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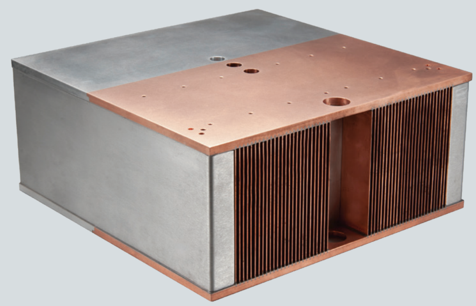
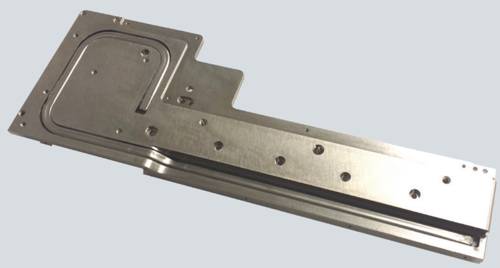
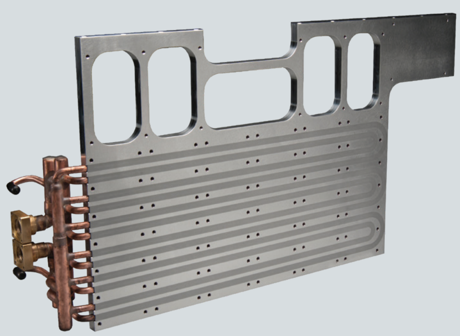
DESIGN GUIDE

HEAT SINKS FOR HIGH-POWER APPLICATIONS







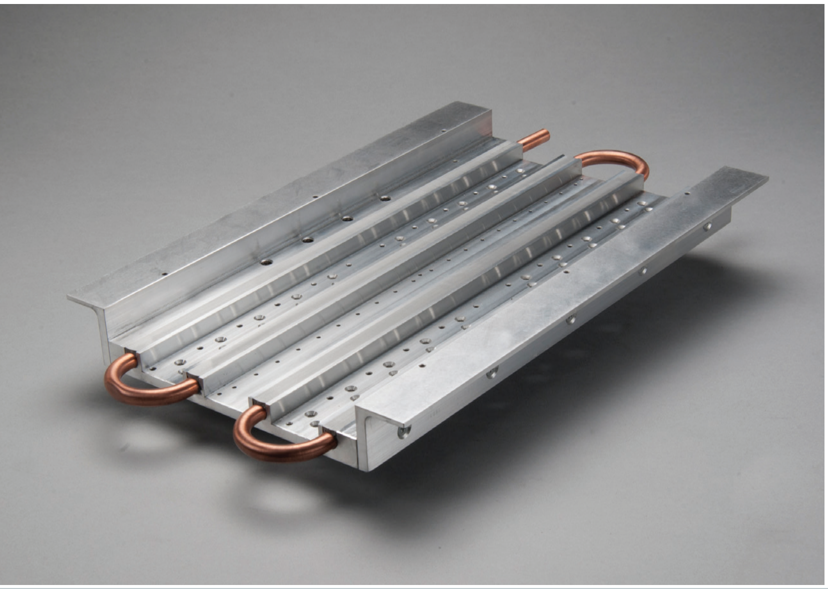
Design Guide: Heat Sinks for High-Power Applications

OUR TECHNOLOGY

Most standard and high-performance electronic components won't withstand extreme heat. Prolonged or excessive heat exposure can lead to problems ranging from minor errors in mild cases and complete malfunction in more serious instances. Even when a component does not fail straight away, heat exposure can harm component integrity and decrease a device's working life. As such, proper thermal management is imperative when designing durable electronics.

Heat sinks are one option for keeping electronics at a sustainable operating temperature. A passive component made from metals with high thermal conductivity, heat sinks disperse heat by drawing it away from sensitive circuitry. Heat sinks may be cooled by liquids or simple airflow to remove heat more effectively from the system. They may also incorporate fins to direct airflow, especially when used in conjunction with fans.

