Application of Geothermal Heat Pump (GeoHP) System at ultra cold area : Changchun city, China

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Abstract

In this paper, the results of monitoring on application of Geothermal Heat Pump (GeoHP) System at ultra cold area: Changchun city, China are introduced. During the monitoring, temperature transition in the borehole heat exchangers had been measured at several depths in order to compare with simulated data (estimated temperature vs. time and so on) due to heating of the test building. Monitoring and analysis of the data while heating by GeoHP system suggested that the temperature transition was measured, although there are some difficulties to compare with the simulated data because of the existence of ground water flow. In addition, temperature recovery were also measured just after the stop of heating.

These data must be quite important to characterize the thermal conductivity considering the ground water flow in the formation in future.

Introduction

Geothermal Heat Pump (GeoHP) system becomes more popular because of economic superiority and less environmental load in north America and Europe particularly past ten years. However, there are almost no data and experience on GeoHP application in the ultra cold area such as Changchun city, China and Hokkaido, Japan.

This project is one of the NEDO (New Energy and Industrial Technology Development Organization) International R&D projects in FY2000, and was entrusted to Geo-E (JMC Geothermal Engineering Co. Ltd.) in collaboration with Institute of Geophysics ETH Zurich, Switzerland, Changchun Groundheat Development Co., Ltd. Changchun city, China, Changchun Uni. of Science & Technology, Changchun city, China and Tohoku Uni., Sendai city, Japan. The object of this project is to confirm the applicability of GeoHP system in ultra cold area such as Changchun city, China using the monitoring data of temperature transition in the borehole heat exchangers while heating the test building.

The background of the project

In Changchun city, hot water, which is warmed by coal boiler, for heating shall supply for 5.5 months in winter. The temperature in winter in Changchun city commonly exceed minus

