

13 Reasons 3D-Printed Ceramic Filters Help Make Better Parts

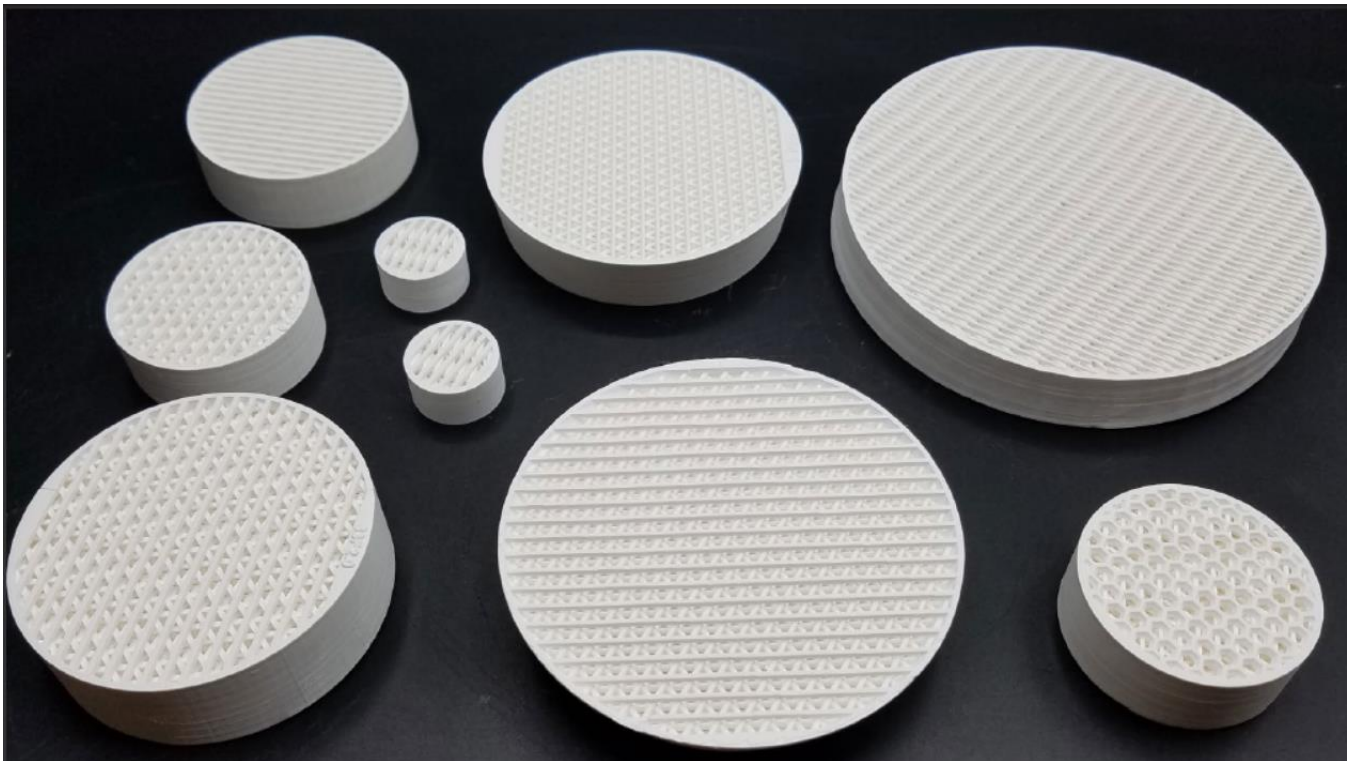
White Paper

Executive Summary

Investment casting using ceramic 3D-printing is a relatively new addition to the foundry's arsenal of techniques. Ceramic additive manufacturing of filters has a wide range of uses.

To address the need for controlled flow rates in castings, Renaissance Services has developed patented techniques for the ceramic 3D-printing of high-quality filters for pour cups and runners.

The precision of Renaissance Services' technical ceramic 3D printers enables very tight control of filter production, which results in greatly improved metal filtering.



3D-Printed Ceramic Filters

This White Paper may not be duplicated, reproduced, stored in a retrieval system, or retransmitted without the express permission of Renaissance Services. Renaissance Services can be reached by e-mail at: info@ren-services.com, or by telephone at: 937-322-3227. © Copyright Renaissance Services Inc., all rights reserved.

