



THERMAL STRAPS

PERFORMANCE, PRICE, AND
PRODUCT OPTIONS

WHAT ARE THERMAL STRAPS?

PASSIVE HEAT TRANSFER | FLEXIBILITY | VIBRATION ISOLATION

Thermal straps (also known as "thermal links," "heat straps," and "thermal braids,"), are heat transfer devices consisting of end fittings (to attach the assembly to a heat sink and source), and a flexible conductive material (copper cable & foil, aluminum foil, graphene, and graphite sheets or fiber bundles).

Thermal Straps:

- Transfer heat between two or more locations and provide attenuation when movements from shock, vibration, mechanical function, and thermal expansion or contraction occur. These can be related to events such as rocket launch, cryostat & cryocooler cool-down, and the day-to-day shock and vibration profiles associated with ground-based and airborne vehicle & equipment operation. They can be paired with vibration isolation systems and heat pipes to provide additional attenuation, heat transfer, and mechanical decoupling.
- Are unique products in the aerospace and cryogenic engineering industries
- Provide a combination of conductive heat transfer, flexibility, and vibration attenuation, damping, and isolation, not found in heat pipes, vapor chambers, nor any other passive or active cooling and/or vibration isolation system.
- Can be used to cool everything from batteries, to cryocoolers, cameras, dewars, and even rocket and missile components.



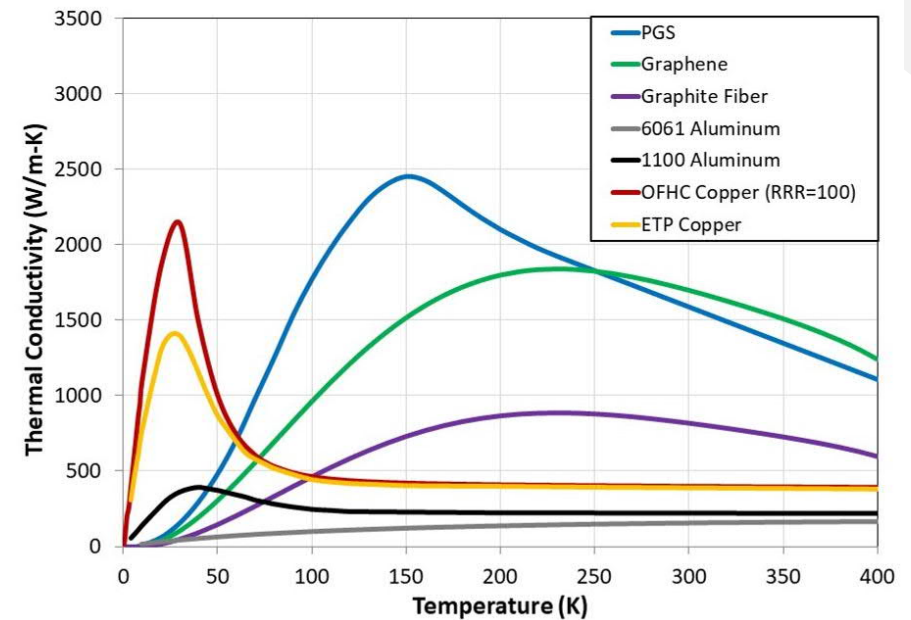
THERMAL CONDUCTANCE & OPERATING TEMPERATURE

| Temperature | mK - 77K | 77K - 250K | 250K - 400K + |
|-----------------------|--|--|--|
| Application | <ul style="list-style-type: none"> Dilution Refrigerators Cryocoolers Stored Cryogenics Cold Boxes Cryomodules Superconducting Magnets, Electronics and other Components Detectors and Sensors Infrared Systems X-Ray Systems Focal Planes Thermal Switches | <ul style="list-style-type: none"> Optical Systems Stored Cryogenics Star Trackers Telescopes Electronics Boxes Detectors and Sensors Microwave Antennas Cryocoolers Radiators Laser-Pointing Systems Photonics | <ul style="list-style-type: none"> Optical Systems Star Trackers Telescopes Radiators Electronics Boxes Cryocooler Compressors Microwave Antennas Laser-Pointing Systems Battery Cooling Medical Instruments Photonics Heat Pipe Connections |
| Thermal Strap Options | <ul style="list-style-type: none"> Cu Cable - \$ Cu Foil - \$\$ Graphite Sheet & Fiber (Thermal Switches) - \$\$\$ 5N Al Foil - \$\$\$\$ | <ul style="list-style-type: none"> Cu Cable - \$ Cu Foil - \$\$ Graphite Sheet & Fiber - \$\$\$ | <ul style="list-style-type: none"> Cu Cable - \$ Cu Foil - \$\$ Graphite Sheet & Fiber - \$\$\$ |

