

Natural Conditions Assessment of Using Seawater Resource Heat Pump in Dalian

Zhen Li¹, Duanmu Lin¹, Haiwen Shu¹, Shuang Jiang¹, Yingxin Zhu²

¹School of Civil and Hydraulic Engineering, Dalian University of Technology

²Department of Building Science, Tsinghua University

Abstract: Speeding up the development of utilizing renewable energy is a significant move for realizing sustainable development in China. Using seawater as an energy resource for heat pumps to provide district cooling and heating offers several advantages. This study is an evaluation of the potential natural conditions for using seawater heat pump to provide heating and cooling for areas in Dalian. The amount of thermal energy produced is dependent upon the water temperature. Therefore, it is important to find out the temperature distribution both in space and time. Through the analysis of the distribution features of the Yellow Sea and Bo Sea temperature in winter and summer, it is shown that distributions in many places are favourable to using a heat pump to produce thermal energy. The investigation is focused on the following: long and short term temperature distributions along the Dalian's coast; salinity and temperature vertical stratification; and optimization of the intake depths.

Keywords: renewable energy, ocean thermal energy, temperature distribution, heat pump

1. INTRODUCTION

Speeding up the development of utilizing renewable energy is a significant move for realizing sustainable development in China. Using seawater as an energy resource for heat pumps to provide district cooling and heating offers several advantages: the energy supply is inexhaustible, renewable, and without adverse environmental impacts. Seawater resource heat pump (SWHP) is one of the technologies that can utilize ocean thermal energy, an unexploited renewable energy until now. But its application scope and operation costs depend on the seawater temperature and depth, etc. Therefore the investigation of seawater nature conditions is the first step of the feasibility analysis.

Dalian covers an area of 12,574 square kilometres with total population of 5.43 million. It is an important port, industrial, trade and tourist city in China. Located on the southern tip of Liaodong Peninsula with Yellow Sea to the east and Bo Sea to the west and between east longitude 120° 58'—123° 31', north latitude 38° 43'—40° 10', its climate belongs to marine climate. Economic centre areas in Dalian are close to the sea. This study is an evaluation of the potential of natural conditions for using SWHP to provide air conditioning for areas in the city.

The temperature in the sea outside a certain location depends on different aspects, such as the kind of ocean current that is passing by. So to be able to judge whether heat pump would be a possible technique or not, information about temperatures in the nearby sea as well as bathymetry data had to be obtained.

2. LONG AND SHORT TIME TEMPERATURE DISTRIBUTION ALONG THE DALIAN COAST

Based on the sectional observation data of North China Sea from 1976 to 1999, the distribution features of the Yellow Sea and Bo Sea temperature in winter and summer have been analyzed. Figures 1-6 show the temperature distribution of different depths in February and August, the coldest and hottest month of sea water^[1]. (The rectangle area is Dalian)

