THE IASA COOLING SYSTEM FOR THE 10 MeV LINAC

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Abstract

A de-ionized water cooling system for the IASA room temperature 10 MeV CW Linac has been constructed and successfully installed. Commissioning is undergoing achieving resistivity larger to 5MΩcm with a temperature accuracy of $\pm 0.1^{o}C$ for all three linacs. Three ways mixing valves with a stepping capability of one thousand different mixing steps fulfil independently for each linac the required temperature stability and the appropriate resonance frequency to our cavities. The RF requirements for the three linacs is ~200kW provided by a single high power klystron tube capable to deliver up to 500 kW CW at 2380 MHz. The klystron is been cooled with a parallel similar cooling system and a third system cools our aluminium waveguide complex. In this paper we will present the design, specifications and results of our preliminary tests. A sophisticated control and interlock system based on EPICS guarantees the proper functioning of the system.

INTRODUCTION

The IASA Microtron [1], a Continuous Wave (CW) Race Track Microtron (RTM), is being built making optimal use of the available components obtained from NIST and the University of Illinois RTM projects [2]. It is based on an optics study, which adopts a two-stage Cascade scheme with variable output energy from 5 to 240 MeV [3]. The Control System for this Microtron is totally revised as we considered the architecture and the implementation of the NIST and UIUC machines outdated. Having in mind the complexity and the large number of elements to be controlled, we decided to develop the new Control System on the EPICS (Experimental Physics and Industrial Control System) environment [4]. EPICS is a distributed process control system built on a software communication bus, scalable from a single test station with a low channel count to a large distributed network with thousand of channels. The physical front-end layer is built from modularized electronics (VME crates, CPU and I/O boards) while the physical back-end layer is implemented on popular workstations running UNIX. Communication between them is achieved with a network layer supporting the TCP/IP protocol. A prime goal of this is to obtain the basic functionality and performance necessary to commission and control the injector of the RTM [5].

In this paper we describe the cooling system applied to the (modified) 10MeV injector of the accelerator. Its expansion to the full scheme is straightforward. We present also the most recent achievements from our high power RF group.

GENERAL DESCRIPTION

The IASA cooling system is divided in several subsystems to cool the accelerating structures. It takes care also of our S-band klystron (2380 MHz, 500kW CW RF power) [6], the 500kW four-port circulator system, and the high power loads and the distribution of our waveguide (WA-430) system. In Figure 1 we can see the main schematic system for all three accelerating linacs, the klystron and loads. In our case the control of temperature of the de-ionized water system guarantees the resonance of the structures to the right frequency. This is done through the mixing of the cold water (from our 560kW chiller) to the heated output water from the linacs, and for each one separately. As we can see in Table 1 the injector has been modified to deliver up to 10 MeV of beam energy. It consists of a 100keV thermionic electron gun and chopping buncher system, followed by a capture structure (0.95m long) β tapered delivering a 1.3MeV electron beam. In addition a Preaccelerator linac (2.7m long) follows and delivers a 5 MeV electron beam and finally a small booster section delivers the 10 MeV for this modified scheme. In normal operation for a full Race Track Microtron scheme the injector needs to deliver only 6.5 MeV. In Figure 2 we see details the of the cooling

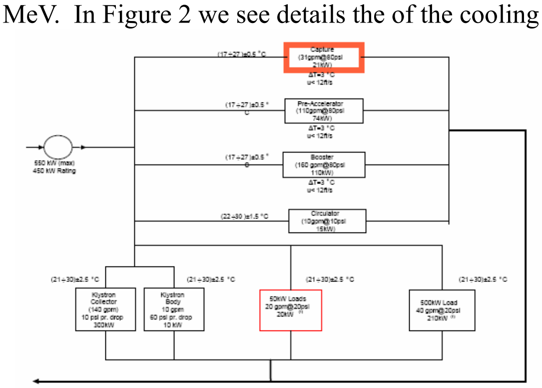

Figure 1: Main cooling system schematic.

