Lab and Production Integration Using SprayCool Enclosures

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ABSTRACT

Military electronics have been cooled via air and conduction enclosures for decades. With increasing demand for computational performance, thermal management of electronics has become a challenge. Liquid cooling has growing appeal especially for those who do not have the luxury of operating electronics in office environments. Direct spray offers substantial performance, size, weight and power (SWaP) and cost benefits. To capitalize on these advantages, electronics integrators must be able to integrate and test electronics within direct spray enclosures. This document discusses methods of integrating and troubleshooting electronics in both lab and production environments within SprayCool enclosures. Engineering and production level testing will also be addressed.

BACKGROUND

SprayCool products utilize evaporative or direct spray, in which liquid droplets are sprayed directly onto the hot electronic components and then evaporate to remove excess heat. Depending on the system configuration, either vapor, liquid, or a liquid-vapor mixture is transported to a heat exchanger where remaining vapor is condensed and waste heat is rejected. Thus, the fluid is continuously recycled for reuse within a closed loop system as shown in Figure 1. The heat exchanger can be mounted with the enclosure or remotely located to reject to any medium such as ambient air, PAO, EGW, PGW, fuel, ram air, etc. SprayCool uses Performance Fluids by 3M as the primary working fluid. Performance fluids are similar to another 3M brand of fluid marketed under the trade name FluorinertTMand are electrically insulating, inert perfluorocarbon fluids which are used in many heat transfer applications.

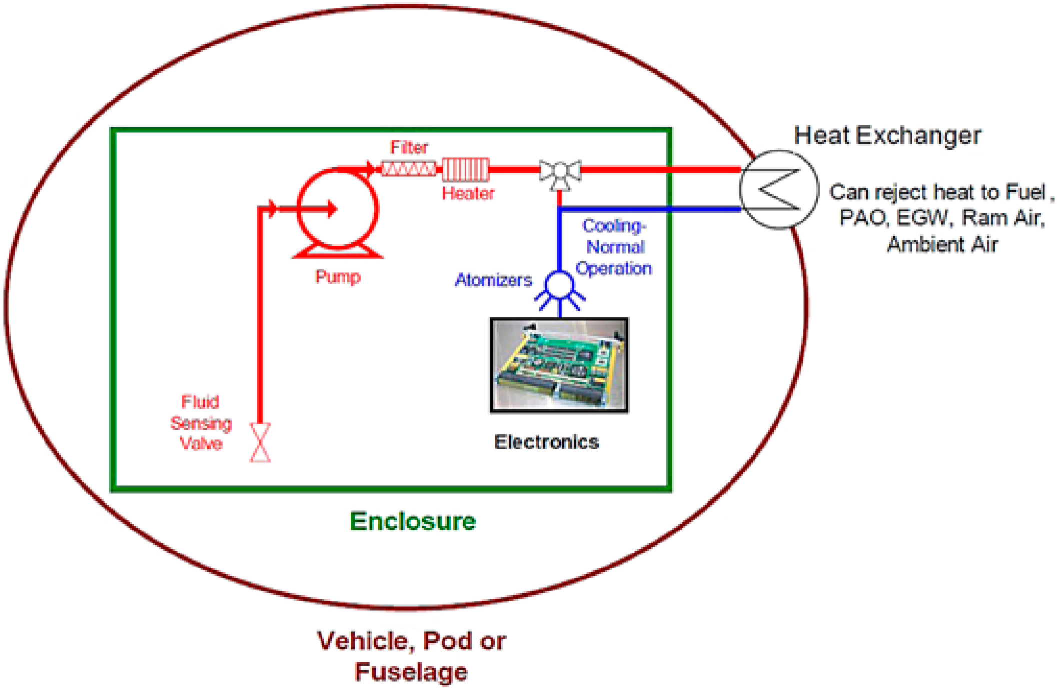

FIGURE 1. SYSTEM DIAGRAM OF DIRECT SPRAY ENCLOSURE

SprayCool enclosures enable the dielectric liquid/vapor environment to remain very close to the saturation temperature of the fluid, resulting in an "isothermal" environment for the electronics. This isothermal environment effectively reduces hot spots and thermal cycling, as well as providing increased cooling efficiency.

The result of reduced thermal mechanical stresses and lower operating temperatures, compared to other cooling methodologies, is increased reliability and higher achievable power density. SprayCool therefore plays a pivotal role in the design of high-reliability, high-performance embedded electronic systems. In many applications of SprayCool products, significant SWaP improvements have been demonstrated.

ELECTRONICS INTEGRATION

The intent of SprayCool enclosures is to use the air and conduction boards unmodified from the OEM. There may be weight or thermal requirements that drive the program to optimize cooling by removing/replacing the heat sinks, but there are countless good reasons to have the same hardware in the lab and on the fielded platform. Advantages to this approach include the ability to employ existing OEM production and test equipment, reduction in configuration management, simplify OEM board sales, reduce spares for customers using direct spray and air or conduction enclosures, enable troubleshooting without board configuration changes, avoid process changes for development, acceptance, and qualification testing, etc.

