	0.06	0.06	0	2.1	44	41	7	21	19	23	18
16	7.7	0.06	0.06	0.4	2.2	44	41	7	22	19	22	18
17	7.8	0.06	0.06	0.3	2.2	44	41	6	21	18	22	18

Note) No.1 ch : Electric current used in GHP system (Amp. 300 V)
No.2 ch : Delivery pressure of circulating water for heat exchanger well (MPaG)
No.3 ch : Delivery pressure of hot water for heating
No.4 ch : Delivery temperature of circulating water for heat exchanger well (°C)
No.5 ch : Return temperature of circulating water for heat exchanger well (°C)
No.6 ch : Delivery temperature of created hot water mass tank for heating (°C)
No.7 ch : Return temperature of created hot water mass tank for heating (°C)
No.8 ch : Outdoor temperature (°C)
No.9 ch : First floor observation room temperature (°C)
No.10 ch : Second floor observation room 1 temperature (°C)
No.11 ch : First floor observation room heating panel temperature (°C)
No.12 ch : Second floor observation room 2 temperature (°C)
Data could not be obtained because May 2-4 was the public holiday of Russia.
(The continuous record chart is under obtaining.)

No. 11 channel could not obtain the data because of a faulty sensor, from May 5th to 10th. Further, the sensor operated after May 18th, but due to air entering the inside of the pipe, the channel could not be heated.

them, three wells for the ground-coupled heat exchanger were drilled at that site, and then the on-site actual test was carried out.

The test was started at the end of April and the observation period was 18 days. The test rooms could be heated adequately in the environment which the outdoor temperature was close to zero (sometimes, below-zero at night). Therefore, it was shown that the heating equipment by the GHP can be used instead of the existing equipment in the severe climate condition in Kamchatka. This will also decrease the discharge of carbon dioxide using the local GHP heating system in Kamchatka.

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