ADOPTION OF WATER-COOLED AIR CONDITIONING SYSTEMS FOR TERRITORY-WIDE ENERGY IMPROVEMENT

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Summary

Air-conditioning accounts for around 30% of the total electricity consumption in Hong Kong, of which 68% is taken up in non-domestic premises. One effective way of territory-wide energy improvement is by wider adoption of water-cooled air-conditioning system (WACS), which can help reduce electricity consumption by air-conditioning systems by 1,185 million kWh per year from 2020 onward. The energy conserved can also be translated into reduction in greenhouse gas emission by over one million tonnes annually.

Among the various forms of WACS, centralised piped supply system for cooling towers (CPSSCT), district cooling system (DCS) and centralised piped supply system for condenser cooling (CPSSCC) are feasible for Hong Kong. For CPSSCT, a pilot scheme for fresh water evaporative cooling towers for non-domestic premises has been put in place. Up-to-date, some 260 applications, which involve 8 million square metres of floor area with potential energy saving reaching 180 million kWh per year, have been received. Many more applications are forthcoming.

On the other hand, provisions have been made in Kai Tak Development (KTD) draft Preliminary Outline Development Plan (PODP) for the development of a DCS in the area. For CPSSCC, a two pressure-head system provided at the central reclamation project for affected government building groups is being commissioned. Permission for one private CPSSCC for a commercial building group in Quarry Bay was granted in August 2006.

In promulgating WACS schemes for territory-wide energy improvement, response and involvement of private sector and the community as a whole is the principal success factor to take forward these initiatives, all of which are sustaining efforts in combating climate change.

Keywords: *Water-cooled Air Conditioning Systems (WACS), Centralised Piped Supply System for Cooling Tower (CPSSCT), Centralised Piped Supply System for Condenser Cooling (CPSSCC), District Cooling System (DCS), Energy Consumption in Buildings, Energy Efficiency*

1. Introduction

Air conditioning in Hong Kong accounts for a large proportion of the total electricity consumption. In 2004, air conditioning accounts for 30% of the total electricity consumption, of which 68% is taken up in non-domestic buildings (Figures 1 and 2). When compared with 1994, the electricity consumption by air conditioning had also increased by about 20% from 9,750 million kWh to 11,740 million kWh. With increasing population and development, the use of air conditioning as well as the electricity demand for air-conditioning will continue to grow.

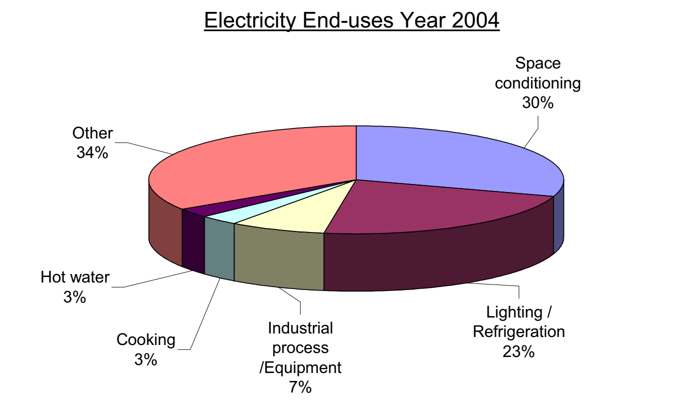

Figure 1 – Electricity end-uses

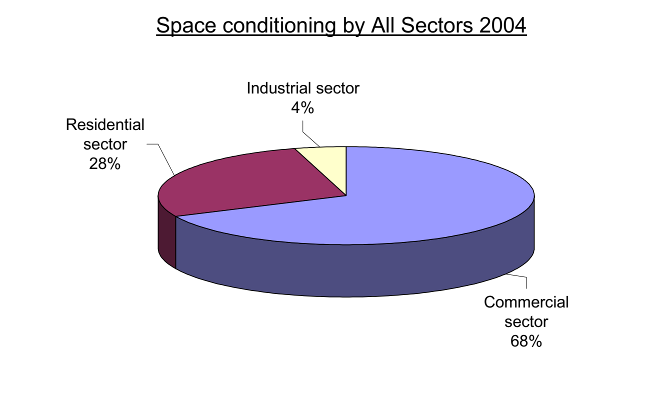

Figure 2 – Air conditioning by residential, commercial and industrial sectors

In order to curb the growth in electricity demand, protect the environment and improve the air quality in Hong Kong, several consultancy studies to look into the possibility of wider adoption of water-cooled air conditioning systems (WACS) have been commissioned by the Electrical & Mechanical Services Department (EMSD) from 1999 to 2004. These include a Territory-Wide Implementation Study for Water-cooled Air Conditioning Systems in Hong Kong and an Implementation Study for a District Cooling System for South-East Kowloon Development. The Executive Summaries of the final reports for all these studies are available on EMSD's website.

