AIR TEMPERATURE CONTROL IMPROVEMENT FOR THE STORAGE RING TUNNEL

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Abstract

Based on the thermal effects on the beam stability formerly studied, a series of measures are taken to improve the air temperature control for the storage ring tunnel at the Taiwan Light Source (TLS). The cooling capacity is increased about two times by rearranging the Air Handling Units (AHU) and the piping system. The PID parameters are optimised to more effectively suppress the air temperature fluctuation. The global air temperature variation in the storage ring tunnel is currently controlled within ±0.1°C related to time. After successful experience of air temperature control for the elliptical polarization undulator (EPU), the mini environment control is also applied on another insertion device, undulator 5 (U5). The ambient temperature variation of this magnet is controlled within ±0.1 °C related to time. The thermal uniformity is much improved than ever.

INTRODUCTION

In order to enhance the beam operation stability, Taiwan Light Source (TLS) had started a series of experiments to established the mathematical model [1] and find out the relationships among the beam orbit position and the utility status, which includes the cooling air temperature and cooling water temperature [2]. The results show the strong correlation between the beam orbit stability and the utility status as the temperature variation of the cooling water and the air exceed 1 °C and 0.2 °C, respectively. More precision thermal and mechanical stability studies were conducted to meet the latest strict requirement of beam intensity variation within 0.1% [3]. The original specification for temperature fluctuations, <±1°C, is far from the requirement. Many efforts thus have been devoted in the air temperature variation improvement in the storage ring.

Most of the main devices for the beam operation are installed in the storage ring tunnel. The air temperature control in this area thus is the most important air conditioning project. Parts of the AHU and piping system are modified to suppress the air temperature variation.

Besides, following the successful experience of mini environment control for the EPU [4], the similar scheme is also applied on U5. This insertion device, purchased from Danfysik Company, has the same length of 3.9 meter as EPU and with 5 cm magnetic period length. The details of the mini environment control will be described in the later section.

AHU AND PIPING SYSTEM REARRANGEMENT

There had been totally four AHUs serving for the most area of storage ring building, i.e., the tunnel and the experimental hall, since the storage ring was constructed in TLS. The detailed specifications of the AHU are list in Tab. 1. The supplied air from these four AHUs was first mixed through the piping system then ventilated to the tunnel and the experimental hall. However, due to the fast growth of the heat load from the later installed beam lines and instrumentations, the cooling capacity becomes insufficient gradually. Lack of cooling capacity affects the storage ring tunnel more than the experimental hall because the former requires more accurate air conditioning control but shares less cooling capacity than the latter. Therefore, increase of the cooling capacity becomes an imperative for the stable air temperature control in the storage ring tunnel.

Another shortcoming of the air conditioning system for the storage is a long section of supplied air duct exploded under the sunshine. The air temperature could rise up to 2 °C as the air flowed through this section due to solar radiation. Thus, the air conditioning system for the storage ring was modified at two places to cope with the shortcomings abovementioned in 2002. First, the air conditioning system of the storage ring tunnel was separated from that of the experimental hall by rearranging the piping system. Second, the section of the air duct exploded under the sunshine was cut. Currently, two AHUs are independently employed for the storage ring tunnel and the cooling capacity for this area is much increased.

Moreover, The air conditioning system PID control program has also been updated. The program system provides a new function, dead band control logarithm, for reducing the temperature control over or under shooting. The optimum PID parameters are related to the characters of the air condition equipments and the local temperature variation. However, sufficient air conditioning capacity will make optimum PID parameters tuning easier.

AIR TEMPERATURE VARIATIONS IMPROVEMENT

The air temperature of the storage ring tunnel is controlled through four variable air valves (VAVs), labelled as R4A-R4D. Each VAV dominates eight air inlets and two air outlets, as shown in Fig. 1. The opening of the valves for chilled and heating water are auto adjusted by the controller according to the temperature difference between the setting value and the real inlet air temperature.

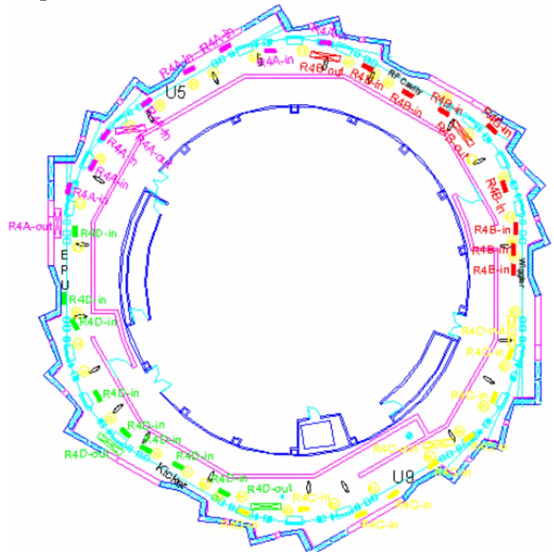


Fig 1: Air conditioning ventilation inlet and outlet distribution in the storage ring tunnel