Heat sinks provide a base level of heat dissipation that forms the backbone of any effective thermal management system. Regardless of the specific layout, thermal management components should be selected early in the electronics design phase to prevent performance problems later.



Modes of Heat Transfer

Heat sinks leverage conduction and convection, the two simple properties of heat transfer in which thermal energy naturally moves from hotter areas to colder ones.

- **Conduction** occurs between two materials that are in contact with one another, allowing the heat sink to draw heat away from the source.
- **Convection** uses the natural tendency of heat to rise in a liquid or gas to transfer heat. Convection is important in heat sink design because it allows the absorbed heat to dissipate safely away from at-risk components.

CONVECTION CONSIDERATIONS

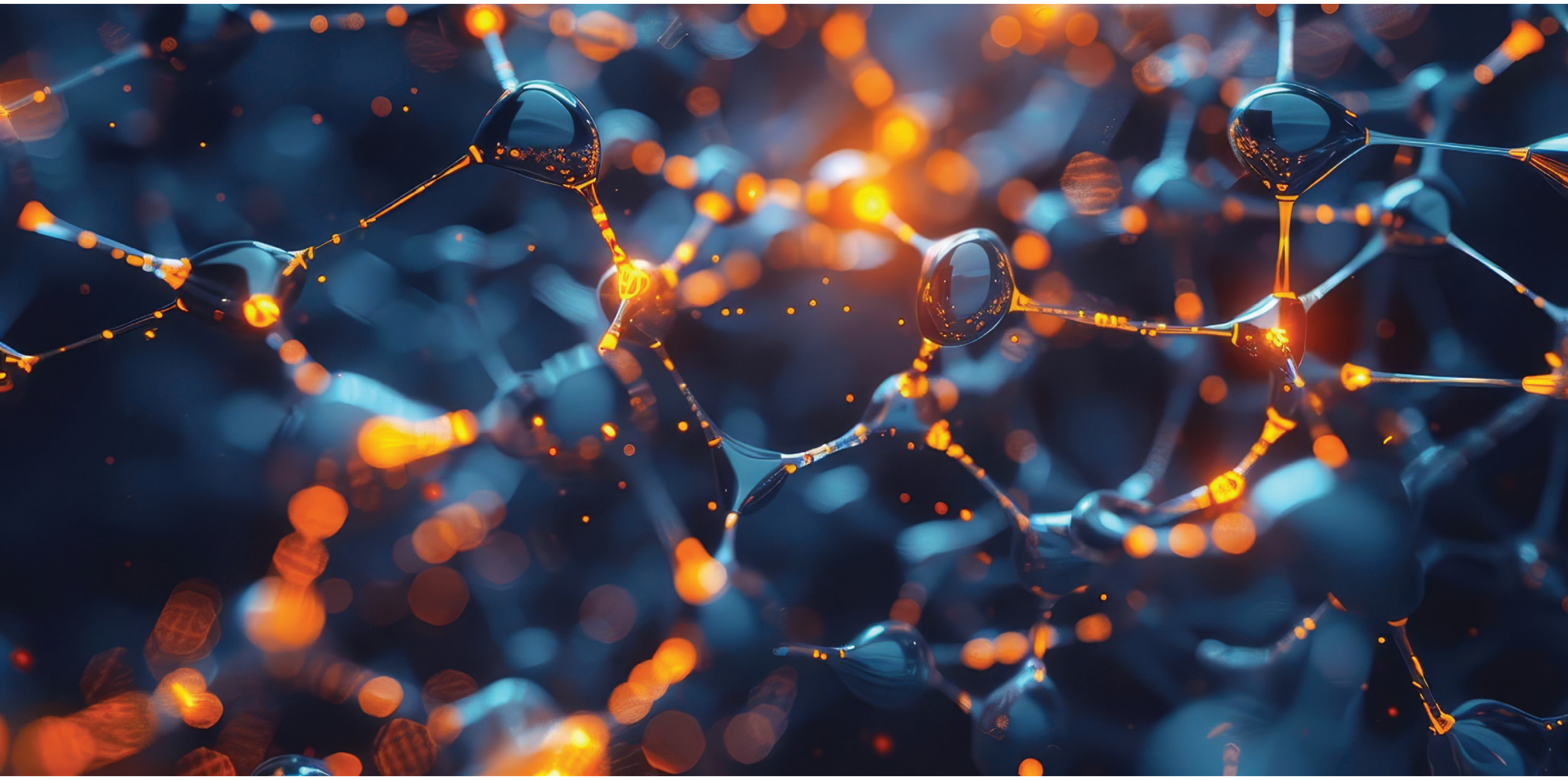
In developing a thermal management system, engineers must consider both natural and forced convection patterns to develop the most effective cooling solution.

