

COMMISSIONING OF THE TPS COOLING SYSTEM: TESTING, ADJUSTING, BALANCING AND NUMERICAL SIMULATION

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Abstract

The civil construction and utility systems of the 3-GeV Taiwan Photon Source (TPS) at NSRRC are ready for machine commissioning in 2014. To achieve a highly precise control of temperature, the thermal load must be carefully controlled and balanced. On analysis of the characteristics between the water pipes and the balance valves, a specified control philosophy can effectively adjust the pressure load on the branch pipes to balance the water flow. With regard to the air flow, we use a damper, baffle plant or variable air-volume (VAV) box to balance the air flow of each diffuser. Here we discuss the mechanism through a numerical simulation of the hydrodynamics and verify the practical influences of the testing, adjusting and balancing (TAB) for de-ionized water and the heating, ventilation and air-conditioning (HVAC) system.

INTRODUCTION

The TPS infrastructure including civil and utility systems has been under construction since 2009 December and was completed in 2014 December [1]. The TPS facility is currently in the stage of commissioning. As the utility system is a most critical subsystem affecting the beam quality and reliability, much effort has been devoted to these designs [2]. Here we address mainly the testing, adjusting and balancing (TAB) design of the cooling system of the finalized utility system.

In the accelerator field in general, thermal waste can be treated through circulating deionized water (DIW) and air conditioning (AC). The main system for cooling water of TPS includes the cooling tower, chilled water, hot water, de-ionized water and HVAC system. Each manifold located near control-instrument areas (CIA) provides four loops for varied demand of facilities, including stable temperature, pressure and flow. The air-handling units (AHU) located at the inner and outer rings provide highly stable cooling air for the storage-ring tunnel, CIA, experimental hall and Linac area. Programmable automation controllers (PAC) and direct digital controllers (DDC) have been implemented in this hybrid utility system for highly precise control and status monitoring. To provide a stable cooling source, we must fine-tune the system to meet our requirements. The TAB process for de-ionized water and HVAC system is a critical procedure in the commissioning stage of the utility system. This paper reports that mechanism through numerical simulation of hydrodynamics and verifies the practical influences of the TAB process.

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NUMERICAL SIMULATION OF HYDRODYNAMICS

We use a software package (fluent) to simulate the air flow in the air ducts with and without taper, as shown in Figures 1a and 1b. The boundary conditions are listed in Table 1. According to Bernoulli's principle, the system must maintain a constant total pressure. When the air flow encounters a divided flow, the dynamic pressure decreases and the static pressure increases, so that the end of the air duct has a larger static pressure, as shown in Figure 2. To overcome this problem with a consistent outlet airflow pressure, we must make tapers for the air duct or use a damper, baffle plant or VAV box to balance the air flow of each diffuser, as shown in Figure 1b. Figure 3 shows that each diffuser can downgrade the static pressure to match our requirement. If we use a damper or VAV box, we can efficiently control the air flow to balance the consistent outlet air pressure.

Aspects of the water system are shown in Figure 4; the water system flows through three loops for subsystem cooling and forms a closed-loop system. The pipe friction decreases the static pressure related to the distance; the divided flow can increase the static pressure as in the red line shown in Figure 5. In the return loop of the water, the pipe friction continually decreases the static pressure related to distance, and the merged flow also decreases the static pressure as in the white line shown in Figure 5. The pressure difference between the red and white lines is thus the actual pressure for each loop. The actual pressure is least in the latest part of the pipe loop, which even leads to no water flow at the end of the pipe. The TAB is so critical for a water system that we use a balance valve to fine-tune the water flow to meet each loop requirement.

Table 1: Boundary Conditions of Cases 1 and 2 of Air Duct

	case 1	case 2
length of air duct /m	20	20
diffuser area/m ²	0.14	0.14
cross-sectional area 1/m ²	1	1
cross-sectional area 2/m ²	1	0.757
cross-sectional area 3/m ²	1	0.49
cross-sectional area 4/m ²	1	0.303
inlet pressure of air duct /Pa	100	100

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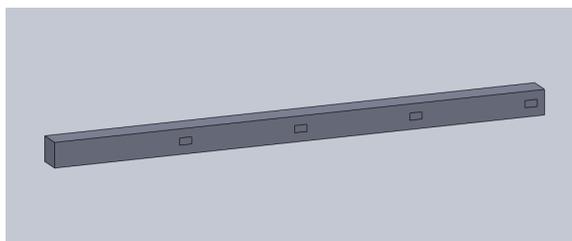


Figure 1a: Air duct without taper design (case1).