Utilizing the same air/conduction board part numbers as boards destined for SprayCool enclosures has not always been possible in years past when fluid compatible thermal interface materials (TIMs) were not as readily available. Today, there is a growing list of TIMs from Bergquist, Al Tech, Aptek Labs, FujiPoly, Chomerics, Emerson & Cumings, 3M, etc. enabling plug-n-play functionality in SprayCool systems.

If it is not possible to use the identical card from an air or conduction-cooled chassis in a SprayCool enclosure, provision may be necessary for testing the SprayCool variant during production and returns. This may include reinstalling the original heat sinks or installing a different heat sink designed for both spray and air/conduction. Again, this is not the preferred method for SprayCool or its customers.

MECHANICAL CONSIDERATIONS

The card cage in the SprayCool enclosure is compliant to the mechanical core specification for VME, cPCI, VXS, VPX, cPCIe per IEEE 1101.1. Air-cooled card guides are integrated with the fluid manifolds as depicted in Figure 2. By design, air-cooled boards from the lab enclosure can be installed directly in a SprayCool enclosure. When using conduction boards, wedge locks are not necessary from a thermal standpoint. The conduction board would then utilize the air-cooled card guides without wedge locks. This means customers can use the same card in a conduction enclosure or SprayCool enclosure with the addition of a faceplate to securely mount the card to the card cage.

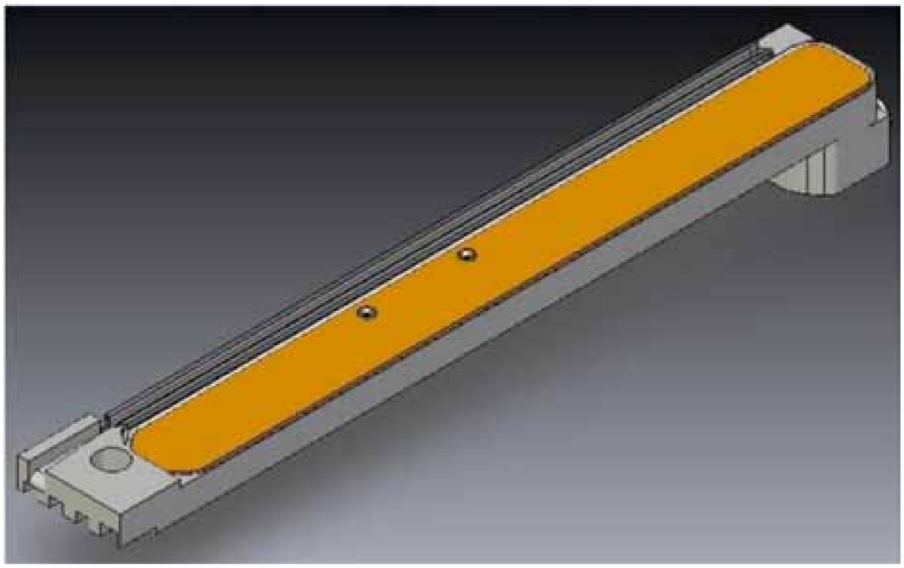

FIGURE 2. SPRAY MANIFOLD WITH INTEGRATED CARD GUIDE

Rear transition modules (RTMs) are used frequently in lab environments to bring out card I/O using commercial connectors for USB, Ethernet, serial, etc. Customers with a desire to utilize off-the-shelf (OTS) RTMs have the option of an extended SprayCool enclosure accommodating both front and rear boards on the backplane. The enclosure is still sealed to prevent fluid loss, but generic cabling can be wired through bulkhead connectors (such as circular military) to commercial connectors that plug into the RTM of a given card. In this manner, the internal wiring doesn't change with every card. The enclosure becomes a quickly configurable test bed for either lab or vehicle environments. The only draw back is physical size, so most programs do not deploy enclosures with perpendicularly (to the backplane) mounted RTMs.

ELECTRICAL CONSIDERATIONS

At some point in the development, qualification testing or integration of electronic systems, integrators will instrument their cards. For air or conduction-cooled cards used without modification in a direct spray enclosure, any board-level diagnostics that do not require the SprayCool system can be done in an air/conduction chassis. For testing that necessitates operational cards in a SprayCool enclosure, several methods for probing exist. One method is to use a feed through connector(s) on an acrylic top lid. The lid allows integrators to see the LED/status lights on the front panels of their cards without fluid loss. The feed-through connector(s) allows them to place temperature sensors, voltage probes, bring additional signals out, or place accelerometers on the cards. Connector styles and types vary depending on the application. Figure 3 depicts an enclosure with an acrylic lid for integration and test.

