A PRACTICAL STUDY ON APPLICATION OF LIFE CYCLE COMMISSIONING TO A DHC PLANT DURING THE OPERATION AND MAINTENANCE STAGE

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Abstract: In Japan, the importance of Commissioning (Cx) or TAB is well known to engineers, but there are as yet few examples of their application especially life cycle Cx. Within this background, analysis for eight years operation results on District Heating and Cooling (DHC) plant were shown. Subject is one of the most effective DHC plant with the greatest thermal storage tank (in total 19,060m^3) that is under operation (Completion: March, 2001). This plant is located near the Tokyo waterfront, and provides chilled and hot water to three office skyscrapers (over 150 m): one tall office building, a commercial institution, and a hall. A redevelopment plan for this area was announced in 1988, and the guidelines for the plan and specific were determined by a committee comprising academic experts, owners, power companies and designers. This was an innovative approach at the time. As for result, there were some interesting results. Enhancement of effectiveness on chillers COP against the aging is one of the topics. By means of continual long term measurement, analysis and readjustment, we demonstrated the advantages of life cycle Cx.

Key Words: District heating and cooling, Commissioning, COP, Thermal storage

1 Introduction.

Increased in public awareness of the need to reduce environmental load has led to growing interest in efficient energy management strategies such as thermal storage systems. However, problems are likely to be encountered if a thermal storage system is would installed without Commissioning (Cx) to ensure that the system operates as intended. A thermal storage system consists of numerous machines, so the system requires Cx or at least “TAB” (Test Adjust and Balancing). In Japan, the importance of Cx or TAB is well known to engineers, but there are as yet few examples (especially long term) of their application.

2 SUBJECT OF STUDY

In this paper, we carried out a practical study of life cycle Cx with the DHC with the largest thermal storage tanks (19,060 m^3) in Japan, (completed in March, 2001, in Tokyo: Fig. 1). Details on the customers are shown in Table 1. This DHC (district heat and cooling) plant is located near the Tokyo waterfront, and provides chilled and hot water to three office skyscrapers (over 150 m): one tall office building, a commercial institution, and a hall. A redevelopment plan for this area was announced in 1988, and the guidelines for the plan and specific were determined by a committee comprising academic experts, owners, power companies and designers. This was an innovative approach at the time. The committee decided the following for both environmental preservation and economic reasons. 1) To

install the main plant in the center of this area; 2) to use a temperature difference of 10 ˚C; 3) to adopt huge thermal storage tanks, and 4) to run the system using only electric power.

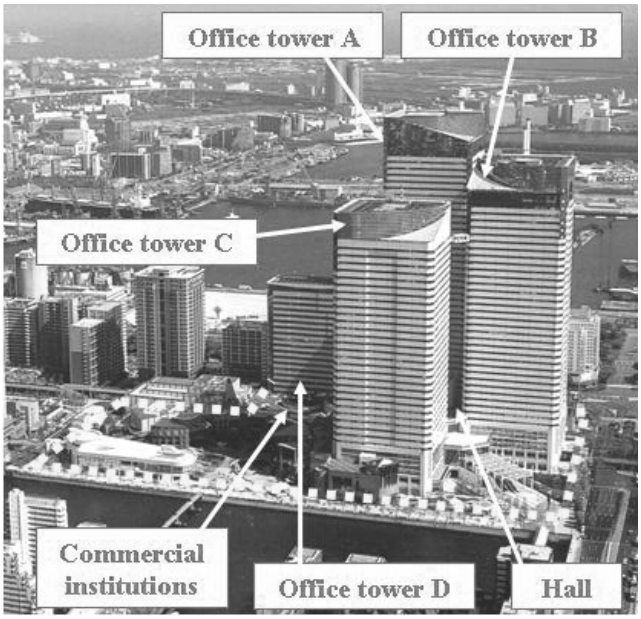


Figure. 1 Buildings in DHC area

Table 1 Detail of customers

		Office tower A	Hall	Office tower B	Office tower C	Office tower D	Common part
Use		Office	Hall	Office	Office	Office	Grand Lobby
						Shop	Shop
Stories	Above ground	45	6	40	34	19	6
	Below ground	4		4	4	1	4
Total floor area		131, 197m^2	4, 871m^2	119, 506m^2	103, 781m^2	31, 610m^2	71, 444m^2
Air conditioning area		83, 400m^2	3, 400m^2	77, 900m^2	63, 400m^2	24, 000m^2	30, 260m^2