Common Applications and Thermal Strap Choices by Operating Temperature



Thermal Strap Material Conductivity Graph



COPPER CABLED THERMAL STRAPS (CuTS®)

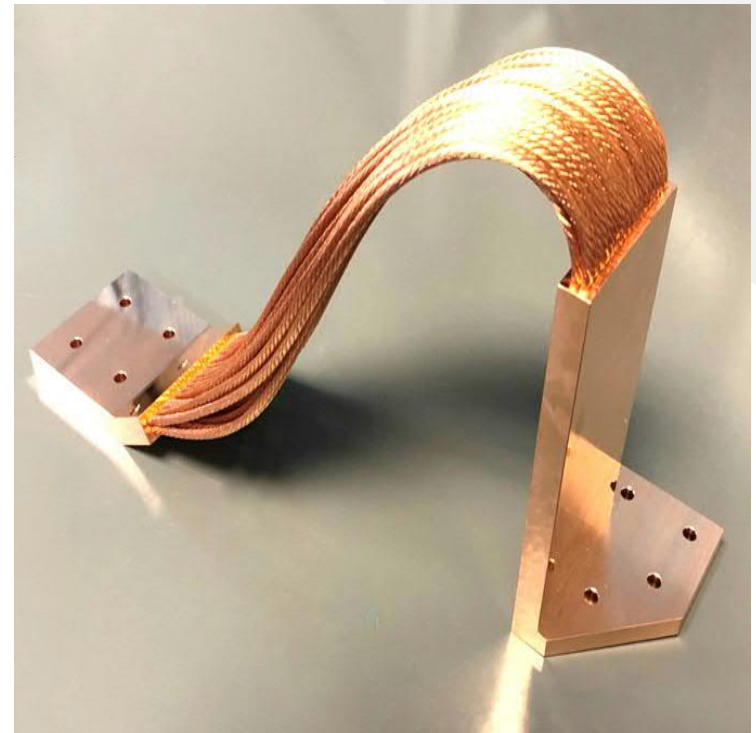
Copper Cabled Thermal Straps (CuTS®) are made with OFHC copper cabling and fittings. They are used across the aerospace, defense, cryogenic engineering, photonics and semiconductor industries. The most common applications include: cryocoolers, dilution refrigerators, dewars, probe stations, radiators, star trackers, and other optical instruments.

Some of the most important benefits CuTS® offer include:

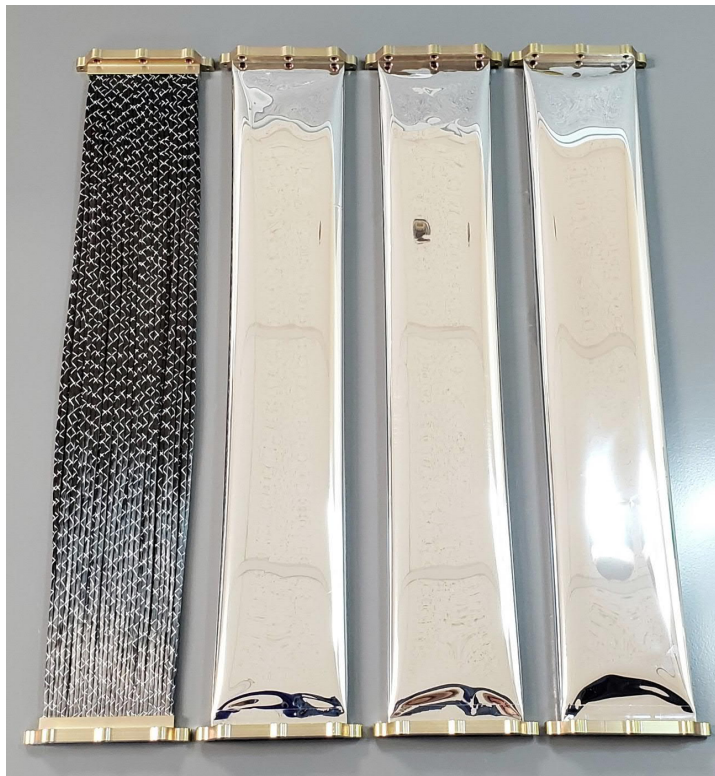
- 3-axis flexibility
- Superior durability over all metallic foil and carbon-based strap types
- High thermal performance at cryogenic operating temperatures
- Efficiency: our unique swage and post-assembly machining manufacturing method preserves flexibility and minimizes resistance losses at each joint (or interface) in the assembly.
- Affordability: most CuTS® products vary in price from as little as \$100 - \$1,500/unit, depending on the complexity of the design and quantity.