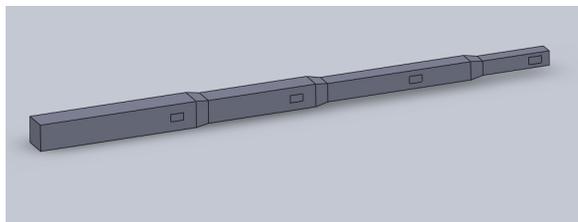


Figure 1b: Air duct with taper design (case2).

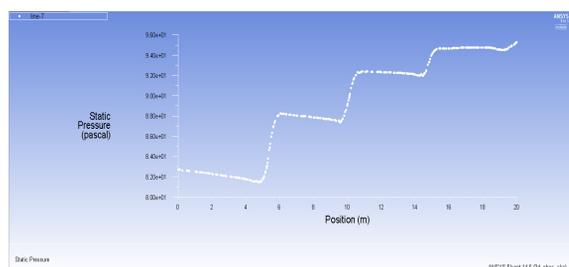


Figure 2: Variation of static pressure related to distance for an air duct without taper design.

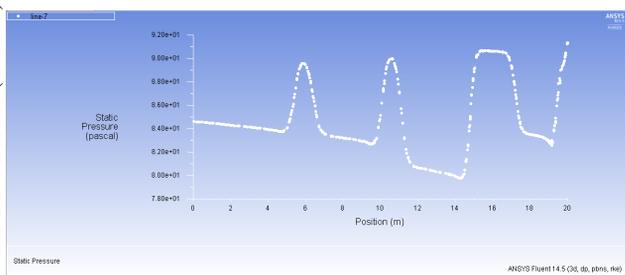


Figure 3: Variation of static pressure related to distance for an air duct with taper design.

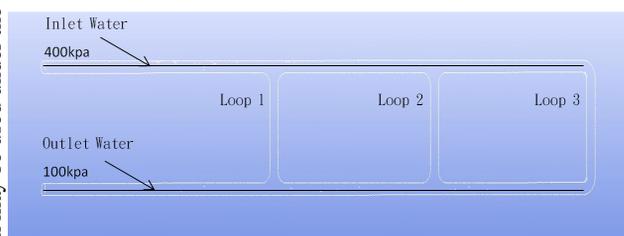


Figure 4: Scheme of a closed-loop water system.

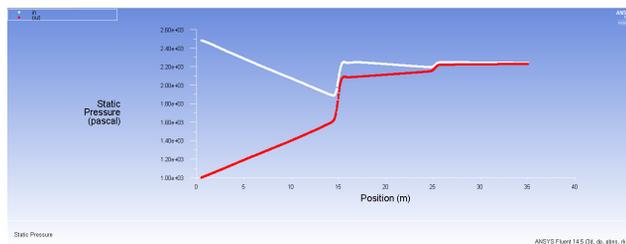


Figure 5: Variation of static pressure related to distance for a closed-loop water system.

TESTING, ADJUSTING AND BALANCING OF THE UTILITY COMMISSIONING

The primary loop of the chilled water must be balanced for a thermal load of three chillers. The primary loop of hot water must also be balanced for a thermal load of two heat pumps. All water circulates in a closed loop of secondary loops, which provide a cooling or heating source for the AHU and DIW facilities. Each branch system flowing through heat exchangers for cooling or heating must be well balanced. In the storage-ring building, each DIW system has been divided into 48 manifolds for the 24 sections of the accelerator machine, as shown in Figure 6. Each manifold has filters, flow-balance valves and sensors for temperature, pressure and flow, which provide an optimal flow balance and real-time DIW status. Each inlet and outlet piping connected with the accelerator machine has a flexible design of piping to prevent the propagation of vibration.

