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DISTRIBUTED COOLING SYSTEM FOR THE AREAL TEST FACILITY*

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Abstract

Following the design specifications of the Advanced Research Electron Accelerator Laboratory (AREAL), a reliable distributed cooling system for the AREAL linear accelerator has been developed. The cooling system provides a high accuracy temperature control for the electron gun, klystron and the magnets. The main requirements and technical solutions for various accelerator components cooling units are presented, including the local and remote control.

INTRODUCTION

The AREAL facility is a laser driven RF electron linear accelerator for the advanced research in the field of accelerator technology and ultrafast processes [1]. The design specifications of the facility implies the stringent requirements to the facility performance, in particular to the cooling system. For phase 1 of the AREAL facility (electrons energy of 5 MeV) the stable and reliable cooling for the RF gun, klystron and solenoid magnet are required. The main parts of the AREAL cooling system have been developed and fabricated at CANDLE Institute.

MAIN REQUIREMENTS TO COOLING SYSTEM

Each device and equipment of AREAL has its individual cooling requirements.

Table 1: The Main Cooling Requirements of the AREAL Components

Parameters	RF gun	Klystron		Solenoid magnet
		Reson,	Magnet	
Cooling capacity (W)	300	500-1'500		2'000
Temperature	30-55	30-55		15-40
Temp. stability (^{0}C)	+/-0.1	+/-0.5	+/-0.1	+/-1
Water flow rate (l/min)	11	3.64	20.5	2-30
Pressure (kg/cm^2)	<4.2	<4.2		1.5-3
Coolant	Deionized water	Distilled water		Demineralized water
Deionization level (MΩ·cm)	5.6	50 MΩ·cm		50 MΩ·cm

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The design and fabrication of cooling systems are based on the AREAL performance specifications which imply the temperature control of the facility subsystems.

Main cooling requirements of the AREAL equipments are presented in Table 1.

Cooling system of the AREAL linear accelerator is divided into three main parts: RF gun thermoregulation system, klystron cooling systems and solenoid magnet cooling system. Each cooling system has its individual parameters depending on specifications of accelerator parts. The cooling systems are located in the AREAL laboratory main building.

THERMOREGULATION SYSTEM OF RF GUN

The AREAL linear accelerator is based on the laser driven RF gun and for high-end performance efficiency the thermoregulation system of RF gun must satisfy all cooling-heating requirements presented above (Table 1).

The hydraulic scheme of thermoregulation system of laser driven RF gun is presented in Fig. 1.

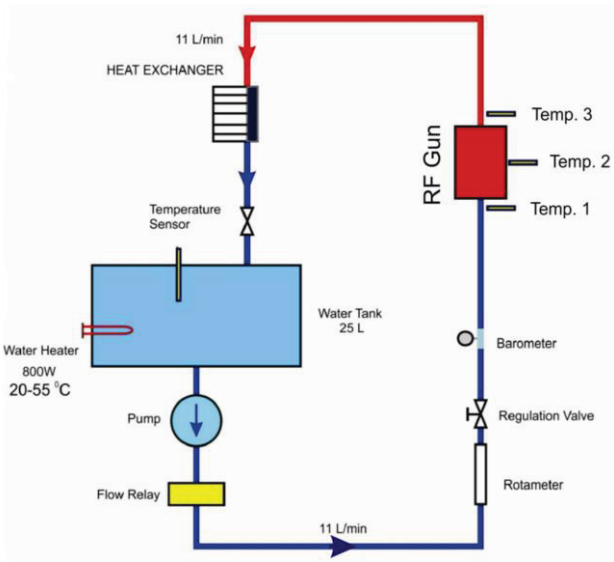

Figure 1: Thermoregulation system-circuit for RF gun.

The main technical parameters of RF gun thermoregulation system are presented in Table 2.

Thermoregulation system of RF gun is reliable and flexible system and can be controlled locally or remotely from control room. Depending on generated heat level from electron gun the thermoregulation system can provide in electron gun laminar water flow rate with accurate temperature.

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Considering the thermal requirements of electron gun as coolant, the de-ionized water with 5.6 MΩ·cm of nominal specific resistance is chosen.

