DESIGN OF THE DE-IONIZED WATER TREATMENT FOR TAIWAN PHOTON SOURCE

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Abstract

For the treatment of water for the Taiwan Photon Source (TPS), the system design is influenced by the quality and quantity of the supplied water and the selected process scheme. The system involves pretreatment, make-up, polishing, dosing and filtration systems at points of use. The make-up system consists of a tank of active carbon and a reverse-osmosis (RO) unit. The polishing system consists of an ultraviolent sterilizer, membrane for dissolved oxygen, a micro-filter and an ion-exchange resin unit. Following the water treatment, the proposed system can provide de-ionized water of quality such that the resistivity is greater than 10 MΩ-cm cm at 25±0.1 ^{o}C and the oxygen concentration is less than 10 ppb.

INTRODUCTION

The TPS infrastructure including a civil and utility system has been under construction since 2009 December. As the utility system is a highly critical subsystem affecting the beam quality and reliability, much effort has been devoted to its design [1]. Here we address mainly the specific design of the water-treatment system of the finalized utility system.

In the accelerator field in general, thermal waste can be treated through deionized water (DIW) and air conditioning (A/C). The cooling systems of the water and air aspects must be well designed so that the accelerator machine can be less subject to thermal effects. The main system for cooling-water involves a cooling-tower water, chilled water, hot water and DIW. This main water treatment facility is located in utility building Ⅲ , including the make-up, polishing and dosing system [2].

In general, we use a dosing pump and a controller to protect the cooling-tower water, chilled water and the hot-water system from the harmful effects of scaling, corrosion and microbiological growth. The conductivity/pH controllers are designed to monitor and to control the total dissolved solids (TDS) in open recirculating cooling systems. In terms of electrical conductivity measured in microsiemens (µS/cm), a set point of the desired conductivity limit and dosing timer is entered into the controller through the touch-screen panel. When the maximum conductivity limit is exceeded, a blow-down valve is opened. The system water with an excess level of TDS is blown down, resulting in fresh make-up water being added, decreasing the concentration of TDS in the cooling system. The conductivity/pH controllers control the dosing pump with a limit timer that acts as a fail-safe device to prevent system overfeed.

Regarding the DIW, the system can not process by dosing, because of de-ionization. Impurities in the DIW water typically include particles, suspensions, electrolytes, micro-organisms, organic substances and gases that must be removed with a physical or chemical mechanism as listed in Table 1. We must therefore design a corresponding process to remove each of these impurities, including a sand filter, active-carbon filter, ion-exchange device, reverse-osmosis device, micro-filter, ultraviolet sterilizer and a membrane for dissolved oxygen.

Table 1: Mechanisms of the Water Treatment System

	Suspension	Electrolyte	Corpuscles	Micro organisms	Organic substance	Gas
Sand Filter	○		△	△	△	
Active Carbon Filter			△		○	
Ion-Exchange Device		◎	△		△	
Reverse Osmosis Device		◎	◎	◎	◎	
Microfilter			◎	○	○	
Ultraviolet Sterilizer				◎		
Dissolve Oxygen Membrane						◎

◎ best, ○ better, △ good

SYSTEM OF POLISHING AND MAKE-UP

All DIW circulates in a closed loop with adequate control, which must provide a cooling source at a stable temperature and pressure. The return DIW flows through heat exchangers for heating and cooling, and then flows via a mixed buffer tank for highly precise temperature control. Of the flow in the primary loop, 5 % DIW flows through this polishing loop as shown in Figure 1. The entire DIW treatment system must meet specifications listed in Table 2. The water flows in sequence through a 1-µm micro-filter, ion-exchange device, 1-µm micro-filter, 0.1-µm micro-filter, dissolved-oxygen membrane and an ultraviolet sterilizer of the polishing loop. The former 1-µm micro-filter is installed to protect the mixed bed from particle pollution; the latter 1-µm micro-filter is installed to protect downstream from broken cation and anion resins, and the 0.1-µm micro-filter must be installed to protect the dissolved-oxygen membrane from becoming blocked.

We design and build mixed-bed polishing units to suit our requirements. Cation, anion and neutral resins are combined in a stainless-steel vessel to produce ultrapure water. The mixed-bed polishing unit contains a strongly acidic cation (SAC) resin, strongly basic anion (SBA) resins and a neutral resin combined at a ratio approximately 40 % cation resin, 50 % anion resin and 10 % neutral resin. All resin volumes are set according to the incoming water quality and the required quantity of treated water. The cation resins in our mixed-bed polishers having a greater specific gravity are located at the bottom of the vessel whereas the anion resin automatically floats to the top. The neutral resin has sufficient gravity to remain always inserted between the cation and anion resins, which can avoid counteraction and save rinsing water in the regeneration procedure.

