HIGH PRECISION TEMPERATURE CONTROL AND ANALYSIS OF RF DEIONIZED COOLING WATER SYSTEM

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Abstract

Previously, the Taiwan Light Source (TLS) has proven the good beam quality mainly depends on the utility system stability. A series of efforts were devoted to these studies. Further, a high precision temperature control of the RF de-ionized cooling water system has been achieved to meet the more critical stability requirement. The paper investigates the mixing mechanism through thermal and flow analysis and verifies the practical influences. A flow mixing mechanism and control philosophy is studied and processed to minimize temperature variation which has been reduced from ±0.1 ℃ to ±0.01 ℃. Also, the improvement of correlation between RF performance and water cooling stability is presented.

INTRODUCTION

In 1997, Keller et al. [1] studied the correlation between the beam orbit stability and the utility conditions for the Advanced Light Source (ALS). TLS has also investigated on thermal effects, thermal paths and improvements of the beam orbit stability since 1998 [2]-[5]. For achieving a high precision water temperature control within ±0.01℃, a serial studies have been continually proceed for RF de-ionized cooling water system. The nonlinear water flow and cooling capacity caused by control valves and heat exchangers affect the high precision temperature control. A new type piping way is presented to isolate coupling problems between control valves and heat exchangers and shift the water flow operating point to optimization. Besides, a buffer tank has also been installed to minimize the temperature variation within ±0.01℃ successfully.

RF-DEIONIZED WATER SYSTEM UPGRADING

TLS has devoted much effort in SRF system, which was successfully committed in 2005. The SRF system planned to be transferred toward the new Taiwan Photon Source (TPS) in the future. In the meantime, the original Doris cavity will be re-functioned and utility upgrade will be continued.

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For decoupling cavity and transmitter temperature interaction effects, the 2nd loop RF de-ionized water system has been installed, as shown in Figure 1. This system mainly includes the independent 2nd loop pumps with variable frequency inverters, two heat exchangers with rising and lowering water temperature to stabilization, an embedded heater assembly for fast heating mechanism and a buffer tank with turbulent flow mixing mechanisms. The 16-bit resolution sensor and controller have also been mounted for a real time control and analysis. The water temperature variation is larger than ±0.2 ℃, which dominate the body cavity behavior. The strong correlation as shown in Figure 2 is expected to improve.

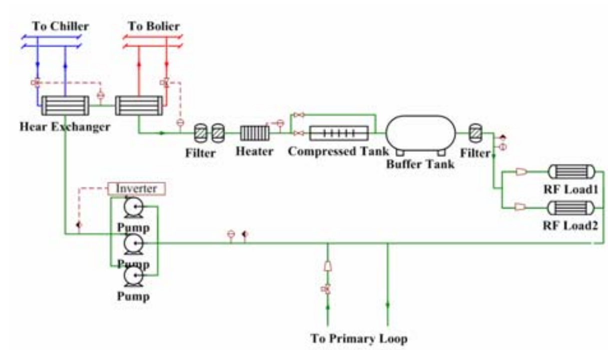

Figure 1: The 2nd loop of RF de-ionized water system.

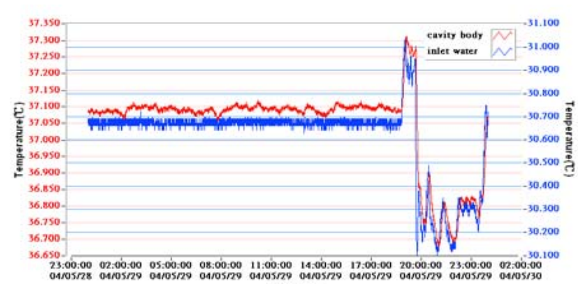

Figure 2: The temperature correlation of the cavity body vs. inlet water.