Introduction & Overview

Filtering is a major factor in ensuring high quality cast parts.

Uniform engineered filters enable consistent and repeatable metal flow rates without becoming a secondary source of contamination. Additive manufacturing (AM) methods can produce filters that achieve consistent filtration efficiency and predictable metal flow into casting molds.

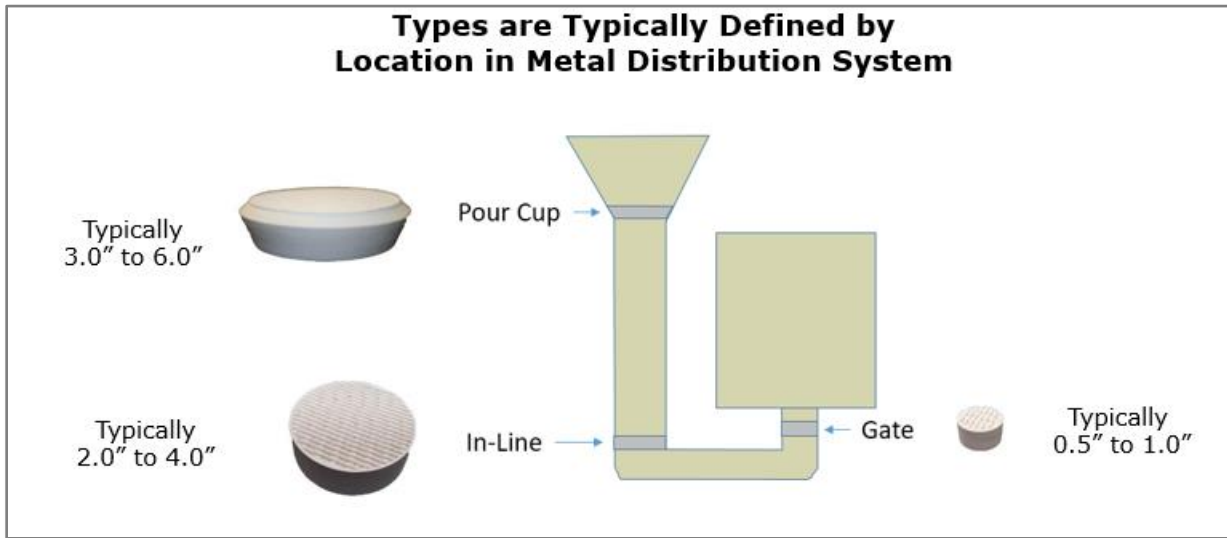
Renaissance Services provides 3D-printed ceramic filters that can meet the demands of foundries for high-performance filtering.



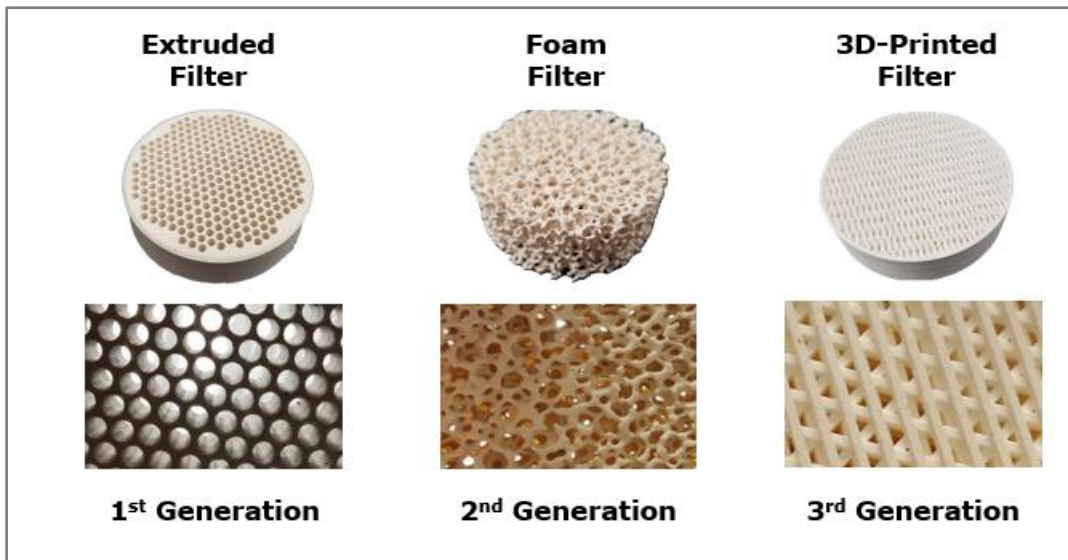
Ceramic Filter – A Key Part of an 3D-Printed Ceramic Tooling

