COMMISSIONING OF THE DE-IONIZED WATER SYSTEM FOR TAIWAN PHOTON SOURCE

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Abstract

The de-ionized water (DIW) system plays a critical role in removing waste heat from an accelerator machine. Through years of design and constructs, the DIW system for Taiwan Photon Source (TPS) was complete at the end of 2013, but it is important to confirm that the quantity and quality of DIW comply with the requirements of the accelerator machine. Testing, adjustment and balancing methods have been applied to verify that the DIW system for TPS can provide flow rates greater than 1659, 380, 1284 and 1238 GPM in the individual Cu, Al, RF and booster subsystems. The proposed system can supply DIW of quality such that the resistivity is greater than 10 MΩ-cm at 25±0.1 °C; the concentration of dissolved oxygen (DO) is less than 10 ppb.

INTRODUCTION

The main utility equipment of TPS includes a deionized water (DIW) system installed in Utility Building III to avoid vibration and power noise induced by these cooling-water facilities, including cooling towers, chillers, heat pumps and water pumps [1]. A utility trench from Utility Building III connects to TPS for the piping system and electric power transmission [2]. Figure 1 has a schematic drawing of TPS and Utility Building III.

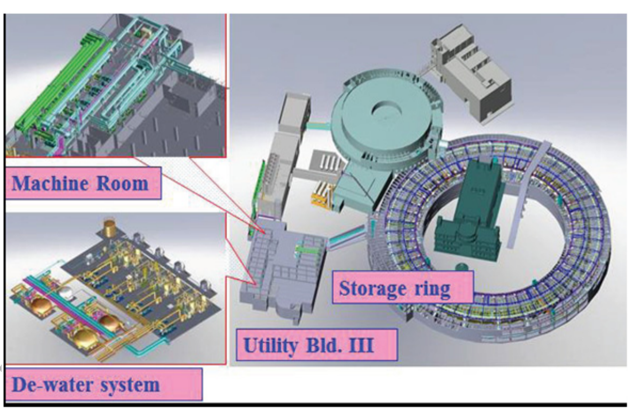

Figure 1: TPS storage ring and Utility Building III.

The DIW system for TPS has four subsystems -- Cu DIW for magnets and power devices, Al DIW for vacuum chambers, RF DIW for the RF facility, and booster DIW for booster devices and beamline optical instruments. The demanded flow rate that depends on the heat load for each portion of the TPS synchrotron accelerator is listed in Table 1.

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Table 1: Flow Rate Requirements of DIW Subsystems

Point of use	flow rate /GPM			
	Cu	Al	RF	booster
magnet	594	-	-	136
power devices	501	-	-	-
vacuum	260	312	-	-
front end	296	68	-	-
RF facility	-	-	1284	-
cryogenics	-	-	-	17
Linac	-	-	-	435
mechanical	8	-	-	-
beamline	-	-	-	650
total	1659	380	1284	1238

All DIW flow circulates in a closed loop and removes heat within a stable range of temperature and pressure. Each return DIW flows through two plate heat exchangers for heating and cooling, then flows via a mixing buffer tank for highly precise temperature control. Respective DIW subsystems possess two pumps with variable-frequency drives (VFD) that achieve flow regulation, energy conservation and uninterrupted commission.

Water treatment is an important aspect of a DIW system. Impurities in DIW typically include particles, electrolytes, micro-organisms, organic substances and gases that must be removed with a physical or chemical mechanism. The activated carbon filter (ACF), reverse-osmosis equipment (RO), resin-mixed bed (MB), micro-filter (MF), ultraviolet sterilizer (UV) and dissolved oxygen membrane deaerator (MD) have been installed to sustain the water quality [3]. Of the primary loop flow, 5 % DIW flows through this recycle loop as shown in Fig. 2; the entire DIW system must meet specifications listed in Table 2.

In the TPS storage-ring building, an individual DIW subsystem has been divided into 48 manifolds for the 24 sections of the accelerator machine, as shown in Fig. 3. Every manifold has filters, flow-balance valves and sensors for temperature, pressure and flow, which provide an optimal flow balance and real-time DIW status. Every inlet and outlet piping connected with the accelerator machine has a flexible hose to prevent the propagation of vibration.

