COOLING SYSTEMS
for
HIGH POWER KLYSTRONS

EMI-Varian Limited

HAYES, MIDDLESEX, ENGLAND.

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COOLING SYSTEMS FOR HIGH POWER KLYSTRON

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INTRODUCTION

The high power levels at which many microwave valves operate necessitate great care being taken in the design and operation of cooling systems. In some klystrons as much as 2 kW per square inch must be transmitted through the collector wall and dissipated in the coolant. Moreover the heat flow in the collector is not uniformly distributed. With high local heat dissipation a small amount of scale can cause a large local rise in temperature on some portions of the collector. Local spot boiling then occurs and reduces the heat transferred to the coolant. This produces a runaway collector overheating condition which adversely affects the life of the klystron, and greatly increases the possibility of its premature failure.

Scale is a deposit on the wetted surface of a cooling system due to the conversion of a soluble salt into an insoluble compound by a chemical reaction in the coolant. Scale may be caused either by not using distilled water, or as a by-product of electrolysis between dissimilar metals in the water system.

Corrosion is the result of a chemical reaction on some portion of the wetted surface itself. It can be caused by gases, especially oxygen and chlorine, dissolved in the coolant, reacting on the hot copper surface.

Cooling channel cross-sections as small as 0.025" x 0.050" are not uncommon. The relative ease with which these channels can be blocked should be recognised, and every effort made to avoid scale, corrosion, particles and contaminants of all kinds.

WATER PURITY

Distilled water, which is chemically stable and has a high heat-transfer capability, is a far better coolant than tap water or other coolant mixtures. Protection against low temperatures can be provided by using electric water heaters or by draining the system during non-operating periods. Before using a coolant mixture for EMI-Varian klystrons consult EMI-Varian Ltd. Whatever happens no stop-leak compounds or soluble oil inhibitors may ever be added to the water.

The cooling system should include some means for continuously purifying the coolant. A purification loop which takes coolant from the main recirculating loop and removes any soluble salts by ion exchange is suitable. The purification loop should remove dissolved oxygen and carbon dioxide and also filter out particulate matter. A suitable system is shown in figure two. Flow and pressure adjusting valves are included, also flowmeters and conductivity measuring cells. Suitable packaged purification systems are available using replaceable filters and ion exchange cartridges, and should be operated according to the manufacturer's recommendations.

The manufacturer's recommendations for maintenance should also be followed, but to obtain long klystron lives the following five minimum requirements are specified.

(i) The resistivity of the water must never fall below 30,000 ohms/cm^3 at 30°C.

(ii) The pH factor shall be between 6.0 and 8.0

If either the resistivity or the pH factor go outside their limits the entire cooling system must be drained and flushed as described later in "Maintenance flushing of transmitter", "Maintenance flushing of klystron" and "Flushing and cleaning the electromagnet". Although tap water is acceptable for an initial flushing, the final flushing and filling must be done with distilled or demineralised water with a resistance of at least 500,000 ohms/cm^3. Always use distilled water for topping up.

(iii) A filter must be provided to trap particles larger than 50 microns.

(iv) Replace filter membranes and de-ionising cartridges exactly as the manufacturer of the purification loop recommends. Rapid exhaustion of the ion-exchange cartridge may indicate contamination, electrolysis, the use of unhibited glycol or that the purification loop has insufficient capacity.

(v) The coolant temperature should be as low as practicable and should be regulated to $\pm 5^{\circ}C$. Its temperature at the klystron inlet ports should never exceed $70^{\circ}C$.

MATERIALS FOR COOLING SYSTEMS

Tubing, fittings, pumps, and every material which will be in direct contact with the coolant should be selected to minimise galvanic action, and only metals from the "noble" end of the electromotive force series should be used. Suitable metals include copper, nickel, bronze, inconel, monel, 304L stainless steel and EN58B or F stainless steel for welded parts. Metals that should not be used in contact with the coolant include steel, cast iron, galvanised iron, aluminium and magnesium. Brass should only be used sparingly, and should be avoided wherever possible.

All bronze or all stainless steel turbine pumps are available and for klystrons requiring flow rates from 5 to 40 gallons per minute at from 85 to 200 p.s.i. Centrifugal pumps of the same materials are suitable for lower pressures.