Natural Convection

Natural convection occurs without the intervention of fans or other devices—it's the pattern of heat transfer that would happen on its own due to buoyant forces. To leverage natural convection, heat sources should be placed toward the top of an electronics enclosure with sensitive components being toward the bottom. The space should also be sufficiently vented to allow for proper airflow. Heat sinks used without forced convention should also incorporate vertical fins with larger spacing between them—at least 0.25 inches or 6 mm. These considerations maximize natural airflow and lead to more efficient cooling, with or without the addition of active thermal management devices.

Forced Convection

Forced convection is aided by fans, pumps, or other external sources of airflow. Forced convection is often necessary when working with higher heat applications, or with enclosures that lack sufficient space for effective natural convection. Heat sinks for these situations should have thicker fins with a high fin density to balance against pressure drops. They may also incorporate copper elements, especially where extreme heat flux is a concern.



What Factors Impact Heat Sink Performance?

Numerous heat sink design features influence performance:

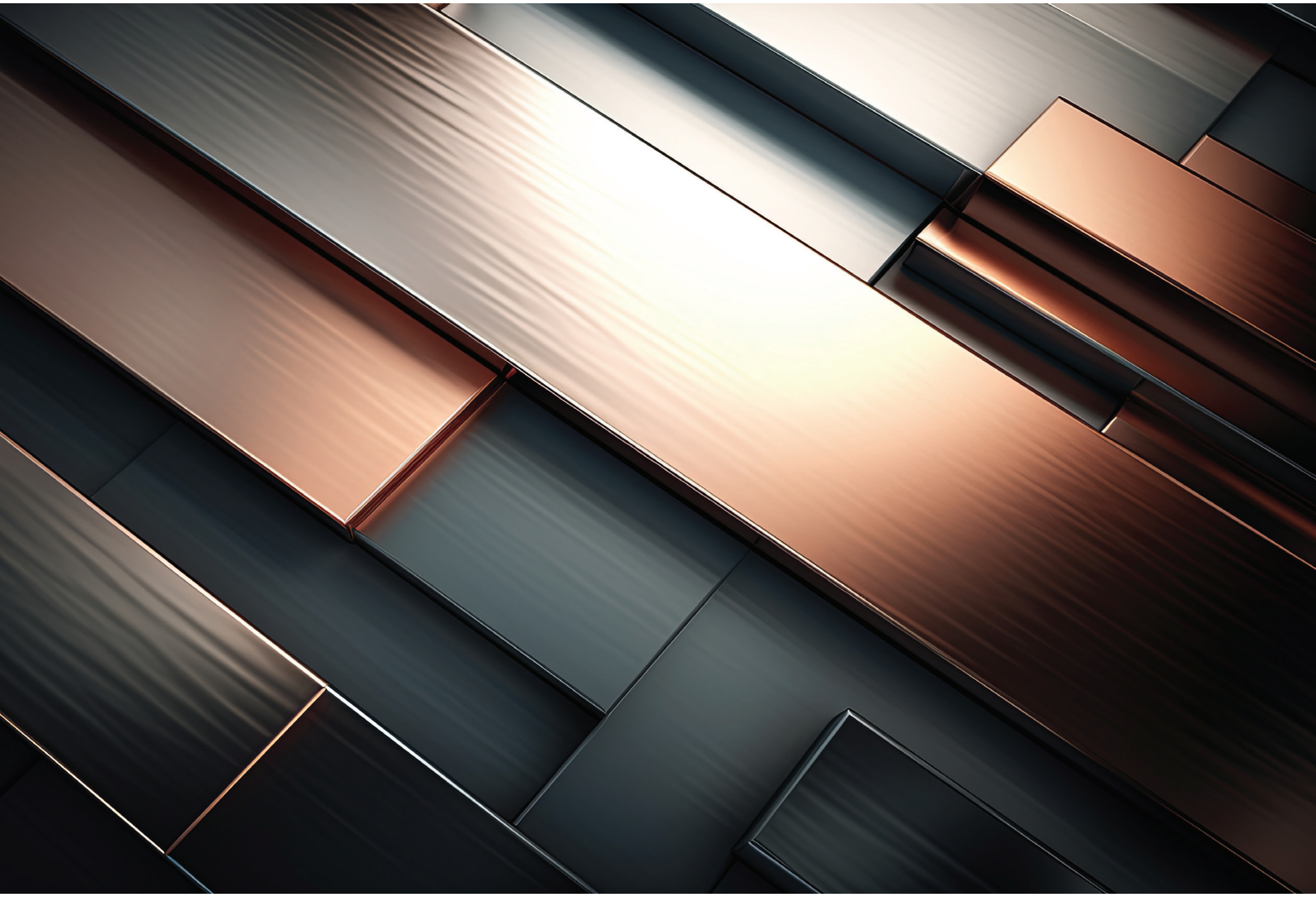
- Patterns of airflow in the system
- Air velocity
- Fin design
- Construction material
- Surface treatments such as anodization