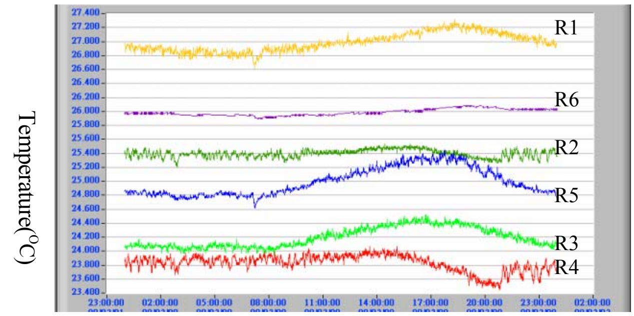
The storage ring tunnel is divided into six sections. There are six thermocouples mounted in each section to remotely monitor and control the air temperature in this area. Fig. 2 (a) and (b) respectively demonstrate the air temperature variation in the six tunnel sections before and after the air conditioning system modification. It is shown from the one day history that the temperature variation is about ±0.2 °C in Fig. 2(a). The apparent rise in the temperature in the afternoon also reflects the insufficient cooling capacity. The valves of the chilled water were usually 100% opened in the summer. This phenomenon almost disappears after modification, as shown in the Fig. 2(b).

Special care is taken to improve the air temperature variation related to time rather than the spatial temperature difference because the former affects the beam stability much more than the latter. Although the temperature differences among each section still exist, the temperature variation during one day is much improved.

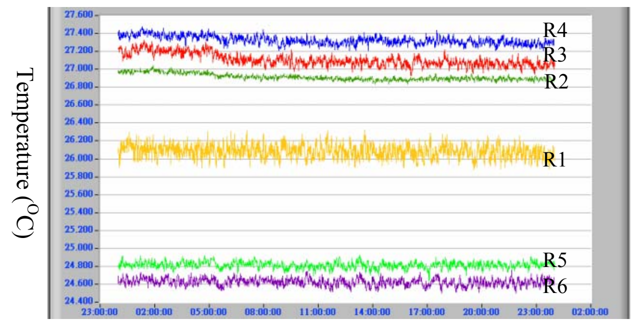
MINI ENVIRONMENT FOR THE U5 AREA

For more accurately and efficiently control the ambient air temperature around U5, isolating this local area and providing the independent air conditioning system, known as the mini environment control, is the best scheme. Fig. 3 shows the isolated U5 area photograph.

U5 is located in the third section in the storage ring tunnel. There are two air inlets supplying sufficient air in the isolated U5 area. There is no air outlet in the isolated area. Accordingly, it can be kept positive pressure in the



(a) Time(hr)



(b) Time(hr)

Fig. 2: Air temperature variation in the six tunnel sections (a) before and (b) after the air conditioning system modification.

area. It is also helpful to keep heat transfer from outside into this area. The surrounding temperature variation can be controlled within +/- 0.1 °C except the beam shut down period.

With sufficient air conditioning capacity in the area, temperature uniformity of the U5 magnet arrays becomes another important issue. Fig. 4 is the sketch of the isolated area of U5. Three cross flow fans are employed to circulate the air around the magnet arrays to achieve the goal of the temperature uniformity. Two small fan units are located on the top in front of the U5 device. One large fan is mounted in the back position. The air flow form the air inlet can be draft down by the top fans and enwrap the U5 magnet arrays, as shown in Fig. 4.

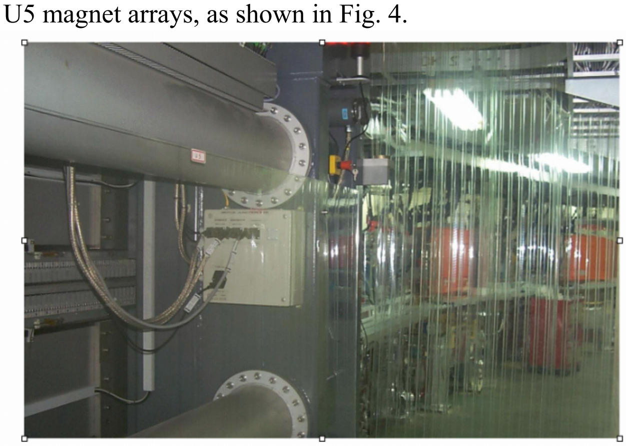


Fig. 3: Photograph of the U5 isolated area.