Unless the water temperature can be maintained below 107°C natural or synthetic rubber hoses should not be used because they deteriorate. High temperature hydraulic hoses or teflon-lined hoses are recommended.

CLEANING COOLING SYSTEMS

(a) New systems

Special care must be taken with a new installation to remove all traces of pipe compound, solder, teflon pipe tape thread seal, brazing fluxes, and so on.

Then all contaiminants such as oils, greases and particulate matter should be removed by degreasing the cooling loop with a solvent or detergent, followed by a number of clean water washes.

All this must be completed before the klystron or its magnet is connected. The system should then be given a normal maintenance flush.

(b) Maintenance flushing of transmitter

(i) Disconnect the klystron and magnet and put jumper leads between the water input and output lines of the klystron and magnet.

(ii) Disconnect or by-pass the pump water.

(iii) Fill the system with hot tap water, open the drain in the transmitter cabinet and flush for 15 minutes or until clean.

(iv) Flush the water line between the tank and the pump separately with hot tap water until they are clean.

(v) Reconnect the pump into the water system, fill the system with hot tap water, add one cupful of non-foaming detergent and operate the water system for half an hour. An immersion heater should be used to keep the water hot. Tri-sodium phosphate is a suitable detergent.

(vi) Drain the system and flush with hot tap water for another half hour.

(vii) Remove and clean the filter element. Drain and refill the system with tap water.

(viii) Operate the water system, maintaining the water level whilst draining and flushing, until there are no signs of detergent or of particles. Test for detergent using the foaming test described on page ten.

(ix) Repeat steps (vii) and (viii) as necessary. The filters must be clean and there must be no foaming.

(x) Flush the system with either distilled or demineralised water, then refill with the same.

(c) Maintenance flushing of klystron

(i) Disconnect the klystron and flush the transmitter cooling system according to the "Maintenance flushing of transmitter" procedure.

(ii) Back flush the klystron body water lines.

(iii) Remove the input water fitting. Add a short length of straight pipe, and attach a hose to the free end of the pipe. This hose should reach a convenient drain.

(iv) Remove the output water fitting, and, by a similar technique, connect via a garden hose to a convenient hot water tap.

BEWARE! On some klystrons the body cooling output line is fed to the base of the vaportron boiler. The hose should be removed at the base of the boiler but do not damage this fitting as it must be used again and it is essential that it seals tightly.

(v) Back flush the klystron body cooling system for 15 minutes or until clean, at full pressure.

(vi) Reconnect the input and output lines to the klystron.

(vii) If there is scale on the collector, fill the cooling system with hot tap water, add one cupful of non-foaming detergent, and operate the water system for 15 minutes only. Ensure that the collector is completely covered by water. An immersion heater may be used to keep the water hot. Tri-sodium phosphate is a suitable detergent.

(viii) Drain the system, and flush for half an hour or more until there are no signs of detergent or of particles. Test for detergent using the foaming test described. Continue flushing until no detergent remains.

(ix) Flush the system with either distilled or demineralised water and refill it with the same.

(d) Cleaning klystron water passages

If there is heavy scaling on the collector, or blocked water passages, both may be cleaned by using "SAN" or other EMI-Varian approved agent to remove scale or corrosion.

(i) Disconnect the klystron and flush the transmitter using the "Maintenance flushing of transmitter" procedure.

(ii) Reconnect the klystron. Fill the system with hot tap water. Add two gallons of cleaning solution to every 50 gallons of water.

(iii) Operate the cooling system for 15 minutes, or until the scale has been removed and the collector has a clean copper colour. Ensure that the water level covers the top of the collector during cleaning.

(iv) Drain the system and flush with tap water.

(v) Remove and clean the filter element. Then replace it, refill the system with distilled or demineralised water, and flush for at least half an hour.

(vi) Use the foaming test and check the pH factor of the water. Continue flushing until there is no detergent, and the pH value is correct.

(vii) Drain the system and refill with either distilled or demineralised water.

(e) Flushing and cleaning the electromagnet

The electromagnet water cooling system is flushed in the same way as the klystron cooling system. If necessary it may be cleaned too, also in the same way as the klystron cooling system.

(f) General cleaning

The sight glass and the float of the water flow indicators need cleaning too. If neither the detergent nor the approved cleaning solution remove the contamination, the flowmeter must be dismantled and cleaned with a brush.

