Experimental study of dew point evaporative cooling air-conditioning unit by inner loop for data-centers buildings

Xiaoqiang Jiang[1*], *Huanjie* Lu[2], *Xiaoming* Chen[2], *Huaming* He[3], and *Hualing* Huang[3]

[1]Shanghai Urban Construction Vocational College, China.

[2]Fujian University of Technology, China.

[3]AOLAN (Fujian) Industrial Co., Ltd, China.

Abstract. According to the climate characteristics, a new dew point evaporative cooling air conditioning unit was design and analysis. Through take return air of the data-center into the dew point evaporative cooling air conditioning unit, then it in dry channel was cooled by wording air come from fresh air at wet channel. The work performance of the unit was test at different outdoor climate conditions of refrigeration performance parameters, and take a data-center project of Lanzhou as an example, the potential of energy saving and economic were analysis. Result showed the energy saving effect was significant and economic recovery within 1.5 years.

1 Introduction

With the rapid development of the Internet plus information technology, the construction of large data center showed a rapid growth trend, financial, communications, electric power, petrochemical, and other large commercial industries have set up their own data center. According to authoritative statistics from 2011 to 2013 in the first half of the national total planning and construction data center 255, has been put into use 173, with a total land of about 7 million 132 thousand square meters, with a total room area of about 4 million square meters. The establishment of large data centers, the power supply has a huge impact, has become a high energy consumption of the industry. Due to the large area and other issues, some data centers have been transferred from the central city to the northwest region (wide, electric power). Due to the continuous operation of the data center throughout the year, the annual cooling, so the air conditioning energy consumption accounts for about 30-45% of the total energy consumption of the data center. Reduce data center energy consumption, research and development of air conditioning equipment applicable to the data center, has become a hot spot for the development of the industry.

2 Characteristics of cooling load and common cooling schemes

2.1 Characteristic of cooling load

Due to the electronic equipment heat release a large amount at work, in order to guarantee the normal operation of the equipment, must be cool to cool the interior and equipment. Because indoor few personnel, so the load characteristic of data center is: a, big load density, year-round operation need cooling; Second, give priority to with sensible heat, usually without moisture load, and even in part time if need to add wet in winter.

* Corresponding author: jxqiang2007@163.com

2.2 The common cooling scheme

About data center cooling equipment and the current scheme, main can be divided into three categories. A precision (constant temperature and humidity) and conventional air conditioning cooling. Consider data center cooling temperature and temperature fluctuation for small. At the beginning of the cooling scheme, the equipment investment, operation of the high cost of energy consumption and running. Second, the equipment room dedicated air conditioning equipment. This kind of cooling equipment, considering the data center without considering the characteristics of the dehumidification, improved the refrigerant evaporation temperature so as to improve the work efficiency of the air conditioning unit. The operation of the rooms is lower than conventional precision air conditioning sets. Three, use (direct evaporative air conditioner) and precision air conditioning cooling scheme. In some areas, some climate conditions, make full use of by running an evaporative air conditioner outdoor natural cold source, reduce the operational time and precision air conditioning energy consumption. This kind of project investment is larger, but less operation cost.

With the expansion of the scale and quantity data center construction, optimizing the data center cooling scheme is imminent. Current some data centers use of precision air conditioning and an evaporative air conditioner joint operation scheme, although with the advantages of energy saving significantly, but because most data centers were built in remote areas, outdoor air quality is poorer, if use direct evaporative air conditioner, poor outdoor air directly into the room inside, will seriously affect the normal operation of electronic equipment and reduce the service life of the equipment; At the same time, direct evaporative air conditioner by wet.

Therefore, this paper designed a circulating inside the dew point evaporative cooling air conditioning unit, made full use of outdoor natural cold source, and to ensure that the poor quality of outdoor air not enter indoor affect the equipment operation.

3 Design of the dew point evaporative cooling air conditioning unit

The inner loop mode, that is, let indoor return air flows through the evaporative cooling equipment, and after cooling to continue into the interior, because the return is not mixed with air, it guarantee the indoor air quality is not affected by outdoor air; At the same time, there is no change in the moisture content of air return, will not lead to equipment failure due to high humidity.

