CURRENT STATUS OF THE DE-IONIZED COOLING WATER SYSTEM AND IMPROVEMENT AT TLS

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2.1

Abstract

This paper studies the stability and improvement of the de-ionized cooling water (DIW) system at the Taiwan Light Source (TLS). The stability of the electron beam orbit was earlier found to be sensitive to the utility conditions [1,2]. Accordingly, a series of DIW system upgrade projects have been conducted. The DIW temperature of the total 1060-GPM capacity DIW system has been globally controlled within ±0.1 °C. A high precise DIW temperature control system for the RF system is implemented to meet the critical stability requirement. A buffer tank with a capacity of two tons is designed in the 200-GPM DIW subsystem to maintain the stability of the supplied DIW temperature, and the RF DIW temperature is currently controlled within ±0.02 °C. In the upcoming top-up operation, the booster DIW system is modified to increase the cooling capacity and reduce the temperature fluctuation. Some crucial water quality parameters are monitored. The conductivity of the water is maintained above 10 MΩ/cm and the pH is fixed at 7± 0.3.

Keywords: *de-ionized cooling water, temperature control, water quality*

1 Introduction

DIW has been widely used in many industrial fields, because it is pure and has high electrical resistance. For years, the Taiwan Light Source (TLS) has performed a series of studies of and made improvements to the DIW system to enhance its stability and quality. The correlation between the beam orbit and the utility index was mathematically simulated in 1998 [1]. The propagation route from the utility index variation and to the fluctuation in the beam orbit was also investigated [2]. DIW temperature is one of the most crucial utility indices and directly affects the beam stability. The originally specified DIW temperature variation was within ± 1 ^{o}C. However, this criterion was found not to ensure the required beam stability. DIW temperature variation of 0.6 ^{o}C was observed to induce a variation of 6μm photon position [3]. DIW temperature control has been continually improved from ±1 ^{o}C to ±0.1 ^{o}C. A “Top-Down” control method has been applied to control the temperature variation of the cooling tower water, the chilled water and the DIW within ±0.5, ±0.3 ^{o}C and ±0.15 ^{o}C, respectively [3]. Increasing the cooling capacity and the two-phase control yielded a global DIW temperature variation of within ± 1 ^{o}C [4].

The beam stability requirement is more crucial than it has ever been. TLS has increased the precision of the photon beam intensity fluctuation in the beam line from ΔI/I of 0.1%. A new high precision DIW temperature control system for the RF system has been accomplished to meet the critical stability requirement of the RF system and the oncoming SRF system. The supplied and return RF DIW temperatures and pressures, the inlet and outlet DIW temperature of the two RF transmitters and the temperatures of the two RF cavities and windows, are monitored online and recorded on in the archive system. The RF DIW temperature variation is currently controlled within ±0.02 ^{o}C. These accomplishments will be valuable in establishing another local high-precision DIW subsystem in the future.

Water purity is another significant issue for the DIW system. As a highly versatile solvent, water will dissolve many impurities after long-term operation, such as suspension, electrolyte, corpuscles, mirco-pranisms, organic substance and gas. The DIW quality has been frequently improved by adding local filters, reverse osmosis and various resins. Section 4 elucidates the control of DIW quality at TLS.

2 DIW system at TLS

2.1 DIW system classification

The water system at TLS comprises four subsystems, -the DIW system, the chilled water system, the cooling water system and the heating water system. All these water systems are operated in a close loop, and their temperatures are monitored and controlled on-line. The DIW system is mainly to cool the accelerator machines, and is divided into five systems, to match the accelerator's subsystems. The DIW system is classified for two main reasons. The first is to prevent an electrical potential difference from the DIW piping system and thus to prevent corrosion induced by the differences between the properties of metals. The second aim is individually to control the temperature, pressure and flow rate of each DIW system, to prevent interference with other systems.

The copper (Cu) DIW system is for the magnet and power supply systems. The RF DIW system is isolated from the Cu DIW system and serves to cool the RF transmitters and cavities. The aluminum (Al) DIW system is designed for cooling use for vacuum chambers. The beam line (BL) DIW systems serve for vacuum chambers, the beam line devices and the booster equipment. In 2003, increasing the cooling capacity and optimizing the PID parameters greatly improved the stability of the booster DIW temperature. The supplied booster DIW temperature variation has been reduced from ±3 ^{o}C to ±0.1 ^{o}C. The superconducting-rf (SRF) DIW system was completed last year for the new SRF system.