The main AHU facility is located in the TPS storage-ring building, which is classified into five main areas -- storage-ring tunnel, CIA, experimental hall, Linac area and Linac control room. In particular, 96 branch air wind ducts distributed in the area of experimental hall must be balanced for their air flow. The make-up air unit (MAU) provides fresh air for each AHU, which must also be well balanced.

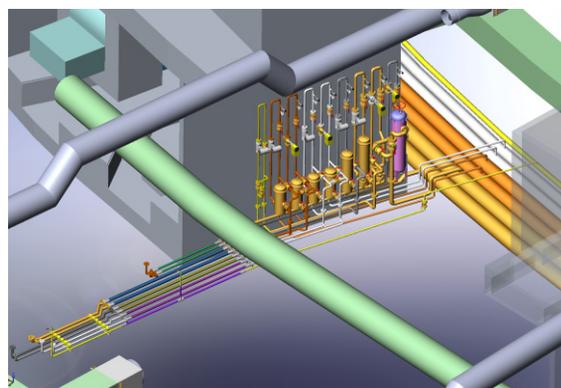


Figure 6: Manifold arrangement near a CIA.

To complete this enormous TAB system efficiently, we have a standard operating procedure (SOP) to ease the difficulty. The process of TAB must have a larger reference flow than the actual flow to obtain a larger opening and smaller pressure drop for a balance valve or damper. The procedure must be implemented from the

end pipe or air duct to ensure a minimal flow. We use a subtotal flow sensor to mitigate the confirmation of the TAB, because the subtotal flow can provide enough information to divide the overall system into smaller TAB systems.

INTEGRATION BETWEEN THE TAB AND THE ON-LINE MONITOR SYSTEM

We traditionally use a portable meter to detect the differential pressure sensor at the balance valve. Then the value of differential pressure becomes converted into a flow value according to the size and turn of the balance valve, but a portable meter cannot respond to the current flow value in all branch pipes instantaneously, which results in a difficult operation of the TAB process, requiring additional time and manpower to implement the TAB process. We thus designed an integrated architecture of a control and archive system for a TAB process to provide the on-line commission status for engineering and to decide an effective strategy for TAB.

The programmable automation controllers (PAC) with a FPGA function have also been implemented in this TAB system for applications of TAB processing and monitoring [3]. This system adopts mainly PSP protocols to enable all human-machine interface (HMI) servers or local touch-screen panels to exchange information, as shown in Figures 7 and 8. A system for TAB monitoring provides information on the flow rate of the water branch piping and the HVAC branch air duct. This system also provides valuable historical data to track the TAB process and to identify system problems.



Figure 7: TAB information of deionized water system.



Figure 8: TAB information of the HVAC system.

CONCLUSION

This paper presents some TAB procedure and the results of numerical simulation related to chilled water, hot water, de-ionized water and the HVAC system. The efforts are devoted to develop a set of monitoring systems with a rapid and convenient approach for the TAB process. The schemes and experience of the TAB approach have been adopted for the current commissioning of the Taiwan Photon Source.

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REFERENCES

- [1] J. C. Chang, Z. D. Tsai, Y. C. Lin, T. S. Ueng, Iris Liu, W. S. Chan, Y. F. Chiu, C. Y. Liu, Y. C. Chung, K. K. Kuo, C. W. Hsu, and J. R. Chen, "Status of the Utility System Construction for the 3 GeV TPS Storage Ring", International Particle Accelerator Conference (IPAC), Shanghai, China (2013).
- [2] Z. D. Tsai, W. S. Chan, J. C. Chang, C. S. Chen, Y. C. Chung, C. W. Hsu and C. Y. Liu, "The Strategy between High Precision Temperature Control and Energy Saving for Air-Conditioning System", International Particle Accelerator Conference (IPAC), New Orleans, Louisiana, USA (2012).
- [3] C. W. Hsu, Z. D. Tsai, C. Y. Liu, and C. S. Chen, "Event Based Maintenance Management System for Taiwan Photon Source", International Particle Accelerator Conference (IPAC), Shanghai, China (2013).