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ENERGY EFFICIENT AIR-CONDITIONING SYSTEM DESIGN

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Abstract

At the Taiwan Light Source (TLS) and Taiwan Photon Source (TPS), several studies related to energy savings in air-conditioning systems are underway, where heat recovery has been considered for laboratory applications. The performance of a run-around coil has demonstrated that heat recovery plays an important role in energy conservation. Based on this design of an air handling unit (AHU), we enhance this model by combining it with enthalpy control for seasonal changes. Here, we construct a new AHU to verify the practical impact of energy usage. The improvements show that both mechanisms can be achieved simultaneously.

INTRODUCTION

In general, thermal waste can be treated by circulating deionized water (DIW) and by air conditioning (AC). The main cooling water system at the TPS includes the cooling tower, chilled water, hot water, de-ionized water and heating, ventilation and air-conditioning (HVAC) systems. The air-handling units (AHU) located at the inner and outer rings provide very stable cooling air for the storage-ring tunnel, CIA, experimental hall and Linac area. The amount of HVAC systems must be well optimized so that the accelerator would be the least subject to thermal waste [1]. Besides the requirement to be stable, the utility system is designed carefully with a good satisfactory energy-efficiency ratio (EER) and coefficient of performance (COP). In general, a HVAC system always consumes energy for processes like dehumidification and reheating to maintain a constant temperature and humidity.

Since the utility system is essentially an energy wasting system, a preliminary study for energy efficiency in the HVAC system with heat moving and moisture recovery systems has been started by reviewing the designs in more detail [2]. Here, we address mainly specific designs with three flow piping schemes to verify energy efficiency. In addition, the HVAC system also should be equipped with enthalpy controls to deal with the return and fresh air damper. The control philosophy should have the goal to decrease usage of chilled water in the cooling coils.

ENERGY EFFICIENT AIR-CONDITIONING SYSTEM STRUCTURE

The main components of an AHU include dampers, supply fans, filters, humidifiers, dehumidifiers, heating and cooling coils, ducts and various sensors. We add a pre-cooling coil before the cooling coil, pre-heating coil before the heating coil and the corresponding flow piping. The proposed AHU with extra two coils integrate into three modes, including a traditional mode, a cascade mode and a run-around mode to determine the performance among different flow methods.

The traditional mode as illustrated in Fig. 1a includes only cooling and heating coils, which serve as the basis of power usage. To maintain a suitable room humidity, the supply air temperature is controlled in a cooling coil to 12 °C, which is the dew-point temperature. To reach a final precise temperature control, the air temperature supplied by a heating coil must be maintained to a constant value of 22±0.05 °C.

Based on the traditional mode, pre-cooling and pre-heating coils are inserted and the water piping of the first three coils is also re-arranged to form a cascade mode as shown in Fig. 1b. The cascade mode has four coils including pre-cooling, cooling, pre-heating and heating coils. In principle, the larger the amount of heat transferred from the pre-cooling to the pre-heating coils by the circulating water, the greater is the required surface area of the coils and the larger is the required circulating water volume.

The run-around mode uses the same coils as the cascade mode with a circulating pump added as shown in Fig. 1c. The heat withdrawn from the warm air along the way to the pre-cooling coils is transferred by the circulating water to the pre-heating coils. The pre-heating coils then return the sensible heat to the cold air leaving the cooling coils and any heat added to the flowing air by the pre-heating coils is then exactly equal to the heat removed by the pre-cooling coils. The required refrigerating capacity thus decreases in the run-around cycle to reheat the cold air supply. In this arrangement, the required heating capacity is reduced as well.

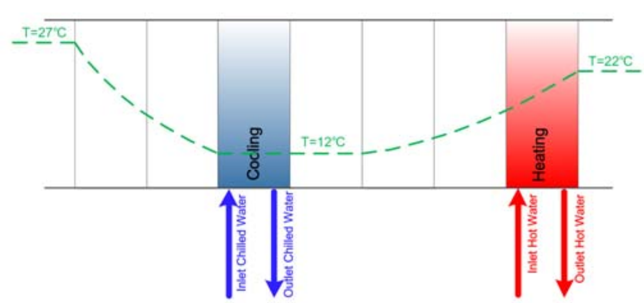

Figure 1a: Scheme of an AHU system operated in the traditional mode.

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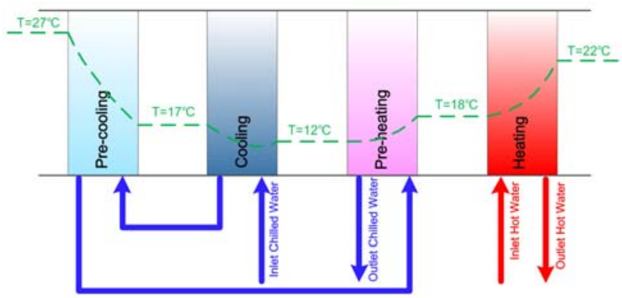

Figure 1b: Scheme of an AHU system operated in the cascade mode.