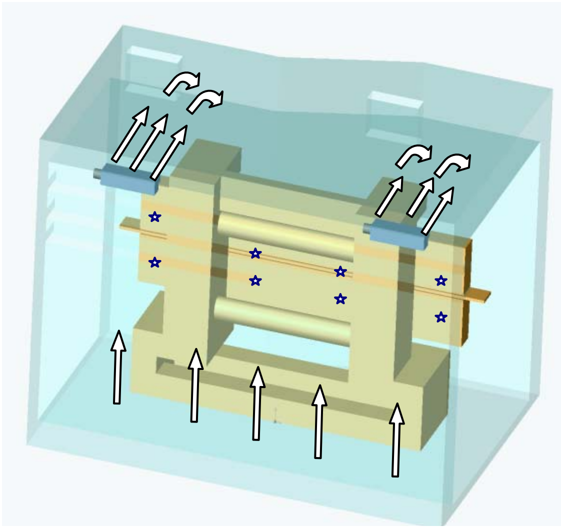


Fig. 4: Sketch of the U5 area.

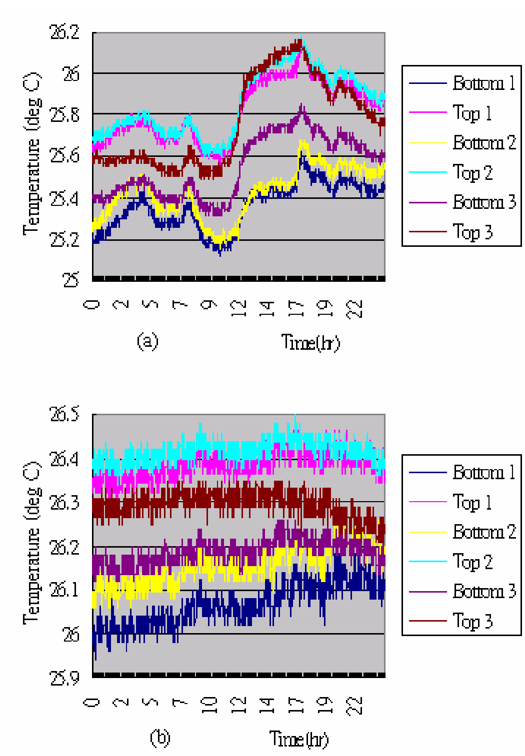


Fig.: 5 Air temperature variation on the U5 magnet arrays (a)before and (b)after the mini environment control.

There are eight thermocouples mounted on the front side of U5 magnet arrays, as shown in Fig. 4. Other eight thermocouples are mounted on the backside. Fig. 5 (a) and (b) respectively show the temperature variation of the U5 magnet arrays before and after the mini environment control is employed. By the forced convection cooling induced by the circulation, the U5 magnet arrays temperature variation of the top magnet arrays can be reduced to 0.2 ^{o}C, while the bottom magnet temperature variation can be reduced to 0.15 ^{o}C. The temperature variation corresponds to the 23.4 um deformation of the top magnet arrays and 16.7 um deformation of the bottom magnet arrays in the longitudinal direction.

The U5 area temperature variation is kept in +/- 0.1 ^{o}C by means of the mini environment control for U5 isolation air conditioning. The circulation air flow can uniform the temperature distribution to 0.2 ^{o}C level. The precise temperature control can reduce the thermal effect on the U5 deformation and further improve the beam stability in TLS.

CONCLUSION

The air conditioning system for the storage ring is modified. The cooling capacity for the storage ring tunnel is much increase by means of the rearrangement of the air piping system. The global air temperature variation in the storage ring tunnel is currently controlled within ±0.1 oC during 24-hour operation.

The U5 area temperature variation is kept in +/- 0.1 oC by means of the mini environment control for U5 isolation air conditioning. The circulation air flow can uniform the temperature distribution to 0.2 oC level. The precise temperature control can reduce the thermal effect on the U5 deformation and further improve the beam stability in TLS.

REFERENCE

1. H.M. Cheng, J.R. Chen, C.R. Chen, and Z.D. Tsai, "Utility Optimization for the Beam Orbit Stability at SRRC", New York 1999.
2. J.R. Chen, H.M. Cheng, Z.D. Tsai, C.R. Chen, T.F. Lin, G.Y. Hsiung, and Y.S. Hong, "The Correlation between the Beam Orbit stability and the Utilities at SRRC", Proc. of 6th European Particle and Accelerator Conference EPAC98, Stockholm, Sweden, June 22-26, 1998.
3. J.R. Chen, D.J. Wang, Z.D. Tsai, C.K. Kian, S.C. Ho, and J.C. Chang, “Mechanical Stability Studies at the Taiwan Light Source”, 2nd Int’l Workshop on Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation (MEDSI02), APS, U.S.A., Sep 5-6, 2002
4. D.S. Lee, Z.D. Tsai, and J.R. Chen, “Mini Environment Control for the Elliptical Polarization Undulator” 2001 Particle and Accelerator Conference (PAC), June 18-22, 2001, Chicago, USA.