2. WACS Schemes

Three types of WACS, namely centralised piped supply system for cooling towers (CPSSCT), district cooling system (DCS) and centralised piped supply system for condenser cooling (CPSSCC) were found feasible to be implemented in Hong Kong.

The generic features of the three schemes are outlined below.

(a) Centralised Piped Supply System for Cooling Towers (CPSSCT) (Figure 3) – For a building adopting CPSSCT, its air conditioning system uses an evaporative cooling tower for heat rejection. Water in the cooling tower will be lost due to the continuous evaporation, wind drift and bleed-off. The water lost in this way will be replenished by water from the city water mains. There will be no need for extra infrastructure provisions, if the water supply from the city water mains is adequate to accommodate the additional demand generated from air-conditioning usage.

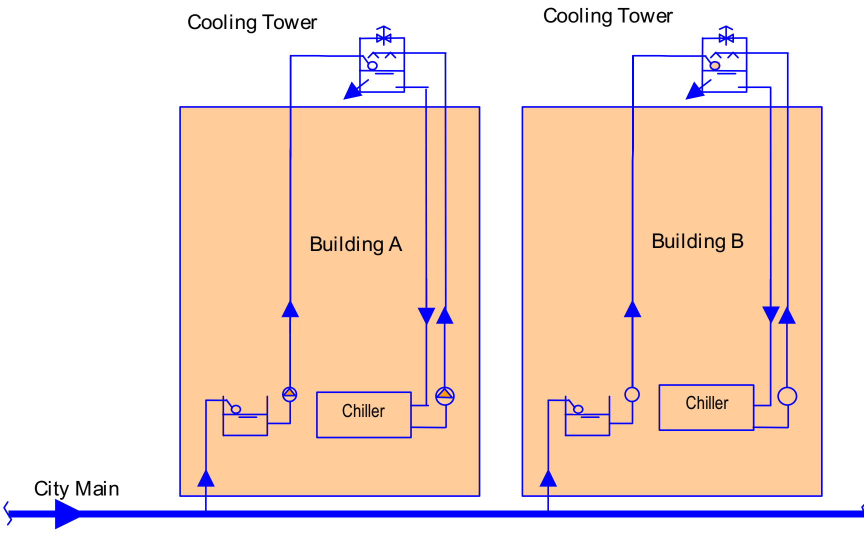

Figure 3 - CPSSCT Scheme

(b) District Cooling System (DCS) (Figure 4) – For buildings served by DCS, their air conditioning system will use chilled water produced by a purposely-built central chiller plant. Individual user buildings will acquire chilled water from the DCS operator and there is no need for them to build their own chiller plants. For this scheme, a central chiller plant, a pump house and a distribution piping system will be required.

