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Effects of utilizing seawater as a cooling source system in a commercial complex

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Abstract

This paper treats energy and cost performance of a cooling source system with indirect seawater utilization for air conditioning in a commercial complex. Seawater utilization has merits as a cooling source, because seawater temperature is lower than outdoor air in summer and it is cost effective because there is no water monetary cost. Actual operating data has been measured for about 2 years and the chiller and system co-efficient of performance (COP) have indicated about 4.77 and 2.93, respectively, even in summer season and the mean efficiency of the thermal storage system was about 89.9% taking into account heat loss of pumps. In addition, we have constructed simulation models for cooling tower systems, air cooling chiller systems and direct seawater utilization systems then compared them to this system. The electric power consumption of the indirect seawater utilization system was almost the same as the other systems except the air cooling chiller system, because using lower seawater temperature made the chiller efficiency higher. In conclusion, our results showed the indirect seawater utilization system was able to improve the system COP compared to air cooling chiller system, and cancel water consumption compared with the cooling tower system, and cut down an initial and maintenance costs compared with the direct seawater utilization system.

Keywords: Seawater utilization; Cooling source system; Measurement; Model-based simulation; Cost performance

1. Introduction

Recently, new energy installation of HVAC&R systems in commercial buildings is recommended from the viewpoints of environmental conservation and energy reduction. The new energy is mainly divided into two types, which are natural energy such as solar photovoltaic power generation and recycled energy such as exhaust heat recovery. Natural energy is widely distributed in nature, and the seawater utilization for building air conditioning in this paper is grouped as a way of using natural energy [1].

We will talk about cooling source systems with indirect seawater utilization for building air conditioning in this paper. The values for the data we have acquired over 22 months have fluctuated due to changing the operation strategy in the 11 months of operation, resulting in more optimal, efficient running at the cooling system. This paper presents the energy and cost performance evaluation based on actual operating data and the model-based simulation analysis.

2. The target building and seawater utilization

2.1. An outline of the target building

The targeted building is a commercial complex containing clothing departments, ornament departments, a supermarket, food courts, etc., located in Nagasaki city, in the southern area of Japan. The complex was completed in February 2000, and it faces the harbor of Nagasaki port as in Photo 1. It has six stories and a gross floor area of 84,000 m × 38,000 m in need of air conditioning. Nagasaki city has a moderate climate in winter and is very hot and humid in summer, therefore only cooling load is required for air conditioning through a whole year. In addition, Nagasaki is a city not blessed with an abundant source of water, so we have planned to make use of unutilized energy, namely seawater for cooling chiller instead of a conventional cooling tower system.

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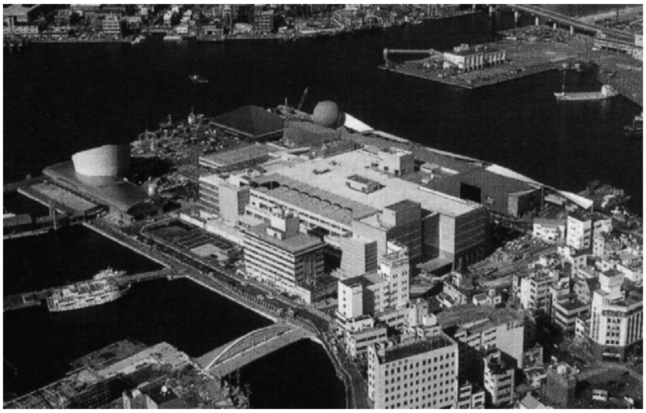

Photo 1. Appearance of commercial complex.

Fig. 1 and Table 1 show the outline of the cooling source system and design parameters, respectively, and it consists of turbo chillers, a thermal storage tank with chilled water, heat exchangers, pumps, etc. One of the characteristics of the system is that seawater is used to cool the cooling water using heat exchangers. The seawater does not pass inside the chiller directly; the heat exchange is carried out between the cooling water and the seawater [2].