Heat exchange in each DIW system has two stages. The DIW temperature is controlled by adjusting the flow rates of the chilled water and the cooling water. Currently, the DIW temperature of both Cu and Al is controlled at 25±0.1 ^{o}C. The BL and SRF DIW temperature variation is controlled within ±0.2 ^{o}C. The high-precision temperature control system, which maintains the temperature of the RF DIW supply within ±0.02 ^{o}C, meets the RF critical stability requirements, and will be discussed in the following section. The DIW pressure variation is controlled within ±0.1kg/cm^2 by regulating the pumping frequency. However, the base temperatures of the abovementioned DIW systems are sometimes modified to meet the requirements of the accelerator subsystems. Table 1 details the specifications of each DIW system.

Table 1: Specifications of each DIW system at TLS.

DIW system	Temperature	Pressure	Flow rate	Accelerator subsystem
Cu	25±0.1 °C	7.5±0.1kg/cm^2	500GPM	Magnet, PS
Al	25±0.1 °C	7.0±0.1kg/cm^2	100GPM	Vacuum
SRF	25±0.2 °C	7.0±0.1kg/cm2	160GPM	Superconducting-RF
BL	25±0.2 °C	7.0±0.1kg/cm2	300GPM	Beam Line and Booster
RF	30±0.02 °C	7.5±0.1kg/cm2	200GPM	RF

2.2 DIW treatment process

Figure 1 presents the Cu DIW system flowchart. The local return DIW, indicated as the green line, first passes through the vapor-liquid separator and the expansion tank to expel the vapor and the air, respectively. Five percent of the return DIW enters the deionizer to be recycled before entering the main return pipe. All return DIW passes through the master pump, the inverter and two heat exchangers. In these two heat exchangers, the DIW is cooled by chilled water, plotted as the blue line; it is then heated by the hot water, plotted as the red line. When the return DIW level is sensed too low, the DIW will be supplied from the reverse osmosis (RO) tank through the recycle pump to the main return pipe.

The temperature variations of the chilled water and the hot water are also controlled within certain range. The chilled water and hot water temperatures are controlled at 7.8±0.3 °C and 50±0.3 °C, respectively. All the aforementioned water temperature data are monitored on-line and stored in the archive system.

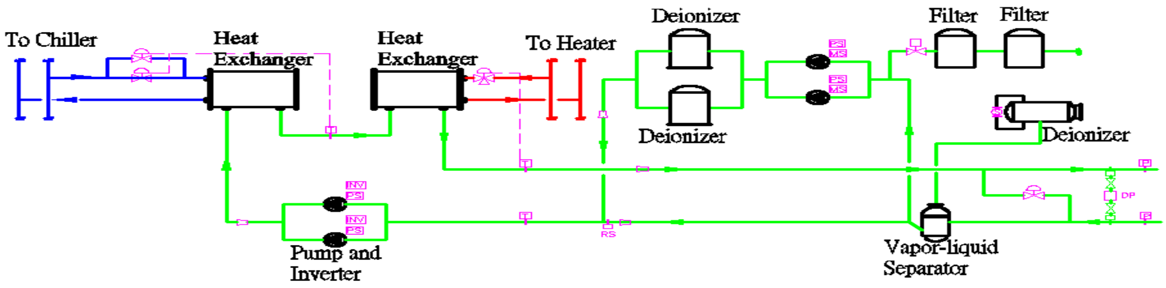


Figure 1: Cu DIW system flowchart.

3 High-precision temperature control for RF DIW system

RF DIW system flowchart

The Cu DIW system was originally also used to cool the RF system. The stability of the DIW temperature is a critical requirement for the RF cavity and transmitter, so the RF DIW system is branched from the Cu DIW system.