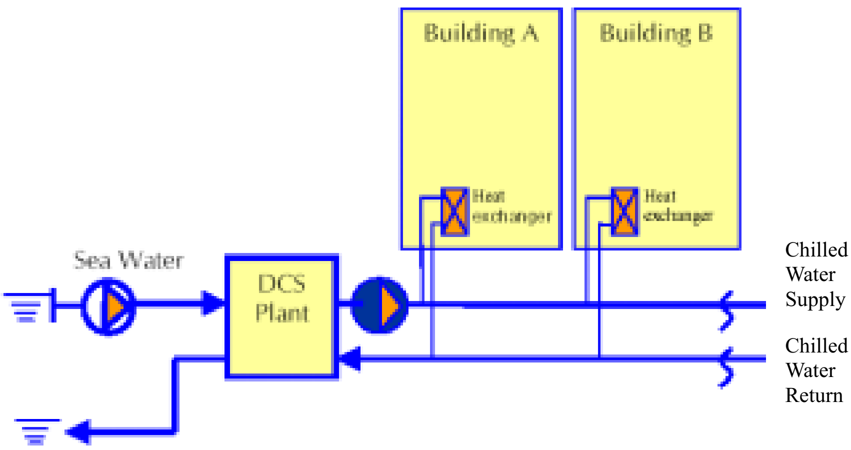

Figure 4 DCS Scheme

(c) Centralised Piped Supply System for Condenser Cooling (CPSSCC) (Figure 5) – For a building served by CPSSCC, its air conditioning systems uses seawater for heat rejection of the chiller condenser, either directly or indirectly through a heat exchanger. A dedicated central seawater supply system will distribute seawater from the seawater pump house to the user buildings through a common supply pipe. The rejected warm seawater from the chiller condensers will be discharged to the sea through another common discharge pipe.

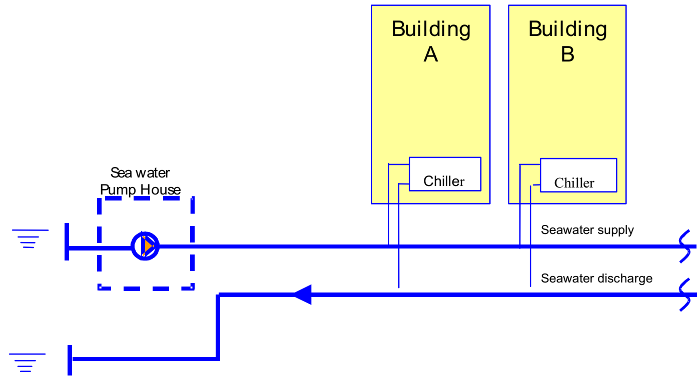

Figure 5 - CPSSCC Scheme

The "common main supply pipe configuration" depicted above is suitable for the situation where a few buildings are located close together in an area some distance away from the sea. An alternative approach is to adopt "common pump discharge header configuration", and arrange separate pipes from the common header in the seawater pump house to each building. This configuration is more suitable for the situation where the buildings are located not too far away from the seawater pump house, and more dispersed.

Energy evaluation using energy modelling shows that CPSSCT, CPSSCC, DCS are more energy-efficient than the conventional air-cooled air-conditioning scheme by 14-20%, 22-28%, and 30-35% respectively, depending on the building type, air-conditioning plant configurations and the piping layout for the particular district zone.

3. Centralised Piped Supply System for Cooling Towers (CPSSCT)

Upon completion of the Preliminary Phase Consultancy Study on Wider Use of WACS in Hong Kong in end-1999 and the well established grounds of water-cooled systems to be more energy efficient than the air-cooled counterpart, an Inter-departmental Working Group was set up and launched a pilot CPSSCT scheme, namely Wider Use of Fresh Water for Evaporative Cooling Towers (Pilot Scheme) on 1 June 2000. The major aim of the Scheme is to promote the use of energy-efficient water-cooled air conditioning systems. Besides, it is also used to assess the impacts on the infrastructures; to assess the health and environmental effects; and to facilitate the territory-wide implementation of water-cooled air-conditioning systems in Hong Kong ultimately

a. Designated areas of Pilot Scheme

When the Pilot Scheme was launched in June 2000, there were only 6 designated areas which covered about 6 million m^2 of non-domestic gross floor area (GFA) in the territory. Subsequent to several reviews in the past six years and the completion of the Territory-Wide Implementation Study for Water-cooled Air Conditioning Systems in Hong Kong, the designated areas have been expanded to 79, covering about 71 million m^2 of non-domestic GFA. The coverage represents about 70% of non-domestic GFA in the territory.

In fact, apart from Central, Admiralty, Sheung Wan, Sai Ying Pun and Quarry Bay, most areas with high cooling load density have been included in Pilot Scheme. The Inter-departmental Working Group of Pilot Scheme will continue making effort to open up more designated areas.

b. Participation of Pilot Scheme

Since launching Pilot Scheme in June 2000, it has attracted about 260 applications. The total cooling capacity and non-domestic GFA of these applications has reached 1,150 MW and 8 million m^2 respectively. It has also been reckoned that 90% of total GFA in new non-domestic development have adopted fresh water cooling towers. This high participation rate reflected that most building services designers prefer to use WACS than the traditional air-cooled systems, having considered the energy efficiency of WACS and the fewer constraints for a new development to comply with the requirements stipulated in Pilot Scheme.

