TAI Graphite Fiber Thermal Straps

Effective heat removal is critical for many aerospace thermal control applications. Generally, heat transport from power dissipating components depends on conduction to the spacecraft thermal bus or radiator using a thermal conductor made from either copper braid or aluminum foil straps. Although these approaches work, they are generally heavy, stiff, and expensive. Technology Applications, Inc. (TAI) of Boulder, Colorado, produces graphite fiber thermal strap (GFTS) assemblies that are light, flexible, and provide a superior method of transferring heat efficiently.

The K1100 graphite fiber (GF) material employed has exceptional thermal conductivity compared to other solid conductors. The thermal conductivity is temperature dependent and peaks at over 1000 W/m-K from 210 K to 265 K, which is 2.5 times better than electrolytic tough pitch (ETP) copper and 5 times better than 1100 aluminum. The thermal conductivity of the graphite fiber declines as temperature decreases however, falling below that of ETP copper at under 90 K and below 1100 aluminum at under 70 K. See Figure 1 below.

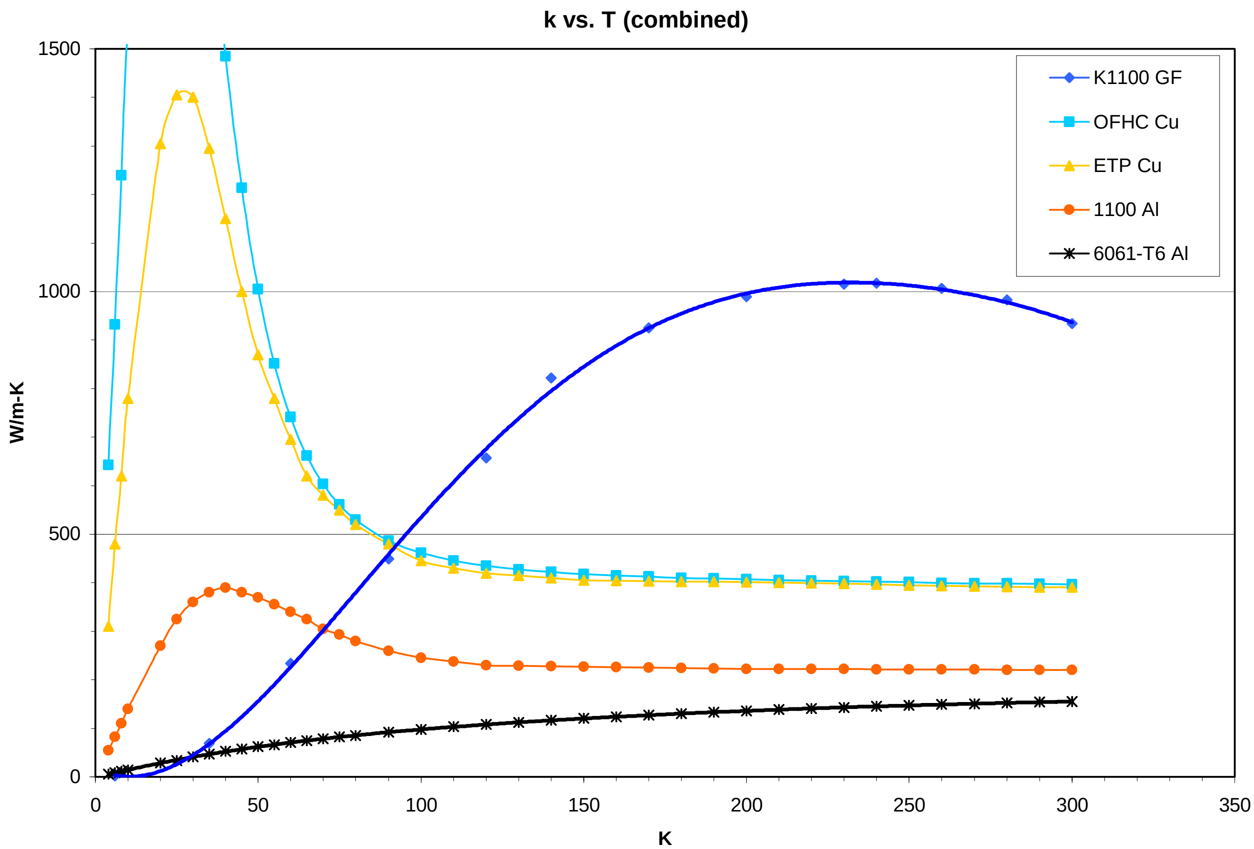

Figure 1. Thermal conductivity of various thermal strap materials.