As temperature sensors the Pt100 platinum resistance thermometers are used. Pt100 temperature sensors are very precise and sensitive with the measurement accuracy of +/-0.03^{0}C at 0^{0}C.

Temperature sensors locations on the electron gun are presented in Fig. 2.

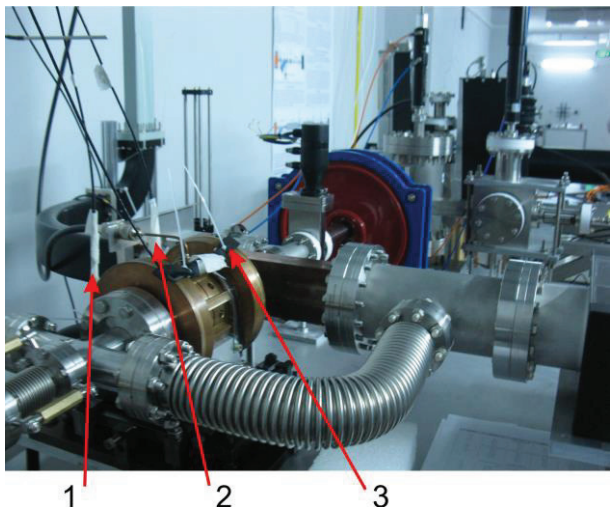

Figure 2: Temperature sensors locations on the gun: 1. Temperature sensor of water flow entrance into the gun, 2. Temperature sensor of water flow exit from the gun, 3. Sensor is located in the middle of the gun.

Table 2: Main Technical Parameters of Thermoregulation System of RF Gun

Characteristics	Value
Cooling capacity (W)	500
Temperature range (^{0}C)	30-55
Temperature stability (^{0}C)	+/-0.1
Water flow rate (l/min)	2-15
Pressure	Not exeed 4.2kg/cm^2
Coolant	De-ionized water
De-ionization level	5.6 MΩ·cm

Part of the temperature measurement results on the electron gun obtained during the accelerator May 2014 operation is presented in Fig. 3. The cooling water temperature at the gun entrance (a), exit (b), middle point (c), tunnel temperature (d), the in-out difference (e) are shown. As it is seen, the cooling system provides the temperature stability at the gun entrance of 37.5 ^{0}C with accuracy of 0.1^{0}C. The gun in-out temperature difference is about 1.5. Fig. 2d presents the stability of air temperature at the accelerator tunnel kept at 22.7 ^{0}C.

The thermoregulation system of RF gun has proportional integral difference (PID) controller and all measurement data are recorded in control room.

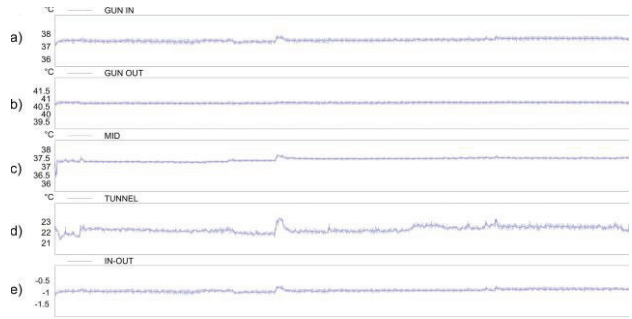

Figure 3: The gun temperature measurement results.

The thermoregulation system of RF gun is located 3.5 meters above from electron gun in the area for cooling systems.

The main drawback of thermoregulation system of RF gun is the water purity decreasing in time. The main influence on the specific resistance of de-ionized water is caused by the corrosion of the cooling system components. For the efficient and reliable operation, the cleaning of gun thermoregulation system before the de-ionized water inlet is very important [3]. To increase the water purification level during the long time operation the hoses of thermoregulation system are changed by the plastic pipes.

COOLING SYSTEM OF RF KLYSTRON

Another important cooling system for the AREAL facility is the cooling system of RF klystron [4].

The main technical parameters of cooling system of RF klystron are shown in Table 3. The klystron cooling system is located near klystron in the RF room.

As the coolant for the klystron cooling system a distilled water is used.