Table 2: Specifications of the Water Treatment System

	Resistivity	Dissolved Oxygen	pH
Cu Deionized water	>10M ohm-cm	<10ppb	7±0.2
AL Deionized water	>10M ohm-cm	<10ppb	7±0.2
RF Deionized water	>10M ohm-cm	<10ppb	7±0.2
Beamline & Booster Deionized water	>10M ohm-cm	<10ppb	7±0.2

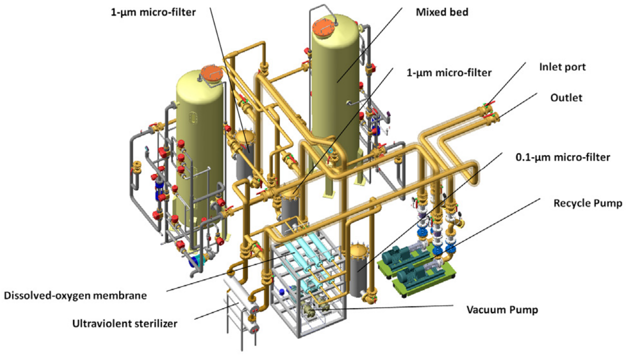

Figure 1: Structure of the water-polishing treatment.

The ultraviolet (UV) sterilizer and dissolved-oxygen membrane have also been installed after the mixed bed as shown in Figure 2. The UV light destroys infectious microbes by directing light to their reproductive mechanisms. The oxygen concentration in a range 20~2000 ppb could increase the rate of corrosion, and a more acidic condition also increases that rate. Even in a closed-loop system without facilities to remove dissolved oxygen, oxygen occurs at a rate greater than the influx of new oxygen. If pH is tending to an alkaline range, these oxide deposits can be easily formed in the conduit. The components including orifices, valves, self-regulating flow-control valves and pressure regulators are subject to clogging. Agglomeration occurs on pump impellers. The risk of a heat process such as of a magnet coil is increased with a large current. An adequate control range with less than 10 ppb is thus determined. The dissolved-oxygen membrane and vacuum pumps are set to eliminate dissolved oxygen efficiently. If necessary, the forthcoming nitride is beneficial to enhance the efficiency of deaeration.

Mixed-bed regeneration is implemented with a water quality of resistivity less than 10 MΩ-cm. We install mixed-bed polishers after a make-up system, including a sand filter, active-carbon filter and a RO device to produce ultrahigh-quality water as shown in Figure 3. The RO units are designed with pre-filtration systems, to operate with fresh and brackish feed waters having TDS values less than 200 ppm and pH range 6~8. RO offers a means of removing ionic and organic components and restraining the passage of insoluble particles from their aqueous solutions. Carbon filtering is a method of water purification that uses a piece of activated carbon to remove contaminants and impurities, utilizing chemical adsorption. The carbon filters are most effective at removing chlorine, sediment and volatile organic compounds from water, which can degrade ion-exchange resins and ruin RO membranes composed of polyamide polymer. The system can output approximately 3 tonne/h and store in a 10-tonne reservoir tank for 4 DIW systems.

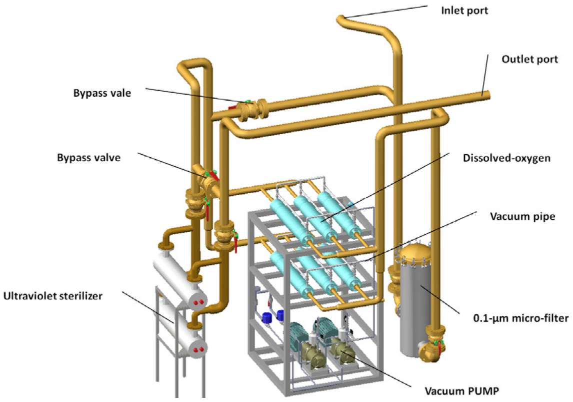

Figure 2: Structure of the deaeration treatment.