The seawater is pumped up via a gate through which it is taken from the sea, and released again from another gate after the seawater has heat exchanged with the cooling water in the heat exchanger. The heat exchanger for the seawater is a titanium plate type to prevent rust and to make taking it apart for the maintenance easy. Washing equipment which uses hot water is also installed in the system to eliminate scales and shells sticking in the heat exchanger, and a net screen is put on the gate to keep them out of the system [3].

The water storage tank of this complex is only for chilled water and is divided into 46 small spaces by partitions. These spaces are connected by holes through the partitions, and the water temperature in each space is uniform. The first space has the lowest water temperature and the last space has the highest. Therefore, the chilled water storage tank can be classified into temperature stratification types. The total volume of the tank is about 4500 m^3, and the difference of the water temperature utilization is 7 K (5–12 °C), and this storage tank is designed to cover 32% of the peak cooling load.

Regarding the control strategies of the chilled water storage tank system, the two chillers' operation is started at 10 p.m. every night, and is stopped when the water temperature in the 45th space of the tank comes to 6.5 °C or below. In addition, the cost of electricity from 10 p.m. to 8 a.m. is lower than daytime. At the starting time of air conditioning, the chilled water in the tank has priority to be used. After that, one chiller is operated additionally if it is judged that the only chilled water in the tank can not provide the complex cooling load any more; storage-priority control.

2.2. The merits of the indirect seawater utilization

There are several merits in using the indirect seawater utilization system compared with the conventional and the direct seawater utilization system. First, condenser temperature of the chiller gets lower because the seawater temperature is lower comparatively and more stable than the outdoor air temperature. As the result, an improvement in the chiller's energy efficiency can be expected. Second, the efficiency of heat exchange seawater to cooling water is higher than air to cooling water in a cooling tower. Finally, using cooling water in the chiller simplifies its maintenance. In the case of using seawater directly in the chiller, it needs more time and cost to wash the inside in order to prevent the scales from sticking. Furthermore, a spare chiller for maintenance is also required for the direct seawater utilization system.

3. Measurements analysis

Energy performance of the system has been evaluated by using actual operating data, which has been acquired on site for about 2 years; April 2000–January 2002. Fig. 2 shows electric power consumption used in heat source system. The system

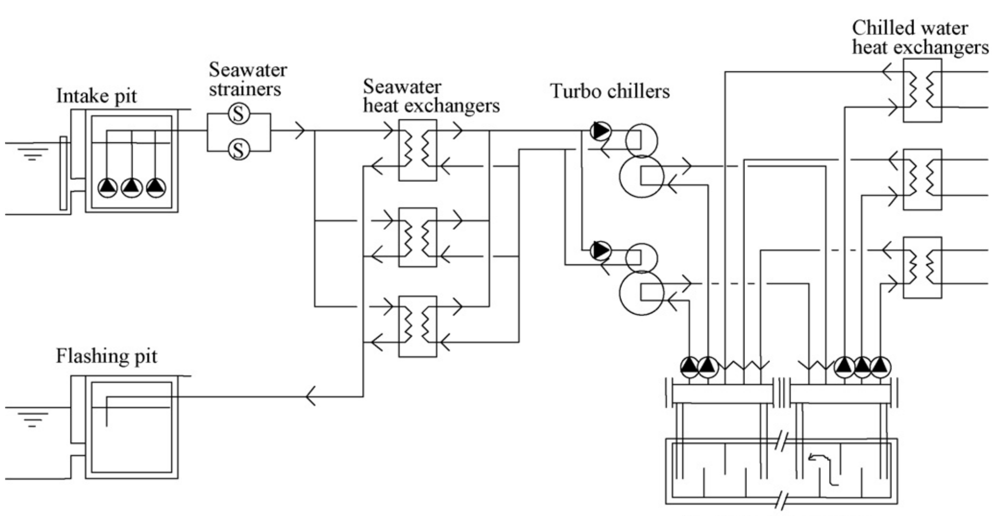

Fig. 1. Schematic diagram of the cooling source system.