Figure 2 displays the RF DIW system flowchart. The primary loop is connected to the Cu DIW system. The RF DIW quality is controlled in the Cu DIW system; and the RF DIW system, shown in Fig. 2, is employed in particular to control the DIW temperature. Similar to the Cu DIW system, the DIW from the primary loop, indicated as the green line, passes first through the master pump, then through the inverter, two heat exchangers and filter A. As in the Cu DIW system, the DIW is cooled by the chilled water using two exchangers and then heated by hot water. The key component of the temperature precision control in the RF DIW system is a buffer tank with a 2-ton capacity, which is located after filter A. The buffer tank is made of stainless steel and its exterior is covered with thermally-insulated material.

The full flow rate of the RF DIW system is designed at 200 GPM and controlled at about 120GPM in normal operation. The capacity of the buffer tank is approximately 3.7 times the normal DIW flow volume in one minute. Accordingly, the buffer tank ensures good DIW mixing and effectively dampens the fluctuation of the DIW temperature. Another 1μm filter (B) is installed after the buffer tank to prevent the RF system form impure particles entering.

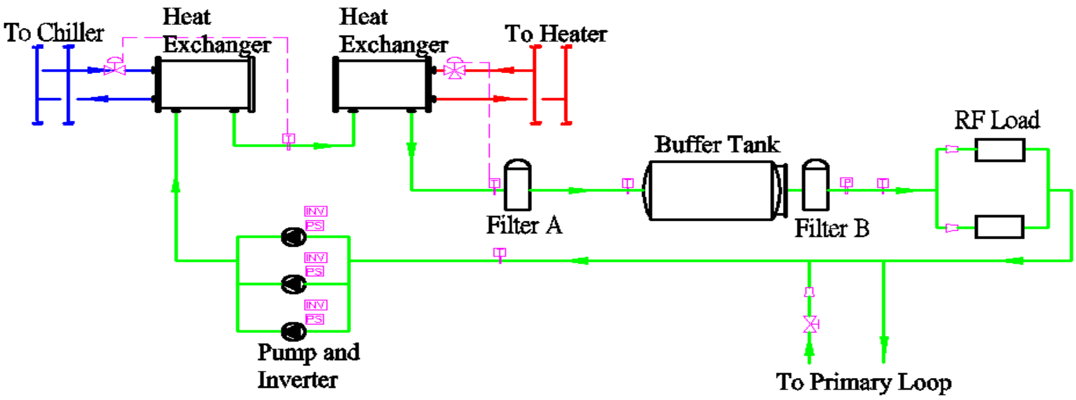


Figure 2: RF DIW system flowchart.

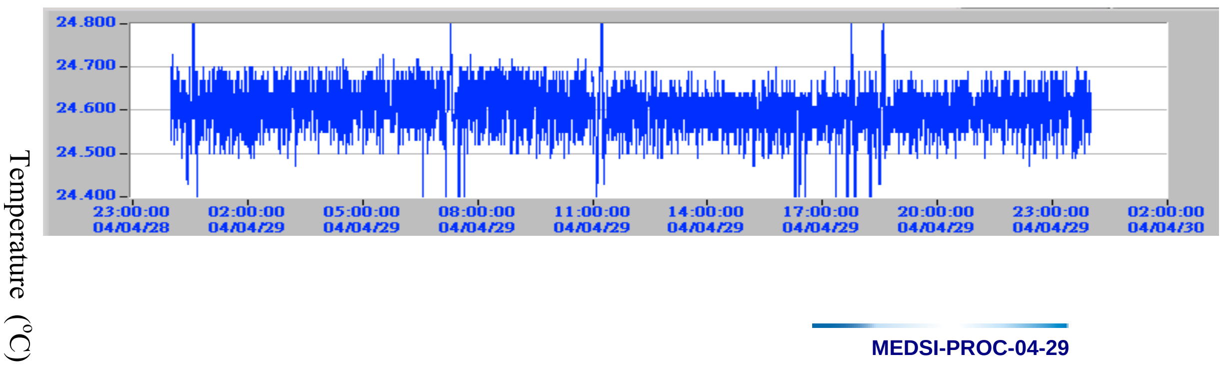
Data acquisition and control system

Two adjustable valves are installed upstream of two heat exchangers to control the flow rate of the chilled water and the hot water, respectively. These two adjustable valves are respectively controlled according to the readings of the two thermometers installed downstream of the two heat exchangers. Two sets of DDC controllers with 12-bit resolution serve as real-time controllers.