Photo.-1 Winter scenes in Changchun city, China

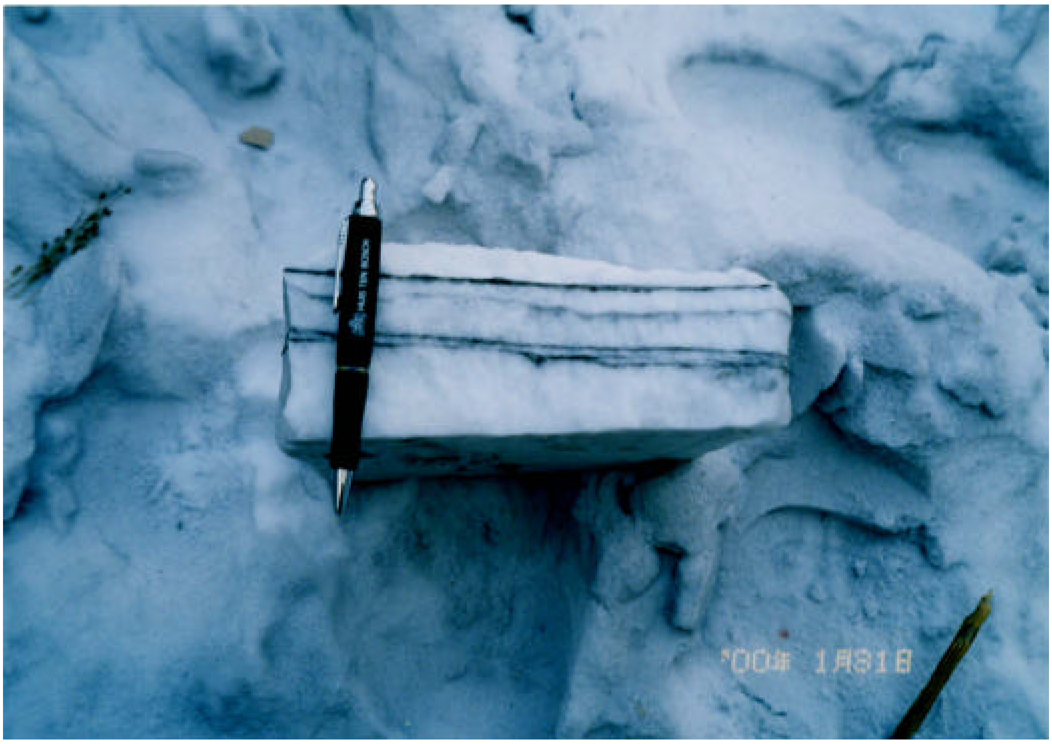

Photo.-2 Soot and Smoke Layers observed in snow in Changchun city, China

Photo.-3 Test Building

20 deg. C, then the air-source heat pump may be of no practical use. The consumption of coal in Changchun city is approx. 250 million tons per year or over, and the amount of CO_2 gas and SO_2 gas exhaust, and soot is respectively 2000 million m^3 per year, 30 kilo tons, 5,000 tons. At the suburb of Changchun city, almost all 26,667 ha greenhouses are heated by coal and firewood etc.. Air-pollution (main ingredients are CO_2 gas, SO_2 gas and soot) in Changchun city are caused by of house heating, greenhouse heating and industry, maybe 65% of air-pollution in winter. The situation of air-pollution in winter due to coal boiler for heating is quite common social problem and environmental problem not in Changchun city but also in other cities in China ref. Photo-1,2- and –3).

It must be also useful for Hokkaido and Tohoku region in order to apply GeoHP widely in near future, to confirm the applicability of GeoHP in ultra cold area and to develop the newly-devised ideas to apply GeoHP in ultra cold area.

The condition of the Test building

The test building we have installed GeoHP system is located near the center of Changchun city and in the corner of residential street. This building belongs to Changchun Groundheat Development Co., Ltd, and is used for the test introduced in this paper. This building has five floors including 23 rooms and entrance hall, and total area is 909.7m^2 in total. 809.9m^2 for heating. All of windows are double-paned windows, then the airtight of test building is so well. Originally, this building has been supplied 90 deg. C hot water for heating using 40 base-board heaters in total in this building (ref. Fig.-1).

Under the project, GeoHP system has been installed, then hot water of approx. 45 deg. C is circulated for heating instead of 90 deg. C hot water. 16 wells which are 100m depth, are drilled near the building as heat exchanger for GeoHP system. Heat pump capacity is 50 HP manufactured by Zeneral Heat Pump Corp. located in Nagoya, Japan (ref. Fig.-2).

Results of monitoring

In order to estimate the applicability of GeoHP system in ultra cold area such as Changchun city, the outside temperature, room temperature and operating parameters of Heat Pump and so on, have been monitored with the sampling rate of every one hour. All data acquired has been stored in the monitoring room onto the PC. Those data also transferred to Japan to analyze the data through telephone line, whenever we want.

Monitoring data has been acquired periodically through telephone line from Dec. 30, 2000 till March 31, 2001. Fig 3 is showing the example of flow rate of circulating water and its outlet temperature and inlet temperature.

