AIR TEMPERATURE ANALYSIS AND CONTROL IMPROVEMENT FOR THE INJECTION AREA AT TLS

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Abstract

This paper presents the air temperature analysis and control improvement for the injection area at the Taiwan Light Source (TLS). The injector consists of a 50-MeV LINAC and a 1.5-GeV booster synchrotron. Because of insufficient cooling capacity, the air temperature was too high (> 27 ^{o}C) and the temporal temperature variation was more than 2 ^{o}C in one day. The air relative humidity was often higher than 60%. The problem of insufficient cooling capacity became more serious after the top-up mode operation. To cope with the above-mentioned thermal problem, the cooling capacity was increased and the PID parameter of the temperature control was also optimized. Totally 27 temperature sensors were distributed in this area to on-line record the air temperature history. The temperature control was improved to suppress temporal temperature variation within ± 0.1^{o}C. The air humidity was also much improved than ever.

INTRODUCTION

We had studied the utility effects on beam quality [1] [2] to verify those effects on the stability of the electron beam orbit at TLS. According to those studies, thermal effect is one of the most critical mechanical factors affecting the beam stability. Accordingly, we had conducted a series of air conditioning (A/C) system improvements of the storage ring and applied the numerical simulation to analyze the flow field and temperature distribution. Those A/C improvements and analyses had been respectively conducted on the experimental hall [3], the storage ring tunnel [4] and the core area of technical equipment [5]. However, the cooling capacity of the injection area was insufficient to keep air temperature low and steady enough three years ago. This thermal problem would become worse after the project of the top-up injection mode was launched because waste heat generated by the top-up injection mode is steadier but much higher than that generated by the decay mode.

Figure 1 shows the 3D schematic drawing of the injection area, which includes the booster area and the transport line area. There are a 50-MeV LINAC and a 1.5-GeV booster synchrotron installed in the booster area. The booster synchrotron is mainly consisted of magnet system, rf system, and vacuum chambers. The transport line is not shown in this figure. Blue ducts and green ducts shown in Figure 1 are supply air ducts and return air ducts, respectively. Air exits and air exhausts are respectively distributed on the ceiling and side walls of the booster area. All air exits and air exhausts are distributed in the ceiling on the transport area.

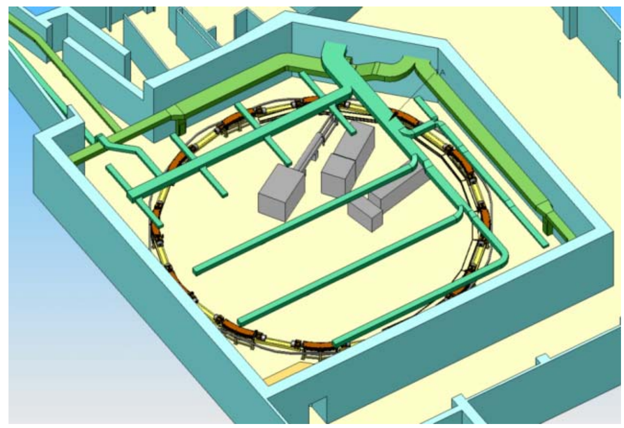

Figure 1: Schematic drawing of the injection area.

COOLING CAPACITY ENHANCEMENT FOR THE TOP-UP INJECTION MODE

As abovementioned, the cooling capacity of the injection area became insufficient while its A/C system was still kept as its original design of 13 years ago. The injection system had been upgraded from its original 1.3-GeV to 1.5-GeV and added some new air-cooled equipment in past decade. The air temperature was usually higher than 27 ^{o}C and the temporal temperature variation was more than 2 ^{o}C in one day even the valve of the cold water was fully opened. The air relative humidity was also often higher than 60% three year ago.

A new AHU was installed to replace the old one in 2004 accordingly. Specifications of both the old and new AHUs are list in the Table 1. The cooling capacity of the new AHU is about double that of the old one, as list in the table.

Table 1: Specifications of the old and new AHUs for the injection area.

AHU Specification		Old	New
Air Flow (CFM)		16900	30000
Fan	Total Static Pressure (in-WG)	3.5	3.5
	RPM	1485	914
	Motor (HP)	20	30
Cooling Coil	Enter air temp(^{o}C DB)	24.8	24.8
	Enter air temp(^{o}C WB)	18.3	18.3
	Face Area (FT^{2})	40.4	71.9
	Energy (RT)	40	80

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EXPERIMENT MEASUREMENTS AND DATA ACQUISITION

To on-line control and monitor the air temperature of the injection area, we install total 27 temperature sensors of PT100 in this area, where 22 and 5 sensors are respectively distributed in the booster and the transport line areas, as shown in Figure 2. Those temperature sensors are also numbered in Figure 2.

