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SINTERED POROUS METAL MEDIA IN FOOD AND BEVERAGE PROCESSING

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Sintered Porous Metal Media In Food and Beverage Processing

Abstract

This paper will discuss the use of sintered porous metal media in the food and beverage processing industry. Applications for sintered porous metal filters in manufacturing processes include carbonation, aeration, ozone treatment, steam injection and oxygen stripping. More advanced particle separation require the use of sintered porous metal for specialized applications such as HPLC separations for chemical analysis, gas/solids separation in steam filtration and solid/liquid filtration designed for the processing of edible oils at various stages of refining.

Increasing consumer demand for quality food product challenge today's industry with more stringent quality standards. Competitive markets drive the need for more efficient production methods to meet economic, health, safety, and environmental concerns. Advances in filtration technology and filter media will assist manufacturers in meeting these criteria.

Sintered Porous Metal for the Food and Beverage Industry

Sintered porous metal is manufactured by compressing powder metal into a variety of shapes, as shown in Figure 1, and sinter bonding the porous metal to form a permanent inert structure. Porous metal can be fabricated into many different configurations and sizes to meet application requirements. For years sintered porous metal media has been designed into food and beverage processes because of its strength, efficiency, longevity and cleanability.

Standard products are fabricated from 316L stainless steel, the alloy of choice for food and beverage processing equipment. Sintered porous metal components have excellent strength and rigidity and chemical compatibility to endure most standard cleaning environments such as exposure to acids, caustics, chlorine, steam and high-pressure washdowns.

Porous metal is bi-directional and will perform equally well flowing from top or bottom, or from inside-out or outside-in direction of a tube or cartridge. It's uniform porosity results in high efficiency particulate removal.

Media grades available range from 0.1 to 100. Media grade is designated by the mean flow pore size of the porous structure.[1]

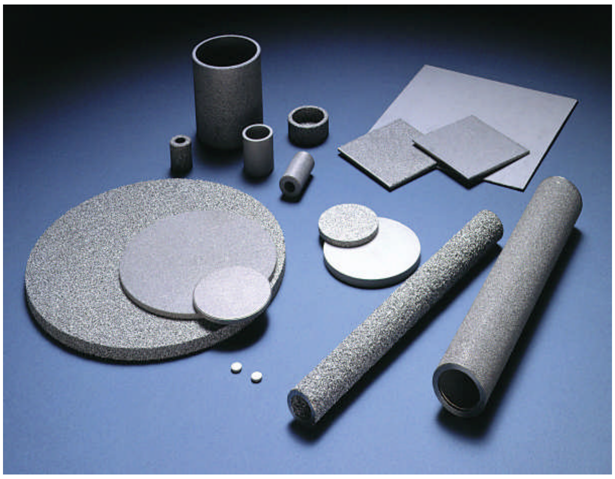

Figure 1. Porous metal components of various media grades.

Food and Beverage Applications

Applications for sintered porous metal filters in the food processing industry include carbonation, aeration, ozone treatment, steam injection and oxygen stripping. More advanced particle separation utilize sintered porous metal for specialized applications such as HPLC separations for chemical analysis, gas/solids separation in steam filtration and solid/liquid filtration designed for the processing of edible oils at various stages of refining.

Process operations that use sintered metal in the food and beverage industry include modifying the processing atmosphere. This is accomplished in liquids using gas injection or sparging for the removal of oxygen as a principle means of increasing the life of perishable products. While improving stability for a longer shelf life, appearance, aroma and taste of food and beverage products are also improved.

Porous metal gas spargers used in direct steam injection lower gas consumption while eliminating steam hammer in processes requiring hot water preparation, heating liquids and other bottling, packaging and canning operations. Other conventional applications for sintered metal in the manufacturing of food products include carbonation, gas bulking of sauces and dressings, pH control by CO_2 injection into waste streams, and the fluidization of dry goods to facilitate transportation. Porous metal spargers are widely used as inline and tank carbonators for beverages such as water, beer, soda and fruit juices.

