D.E. Trap Filtration with 3M Purification Betapure™ NT-T Filter Cartridges

Introduction

Diatomaceous earth (DE) filters, sometimes called Kieselguhr, pressure leaf, or primary filters, are one of the most prevalent filters found in modern breweries. Virtually all beers, pasteurized or not, will pass through a DE filter.

One of the drawbacks with DE filters however, is that they can shed DE fines into the beer, resulting in unacceptable turbidity in the beer and a sediment in the bottom of the beer bottle once allowed to settle. To prevent this, DE trap filters are installed downstream of the DE filter, just before the bright beer tank.

This Application Brief discusses the benefits of the 3M Purification Betapure NT-T cartridge filter including:

- absolute retention that provides consistent performance
- a novel media construction that results in a robust fast flowing, high retention filter

DE Filter Construction and Operation

Diatomaceous earth is composed of the skeletal remains of microscopic plants, diatoms, that lived millions of years ago (see Figure 1). The structure has an extremely high surface area, making it ideal for filtration purposes. Diatomaceous earth is mined, purified, and graded according to filtration characteristics, and sold to breweries in bulk powdered form.

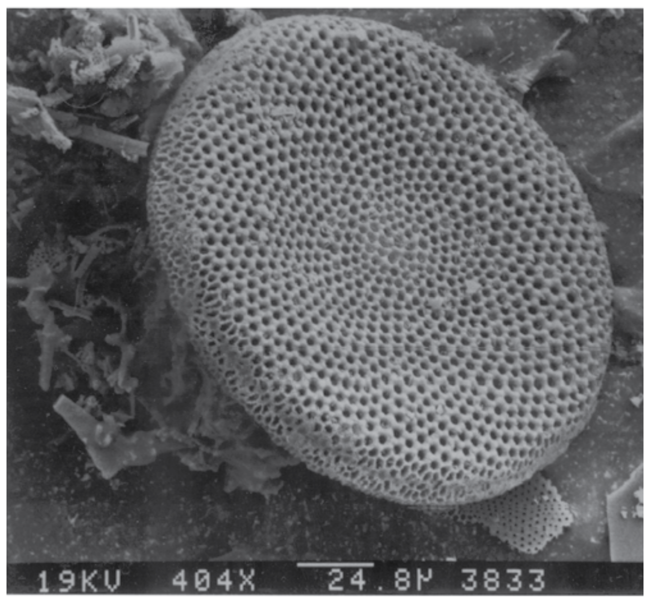
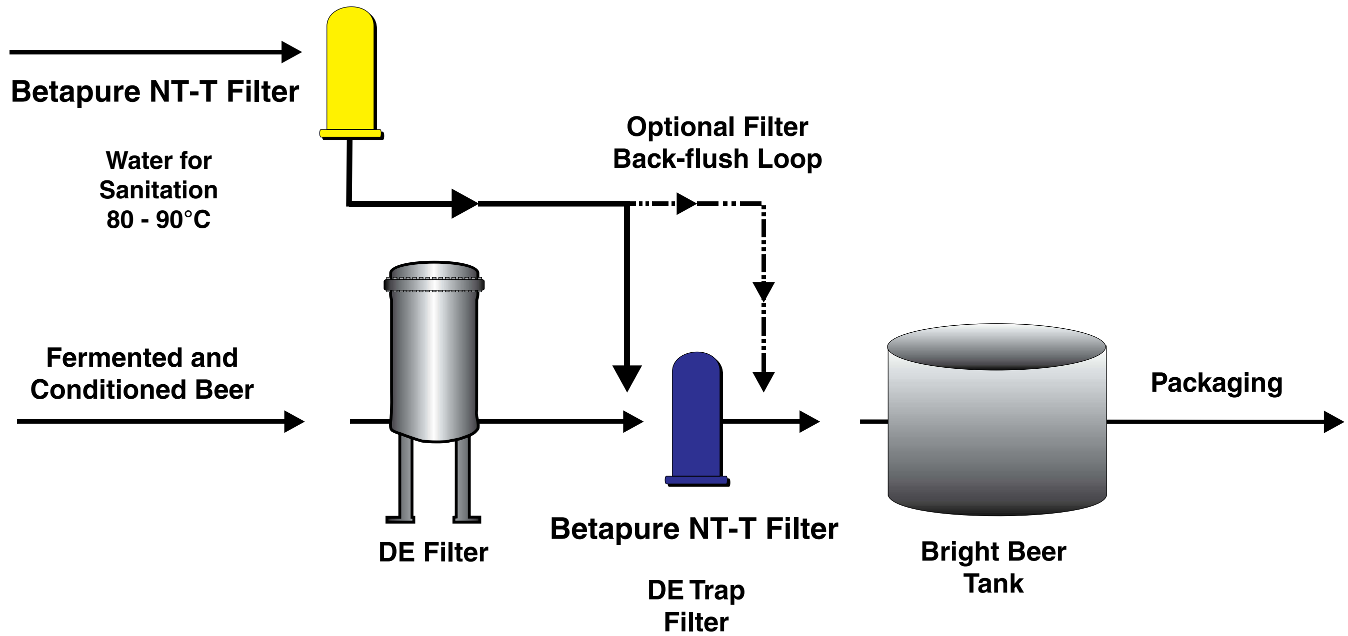


