saes group SMI
a SAES Group company
Spectra-Mat, Inc.
100 Westgate Drive • Watsonville, CA 95076, USA
www.spectramat.com
www.thermalmanagementsolutions.com

TECHNICAL BULLETIN

HEATER POWER SUPPLY RECOMMENDATIONS A.C. or D.C?

Background

A cathode or other assembly with a potted heater can have a filament life of tens to hundreds of thousands of hours with the proper power supply and connections. The preferred power supply for heaters potted in alumina is A.C. Furthermore, it is preferred that one end of the heater be grounded to the assembly it is in. Other configurations may reduce heater life, often by only a few percent, but in worst cases to only a few hours or minutes.

With D.C. power, if the heater wire is positive with respect to the assembly (or adjacent portions of the heater), tungsten ions forming on the hot wire surface will react with the oxygen in the alumina potting and form aluminum tungstate, $Al_2(WO_4)_3$ in the potting. The aluminum tungstate is electrically conductive, and a partial short may result. This partial short can quickly become a catastrophic failure of the heater.

The reaction between the heater wire and the alumina will not occur if the heater wire is negative with respect to the heater body or adjacent portions of the heater. However, the same reaction will occur on the surface of the heater body forming aluminum molybdate (if the body is molybdenum). The reaction between the body and the alumina is less harmful than the above reaction because the heater body will be 100°C to 300°C cooler than the heater wire.

This reaction does not occur if the heater is running on A.C. power and one end of the heater is grounded to the heater body. If the heater cannot be grounded to the body it is critical that the potential between the heater and the body be negative and minimized with respect to the body.

The above statements are somewhat simplified and there is much more going on in the potting. However, following the guidelines below will maximize heater life.

The Ideal Heater

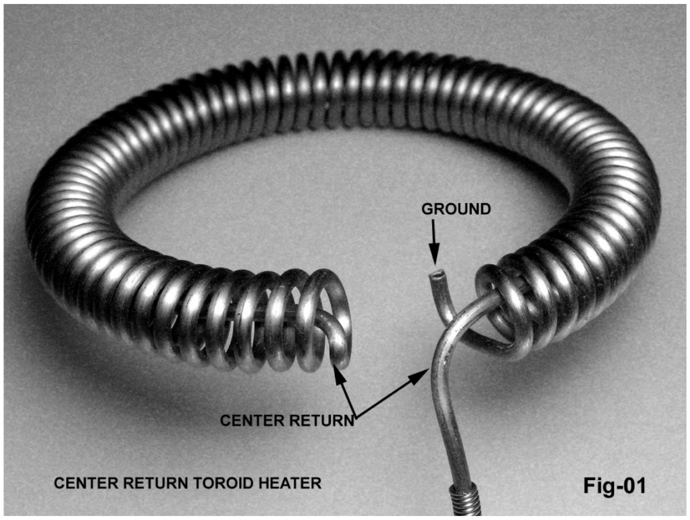
1. The heater should be grounded to the body (internally or externally) if possible.
2. The heater should run on A.C. power.
3. If D.C. power is a requirement, the wire must be negative with respect to the body.
4. Problems may occur if the heater is a non-inductive design such as center return toroid (see figure 1), or bifilar arrangements of either toroid or cylindrical heaters (see figure 3).
5. If the heater is ungrounded (A.C. or D.C.) its bias must be negative with respect to the body and as low as possible.
6. Maximize the heater wire surface area to minimize the wire temperature.

Testing of Non-inductive Heater Assemblies with D.C. Heater Power

1. The heater should be grounded to the body (internally or externally) if possible.
2. The heater should run on A.C. power as much as possible switching to D.C. power for a short period of time only to evaluate temperature, volts and amps. Switch back to an A.C. supply as soon as possible.
3. If only D.C. power is available for testing of non-inductive heaters it is important to minimize the time, temperature and voltage.

Spectra-Mat, Inc.
100 Westgate Drive • Watsonville, CA 95076, USA
www.spectramat.com
www.thermalmanagementsolutions.com

TECHNICAL BULLETIN



CENTER RETURN TOROID HEATER

Fig-01

Figure 1 is a center return toroid. A few alumina fish-spine beads would be placed around the center return wire to ensure that it will not touch the toroidal coil.

