Water, Glycols and Resistors

A Tale of Compatibility

by James L. Keyes

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I. BACKGROUND

The removal of heat from industrial and electronic devices has engaged engineers almost from the start of the modern industrial age. It seems a never-ending battle, as the trend toward miniaturization and lighter materials has given us smaller devices which produce more waste heat per unit of mass. This general problem for industry is a special problem for resistive load manufacturers.

It has been less than fifty years since the film resistor with direct fluid cooling was introduced to the industry. Great advances in film technology and materials have brought us to the point that the direct liquid-cooled load is a standard part of thousands of radio and television stations, every linear accelerator and varied industrial RF heating systems. In spite of new designs, better materials and modern manufacturing techniques, there has remained one constant: the best coolant is plain old water.

II. RESISTORS

Resistors have progressed from the early tin oxide film devices, often built on glass or quartz forms to ceramic-metallic film types built on beryllium or alumina forms. They are available in rod, plate and tube forms. For our discussion, we assume the tube form, but the thermal principles are the same for all shapes.

The manufacture of the resistor involves the deposition of conductive bands of metal for contact points, application of resistive material between the bands and application of a protective coating over the resistive material. For the most part, the bands are silver. Some platinum, palladium or other element may be added for improved strength or corrosion resistance, but the band is at least 95% silver. This is a real strength, as oxidation of most metals creates an insulator, but silver oxidizes to silver oxide, an excellent conductor.

III. WATER

Water is a real enigma for engineers in the heat transfer business. It is the most effective heat transfer fluid for almost any application imaginable, but it freezes or boils at the worst possible times, supports the growth of algae and slime bacteria, dissolves all manner of contaminants [and carries them to places where they don't belong!], deposits soluble minerals on heat-producing elements and becomes an acid medium over time.

We filter it, chlorinate it and pipe it around our cities, calling it clean, potable and good to drink. When we analyze it, we find that it is a veritable chemical cocktail, because water is a universal solvent and has been busy dissolving the iron pipes used to carry it, the iron ions have fed iron-reducing bacteria which are quite immune to the chlorine and the chlorine has reacted with the dissolved organics to produce nitrosamines and other secondary contaminants.

Typical of good engineers, we have attacked those problems with distillation systems and de-ionization systems. We have produced distilled water which is so pure that it dissolves glass labware, but we can't <u>keep</u> it free of contaminants. With modern reverse osmosis plants and activated charcoal filters we have produced millions of gallons of ultra-pure D.I. water and piped it about in elaborate chilled coolant systems. But it still grows bacteria rather well!

The two contaminants in water which we are most likely to see are slime bacteria and algae. Algae is the green stuff you see growing in ponds in the summer time. It needs heat and light to grow well. With algae, what you see is what you get. The principal problem it presents is the mat of filamentous material which clogs pumps and filters. Slime bacteria are any of several genera of bacteria. They don't need any light and will grow in very cold conditions. Like any bacteria, the individuals in a colony have very short lives. When they die, they decay and produce hydrogen sulfide [H_2S] and some solids. The hydrogen sulfide dissolves in the water and becomes sulphurous acid [H_2SO_3]. The solids show up in filters as fine black sediment with a 'pond' smell.

When the slime bacteria problems appeared in distilled water systems on board U. S. Navy vessels in the early 20^{th} century, the solution was simply to add potassium permanganate to the water. [The water was intended for boiler feed water and small amounts of potassium were unimportant, whereas chlorine would have been a major problem.]

As time and science progressed, D.I. water changed from a laboratory curiosity to a required part of klystron cooling systems, due to it's very low conductivity. The operators of large D.I. water systems were very successful as long as the systems were kept in continuous operation. They often found that the systems were out of specification after weekend or holiday shutdowns. Complaints of excessive filter changes and large increases in resin cylinder requirements following shutdowns began to surface. Soon a national laboratory found that all of the silver was gone from several resistors cooled by the D.I. system. This triggered a major investigation and, subsequently, retrofit of many resistive loads with gold-plated components.