Porous metal filters or “frits” are used in chromatography columns for High Performance Liquid Chromatography (HPLC) to separate and analyze mixtures of chemical substances ensuring food product quality. Media alloys include 316L SS, titanium, Hastelloy® C-276[*] and Nickel 200 for high-pressure applications (up to 2000 PSI) and exposure to caustic solvents. Titanium is preferred over stainless steel when solvents containing halides are used. In addition, titanium is favored for reduced protein absorption. Sintered porous metal frits protect HPLC columns from particulate contamination, while distributing dissolved sample uniformly in the chemical analysis of food products to determine nutritional content and contamination levels. [2]

A significant innovation applies porous metal components in the electrolysis of water to generate highly concentrated ozone gas. Ozone in water is used for sanitizing food and equipment. Ozone is a natural disinfecting agent to deter bacteria and viruses. Ozone treatment is another means to improve taste, minimize spoilage and increase product shelf life of food, water and other beverage products.

Gas/Liquid Contacting Applications

Gas/liquid contacting using nitrogen gas with porous metal gas distribution spargers is a practical method of decreasing the concentration of dissolved gas (usually oxygen) in a liquid. The high surface area of the porous metal increases the gas/liquid contact area, which reduces the reaction time and volume of gas required. The enhancement of mass transfer increases productivity and economic efficiency of the process.

Sintered metal media is available as either static or dynamic spargers. Static sparging relies on the gas pressure to form the bubble and self release into the liquid. In dynamic cases, the bubble is formed at the surface and is sheared off by high fluid velocity. There are two types of dynamic spargers, intrusive and non-intrusive. Intrusive spargers are inserted directly into a pipeline, while non-intrusive spargers are a shell-and-tube design fitted into the side of the pipeline. Non-intrusive sintered metal spargers were compared with traditional drilled pipe tank sparging under both agitated and non-agitated conditions. Absorption using sintered metal media can increase gas savings by 60 – 74%, as indicated in Table 1.

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[*] Hastelloy is a registered trademark of Haynes International, Inc.

Table 1. Oxygen absorption efficiency comparison data

Sparger Type	Drilled Pipe	Mott (Non-intrusive)	Reduced Time	Gas Savings
Dynamic Sparger	mg/ L/ min	mg/ L/ min		
Agitated tank	2.7	8.4	3.1 x	68%
Non-agitated tank	1.1	4.2	3.8 x	74%
Static Sparger				
Non-agitated tank	1.1	2.7	2.5 x	60%

Nitrogen blanketing and sparging of edible oil is a method to prevent oil from deteriorating during shipment. The process can be batch or continuous - in vessels and pipelines. Sparging prevents oxidation of stored materials to preserve flavor and fragrances, and averts reactions between oxygen and acidic materials. The nitrogen gas bubbles displace the dissolved oxygen to reduce the oxygen content.

Direct injection in steam processing produce very fine bubbles and almost instantaneous condensation. Typically steam is introduced into the process from an open-ended pipe, or drilled pipe. This results in large steam bubbles which collapse and cause steam hammer. Much higher steam flows are achieved without steam hammer using spargers manufactured from sintered metal media. A direct comparison of (intrusive) static and dynamic spargers for steam processing indicates that four times the flow was obtained using dynamic sparging (750 CFM/ft^2) compared to static sparging, where rates were 185 CFM/ft^2. [3]

Ozone Treatment

New developments in the food industry include the FDA approval of ozone on food products.[4] Ozone is a highly reactive oxidizing agent that has been used commercially to disinfect and deodorize air, purify water and treat industrial wastes. Ozone is currently used in the processing of meat, poultry, fruits and vegetables. Ozone can be used to replace chlorine and effectively sanitize equipment, water, and food processing surfaces without toxic byproducts or other potential hazards.

Ozone can be generated on the food processing line, which makes it economical. Novel applications utilize sintered porous metal diffusers in an ozone generating application. Ozone contacting is directly affected by bubble size, pattern and method of dispersion, mixing efficiency, contact time, and liquid/gas volume mass ratios. These parameters affect the transfer process and allow the ozone to come onto contact with the water for the necessary reaction time.[5] Sintered porous metal diffusers effectively maximize water to ozone contact. Sintered porous metal diffusers are manufactured from 316L stainless, Hastelloy C-276 and titanium. Table 2 lists the recommended material based on ozone concentration levels.