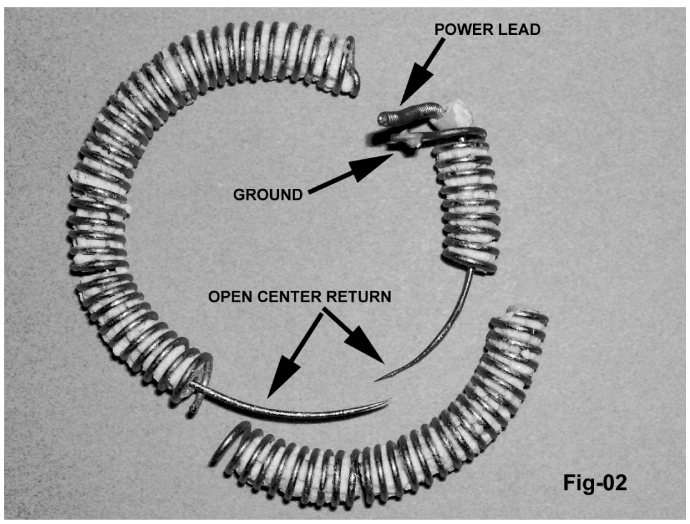
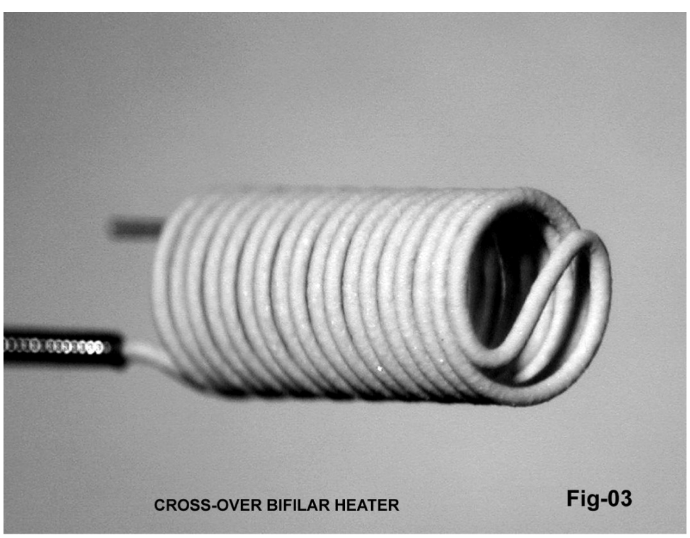


Fig-02

Figure 2 is a center return toroidal heater that was run on D.C. power. The heater lead is relatively cool with respect to the coil and this reduces the temperature of the center return wire as it enters the coil, this cooling effect diminishes as the center return get deeper into the coil. The potential between the center return wire and the coil is greatest at the point where the center return enters the toroidal coil however the return wire is cool here. The failure point occurs at the point where temperature and potential produce the greatest chemical reaction.