Out of the applications, 135 of them have already obtained support from EMSD to install fresh water cooling towers. Their installation work is in progress and it is anticipated that more installations will be completed in the coming years.

Up to now, 70 applications have been completed, with their installations commissioned and put into operation. The total non-domestic GFA of completed installations is 3 million m^2 and the total cooling capacity is about 450 MW.

c. Water consumption

Based on an energy saving intensity of 28 kWh/m^2/annum, and taking into account factors such as the type of existing air-conditioning system in the case of retrofit, the 70 completed installations under Pilot Scheme could contribute energy savings of 60 million kWh per annum. The respective annual water consumption of these installations is 2.4 million m^3 (based on 0.77 m^3/m^2/annum).

When all applications are completed, the energy saving could possibly reach some 180 million kWh per annum and the associated water consumption will be 6.2 million m^3 per annum, which is merely

0.6% of the annual water consumption in the territory.

d. Energy saving potential

It has been mentioned in the above paragraphs that the completed installations could save about 60 million kWh of electricity per annum. This saving can also reduce about 42,000 tonnes of carbon dioxide emission per year. At present, there are only 8% of non-domestic GFA in the territory with their owners intending to use or already using fresh water cooling towers for their air conditioning systems. If 50% of the non-domestic GFA in 2020, which is about 37 million m^2 [1], is converted to use fresh water cooling towers, the anticipated energy saving is estimated to be about 1040 million kWh per annum and the associated reduction of carbon dioxide from power plant will be about 730,000 tonnes per annum.

Pilot Scheme demonstrates that by using fresh water cooling tower type water-cooling air conditioning systems, significant energy saving could be achieved without posing significant burden to our water supply infrastructures.

4. District Cooling System (DCS)

Since the 1960s, district cooling has become more commonly used in Western countries for air-conditioning purposes in densely built-up downtown areas. In the East, DCS have also been implemented in Japan, Singapore, Malaysia, and in the Mainland.

a. Benefits of DCS

In a DCS, chilled water supply is available for the served buildings. At each building, a water-to-water heat exchanger transfers the heat from the interior chilled water circuit to the district cooling chilled water circuit. The plant room space requirement of the heat exchanger is much smaller than a chilled water plant for the building. The interior space and penthouse area of the building can therefore be maximized and neither will there be any need for installing a cooling tower or air-cooled condenser for heat rejection. The building owner also does not have to care about maintenance of the chiller plant, or about replacement of chiller plant upon the end of its service life.

From a broader perspective, DCS have the benefit of economic of scale and thus can reduce energy consumption and hence there will be less greenhouse gas emissions and atmospheric pollutants from power plants, and it can contribute to a more pleasant urban environment due to more flexible building

[1] The GFA is derived from the methodology adopted in the "Territory-wide Implementation Study of Water-cooled Air Conditioning Systems in Hong Kong".

design and elimination of in-building chiller plants.

b. Types of DCS according to the way of operation

According to the way of operation, there are two main types of DCS - institutional type and utility type. For the institutional type DCS, the DCS is built to serve a number of buildings under the same owner. Examples are DCSs for university campuses, holiday resort areas and large commercial development with several buildings under same owner. For the utility type DCS, the DCS operator sells cooling energy to subscribers. In some places, the requirement of mandatory connection to the DCS is imposed on the building owners within the DCS service area. In other places, building owners can choose to connect or not to connect.

c. Implementation Study for a District Cooling System at Kai Tak Development

During the Kai Tak Planning Review, provisions have been made in the draft KTD Preliminary Outline Development Plan in 2006, as an environmentally friendly feature. The Government will examine the feasibility of developing DCS in future KTD area.

