PHASE CHANGE MATERIAL HEAT EXCHANGERS

Thermal Energy Storage with PCM

Phase Change Materials (PCMs) store thermal energy during the phase change from solid to liquid, since the latent heat from melting or freezing is at least 1-2 orders of magnitude higher than the energy stored by the specific heat. PCM applications in electronics thermal management include:

- Smoothing out the thermal energy during pulsed operation, allowing the heat removal system to be designed for the average heat load rather than the peak load
- Short-term thermal storage, where a suitable heat sink is not available
- Protection from failure during coolant interruptions, when the cooling system is temporarily unavailable

Due to the dynamic, time-dependent thermal properties of the PCM heat exchanger, advanced modeling capabilities and experience in thermal design is essential. ACT has experience in designing PCM based cooling systems, ranging from milli-watts to kilo-watts.

APPLICATIONS INCLUDE

- Directed Energy Weapons
- Pulsed Electronics
- Missiles
- Battery Cooling

ACT's Phase Change Material (PCM) Heat Sink

The PCM heat exchanger/cold plate design also plays a large role in ensuring a low-weight solution is built. PCMs, such as paraffin wax, commonly used in these heat exchangers, have poor thermal conductivities, often < 1 W/m-K. This causes a need for additional features, such as extended surface fins to effectively melt the entire PCM with minimal thermal resistances. Accurate predictions of the effective thermal conductivity of the PCM heat exchanger will help in developing a lean solution. ACT is experienced in design and fabrication of complex PCM packaging, including:

- Corrugated surfaces
- Fins (folded, integral, bonded, etc.)
- Heat pipe embedded enclosures
- Heat exchangers

PCM Assemblies for heat storage use a variety of PCMs and wall materials to meet application-specific requirements. Our modeling and manufacturing experience includes paraffin wax, hydrated salts, and metal based PCM assemblies for powers ranging from 1 to 100 KW.

Smoothing Out Pulsed Operation

Several applications have pulsed heating, with a period of high heating, followed by a longer period of lower heating. PCM thermal storage devices can provide thermal storage for repeated duty cycle components, allowing the heat rejection system to be sized for the average rather than the peak heating. ACT has demonstrated the benefits of load leveling in system that range from individual transistors up to large heat exchangers for Directed Energy Weapon (DEW) systems.

Figure 1 shows how a PCM heat exchanger can smooth out the heat removal rate, leveling the load for a vapor compression system (VCM). The PCM melts and absorbs heat during the power on condition. It then gradually freezes over the rest of the cycle, so that heat can be dissipated over the full duty cycle. By dampening the heat load, the PCM heat exchanger allows the ultimate heat rejection system to be sized for much lower heat loads, as indicated in Figure 1. For applications with extreme heat loads, such as DEWs, PCM can drastically reduce the overall size of the required heat sink. The basic technology can be leveraged in all cooling systems:

- Vapor compression systems – reduce condenser / compressor size
- Air cooled system – reduce fin volume
- Liquid cooled systems – reduce pump size
- Space systems – reduce radiator area

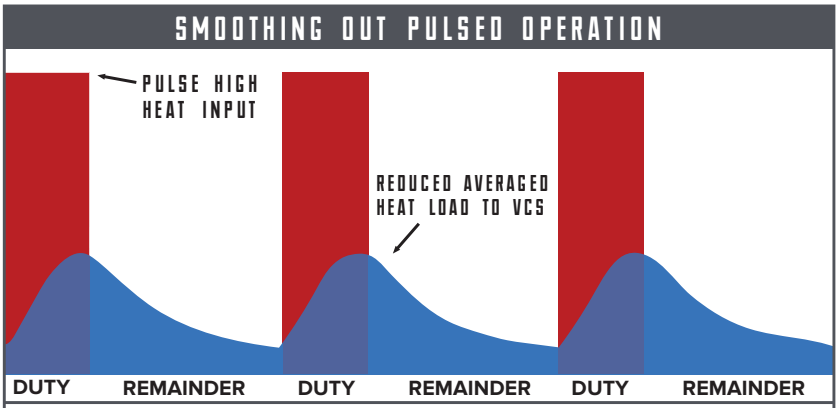

Figure 1. A PCM heat exchanger can smooth out the heat removal rate, leveling the load for a vapor compression system.

Short Term Thermal Storage

The heat storage capacity of PCM is advantageous to designers of short duration applications without a suitable heat sink, such as missile electronics thermal management. Limited space and system weight do not allow for a bulky thermal solution.

PCM heat sinks are exceptionally compact, lightweight, and offer increased reliability due to their passive operation. This is a significant advantage compared to traditional, active, steady-state solutions. For one-time use applications, unlike pulsed operation, the PCM can act as the final heat sink, absorbing the heat load during full operation. PCM heat sinks can be designed for:

- Short-term thermal storage
- Long term storage before use
- Large accelerations
- Moderate loading stresses
- Ambient pressure changes

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With ACT's expertise in capable conduction paths to fully melt the PCM with minimal temperature rise, a solution can be realized for challenging, high heat, one-time use applications.

Protection From Failure During Coolant Interruptions

In many systems there are periods of time where the primary coolant is unavailable or experiences a momentary failure. During these periods, most primary power systems are shut down, however, the need for batteries or auxiliary power may be required. A PCM cooling solution will reliably extend the period of operation before electronics or batteries overheat by storing thermal energy. Solutions can be customized based on the duration and max temperature of electronics to assure safe operation during episodes of primary coolant loss. This provides a cost effective, lightweight solution to increase thermal management system reliability.