Figure 1 — Diatom

The DE filter's job is to clear the recently fermented and conditioned beer of any residual yeast and insoluble colloid material. This results in "bright beer". DE filters are usually composed of a pressure vessel containing septa of horizontal or vertical screens, or "candles" on which a diatomaceous earth slurry is deposited.

This deposition is accomplished by two methods, pre-coat and body-feed. The filter septa is first pre-coated with diatomaceous earth and/or cotton fibers, usually using degassed beer or water as the carrier fluid. The pre-coat provides the initial support for the deposition of the remaining DE during body-feed operation. When the beer is ready to be filtered, a small, measured amount of DE is continually mixed with the beer prior to passing through the filter. This "body-feed" allows the yeast and other undissolved particulate to become trapped and retained as the DE forms a cake on the pre-coated septa, thus allowing "bright" beer to pass through the filter.

The Process: D.E. and D.E. Trap Filtration



DE filters are typically located in the cellar operations area, downstream from the conditioning tanks and prior to the bright beer tanks. DE filtration systems can run the gamut from manual operations to full automation monitored from a remote control room. Mixing, pre-coat, and body feed tanks are omitted from the above schematic for clarity. DE trap filter housings are typically installed just downstream and adjacent to the DE filter. An optional back-flush loop is occasionally present to run water in the reverse direction through the DE trap filter. It is important that this water line also employs a filter to remove particles in the water before the water reaches the DE trap filters. If not filtered, water used to back-flush the DE trap filter can foul the downstream or "clean" side of the DE trap filter, compromising it's performance.

The Problem

DE filters can occasionally allow DE fines into the filtrate. This release usually occurs gradually, but in some instances, a great quantity of DE fines may enter the filtrate. The latter condition is usually the result of a ruptured or bypassed screen, or a sudden change in hydraulic pressure in the system. Gradual DE fine release is usually a function of 1. the type and age of DE filter employed, 2. the grade(s) of DE used, and most importantly, 3. the skill of the operator as well as the design of the system.

The DE fines, ranging in size from 1 – 50 µm, once in the filtrate can cause a variety of concerns to the brewer. Among them are:

- Excessive and unacceptable turbidity in the beer
- DE sediment in beer bottles
- A poor perception of the beer quality by the customer
- DE fine contamination in downstream operations