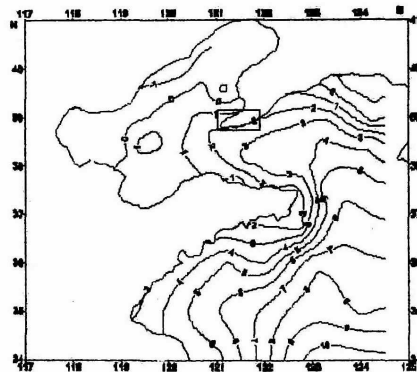


Fig1: Perennial mean curve of surface seawater temperature in February

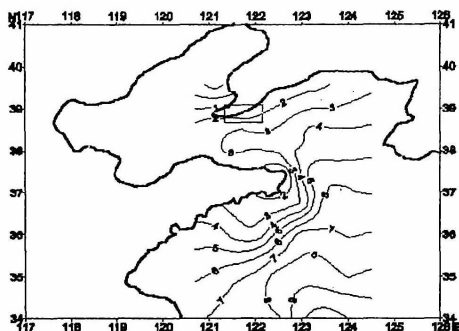


Fig2: Perennial mean curve of surface seawater temperature at 25m in February

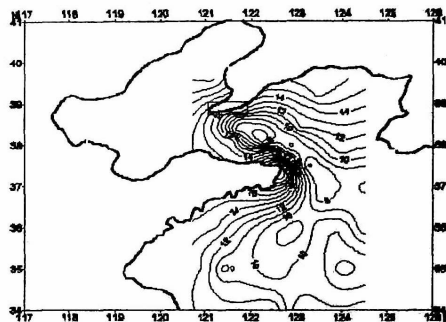


Fig5: Perennial mean curve of surface seawater temperature at 25m in August

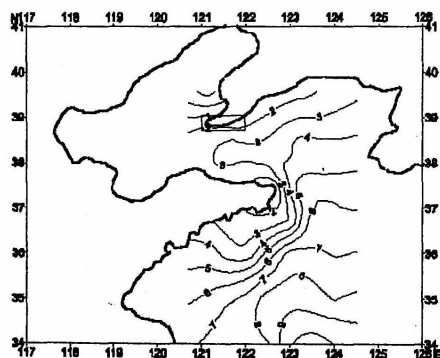


Fig3: Perennial mean curve of surface seawater temperature at 35m in February

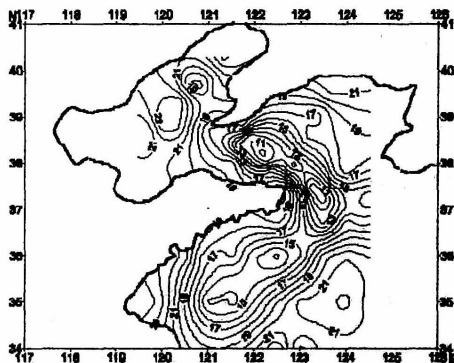


Fig6: Perennial mean curve of surface seawater temperature at 35m in August

According to the observation of bathing beach, figure7 shows the surface temperature of four bathing beaches in Dalian.

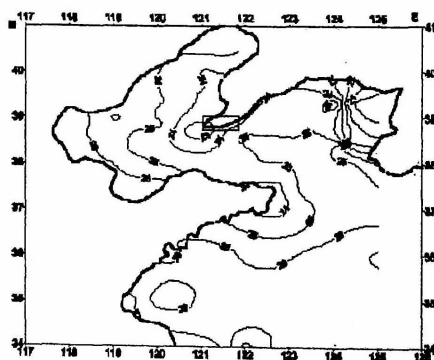


Fig4: Perennial mean curve of surface seawater temperature in August

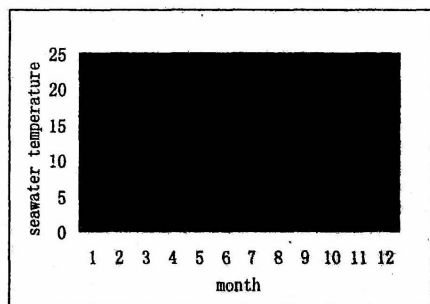


Fig7: Mean Surface seawater temperature distribution of bathing beaches in one year

From the above figures, it can be seen that:

1. In winter, different layers mix strongly and temperature gradient is low in vertical direction. In most places the least temperature is higher than 2°C, which is the utmost temperature heat pump can operate on.
2. In summer, surface seawater temperature varies between 25°C–28°C, which is suitable to be used as cooling water. While in deep layers, isotherm are densely distributed because cold water mass develop strongly and seawater temperature at 35m varies between 12°C–16°C, which can be considered to be used as free cooling in part load or transition seasons.

3. SEAWATER DEPTH

Seawater depth is another important parameter of SWHP besides seawater temperature. According to an investigation, the capital cost and energy use of a SWHP system was sensitive to the pipeline length, which was dependent on the intake depth and the distance to shore at the site^[2].

The intake tower must be designed to withstand high forces appearing from water movement caused by storms and tidal water. In general, intake depth design should consider the following factors: First, the intake tower must be designed to withstand high forces appearing from water movement caused by storms and tidal water. Next, the intake should be positioned so that the distance from the intake area to the bottom is 2.5 m to avoid bottom materials being sucked in. Then, to that some margin for high waves is needed. Air can not be permitted in the tubes, so it is important that the tower at all times is under the water surface. Largest wave height is 10 m, and assuming half of that is below normal sea water level gives us 5 m as needed depth for waves. In addition, some extra space is needed so that small boats don't hit the tower with the keel. This all together gives us a necessary depth from the low tide level to sea bottom.

The pipe will normally be installed in trenches in the soft soil under water; the trench depth depends on pipe diameter.

But in Dalian, besides the above mentioned factors, another factor should be considered: the possibility of using deep cold ocean water as a direct means of cooling building. Dalian has some shorelines that have good access to deep, cold seawater. Due to the geographic conditions and low water temperatures in summer, Water at a 14 – 16°C or less can be withdrawn from a depth of 25-35m and be pumped through the primary side of a heat exchanger. On the secondary side, clean chilled water will be produced. Distance to the required water depth is approximate 3000 m, comparatively closing to shore. Figure8 shows the seawater depth distribution along the Dalian coast^[3]. (The rectangle area is the layout of Dalian Software community and xiao ping Dao project, a total floor area of 3,000,000m²)

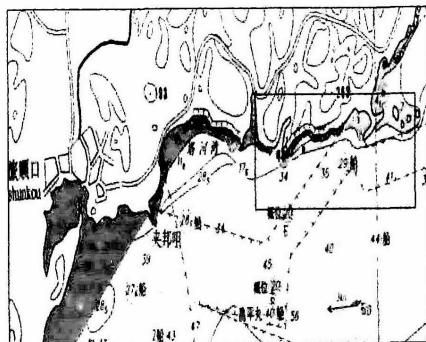


Fig8: seawater depth distribution of Dalian Software Park community.