Based on the above assumptions, by adopting the combination of direct and indirect evaporation cooling technology, in the dry wet bulb temperature of air as the driving force, the difference between the fresh air and return air, the heat transfer between the minimum supply air temperature can be reaching the dew point temperature of the outdoor air. The enthalpy wet diagram as shown in Fig.1.

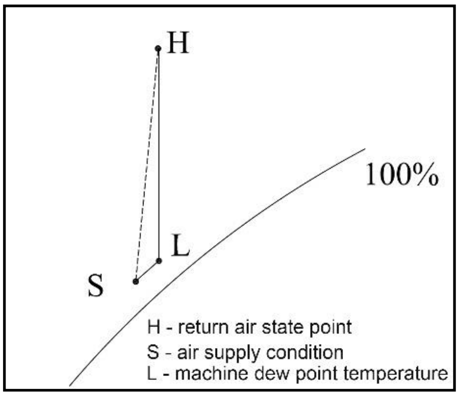

Fig.1. Enthalpy humidity diagram of Dew point evaporative cooling by Internal circulation

In Fig.1 H point for the data center, indoor design temperature, dry bulb temperature is 17-27 ℃, relative humidity of about 50%. Return air flows through the indirect evaporative cooling air conditioning unit, heat exchange with fresh air. This kind of indirect evaporative cooling air conditioning unit, not only to return air humidification, and under the certain condition of climate dehumidification is also available.

When the fresh air through the filter into the refrigeration core body; Core body after evaporation liquid water to form water film and take away heat, fresh air will become the work flow of low temperature and humidity air; Work in low temperature air return through the tube wall heat exchange with high temperature, return air is damp or wet but, become output flow of low temperature, to use place, as shown in Fig.2.

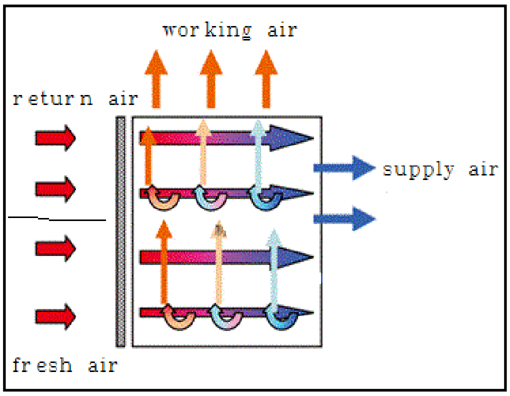

Fig.2. Working principle of the dew point evaporative cooling by Internal circulation

4 Results and discussion

4.1 Test parameters and test platform

According to the working principle of evaporative cooling air conditioning unit, air return type developed corresponding unit, the unit of structure diagram as shown in Fig.3 and Fig.4.

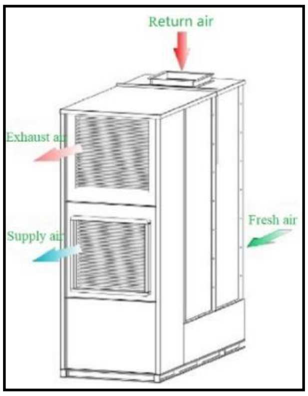

Fig.3. Appearance of return air evaporative cooling air conditioning unit

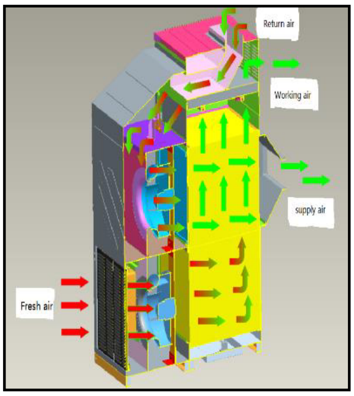

Fig.4. Internal structure diagram of return air evaporative cooling air conditioning unit

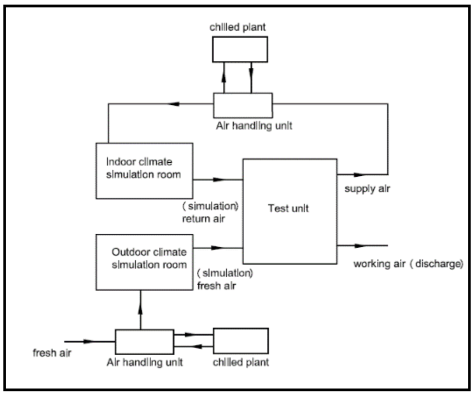

Fig.5. Circulating dew point evaporative air conditioning unit test platform

To find out the return type of evaporative cooling air conditioning unit performance and environmental adaptability, equipment for the performance testing and analysis. Mainly on return air temperature, air supply air flow (output) parameters such as temperature, air temperature, air volume, power consumption was tested. The test platform is shown in Fig.5.