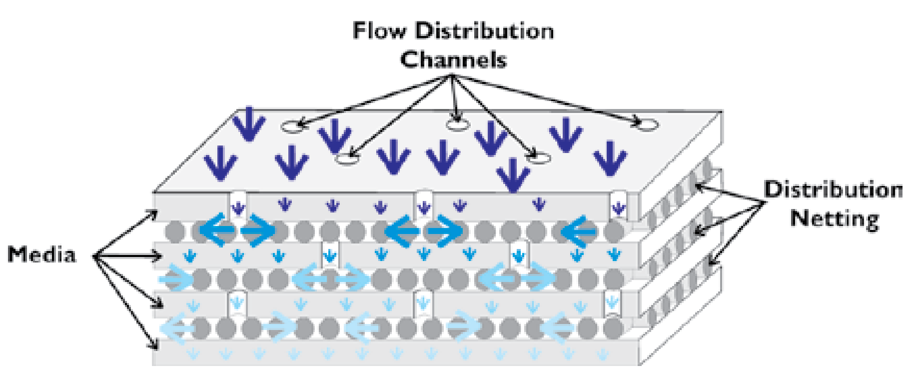


Figure 2 — Betapure NT-T filter media cross-section

The 3M Purification Solution

3M Purification Betapure NT-T filters provide the consistency of absolute rated filtration, as well as the high DE fine holding capacity needed in the brewery. For most brewery operations, the Betapure NT-T 10 µm absolute rated filter is recommended, although a brewery may choose to employ either the 5 µm or the 20 µm, depending on local process conditions.

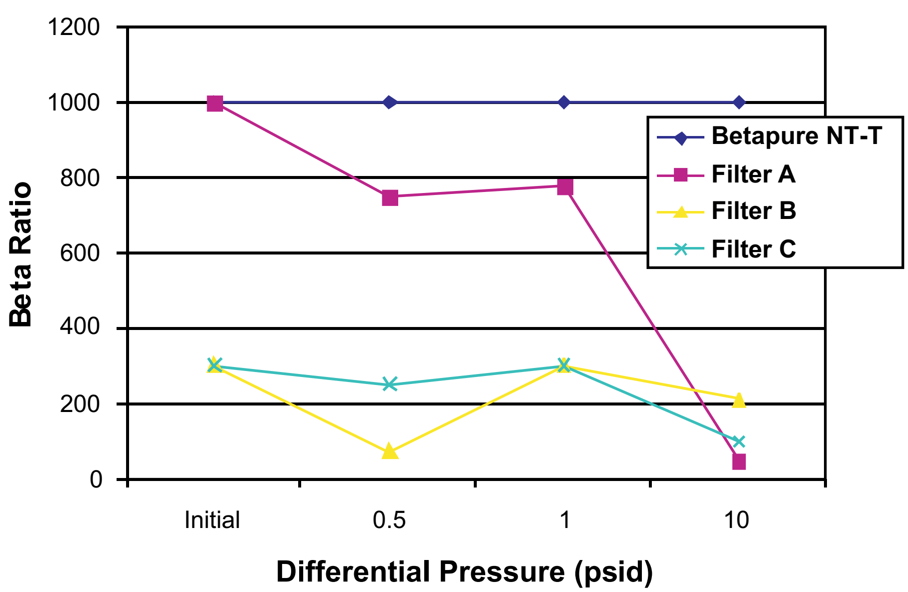
Betapure NT-T filter construction combines a unique polypropylene filter media with fluid distribution netting to form multiple layers. Critically positioned media flow channels allow greater movement of fluid from layer to layer (Figure 2.). Three distinct media sections, made from multiple media/netting layers, are combined to form a filter cartridge (Figure 3). The outer and middle sections contain multiple layers of interleaved filter media and fluid distribution netting. Within each media layer, a portion of the fluid travels through the media while the balance of fluid is delivered directly to the next distribution layer through the flow channels. The fluid distribution netting provides longitudinal and latitudinal flow paths to evenly distribute fluid flow across the surface of each successive filter media layer.

Figure 3 — Cut-away of the Betapure NT-T filter cartridge showing the three sections

Absolute Ratings

Unlike common string-wound or melt-blown filters, Betapure NT-T filters are absolute rated at the stated micron rating. Absolute removal ratings for Betapure NT-T filters are determined using a filter performance method complying with the general procedures outlined in ASTM STP 975. The absolute ratings are defined as the particle size (x) providing an initial Beta Ratio (ßx) = 1000. At this Beta Ratio, the removal efficiency is equal to 99.9%. Additionally, 3M Purification defines an absolute rating as being maintained over the life of the filter, even as differential pressure builds across the filter as DE fines are captured.

