DISC FILTRATION: SOMETHING OLD, SOMETHING NEW

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ABSTRACT

Starting over the skies of Europe during World War II filtering hydraulic fluid in the "Flying Fortress" B-17 Bomber and continuing today around the world removing suspended particulate matter from untold numbers of wastewater streams, disc filtration is a proven technology continually finding new uses. With nearly thirty years of exclusive irrigation use, today's applications of disc filters include the realms of municipal wastewater treatment, on-site domestic waste treatment, industrial waste treatment, food processing, textile manufacturing, steel mills, cooling towers, and many other manufacturing and processing industries. Disc filters provide the same positive two dimensional filtering surface as a screen filter with the added dimension of depth filtration. Recent additions of resistant plastics, stainless steel and a revolutionary automatic backflushing process adds to the versatility of this technology. Filters are offered in a choice of grooved discs with degrees of filtration between 400 and 25 microns and flow rates up to 770 m3/h (3400 gpm). The automatic sequencing of fifteen second backflushes between multiple filter units based on differential pressure provides uninterrupted flow, minimal amounts of flush water and complete cleaning of all discs.

HISTORY

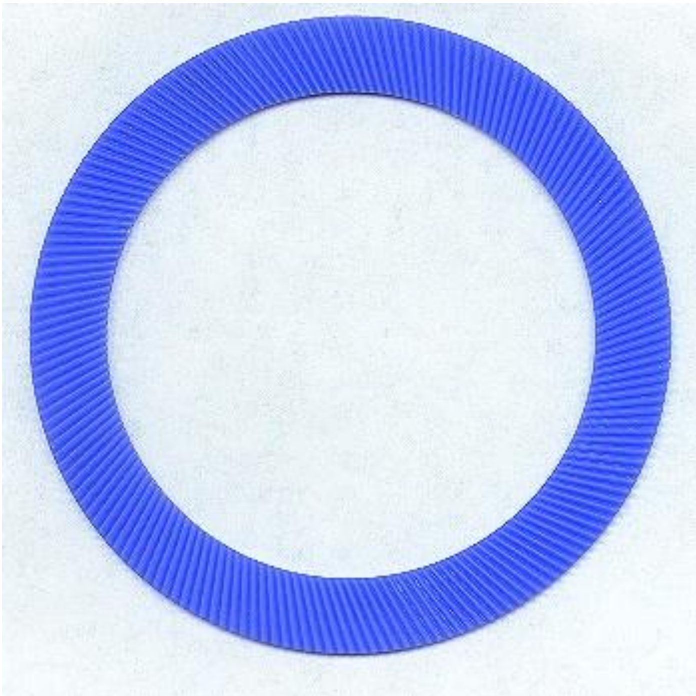
Woven, non-woven and media filters have a long history in filtration applications. Woven materials have been used to strain out unwanted particles as long as man has manufactured cloth materials for clothing. Non-woven material has been used since before recorded history when early man used animal skins for body protection from the elements. Long before Henri Darcy described the flow of liquids through saturated porous material in Dijon, France in 1856, sand media filters were old technology for filtering drinking water. These proven methods of liquid/solid separation are still the most widely used today. Newer technologies include centrifugation and selective porous membranes.

An English company called Relomit was contracted in 1936 by the Boeing Corporation to develop a compact, lightweight, non-destructible device to filter hydraulic fluid for Boeing's B-17 Bomber, later known as the "Flying Fortress." The result was a series of stacked discs forming a hollow core cylinder. The faces of the discs contained finely machined grooves. The materials of choice for these discs were stainless steel and brass.