"SAN" is a product of Mobile Chemical Company, 401 East Main, Richmond, Virginia, U.S.A.

For further information about this and other approved cleaning agents consult EMI-Varian Limited.

FOAMING TEST

To ensure that there is no detergent left in the system this test should be made after each water change, or system modification or cleaning. A 0.5" dia glass test tube with a rubber stopper and a one pint sample bottle with cap are needed. Both must be clean.

(i) Run the cooling system for about half an hour until the water is thoroughly mixed.

(ii) Drain a sample of water into the bottle and allow to cool to room temperature. If the water is left standing for more than an hour slowly invert the capped bottle about ten times WITHOUT SHAKING it.

(iii) Rinse the test tube and the stopper three times with the sample water.

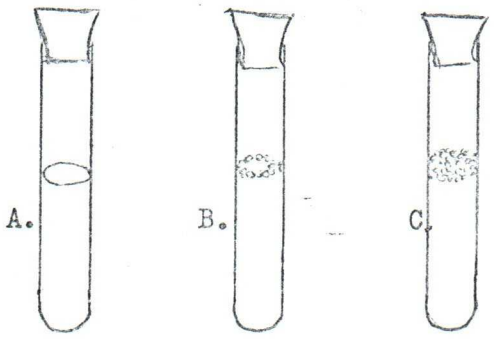
(iv) Half fill the test tube with water and put the stopper in.

(v) Shake vigorously for 15 seconds using 3 up and down motions a second. Allow to stand for 15 seconds, then compare with sketches A, B and C.

Sketch A A complete foam free surface indicates that no foam producing impurities are present.

Sketch B A circle of clear water in the centre but some foam at the test tube wall indicates a temporarily acceptable level of impurities. A second test should be made one week later.

Sketch C If the foam layer completely covers the water surface the system should be flushed again.



