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EXPERIMENTAL STUDY OF THE CIRCULATION AIR VOLUME OF RECIRCULATION EVAPORATIVE COOLING

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ABSTRACT

This paper introduces the technology of re-circulation evaporative cooling (REC), which uses a portion of supply air as secondary air to make cool water used to indirectly cool outside air through a heat exchanger. The circulation volume of secondary air is one of the main factors that have an impact on the effectiveness of REC. According to the technology, a set of apparatus was set up. The cooling effect was tested under different circulation volumes of secondary air in summer. The test results show that the cooling effectiveness rapidly increases and then levels off with the increase of the ratio of circulation volume. We conclude that there is a proper range of the circulation volume.

KEYWORD: Re-circulation evaporative cooling; effectiveness; Experimental study; Circulation air volume; Evaporative cooling

INTRODUCTION

Evaporative cooling technology is a new way with characteristics of saving-energy, environmental protection and improving the IAQ, which can pro- mote the energy efficiency in the buildings. Evaporative cooling is used for some public and civil buildings in the low humidity areas of the china northwest specially in the some districts of Sinkiang. How to extend the use range of evaporative cooling in different climates and how to promote the efficiency of evaporative cooling have been becoming a focus research project. For the former issue, different combinations of direct evaporative cooling, indirect evaporative cooling and conventional mechanical cooling are main methods to get thermal comfort. For the latter issue, the main ways are to promote the efficiency of heat and mass transfer.
Basing on the technology of direct and indirect evaporative cooling, a method of re-circulation evaporative cooling is put forward in this paper. In the common indirect evaporative cooling (IEC), primary air and secondary air both are outdoor air. If improve the IEC as follow: utilize a portion of supply air(circulation air volume) as secondary air to make cool water by direct evaporative cooling(DEC) , then employ the cool water to indirectly cool the primary air through a water-to-air heat ex- changer. This method is re-circulation evaporative cooling (Fig.1).
In the case of actual weather in summer, the pa- per studied the rate of circulation air to supply air volume is how to influence the efficiency of evaporative cooling by doing many

experiments. As a result, a proper rate of circulation air to supply air volume is got.

EXPERIMENTAL SETUP

The experimental set consists of re-circulation evaporative cooling apparatus, measuring instruments and data collection system.

2.1 Recirculation evaporative cooling Apparatus

This apparatus mainly consists of a direct evaporative cooler and an indirect evaporative cooler. The pads are key components of direct evaporative cooler which influence the efficiency. The most popular evaporative coolers employ two categories of cooler pads: aspen excelsior and rigid cellulose media. .In our laboratory experiment. The rigid pads of Celdek7090 are chosen due to good properties of chemically inert, easily absorbent and longer useful life. Indirect heat exchanger of indirect evaporative cooler is air-to-water heat exchanger. The rated volume of fan is 3000m^3/hr.

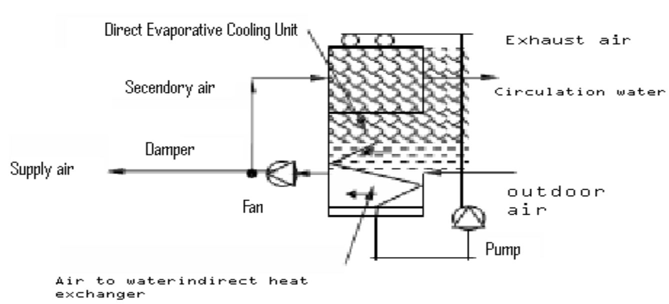

Fig. 1: Schematic of a re-circulation evaporative cooling

The air volume can be continuously adjusted by an inverter. The ducts are 320*250 rectangle made of PVC with heat preservation. The chilled-water made by DEC indirectly cools the primary air through a water-to-air heat exchanger. After absorbing heat the water comes back to the direct evaporative cooler. The pump keeps water re-circulating. The main components are listed in table 1. Here is the view of the REC apparatus (Fig2).