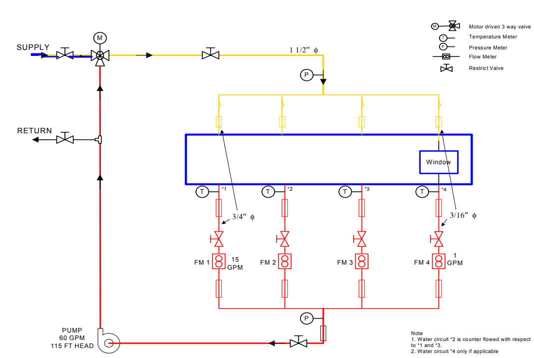

Figure 2: The mixing of cold and heated water for one of the structures and associate monitoring devices.

[#]Dept. of Physics, Univ. of Athens, Greece system for one linac. In our case we have side-couple structures from Los Alamos operating in room temperature. Each linac is divided in subsections of three cells and there is a separate water entry for its one. In this subsection is possible to monitor temperature and regulate the flow. The flow from all subsections is been monitored in temperature and measured on line and regulated in flow. The driving pump is at the outlet of the water system and through an automated three way mixing valve guarantees the right temperature for the resonance of the cells for each linac.

Table 1: Modified Injector and RTM parameters
(* injector parameters for the full RTM system)

	INJ	RTM1	RTM2
Injection Energy [MeV]	-	6.5*	41
Gain per Turn [MeV]	-	1.32	8.04
Number of Recirculations	-	26	25
Max Output Energy [MeV]	10 (6,5*)	41	240
Max Current [uA]	600	100	100
Frequency [MHz]	2380	2380	2380
Incremental Number	-	1	1
Magnetic Field [Tesla]	-	0.2196	1.338
RF Power Consumption [kW]	215 (118.7*)	29.0	169.3
Magnet Spacing [m]	-	3.25	8.7

CONTROL LOOP OF TEMPERATURE

General Description

The most delicate task in the injector scheme is the coupling of the cooling system to the resonance frequency for the cavities. As we can see in Figure 3 RF is feeded to each cavity through an RF Wave Guide system. This system is been controlled for its amplitude and for its phase through a stepping motor automated phase shift control system. A thermistor provides a precise value of temperature to a control unit which, in return, activates a three way mixing valve. These valves can provide 1000 steps of different water temperature mixing. The system is very sensitive to the resonance frequency so a stability of $\pm 0.1^{o}C$ is desired.

Description of Monitoring Devices

The cooling system includes a series of devices and interlocks. In each subsystem we measure water temperature (in and out) as well as the temperature of each group of cells for each structure. We also measure water flow, pressure (in and out). There is also a series of (regulating) flow switches and regulating valves in order to attend the appropriate water flow. Water speed is around 12ft/s and flow stability below 1%.

Cooling is guaranteed through the operation of a powerful YORK's chiller (YCAS 0623SC delivering 560kW of cooling capacity, we only need 70% of it). A secondary loop circulates the 10% of the water through a de-ionizing system, coupled to our control loop for a constant measurement of water conductivity. Values down to 0.1μsievert are easily attended and our system works properly between 0.2-0.4 μsievert. A system of killing the bacteria through powerful UV lamps is also included in this secondary loop along with a series of micro filters (few microns) so the system guarantees the proper internal cooling of each cell in each cavity.

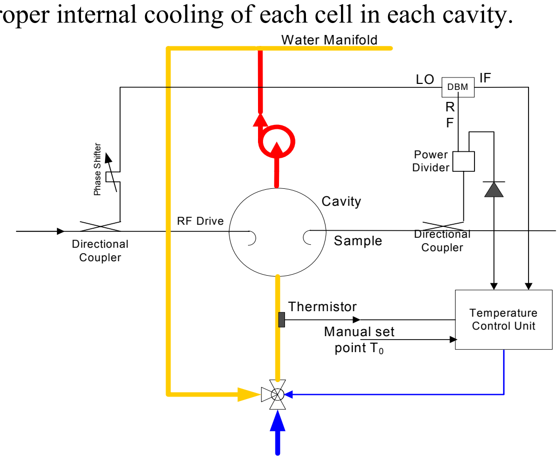

Figure 3: Small deviations of RF drive with respect to sampling signals result, through a temperature control unit, to an error signal activating an automated mixing valve to optimized temperature of each cavity independently.