In designing and placing a heat sink, it's important to consider how these variables play together to dissipate heat. Higher heat applications may require a different material selection or fin design than lower heat use cases, for instance.

COMMON HEAT SINK MATERIALS

Heat sinks are made from thermally conductive metal to allow for adequate heat absorption and dissipation. The two most common choices are aluminum and copper.

- **Aluminum** is the standard choice for heat sinks thanks to its high conductivity, cost-effectiveness, and low maintenance requirements. Unfortunately, the thermal conductivity aluminum is only about half that of copper, limiting its ability to transfer heat across longer distances.
- **Copper** is denser and more expensive than aluminum, but it comes with twice the thermal conductivity. This makes it a better choice for certain large-scale or high-heat applications.



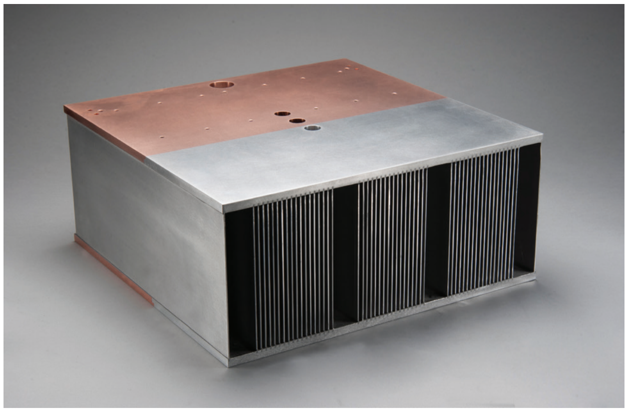
Heat Sink Types

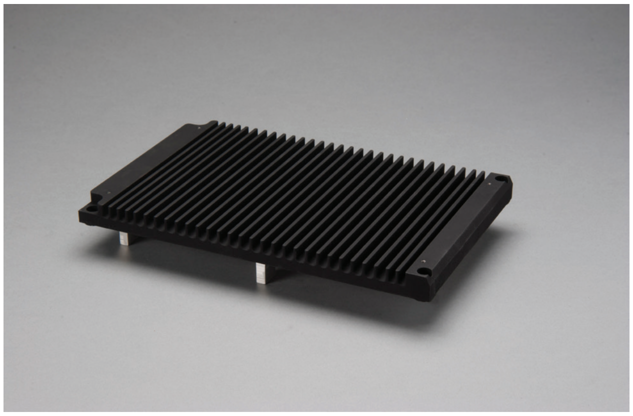
Heat sinks come in many varieties to suit a broad range of thermal management applications. The choice of heat sink depends on several factors, including the heat level produced, the heat sink's thermal budget, and the density of the enclosure.

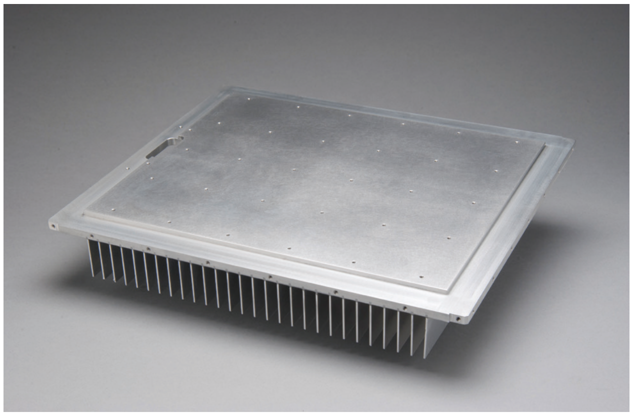
AIR-COOLED HEAT SINKS

Air-cooled heat sinks are the simplest to design, drawing on convection from natural or forced airflow to release heat into the environment. Specific design elements include:

- **Extrusion.** Extrusion heat sinks are usually a single piece of aluminum extruded into a desired profile. Extruded heat sinks are simple to manufacture and can often be produced quickly using existing molds.