TAI's CuTS® products have been extensively qualified in the mK – 10K range by US national laboratories, and from 10K – 873K+ by hundreds of engineers at aerospace organizations, publicly-funded labs, and universities across the globe.

TAI offers over 100 standard model thermal straps in our CuTS® Catalog; from simple rectangular and L-shaped fitting designs, to complex models for the first and second stages of popular cryocoolers from Sumitomo Heavy Industries™, and Cryomech™.



GRAPHITE FIBER THERMAL STRAPS (GFTS®)



Graphite Fiber Thermal Straps (GFTS®) are made onsite, by our expert technicians, from high conductivity graphite fibers (woven into bundles). These bundles are contained in/attached to aluminum or highly conductive carbon fiber end fittings (brackets), using our trademarked Condux™ epoxy. All materials used fall well below NASA's published outgassing limits, and GFTS® assemblies are available with optional aluminumized mylar sleeves for optical instruments and other contamination-sensitive applications.

GFTS® products offer the following benefits:

- 3-axis flexibility
- Superior durability over graphite and graphene sheet strap types
- Unrivalled vibration damping
- Low Mass: GFTS® assemblies offer roughly the same thermal performance of equivalent copper thermal straps at just 1/5 the 1/10 the mass

TAI's GFTS products have extensive spaceflight heritage, and have been qualified from 40K – 350K by NIST, NASA, ESA, DLR, JAXA, and aerospace companies across the globe. Our experts can make highly accurate thermal conductance projections for any custom or standard design in this range.

TAI offers 6 standard model thermal straps (with multiple end fitting configurations), available in our [GFTS® Catalog](#). Most GFTS® assemblies cost between \$1,000 - \$5,000/unit, depending on complexity, size, and quantity.

Stiffness, Vibration, Shock, and other spaceflight qualification data are available for our GFTS® products upon request, as well as our test procedures and work instructions.

PGS & GRAPHENE THERMAL STRAPS (X-SERIES®)

X-Series® Thermal Straps are made with Pyrolytic Graphite Sheets (PGL®), and are also available with Graphene Foil (GTL®). All materials used fall well below NASA's published outgassing limits, and X-Series® assemblies are available with optional aluminized mylar sleeves for optical instruments and other contamination-sensitive applications.

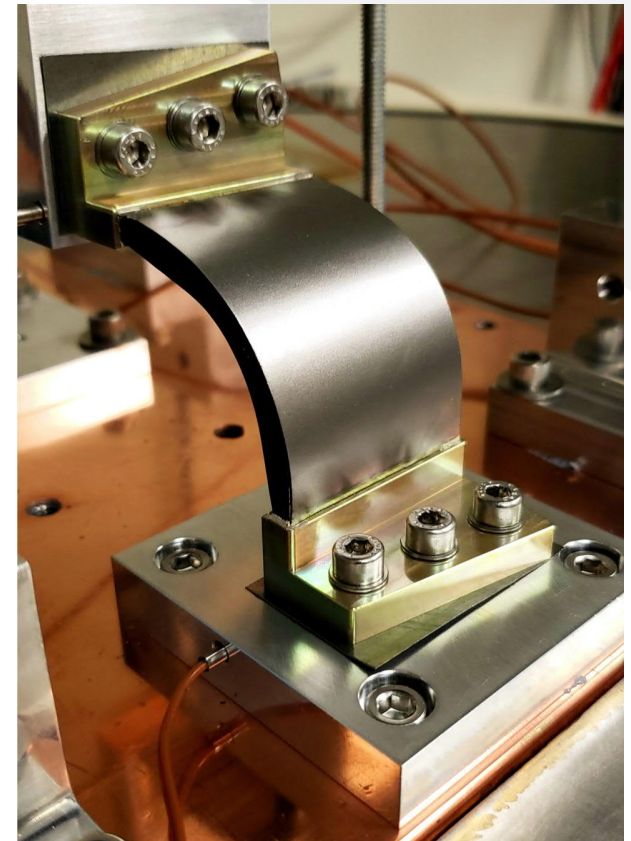
When combined with TAI's proprietary design and assembly methods, they are entirely unique in the industry, offering a number of important benefits over other strap types including:

- 3 – 4X the performance of equivalent copper and graphite fiber straps
- PGS offers 6X the thermal performance of aluminum and 4X the performance of copper at room temp
- X-Series® PGS straps (PGL™) are the industry's most flexible thermal straps; with stiffness measurements on multiples axes in the mN/mm range.
- X-Series® straps are exceptionally clean and have passed strict PCL/PAC/FPAC testing performed by NASA and other test facilities.
- X-Series® straps can be used both as thermal straps and passive thermal switches at certain cryogenic temperatures. For more information, contact TAI.