3 OUTLINE OF FACILITIES

The area plan of this plant is shown in Fig. 2 and the facility outline is shown in Figure 3. This DHC has huge storage tanks that can supply half of the peak day load in summer. They are installed under office towers B and C and consist of five tanks and with a total capacity of 19,060 m^3: two tanks exclusively for cooling, one tank for heating only, and two switch tanks for cooling and heating to adapt to seasonal changes. All are temperature-stratified-type thermal storage tanks. The capacity of the chillers is 16,088 kWh in total. They consist of two electric turbo refrigerators (TRs), two heating tower heat pumps (HTHPs), and two double bundle heat-recovery turbo refrigerators (DBs). Concerning the supply conditions, the chilled water temperature is 6 ˚C (supply) - 16 ˚C (return) and the hot water is 47 ˚C (supply) - 37 ˚C (return). Reduction of transporting power and pipeline diameter was realized by using large temperature differences. It also appears feasible to improve the performance of the thermal storage tanks. All the customers' secondary systems employ closed circuits with heat exchangers. Secondary pumps are controlled by VWV with inverters and contribute to maintaining the temperature differences and reducing transporting power. Moreover, fan-coil units and air-handling units which can maintain a temperature difference of 10 ˚C were adopted.

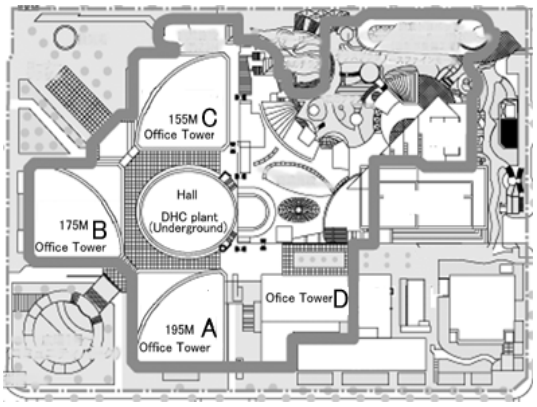


Figure. 2 Area plan of plant

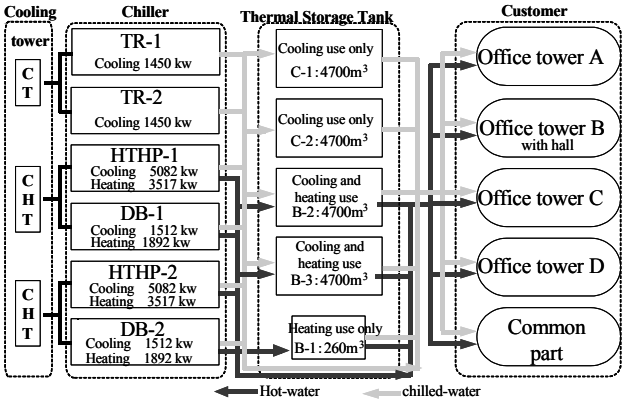


Figure. 3 Facility outline

4 OVERVIEW OF OPERATION RESULTS

4.1 Cooling and heating loads

Fig. 4 and Fig. 5 show the monthly heating and cooling loads. The peak cooling load comes in July or August and the peak heating load is in June. Although the common part makes up one eighth of the entire air conditioning area, the cooling and heating loads for the part occupies a quarter of all. The principal reason for this is that the common part includes restaurants. Cooling load in the winter is much lower than estimated when the plan was formulated, since the customers' interior systems use double piping. Therefore, most of the zones change to only heating in winter.