- **Bonded fin.** Rather than relying on a single piece of aluminum, bonded fin heat sinks incorporate multiple fins, each of which is individually bonded into the base of the heat sink. As a result, bonded fin heat sinks can have taller fins and tighter densities, increasing the surface area available for convection cooling.
- **Pressed (swagged) fin.** Pressed fin designs use cold welding instead of a bonding agent to join the fins to the base. Secure pressed fin designs are often preferred when working with highvelocity airflow.
- **Soldered fin.** Soldered fin heat sinks resemble bonded fin designs, but they are typically made from copper and the fins are soldered onto the base rather than joined with a bonding agent. Soldered fin heat sinks are among the most efficient, making them an excellent choice for high-power, high-heat applications—especially where space constraints exist.







Heat Sink Types

HEAT PIPES

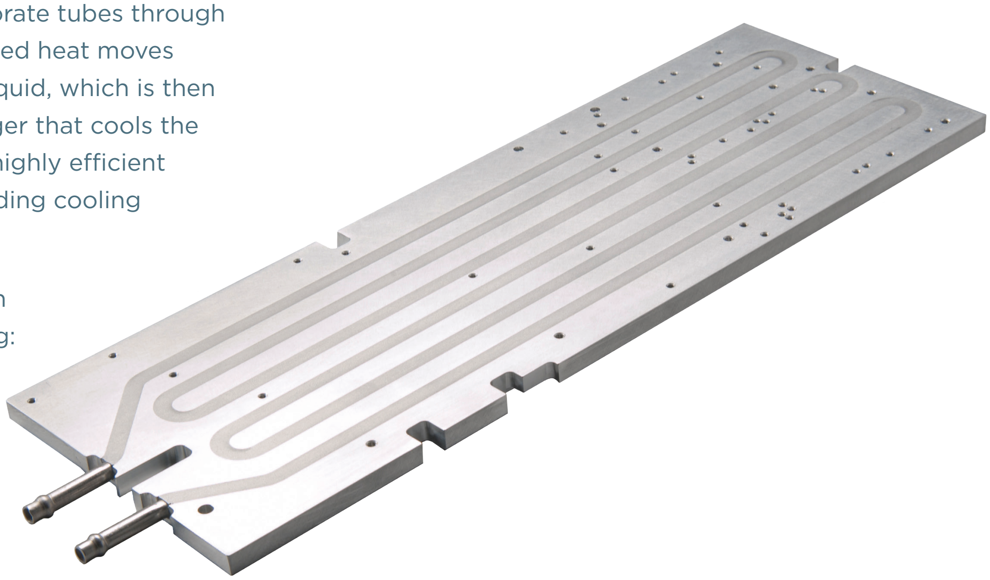
Featuring a two-phase heat transfer system, heat pipes offer a greater degree of cooling than air-cooled heat sinks. Heat pipes consist of a metal tube, a wick lining, and a fluid medium. When a portion of the pipe heats up, the fluid evaporates, moving along the wick toward a cooler portion of the pipe where it condenses. This process efficiently removes heat from the source where a heat sink would be too bulky or too passive. A heat pipe may also transfer heat to a heat sink elsewhere in the enclosure, which is helpful in crowded electronics enclosures.