5. Centralised Piped Supply System for Condenser Cooling (CPSSCC)

While great benefits can be derived from the implementation of a DCS, in areas near to the sea and where there are constraints to the implementation of DCS such as in the case of existing developed areas, CPSSCC (i.e. central seawater scheme) will be an alternative choice for saving energy.

a. Benefits of CPSSCC

For a CPSSCC, a seawater pump house located at the seafront supplies seawater to a number of buildings for condenser cooling purpose. The use of a central pump house has several advantages over separate seawater pump houses for individual developments. It is easier to allocate land to a central seawater pump house than to several pump houses. The central seawater pump house can be designed to be mostly underground, thus preserving valuable seashore space for public use.

b. CPSSCC for government buildings

The Central Reclamation Phase III (CRIII) Project is the final phase of planned waterfront reclamation in the Central District of Hong Kong Island. The reclamation affected the cooling water pumping stations for a large number of existing private and government buildings. There is therefore a need to relocate the seawater pump houses to the shore and a CPSSCC (Figure 6) is implemented for the affected government buildings. The total chiller plant capacity that could be served by this pumping station is about 20,000 TR.

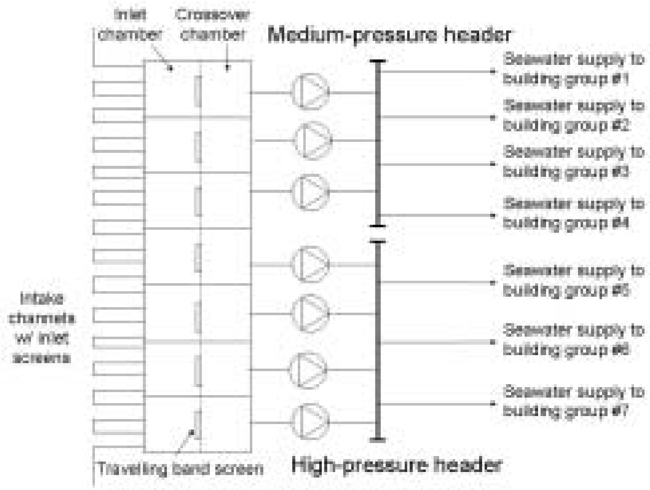

Figure 6 – Simplified schematic diagram for the CPSSCC

As in early 2007, the centralized government pumping station is under testing and commissioning and will be put into operation later this year.

c. CPSSCC for private development

A private developer has submitted a town planning application for utilising the existing seawater pump house to serve a number of buildings. The application was approved by the Town Planning Board in August 2006. The proposal is to build a seawater pump house with seven pumps to serve a group of buildings owned by the private developer. The planned total chiller capacity to be served by the pump house ultimately is 15,000 TR. This seawater pump house will be a showcase of the use of CPSSCC in the private sector.

d. Energy saving potential

It is estimated that for the two CPSSCC systems described above, the energy advantage over air-cooled air conditioning if fully realized could reach 35 million kWh per annum.

6. Conclusions

From the experience gained from the promotion of different types of WACS in Hong Kong, it is observed that the success of implementing any type of WACS depends on a multitude of factors, other than engineering considerations. Infrastructure provisions, acceptance by the private sector and the community, the prevailing investment climate, land constraints, etc. are all important factors affecting the success of WACS initiatives.

Nonetheless, the energy saving potentials and environmental benefits of WACS are undoubted. With the implementation of CPSSCT scheme in all potential zones in Hong Kong, the energy saving could reach 1,040 million kWh per annum. The two confirmed CPSSCC schemes and other potentially viable CPSSCC schemes offer the opportunity for saving 145 million kWh per annum.

Energy saving from those WACS schemes now in place and those with potential for implementation in Hong Kong over the next fifteen years could reach some 1,185 million kWh per annum, with associated reduction in carbon dioxide emission of about 830,000 tonnes. This is equivalent to about 10% saving of the current level of electricity consumption of all air-conditioning systems in Hong Kong. Undoubtedly, the successful promulgation of WACS is one of the key factors in the sustainable development and contribution to combat climate change for Hong Kong.

References

1. Electrical & Mechanical Services Department, HKSAR – Hong Kong Energy End-use Data (1996 – 2004)
2. Electrical & Mechanical Services Department, HKSAR – Final Report of “Territory-wide Implementation Study of Water-cooled Air Conditioning Systems in Hong Kong” (2003)
3. Electrical & Mechanical Services Department, HKSAR - Final Report of "Implementation Study for a District Cooling System at South East Kowloon Development" (2003)