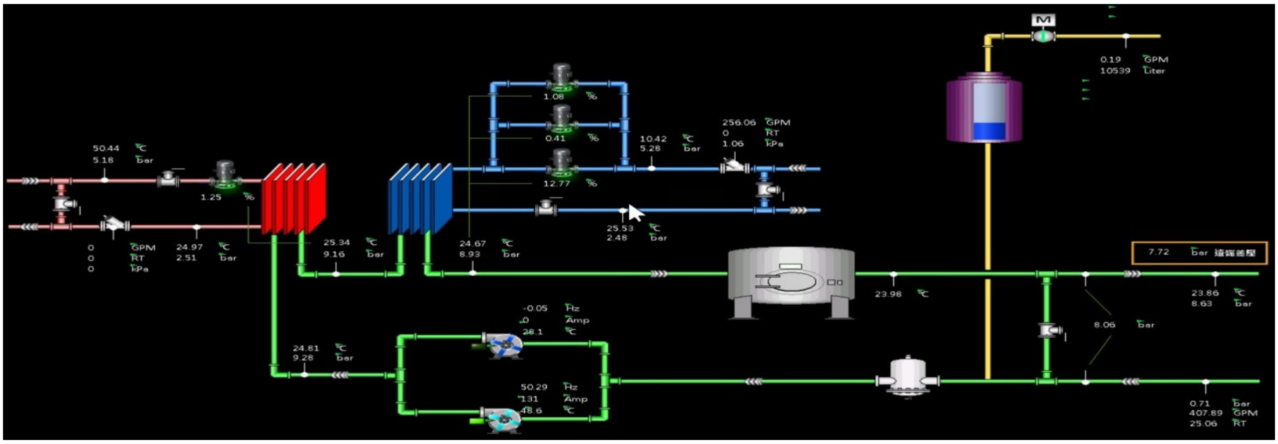

Figure 2: DIW system diagram.

Table 2: Specification of DIW Subsystems

	Cu	Al	RF	booster
resistivity/ MΩ-cm	>10	>10	>10	>10
DO /ppb	<10	<10	<10	<10
pH	7.0±0.2	7.0±0.2	7.0±0.2	7.0±0.2
temperature /^{o}C	25.0±0.1	25.0±0.1	25.0±0.1	25.0±0.1
pressure /kgf cm^{-2}	7.5±0.1	7.5±0.1	7.5±0.1	7.5±0.1

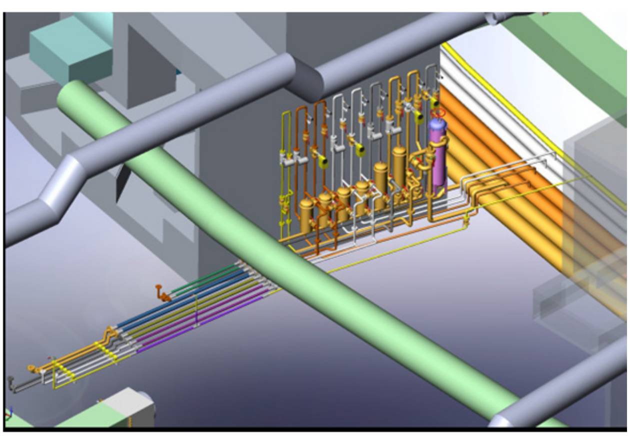

Figure 3: Manifolds for each section of the accelerator.

COMMISSIONING PROCEDURE

The objective of DIW commissioning is to achieve, to verify and to document that the performance of facilities, systems and assemblies meets defined objectives and criteria. The commissioning of the DIW system includes three phases -- visual inspection, a functional test and an integrated system test.

Visual Inspection

The first phase of commissioning is a visual inspection that comprises these major items: a system diagram, report of sensor and instrument calibration, pipeline, support, thermal insulation, water treatment and transport equipment, electrical input, chilled-water and hot-water supplies, compressed dried-air supplies, control sequence and wiring, and wastewater discharge. A valve to vent gas installed at a high point can increase the rate of decay of dissolved oxygen in the DIW system.

Functional Test

The second phase of commissioning is a functional test that comprises main tests of pipeline leakage, the performance of water treatment and transport equipment, electric demand and power quality, VFD, actual flow rates and pressures at pump outlets, a pressure drop between inlet and outlet of each plate heat exchanger, and trend logs.

Integrated System Test

The final phase of commissioning is an integrated system test that comprises principal tests: sequence of responses to control signals at a defined condition, actual temperatures and flow rates at defined conditions in each manifold, water pressures and pressure drops at defined conditions, DIW quality, responses to defined temporary upsets of system operation, and safety interlocks.

COMMISSIONING RESULTS

Flow Rate Testing, Adjusting and Balancing

We first confirmed that the flow rate and head of the DIW pump at shutoff, 100 % and 150 % of rated capacity, meet the curves for the pump characteristics. We verified that the pressure drops between the inlet and outlet of each plate heat exchanger conform to the contract requirement. We transported DIW to the TPS accelerator machine. At each point of use, the flow rate can increase or decrease on adjusting flow-balance valves. We acquired the pressure drop of a flow-balance valve to

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determine a flow rate. For example, the target flow rate is 642 GPM for each point of use in the RF DIW subsystem, but the actual flow rates are 758.95 and 746.54 GPM respectively. After adjustment, the flow rates became 647.7 and 646.9 GPM, slightly greater than the target flow rate as shown in Fig. 4. We concurrently maintain the pressure of the return DIW with an expansion tank, because the flow rate is affected by the pressure drop between the supply and return sides. The other three DIW subsystems -- Cu, Al, and booster – perform also to approach their target flow rate.

