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

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ABSTRACT

“Fundamental investigation and promotion of joint implementations for the fiscal year 1998 - The fundamental investigation related to local heating utilizing geothermal energy in Kamchatka, Russia” was carried out by for the New Energy and Industrial Technology Development Organization (NEDO). It was carried out as a project of F/S investigation, and in order to connect to the “joint implementation”.
It is verified that heating by geothermal heat pump (GHP) can be used instead of the current boiler heating in the severe climate condition of Kamchatka. In this report, the GHP test as a part of this F/S investigation result is summarized.

1. 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 global warming by greenhouse gases such as carbon dioxide, the Kyoto protocol providing targets for the reduction of greenhouse gas emissions by developed countries. Further, in the Kyoto protocol, measures making methods of achieving the targets flexible, such as “joint implementation”, among developed countries were decided.

It is with this background that “The fundamental investigation related to local heating utilizing geothermal energy in Kamchatka, Russia” was carried out. The objective region of the project is Petropavlovsk-Kamchatky, the capital of Kamchatka (hereinafter called "P-K city") and its environs (Fig. 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 lives in the city and it is the center of administration and industry for 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, one from exhaust thermal energy of the power plant and the other from heavy oil fired boilers. Sixty five percent of local heating in P-K city is supplied by hot water prepared by heavy oil combustion. This oil is supplied by pipeline.

The purpose of the work described here was to verify that these oil fired boilers may be replaced by geothermal heat pumps (GHP).

2. GEOTHERMAL HEAT PUMP TEST PROGRAM

2.1 Selection of Test Site

The GHP test was begun by selection of the test site. The vertical ground heat exchanger type of heat pump system was adopted because this is comparatively unrestricted by the site area and the conditions although it must be possible to drill a bore hole. As the result of a proposal by Russia and the results of preliminary discussions, four locations were selected as possible test sites. The final selection of a test site was based the following into considerations:

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,
6) issue of ownership and possibility of approval of test.

The result of the comparison and observation of four the proposed sites was that the sanatorium of Kamchatka Energo Company (electric power company) in Aginuk region was selected. This sanatorium is located in Paratunsky hot spring area about 60 km from P-K city.

This sanatorium is the property of Kamchatka Energo Company, used as a childrens training camp in summer and used a the lodging facility for Kamchatka Energo Company personel and their families of in winter. The facility consists of 2 hotel type residential buildings, an administration building, a pool and auxiliary buildings. The site area is most suitable for the GHP test site and a well can be drilled anywhere. Electricity is supplied by independent power generation twenty-four hours a day. The heating of all buildings is by a centralized heavy oil boiler. The temperature control conforms to a special schedule and is set manually depending on the outdoor temperature. There are no problems in using the site, in drilling or gaining required approvals. The room for the test can be selected and has the advantage of being easily compared with the adjacent room in which the existing equipment is used. Further, there is no problem in allowing public access or publicity. As it is a public building the facility is suitable for PR such as observation.

It is expected that underground water level exist at a depth of about 3m. The static formation temperature is 7-8^{o}C at a depth of approximate 90 m measured at existing bore hole.

This facility has the administration building in the sanatorium and the lodging building, the administration building is now under construction and the piping work is very easy and the observation of the heating conditions is also easy. Further, half of the administration building is not currently in use. For these reasons the administration was used for the demonstration. The GHP system was installed in a container on the side of the administration building.

2.2 Trial Design of Heat Pump Test

The test facility was designed taking the site conditions at the sanatorium of Kamchatka Energo Company into consideration. Half of the rooms of the administration building are assigned to be observation rooms in which the test is carried out; that is, five rooms are heated by GHP. The observation rooms can be selected by designing the piping for heating the administration building so that the existing hot water may not enter approximately half of the rooms. To heat half of the administration building, the 5.7 kW or more of the capacity of GHP is enough. The building is made of concrete and has double glazing. Therefore a GHP with a maximum output 6.7 kW was used to give some excess capacity. In Switzerland, the peak heat output to be recovered from the heat exchanging well in the 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 depth 100 m. The formation temperature is low in the severe cold district such as Kamchatka, then the COP must be poorer than in a warmer district and the heat output from the well is thought to be less than that described by Rybach and Eugster (1977). Since the capacity of the GHP used in this test is 6.7 kW, 2.2 wells of depth 100 m are required assuming 3 kW can be obtained from a well of depth 100 m. Therefore, 3 wells of depth 100 m were drilled in this test. The system diagram is shown in Fig. 2.

3. GEOTHERMAL HEAT PUMP TEST

3.1 Purpose of Investigation

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

3.2 Result of Investigation

Temperature measurement of heat exchange bore hole

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

Conditions of GHP installation

The drilling was carried out using a truck mounted rig. The Polyethylene U-shape tubes with an outside diameter of 33.4 mm for use as heat exchangeres were inserted just after the finishing of drilling to (Oklahoma state university (1997)), but the casing was set for the reason of the problem of timing in the installation. The space between the casing and the U-shape tubes were back-filled with pure bentonite. After that, the heat insulating glass wool was wound on the surface piping. The container housing the heat pump system was installed in the space between the administration building and the wells, and the heat pump, the observation unit and so on were set in this container.