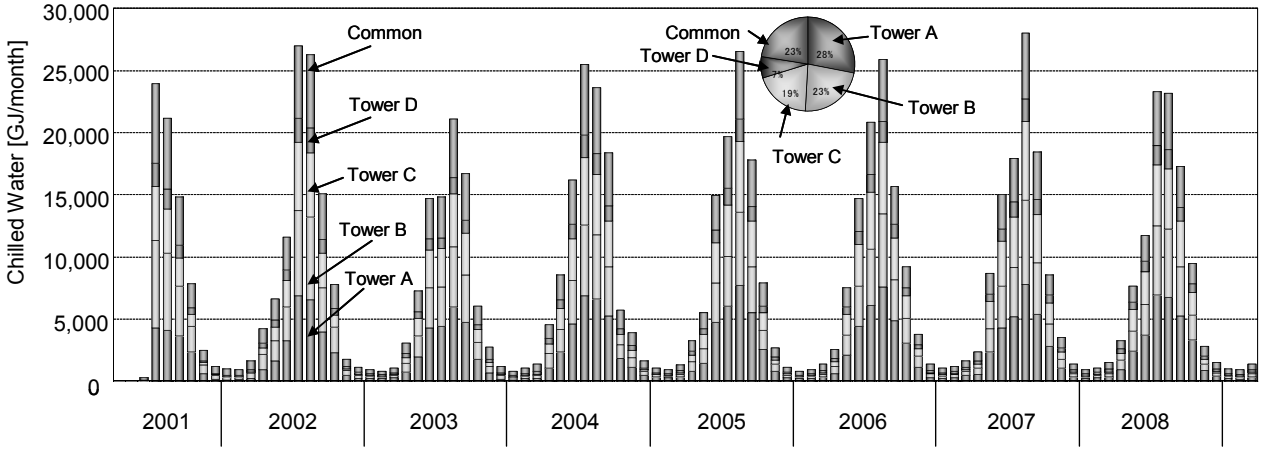


Figure. 4 Cooling loads (2001-2008)

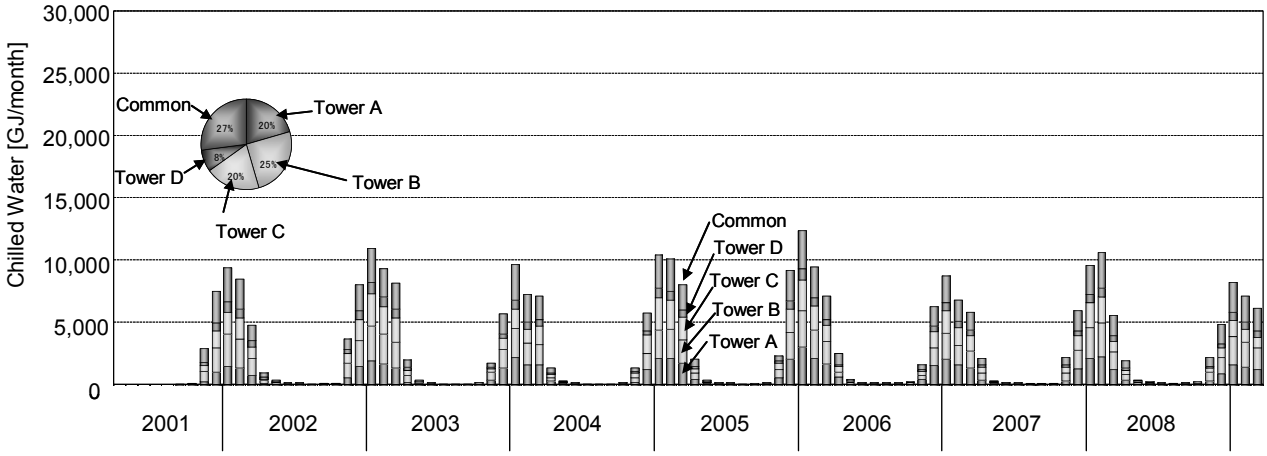


Figure. 5 Heating loads (2001-2008)

4.2 Electric power consumption

Fig. 6 shows the details of electric power consumption over eight-year period. Chillers occupied about three quarters of the total (74%). However, the ratio accounted for by transportation pumping is very small (11%). VWV control with inverters, appropriate quantity control and the short distance from the plant to customers are the reasons for this low pump ratio.