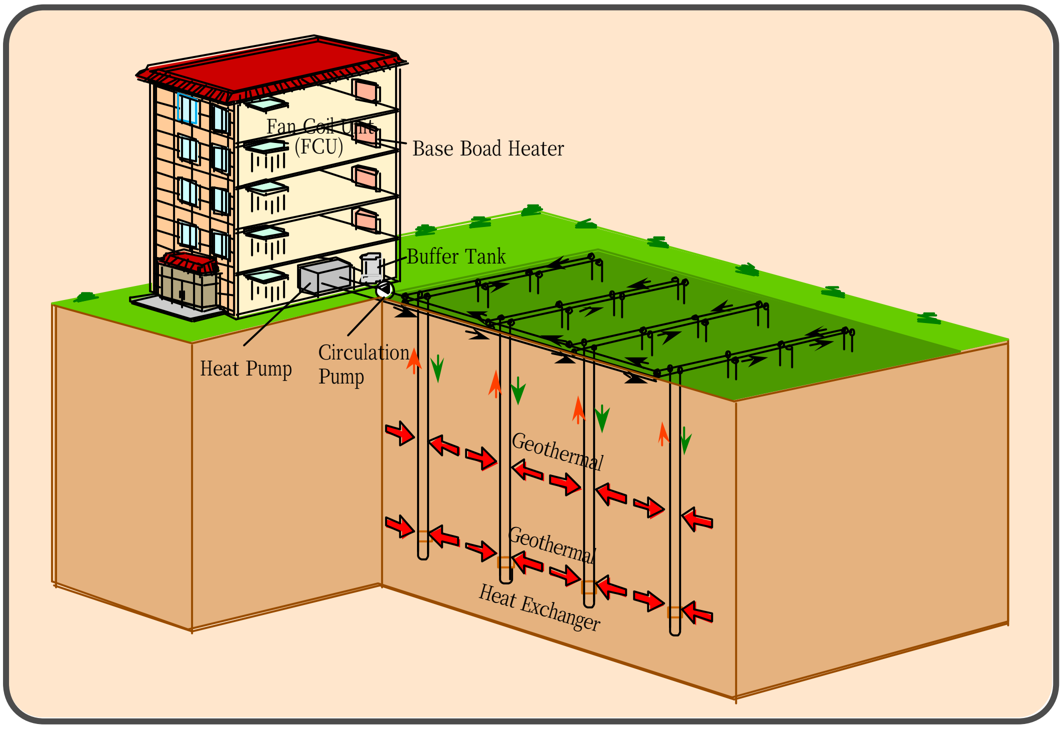

Fig.-1 Outline of the project

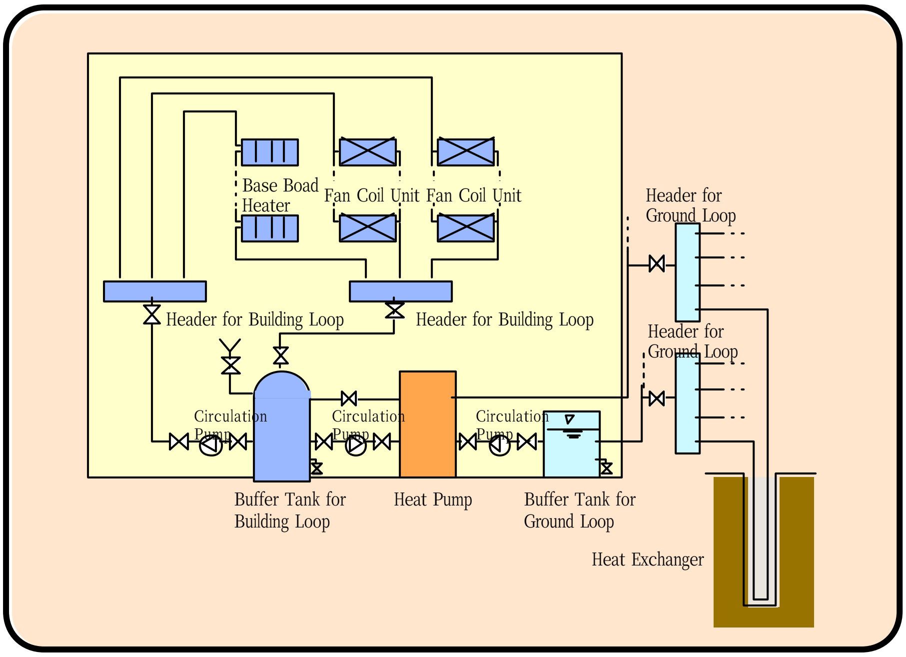

Fig.-2 Outline of the system

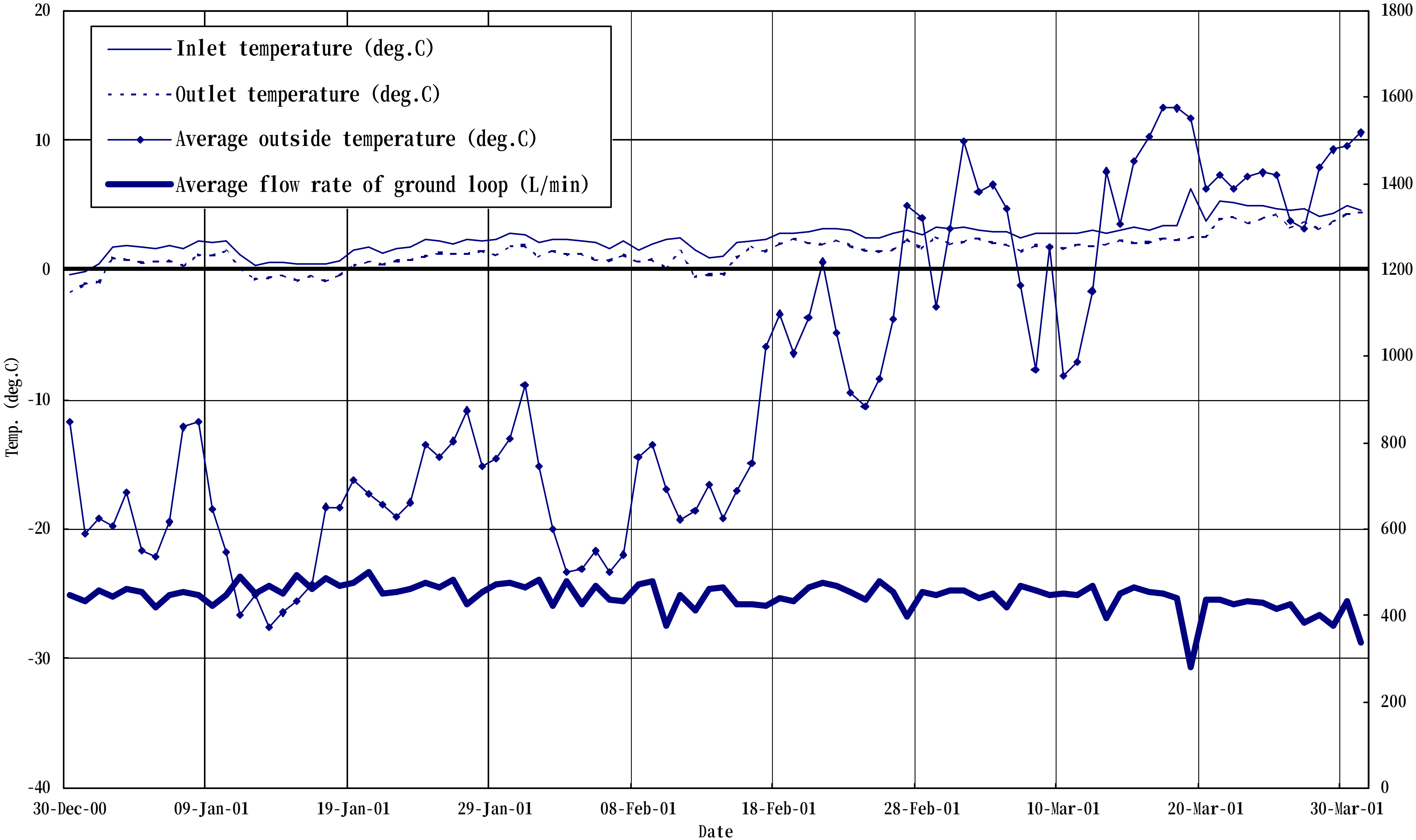

Fig.-3 Example of monitoring

Both outlet and inlet temperature rose moderately according to the outside temperature variation. This phenomenon is interpreted that the heating load became small, because outside temperature rose. Difference between outlet and inlet temperature was usually approx. 1 deg. C. Monitoring the system has been tested the coldest duration, when minus 30 deg, C of minimum temp. was recorded more than 10 days. Even like this severe condition for the GeoHP system, the system run without any problem and could keep the room temperature as expected: 15 – 20 deg. C.

Discussion

COP (Coefficiency Of Performance) of the system while the test and reduction of CO_2 gas emission and SO_4 are analyzed to estimate the applicability of GeoHP system in ultra cold area as shown below. In addition, life length of the system is simulated using circulation water temperature variation while the test.

COP and reduction of CO_2 gas emission and SO_4

The average COP while the test is almost 3.1. This COP is adequate value with careful consideration of Changchun city where it was colder than usual winter, although the value is not enough for the COP target (3.5) in Japan. Therefore, GeoHP system could be useful in ultra cold area such as Changchun city, in case the system will be designed correctly applying the subsurface information carefully.