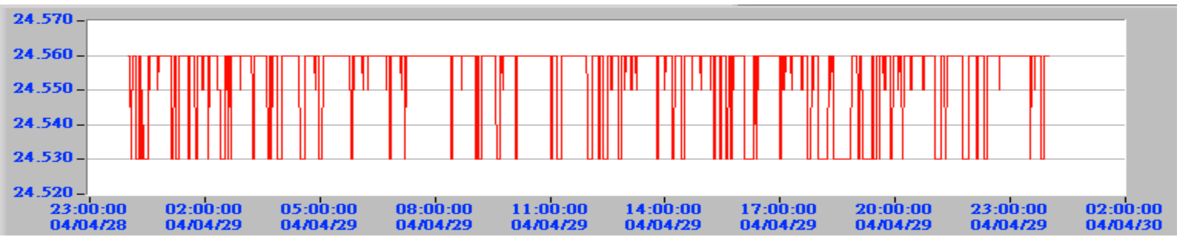
Two thermometers and an NI FieldPoint modular distributed I/O system with 16-bit resolution from 4 to 20 mA and 20 °C to 40 °C are installed upstream and downstream, respectively, of the buffer tank. A pressure probe with transducers with an accuracy of ±0.1kg/cm^2 is installed downstream of the buffer tank. Three flow rate meters with an accuracy of ±0.5% are installed at the inlet of the RF DIW system and upstream of the two RF systems. Related data are also monitored on-line and stored in the archive system.

Results and discussion

Figures 3a and 3b show the DIW temperature histories at the inlet of the RF DIW system and the outlet of the buffer tank, respectively, over the same period in one day. The RF DIW comes from the Cu DIW system, so the data shown in Fig. 3a are close to the Cu DIW temperature, and the temperature variation is about ± 0.1 °C. The temperature variation is determined mostly from the PID control. Some spikes in Fig. 3a result from a huge local load variation. Fig. 3b indicates a ± 0.015 °C temperature variation. Such regular temperature variation as is shown in Fig. 3b is truncated by the resolution of the thermometer and the controller.



a



b

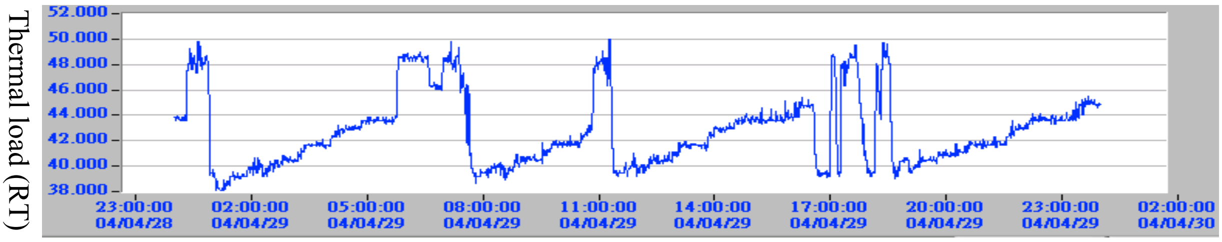
Time (hour)

Figure 3: DIW temperature histories at the inlet of RF DIW system (a) and the outlet of buffer tank (b).

Figures 4 and 5 present the RF DIW thermal load and flow rate histories, respectively. The thermal load is derived from the difference between the temperatures of the supplied and the return DIW, as well as from the flow rate. Although the thermal load varies by ±10% in one day, the flow rate variation is controlled within ±1%. The data shown in Figs. 3, 4 and 5 are recorded over a one-day duration. Therefore, the local thermal load variations, inducing the RF DIW temperature spikes shown in Fig. 3a, are clearly observed in Fig. 4.