The density of graphite fiber, only 2.2 g/cm^3, is lower than both ETP copper at 9.0 g/cm^3 and 1100 aluminum at 2.7 g/cm^3, as well. The combined differences in thermal conductivity and density result in required mass of ETP copper that can be up to 10 times greater than that of the graphite fiber and mass of 1100 aluminum of up to 6 times greater, in order to transfer the same amount of heat across the same temperature differential. Because the graphite fibers are mounted into a metallic end fitting at each end of the GFTS that acts as a transitional interface, the actual mass advantage may be reduced by about 50 percent. Therefore, for the same conductance, a 65 to 80 percent weight savings over aluminum or copper thermal straps can be realized by using a GFTS.

An additional advantage of the GFTS compared to metallic braid or foil thermal straps is flexibility. Although graphite is a very stiff material, the narrow 10-micron diameter fibers are quite flexible. The GFTS has sufficient flexibility to accommodate installation and alignment tolerances, relative structural movements due to vibration and thermal contractions, and some limited bending motion. Many applications, particularly focal plane instruments, require a thermal strap that transmits minimal force.

Because the graphite fibers are high modulus, the GFTS assemblies are fracture critical and require reasonable care in handling. However, they have demonstrated sufficient robustness for normal handling during installation and can survive launch vehicle shock and vibration loads. Typically, the fiber portion of the GFTS is wrapped with Mylar to form an effective contamination barrier, though other methods are under consideration, including a conformal coat of RTV silicon.

A GFTS often costs less than a metallic braid or foil thermal strap as well. Even though the graphite fiber material itself costs more than copper or aluminum, the GFTS can be fabricated more efficiently. Cost savings of 50 percent have been demonstrated.

Four GFTS assemblies, as shown in Figure 2, were manufactured and delivered to Ball Aerospace for their Visible Camera System program, to be launched on a ground-based interceptor. These thermal straps successfully passed rigorous shock and vibration qualification tests.

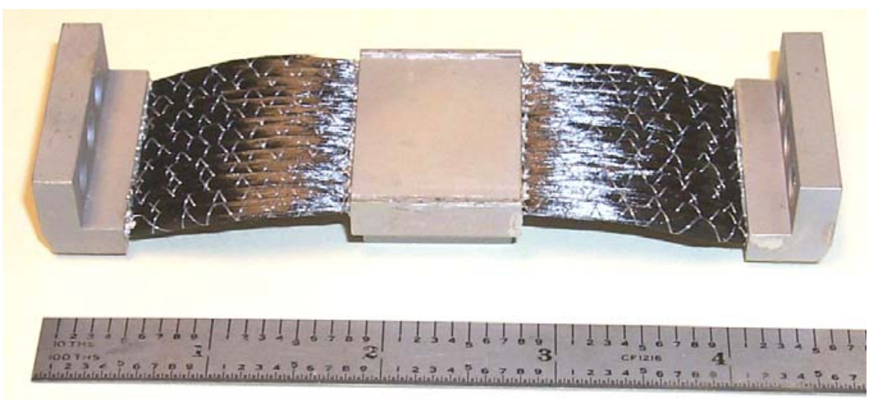

Figure 2. Ball Aerospace Visible Camera System GFTS.

The design of a GFTS can be optimized for each application's geometry and thermal conductance requirements, such as the thermal strap displayed in Figure 3.

Figure 3. U-shaped GFTS for minimal force and vibration transmission.

After fabrication, each GFTS unit undergoes inspection and thermal conductivity measurement, as shown in Figures 4 and 5. This assures compliance with the customer's geometric, stiffness, and thermal conductivity requirements.