Result of GHP test

The piping system diagram of the GHP test is shown in Fig. 2 and the results of observation 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 Fig. 2, a system to heat the whole administration building was adopted because of a problem in the welding work of the piping at the site. Unfortunately the head of the circulating pump from the initial plan was too small and insufficient hot water could be circulated to heat the whole administration building. The measurement positions of the respective measurement channels in Table 2 are shown in Fig. 2. Since May 2-4 during the measurement period was a public holiday in Russia, data were not obtained on these days. Further, channel 11 which measured the temperature of the face of heating pipe did not measure the temperature from May 5 to May 10 because of a faulty sensor. After May 11, since the air entered into the heater, hot water could not be circulated around the temperature sensor and heating was not carried out enough. Therefore, channel 11 values were small.

As shown in Table 2, the outdoor temperature is about 5^{o}C and the room temperature is kept at 18-20^{o}C. This temperature is sufficient in the heating condition of the periphery of P-K city. Further, in this GHP test, as shown in Fig.2, the system in which a buffer tank (called the mass tank) is provided and the hot water created by the GHP is stored once in the tank is adopted. The stored hot water in the tank is circulated. As shown in Table 2, the temperature of the hot water delivered from the mass tank is about 44^{o}C to 46^{o}C and the return temperature is about 41^{o}C to 43^{o}C, resulting in the discharge of heat equivalent to about 3^{o}C.

The temperature difference between the delivery hot water and the return hot water is maintained about 3 ^{o}C. The room temperatures of channel 9, 10, 12 are kept at 18-20^{o}C, while the output temperature of the hot water on channel 6 is decreased day by day. This is means that the capacity of the GHP is insufficient 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 twice of the number of test rooms as planed when we designed.

Because of above-mentioned reasons, we could not circulate the hot water sufficiently. However, the test room could be heated enough in the environment which the outdoor temperature was closed to below-zero (sometimes, below-zero in the night).

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

4. CONCLUSIONS

With regard to the hot water supply test, the proposed test sites were selected first, the test site was decided among them, three wells for ground coupled heat exchanger were drilled at that site and then the on-site actual proof test was carried out.

The test was started from the end of April and the observation period was 18 days. The test room could be heated enough in the environment which the outdoor temperature was close to zero (sometimes, below-zero at night). Therefore, it is verified that the heating equipment by the GHP can be used instead of the existing equipment in the severe climate condition in Kamchatka. It indicates the possibility of decreasing discharge of carbon dioxide using the GHP local heating system in Kamchatka.

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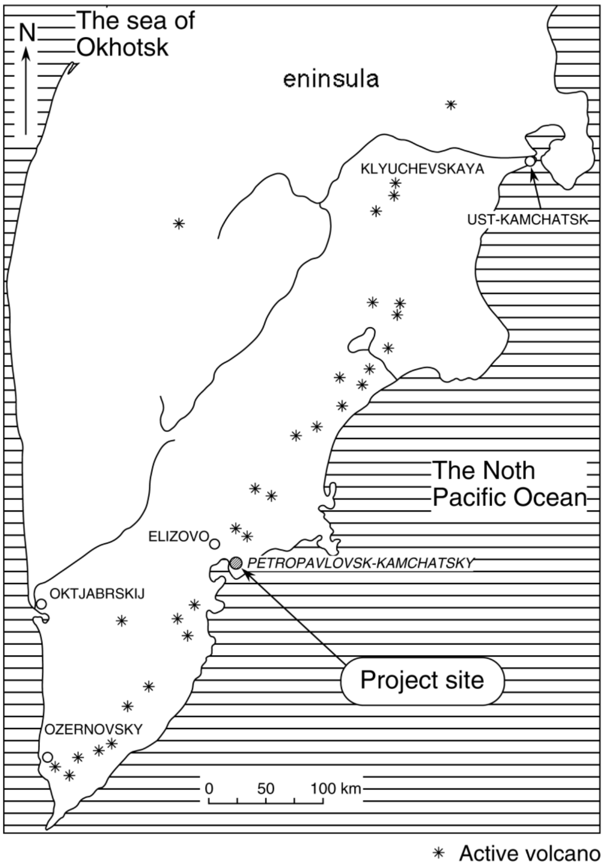

Figure 1. Southern part of Kamchatka peninsula

Table 1. Results of Well – 2 temperature measurement

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

(Measured on April 17, 1999)