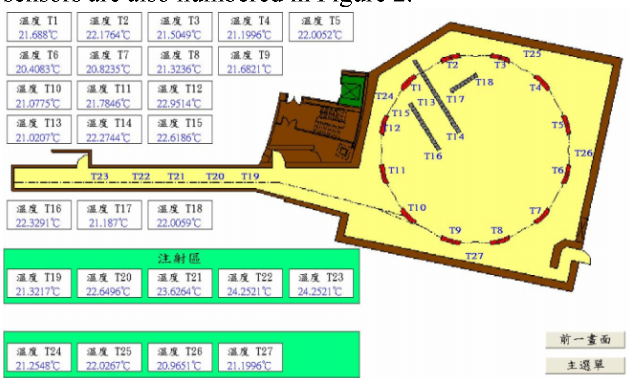

Figure 2: Injection area layout and temperature sensors distribution.

We had also developed a utility archive system to on line monitor thousands of utility parameters. Although each of the utility subsystem, such as the electrical power system, the cooling water system, the A/C system etc. is equipped with its own monitoring and control systems, the utility archive system still successfully integrates all those subsystems. The utility archive system is an integrated software written by the LabView language. This archive system consists of a remote viewer level, a data service level, a data processing level, a control level and a device level. The remote viewer level is opened for all in house and outside users. The archive viewer in the remote viewer level is a software of viewing for the whole archive system. Figure 1 is the network of the utility archive system for the A/C system.

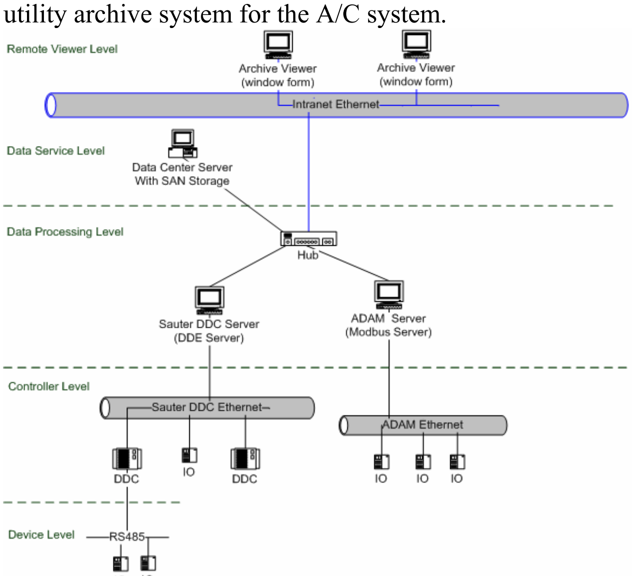

Figure 3: Network of the utility archive system for the A/C system.

TEMPERATURE AND HUMIDITY CONTROL SCHEME

Figure 4 demonstrates the control system of the AHU for the injection area. As shown in the figure, return air from the injection area is mixed with outdoor air then flows through a cold water heat exchanger, which is controlled by a cold water control valve to control the mixed air temperature to 13 °C, where the relative humidity of the air is near saturation and the air temperature is accordingly close to the dew point temperature. Cooled air then flows through a hot water heat exchanger, which is controlled by a hot water control valve to control the mixed air temperature to 17 °C. The relative humidity of the return air from the injection area is controlled within 45% ± 2%.

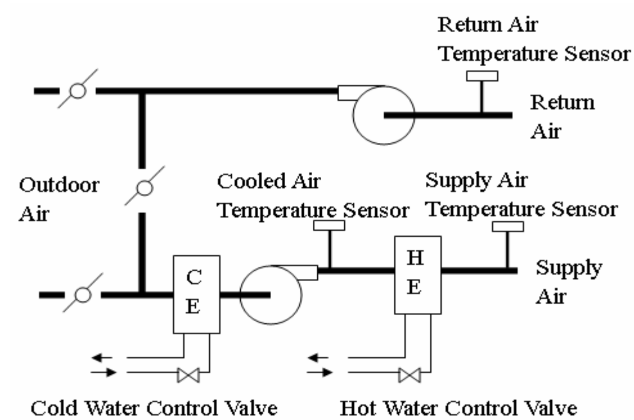

Figure 4: Control system of the AHU.

The basic structure of the controller of the cold water or hot water control valve includes an input variable, a set point variable and PID controller variables. The controller may also be defined as either direct or reverse acting.

The control histories of the new AHU are shown in Figure 5. The dew point temperature, supply air temperature and the return air temperature were stably controlled at 13 °C, 17 °C and 22 °C, respectively. The relative humidity was control at 44%. The openings of the cold water valve and hot water valve were operated at 28% ± 2% and 40% ± 10%, respectively.