This aspect is particularly important in retention of DE fines by trap filters, since the filters can remain in service for months at a time and are required to operate consistently over the life of the filter. Common string-wound or melt-blown filters have been shown to unload previously retained particles as differential pressure builds across the filter. This is due to the nature of the filter construction, which is typically composed of unfixed yarn or polypropylene fibers. As pressure builds, the yarn or fiber can shift and compress, allowing previously retained particles to enter the filtrate. This phenomenon is called unloading and it is typically the cause behind intermittent unacceptable beer turbidity.



Filter A: polypropylene gradient pore structure melt-blown filter with core
Filter B: polypropylene graded density structure melt-blown filter without core
Filter C: cotton string-wound filter (10 micron nominally rated)

Graph 1 — Beta Ratio Comparisons of 20 Micron Filters

As Graph 1 shows, Betapure NT-T filters maintain their absolute rating throughout the entire life of the filter, retaining particles even as the differential pressure builds. Filters A, B, and C show degradation in the Beta Ratio as the differential pressure increases. These filters exhibit a pattern of unloading previously retained particles or a loss of filtration efficiency.

Enhanced Flow and Lower Pressure Drops

The unique design construction of the Betapure NT-T filter allows for significantly lower pressure drops compared to equivalently rated common string-wound or melt-blown filters. In existing applications where the filter housing is already installed, employing Betapure NT-T filters can provide a sharp reduction in the initial differential pressure across the filter housing, resulting in an extension of filter throughput. Additionally, since Betapure NT-T filters provide higher flow rates at a given pressure drop, a filter housing with Betapure NT-T filters will provide greater flow to meet peak filling demand periods in the brewing season, without the expense of purchasing a larger filter housing.

Consider the following examples.[1]

A brewery installs 5 micron, absolute rated Pall™ Profile polypropylene depth filters in a filter housing that accommodates 60, 30" filters. At a 1 psid pressure drop, this housing can provide a flow rate of 450 bbl/hr (540 HL/hr). The same filter housing, installed with 5 micron, absolute rated 3M Purification Betapure NT-T filters can provide a flow rate of 1080 bbl/hr (1300 HL/hr) – more than enough flow to allow for faster production during peak beer demand - without the expense of a new and larger filter housing.

In a second brewery, 1 micron, nominally rated Parker Hannifin Fulflo string-wound filters are installed in a filter housing that accommodates 47, 30" filters. With a flow demand of 500 bbl/hr (600 HL/hr), the clean, initial differential pressure across the housing is 4 psid. The same filter housing installed with 10 micron absolute rated 3M Purification Betapure NT-T filters exhibits less than a 1 psid pressure drop at the same flow demand. Since the filters are changed out based on a maximum differential pressure, typically 20 – 25 psid, the brewery would gain significantly longer filter life, sometimes as much as 30 -50% longer, by selecting the filter that provides a much lower initial differential pressure.

Cartridge Back-flushing

Back-flushing is a common practice in the brewing industry. The purpose of back-flushing a DE trap filter is to eject trapped DE fines from the filter surface, thereby lowering the differential pressure and extending the useful filter life. However, a number of variables can impact the performance of back-flushing. For instance, as DE fines accumulate on the filter surfaces over time, they become more difficult to dislodge by back-flushing. This is exacerbated by undissolved colloids containing proteins, beta-glucans, or carbohydrates that can act like an adhesive, fixing DE fines within the filter matrix. Also, DE fines that accumulate on the outer surfaces of the filter are typically easier to eject during back-flushing than those retained deeper within the filter media.

Due to these and other process variables, it is not possible to recommend a single method and set of parameters to back-flush a DE trap filter. In fact, in some breweries back-flushing may prove to offer little or no economic benefit in regards to extending filter life. It is recommended that each system be evaluated individually to determine the optimum conditions. Most effective back-flushing programs are performed regularly, before differential pressure even begins to build on the filter.

Additionally, since all filter cartridges are designed to provide optimum flow in the forward direction, flow in the reverse, or back-flush, direction should be closely monitored to ensure that it is within the physical limits of the filter cartridge.