TEMPERATURE VARIATIONS AND WATER FLOW CONTROL OPTIMIZATION

A series of experiments and observations have been performed to stabilize the temperature variation. The water flow has significant effect on the high precision temperature control because water always flows

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nonlinearly or discontinuously through the control valve of the water piping. In general, the phenomena result from the water tuning valve with a backlash gearmotor, initial no-response deadband and nonlinear valve design as shown in Figure 3,4. The traditional 3-way valve only tunes the total water flow rate through heat exchangers. The excess water would bypass heat exchangers, which result in the upstream chilled or hot water pump waste power. And, the valve with a larger tuning range would take more time to actuate valve gearmotor and change valve state. These lead to control valve with a slow response relative to the overall system. Besides, the control valve coupled with a heat exchange induces a nonlinear cooling capacity problem.

For overcoming the nonlinear and discontinue problems, a new type of piping way around a heat exchanger would be presented as shown in Figure 5. The method would let water flow through control valve and heat exchanger is independent control. Therefore, the operating point for water flow through the control valve and heat exchanger could be optimized. The temperature variation within ±0.1 ℃ is easy to achieve.

Besides, the 16 bit resolution of controller, driver and sensor has been implemented. The low resolution device will lose control mechanism and the temperature variation couldn't meet a high precision control goal as shown in Figure 6,7. The variable frequency pumps for tuning water flow are also implemented to provide a stabilized and sufficient water flow rate to each device. Each branch water piping with flow balance valves would balance overall branch flow. The temperature of the upstream chilled and hot water for de-ionized water cooling and heating should be stabilized within ±0.5°C, because the small source temperature variations is assistant for high precision temperature control.

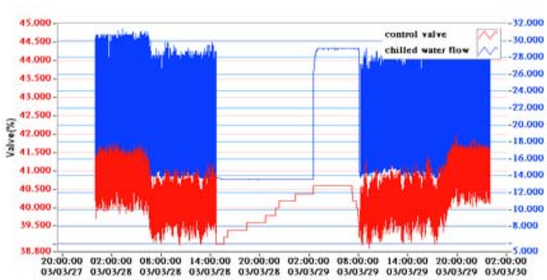

Figure 3: The valve with a backlash gearmotor vs. water flow variation.

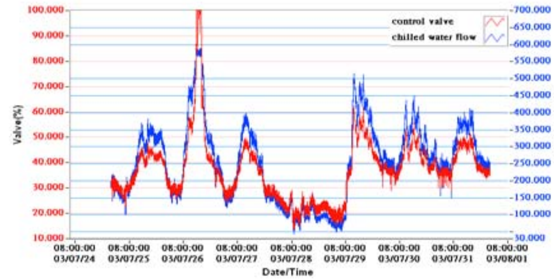

Figure 4: The nonlinear valve vs. water flow variation.

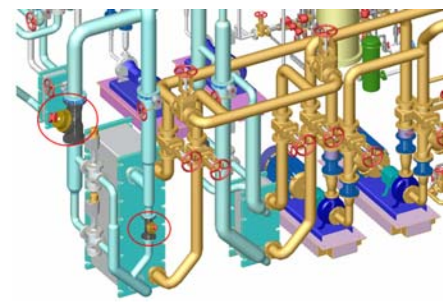
Figure 5: The new type piping way around a heat exchanger.

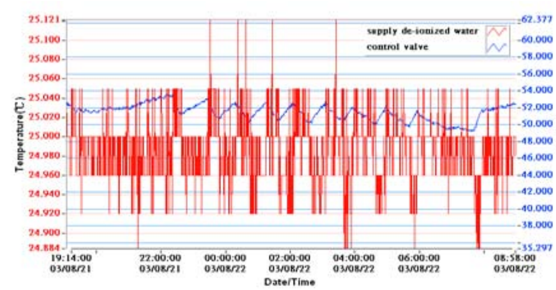

Figure 6: 12-bits control valve vs. temperature variation.

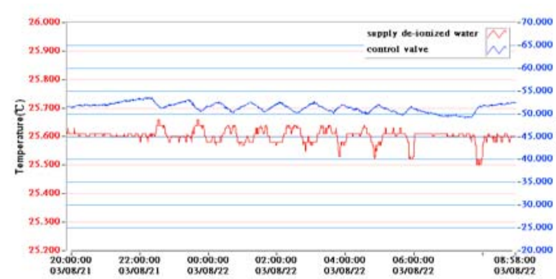

Figure 7: 16-bits control valve vs. temperature variation.