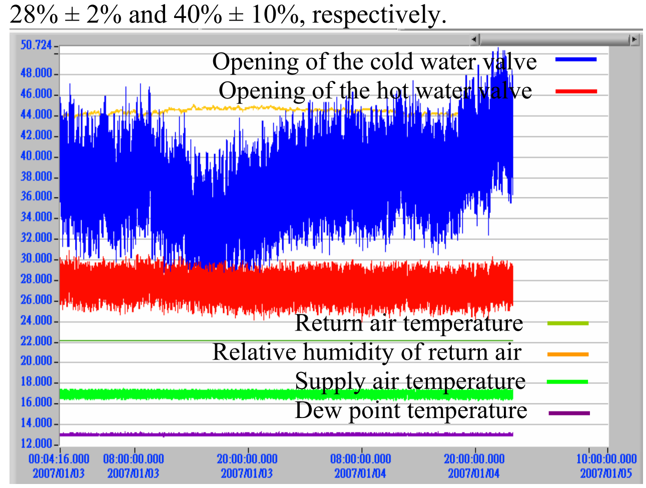

Figure 5: Control histories of the new AHU.

RESULTS AND DISCUSSION

Figure 6 shows the control histories, which were recorded in 2003, of the old AHU. As shown in the figure, the supply air temperature and the return air temperature were controlled at 13 °C, and 20 °C, respectively. However, the relative humidity was about 65% even the openings of the cold water valve was almost kept 100%. This phenomenon reveals insufficient of the cooling capacity of the old AHU.

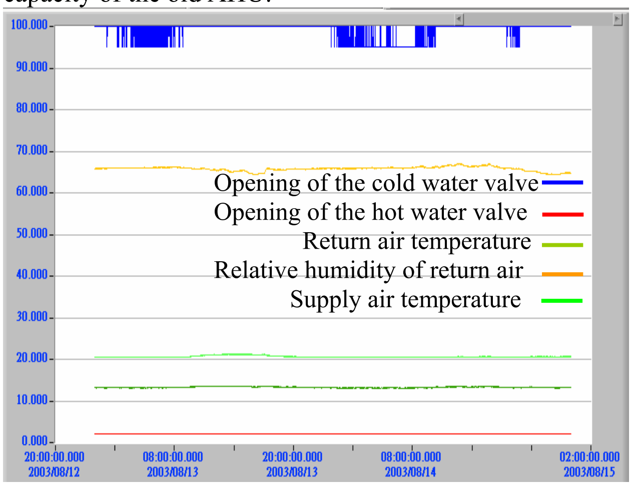

Figure 6: Control histories of the old AHU.

Figure 7 shows eight temperature histories of the injection area. These temperature histories were respectively recorded by sensors 4, 6, 8, 12, 14, 17, 19 and 21, whose locations are shown in Figure 2. Sensors 4, 6, 8 and 12 are respectively located on four sides of the booster synchrotron ring. Sensors 14 and 17 are located on the linac and sensors 19 and 21 are located on the transport line.

Data shown in Figures 5 and 7 were recorded in the same two day, i.e., Jan. 3rd to 5th, 2007. In those two-day temperature histories, almost all temperature variations along time were controlled within ± 0.1°C. Some of those temperature histories even varied less than ± 0.05°C. Those differences of temperature variations were basically influenced by local cooling loads, flow fields and noise to temperature sensors.

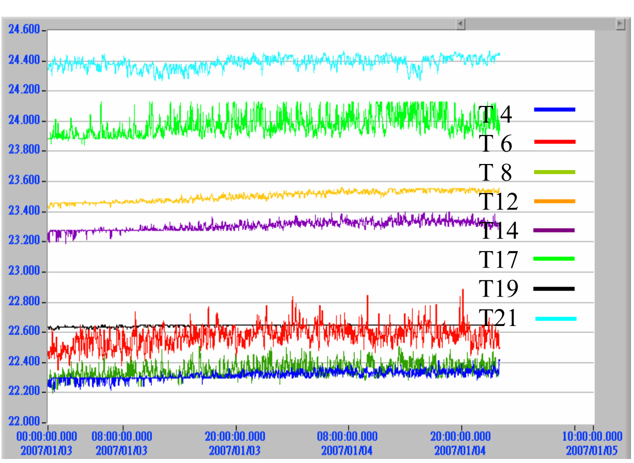

Figure 7: Temperature histories of the injection area.

CONCLUSION AND FUTURE WORKS

We have improved the A/C system by increasing about double cooling capacity of the AHU for the injection area, which includes the booster area and the transport line area. There were 22 and 5 temperature sensors respectively installed in the booster area and the transport line area to online monitor temperature variation. The dew point temperature, the supply air temperature and the return air temperature of the new AHU were stably controlled at 13 °C, 17 °C and 22 °C, respectively. The relative humidity of return air was also control at 45% ± 2%. The temporal temperature variation in the whole injection area is globally controlled within ± 0.1°C more than one day's operation.

However, the spatial temperature differences in the injection area are still more than 2 °C. Local temporal temperature variation is also effected by local cooling loads, flow fields and noise to temperature sensors. Therefore, to improve the local temperature variation, we will perform the numerical simulation to analysis temperature and flow fields in near future.

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