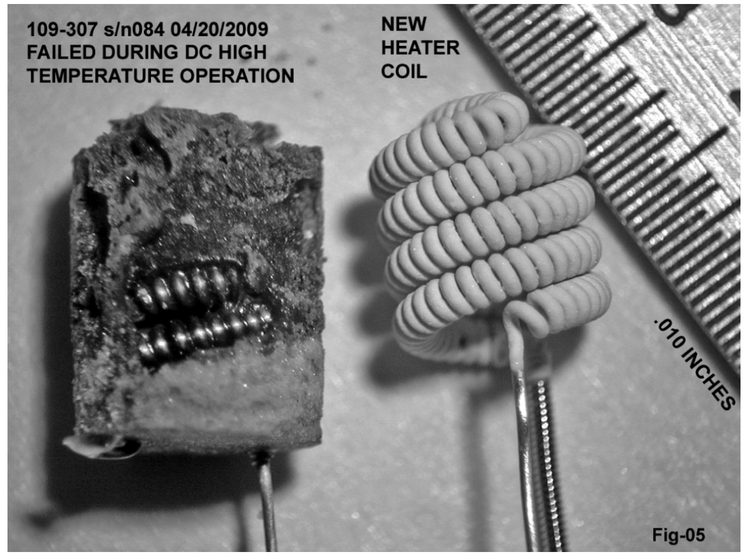
CROSS-OVER BIFILAR HEATER

Fig-03

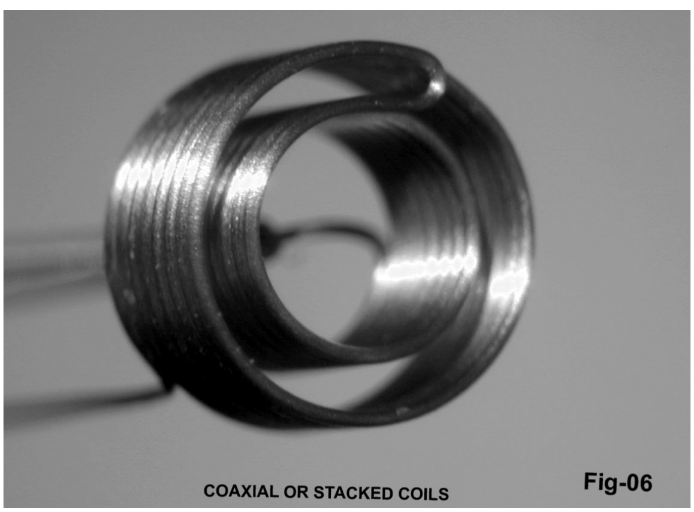
Figure 3 is a typical cylindrical cross-over bifilar heater; bifilar heaters may also be toroidal.

TECHNICAL BULLETIN

Figure 4 shows the D.C. damage to the bifilar shown in Figure 3. This heater is grounded to the heater can. However, heater power lead polarity makes no difference as each turn is the opposite polarity to its neighbor.



The potted heater on the left of Figure 5 shows D.C. damage between coils. The black material between the coils is a mixture of alumina and aluminum tungstate, this produced a coil to coil short that increased the heater power by several fold. It occurred after approximately nine minutes of operation at 1200°C on the cathode face. Hot resistance of the heater prior to failure showed a filament temperature of ~1600°C.



The heater in Figure 6 will cope with D.C. power better than most non-inductive heaters. In this type the coils have a much larger spacing between inner and outer coils. Each turn of a coil is close to the next turn but the voltage between these turns is quite small. The major voltage potential is between the first turn of the inner coil and the final turn of the outer coil and these coils have a relatively large spacing.

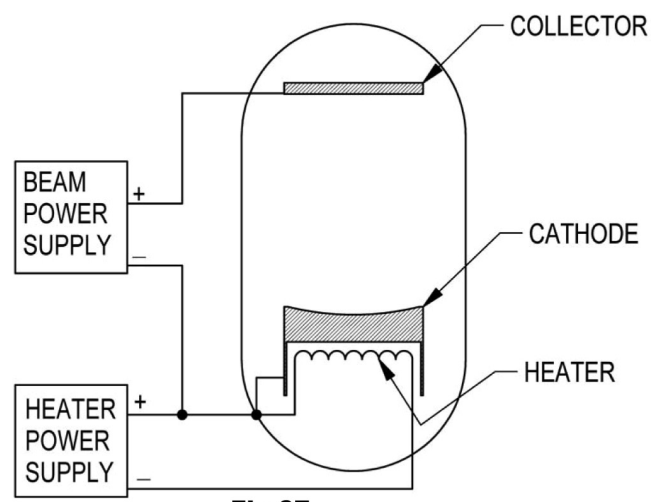


Fig-07

The schematic in Figure 7 at left depicts the correct filament polarity for a device that must use a D.C. power supply for its heater.

Conclusion

All non-inductive heater configurations are susceptible to D.C. power damage regardless of connection polarity. Of the non-inductive heater designs the coaxial or stacked coils suffer least, if connected negative with respect to the assembly. The severity of D.C. damage during testing can be reduced by lowering temperature and/or reducing high temperature time.

It should be noted that “non-inductive” heater filaments do not exist in the real world. We can only make minimally inductive heaters.

D.C. heater problems will not occur if the heater is free-standing, not potted.

References: Allentown Laboratory, Bell Telephone, Inc. 1959; Philips Technical Review, 1950; Studies at Eitel-McCullough, Inc (Eimac), 1965; Unpublished studies at Spectra-Mat, Inc. 2002/2003