IV. GLYCOLS

It has been observed that many systems using 20% to 50% inhibited ethylene glycol have been operated for years without bacteria or algae problems. Thus, some have ascribed some magical anti-bacterial property to ethylene glycol and decided that it is a great way to avoid the algae/bacteria problems. In a way, that is true, but...the glycols really have no demonstrated algacidal or bacteriacidal properties! In fact the common glycols [ethylene and propylene] are biodegradable under aerobic conditions. They are food for some common bugs which are probably already in the feedwater!

It's the corrosion inhibitor package used to protect the metals in the system that really suppresses the bugs.

The most common inhibitor is di<u>potassium</u> phosphate. There's that potassium again! The Navy boilermen knew the answer all along!

We have extensive experience with the inhibitor package in DOWTHERM7 SR-1. Thousands of resistors run in this formulation with no problem. Unfortunately, we cannot say the same thing for UCARTHERM7. There is some difference in the inhibitor package which causes deposits to build up on the resistor and early failure of the load. Despite several years of collaboration with Union Carbide chemists we have found no solution for this problem.

The principal problem presented by coolant with ethylene glycol added is the drastic loss of cooling capacity. 50% glycol costs you one-third of your cooling capacity. You must either derate your or overbuild your cooling system. Added to that are pumping losses for the higher viscosity fluid, annual maintenance costs, etc.

One note here: Ethylene glycol gets a bad rap from a lot of 'tree huggers' who want to treat it as a dangerous or hazardous toxic substance. Nothing could be farther from the truth!

Yes, if you drink it, it will kill you! So will chlorine, but we add that to drinking water for a valuable function. Ethylene glycol can be diluted and discharged into a public sewage treatment system with no harm to the system or the environment. It's far less harmful than a few quarts of used motor oil, so don't get stampeded into paying someone to cart off your 'toxic chemical waste'.

V. CHEMICAL ADDITIVES

I'm not a chemist, so all I can tell you is what I have observed in a long career of water management.

1. Most inorganic additives will increase the conductivity of the coolant. As an example, here are the data for DOWTHERM7 SR-1 for 25EC:

% Glycol [by weight]	Conductivity [mhos/cm]
0	9.69×10^{-7}
12.5	2.45×10^{-3}
25.0	3.48×10^{-3}
50.0	3.42×10^{-3}
100.0	8.66×10^{-3}

2. If this is undesired, use only enough inhibitor to maintain pH in the 7.0 to 7.4 range and use organic algacide and organic bacteriastatic additives. ICI Americas sells an

excellent line of products for swimming pool and spa maintenance [BAQUACIL and BAQUASTAT 50]. Other companies may have similar products. These are known to me to be quite benign and safe for use with silver-bearing components.

VI. RECAP

The maintenance of a closed loop water system is a challenge, but not rigorous once the principles are understood. The object is to remove heat from something and get rid of it. In order to protect the components of the system, we need to maintain control of pH, algae and bacteria growth and conductivity. Use dipotassium phosphate to raise the pH, use organic algacide and organic bacteriastat to control the bugs and learn to live with the resultant conductivity. If that becomes an issue, use distilled water for the base and makeup water. Just remember that an acidic pH is going to give you problems and an untreated system is an uncontrolled system.

About the author:

Commander James L. Keyes is a retired U. S. Naval officer and pilot who has specialized in Safety and Environmental Science since graduation from the Aviation Safety curriculum at the University of Southern California in 1964. He is the author of manuals on aviation fuels, aircraft accident site remediation, industrial process control, and the removal of leaking underground storage tanks in northern Arkansas karst formations.

From 1974 until 1980, he was responsible for environmental assessment, planning and mitigation for the U. S. Navy in Bee, Live Oak, McMullen and Refugio counties in Texas.

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