Table 2. Sintered porous metal material selection based on ozone concentration level

Sintered Metal Material	Ozone Concentration
316 L Stainless Steel	Less than 3%
Hastelloy C-276	3-6%
Titanium	6 – 10%

Solids/ Liquid Separation Applications in Edible Oil Processing

Solids/liquid filtration using sintered metal filters allows for high efficiency filtration, cake washing and cake removal using a completely closed system that minimizes product and operator exposure. Applications using precious metal and nickel catalyst have increased catalyst removal efficiency and minimized catalyst poisoning. Sintered porous metal cartridges have excellent strength, rigidity and chemical compatibility to endure most standard cleaning environment including acids, caustics, chlorine, steam and high-pressure washdowns. Fully automated filter systems with PLC controls are recommended for advanced food and beverage processing.

Porous metal filtration media can be a key ingredient in enhancing productivity in edible oil processing. As previously mentioned, applications include using nitrogen atmosphere sparging and blanketing. Nitrogen gas introduced both in the pipeline, at storage locations, and during tanker loading and unloading, eliminates oxidation therefore minimizing deterioration, foreign odors and taste. Solids/liquid filtration is necessary to remove foreign particles from the various processing stages that can also cause deterioration.

Process Description

When processing of crude edible oil to create end products such as cooking oils, margarine and shortening, processing steps such as refining, bleaching, hydrogenation, post-bleaching and deodorization are often required. In the refining step free fatty acids are removed from the crude oil. The bleaching step eliminates color bodies in the oil with bleaching clay. The oil is saturated with hydrogen in the presence of catalyst in the hydrogenation step. The oil is further bleached with bleaching clay and a stabilizing agent is added in the post-bleaching step. The last major processing step is deodorization, which utilizes steam injection at elevated temperatures under vacuum to remove undesirable materials.

Filter System Description and Operation

Sintered metal tubular backwash filters, with unique inside-out flow[6], were used to validate filter operating performance in the bleaching, post-bleaching and hydrogenation stages of edible oil processing. The filter configuration is described in Figure 2. Slurry enters the filter elements through the inside diameter (ID) of the element. This design immediately provides a high packing density of the filter elements within a vessel, and eliminates cake bridging, since the cake is contained within the ID of the element. Inside-out design allows for efficient solids handling, washing and discharge from the filter vessel.

Test Parameters

Filtration studies were conducted with process slurry from three steps of this process: Bleaching, hydrogenation, and post bleaching. The objectives were to produce acceptable (optically clear) filtrate at economical flux rates, while optimizing product yield using the inside-out filtration mode. Operating parameters such as flow rate, throughput, pressure drop and filtrate quality was monitored throughout testing. Backwash capabilities using both slurry backwash and wet cake discharge were also investigated. Filtration was conducted at process operating temperatures of 250 – 300°F.

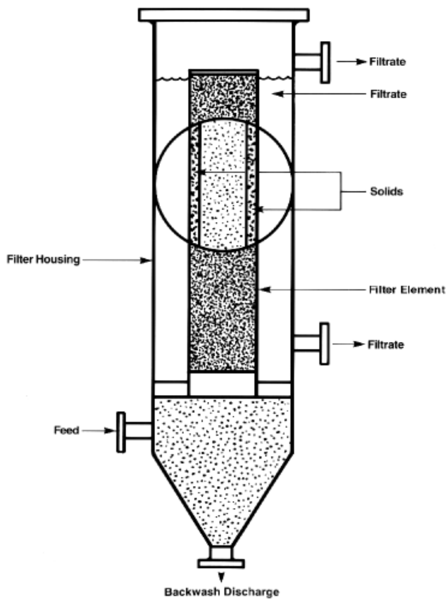

Figure 2. Inside-out barrier filtration mode

Case Study 1: Bleaching

Bleaching clay is added to refined oil to remove color impurities from the refined oil. Color bodies absorb onto the clay and are filtered out of the oil. The used clay is then washed and recycled for further use. The feed slurry samples used in this study contained different grades of bleaching clay.