Ceramic 3D-printing of filters provides a consistent flow and material cleanliness that is not achievable with conventional filters. Also, non-porous 3D-printed ceramic filters avoid the introduction of inclusions that are very common with conventional porous ceramic foam filters.

Mold Filters Overview



Evolution of Filters

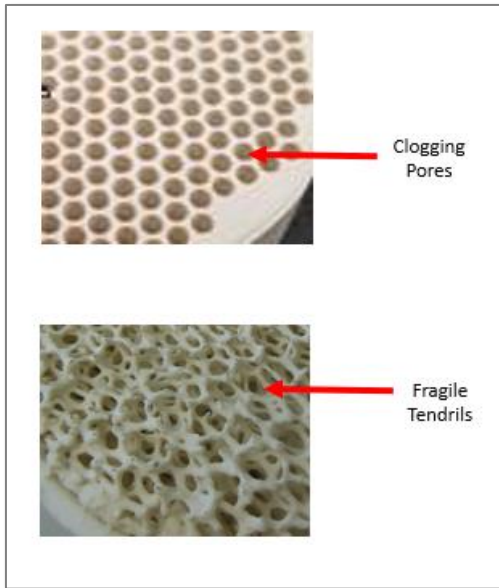


The PERFECT-3D Division of Renaissance Services makes and sells only 3rd generation 3D-printed filters. These have all the benefits and none of the problems of earlier filters.

Problems Conventional Filters Pose for Castings

To produce castings, foundry workers pour molten metal through porous ceramic foam filters to minimize dross and other forms of contamination. These filters are the last line of defense against inclusions that result from contaminants.

However, they can cause problems, such as:



1. Conventional ceramic foam filters have small dendrite-like ceramic protrusions that can break off during the casting metal pour. When one or more minute pieces of the filter ends up in the casting, flaws in the casting, including secondary grain nucleation, can occur.

2. Conventional filters are essentially random ceramic sponges. Filtering with these is basically surface sieving, which is not greatly effective.

3. Conventional filters do not tightly control the metal flow rate. Conventional filters, especially those with many clogged pores, can often restrict metal flow. Because of variations in

their physical structure, conventional filters can cause wide disparities in metal flow rate into the casting molds. All of these factors can lead to excess scrap.

Why do filters cause problems?

Filters are typically treated as a commodity by the purchasing department, which picks the low bidder. The use of filters on specific mold trees is typically a decision for the process engineer. The typical evaluation approach is not too analytical. All too often, it's like this:

"If we have a problem in making a casting, we'll throw a filter on the mold tree ... or if we already have a filter, we'll remove it and pour without a filter."

Bottom Line

There is a need for improved filter technology for high-temperature casting mold materials to mitigate these problems.

Four Goals of Filter Design

There is no reason foundries should have to put up with low-performing conventional filters. Additive manufacturing pros should be able to help foundries get the filters they need that meet the following goals:

1. Build a filter effective enough to filter out virtually all impurities in a molten metal pour without failing and without adding material from the filter into the pour.
2. Build a filter that is large enough and pour-efficient enough to filter the molten metal without slowing normal metal flow or interfering with homogenous solidification of metal.
3. Build a filter specific enough for a given molten metal to handle the flow of the given metal without failing during pour or part cooling.
4. Make a ceramic filter design that allows on-demand adjustment to address the needs of specific alloys and shapes applied in the production of castings.

