AIR TEMPERATURE ANALYSIS AND IMPROVEMENT FOR THE TECHNICAL ZONE AT TLS

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Abstract

This paper presents the air temperature analysis and improvement for the technical zone, where many critical instrumentations of power supply, rf, vacuum and control apparatuses are located, at the Taiwan Light Source (TLS). The circular-shaped technical zone is located on the core area of the storage ring. The diameter and height of the technical zone are 28.5m and 3m, respectively. Totally 13 temperature sensors are installed in this zone to on-line record the air temperature history. Because of insufficient cooling capacity and poor air circulation of the air-conditioning (A/C) system, the air temperature may reach to 30 ^{o}C and spatial air temperature difference may be more than 7 ^{o}C. To cope with those problems, a computational fluid dynamics (CFD) code is applied to simulate the spatial temperature distribution. The A/C cooling capacity will be increased and the air exit and exhaust distribution will be modified according to the simulated results.

INTRODUCTION

According to our studies of the utility system at TLS, thermal effect is one of the most critical mechanical factors affecting the beam stability [1] [2]. The propagation routes from the temperature variation to the beam quality were also presented. Based on those studies, TLS had made a series of thermal simulation and improvements on the air temperature control of the A/C system for the storage ring. Computational Fluid Dynamics (CFD) technique was applied on the simulation of the air-cooling magnet lattice girder [3]. Mini environment control technique was applied on the elliptical polarization undulator [4] and a beam current monitoring system. We had also made much improvement on air temperature control for the storage ring tunnel in 2003 [5]. The A/C system of the experimental hall was also simulated [6]. After those abovementioned studies and improvements, A/C systems of most areas in the storage ring were remarkably improved.

However, the cooling capacity and temperature control of the core area became worse as some equipment was added these years. This study is aimed to simulate and analysis the A/C system in this technical zone as important references for future improvement.

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COOLING LOAD AND CAPACITY

The technical zone may be basically divided into three areas, i.e., upper area of the RF system, middle area of the magnet power supply system and the lower area of the vacuum system. Figure 1 shows main equipment of each subsystem located in the technical zone.

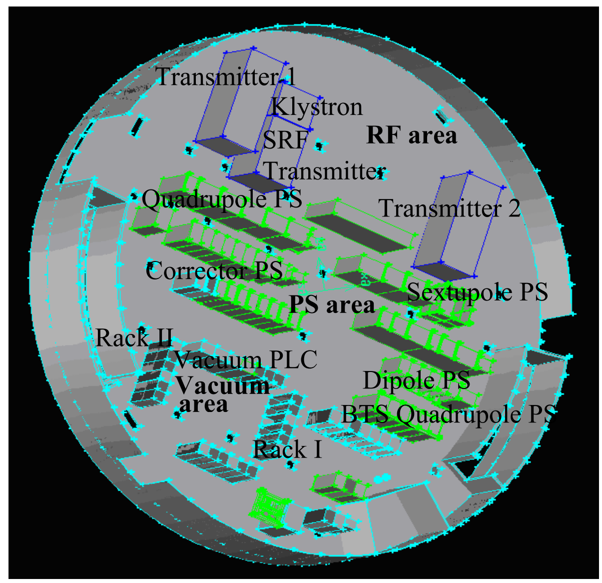

Figure 1: Main equipment of each subsystem located in the technical zone.

Table 1 indicates power input and efficiency of equipment installed in the technical zone. Table 1 shows that the RF equipment consumes high power but performs low efficiency. Power supply system consumes most power and occupies the largest space. Vacuum equipment in the technical zone mainly includes monitor and control apparatuses.

Table 1: Power input and efficiency of equipment in the technical zone

Equipment	Power input	Efficiency
Transmitter I	120 kW	40 %
Transmitter II	120 kW	40 %
Low level	30 kW	90 %
SRF transmitter	200 kW	40 %
Dipole PS	450 kW	75 %
Quadrupole PS	7.5 kW x 18	80 %
Sextupole PS	19 kW x 2	75 %
Corrector PS	400 W x 18	30 %
Rack I, II	80 kW	90 %

There is only one AHU providing the A/C in the technical zone. There are total 33 air exits and 5 air exhausts distributed on the ceiling, which are also illustrated in Figure 1. The specifications of the AHU are listed in Table 2.