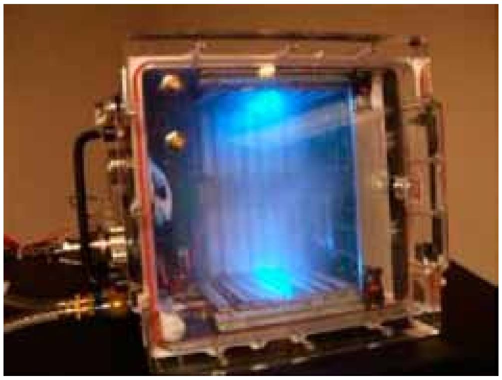

FIGURE 3. ENCLOSURE WITH ACRYLIC LID

For O-Scope leads and current probes, it is preferable to drain the chassis and use directed fans to cool the boards as you would in an air-cooled chassis. This requires lab firmware for the cooling system to enable backplane power without fluid. The code is available upon request. Additionally, extender cards have proven useful in gaining complete access to boards during troubleshooting, characterization, or diagnostics. Card cooling with the extender is simplified as the board under test is entirely outside the enclosure providing unrestricted air flow to the components.

FLUID LOSS

When SprayCool enclosures are operational, the access panels are closed to prevent fluid loss. For frequent card access, the acrylic lid with quick-release clamps can be removed without tools to access the electronics for troubleshooting or remove/replace. Leaving the access panels off for long periods of time without draining the fluid will result in fluid loss because Performance Fluids readily evaporates at atmospheric conditions. If access panels must be removed for more than two hours and fluid cannot be drained, covering the enclosure to prevent stirring of fluid and air from fans or facility air conditioning systems will lessen loss of fluid. Ultimately, draining the fluid using a fluid handling tool (FHT) available from SprayCool shown in Figure 4, is the best method for reducing fluid loss in normal lab environments.

FIGURE 4. FLUID HANDLING TOOL (FHT) FOR LAB, DEPOT AND FIELD ENVIRONMENTS

MANUFACTURING

Product Flow

As discussed earlier in this paper, it is the objective to use the same part numbers for air or conduction boards as the cards in a SprayCool enclosure. When this is the case, flow of hardware in a production setting is unaltered to the greatest extent possible. Depending on volume, it may be efficient to utilize a direct spray enclosure for test or debug at the system level.

If program requirements drive integrators away from using the same air/conduction part numbers for thermal or SWaP constraints, adjustments to product flow may be required. The impact to product flow will vary depending on the board OEM and modifications required by the program.

CONTAMINATION AND CLEANLINESS

Environments established for the production, integration, and test of electronics will be adequate for direct spray enclosures. No additional standards for cleanliness or air quality are necessary for SprayCool systems.

FILLING/DRAINING

The FHT shown in Figure 4 is used for lab, depot, and field environments. Quick Disconnect (QD) fittings on the enclosure that interface with the FHT reduce task time without contamination or fluid loss during fill or drain tasks. The FHT filters and conditions the fluid whenever fluid is removed or replaced from a unit. Assembled into a rugged transit case, the FHT is designed for transportation and storage in harsh environments.

For higher-volume production and integration of direct spray enclosures, a larger stationary FHT can be used to expedite the fill and drain processes.

VENTILATION

The MSDS for Performance Fluids from 3M recommends ventilation in areas where the fluids will be handled. Performance Fluid MSDS is available from 3M for ventilation details.

TEST

It is anticipated that testing at this level will eventually include design verification testing, qualification testing, or acceptance testing. One product available from SprayCool to assist with integrated system testing (enclosure with electronics) is a lab air heat exchanger. It is sized for 1000 watts at 30°C enabling system integration at anticipated thermal loads. The lab air heat exchanger shown in Figure 5 does not represent hardware deployed on vehicles as platform cooling options vary greatly. It is intended only for lab use and is not optimized for size or weight constraints of mobile applications.

The lab air heat exchanger can be remotely located outside an environmental chamber during thermal testing, adjacent to a vibration table performing operational test profiles, mounted to a rack of production enclosures under environmental stress screening, or on the bench in an engineering lab for characterization tests of a new board set. The heat exchanger can be located up to 10 feet from the unit under test.

FIGURE 5. LAB AIR HEAT EXCHANGER FOR LAB USE ONLY

SUMMARY

As the trend for increasing electronics performance in harsh environments continues in military and industry alike, the demand for direct spray systems grows. To realize the benefits of superior thermal performance while reducing SWaP at the platform level, integrators must be able to test and integrate boards in SprayCool enclosures. Using unmodified air or conduction-cooled boards in direct spray systems facilitates integration, test, and production of electronics. Tools are available that simplify accessing cards, handling fluid, and operationally testing electronics and integrated systems.

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