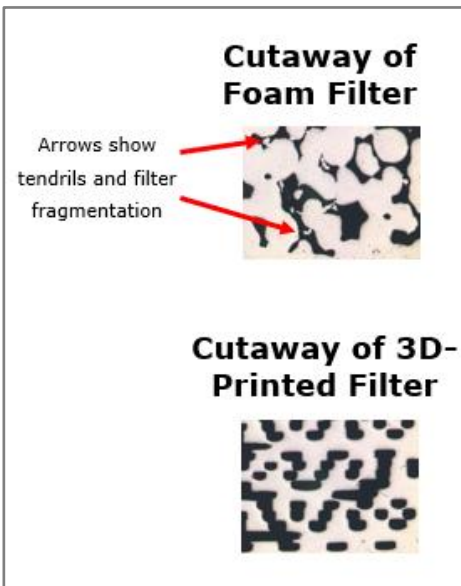
Four Filter Performance Metrics

1. **Capturing** – Ensuring the capture of contaminants
2. **Flowing** – Providing consistent metal flow rates
3. **Containing** – Avoiding breakdown of ceramic mold
4. **Smoothing** – Providing a smooth laminar flow of metal

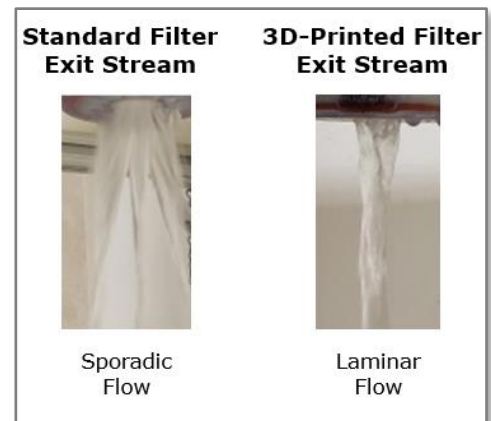
Filtering Solution: 3D-Printed Ceramic Filters

A stable filter structure is critical to ensure that the filter itself does not introduce contaminants. A 3D-printed engineered filter will not break down during metal flow.

Conventional filters split the pour into individual streams. This can potentially increase surface area and create erosive flow on sprues and runners.



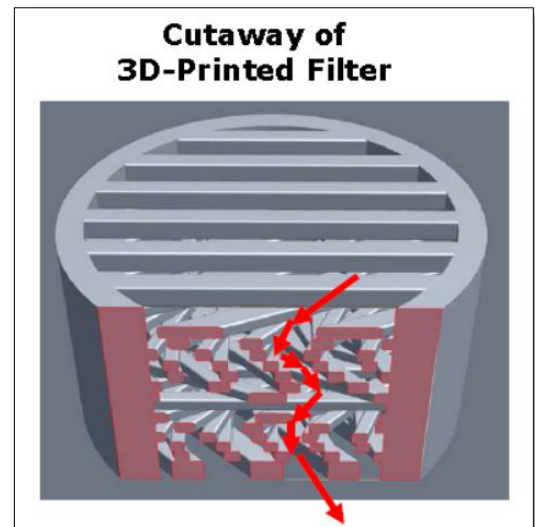
A stable laminar metal flow prevents air from getting into the molten metal. This drops oxidation and porosity. A 3D-printed engineered filter can ensure filter output is a smooth laminar flow.



Conventional ceramic foam filters have random passages.