Table 2: Specifications of the AHU for the technical zone

Air flow (cfm)	Fan (RPM)	Fan static pressure (in WG)	Motor (HP)	Cooling water flow rate (GPM)
18880	1562	3.5	25	110

TEMPERATURE AND AIR FLOW MEASUREMENTS

To on-line control and monitor the air temperature, we installed 13 temperature sensors of PT100 in the technical zone. The temperature histories are on-line recorded on the archive system. The air flow rate was measured by the TSI flow meter of 8373-M-GB AccuBalanve Plus type. The measurement range is 50~3500m^3/h with ±5% precision. The flow velocity at the air exit was measured by a hot wire equipped in the Testo 400 multi-meter. The measurement range is 0~10 m/s, -20~70 ^{o}C.

Figure 2 shows the 8 temperature histories during one day in the technical zone. The average temperature variation during one day is about ± 0.15 ^{o}C. The maximum spatial temperature difference is about 7.5 ^{o}C. The highest temperature history is RF 1, which is installed near the RF heat source. On the other hand, RF 2 installed in the RF area but away from the heat source shows the lowest temperature.

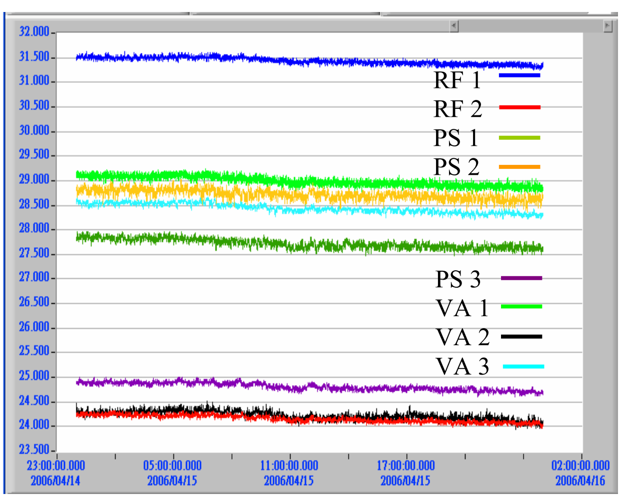

Figure 2: Temperature histories in the technical zone.

Table 3 shows the measured flow rate and air velocity. Basically, the flow rate and air velocity are spatially uniform. The average flow rate and air velocities at each air exit are 519 cfm and 5.0 m/s, respectively. These numbers are also set as the boundary conditions for the CFD simulation.

Table 3: Measured flow rate and air velocity

	1	2	3	4	5	Ave
Flow rate (cfm)	505	535	520	510	525	519
Velocity (m/s)	4.8	5.2	5.0	4.9	5.1	5.0

NUMERICAL ANALYSIS AND SIMULATION

We use FLUENT 6.2, a CFD code, to perform the numerical simulation. Two cases were simulated in this study. One is the current actual case and the other is an improved case. The number of air exits is increased from 33 in the current case to 55 in the improved case. Both steady-state and transient flows are simulated. We apply the k-ε turbulence model and SIMPLEC to solve the velocity and pressure problem.

More than one million grids were generated to simulate the whole area. The boundary condition of the simulation is based on results of the actual measurements. The heat flux from the ceiling is calculated according to the ASHRAE Handbook Fundamentals [7]. All the boundary conditions are list in the Table 4.

Table 4: Boundary conditions for CFD simulation

Air exit (On the ceiling)	Air velocity	5.0 m/s
	Air temperature	20 ^{o}C
Heat flux from the ceiling		5 W/m^2
Heat source	PS and vacuum	5 W/m^3
	RF	10 W/m^3
Wall and floor		Adiabatic

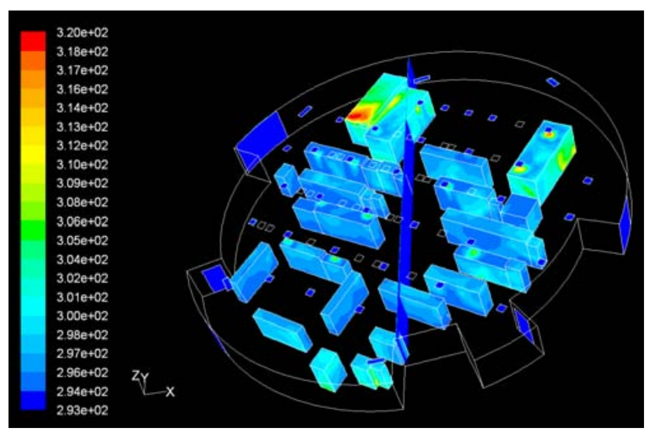

Figure 3: Simulated temperature field for the current case.