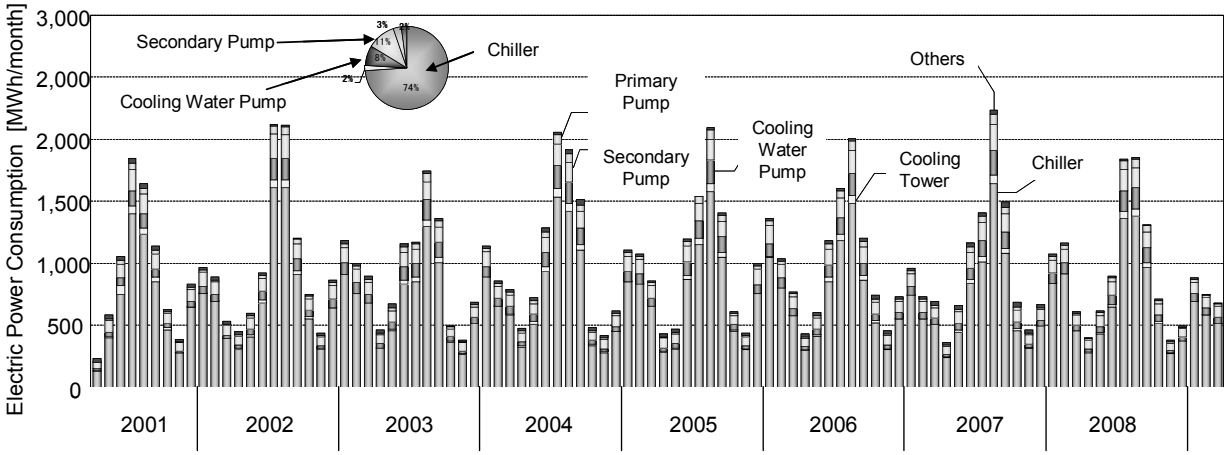


Figure. 6 Details of electric power consumption (2001-2008)

4.3 Operation of chillers

Fig. 7 shows monthly COP values for the chillers, calculated from the total electric power consumption by the chiller compressors and auxiliary heaters (not including transportation pumps). When different operation modes (chilling, heating and heat recovery mode) are mixed in the same month, the COP is calculated simply as the total of electric power consumption and quantity of heat. The COP of the TRs in summer exceeded 5. However, this performance afforded no advantages in winter, since the cooling load in winter was very small. The COP of the HTHPs dropped in winter since they switch to heating mode (COP: 3.2). Between autumn and spring, the DBs had been operated in cooling and heating mode at the same time (heat recovery mode), so they had operated very efficiently.

Fig. 8 shows the changes on annual COP and load factor of chillers in each of operation mode. The load factor of the chillers had been enhanced. Especially TR is almost 1. This result shows the rare case that against the aged deterioration, COP of TR is increasing. This ideal state was due to the use of a huge thermal storage tank, showing that installing sufficient thermal storage tanks leads to the chillers high load factor.