Table 3: Main Technical Parameters of RF Klystron Cooling System

Characteristics	Value
Temperature range	30-55
Temperature stability	+/-0.5
Temperature sensor type	Pt100
Coolant	Distilled water
Water deionization range Ω·cm	25'000 to 18'000'000ohms-cm
Nominal pressure (bar)	3.3

As construction materials of klystron cooling system with distilled water circulation the stainless steel, copper, bronze and plastic are used. The influence of those

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materials on the distilled water quality is very low which saves the water purity level during long time (1400 hours).

Fig. 4 presents the scheme of klystron cooling system.

All components, subsystems and junctions of cooling system are tested in laboratory conditions before the final assembly.

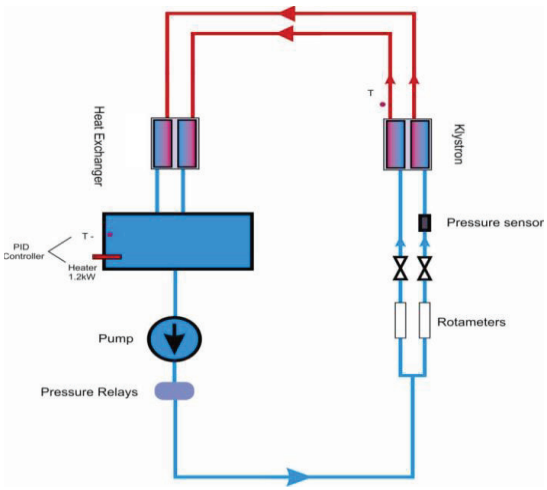

Figure 4: Operation scheme of klystron cooling system.

WATER PURIFICATION LEVEL

The water purification level is very important for the efficient and reliable operation of accelerator devices and equipments [2].

Cooling laboratory of the CANDLE Institute contains water treatment system: de-ionizer, distiller and the measurement equipments (water conductometer, etc.). Other laboratory equipments and conditions for processing the appropriate purified water are available as well.

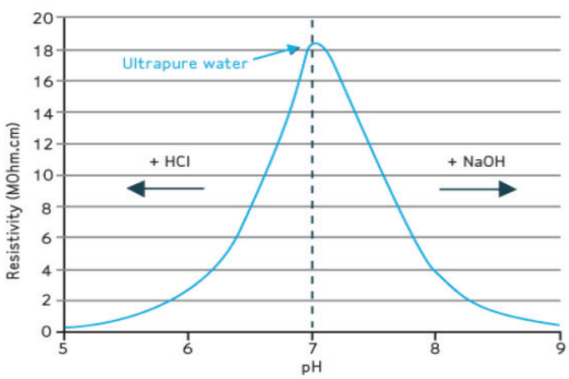

Figure 5: Specific resistance level depends on pH for ultra pure water.

The pipes of cooling systems for RF gun, klystron and solenoid magnet consist of copper, plastic, bronze and brass. Cooper and other materials corrosion rate depends on conductivity, dissolved O_2, CO_2, level of pH, temperature, flow velocity of water and imposed electrical and galvanic potentials difference (different metallurgy).

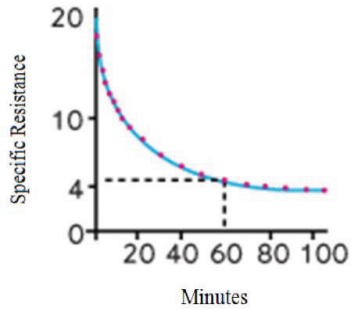

Figure 6: Ultra-pure water contamination level depends on time.

In the accelerator cooling systems the components corrosion in de-ionized and distilled water is unavoidable but can be limited.

The specific resistance level dependence on the pH level is presented in Figure 5. The contamination level of purified water is shown in Figure 6.

The cooling laboratory of CANDLE Research Institute is providing the appropriate ultra pure water for the cooling systems of AREAL.

CONCLUSIONS

The AREAL water cooling systems for RF gun, klystron and solenoid magnet are reliable, flexible and stable systems which provide facility operation according to the design specification. It also gives the possibility to do advanced experiments and obtain desirable results from accelerator. All cooling parts, junctions, components and subsystems of cooling systems are selected and tested in the test bench of cooling laboratory before implementing into the facility. Stable and reliable parameters for cooling systems during accelerator operation were achieved.

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