WATER PURITY REQUIREMENTS IN LIQUID COOLING SYSTEMS

CPI, EIMAC Division

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INTRODUCTION

The high power density at which water cooled vacuum tubes operate, make careful attention to maintenance of adequate coolant flow and purity essential to proper operation and long tube life. Ordinary tap water will not meet these requirements and distilled or de-ionized water should be used when initially filling such a cooling system. The water purity and flow protection should then be periodically checked to insure against excessive degradation. Water purity can be seriously degraded by contaminants from the various cooling system components. For example, free oxygen and carbon dioxide in the coolant will form copper oxide on the surfaces of the coolant courses, particularly the anode itself, thereby, reducing the cooling efficiency. The formation of these oxides is greatly accelerated by the elevated temperatures within the system. Electrolysis may also take place due to the presence of ions in the liquid and the electric potential across the coolant courses. Electrolysis may actually destroy the coolant passages, whereas, the oxide compounds can drastically reduce the heat transfer to the liquid coolant. In extreme cases, heavy oxide deposits can actually plug up coolant passages and reduce flow. Either of these conditions may result in premature tube failure.

For long life of water cooled EIMAC tubes, the coolant must be maintained at a resistivity of 1 meg-ohm-cm minimum at 25°C. Other factors concerning water quality are specified herein.

BASIC SYSTEM DESIGN

The liquid cooling system consists of a source of coolant, circulation pump, heat exchanger, coolant purification loop, and the attendant connection pipes, valves, gauges, and flow interlocking devices required to insure coolant flow anytime the equipment is energized. Such a system is shown schematically in Figure 1. In most instances, the liquid coolant will be water; however, if there is danger of freezing, it will be necessary to use an anti-freeze solution such as ethylene glycol. In these cases coolant flow must be increased or plate dissipation reduced to allow for the proper heat capacity of the ethylene glycol solution. A mixture of 60% ethylene glycol to 40% water by weight will be about 75% as efficient as pure water as a coolant at 25°C. Regardless of the choice of liquid, the system volume should be kept to the minimum required to insure proper cooling of the vacuum tubes.

The main circulation pump must be of sufficient size to insure necessary flow and pressure as specified on the tube data sheet. Care must be taken when connecting the coolant lines to the tube to be certain that flow is in the direction specified. Improper direction of flow may result in inadequate cooling as well as excessive pressure and possible deformation of the anode. Precautions should be taken in the system design to protect against water hammering of the anode. A filter screen of at least 60 mesh should be installed in the pump outlet line to trap any circulating debris which might clog coolant passages in the tube.

The heat exchanger must be sized to maintain its outlet temperature such that the outlet water from the tube at full plate dissipation is never allowed to be in excess of 70°C. Filament and grid coolant courses may be connected in parallel or series as long as the maximum outlet temperature is not exceeded. *(Note: this applies to a conventional water-cooled system. Hyper- vapotron or Vapor Cooling techniques will range in outlet temperaturesfrom 70°C to 100°C.)*

Valves and pressure meters should be installed on the input lines to the tube to allow for adjustment of flow and pressure drop. A pressure meter and check valve should be employed in the outlet line. In addition, a flow meter, sized in accordance with the tube data sheet, and a thermometer should be placed as shown in the OUTLET line of each coolant course. The flow meters must be equipped with automatic interlock switches, wired into the system electrical controls such that the tube is completely de-energized in the event of loss of coolant flow in any one of the coolant passages. In some tubes, filament power alone is sufficient to damage the tube structure in the absence of proper water flow.