Tab.1: The physical dimensions and models of the main components.

Description	Model	Specification
Direct Evaporative cooler	no	400x400x600mm
Indirect Evaporative cooler	no	3000m^3/hr
Rigid media pad	Celdek7090	400x400x150mm
Inverter	HB280-3022	380V, 5.5A

2.2 Measure and Data Collection System

The main measured parameters are the dry-bulb and wet-bulb temperature of air and the air volume in the course of test. The volume of air flow is measured trough the method of speed & area by Pitot tubes. The dry-bulb and wet-bulb temperatures of air flow are measured trough T-type thermocouple. The temperature data are collected and downloaded to a computer by model 2700 data acquisition system.

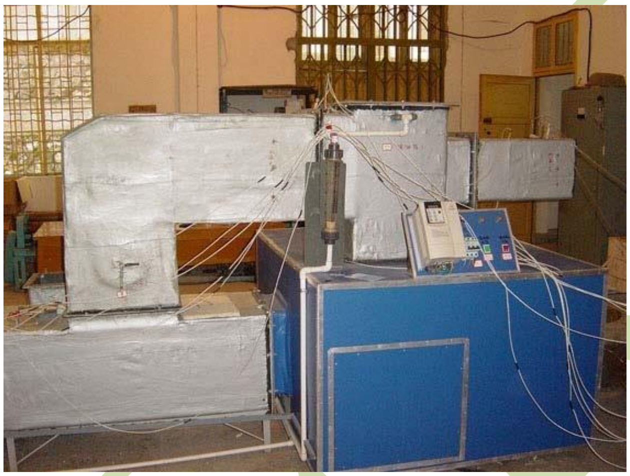

Fig2 view of the REC apparatus

EXPERIMENT METHODS

Our research objective is to determine the effect of different rate of circulation air to supply air volume on the efficiency of evaporative cooling. Therefore, to avoid the effect of other factors we kept the flux of the circulation water as maximum 1650liter/hr, and control the influx of outdoor air about 2200m^3/hr by regulating the inverter so as to keep the velocity of air flow about 1.8m/s in the pads. Then adjusted the damper of duct to acquire seven different rate of circulation air. When the system was steady-going at some rate of circulation air the dry bulb and wet bulb temperatures of outdoor air, secondary air (circulation air) and exhausted air were measured by the data collection system automatically.

TEST RESULTS AND ANALYSIS

Following the definition of the IEC efficiency, we defined REC efficiency as described:

$$Er = (t1 - t2) / (t1 - t1s) \qquad (1)$$

Where Er is the effectiveness of REC; t_1 is the dry-bulb temperature(DBT) of primary air(^{0}C); t_2 is the dry-bulb temperature(DBT) of supply air (^{0}C), t_{1s} is the wet-bulb temperature(WBT) of primary air(℃). Following the definition of REC as shown we have done data processing. Here are the results as table 2.

The data processing results:

DBT of Primary air	WBT of Primary air	DBT of Supply air	The ratio of secondary to primary air	*Er*
32.26	26.30	28.36	23%	0.65
31.44	26.10	27.80	33%	0.68
31.13	26.40	27.33	38%	0.80
32.77	25.76	27.16	50%	0.80
32.46	26.47	27.33	61%	0.86
32.73	26.22	26.86	71%	0.88
33.07	26.19	26.91	80%	0.89

As shown in table 2 when the relative humidity of primary air is in the range 60%~65%, the primary air DBT is lowed about 3.6~6 ℃ while the humidity ratio remains constant through the process of REC.
Here is the relationship between the rate of circulation air and the efficiency of evaporative cooling(Fig.3).