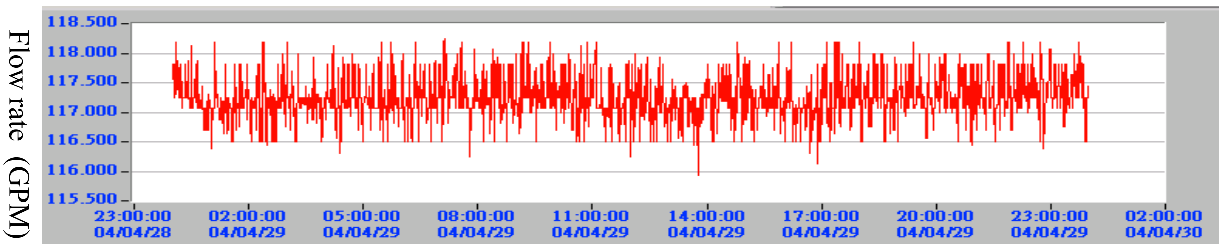
4 DIW quality control

The chemical and physical composition of raw water tends to be various. The specifications of treated water are also independent to meet various requirements. Therefore, there is no specific water treatment scheme that may fit all raw water and requirements. There are many water treatment schemes and equipments to keep DIW quality in good condition. The recycle system, RO system and deoxygenating system, described in this section, are main systems to control DIW quality.



Time (hour)

Figure 4: RF system thermal load history.



Time (hour)

Figure 5: RF DIW flow rate history

4.1 DIW recycle system

According to requirements of accelerator subsystems and the DIW recycle capacity, it is designed 5% of DIW will flow into the recycle loop as abovementioned in Section 2. The DIW will flow through a 5μm filter, two resin mixing beds, a 1μm filter, and an ultraviolet sterilizer sequentially in the recycle loop, as shown in Fig. 6.

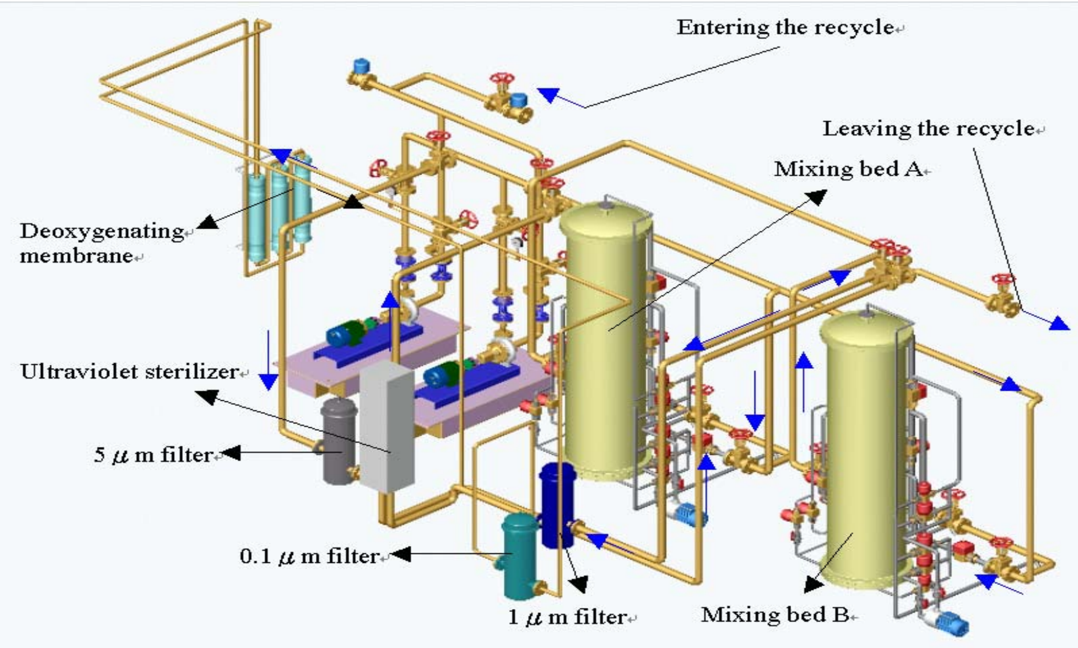


Figure 6: DIW recycle system.

4.2 RO system

The raw water flow through the RO system then into the DIW system as it is supplied to the DIW system. The RO system serves to remove ionic components and most soluble organic compounds from DIW. The RO system includes a 10μm filter, a set of RO membrane, a pressure pump, a medicine tank, a mixing pump, an 8-ton reservoir and an electrical control system, as shown in Fig. 7.

In Fig. 7, sand-bed filtration and the activated carbon bed serve as pretreatment of city water to obtain better processing effect and protect RO membranes. The sand bed filters are used to remove suspended solids and the activated carbon bed is applied to control microorganism growth.