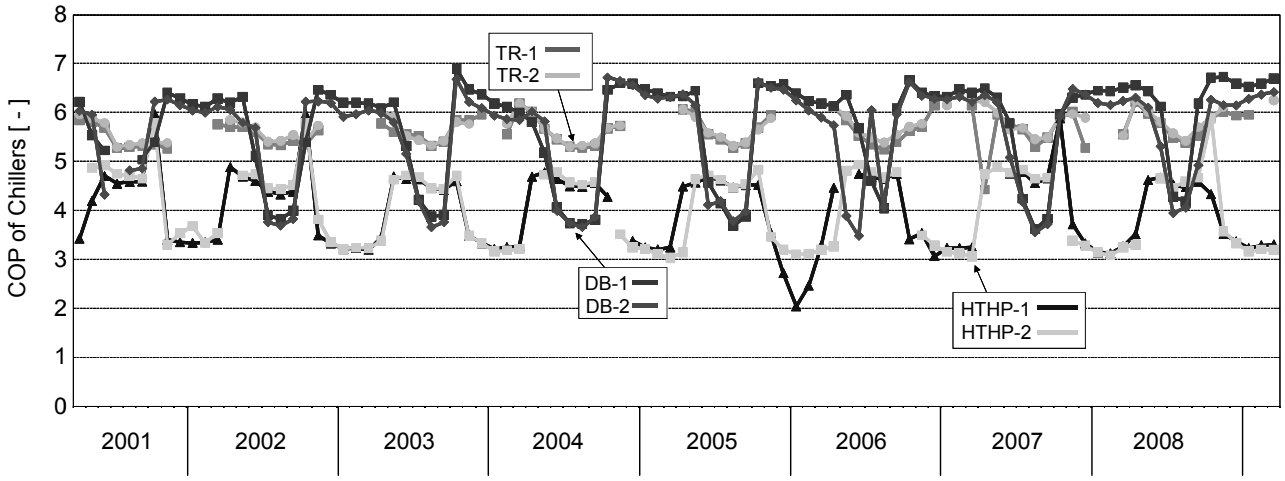


Figure. 7 COP in each of Chillers (2001-2008)

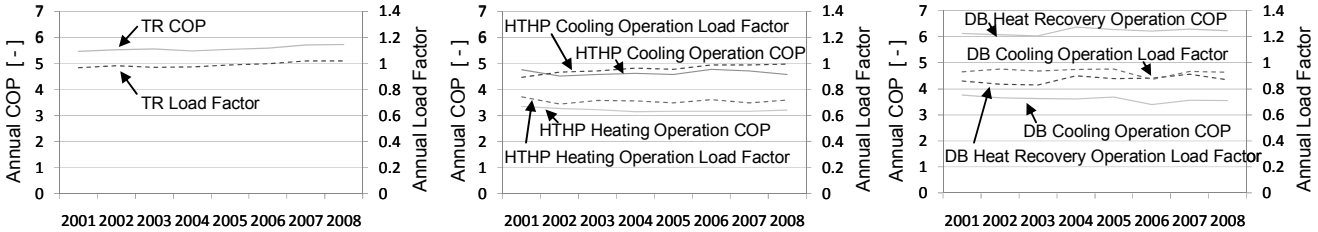


Figure. 8 Changes on annual COP and load factor of chillers in each of operation mode

4.4 Enhancement of temperature difference

The temperature difference of this DHC was set high at 10 degree C. However, it was not easy to maintain such a large difference of temperature, especially at lower flow volumes such as night-time. Fig.9 shows the annual average temperature difference between DHC supply and return header. Except 2001 and 2002, both of chilled water and hot water temperature difference at day-time came close to almost 10 degree C. Also even in night-time, both of temperature difference was maintained more than 7 degree C. Considering other DHC value, it is thought that these result is one of the best result in Japan.

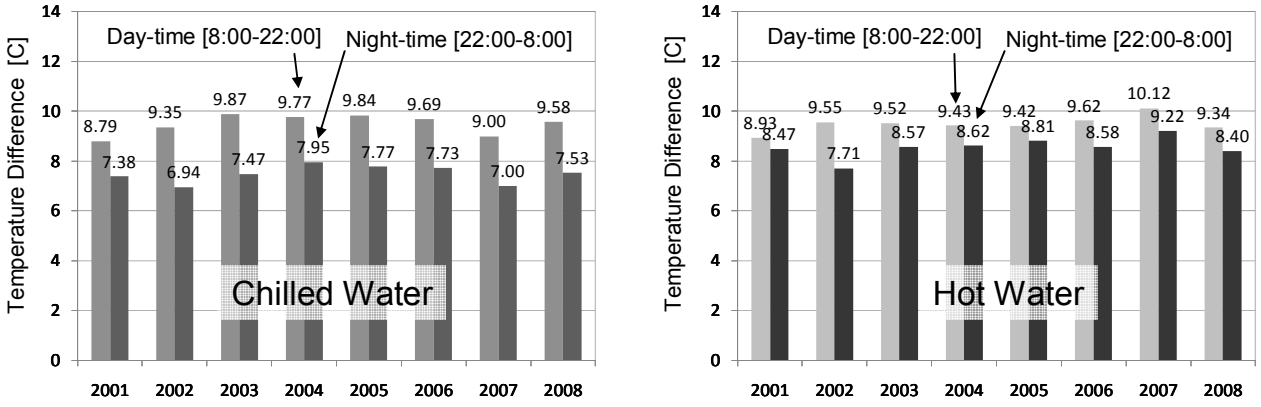


Figure.9 Annual average temperature difference between DHC supply and return header