PGL™ straps are now at Technology Readiness Level (TRL) 7 and have been qualified from 10K – 300K by organizations including NIST, NASA, DLR, Airbus, and aerospace companies across the globe. Our experts can make highly accurate thermal conductance projections for any custom or standard design in this range.

TAI offers 6 standard model thermal straps (with multiple end fitting configurations), available in our [X-Series® Catalog](#). Most X-Series straps cost between \$1,000 – 5,000/unit depending on complexity, size, and quantity.

Stiffness, Vibration, Cleanliness, and other spaceflight qualification data are available for our X-Series® products upon request, as well as our test procedures and work instructions.

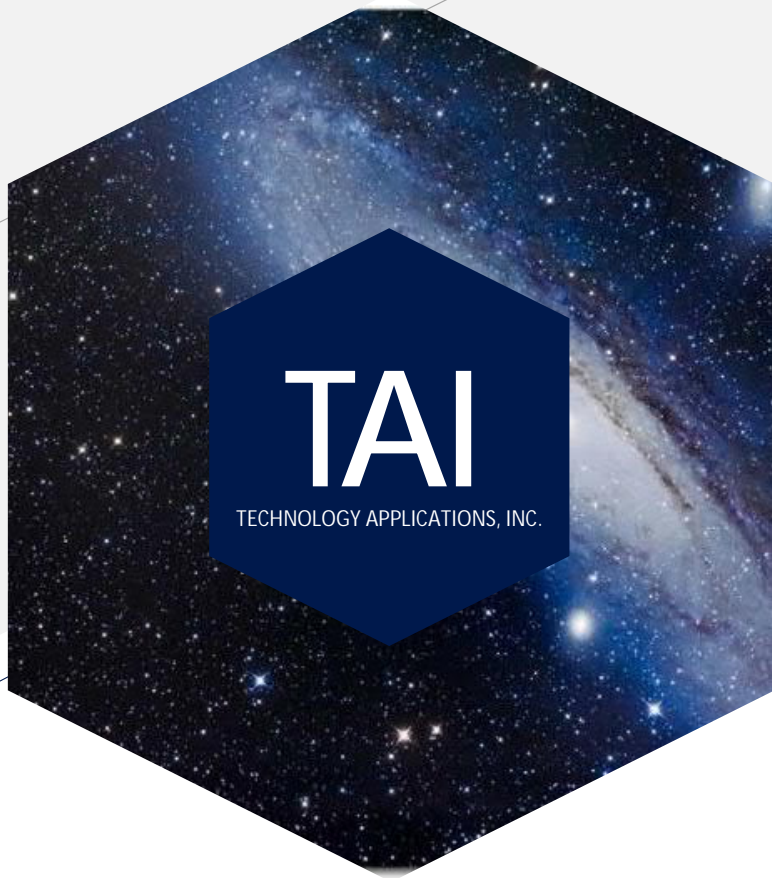


DESIGN. TEST. DELIVERY.





EXPERT SUPPORT FROM INTRODUCTION TO INSTALLATION

- All thermal strap design, projection, and consultation services are provided upfront and free of charge, so you know exactly what you are getting before a purchase order is ever placed.
- TAI offers thermal conductance, cycling, stiffness, and tensile strength testing onsite, and uses nationally-renown test facilities for shock and vibration testing.
- All thermal strap products are available at heavily discounted prices to university aerospace and physics customers, as part of our [University Showcase Program](#). Contact TAI to learn more.
- Each of our thermal strap products is warrantied and all products are manufactured at our facility, by our staff. TAI does not outsource our thermal strap products, and we are the only supplier across the globe with the necessary equipment, personnel, facilities, and expertise to fill production orders for hundreds to tens of thousands of straps.
- Our team is here to support your program from the initial outreach through installation of your straps. We are available from 6 AM – 9 PM 7 days/week, and offer support during the design, manufacturing, and testing phases. Our team even provides all handling and test instructions needed, and can support onsite installation of our products in your spacecraft or equipment.





CONTACT TAI TODAY

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