4. SEAWATER SALINITY

The choice of heat exchangers is not only dependent on cost and thermal performance but also on how suitable they are together with the water type of the source. Seawater has strong corrosion because of high salinity. Due to the risk of high corrosion rates, mild steel should not be used as material for the heat exchangers, heat pumps and seawater intake and outfall system exposed to the sea water. Materials to choose for this application should depend on seawater salinity. Figure9, 10 shows the salinity along the Dalian coast in winter and summer^[4].

From the above figure, it can be seen that salinity distribution in winter and summer is quite similar, approximate to 31‰. So the material for heat exchanger or heat pump should be stainless steel or titanium and for seawater pipeline should be high-density polyethylene.

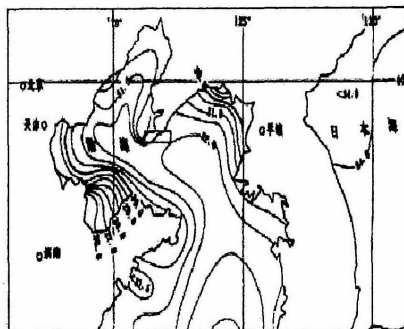


Fig9: salinity distribution of surface seawater temperature in February

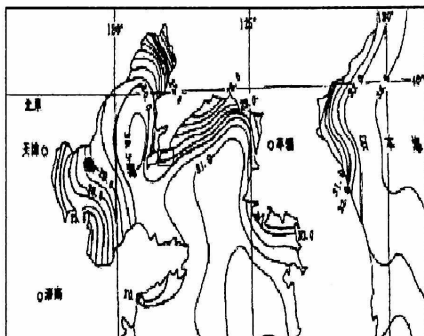


Fig10: salinity distribution of surface seawater temperature in August

5. ENVIRONMENTAL MANAGEMENT

In Dalian, spent cooling seawater discharges are at a temperature 8-10 °C higher than the influent. Although a strong degree of mixing is usually available at the outfall and the heated surface plume are expected to be dispersed relatively quickly, the thermal impact on the receiving environment of a continuous heat effluent discharge at a small temperature rise can be significant^[5].

According to our Sea water quality standard, the discharge temperature elevation of once-through seawater cooling systems limits 4 degree higher than the ambient water. So to minimize the effects of thermal stress, longer outfalls or diffusions could be adopted to allow greater dispersion of the heated effluents.

According to our inquiry, biology fouling and corrosion are common problems in the operation of seawater cooling systems. Screen and corrosion material has been used in seawater cooling system, In China, to combat the biofouling, chemicals such as chlorine are used, but the residual chemical are discharged together with the spent cooling seawater directly to the marine environment. Chlorinated effluents are known to be toxic to marine organisms even at very low concentrations. Dalian Software

Park and Xiao ping Dao vicinity is breeding zone. Therefore based on the residual chlorine toxicity, a total residual chlorine effluent discharge should be limited. At present, Sea water quality standard has not specified the provision.

6. CONCIUSISON

The natural conditions associated with SWHP are primarily related to the initial capital expenditure and operation costs. This, in turn, is related to the temperature distribution, to the distance and depth to cold water, to the salinity. It shows that, from Summaries of the results for the above analyses, natural conditions are suitable for using SWHP to provide district heating and cooling in Dalian, especially in summer free cooling can be used to cooling buildings. The technology is technically reliable in natural conditions, and the application perspective is wide in Dalian.

At the same time, for minimizing its adverse environmental impact, Sea water quality standard should be mended to establish the regulatory of the residual chemical discharge standards and sound management is necessary to allow efficient use seawater.

REFERENCES

- [1] Jia Ruili, Sui Lu. Distribution Features of the Yellow and Bohai Seas Temperature in Winter and Summer. MARINE SCIENCE BULLETIN. Aug, 2002vol.21, No.pp1-8.
- [2] Hazen E. Burford, Les Wiedemann, W.S. (Lanny) Joyce, Robert E. McCabe. Deep water Source cooling-an untapped Resource. In: 10th Annual district cooling conference. Florida.1995. 1-3.
- [3] The MAP OF WAI CHANGSHAN LIDAO TO FUZHOU WAN. THE NAVIGATION GUARANTEE DEPARTMENT OF THE CHINESE NAVY HEADQUARTERS. Sept. 2002.
- [4] Xu yudong, Liu xiqing, Zhang xunhua. Sea Current Field of China Offshore Areas. Geological publishing company.1997.pp29-30.
- [5] S.W.Y.Ma. Environmental management of coastal cooling water discharges in Hong Kong. Wat.Sci.Tech.1998 (38)267-274.