Figure 3 shows the simulated temperature field for the current case. It is clear that the temperature of the RF equipment is higher than that of other equipment. Five blue rectangular zones around the side wall are normally opened exits, which are also set as air exhausts. A virtual vertical cross sectional plane in the figure shows lower temperature than that of equipment. Figure 4 shows the simulated flow field for the current case. It is illustrated that the air velocity near the air exits is higher than that of other area. Air velocities near the air exhausts and exits on the wall are also higher than that of other area but less than that near air exits.

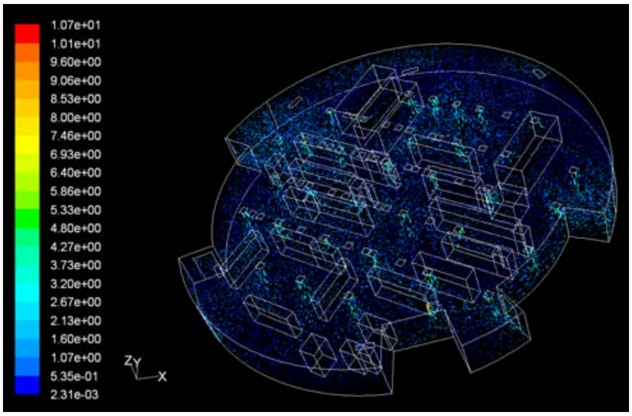

Figure 4: Simulated flow field for the current case.

Figures 5 and 6 respectively show the simulated temperature and flow fields for the improved case. The temperature field shown in Figure 5 is generally lower and more uniform than that of the current case.

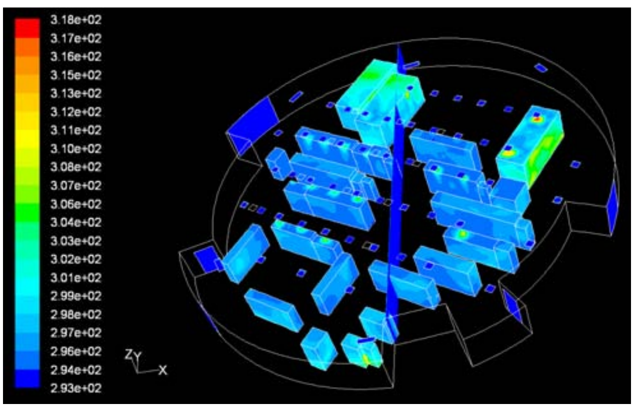

Figure 5: Simulated temperature field for the improved current case.

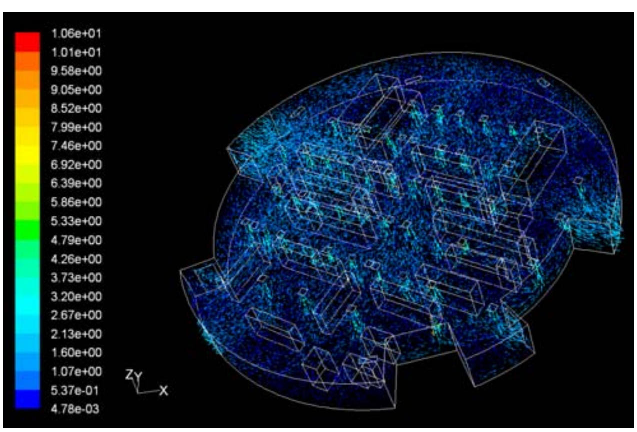

Figure 6: Simulated flow field for the improved current case.

High air velocity near 55 air exits is clearly illustrated in Figure 6. Because air exits are increased but the air exhausts keep the same in the improved case, the air velocity vectors near the air exhausts and exits are clearly higher and denser than that of the current case.

To simulate the transient state, we modified boundary conditions as functions of time. We also selected 10 points respectively above heat source 10cm or 20cm to examine temperature variation. The simulated results show that the average temperature temporal variations of the current case and the improved case are ±0.1 ^{o}C and ±0.08 ^{o}C, respectively. The former number is close to the actual measured data.

CONCLUSION

The cooling loads in the technical zone were surveyed. The cooling capacity of the A/C system was estimated insufficient. The air temperature and the air flow in the technical zone were measured and simulated. The A/C system will soon be improved according to analysis results.

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