Test platform outdoor climate Chambers, indoor climate Chambers, and by the testing system of three parts. Among them, the outdoor Chambers simulation parameters changing climate throughout the year, through the air conditioning units and air handling units; Interior Chambers simulate interior design climate parameters, also with a set of air conditioning units and air handling units; Unit tested in indoor, two root into the duct from the two Chambers; High temperature and high humidity air exhaust duct to outdoor, supply air into the wind tunnel, after the measurement of temperature and humidity and air flow into the air handling unit (indoor Chambers use).

4.2 Measured results

Considering the inner circulating dew point evaporative air conditioning unit to use all the year round, so during the test, the indoor design parameters according to the data center, return air climate parameters selected for: 24 ℃ dry bulb temperature, wet bulb temperature 18.5 ℃ or so; Outdoor air full range climate parameters, considering the characteristic of evaporative cooling, assuming that the outdoor air temperature change between 9 ℃ to 30 ℃, selected five kinds of climate conditions, the working condition of each point measured five times, and then averaged. Test results are shown in Tab.1.

Tab.1. Under different outdoor climate parameters of test results

Return air Dry bulb temperature /℃	Return air wet bulb temperature /℃	Fresh Air dry bulb temperature /℃	Fresh air wet bulb temperature /℃	Output air dry bulb temperature /℃	Output air wet bulb temperature /℃	Air volume / m³/h	Sensible heat capacity /kW	All heat capacity /kW	The input power /kW	Outlet pressure /Pa	(full heat) can effect comparing
24.00	18.50	9.30	6.00	9.80	9.40	1361.60	6.47	11.12	0.42	2.36	26.48
24.00	18.50	9.40	5.30	12.30	11.70	1431.10	5.61	8.92	0.40	2.74	22.30
24.00	18.60	18.20	12.20	13.40	13.00	1403.10	4.98	7.58	0.42	2.52	18.04
24.00	18.57	23.40	20.00	20.00	17.20	1404.50	1.89	1.89	0.41	2.49	4.60
24.10	18.60	30.70	20.80	20.80	17.50	1395.80	1.54	1.54	0.41	2.40	3.76

4.3 The analysis of experimental results and discussion

According to the result of the return air temperature and humidity measurement, it can be seen that indoor air parameters of Chambers can better maintain the dry bulb temperature 24 ℃, relative humidity 60%, wet bulb temperature at about 18.50 ℃.

When the outdoor climate parameters change, the temperature and humidity of the air supply air flow (output) have great changes, the related refrigerating capacity and can effect comparing also there is a big change. When outdoor temperature is higher, the dry bulb temperature 30.70 ℃, the wet bulb temperature 20.80 ℃, for example, due to air dry bulb temperature and wet bulb temperature difference only 3.3 ℃. The experimental results show that the output air dry bulb temperature can drop to 20.80 ℃, at this point, the return air generating condensate, therefore all refrigerating capacity for sensible heat capacity, can effect comparing is 3.76, higher than general precision air conditioning around 3.0.

When outdoor temperature is low, such as outdoor air dry bulb temperature at around 9 ℃, back to the dry bulb temperature can drop to 9.8 ℃. And as a result of the air temperature is lower than the return air dew point temperature (15.7 ℃), so the return air through the unit with condensed water, refrigerating capacity, including sensible heat capacity and latent heat of the refrigerating capacity. Under the working condition of two points, the sensible heat refrigeration can effect comparing, respectively up to 15 or so, the whole thermal capacity can reach more than 22.

Circulating power of dew point evaporative cooling air conditioning equipment is two main fan and a water pump, fan of the test machine power is about 0.41 kW; Export pressure at about 2.5 Pa.