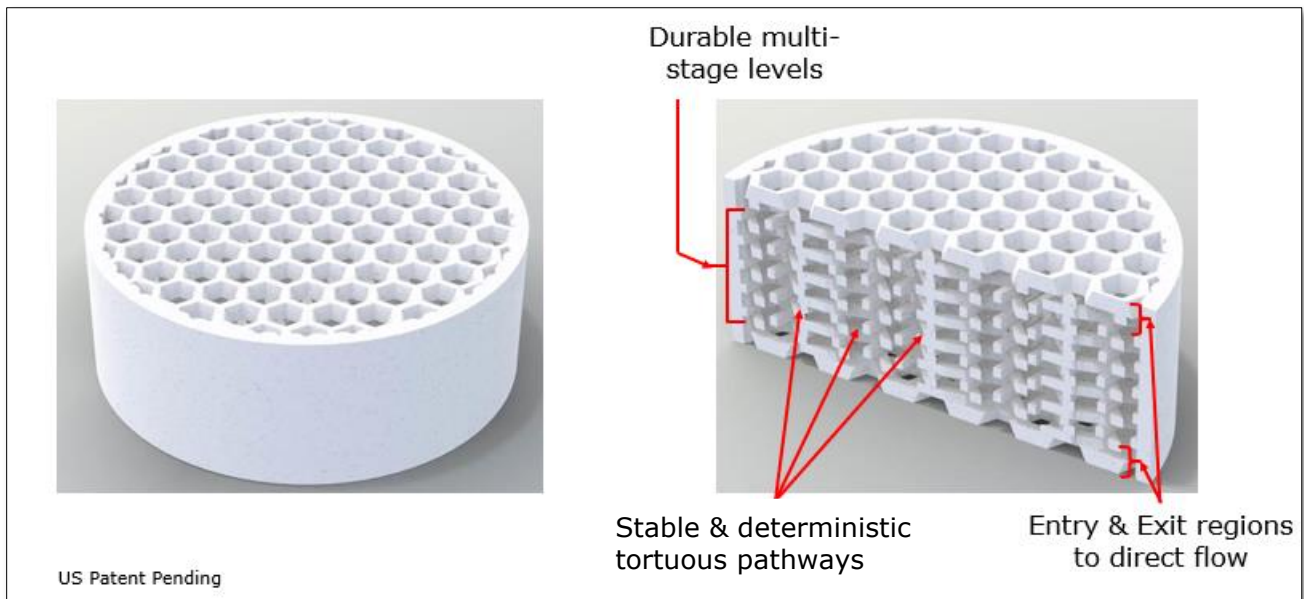
A deterministic (non-random) tortuous path through the filter body is the basis for depth capturing of contaminants.

3D-printed filters provide pre-determined tortuous passages through the filter body.



Do Renaissance Filters Meet Four Filter Performance Metrics?

1. **Capturing** – Ensure capture of contaminants. Tortuous pathways allow effective deep filtering.
2. **Flowing** – Provide consistent metal flow rates. Stable and deterministic (not random) tortuous pathways ensure such flow rates.
3. **Containing** – Avoid breakdown of ceramic mold. Durable multi-stage filter levels and ligaments make a 3D-printed filter more durable.
4. **Smoothing** – Provide a smooth laminar flow of metal. Ligaments direct output from filter exits.



Renaissance Tests Filters Side-by-Side

One key to the success of filters from the PERFECT-3D Division of Renaissance Services is the focus on an objective evaluation of filter performance.

Renaissance conducted detailed testing of the performance metrics for 3D-printed ceramic filters versus conventional filters. Renaissance conducted production testing and validation with eight different foundries across North America and Europe

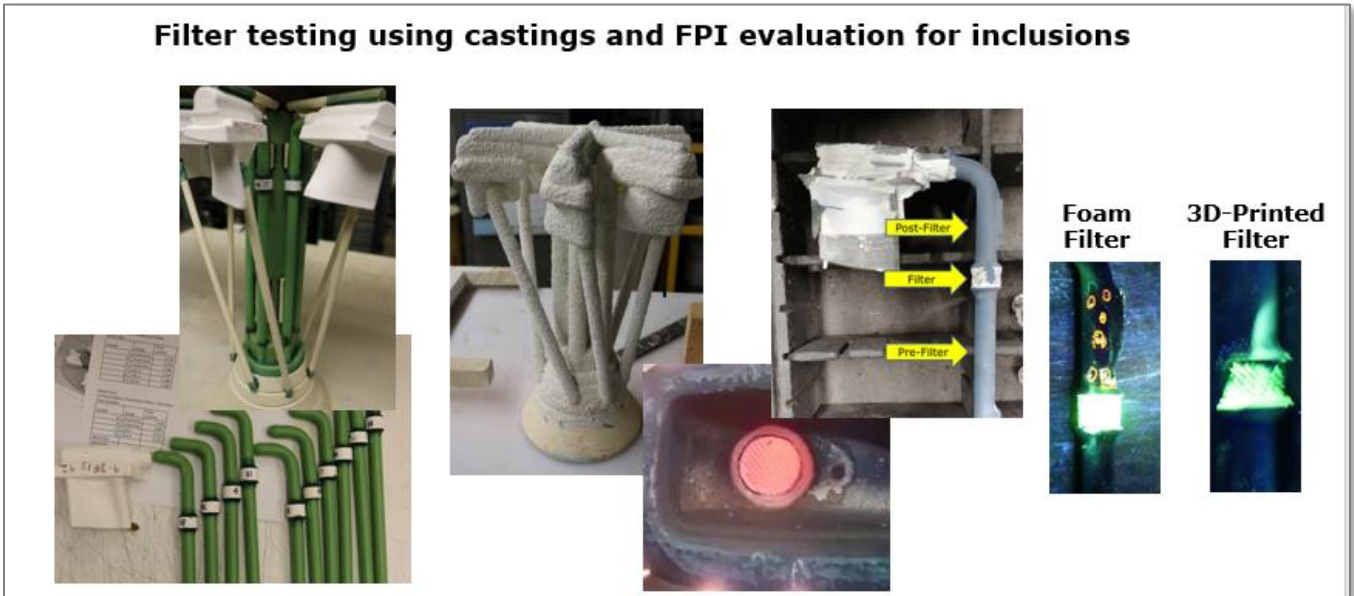
The verdict? Engineered 3D-printed filters have superior performance versus conventional extruded and foam filters.