TEMPERATURE VARIATION AND MIXING MECHANISM

In general, the PID control logic is applied in the water system to stabilize water temperature. The control valve would be tuned according to the heat load and temperature sensor variation. The small variation of the steady state is always difficult to release, because of nonlinear water flow caused by valves and heat exchangers. For achieving an ultra high precision temperature control within ±0.01℃, the mixing mechanism would be introduced. The buffer tank with turbulence fins for mixing purpose has been designed. The 2000 liter buffer tank has been implemented for the 2nd loop of RF de-ionized water system with 200 gpm flow. These mechanisms make water stay for 2.5 minutes between the inlet and outlet port of the buffer tank. In the meantime, the mixing mechanism interacts in the tank continually and reduce temperature variation from ±0.1℃ to ±0.01℃as shown in Figure 8.

In consequence of good performance about mixing mechanism, the extended study is also performed. Another piping type of buffer tank has begun to study as shown in Figure 9. The tank has a compressed volume 10 times smaller than the original one and a dedicated water flow path design to optimize the full mixing interaction. For observing the mixing situation step by step, 9 temperature sensors have be installed as shown in Figure 9. Because the water staying time in the tank is short, the faster valve control can obtain better performance. The dynamic vibration control mechanism is helpful for the front and rear water flow mixing completely. Currently, The temperature variation of the outlet water have been depressed 8 times smaller than the inlet water from ±2.4℃ to ±0.3℃ as shown in Figure 10. In the future, the reducing capacity needs upgrade and the inlet water temperature variation with dynamic vibration control requires minimization.

CONCLUSION

1. The paper exams nonlinear effects of water flow relative to temperature variation.
2. A new type of piping way around a heat exchanger has been performed to solve nonlinear effects of valves and heat exchangers.
3. The water temperature control within ±0.01℃ has been achieved with a large buffer tank, which upgrade RF performance.
4. A buffer tank with the compressed volume has also been presented to provide 8 times reducing capacity about the temperature variation
5. Further studies are needed, FEM analysis with relations to the turbulent flow optimization in buffer tank especially.

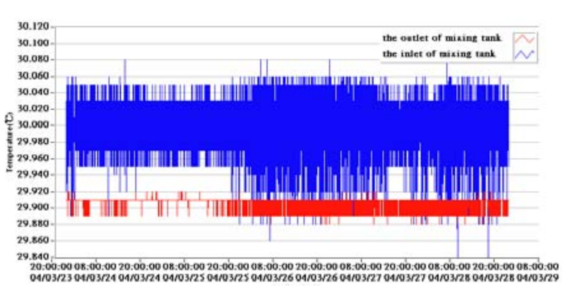

Figure 8: The mixing mechanism effect.

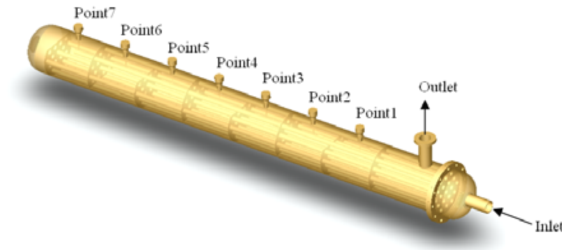

Figure 9: The buffer tank with the compressed volume

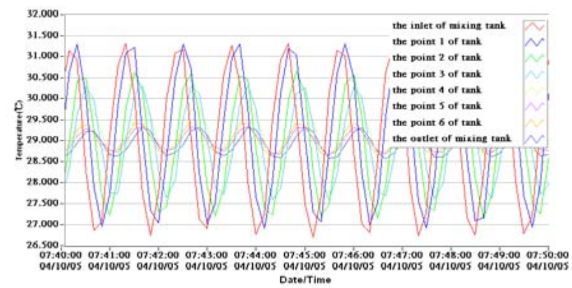

Figure 10: The temperature variation in the compressed buffer tank.

ACKNOWLEDGEMENT

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