VAPOR CHAMBER WICK DESIGNS

> Their Impact on Performance

radian
THERMAL PRODUCTS

WHITE PAPER
February 2025

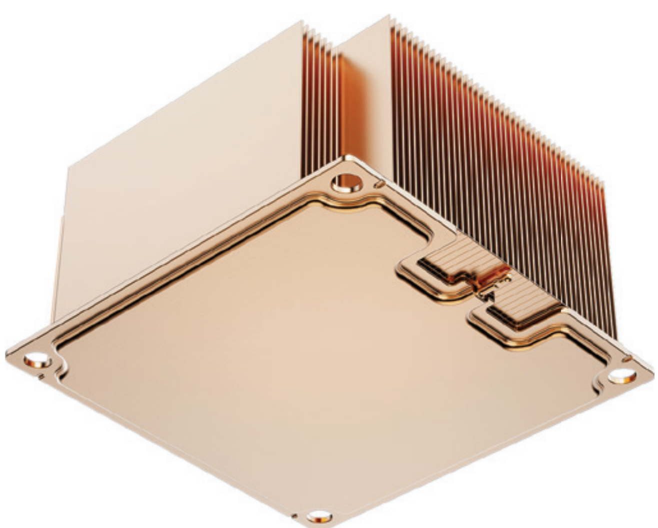
This paper helps to illustrate how some internal design parameters can impact the performance of a vapor chamber. It focuses on capillary structures.

1. EXECUTIVE SUMMARY

Vapor chambers are the unsung heroes of thermal management, keeping everything from smartphones to electric vehicles cool under pressure. But all vapor chambers are not made equal. There are several parameters that can impact the effectiveness of a given vapor chamber, such as the vapor space, working fluid & fluid volume and the wick (capillary) structure, amongst others.

In this white paper, we'll explore wick structures, focusing on two key wick types: sintered copper powder and copper mesh, highlighting their impact on performance.

At Radian Thermal Products, we specialize in designing and manufacturing vapor chambers tailored to your needs, ensuring optimal thermal solutions for any application.



2. OVERVIEW OF VAPOR CHAMBERS

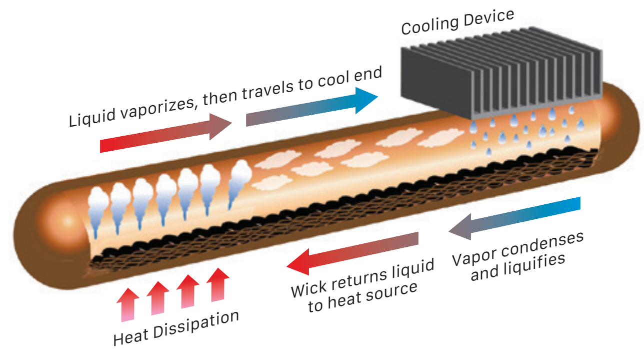
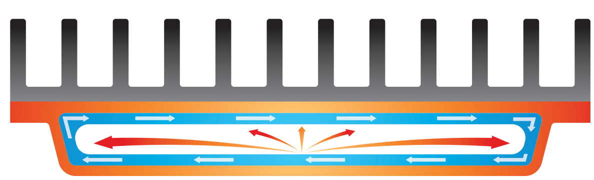


Figure 2-1: Working of a Heat Pipe and Vapor Chamber illustration

As covered in our ***Heat Pipes and Vapor Chambers White Paper***; Vapor chambers (or VCs) operate under the same principles as heat pipes and are sometimes loosely described as "flattened heat pipes". The main difference being that there is 2-Directional heat spreading with vapor chambers, while heat pipes have 1-Directional heat spreading. Vapor chambers are flat, sealed devices that use phase change (evaporation and condensation) to transfer heat efficiently (via latent heat of vaporization). The wick structure inside the vapor chamber is critical, as it is responsible for the return of liquid to the heat source, maintaining the cycle.

