Lubrication Of Electronic Connectors And Equipment In Radiation Environments

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When electronic connectors or other types of equipment are lubricated, the chief aims are to prevent wear and subsequent corrosion. The wear often comes from micron-sized movement over long periods of time.

In environments exposed to significant radiation the choice of lubricant becomes critical, particularly when the radiation consists of short-wavelength, highly energetic ionizing radiation such as gamma rays, x-rays and subatomic charged particles. Examples include nuclear power plants, space satellites, nuclear submarines, food sterilization equipment, radiation chemistry systems, and medical imaging systems. Although these environments appear very different, the chief form of radiation in each is high-energy electrons and charged particles. The form of radiation is actually unimportant for connector lubricants. Gamma or beta radiation would have the same effect - an increase in the viscosity of the lubricant until it stops functioning.

One class of lubricants largely escapes this damage. Polyphenyl ethers (PPEs) undergo only a slight increase in viscosity at radiation levels that turn other hydrocarbon-based lubricants into highly viscous gels. For this reason, PPEs are widely used in nuclear reactors and on satellites, and in other environments where radiation is a concern.

PPEs, whose sole manufacturer is Santovac Fluids [www.santovac.com], are short chains of aromatic rings linked by oxygen atoms. The commonly used PPE lubricants have 3 to 6 rings. The key to the molecules' stability in radiation zones lies in the very high resonance energy of the molecule - meaning that a great deal of energy is required to pull the molecule apart. In the molecules of other lubricants, the energy of radiation rapidly overcomes the binding energy of electrons, significant portions of adjacent molecules combine into a three-dimensional lattice, and what was a fluid becomes a gel.

Thus a PPE exposed in tests to 10^{11} ergs/gram of radiation at 210° F experiences an increase in viscosity of only 35%, while members of four other classes of hydrocarbon-based lubricants at the same radiation exposure increase their viscosity by 1700% and become gels. All four classes top out at 1700% because, once lattice formation and viscosity have increased to this level no further testing is possible. In some lubricants, radiation also creates free radicals that can cause corrosion.

The opposed surfaces of an electronic connector - a pin in a socket, for example - do not present an unbroken area for electrical conduction. Each surface is microscopically uneven, consisting of subtle peaks and valleys. It is only where the peaks on one surface happen to coincide with the peaks on the opposing surface that conduction actually takes place. To incoming current, a connector acts like a screen that has only a few widely scattered holes where conduction is possible. The real area of metal-to-metal contact is far less than 1% of the potential area.

Connector lubricants are typically moved away from the peaks (called asperities) by micro-motion from vibration or from thermal cycling. The absence of lubrication from the area where they are most needed can of course cause a connector to fail by the buildup of corrosion. This explains why a failed connector is sometimes resurrected by a sharp tap, or by being unmated and remated.

In addition to having a high resonance energy, PPEs have high surface tension. They lie on a surface not as a flat film but as a tight field of micro-droplets. Each micro-droplet vibrates with something akin to Brownian motion, but the whole field tends to stay where it has been applied. In the microscopic world of the connector interface, even the asperities have asperities - that is, the microscopic peaks have even smaller peaks and valleys within them. PPE micro-droplets occupy these valleys as well.

In addition to lubricating the connector, the PPE captures and "inerts" particulate contaminants arriving by an airborne route. This action prevents the accumulation of corrosion products that can prevent conduction. A corroded, non-functioning connector can be instantly and permanently cured by the application of a PPE that captures existing corrosion particles and lets conduction resume.

The usual sequence of events is that micro-motion gradually causes the asperities to wear down and flatten, but only slightly. The increase in the metal-to-metal contact area is negligible. PPEs lubricate the surrounding area and prevent the opposing surfaces from abrading each other, a risk that is especially great if the connector is plated with gold. "The gold molecules," one researcher noted, "don't know which surface they belong to." PPEs are thus used in applications where radiation is not a threat.

Where radiation is present, though, they endure because they have "the highest heat-, acid- and radiation resistance of all the liquid organic compounds[1]." Their boiling point is very high (476° C, versus around 200° C for other hydrocarbon-based lubricants), and they have a very low vapor pressure - meaning that they evaporate very slowly. A low rate of evaporation is a useful attribute in space, and also on earth, where the anticipated life of PPEs used to lubricate connectors in systems such as cell phones is between 40 and 50 years. The lifetime of PPEs used around nuclear furnaces is about the same.