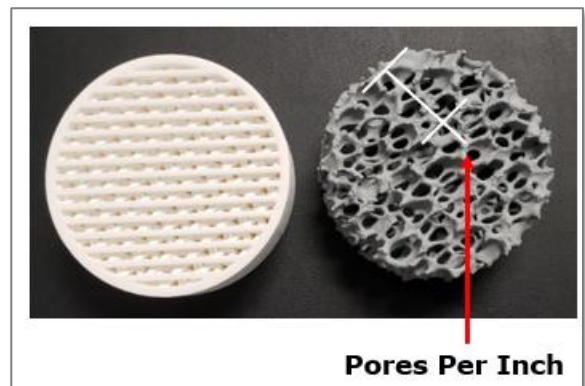
Multiple foundries agreed to work with Renaissance Services on the testing of the filters. The following table lists the mold locations and specifications for the tests.

| Foundry | Metal | Mold Location | Dimensions |
|------------------|--------------|----------------------|-------------------|
| Foundry 1 | Nickel | Pour Cup | 2.5" dia. |
| Foundry 2 | Nickel | Pour Cup | 3.3" dia. |
| Foundry 3 | Nickel | Pour Cup | 5.0" dia. |
| Foundry 4 | Nickel | Gate | 1.0" dia. |
| Foundry 5 | Steel | Pour Cup | 3.5" dia. |
| Foundry 6 | Steel | Pour Cup | 2.0" dia. |
| Foundry 7 | Aluminum | In-Line | 2.0" x 2.0" |
| Foundry 8 | Aluminum | In-Line | 2.0" x 2.0" |

The objective of the testing was to improve yield by removing contaminants and avoiding non-metallic inclusions. Inclusions can come from foundry sprues, runners, and molds, ladle refractories, oxidation, and ceramic filters.



Flow rate has commonly been expressed as PPI (pores per inch) for foam filters. PPI is useful for broad idea of flow rate but is not precise enough for emerging demands. Filter flow rate needs to be defined as volume/mass of material per time unit.