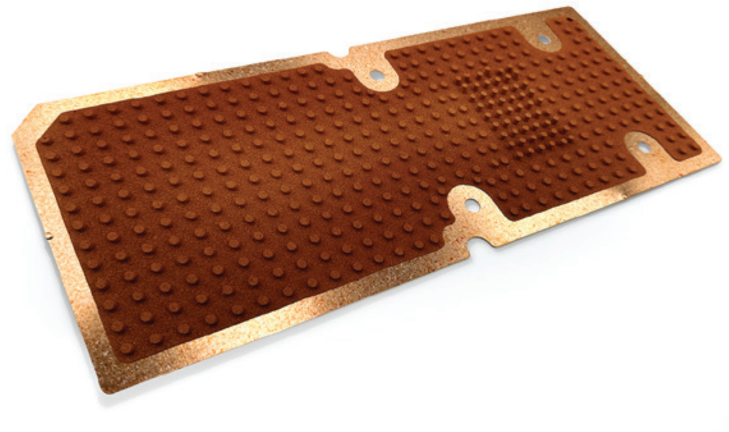
At Radian, we understand that the right wick design can make or break a vapor chamber's performance and so a lot of work has gone into optimizing our wick designs for our customer use cases.

Figure 2-2: Vapor Chamber Heat Spreading illustration ▸



3. CAPILLARY (WICK) STRUCTURES

3.1. OVERVIEW



Wicks are the backbone of vapor chamber power handling capability. The wick is responsible for pulling liquid back to the heat source, via capillary action; preventing short-circuiting of the vapor chamber, commonly referred to as "dry out". The maximum power a vapor chamber can handle before reaching dry-out is described as Qmax and this value, as well as the effective thermal resistance of the vapor chamber, is of interest to thermal engineers looking to cool their components. The more efficiently the wick returns fluid to the heat source, the higher the Qmax potential.

There are several ways to create this wicking structure for vapor chambers, but the two popular methods for conventional VCs are via sintered copper powder or copper mesh.

Each method has unique strengths, and choosing the right one depends on your application

3.1.1. SINTERED POWER WICK

Imagine a metal sponge made of tiny particles fused together, you've just pictured a sintered powder wick. It's created by heating copper powder until the particles bond forming a porous structure with a high surface area. Note that the powder particle size selected will affect the resultant porosity of the wick. This design gives some significant benefits.

High capillary pressure: The fine pores create strong suction efficiently pulling the liquid back to the heat source.

High Heat Flux Handling: excellent for high heat flux applications where heat needs to be moved quickly and effectively.

But it's not all sunshine and roses for the sintered powder wick, they can be relatively more expensive to make, they may lack the mechanical strength of a mesh solution and, controlling the uniformity of the wick's pores can be a bit tricky.

However, at Radian, we've mastered the art of sintering, delivering wicks that excel in demanding environments.

3.1.2. COPPER MESH WICK

This wick structure is made from fine copper wire woven into a mesh sheet. These mesh sheets come in a variety of opening sizes, identified by a mesh number. The mesh number specifies the number of holes per wire linear inch. So, a100-mesh has 100 holes along an inch of copper wire. The higher the mesh number, the smaller the openings (pores).

In some respects, it's simpler to manufacture than sintered powder wick and offers its own set of benefits.

Cost-Effective: Easier and cheaper to produce, making it a go-to choice for mass market products.

Flexible Design: Design flexibility for engineers, as they can tweak the mesh density more easily, to optimize performance.

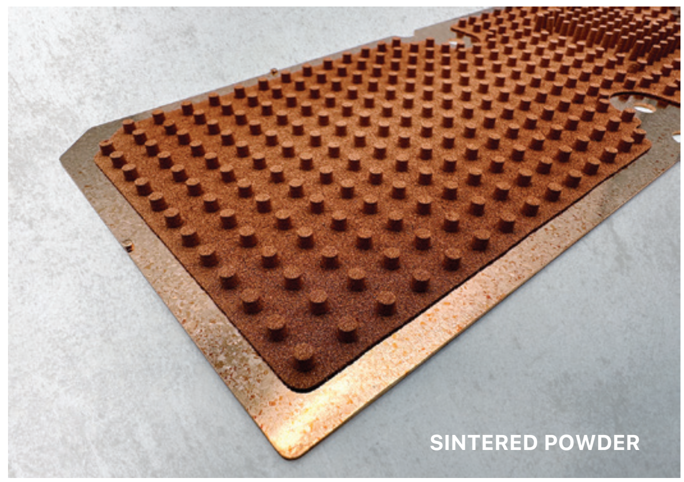
Versatile: Can be used for thin vapor chambers, where the cavity height constraint may preclude a sintered powder solution from being feasible.