4.5 Result of plant operation.

Fig.10 shows the primary energy conversion COP of this plant. In summer, plant COP is more than 1.4 (2008). This reflects effectiveness of base operation of TRs (COP: 5.3) in generating cold energy. On the one hand, in winter, the plant COP falls to less than 1.0. This is due to basic operation of HTHPs (heating mode COP: 3.2). The original design assumed greater cold energy demand in winter than was actually the case. For this reason, the DB heat recovery mode could not generate enough cold and hot energy. The COP for primary energy conversion had been slightly enhanced year after year. As the result, in 2008, it marked maximum value 1.28. This result shows that this DHC is one of the most efficient DHC plant in Japan. Also this figure shows that the DHC system had been operated at a high COP that had not been influenced by aged deterioration.

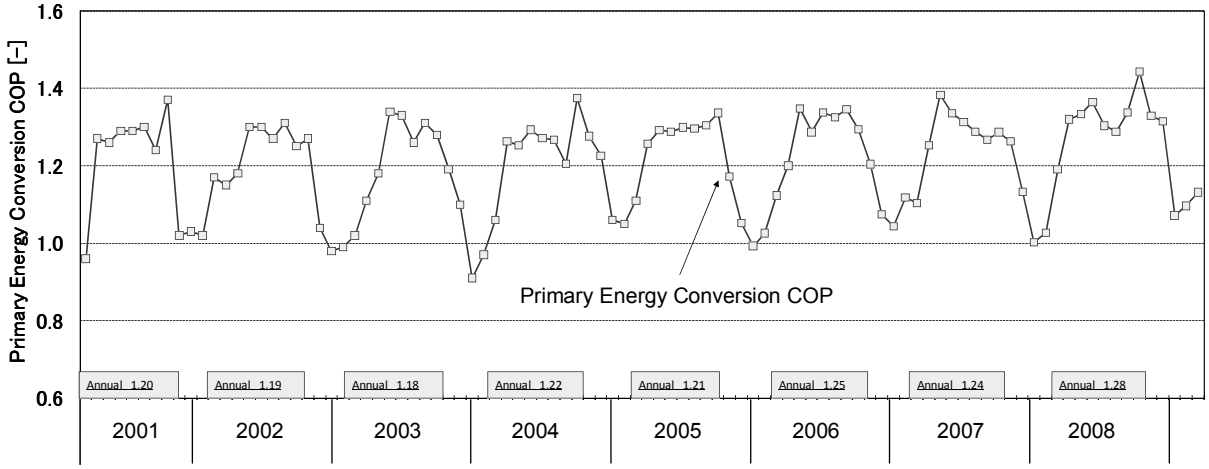


Figure. 10 primary energy conversion COP of the DHC

5 CONCLUSION

By means of eight years long term measurement, analysis and readjustment, we demonstrated the advantages of life cycle Cx. The following results were shown in the "Operation & Maintenance Stage".
1) It was shown that this DHC had been operated at a high primary energy conversion COP (Maximum 1.28 in 2008) that has not been influenced by aged deterioration.
2) As the result of life cycle Cx, the temperature difference rose to about 10 degree C.
3) Due to the efficient operation of large thermal storage tanks, most of the energy consumption was shifted to the nighttime and chillers were operated with a high load factor.
These results are one of the first case examples of a practical study of life cycle Cx during the "Operation & Maintenance Stage" in Japan.

6 Nomenclature

COP [-] = energy production / electric power consumption
Night-shift-rate (electricity) [-] = electric power consumption in the daytime [kWh]
/ electric power consumption on all days [kWh]
Night-shift-rate (quantity of heat) [-] = quantity of heat production at night [MJ]
/ quantity of heat production on all days [MJ]
Primary energy conversion COP[-] = quantity of heat production on all days [MJ]
/ electric power consumption on all days [kWh] * 9.97[MJ/kWh]

7 References

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