Test Research on Air-conditioning Water Chiller of an Office Building

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Abstract. In this paper, an office building in Beijing is taken as the research object. This collected the operation data of the air-conditioning water chiller on a typical summer day. The performance of the air-conditioning water chilling unit and system is tested. This evaluates energy efficiency according to national standards and puts forward optimization suggestions. The results show that under low-load operation, the performance coefficient of the chiller reaches the detection index, but the efficiency of the air conditioning system is low. It is recommended to reduce the number of corresponding air conditioning equipment to optimize the performance coefficient of the air conditioning system. And the chiller can be installed a frequency conversion device to improve the operating performance of the chiller.

1. Introduction
In recent years, energy and environmental issues have gradually become important factors restricting the survival and development of human beings. Energy conservation, emission reduction and building energy conservation have attracted more and more attention. The air conditioning system provides building users with a comfortable and healthy indoor environment. A well-designed air conditioning system can greatly reduce operating energy consumption[1]. Air-conditioning energy saving is mainly reflected in the improvement of the energy efficiency of air conditioning equipment or systems, performance testing of chillers and systems[2]. And further energy-saving optimization is of great significance for energy-saving research of air conditioning systems.

2. Project Overview
2.1. Project status
This project is an office building in Beijing, with a total building area of 38520 m², and the equipment room on the first floor of the underground building. The end of the air conditioning system is a fan coil unit. The fresh air naturally permeates through doors and windows. The air flow is organized from top to back.

2.2. Equipment
In summer, the cold source of the air conditioning system is provided by two screw chillers on the basement floor to produce chilled water at 7~12 ℃. Figure 1 shows the physical map of the screw chiller. The equipment parameters are shown in Table 1.
Table 1. Water chiller equipment parameter table.

| Number | Device name       | Refrigerating capacity (kW) | Power (kW) | COP | Quantity |
|--------|-------------------|-----------------------------|------------|-----|----------|
| 1      | Screw chiller     | 1452                        | 288        | 5.0 | 2        |

The air conditioning system is equipped with 3 chilled water circulating pumps, 3 cooling water circulating pumps, and 2 supplementary water pump. Figure 2 shows the physical diagram of the air conditioning circulating water pump. The parameters of each pump are shown in Table 2.

Table 2. Pump parameter table.

| Number | Device name                        | Flow (m³/h) | Head (m) | Power (kW) | Number |
|--------|-----------------------------------|-------------|----------|------------|--------|
| 1      | Chilled water circulation pump    | 300         | 38       | 55         | 3      |
| 2      | Cooling water circulation pump    | 400         | 32       | 75         | 3      |
| 3      | Air conditioning water supply pump| 12          | 50       | 4          | 2      |

3. Testing and evaluation program

3.1. Testing equipment and content

Table 3. Test Instruments and Content.

| Test instrument          | Test content                                      |
|--------------------------|---------------------------------------------------|
| Ultrasonic Flowmeter     | Chilled water flow; cooling water flow            |
| Clamp Power Meter        | Water chiller power; water pump power             |
| Contact Thermometer      | Wall temperature of chilled water pipe;           |
|                          | wall temperature of cooling water pipe            |

3.2. Testing condition

According to the standard[3], the chillers should be tested under a stable load, and the test time should be more than 1 hour. This test selects a typical summer day. On the test day, 1 chiller, 2 chilled water circulating pumps, 2 cooling water circulating pumps, and 2 cooling towers were operated.

3.3. Testing process

3.3.1. Install Ultrasonic Flowmeter to test flow

Determine the flow measuring point (The position where the sensor is installed). Lubricate, remove and remove the paint at the flow measuring point pipe. Install and secure the slide rails. Install the
sensor and connect it to the monitor. When the test conditions are stable, the number of readings is taken every 10 minutes and the average value of each reading is taken continuously for 60 minutes as the measured value of the test.

Figure 3. Lubricate, remove and remove the paint at the flow measuring pipe.  

Figure 4. Installed the Ultrasonic Flowmeter.

3.3.2. Test power using a clamp-type Power Meter  
Open the control panel of the water chiller and the water pump. Connect the jaws and connectors of the clamp Power Meter to the various connections of the internal circuit of the control panel (The jaw clamp is on the wire to be tested, and the metal clip connected to the interface is connected to the live wire and Zero line). Wait for the indicator to stabilize and read the voltage and current indication. The number of readings is taken every 10 minutes and the average value of each reading is taken continuously for 60 minutes as the measured value of the test.