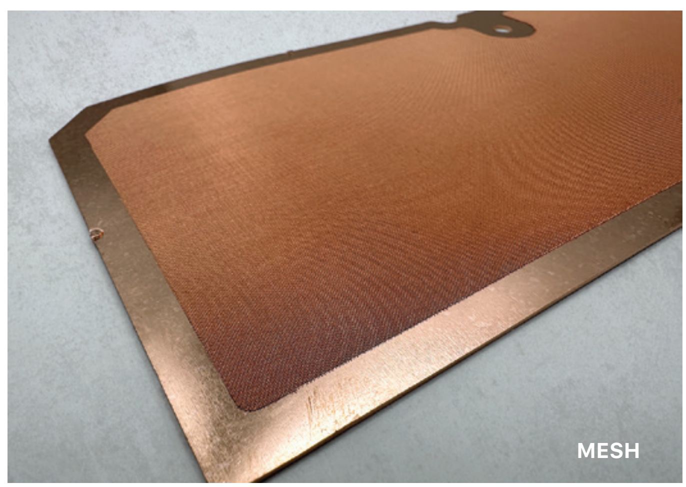
3.2. SINTERED POWDER OR MESH:

So which wick type reigns supreme? Cliché but the answer depends on your application; vapor space, heat flux etc. In theory the following rule of thumb would apply:

- For high performance, sintered powder wicks are superior and ideal for high density heat flux requirements while mesh wicks are better suited for moderate heat density requirements.

For cost effectiveness, mesh wick solutions are much cheaper, so where cost is a big factor, this would be the way to go.


SINTERED POWDER


MESH

3.3. WICK IMPACT ON VAPOR CHAMBER PERFORMANCE

At Radian, we have developed a high-performance wick VaporCore, which has proven to outperform typical sintered powder wicks, in some cases.

Below is an example where our ***Radian VaporCore wick*** performance is compared with a sintered powder wick.

The table summarizes the thermal test data for the 2 wick designs in the same vapor chamber.

The tests were conducted with a 690W heat source over a 30x30mm area and 127CFM airflow through the VC heat sink fins. 3 samples of each wick type were tested in the horizontal orientation.

Each VC is physically identical, with just the internal structure differing; so, the same vapor chamber plate geometry and material (C1020 alloy), same methodology for determining the mass of working fluid and the same build process and machinery.

Sample	Power /W	VC Performance /°C/W	
		Sintered Powder	VaporCore Wick
01	690	0.066	0.554
02		0.066	0.554
03		0.065	0.057

3.3.1. PRACTICAL IMPLICATIONS:

So, what does this mean in real terms for the end use application? If a customer was to install both VC types in their systems (bearing in mind they're physically identical VCs) to components dissipating 690W, there would be over 7°C variation in temperature between the sintered powder and the Radian VaporCore wicks.
A 7°C is very significant:

- This could pose an impact on component reliability,
- Or increase running costs, having to run some system fan speeds higher
- Or in an extreme case, it could cause a protective shutdown of a system to prevent overheating.