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Footnote: Sewaki, Nobohiro, "Resistance of Phenyl Ether Type Synthetic Lubricants to Radiation," Jyunkatsu Keizai 23-26, April 1993

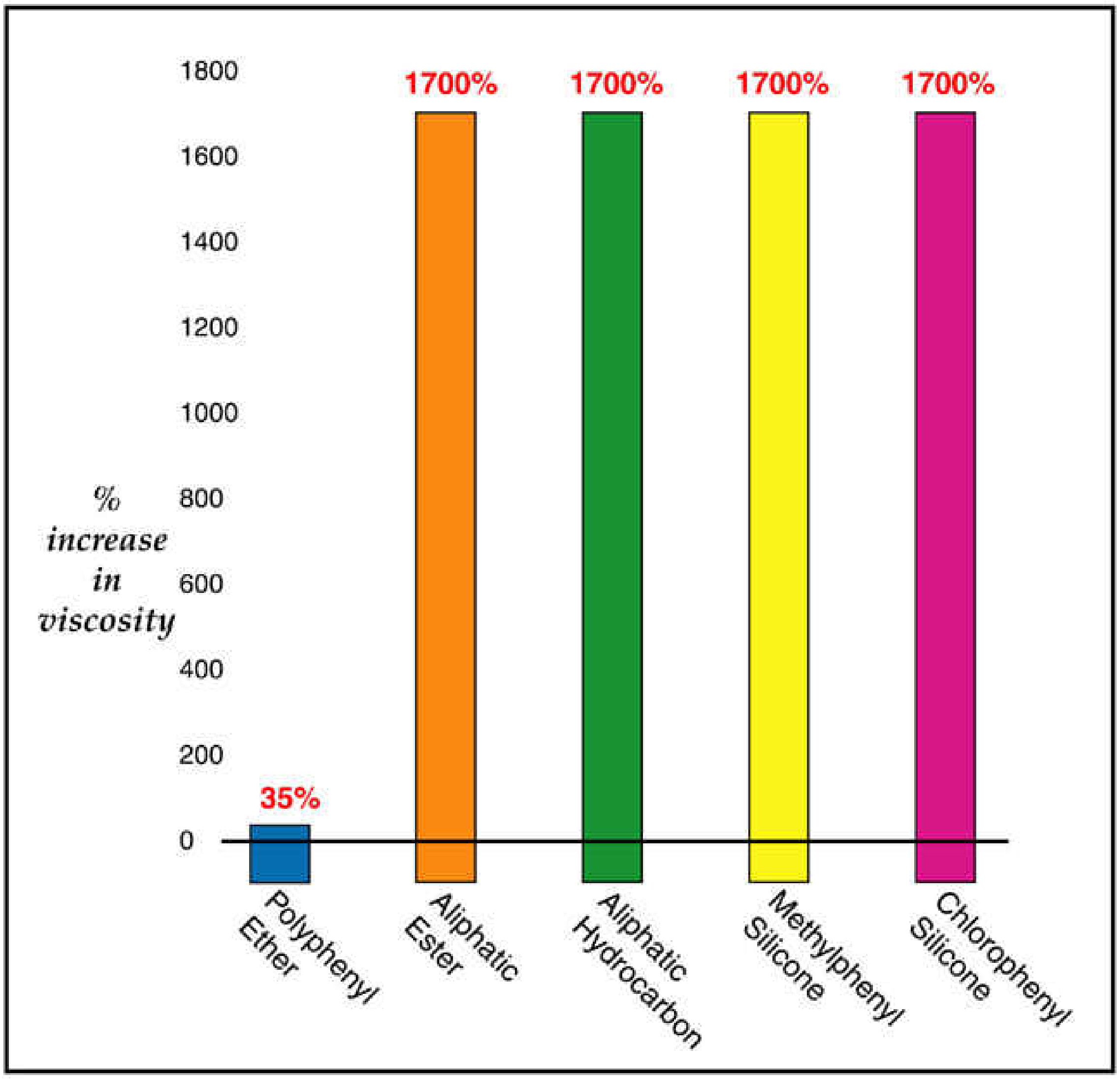

Figure 1 Increase in viscosity of various lubricating chemical classes after exposure to 10^{11} ergs/gram (equivalent to 10^{9} rads) of electron radiation.

This exposure is close to the level at which electronic circuits are affected, and approximates the level often encountered by space satellites.

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