Reduction of CO2 gas and SO2 gas exhaust might be respectively approx. 30 tons/165 days and 1.5 tons/165 days, to our surprise. This means the GeoHP system has big advantages particularly in environmental aspects.

Simulation of inlet and outlet circulation temperature variation

Subsurface temperature transition is estimated due to heating by computer simulation. Subsurface temperature and circulation temperature has closely related each other. Then, circulation temperature is related to the COP of the GeoHP system. Therefore, this simulation may suggest the system life length, too. In this project, EED (Earth Energy Designer) developed by Prof. P. Eskilson of Lund University, Sweden and Prof. B. Sanner of Justus-Liebig Univ. has been applied.

When minimum inlet temperature to heap pump is set up zero (0) deg. C in the EED simulation, the life length of the system is estimated 15 – 20 years. If the number of heat exchange well will increase, the COP may become higher and the life length of GeoHP system take longer (ref. Fig.-4 and –5).

Conclusion

This project stared in July, 2000 and completed in March, 2001. The system design and installation of GeoHP have been done by Japanese side, and the piping and electronics/measurement have been done by Chinese side as the collaboration of R&D supported by NEDO. It takes more time as planed, then the measurement started at the end of December, 2000 and continued by the end of March, 2001. The average COP is amazingly good: 3.1 even in the winter of Changchun city, when more than 10 days were below minus 30 deg. C. Also computer simulation by EED suggested the life length of the system is long enough.

As the results of this project, the applicability of GeoHP system has been confirmed in Changchun city and in ultra cold area. This results, additionally, give us that GeoHP system will gain in popularity in northern Japan such as Hokkaido and Tohoku region, too. However, it is quite important that the system must be designed correctly applying the subsurface information carefully, particularly ultra cold area.

Acknowledgement

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References

GeoExchange (1998): Materials and publications catalog and reference guide, Geothermal Heat Pump Consortium (GHPC)

Heat Pump & Thermal Storage Technology Center (HPTC) (1998): HPTC-185, pp.114

Kavanaugh, S. (1991): Ground and water source heat pumps – A manual for the design and installation of ground-coupled, ground water and lake water heating and cooling systems in southern climates, the University of Alabama in cooperation with the Alabama Power Company, pp154

Hellström, G., Sanner, B., Klugescheid, M., Gonka, T. and Mårtensson, S. (1997): Experriences with the borehole heat exchanger software EED. Proc. MEGASTOCK 97, Sapporo, pp. 247-252.

Ikeuchi, K., Takasugi, S. and Miyazaki, S.: Hot Water Supply Test Using Geothermal Heat Pump Systems at Petropavlovsk-Kamchatka, Russia, GEO-HEAT CENTER Quarterly Bulletin, Vol. 22, No. 1, pp. 9-12.

NEDO (1999): Feasibility study on utilization of Geothermal Heat Pump (GHP) system for space heating/cooling, warm-water supply and road heating in Japan (in Japanese). pp.133

Oklahoma state university (1997): Geothermal Heat Pumps Introductory Guidance, International Ground Source Heat Pump Association (IGSHPA), pp99

Takasugi, S., Akazawa, T., Okumura, T. and Hanano, M. (2001): Feasibility Study on the Utilizaton of Geothermal Heat Pump (GHP) Systems in Japan, GEO-HEAT CENTER Quarterly Bulletin, Vol. 22, No. 1, pp. 3-8.

