

# COOLING SYSTEMS FOR THE NEW 201.25 MHz FINAL POWER AMPLIFIERS AT LOS ALAMOS NEUTRON SCIENCE CENTER (LANSCE)\*

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## Abstract

Two new 201.25 MHz RF Final Power Amplifiers (FPAs) have been designed, assembled, installed and successfully tested at the Los Alamos Neutron Science Center (LANSCE), in Module 2 of the Drift Tube Linac (DTL). These production units were fabricated at Continental Electronics Corporation. In this paper, we summarize the FPA air and water cooling requirements and cooling systems [1].

## Description of Systems

Figure 1 shows a CAD model of the FPA installation.

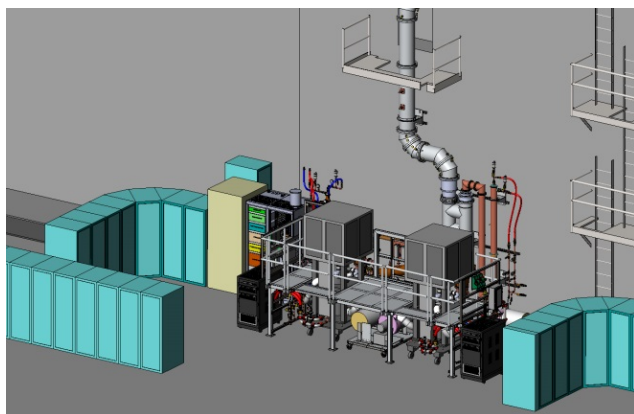


Figure 1: Model of FPA Installation.

Three separate water systems were required to fully cool each FPA and its auxiliary components. Two existing systems were modified and a new system was installed to meet the cooling requirements. A deionized water system (A01), cools the two power-combined FPAs and Intermediate Power Amplifier (IPA) directly. A chilled water system (A05), cools the RF reference source for the LANSCE accelerator and ignitrons in each of the four capacitor rooms. A treated water system (A06), cools the solid state driver amplifier (Rack 5), FPA and IPA water loads.

Flow requirements for the three water systems were developed for combined amplifier power, 3.4 MW at 13% duty factor or 442 kW each [2]. In addition, air cooling was implemented where water cooling was not practical.

## The A01 System

The A01 system is an existing deionized water system that served the obsolete power amplifier that was

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previously located at Module 2 of the DTL. Centrifugal pumps, located in an adjacent mechanical room, deliver 88 psi, 1,250 gpm for the four DTL modules. One pump operates while the other serves as a backup. Adaptation of this water system consists of demolishing the existing plumbing at the module and installing the new plumbing as depicted in Fig. 2. Deionized water is required to eliminate the potential electrical path to ground in an ionized system. The A01 system is adapted to cool both FPAs and the IPA which is not shown in Fig. 2.

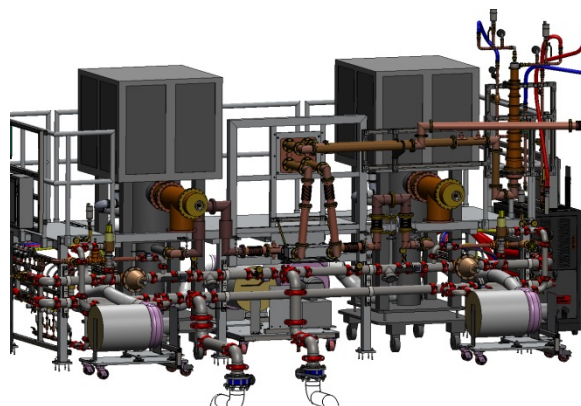


Figure 2: A01 Water System Adapted to the FPA Installation.

Note that the gray-colored piping and associated components in Fig. 2 are the distribution hardware for the A01 water system, and the brown colored piping is the 3 1/8 inch coax RF transmission lines. The A01 piping is mounted to the legs of the platform, and the legs of the platform are anchored to the concrete.



Figure 3: Side View of A01 Water System Mounted to Platform.



Figure 4: Rear View of A01 Water System Mounted to Platform.