Betapure NT-T filters have been tested in the reverse or back-flush direction at three different pressures, 30 psid, 25 psid, and 15 psid, and at three temperatures, 77°F (25ºC), 122°F (50ºC), and 176°F (80ºC) respectively, to guide users who wish to back-flush the filter. Under all three conditions, Betapure NT-T filters were alternately flowed in the forward and reverse directions to simulate brewery conditions. The filter turbidimetric efficiencies were also measured both before and after the testing using ISO test dust, to determine the effect, if any, of the back-flushing cycles on the filters. Turbidity and efficiency measurements were also made to demonstrate the integrity of the filter at the end of the experiment.

[1] Flow and pressure data for these examples are from published literature

At all three temperature/pressure combinations, after a minimum of ten forward and back-flush cycles, Betapure NT-T filters remained integral and exhibited equal or improved efficiency in trapping particles (Table 1).

Table 1. Back-Flushing Pressures and Temperatures

Temperature - °F (°C)	Reverse Pressure - psid (bar)	Number of Back-Flush Cycles
77 (25)	30 (2.07)	10
122 (50)	25 (1.72)	10
176 (80)	15 (1.03)	10

Hot Water Sanitation

Most breweries will flush equipment, such as DE trap filters, with hot water to "sanitize" them. The primary purpose of this procedure is to keep microbial growth in check. Sanitation temperatures typically range from 176 – 194ºF (80 – 90ºC) with a duration of 20 to 45 minutes and a frequency ranging from once a day to once a week. Temperature, duration, and frequency can vary according to the system design.

3M Purification Betapure NT-T filters have been extensively tested to demonstrate consistent performance under these conditions. To demonstrate this, sample Betapure NT-T filters were exposed to 100, 60 minute cycles of 194°F (90ºC) water, each cycle followed by a 15 minute flush with cold water to simulate conditions in a brewery. The test assembly, as seen in Figure 4, was employed.

To determine the effect of the hot water exposure on the Betapure NT-T filters, the filters were then examined via Fourier Transform Infrared Spectroscopy (FTIR) as seen in Figure 5 and dynamic air flow instrumentation (DAF) as seen in Table 2.

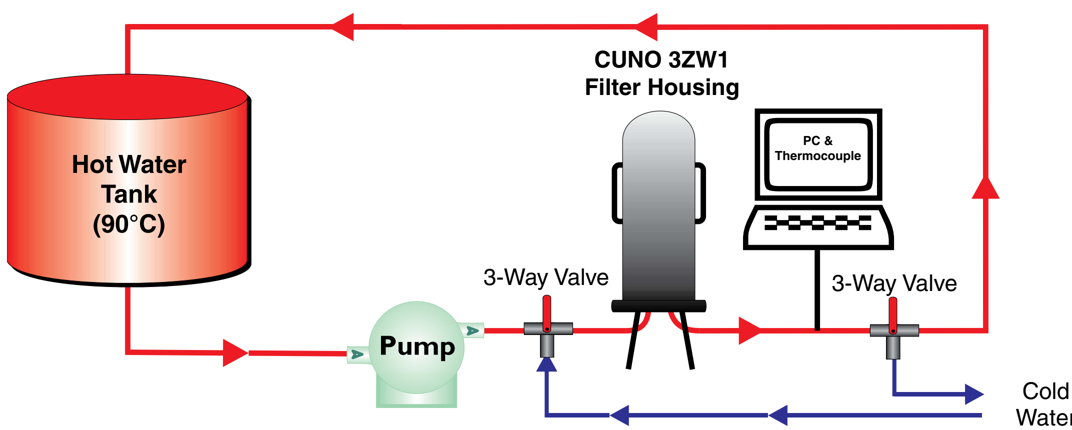


Figure 4 — Hot Water Test Assembly

Control filters (filters that had not been exposed to hot water) were also examined as a comparison.

FTIR spectroscopy, a lab technique that reveals the molecular structure of a substance, was used to detect if any chemical degradation of the polypropylene media had taken place during the exposure to hot water. Data from this test are represented in a "spectrum" of peaks and valleys which essentially represent the presence or absence of various molecular functional groups. Spectra that exhibit a number of differences between the control filter and the test filters would indicate that the filter media was altered due to the exposure to the hot water.