Figure 5. Installing a clamp-type Power Meter.  

Figure 6. Record the clamp-type Power Meter readings.

3.3.3. Install a Contact Thermometer to test the temperature.  
Select the appropriate test point. Disassemble the insulation material and attach the temperature sensing end of the Contact Thermometer to the wall of the pipe. Cover it with insulation material and fix it at the test point. When the test conditions are stable, the number of readings is taken every 10 minutes and the average value of each reading is taken continuously for 60 minutes as the measured value of the test.

3.3.4. Test water pump pressure  
The pressure measuring points should be set at the inlet and outlet of the water pump. Since the pressure gauges that meet the requirements are installed before and after the water pump, the pressure value can be directly read.
4. Test results and data analysis

4.1. Test results in the cooling condition
The actual coefficient of performance of the compression cycle chiller ($COP_d$) should be calculated according to Formula 2:

$$COP_d = \frac{Q_0}{N_i}$$  

In the formula:

- $Q_0$ — Cooling supply of the chiller unit (kW);
- $COP_d$ — Actual number of pieces of the electric-driven chiller;
- $N_i$ — The average input power of the unit under test conditions (kW).

4.2. Test results of the Water Chiller

Table 4. Calculation table of chillers test results.

| Serial number | Test content                          | Test Results | Average value |
|---------------|--------------------------------------|--------------|---------------|
| 1             | Chilled water supply temperature(℃)  | 13.3 13.4 13.4 13.4 | 13.5 13.5 13.4 |
| 2             | Chilled water return temperature(℃)  | 9.9 10.0 10.0 10.0 | 10.1 10.2 10.0 |
| 3             | Average temperature difference between import and export(℃) | 3.4 |
| 4             | Chilled water flow(m³/h)             | 323.8 322.5 323.4 323.0 | 322.9 323.6 323.2 |
| 5             | Density(kg/m³)                       | 999 |
| 6             | Specific heat capacity [J/(kg·°C)]   | 4.18 |
| 7             | Cooling capacity(kW)                | 1270.46 |
| 8             | Unit input power(kW)                | 262.26 |
| 9             | $COP_d$                              | 4.84 |

According to the standard [4], the evaluation index of the gas compression cycle chilled water unit of the electric drive compressor under the rated cooling conditions and specified conditions, when the cooling capacity exceeds 1163 kW ($COP_d$) should be greater than 4.60. Through calculation, the COP of the chiller is 4.84, which is greater than 4.60 and meets the requirements of the assessment index.

4.3. Test results of the air conditioning system
According to the standard [3], the actual coefficient of performance ($COP_s$) of the air conditioning system should be calculated as follows:

$$COP_s = \frac{Q_0}{N_i + p_0 + p_1}$$  

In the formula:

- $COP_s$ — The actual coefficient of performance of the air conditioning system;
- $N_i$ — The average input power of the unit under test conditions (kW);
- $p_0$ — Average input power of water pump (kW);
- $p_1$ — Cooling tower input power (kW).

Table 5. Calculation table of the air conditioning system test results.

| Serial number | Test content               | Test Results | 1# | 2# |
|---------------|---------------------------|--------------|-----|-----|
| 1             | Unit cooling capacity (kJ) | 1270.46      | 0.00 |
According to the Standard[5], since the rated air conditioning capacity of the air conditioning system of this project is more than 1758 kW, the system energy efficiency assessment standard: the system COP of the three-level energy efficiency should be not less than 3.50, the COP of the secondary energy efficiency system should not be less than 4.10, and the COP of the primary energy efficiency system should not be less than 5.00.

By calculating, the COP of the entire air conditioning system is 2.33, which is lower than the three-level energy efficiency assessment index(3.20). The main reason is that only one chiller was operated during the test phase, but 2 chilled water circulating pumps, 2 cooling water circulating pumps, and 2 cooling towers were all operating normally. The increased power consumption of the system resulted in a lower coefficient of performance.

5. Conclusion
The performance coefficient of the chiller in this project is greater than the assessment index, and the COP of the air conditioning system is lower than the inspection index requirement. It is recommended to reduce the number of chilled water pumps, cooling water pumps and cooling towers to restore the coefficient of performance of the air conditioning system to a greater level.

Since the air conditioning unit is the main energy-consuming equipment of the air conditioning system, a frequency conversion device can be added to the chiller to change the compressor operating frequency according to actual need. It can save power consumption, improve the operating performance of the chiller and optimize the coefficient of performance of the air conditioning system.

References
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