Figures 3 and 4 are photos of the A01 system's distribution plumbing from the side and rear of the platform. The piping and piping components are pre-assembled before the maintenance outage in a separate building to help minimize the schedule impact of assembling this hardware in situ. This preassembly saves two weeks in the outage schedule. To accommodate the relocation of the assembled A01 system to the accelerator equipment aisle, the platform and water system are disassembled into thirds making it easier to transport and fit into the doorways. Skilled technicians facilitate the disassembly, transport and reassembly of this important hardware using forklifts and a flat-bed truck.

Table 1 is a summary of the A01 cooling requirements for the Module 2 amplifier installation. The flow rates were specified to control the temperature rise to between 5 and 10°C for the multi-phase (Hypervapotron<sup>®</sup>) cooled anode of the Thales model TH628 electron tube [3]. Note that there are 2 FPAs per module and one IPA, so the total flow rate required for this system is 206.1 gpm. By comparison, the old system required 323 gpm per RF module.

Table 1: A01 Water Cooling Requirements

Unit	Description	Flow Rate (gpm)	$\Delta T$ (°C)
FPA	Anode	85	5
	Lower Screen grid	1	5
	Filament terminal	1	6.6
	Upper screen grid	1	5
	Upper blocker	1	5
IPA	Anode	25	5
	Screen Grid	0.6	5
	Cavity Body	2.5	2
<b>Total</b>		<b>206.1</b>	

Calculations predict that the temperature change of the A01 water while cooling the amplifier at full power (360 kW) should rise by 6°C. This value was confirmed during commissioning of the water system.

### The A05 System

The A05 system is an existing chilled water system that also served the obsolete power amplifier that was previously located at Module 2 of the DTL. Adaptation of this water system consists of demolishing the existing plumbing and installing the new plumbing as depicted in Fig. 5. Chilled water is required to cool the RF source for the accelerator and each of the ignitrons in the four capacitor rooms.



Figure 5: New Chilled Water Lines (insulated pipes in this photo).

Table 2 is a summary of the flow requirements for the A05 water system. The flow rates did not change from the previous installation in Module 2, however, the amplifiers themselves no longer require chilled water cooling.

Table 2: A05 Water Cooling Requirements

Description	Flow Rate (gpm)
Module 1, Rack 5	5
Module 1, Ignitron	1
Module 1, Air/Water Heat Exchanger	1
Module 2, Ignitron	1
<b>Total</b>	<b>8</b>

### The A06 System

The A06 system is a new, treated water system that was designed and installed for the LANSCE-LRM project. This water system cools the solid state driver, FPA and IPA water loads. The two new Grundfos pumps and pipes for the distribution system were sized based on the results of modeling with AFT Fathom<sup>®</sup> software. The distribution piping was installed in the year 2013 for Modules 2, 3 and 4. Because Modules 2 and 3 are located west of the pump skid and Module 4 is located east of the pump skid, a piping configuration was selected in which Modules 2 and 3 share a 3 inch distribution pipe and Module 4 has an exclusive 2 inch distribution pipe.

Figure 6 is a photo of the pump skid designed at LANL and built at an outside vendor, taken during acceptance at



the vendor. This pump skid is now installed at LANL and delivers  $25 \pm 4^\circ\text{C}$  treated water to the Module 2 installation. The pump motors are variable frequency, and an output pressure of 65 psi was selected to accommodate the entire system. A total flow rate of 120 gpm is the requirement once Modules 2, 3 and 4 are all upgraded. The plate-type heat exchanger, shown in blue in Fig. 6, is cooled by tower water supplied to the facility.