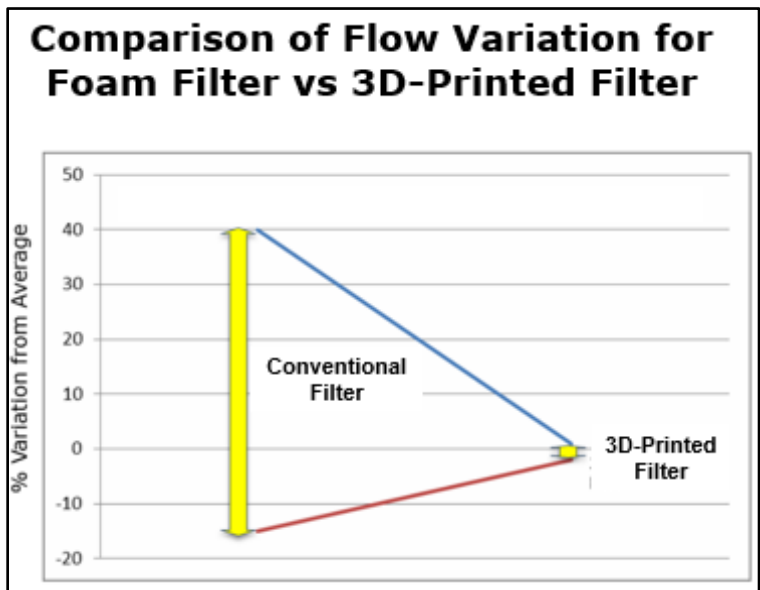


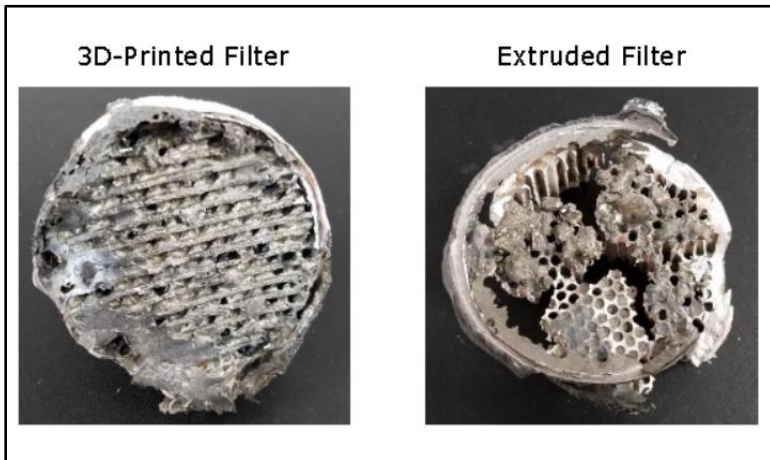
Flow Testing Machine



A flow testing machine precisely measures the flow rate through ceramic filters of various sizes.

A flow testing machine also provides high-speed videography of liquid exiting a filter to help determine "smoothing" performance.





The 3D-printed filter handles a much hotter pour than a first-generation extruded filter can handle. The contamination of the pour from filter failure renders many castings into scrap.

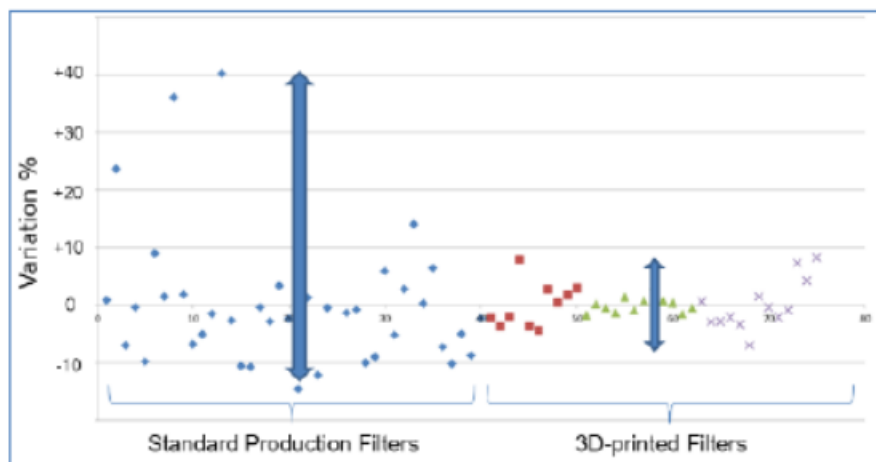
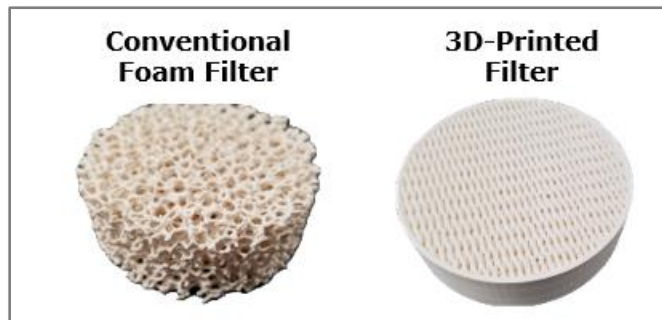
This picture alone shows the superiority of 3D-printed ceramic filters.