Circulating within the analysis results show that mentioned above dew point evaporative air conditioning unit in the outdoor climate is not at the same time, the refrigeration capacity and eer is different. To find out the comprehensive energy saving potential of circulating dew point evaporative air conditioning unit, it is necessary to analyze its usage for the whole year.

4.4 Energy saving potential analysis

4.4.1 Output air temperature and humidity change rule

Proven circulating within the energy conserving potential of the dew point evaporative air conditioning unit and its influencing factors, is conducive to the application of engineering design and operation control. Effect in circulating dew point evaporative air conditioning unit energy saving potential under different climate conditions are the main factors of output of air temperature and humidity and refrigerating capacity. For year-round climate output of air temperature and humidity data, the following will be on the basis of the experimental data fitting to get the corresponding empirical formula, and then according to the import and export of enthalpy difference refrigerating capacity.

$$t_{sd} = 0.015t_{xs}^2 + 0.3t_{xs} + 7.5 \qquad 0 < t_{xs} \le 6 \quad (1)$$

$$t_{sd} = 0.013t_{xs}^2 + 0.34t_{xs} + 7.33 \qquad 6 < t_{xs} \le 12.2 \quad (2)$$

$$t_{sd} = 0.071t_{xs}^2 - 1.3t_{xs} + 18.86 \qquad 12.2 < t_{xs} \le 34 \quad (3)$$

Under different wet bulb temperature cooling effect is also different. According to the comparison of fitting results and the experimental results, the above formula can be drawn from the error is within 10%.

4.4.2 Engineering case analysis

In a data center room project as an example, in Lanzhou internally circulating the energy conserving potential of the dew point evaporative air conditioning unit are analyzed. The project for small data center, precision air conditioner and circulate in evaporative cooling air conditioning unit according to 1:1 configuration.

Distribution of all-year hourly wet bulb temperature interval in lanzhou, hours, corresponding to the unit under the condition of refrigeration capacity are shown in table 2, and output of return air it for fixed air volume for 1500 m3 / h, fixed return air conditions for 24 ℃ dry bulb temperature, wet bulb temperature of 18.5 ℃, the dew point temperature 15.7 ℃, the absolute moisture content of 11.3 g/kg.

Consider below 0 ℃ water condensation phenomenon will happen, so set preconditions for the working temperature of wet bulb temperature greater than 0 ℃. According to the all-year hourly climatic data in Lanzhou, wet bulb temperature greater than 0 ℃ time number is 6102, the highest temperature of 21.5 ℃. In fact, when the outdoor air wet bulb temperature is lower than 0 ℃, dew point evaporative cooling unit can still as air - air heat exchanger, cold quantity for the data center. Did not limited to, below are analyzed.

From tab.2, you can see that under different outdoor conditions, the refrigeration capacity of the unit is different. With the increase of outdoor dry wet bulb temperature, output air temperature will increase; When outdoor wet-bulb temperature above 18 ℃, refrigerating capacity becomes a negative, that there is not only not refrigeration, instead of return air heating. With the outdoor air enthalpy value is greater than the return air enthalpy. It also can be seen that some climate throughout the year, unfavorable open the inner loop of indirect evaporative cooling unit.

Tab.2. Outdoor wet-bulb temperature statistics in Lanzhou and the corresponding working conditions of refrigeration capacity

Wet bulb temperature range ℃	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22
Number of time	550	534	526	524	646	614	736	991	691	278	12
Average dry bulb temperature℃	4.6	7.1	9.6	12.6	14.5	17.0	18.8	20.9	23.9	27.3	29.7
Average wet bulb temperature℃	1.0	3.0	5.0	7.0	9.0	11.0	13.0	15.0	17.0	19.0	21.0
Output air temperature℃	7.8	8.5	9.4	10.3	11.4	12.6	14.0	15.3	17.3	19.8	22.9
Output of air relative humidity %	95	95	95	95	95	95	95	95	90.4	77.4	64
Wind enthalpy kJ/kg	22.9	24.4	26.3	28.4	30.8	33.7	36.9	40.5	46.0	48.7	51.9
Refrigerating capacity kW	15.0	14.3	13.3	12.3	11.1	9.6	8.0	6.2	3.5	2.1	0.5
Total Refrigerating capacity kW	825 0	761 2	701 4	643 9	713 8	5915	5888	6154	2443	584	-

Note: 1, when output air temperature is lower than 15.7 ℃, the output air relative humidity of 95%; 2, when the output air temperature is higher than the return air dew point temperature, air relative humidity according to the output; 3, when the air wet bulb temperature above 20 ℃, open the dew point evaporative units is not recommended.