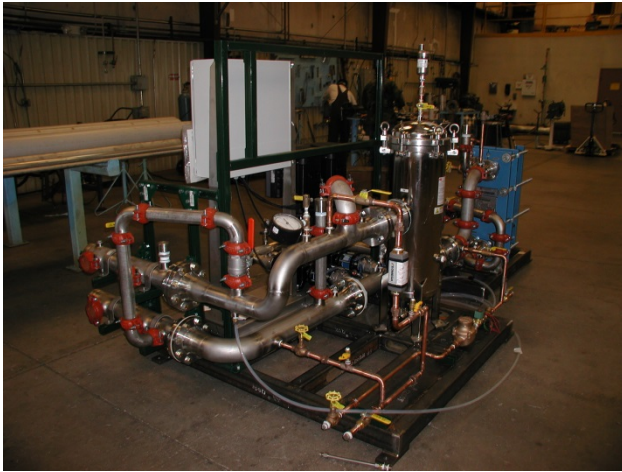


Figure 6: A06 Pump Skid (shown at fabrication facility).

Table 3 is a summary of the A06 cooling requirements for the Module 2 amplifier installation. The total flow rate required for this system is 40 gpm per module.

Table 3: A06 Water Cooling Requirements

Description	Flow Rate (gpm)
IPA Water Load	15
FPA Water Load	20
Solid State Driver, Rack 5	5
<b>Total</b>	<b>40</b>

### Air Cooling

Air cooling for the amplifier consists of cooling both the filament pipe and ceramics. The filament pipe is at the center of the amplifier, and the ceramics of the tube consist of an upper and lower ceramic as shown in Fig. 7.

The air flow requirement from the tube manufacturer, Thales, is shown in Table 4.

Table 4: Air Cooling Requirements

Description	Flow Rate (cfm)
Upper Ceramic	177
Lower Ceramic	177
Filament Pipe	177
<b>Total</b>	<b>531</b>

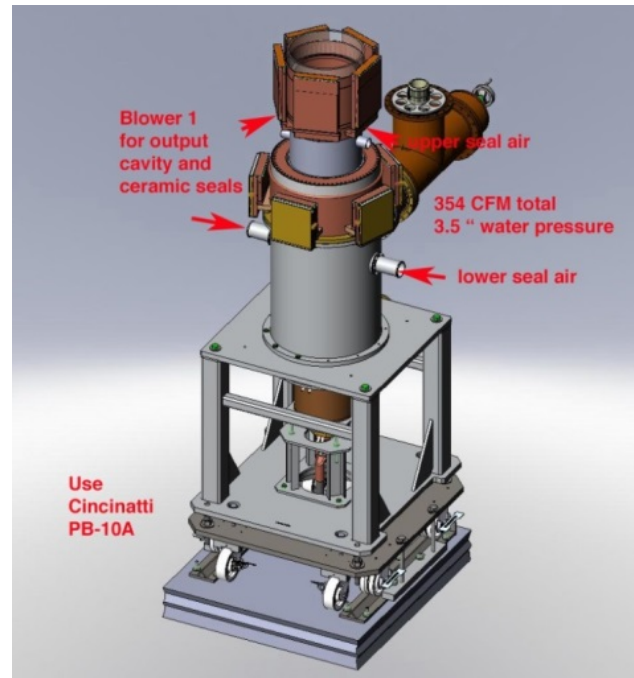


Figure 7: Air Cooling Model (stripped down FPA).

To deliver the cooling air, blowers, manufactured by Cincinnati Fan, were selected based on the flow rate requirement and the density of air at Los Alamos (7,000 ft. elevation). Model PB-14A was selected for the filament pipe and model PB-10A was selected for the ceramics. The model PB-14A (250 cfm) blower was connected directly to the filament pipe using a non-conductive hose and 3D printed plastic elbow. The model PB-10A (354 cfm) was connected by non-conductive hose to a 3D printed plastic manifold that splits the air flow into four flow paths; to cool the upper and lower ceramic on each side as shown in Fig. 7.

The cavity power dissipation from RF losses is estimated from Q measurements to be approximately 2% of the DC input power. For a single amplifier generating 1.7 MW of RF at 13% duty factor, this power is approximately 10 kW. Forced air transfers a portion of this heat, simultaneously cooling the ceramic seals of the tube. Conduction is enhanced by the copper construction of the various resonator cylinders, which affects the radiative cooling.

### REFERENCES

- [1] Z. Chen, D. Baca, et. al., "Mechanical Design and Fabrication of a New RF Power Amplifier for LANSCE", PAC'11, New York, NY, pp. 1085-1087.
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