PERFECT-3D 3D-Printed Ceramic Filter Solutions

The PERFECT-3D division of Renaissance Services has a method of making ceramic filters that includes using ceramic additive manufacturing to make a number of layers in each filter. Each layer includes individual ceramic ligaments arranged in a grid pattern having a two-dimensional rotational orientation. The method further includes stacking the layers along a thickness direction to form the filter.

These 3D-printed filters provide greatly improved metal filtering for foundries, which improves the yield rate of castings. The filters can be any shape, including all current standard geometries (tapered, straight-sided, square, rectangular and round) and can range in size from 0.5" gate filters to 5.0" pour cup filters.

13 Reasons 3D-Printed Ceramic Filters Rock



1. Ceramic filters made by additive manufacturing enable consistent and repeatable metal flow rates without becoming a secondary source of contamination.
2. Use of 3D-printing to print ceramic filters enables on-demand production of filters tailored to meet specific requirements of the metal being cast.
3. The filter includes several layers. Each layer comprises of individual ceramic ligaments in a grid pattern having a two-dimensional rotational orientation.
4. A well-planned manufacturing process makes a series of precisely produced and controlled ligaments to form the filter. These ligaments can be adjusted for individual filters through the AM process to control flow of material through the filter and to capture impurities efficiently.
5. This ability to engineer a filter for specific applications answers the need to address differences in alloys and the material flow rate required to achieve optimal thermal and mechanical properties within the casting process.

6. Engineering and production processes for the engineered filters include systematic layering of individual ligaments, which are arranged in a grid pattern within the filter. The number of ligaments, and their twist, thickness, and orientation can be varied through on-demand adjustments of a Computer Aided Design (CAD) model applied to produce the filter using AM. Compared to standard filters, which are perfect in their construction and asymmetrical in their geometry, the PERFECT-3D process offers consistent, symmetrical filters that yield predictable results.
7. The filter makers can arrange the ligaments of an engineered ceramic filter to meet the needs of the casting. They make the ligaments and specify their orientations through a combination of the CAD model and control of the AM process to meet the geometries and dimensions specified in the CAD model.
8. The filter can range in size from small (1" diameter or so), for in-line applications, to larger (3" to 4" diameter or so) for pour-cup applications. It is possible to vary the height of the filter, and vary the number of ligaments to correspond to the height. AM-made ceramic filters can vary in size, orientation, height, and diameter to provide the filtering capabilities needed.
9. Custom 3D-printed ceramic filters provide superior filtering. They stop virtually all impurities and capture the vast majority of inclusions, compared with an inclusion rate as high as 40% for some conventional ceramic foam filters. Also, they will not add filter debris into the pour there are no ceramic foam "tentacles."
10. Custom 3D-printed ceramic filters can provide consistent and tightly controlled flow rates for filling molds compared to conventional filters. This ensures efficient, quick, and trouble-free pours into molds.
11. Custom 3D-printed ceramic filters can be made for specific metals and specific casting sizes and shapes. They can be made on demand.
12. Capacities of custom 3D-printed ceramic filters can be sufficient to meet foundry demands, comparable to conventional filters.
13. Costs for custom 3D-printed ceramic filters are comparable to costs for conventional filters, depending on size and application.

Conclusion

Ceramic additive manufacturing is an excellent way to make short-run parts quickly. Custom made 3D-printed ceramic filters should be a part of the ceramic mold package a parts engineering firm should provide to foundries.

PERFECT-3D engineers invented 3D-printed ceramic filters and secured a patent for their ceramic filter process in 2017. PERFECT-3D is not a Johnny-come-lately to ceramic additive manufacturing, but an industry leader that has pioneered a number of ceramic additive manufacturing processes.

Compared to conventional filters for molten metal pouring, the PERFECT-3D Division 3D-printed ceramic filters, designed for the individual mold and metal in use, provides better filtering, quicker and more complete mold fills, and more even cooling – at a price that won't melt a budget.

To learn more, please contact:

PERFECT-3D Division
Renaissance Services Inc.
1 Herald Square
Fairborn, Ohio 45324
937-322-3227
www.perfect3d.com
info@ren-services.com