Preliminary screening was conducted using disc feasibility testing to determine which media grade provided clear filtrate. Bench scale tests were conducted with porous metal media grades 0.5, 1 and 2. Table 3 summarizes the operating parameters in the filtration of animal and vegetable oil containing bleaching clay. Test results represent characteristic operating parameters after several backwash cycles.

Test results illustrate the importance of feasibility studies, as each feed material behaved slightly different with regard to average flow rate. The average flow rate varied from 0.3-0.6 gpm/ft^2 at terminal pressure (pressure drop across the media at end of filtration cycle) of 40 PSI and 12 PSI respectively.

Filtration of both the bleaching and post-bleaching slurry produced a filter cake that was effectively backwashed using wet cake discharge. In order to ensure uniform cake distribution for optimum filtrate quality, filtrate must be taken from the top of the filter shell during normal operation. Removal of liquid from the housing shell results in optimized product yield.

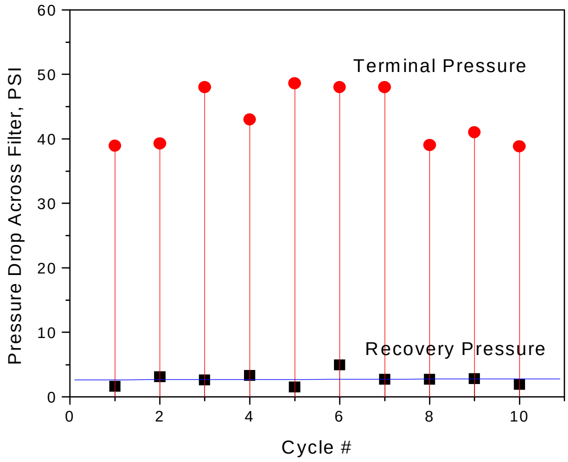

Figure 3. Terminal and recovery pressure trends in filtration of bleaching clay oil using media grade 2.

Figure 3 shows a stable recovery pressure drop after backwashing in repeat cycle testing of oil from animal fat containing bleaching clay in testing conducted using media grade 2.

Table 3. Edible oil bleaching/post-bleaching filtration study using sintered metal media

Test Parameter	Bleaching	Bleaching	Post-bleach
Media Grade	2	1.0	0.5
Oil Type	Animal fat	Vegetable Oil	Soybean Oil
Bleaching clay wt. %	0.5	0.05	0.5 **
			*** 0.16% citric acid*
Average flux, gpm/ft^2	0.3	0.6	2.3
Thruput, gal/ft^2	24	25.6	68
Cycle time, min	35	42	30
Terminal pressure, PSI	40	12	40
Discharge type	Wet cake	Wet Cake	Wet cake
Blowdown pressure, PSI	25	35	60
Filtrate Quality	Optically Clear	Optically Clear	Optically Clear
Filtrate, PPM TSS	5.0	3.3	< 0.10

Case Study 2. Post Bleaching

The post-bleaching step is used to further bleach and stabilize the oil. Stabilizing is necessary to give the oil resistance to oxidation and hydrolysis. A small amount of bleaching clay is added to absorb the remaining color bodies. Citric acid is mixed into the solution and used as a stabilizing agent. The used clay and nickel citrate precipitate are filtered out of the oil. This post-bleached oil is sent to the deodorizer. Test results indicate this process is an excellent application for sintered metal filters. Media grade 0.5 media processed 68 gal/ft^2 to a terminal pressure of 40 PSI. Average flux was 2.3 gpm/ft^2. Filtrate was optically clear. Filtrate quality measured < 0.1 ppm. The filter was effectively backwashed using wet cake discharge.

In filtration of both bleaching and post-bleaching oils, filter aid precoating was not necessary, which will result in lower operating costs based on filter aid usage and solids disposal costs. Precoat filter aid is generally added to protect the media and improve cake release. Filter aid application levels can be greatly reduced from ordinary practice using sintered metal media. Filter aid solids loading of 0.05 lbs/ft^2 or less will be sufficient. Filtrate must be taken from the top of the filter shell to ensure even precoat distribution. The uniform porosity of the media results in uniform cake distribution and high quality filtrate. Typically, the amount of filter aid can be reduced, and finer grades of filter aid material can be used with sintered metal media. Wet cake discharge of solids (about 50% moisture) is feasible.