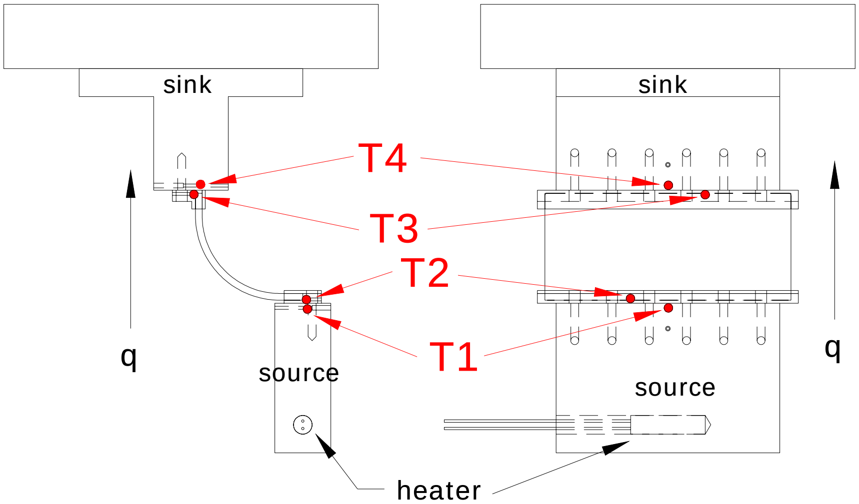

Figure 4. Thermal conductivity test schematic.

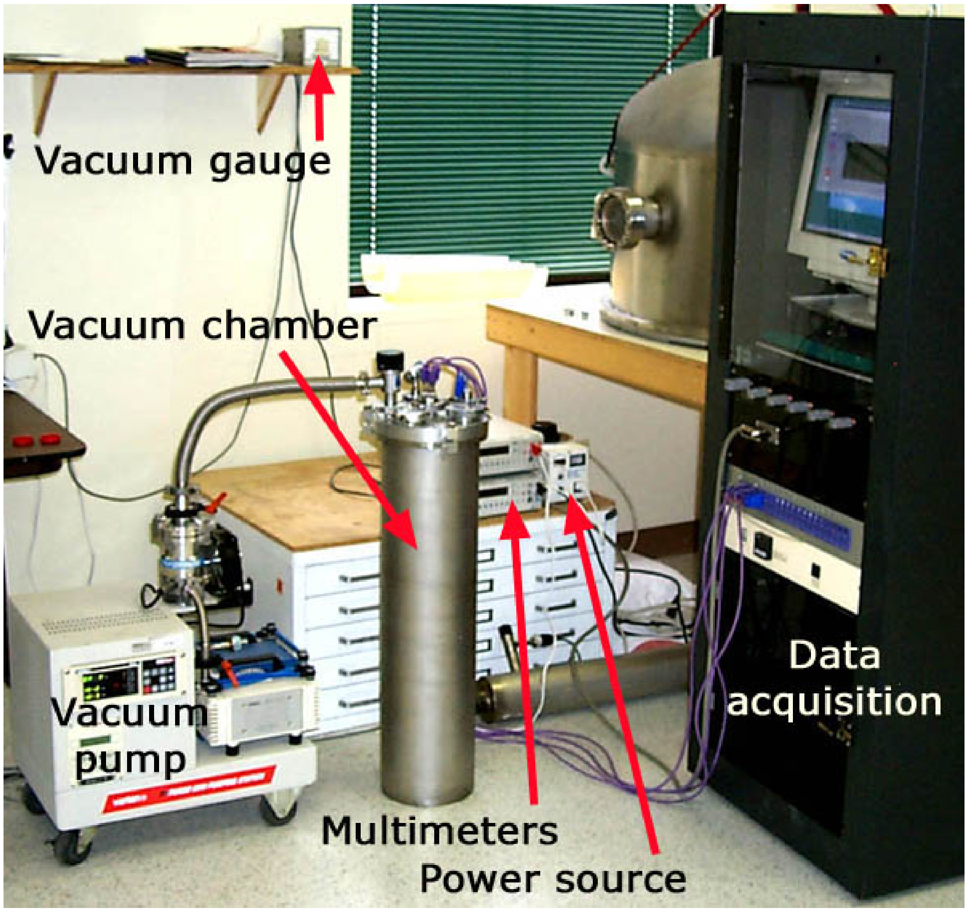

Figure 5. Thermal conductivity test equipment.

The GFTS has demonstrated high thermal and weight efficiency, can meet launch loads, and is sufficiently developed for commercialization. For more information, please contact Ed Myers at Technology Applications, Inc., 303-443-2262 ext. 114.