Are shown in table 2, in the year to provide refrigerating capacity is 57439 kW. Using traditional precision air conditioning cold quantity, it can effect comparing is 4.5, provides 57439 kW refrigerating capacity to 12764 KWH. Circulating within a dew point evaporative air conditioning unit at full capacity run 6090 hours, rated power is 0.42 kW, is an electricity consumption of 2558 year saves 10206 KWH, save electricity, 10206 yuan (electricity by 1 yuan/degree computer), rated water consumption for 44 kg/h, running 6090 hours, 268 tons of water consumption, costs 804 $ (water price by 3 $/ton). Set the unit cost is 10000 $, the payback period is 1.5 years.

5 Conclusions

For dry and outdoor air quality is poorer regions, we design a dew point evaporative, indirect cooling circulating inside the dew point evaporative cooling air conditioning unit, after performance testing and energy saving potential analysis, can get the following conclusion:

1) test conditions, the circulating of dew point evaporative cooling air conditioning unit can be up to 26.48 what effect;

2) when the outdoor air wet bulb temperature is greater than 20 ℃, the low efficiency of circulating dew point evaporative cooling air conditioning, strong suggestion unit;

3) the climate in Lanzhou area as an example, the use of circulating inside the dew point evaporative cooling air conditioning unit, energy-saving effect is remarkable, the economic recovery period in 1.5 years.

Acknowledgments

This study was supported by Fujian Provincial Science and Technology Plan Pilot Project (Project No.2019H01010175).

References

1. X. Huang. Evaporative cooling air conditioning theory and application [M]. Beijing: China building industry press, 2010.
2. V. Maisotsenko, L. Gillan. The Maisotsenko cycle for air desiccant cooling[C]. The 4th International Symposium on HVAC,2003.
3. JY. Yi. Genius can wet air conditioner [J]. Journal of hvac, 2000, 30 (3):46 and 47.
4. CHOI. Bong Su, HONG. HiKi, LEE. Dae-Young.Optimal configuration for a compact regenerative evaporative cooler[C]MThe 3rd Asian conference on refrigeration and air-conditioning. Gyeongju, 2006:697-700.
5. Jl. Liu, X. Huang，Z. Sun. New composite dew point indirect evaporative cooling air conditioning unit test research [J]. Journal of fluid machinery, 2014,42(5):61-66.
6. X. Huang，XW. Liu，ZX. Wu. Dew point indirect - direct evaporative cooling air conditioning unit of the experimental study [J]. Journal of hvac ， 2011,41(5):104-108.
7. B. Riangvilaikul, S. Kumar. An experimental study of a novel dew point evaporative cooling system[J].Energy and Building,2010,42(5):637-644.
8. M. Jradi, S. Riffat. Experimental and numerical investigation of a dew-point cooling system for thermal comfort in buildings.Applied Energy, 2014,132(1):524-535.
9. MS. Buker, B. Mempouo, SB. Riffat. Experimental investigation of a building integrated photovoltaic/thermal roof collector combined with a liquid desiccant enhanced indirect evaporative cooling system.Energy Conversion and Management, 2015,101(1): 239-254.
10. X. Cui, K.J. Chua, W.M. Yang. Numerical simulation of a novel energy-efficient dew-point evaporative air cooler. Applied Energy,2014,136(11): 979-988.
11. WZ. Gaoa,∗, W. William, K. Vinaykumar. Numerical study on performance of a desiccant cooling system with indirect evaporative cooler. Energy and Buildings,2015,86(1):16–24.
12. X.Cui,K.J.Chua,W.M.Yang.Studying the performan ce ofan improved dew-point evaporative design for cooling application.App lied Thermal Engineering, 2014,63(2): 624-633.
13. S. Anisimov, D. Pandelidis. Theoretical study ofthe basic cycles for indirect eva porative air cooling. International Journal of Heat and Mass Transfer, 2015,84(5): 974-989.