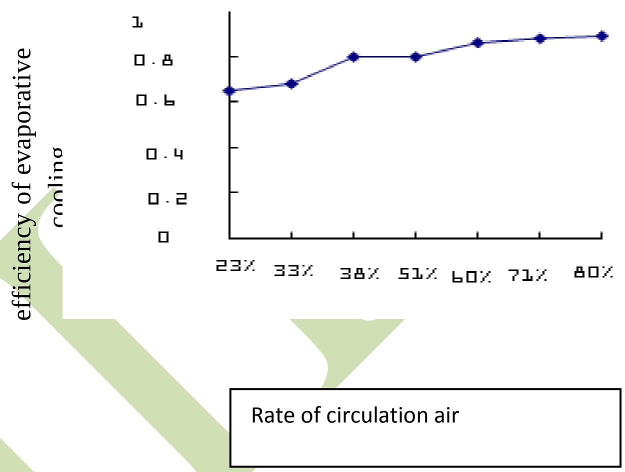

Fig.3 Relationship b/w the rate of circulation air & the efficiency of evaporative cooling

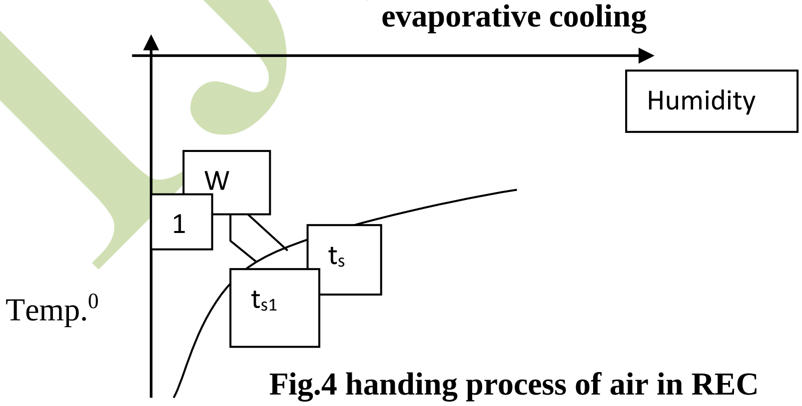

Fig.4 handing process of air in REC

As shown table and Fig.3, we can know that the efficiency of evaporative cooling goes up from 0.68 to 0.80 rapidly while the rate of circulation air increases from 33% to 38%, and the efficiency of evaporative cooling only varies from 0.80 to 0.86 when the rate of circulation air from 51% to 60%. But it is known that the increase of the rate of cir- culation air means the decrease of supply air vol- ume. The part of fan energy is used in transporting the circulation air. According to Fig.3 we can find that the rise of the efficiency of evaporative cooling becomes slow when the rate of circulation air adds up to about 40%. Accordingly, the proper ratio of secondary air to primary air is about 40%.

What is the merit in using the circulation air as secondary air? According to Fig.4, W point ex- presses the state of outdoor air, ts is its wet-bulb temperature. After re-circulation evaporative cool- ing the state point reaches the point 1, where ts1 is its wet-bulb temperature. Obviously, ts is bigger than ts1 in numerical valve. So using a portion of supply air as secondary air for DEC, the tempera- ture of the cold water made by DEC must be less than that of the cold water by using outdoor air. Accordingly, the supply air of REC should be cooler than that of IEC. Basing on the formula (1), the efficiency of REC will be higher than that of IEC when the rate of circulation air adds up to 40%.

CONCLUSION

The innovation of REC compared with IEC is: the temperature of supply air is lower in the same conditions such as same state of outdoor air and the same heat exchanger. Hence it extends the use range of evaporative cooling in different climates and promotes the efficiency of evaporative cooling.

The rate of circulation air will influence the ef- ficiency of evaporative cooling and the state of the supply air. The rise of the efficiency of evaporative cooling becomes slow when the rate of circulation air adds up to about 40%. Accordingly, the proper ratio of secondary air to primary air is about 40%.

Because the experiment data are inadequate the paper only gives a qualitative analysis of the proper range of circulation air. If we want to do a quantificational research on the relationship between the rate of circulation air and the efficiency of evaporative cooling it need do more experiments to get all-around data.

We only do some experiments in summer. It need do more experiments to get more data in other seasons.

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