Case Study 3: Hydrogenation

The hydrogenation step chemically adds hydrogen to the double bonds of the unsaturated fatty acids contained in the bleached oil to make it plastic or firmer. Hydrogenation also retards the development of rancidity of fat by reducing its reactivity towards oxygen. The process begins in a reactor where the bleached oil is saturated by hydrogen in the presence of catalyst at elevated temperatures. After this reaction the oil is cooled, filter aid is added as a bodyfeed, and the catalyst is filtered out. The catalyst is recycled. The hydrogenated oil is sent to the post-bleaching process.

Again, test results in Table 4 show the importance of feasibility testing, as filtration of catalyst from different manufacturers showed slightly different operating performance. All tests required media grade 0.5 media to capture particulate and provide optically clear filtrate. Flux rates varied from 0.2 – 0.75 gpm/ft^2, reflecting differences in particle size and cake properties of the feed slurries tested. All testing required slurry backwashing to effectively remove the filter cake from the media.

Table 4. Edible oil hydrogenation filtration studies using sintered metal media

Parameter	Hydrogenation	Hydrogenation	Hydrogenation
Media Grade	0.5	0.5	0.5
Oil Type	Animal fat	Animal fat	Soy/Cotton Oil
DE Bodyfeed wt.%	0.5	0.5	0.015
Ratio Filter aid: Catalyst		2:1	
Average flux, gpm/ft^2	0.75	0.57	0.2
Thruput, gal/ft2	44	35	34
Cycle time, min	60	60	182
Terminal pressure, PSI	40	40	50
Discharge type	Slurry backwash	Slurry backwash	Slurry backwash
Backwash pressure, PSI	60	50	70
Filtrate Quality	Optically Clear	Optically Clear	Optically Clear
Filtrate Turbidity, NTU	0.5	1.0	0.89
Filtrate Quality, PPM (*Ni)	0.22*	< 0.10*	N/A

Recent developments in the filtration of nickel catalyst indicate a benefit in using a low velocity inside-out cross flow mode of operation with a top feed configuration. This incorporates a fluid flow of circulating solution axially through the element at a sufficient velocity to prevent significant solids accumulation. The resultant effect is to concentrate a dilute feed stream to high solids content and reduce pressure drop due to flow through a solids cake.

Dynamic operation of the filter incorporates the re-circulation loop described in Figure 4 to maintain a moving stream, preventing appreciable solids buildup until the concentration is increased. The system can be operated continuously with a side stream removal of the concentrate or it can be a batch process. The recirculation can be terminated after desired concentration is reached, and the usual barrier filtration commences to finish filtration of the concentrated solids. The system lends itself to both thin and thick slurries and can be modified for wet cake removal. The backwashing operation may be controlled either manually or automatically.

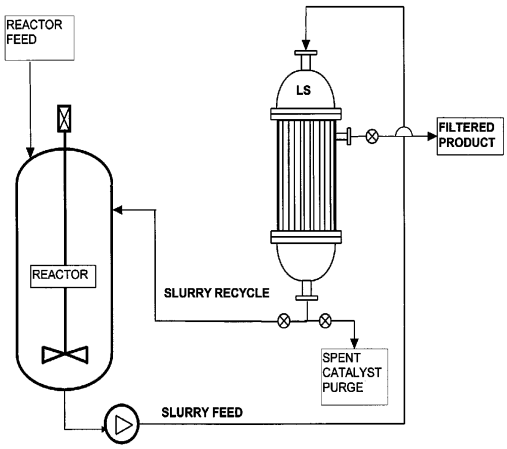

Figure 4. Inside-out crossflow filtration mode.