Rybach, L., and Eugster, W., J., Hopkirk, R., J. and Kaelin, B. (1992): Borehole Heat Exchangers: Longterm Operational Characteristics of a Decentral Geothermal Heating System, Geothermics, 21, 5/6, 861-867

Rybach, L., and Eugster, W., J., (1997): Borehole Heat Exchangers to Tap Shallow Geothermal Resource: The Swiss Success Story, Proc. 19th NZ Geothermal Workshop 1997,63-68

USA Environmental Protection Agency (EPA) (1993): Space Conditioning: The Next Frontier-The Potential of Advanced Residential Space Heating Technologies for Reduction Pollution and Saving Customers Money, pp103

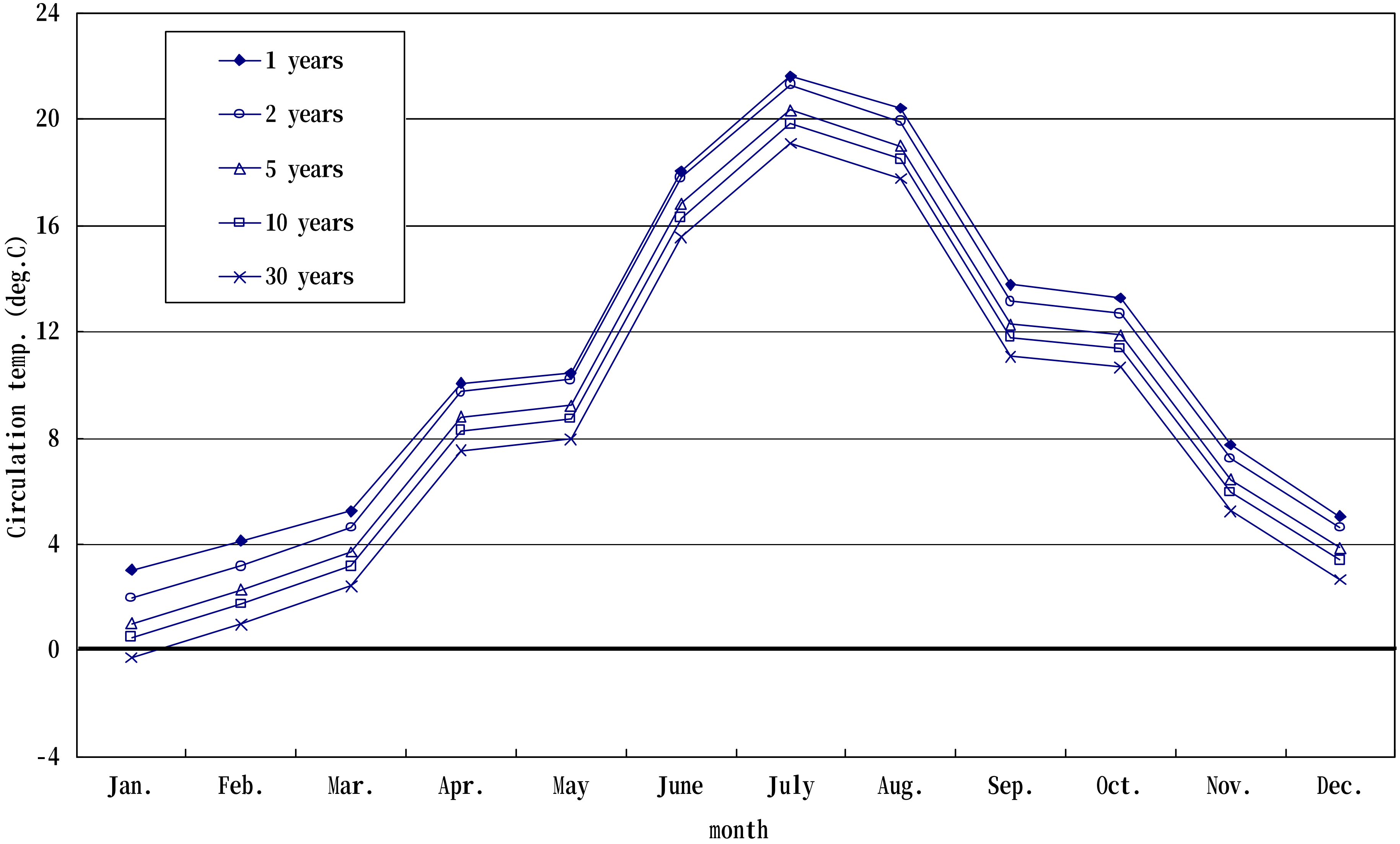

Fig.-4 Simulation example of circulation temp. transition for max. 30 years

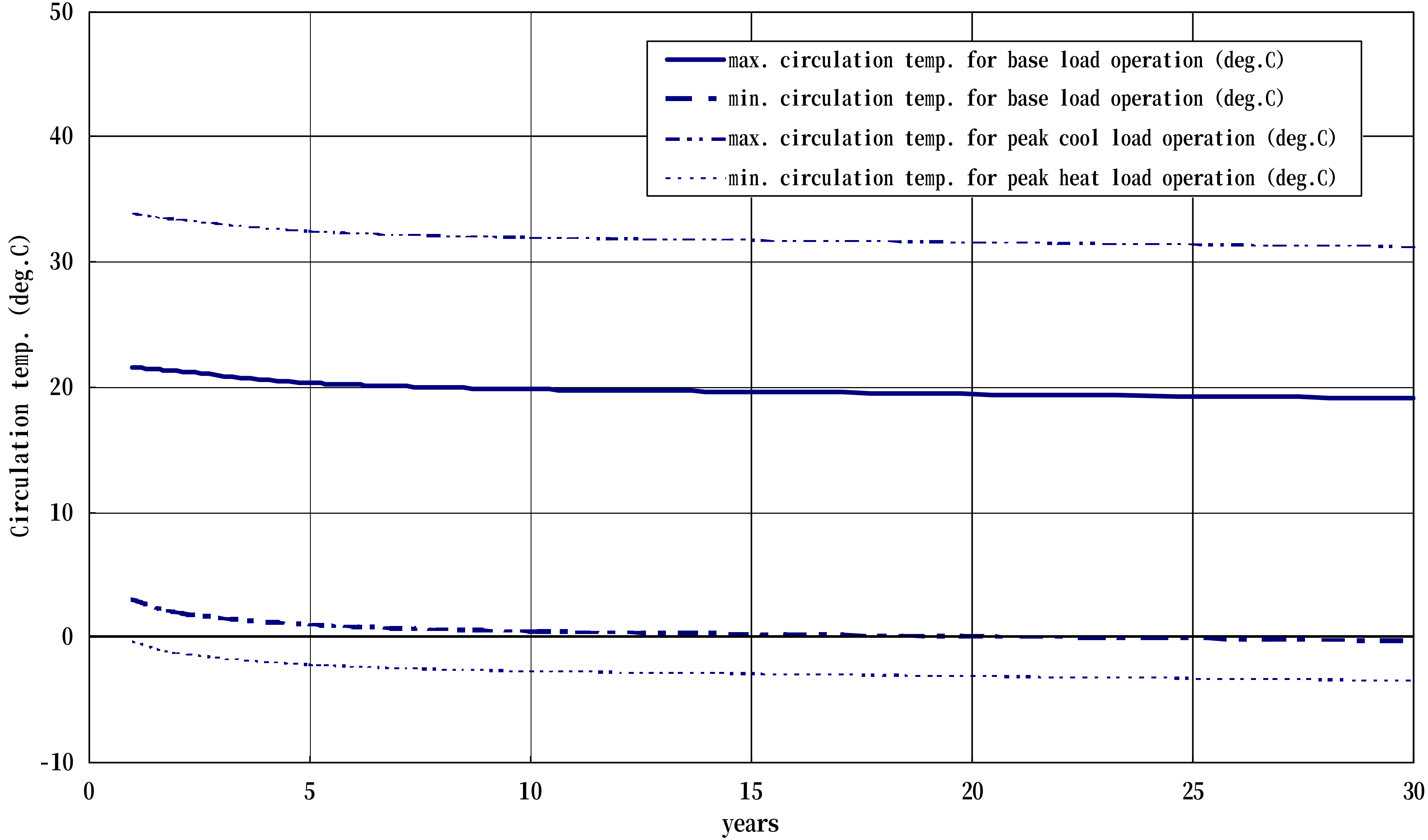

Fig.-5 Simulation example of max. and min. circulation temp.

Figure captions

Photo-1 Winter scene in Changchun city, China
Photo-2 Soot and smoke layers observed in snow in Changchun city, China
Photo-3 Test building

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