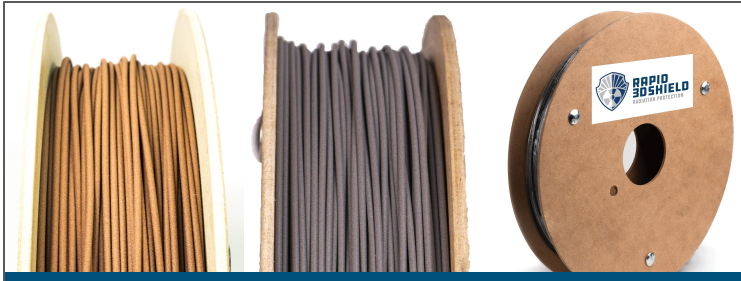


The Virtual Foundry

## Case Study: Large Copper Print

## Fairfield Product Engineering Corp

# Specialized, super-compact, fluid-to-fluid heat exchanger


These photos show two different parts.

## Equipment

**Printer:** QIDI X-Max printer

**Nozzle:** Either a 0.6 or 0.8mm stainless steel nozzle

**Furnace:** Vulcan 550 muffle furnace

**Crucible:** 5mm thick aluminum oxide crucible, 180mm outside diameter, 100mm deep

**Crucible Cover:** Alumina flat plate that is cut to size, which keeps out atmospheric gasses and makes the carbon much more effective (so less part oxidation)

## Why FFF Metal

**Benefits:** Prototyping cost and time per iteration and accuracy of material properties

Machining was the only other way to make these, which was very expensive - $thousands per part

Casting is possible but there are material issues with copper purity and cracking.

The production parts will be cold forged when/if the product makes it into production.

## Results

While the copper content of Copper Filamet™ is high by weight (90%), by volume it is more like 50%. Since almost all important engineering properties are functions of volume, such as strength, modulus, and thermal conductivity, these properties will be about half of a solid metal. Sintering shrinkage would need to be in the 20% - 30% range for the material to become 97% dense. The part remains as fused micro-spheres after sintering so it is microscopically quite porous and needs to be sealed in certain applications, like this one.

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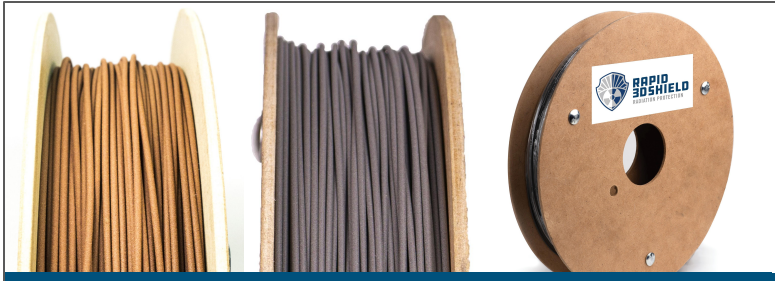


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## Sintering Process

**Ramp:** 1.6°C (2.9°F) /min

**Debind Hold:** 10 hours at 483°C (901°F) - vented* with no carbon

**Ramp:** 1.6°C (2.9°F) /min

**Sinter Hold:** 30 hours at 1065°C (1949°F) - unvented* with 25mm (1") of carbon on top of the refractory ballast

**Cooldown Ramp:** 1.6°C (2.9°F) /min

**Temperature Verification:** Temperatures in the center of the refractory ballast in the crucible were verified with thermocouples (those temperatures lag the chamber temperature by about one hour).

* Vented means the vent hole on top of the furnace chamber is open to let out the escaping products of PLA combustion. The vented gas is drawn out of the lab through ducts.

The slow ramp during heating and cooling serves two purposes:

- Preventing the large crucible, which is very close to the heating plates, from cracking
- Keep the copper parts from cracking upon cooling

Since the parts are somewhat cylindrical in shape, they are constrained in shrinking in diameter by the refractory ballast. If temperatures change too quickly they are prone to cracking.

They need to be sintered very slowly for quite a long time to produce even and reliable results.

## Time

**Printing:** 20+ hours, **Sintering:** 40+ hours

It takes time, but if the job is rushed and the part fails and has to be restarted, even more time has to be spent.

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