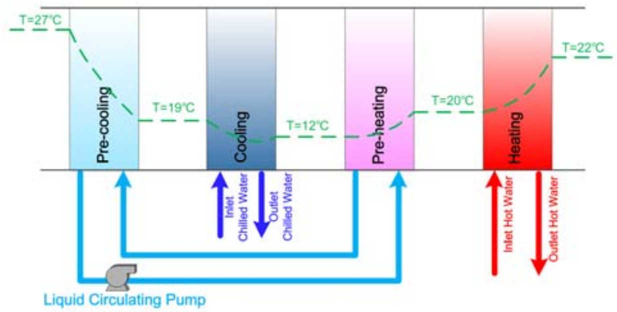

Figure 1c: Scheme of an AHU system operated in the run-around mode.

PERFORMANCE COMPARISON OF RUN-AROUND HEAT AND MOISTURE RECOVERY SYSTEMS

In traditional mode, the return air at 27 ºC flows through the cooling coils and will be well controlled at the dew point of 12 ºC. Thereafter, the cold air flows through the heating coils and is also well controlled to 22 ± 0.05 ºC. According to this mode, the cooling and heating will operate at full or 100% power usage as shown in Fig. 2a.

In the cascade mode, inserting extra pre-cooling and pre-heating coils form a cascade of coils. The pre-cooling coils absorbs heat from the return air and the absorbed thermal energy is transferred to the pre-heating coils, where the cold supply air is heated. This design requires only 68% of cooling load and 44% heating load as shown in Fig. 2b. The chilled water flow is determined by the cooling coils, according to the dew point, which affects the amount of heat recovery related to the pre-heating coils. This uncontrollable heat source can lead to an overheated air supply, especially in summer.

Therefore, we insert a circulation pump to isolate the heat recovery, cooling and heating mechanisms. The pre-cooling and pre-heating coils having independent run-around water piping reduce cooling energy because of the lower air temperature entering the cooling coil. Water is circulated continuously through two coils. This system reduces the need for a dehumidifying and reheating source and thereby decrease system operating costs. As shown in Fig. 2c, this design involves a cooling load of only 71% and a 25% heating load.

The actual power usage as described in Table 1 is similar between cascade mode and run-around mode. However, the run-around mode includes more tuning mechanisms to adapt seasonal changes. The water circulating pump with an inverter can distribute thermal energy among four coils to achieve energy savings. The inverter can be tuned to an optimal working point of 18 Hz instead of 60 Hz as shown in Fig. 3.

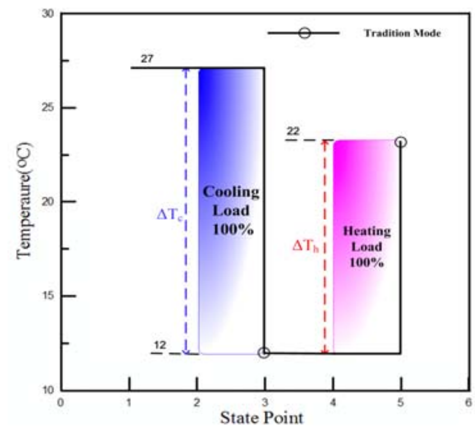

Figure 2a: Traditional mode power usage of an AHU system.

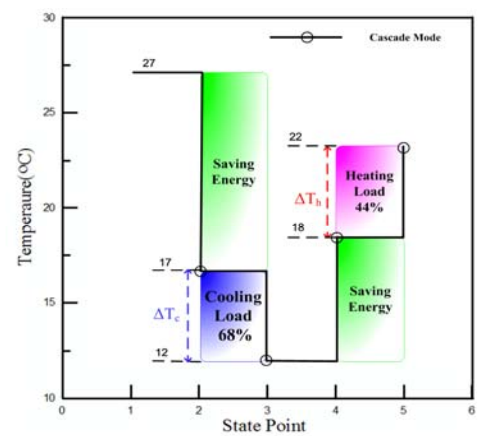

Figure 2b: Cascade mode power usage of an AHU system.

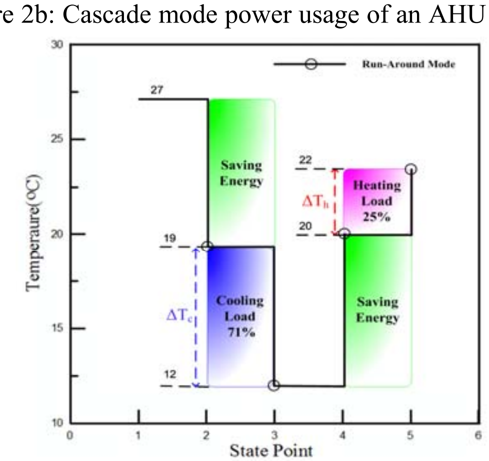

Figure 2c: Run-around mode power usage of an AHU system.