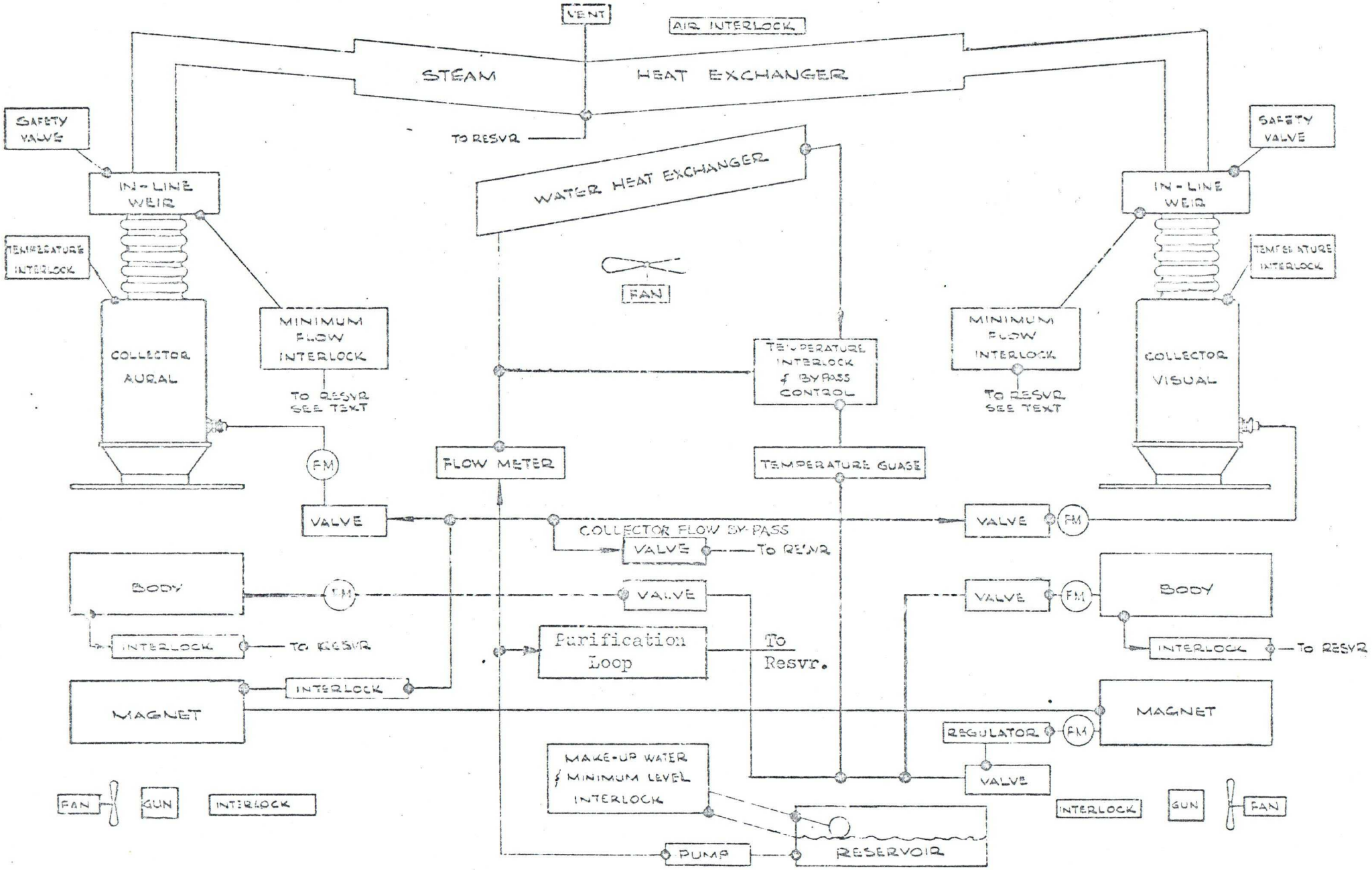


Figure 1 — A suggested vapor-cooling system.

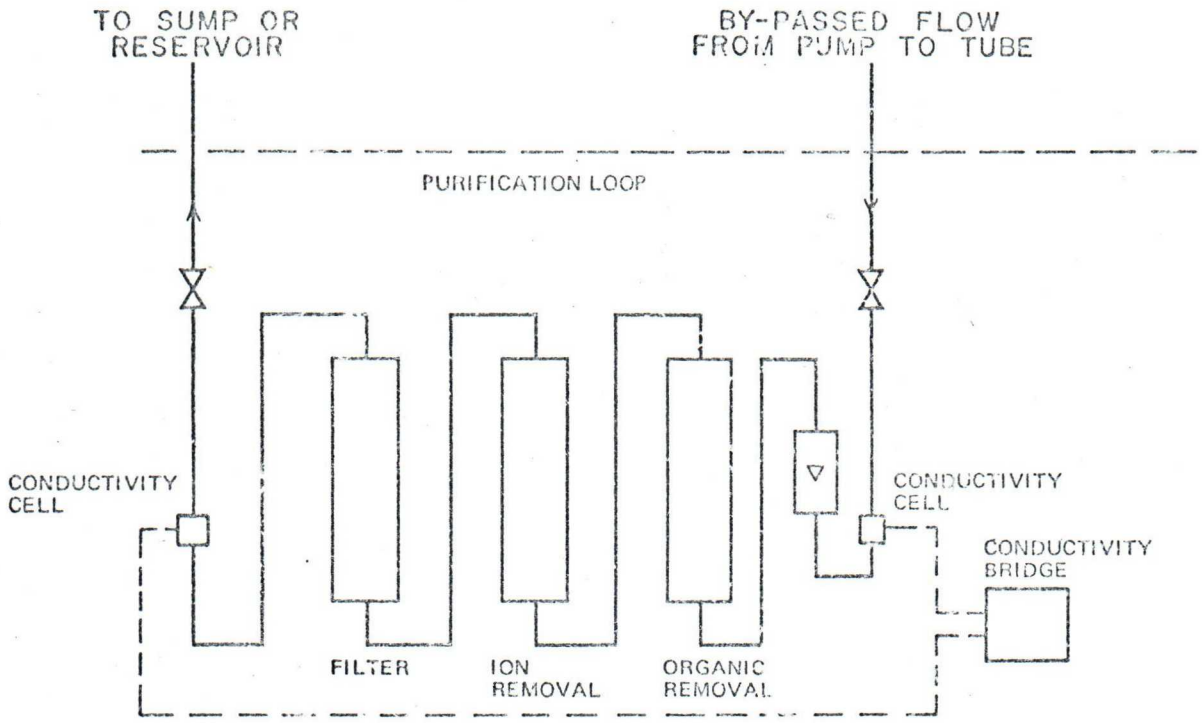


Figure 2 — A typical purification-loop arrangement.