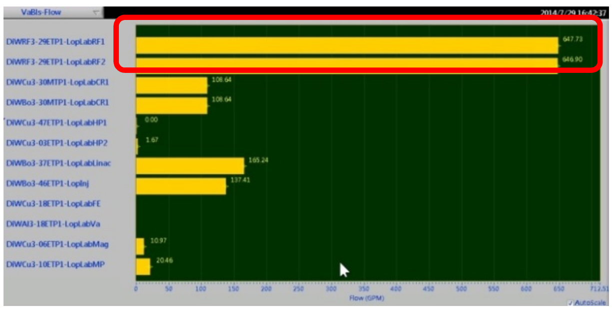

Figure 4: Flow rate at point of use for the RF subsystem.

Precise Control of Temperature

For highly precise control of the temperature of the DIW supplies, we adopted a commercial controller (NI PAC) with a current module (24 bit), high-performance transmitter (accuracy 0.05 % full scale) and temperature sensors (1/10 DIN Class B). A buffer tank in each DIW subsystem was built to stabilize the temperature variation with a mixing mechanism. There are two or three control valves in parallel connection on the chilled-water side of a plate heat exchanger for each DIW subsystem. One is a small valve and the other one or two are large valves. The small valve applies a traditional PID algorithm to fine-tune the temperature variation below ±0.1 ^{o}C. The large valve is responsible for a large temperature fluctuation such as on-off heat loading, with a fuzzy algorithm. The thermal isolation of the piping and facilities must be inspected carefully.

The commissioning results revealed that temperature variations were eliminated to ±0.02 ^{o}C as mentioned above, shown in Fig. 5.

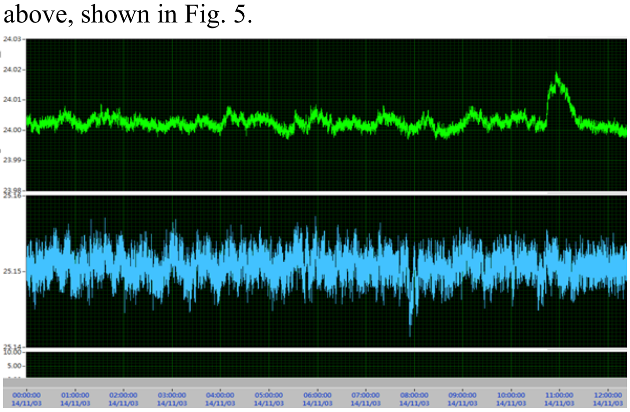

Figure 5: Temperature control of booster and RF DIW.

DIW Quality

The water quality of all four DIW subsystems achieved the specifications listed in Table 2. For instance, the pH of the booster DIW subsystem is about 7.1. A monitoring chart of resistivity and dissolved oxygen in 24 h is shown in Fig. 6. We obtain a steady resistivity located at 17.3 to 17.6 MΩ-cm. The concentration of dissolved oxygen is generally about 7.1 - 7.5 mg/L, but we discovered a maxima at 8.1 mg/L. This result might be caused by the residual air chamber exiting in the pipeline. When we executed a vent process at relative high point of pipeline could improve. The other three DIW subsystems, i.e., Cu, Al and RF subsystems conform to a similar trend.

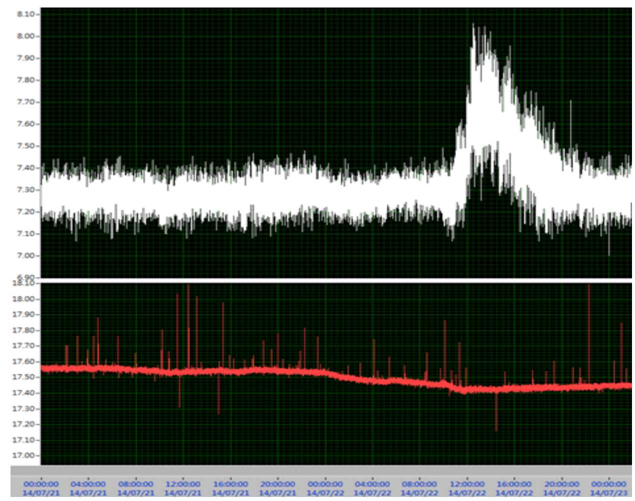

Figure 6: DIW quality of the booster subsystem.

CONCLUSION

A buffer tank and a parallel connection of small and large control valves provide precise temperature of individual DIW subsystems. We vent air at a high point of the pipeline to decrease the concentration of dissolved oxygen.

ACKNOWLEDGMENT

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