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Table 1: The Comparison of Power Usage Among the Three Modes

	Traditional Mode	**Cascade Mode**	**Run-around Mode**
Chilled Water	98.6 kW	66.9 kW	70.4 kW
Hot Water	28.2 kW	12.3 kW	7.1 kW
Pump	0 kW	0 kW	1.4 kW
Power Usage	126.8 kW	79.2 kW	78.9 kW
Power Usage	100%	62%	62%

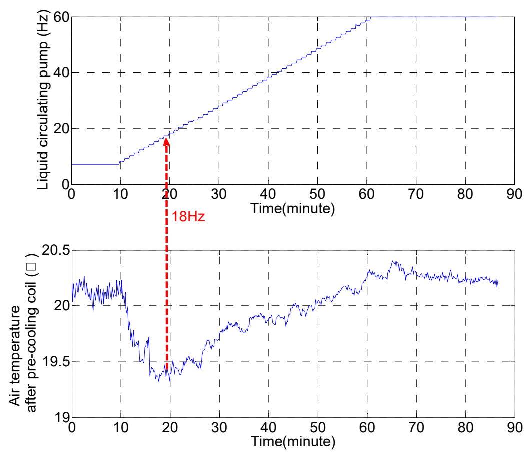

Figure 3: Temperature difference along with pump tuning with an inverter.

ENTHALPY CONTROL FOR SEASONAL CHANGES

We use enthalpy control for seasonal changes. In general, the air damper of an AHU can be controlled with a 10% opening to introduce fresh air. When the fresh air temperature is lower than the return air temperature, we open the damper more to save energy. According to the psychrometric chart, as shown in Fig. 4, the damper opening, can be controlled more efficiently based on enthalpy than temperature. Operating in zone A (Fig. 4) at a lower dry temperature and higher humidity leads to a higher load for dehumidification, while operating in zone C at a lower dry temperature and humidity can decrease the required cooling capacity. Therefore, we regulate the damper open settings for the fresh and return air by a new control logic to optimize energy efficiency and control stability.

Figure 5 shows that the enthalpy can be controlled to around 36.7 kJ/kg by adjusting the damper when the fresh air enthalpy is lower than the return air enthalpy as shown in Zone A of Fig. 5. If the mixing air enthalpy is higher than the setpoint, the damper will be fully opened as shown in Zone B of Fig. 5. Once the fresh air enthalpy is higher than the return air enthalpy, the damper will be kept at a constant 10% opening to maintain supply air quality as shown in Zone C of Fig. 5. Therefore, the cooling capacity can be evaluated by mixing air enthalpy to obtain the lowest energy usage.

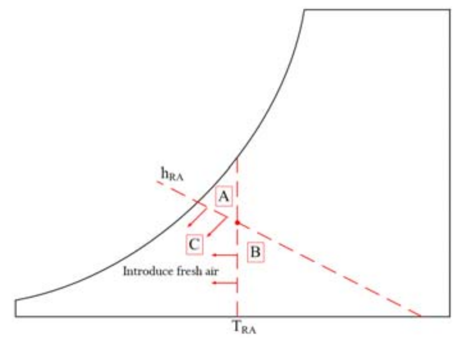

Figure 4: Difference of damper control between enthalpy and temperature on Psychrometric chart.

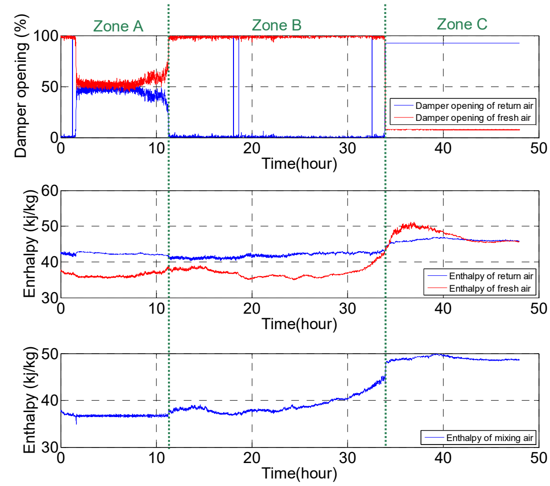

Figure 5: Enthalpy control of the damper opening.

CONCLUSION

This paper presents some heat recovery models and enthalpy controls to determine the practical influences of power usage. The efforts are devoted to developing a set of AHUs with high temperature stability and efficient energy usage at the same time. These upgrade schemes will be implemented at the Taiwan Photon Source in the future.

ACKNOWLEDGEMENT

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