Control of the Mixing Water Valves

The mixing water valves are primarily controlled by stand-alone, electronic temperature controller units, which are programmable for P (Proportional) or PI (Proportional + Integral) response. The installed temperature controllers RWC62 (SIEMENS) are the most commonly used in HVAC applications, where a high precision and quick response is required. Each unit has two modulating outputs (Y1 and Y2) operating at the 0-10Vdc range; the first of them is directly connected to the actuator of the water mixing valve. There are two analogue inputs (B1 and B2) for the temperature sensors and several digital input and output connections for auxiliary controls. The required temperature set point can be entered either directly to the unit or remotely by means of the analogue input B2.

In a normal operation the sensor B1 senses the water temperature. On any deviation in the desired temperature, as it is defined by the set point, Y1 output regulates the water valve actuator. For the correct performance of each cooling branch the proportional band (P) and the common integral action time (I) of the controller algorithm has to be properly adjusted. The proportional band parameter is normally set in degrees and reflects the proportionality of the error signal generated by the controller. The integral action time is strongly dependent on the water flow and the dissipated energy of each cooling section. It is therefore absolutely necessary to study the behaviour of every cooling section separately and to adjust the PI parameters correspondingly. Such a realistic case is illustrated in Figure 4, where the operation of the wave-guide cooling controller is shown.

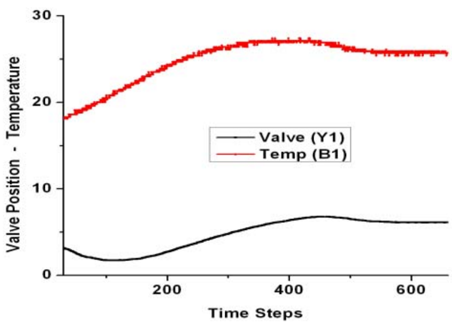

Figure 4: Operation of the cooling controller for the wave-guiding subsystem: The sensed temperature is the input signal (B1) to the controller; the generated analogue output signal (Y1) is directly connected to the mixing valve actuator. The requested temperature (set point) in this case is 26° C.

In Figure 5 we see a view of the cooling complex of the klystron area

Figure 5: A view of the klystron cooling area (left side) and the 500kW, CW 5-cavity VKS-8270 Varian permanently tuned klystron (right side). The klystron has a 57-dB gain. It takes only 1 W to saturate.

In Figure 6 we can see the detailed schematic of the klystron's HV supply and protection system with a very fast operating crowbar module (2, 5 μs).

There is also a sophisticated interlock system both for the HV and the RF operation of the system. It includes through PLC information from HV condition, cooling performance, RF operation and decides on how to respond to each situation. It has been successfully tested. Recently a 6kW RF power came out from the klystron for the first time and commissioning is actively going to the ~200kW RF power needed for the 10MeV IASA linac.

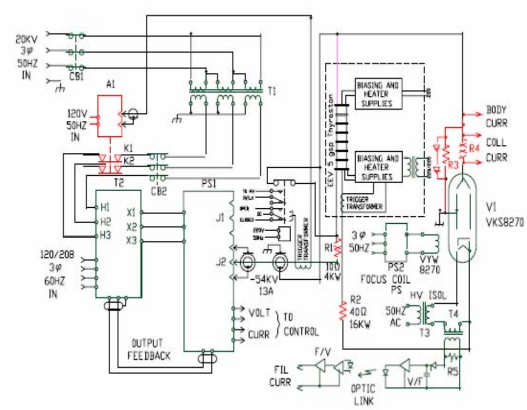

Figure 6: A schematic of the HVAC and crowbar operation of the high power RF system.

CONCLUSIONS

The IASA cooling system is now operating within the specifications. It has been monitored for its stability, water quality and temperature regulation. Beside this the RF system has been tested and the interlock HV and RF system performs successfully. The first kW RF power came out from our klystron with great stability. Commissioning is going on to the complete operation of the IASA 10MeV linac.

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