4.3 Deoxygenating system

In the usage of ultrapure water, dissolve oxygen effect is a critical issue. Special consideration is given to the reaction of oxygen and silicon to yield silicon dioxide, which is crucial in the electronic chip semiconductor industry [5]. Membrane process for the water treatment is one of the most effective deoxygenating schemes. A set of Liquid-Cel membrane contactors of 4x28-X40 Extra-Flow is installed in the end of the DIW recycling system, as shown in Fig. 6. The membrane contactor applies vacuum and a nitrogen sweep to remove oxygen from DIW. Each membrane contactor consists of hydrophobic polypropylene microporous and nonselective hollow fibers. The flow rate of the deoxygenating system is controlled at 25 GPM.

An Orbisphere 3600 analyzer is installed to detect dissolved oxygen in the DIW. The accuracy of the O2 sensor is ±1% of reading. The dissolved oxygen in the DIW is kept under 10 ppb. Some other crucial water quality parameters are also kept monitored. The conductivity of the DIW is maintained above 10 MΩ/cm and the pH value is fixed at 7±0.3.

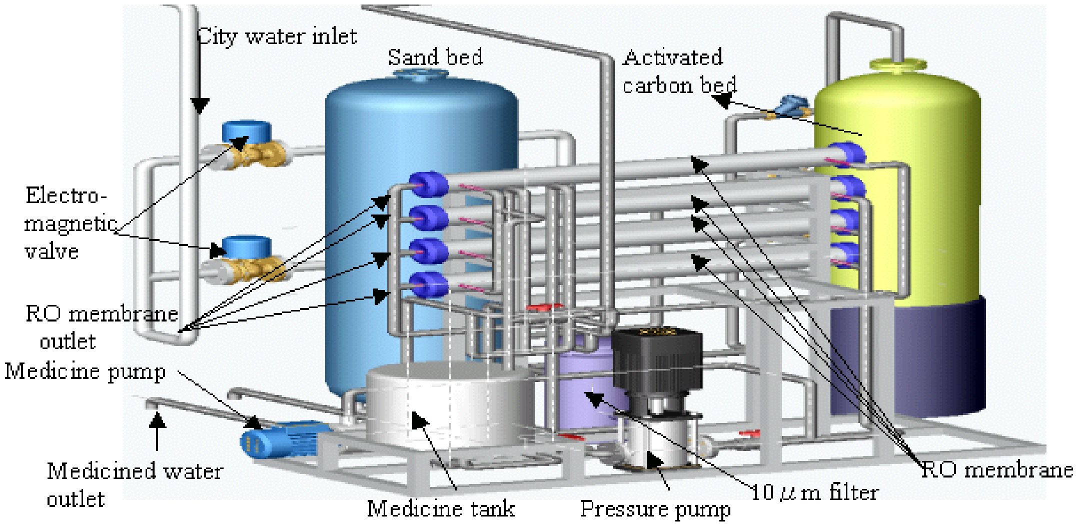


Figure 7: RO system.

5 Conclusions

Some major DIW system studies and upgrade projects were implemented to improve the DIW temperature stability and the DIW quality. The DIW system is divided into five main systems according to the accelerator subsystems. All DIW temperature variations were globally controlled within ±0.1 °C. The supplied booster DIW temperature variation was also reduced from ±3 °C to ±0.1 °C by increasing the cooling capacity and optimizing the PID parameters to support the upcoming top-up operation.

A high-precision DIW temperature control system for the RF system is established to satisfy the critical stability requirement of the RF system. A buffer tank with a capacity of 2-ton is installed in the 200-GPM DIW system to suppress effectively the temperature fluctuation of the supplied DIW. The RF DIW temperature variation is presently controlled within ±0.02 °C.

The water quality was improved by upgrading local filters, reverse osmosis, and installing conductivity meters, pH monitors, flow meters and various resins. The conductivity of the water is maintained above 10 MΩ/cm and the pH is maintained at 7± 0.3. A set of Liquid-Cel membrane contactors 4x28-X40 Extra-Flow are installed to keep the dissolved oxygen concentration under 10 ppb.

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7 References

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