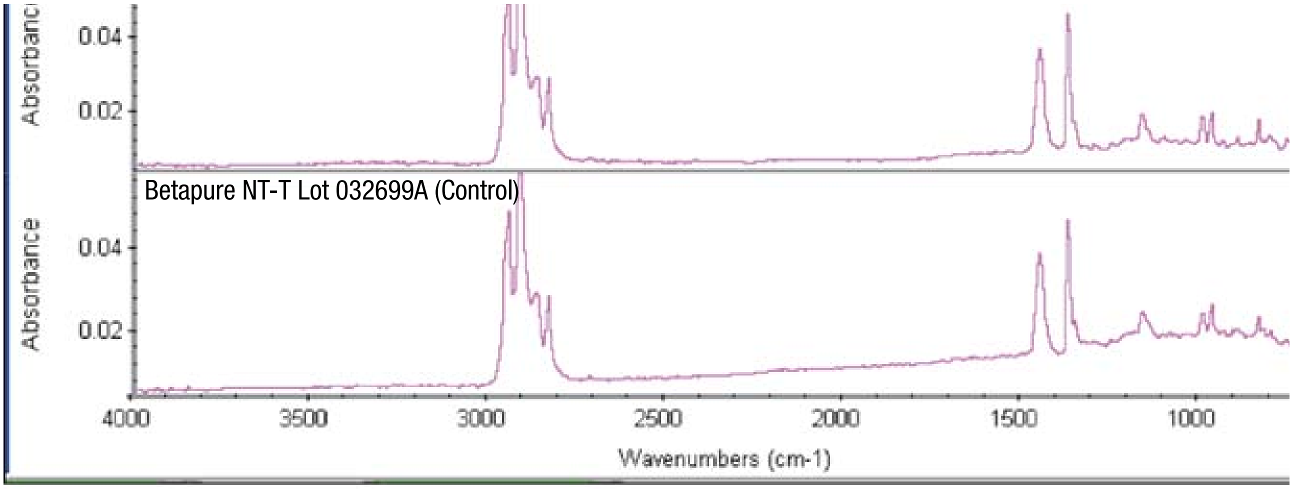


Figure 5 — FTIR Spectra of control (unexposed) and test filters

DAF instrumentation, a test that measures the resistance to flow of a given filter, was used to detect if any physical deterioration had taken place. If a filter material was physically altered due to the exposure to hot water, one would expect either a significant increase in the resistance to flow (as would occur if the filter media had melted) or a significant decrease in resistance to flow (as would occur if the filter media had deteriorated).

Table 2 — Dynamic Air Flow (DAF) Results[2]

Filter	DAF (before hot water)	DAF (after hot water)
1	3.58	3.62
2	2.96	2.99
3	3.78	3.72

As Table 2 and Figure 5 demonstrate, repeated hot water exposure did not significantly alter the Betapure NT-T filter physically or molecularly. In the FTIR spectra, no absorbance peaks associated with degradation by thermooxidation were evident in the filter that was exposed to hot water. Additionally, the post-exposure DAF values for the Betapure NT-T filters were only slightly higher than at the beginning of the test, indicating that the filters have not been physically altered in a manner that would diminish filtration performance.

Conclusion and Summary

DE filters intermittently shed DE fines into the beer filtrate, causing "out-of-turbidity" specification beer, DE fine contamination in downstream equipment and tanks, and a negative customer perception of beer quality. 3M Purification Betapure NT-T DE trap filtration prevents DE fines from contaminating the beer.

This Application Brief describes the benefits of using 3M Purification Betapure NT-T filters as DE trap filters. These benefits include consistent absolute removal ratings, long service life, and a robust filter cartridge design, tested and optimized for the brewing industry.

References

B. Robinson, "DE Filtering 101", The New Brewer, 2, 1997

Siebel Institute of Technology, "Kieselguhr (D.E.) Filtration", 1995

Related Product Literature

Betapure NT-T Filter Cartridges LITCPN1, 70-0201-8720-2

SD Model Filter Housings LITHSSD1, 70-0201-8760-8

Express Series Filter Housings LITCHSES1, 70-0201-8711-1

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3M Purification Inc.
400 Research Parkway
Meriden, CT 06450, U.S.A.
Tel (800) 243-6894
(203) 237-5541
Fax (203) 630-4530
www.3Mpurification.com

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