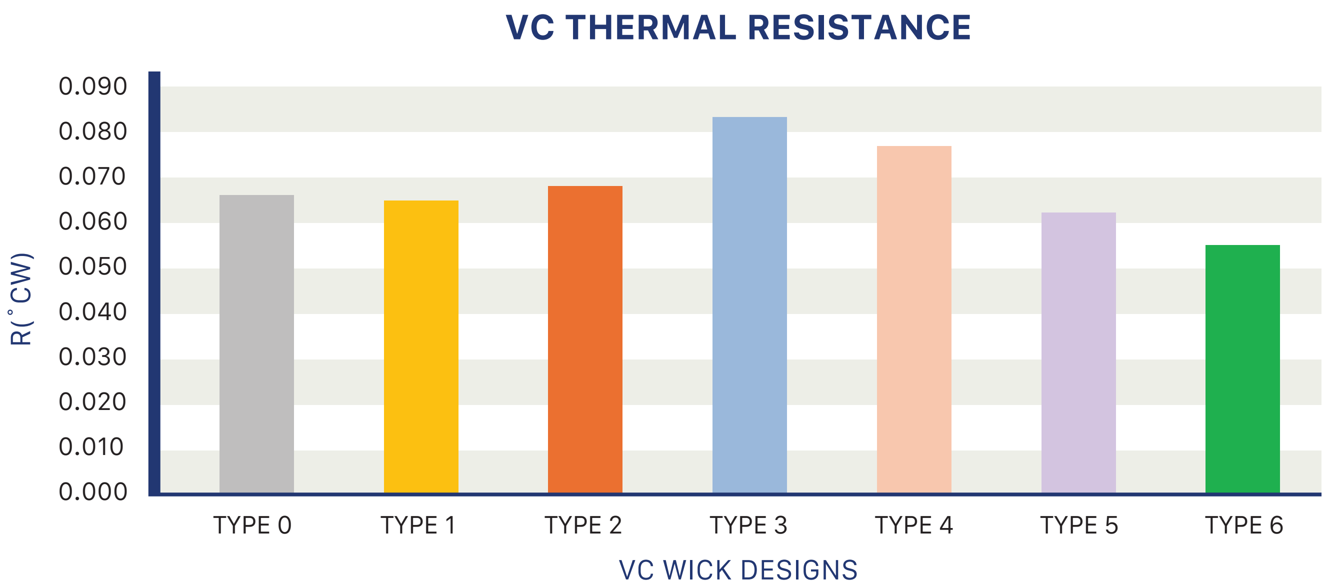
This is why at Radian Thermal Products we don't just build you a generic VC, we make sure the internal design is optimized for the application with our custom vapor chambers.

3.4. NOT ALL VCs ARE MADE EQUAL

More examples of performance variation between wick designs of the same vapor chamber.

The chart below summarizes test data for 7 designs of the same VC. Each VC type (SKU) is physically identical, with just the internal structure differing.

The Wick-Types comprise various sintered powder designs, mesh designs and the Radian VaporCore wick design. 3 to 5 pieces of each SKU were tested and the chart below shows an average thermal resistance for each SKU. They were tested under the same conditions as described in Section 3.3.



4. CONCLUSION

In the world of thermal management, the choice between sintered powder and mesh wicks is just the beginning. What truly matters is having a partner who understands your unique needs and can deliver tailored solutions that excel in performance, reliability, and cost-effectiveness. At Radian Thermal Products, we specialize in designing and manufacturing high-quality vapor chambers that meet the most demanding customer requirements.

With 50 years of expertise in advanced thermal solutions, we combine cutting-edge technology with a deep understanding of materials, wick structures, and manufacturing processes.

Whether your application calls for the high-performance capabilities or the cost-efficient durability, we have the knowledge and tools to deliver.Our commitment to innovation, precision, and customer satisfaction ensures that every vapor chamber we produce is engineered to perfection.

At Radian Thermal Products, we don't just build vapor chambers—we build trust. From concept to production, we work closely with our clients to create solutions that push the boundaries of thermal management. Let us help you tackle your toughest thermal challenges and bring your ideas to life.

HOW CAN WE DESIGN AN OPTIMIZED COOLING SOLUTION FOR YOU?

Ready to take your thermal management to the next level? Whether you're developing the next generation electronics platform automotive systems or aerospace technology, we can provide the all the cooling expertise you need to bring your project to fruition.

Visit our website below to learn more about us or contact our sales team for a quote or any inquiries.