Heat pipes are suitable for temperatures ranging from -40°C up to 275°C, operating for years with little or no maintenance required.

LIQUID-COOLED HEAT SINKS

Liquid cooling is more effective than air cooling because it draws on fluids with higher heat density, heat capacity, and thermal conductivity, allowing for optimal cooling with a small footprint.

Liquid-cooled heat sinks incorporate tubes through a conductive cold plate. Generated heat moves through the plate and into the liquid, which is then pumped through a heat exchanger that cools the fluid back down. The result is a highly efficient cooling loop suitable for demanding cooling applications.



Liquid-cooled heat sinks come in many different designs, including:

- Exposed tube
- Buried tube
- Deep-drilled
- Vacuum-brazed

The best choice depends on the constraints of your application, including both space and thermal considerations.

Thermal Management Solutions

COMMON INDUSTRIES FOR HIGH-POWER HEAT SINKS

High-power heat sinks are used when thermal management is mission-critical. The following represent just a few of the challenging, extreme-temperature applications requiring premium heat sinks:

Military and Aerospace:

Airborne systems, naval ships, and submarines.

Medical

Imaging equipment, surgical lasers.

Industrial

Medium to high-voltage motor drives, laser-cutting machines, power stations, electrical infrastructure.

Transportation

Railways, mass transit.

THERMAL MANAGEMENT SOLUTIONS

Thermal management should be among the first layout considerations in the design process. Waiting until later in production substantially limits your choices and may result in a less efficient product. In the worst cases, a haphazard thermal management plan can lead to device malfunctions that require a complete redesign. To avoid this, you should consider working with a thermal engineer from the very start and consulting with an expert on design, prototyping, and manufacturing. Mersen's thermal experts work within your constraints to identify the most effective components for your needs and budget.

Mersen is a leading provider of custom, high-performance cooling solutions for the electronics industry. Our catalog includes air-cooled and liquid-cooled heat sinks, heat pipe assemblies, and custom chassis for high-powered electronics. We also offer advanced engineering services, including design and simulations, 3D renderings, and thermal calculations for both natural and forced convection designs.

ENGINEERING AND TESTING CAPABILITIES

Mersen design engineers have extensive experience in thermal management design, prototyping, and manufacturing. Our engineers have the experience and knowledge to understand your thermal management challenges and help you find a solution. We take on projects that others shy away from.

We offer:

- Thermal interface design and simulation
- CFD thermal simulation
- 3D CAD / CAM
- Natural and forced air quick thermal calculators
- Thermal testing
- Infrared thermal imaging

Quality

As an ISO 9001:2015, AS9100 (D), and ITAR registered company, we are committed to meeting your exact specifications and providing you with only the highest uality thermal solutions.

Expertise, our source of energy

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