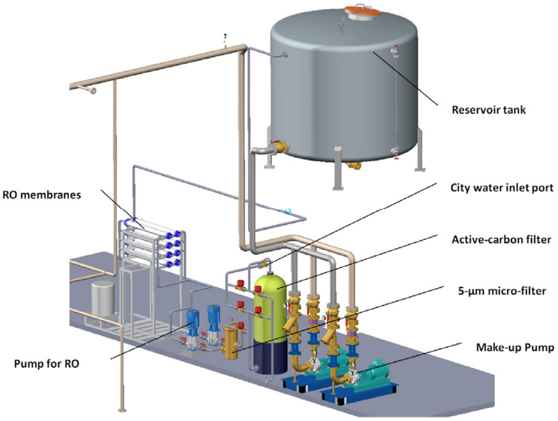

Figure 3: Structure of the water RO treatment.

CONTROL AND MONITORING SYSTEM FOR WATER TREAMENT

We designed an integrated architecture of a control and archive system for a utility facility [3]. The programmable automation controllers (PAC) with a FPGA function have therefore also been implemented in this regeneration control system for applications of highly reliable control. This system adopts mainly PSP protocols to enable all human-machine interface (HMI) servers or local touch-screen panels to exchange information. The system must implement eight steps of regeneration procedures including backwash, settling, regeneration, slow rinse, rapid rinse, air mixing, refill and recycle rinse to attain the requirement of resistivity above 10 MΩ-cm, which have an empirical operation in Taiwan Light Source (TLS) as shown in Figure 4. Each regeneration procedure timing is adjustable through a local intuitive touch-screen panel or a HMI system. A strongly acidic cation resin is washed with approximately 30 % hydrochloric acid; a strongly basic anion resin is washed with approximately 26 % caustic soda. These regeneration strengths refer to values before dilution with the standard polisher systems and expert experience. Adequate pH, resistivity and dissolved-oxygen sensors have been installed in the primary and polishing loops to monitor the entire status of water treatment.

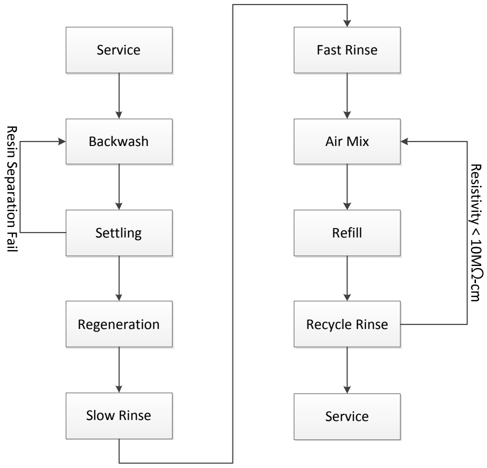

Figure 4: Regeneration procedure of a mixed-bed resin.

FILTRATION SYSTEMS AT POINTS OF USE

In this aspect of 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 5. Each manifold has seven micro-filters, four flow-balance valves, and 20 sensors for temperature, pressure and flow, which provide optimal flow balance and real-time DIW status as shown in Figure 6. Each inlet and outlet pipe connected with the accelerator machine has a flexible design of piping to prevent the propagation of vibration. Each system has inlet and outlet 1-μm micro-filters, which act as an interface with the subsystem to clarify the piping contamination. The filter is manufactured with melt-blown polypropylene fiber media. The pleated filter cartridges combine exceptional dirt-holding capacities with large rates of flow and small loss of pressure.

Figure 5: Manifolds for each section of the accelerator.

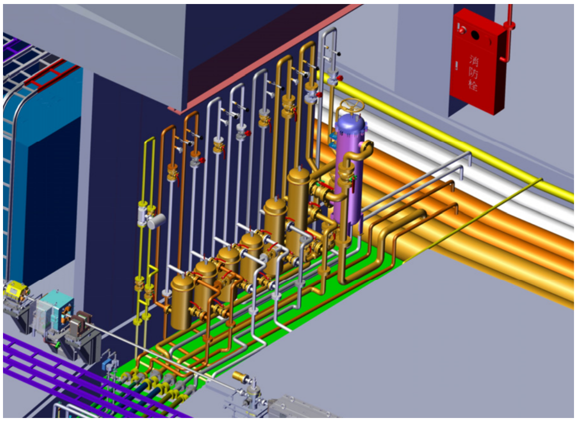

Figure 6: Manifold arrangement near a CIA.

CONCLUSION

Some utility schemes and experience of the TLS have also been adopted, including a design philosophy and facility. For intuitive control, the traditional local controller has been replaced with a PAC and integrated with a HMI system. All water treatment can provide water of a reliable quality for the subsystems.

ACKNOWLEDGEMENT

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