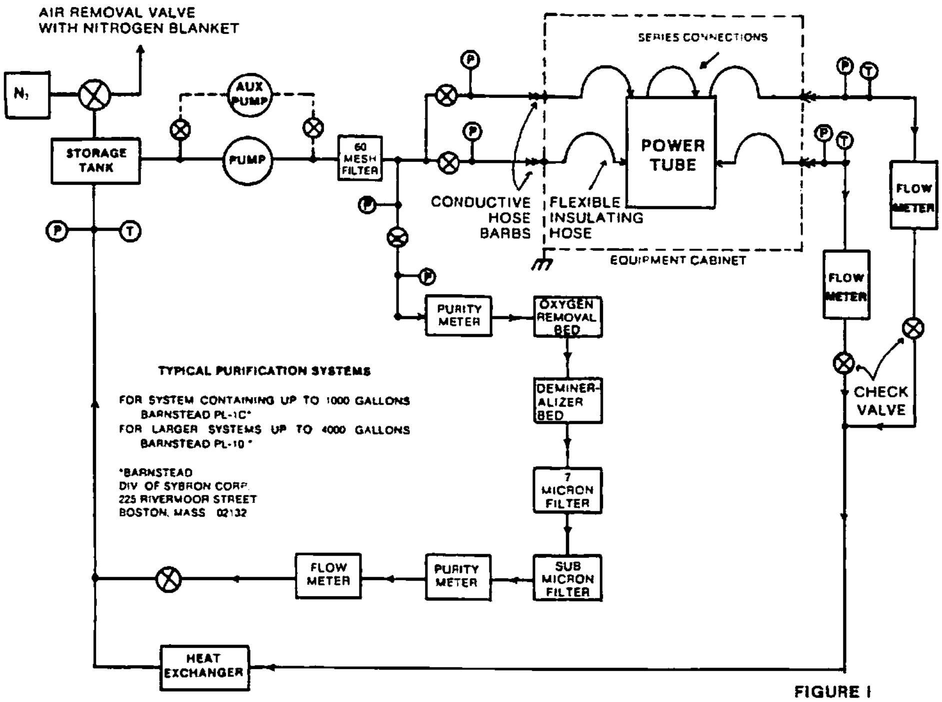

FIGURE 1

The lines connecting the plumbing system to the inlet and outlet ports of the tube should be of an insulating material flexible enough and arranged so as not to put excessive strain on the tube flanges. Polypropylene tubing is the best choice for this service, but chlorinated oxygen in the water make the use of a coolant purification loop essential. In order to extend the life of the resin beds in the purification loop, polyvinyl chloride (CPVC) pipe is also acceptable and is stronger. Reinforced polypropylene, such as Nylobraid, is expensive, but is excellent in this application. These lines must be of sufficient length that at operating voltages up to 40 KV at least 4 meg-ohm resistance at maximum water temperature is provided in the water column between the high voltage ends and ground for every 1000 volts applied up to a maximum of 10 meg-ohms. For operation above 40 KV, enough water column resistance should be provided to keep leakage below 4 ma. (the 40KV includes DC plate voltage plus modulation peak voltages.)

The hoses should be coiled or otherwise supported such that they do not contact each other or any conductive surface between the high voltage end and ground. Conducting hose "barbs" (also referred to as "targets") connected to ground, should be provided at the low potential end so that the insulating column of water is broken and grounded at the point it exits the equipment cabinet.

All metallic components within the water system, including the pump, must be of copper, stainless steel, unleaded brass or bronze with copper or stainless steel (preferred). If brass or bronze is used, some zinc may be leached out of the metal into the system. Any other material, such as iron or cold rolled steel will grossly contaminate the water. Even if the system is constructed using the recommended

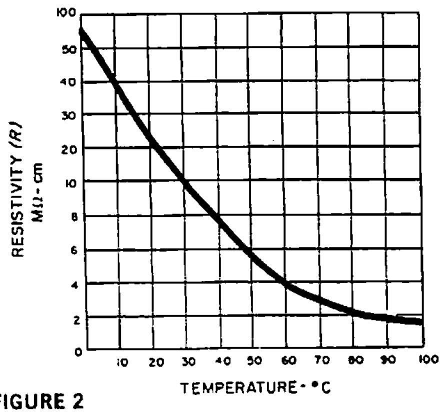

FIGURE 2

materials, and is filled with distilled or de-ionized water, metal solubility, carbon dioxide or free oxygen in the water make the use of a coolant purification loop essential. In order to extend the life of the resin beds in the purification loop as long as possible, all the coolant lines should be flushed with a non-sudsing detergent and a citric acid solution[1], then rinsed repeatedly with tap water before initially connecting the resin beds and filling with distilled or filtered de-ionized water. It is also good practice to sterilize the coolant lines with a chlorine solution[2] before filling to prevent algae and/or bacteria growth.

The coolant regeneration loop should tap off 5-10% of the total cooling system capacity, circulate it through the oxygen scavenging, de-ionization beds, and sub-micron filter, then return it to the main system. The purification loop can theoretically process water to 18 meg-ohm resistivity at 25°C. In practice it will be somewhat below this value. The strong temperature dependence of ultra pure water resistivity of is shown in Figure 2. The water resistivity in the main coolant loop should be maintained at all times in excess of 1 meg-ohm-cm at 25°C. After normal operation for an extended period, the system should be capable of holding 3-4 meg-ohm-cm until the filter beds become contaminated and need to be replaced. The need to replace filter bed resins is indicated when the purification loop output water falls below 5 meg-ohm-cm. Because the resistivity is not a test for free oxygen in the coolant, the oxygen filter bed should always be replaced when replacing the de-ionizing bed. It is recommended that the coolant be circulated at all times to keep the resistivity up, reduce bacteria growth, and to minimize oxidation due to coolant stagnation. If it is desirable to circulate the coolant at the regular rate when the tube is de-energized, a secondary circulating pump should be used to move the coolant at a lower rate to purge any air that has entered the system and to prevent stagnation. Recommended minimum circulation rates within the coolant lines are 2 gallons/min (7.6 l/min) during normal operation and 0.5 g/min (1.9 l/min) during standby. Circulation rates within the tube itself should be obtained from the tube's data sheet. When it is necessary to turn the coolant flow completely off, it should be restarted, and allowed to return to a minimum of 1 meg-ohm-cm resistivity before energizing the tube. The regeneration loop should be capable of maintaining the cooling system such that the following maximum contaminate levels are not exceeded:

Copper	0.05 PPM by weight
Oxygen	0.5 PPM by weight
CO_2	0.5 PPM by weight
Total Solids	3.0 PPM by weight

The levels above are meant to be maximum allowables, but if the precautions outlined herein are taken, actual levels will be considerably lower. If the cooling system water temperature is allowed to reach 50°C, it will be necessary to use cartridges in the coolant regeneration loop which are designed to operate at elevated temperatures. Ordinary cartridges will decompose in high temperature service. Components for the coolant purification loop may be purchased from sources other than shown in Figure 1. Technical advice in sizing purification loops or special applications should be obtained from the water processing component manufacturers. The coolant purification loop shown is for systems using water as a coolant. If it is necessary to use anti-freeze solutions similar equipment may be purchased from the same sources.

Contact EIMAC Application Engineering, 301 Industrial Way, San Carlos, CA 94070, if you should require assistance in the cooling of EIMAC high power tubes.

1 Citric acid solution - 75 g. citric acid, 220 ml household amonia, 4.0 liters H_2O

2. Chlorine Solution - Sodium hypochlorite bleach added to an amount sufficient to give the odor of chlorine in the circulating water.