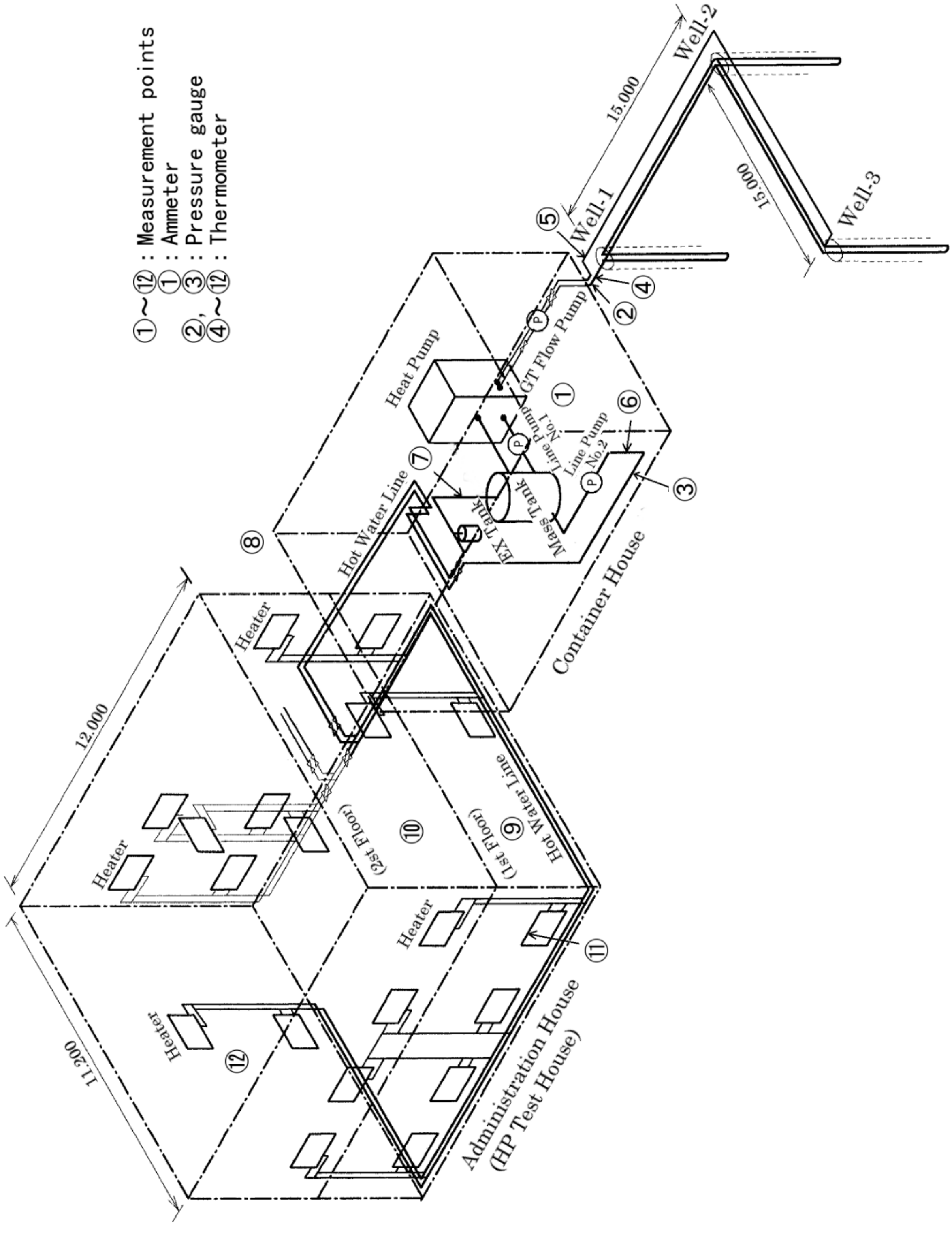

Figure 2. GHP piping system diagram

Table 2 Result of GHP test observation

Measurement item / Date	No.1ch (Amp)	No.2ch (MPaG)	No.3ch (MPaG)	No.4ch (^{o}C)	No.5ch (^{o}C)	No.6ch (^{o}C)	No.7ch (^{o}C)	No.8ch (^{o}C)	No.9ch (^{o}C)	No.10ch (^{o}C)	No.11ch (^{o}C)	No.12ch (^{o}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. 300V)
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 (^{o}C)
No.5 ch : Return temperature of circulating water for heat exchanger well (^{o}C)
No.6 ch : Delivery temperature of created hot water mass tank for heating (^{o}C)
No.7 ch : Return temperature of created hot water mass tank for heating (^{o}C)
No.8 ch : Outdoor temperature (^{o}C)
No.9 ch : First floor observation room temperature (^{o}C)
No.10 ch : Second floor observation room 1 temperature (^{o}C)
No.11 ch : First floor observation room heating panel temperature (^{o}C)
No.12 ch : Second floor observation room 2 temperature (^{o}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 the wrong operation of the sensor from May 5th to 10th. Further, the sensor could operate after May 18th, but the air entered the inside of the pipe and the panel observation part could not be heated.