Commercial Hydrogenation Applications

Precious Metal Catalyst Recovery - Batch Process

A customer has a batch hydrogenation process that requires a filter for recovery of precious metal palladium-on-carbon catalyst. The process requires cake washing with solvent and acid cleaning. The customer wanted to minimize operator exposure and eliminate fire hazards. Installation of an automated filter system, as shown in Figure 5, using sintered metal media allowed fast start-up and shut down operation. The closed system minimized exposure of catalyst and oil to the atmosphere, as well as reducing operator exposure and fire hazard. The filter has demonstrated 8 years of successful operation.

Figure 5. Skid-mounted automated filtration system manufactured by Mott Corporation.

Recovery of Precious Metal Catalyst – Continuous Process

A second hydrogenation process utilized sintered porous metal to replace bag filters. The filter installation paid for itself within one year based on savings in catalyst costs. The closed system minimized catalyst poisoning, while the improved filter performance eliminated catalyst loss during processing.

Gas/Solids Separation for Process Steam Applications

Steam filtration is required to remove rust, pipe scale, and other contaminants picked up in the steam distribution system. These particles can damage equipment or contaminate the final product. Sintered metal filters offer an economical means for removing particulate from steam. Figure 6 shows the filter flow schematic diagram, along with a photograph of the filter housing. A gas-solid mixture enters the unit (1) with solids collecting on the outside of the filter element (2). Clean steam passes through the element wall to the plenum chamber and exits the filter housing (4).

Commercial Steam Filtration Application

A manufacturer requires 26,400 lbs/hr clean saturated steam (2095 ACFM) for processing, and for protection of downstream components. Process conditions required all 316L SS materials of construction for operation at 78 PSIG with process temperatures of 322°F. The 72.5 square foot sintered metal filter has provided more than four years of plant service. Filter elements are removed for cleaning during normal plant turn-around.

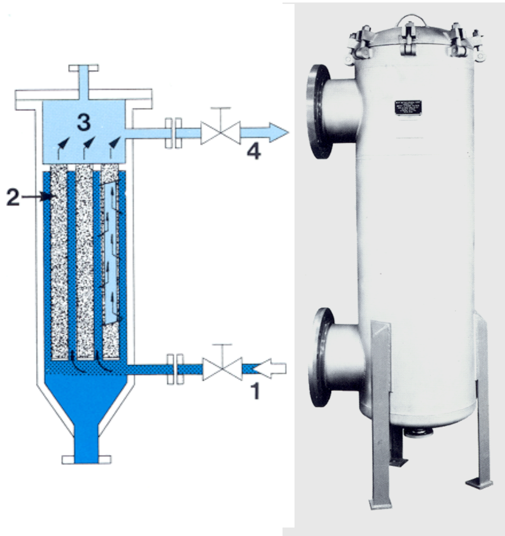

Figure 6. Mott flow diagram and filter housing used for gas (steam) filtration.

Summary

For years sintered porous metal media has been designed into food and beverage processes because of its strength, efficiency, longevity and cleanability. Numerous applications have time-proven service performance using sintered porous metal media in the manufacture of food products. Applications are varied and include processing that require gas injection or sparging, gas bulking, carbonation, de-oxygenation, CO_2 injection to control pH in waste streams, and the fluidization of dry goods to facilitate transportation.

Porous media filtration can be a key factor in enhancing productivity in the processing of edible oils. Nitrogen gas introduced both in the pipeline, at storage locations, and during tanker loading and unloading eliminates oxidation therefore minimizing deterioration, foreign odors and taste. Filtration is necessary in bleaching, hydrogenation and post-bleaching stages of edible oil processing to remove foreign particles that cause deterioration of the oil. Successful bench scale testing has been performed in the filtration of edible oil from the bleaching and post-bleaching stages. Filtration of hydrogenated oil using sintered metal media has many documented successful applications in several commercial installations.

References

[1] *Mott Technical Handbook*

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[4] *Mark A. DeSorbo, Ozone Food Treatment OK'd by FDA, Cleanrooms, Volume 15, No.9, September 2001.*

[5] International Ozone Association Pan American Committee, Design Guidance Manual for Ozone Systems, 1990

[6] *U.S. Patent No. 4,552,669, R. Sekellick, assigned to Mott Metallurgical Corporation, (November 1985).*