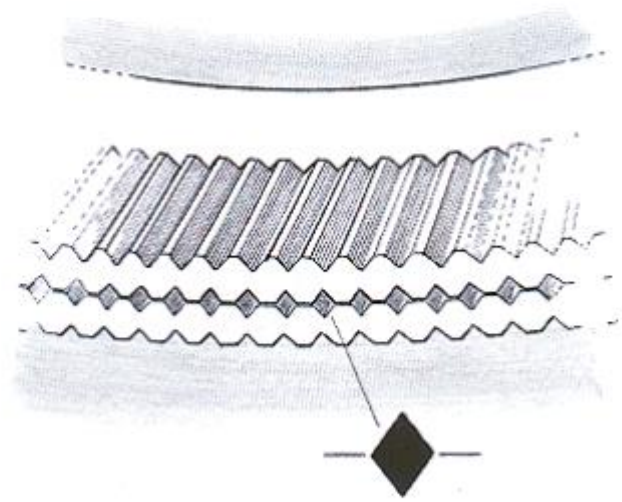
An Israeli company obtained the patent for the disc filter in the 1960s and began developing its application to protecting irrigation equipment for agricultural production. By converting to injection molded plastics for the discs to save costs and developing an automatic backflushing system to improve field operation, a unique aviation wartime device was spread around the world to grow food for the table. Recent changes including stainless steel manifolds, polypropylene discs and electronic controllers have made this technology adaptable to the industrial community.

MECHANISM OF OPERATION

The thin polypropylene discs come in various diameters depending upon the particular filter model. The larger models have discs approximately 115mm OD X 85mm ID (4.5in X 3.3in). The face on each side of the disc has uniform sized grooves set at an angle to the rays of the circle as shown in Figure 1. The cross-section of each groove forms an equilateral triangle. This cross-section remains constant throughout the length of the groove. The diameter of the largest circle inscribed inside this triangular cross-section is the filtration size rating, e.g. if the diameter of the largest circle that will fit inside the triangular cross-section of the grooves of a particular disc is 100 microns, then the disc has a separation rating of 100 micron. When multiple discs are stacked and centered around a skeletal cylindrical structure called a spine, the discs form a hollow cylinder with the ends of the grooves exposed to both the inside and outside surfaces. When looking down on a single disc lying flat on a horizontal surface, the grooves on the top surface of the disc angle out and to the right of a ray to the circle. The hidden grooves, on the underside of this same disc, angle out and to the left of the circle's rays. This geometry dictates that the grooves form a crisscross pattern at the interface between any two stacked discs. This pattern forms numerous intersections of groove troughs and ridges along the length of each groove. Depending on the separation grade of the discs (available in 400, 200, 130, 115, 75 and 25 microns), the number of intersections for each groove will vary between 12 and 32.



The groove cross-section formed by any two adjacent discs will vary along the length of the groove as shown in Figure 2. Panel 1 of Figure 2 shows how the cross-section would appear to the flow stream when the cross-section of two grooves align perfectly. Panel 2 shows how the combined cross-section of the same two grooves appears a little further along the groove length. The change in cross-section causes turbulence in the flow. The cross-section of the flow path in panel 3 has divided into two separate sections each with equal cross-sectional areas shearing the flow. As the flow stream moves further along the groove length turbulence is enhanced as the cross-section changes as in panel 4. The flow stream and suspended particles move along the length of each groove following the sequence shown in the five panels of Figure 2 anywhere from 12 to 32 times. A perfectly spherical particle smaller than the separation rating of the discs will pass through the filter without entrapment. However, most suspended particles are irregular in shape. If the long axis is parallel to the flow stream as you would expect in laminar flow, it would pass through a two dimensional screen. The disc filter causes the flow stream cross-sectional pattern to oscillate while travelling along the length of the grooves. As irregular shaped particles tumble through the groove, the opportunity for entrapment as the particle reaches the next intersection is greatly enhanced. This mechanistic process is very effective on separating rigid suspended particles from a liquid stream.



Soft organic material, such as algae, tends to extrude and shear when differential pressures act upon it through a two dimensional porous substrate such as a screen. Unlike two dimensional separation devices that must possess openings that are physically smaller than the organic particles being targeted, disk filtration devices depend upon the process of particle/surface adhesion. Each particle that is trapped by a screen blocks nearly all of the flow through the trapping opening. Since the organic particles adhering to the groove surfaces of a disc filter can be relatively small compared to the groove cross-section itself, flow continues to go around the trapped particle carrying additional particles to adhere to other areas of the same groove. This multiple entrapment of organic particles per groove give this process the ability to continue three to five times longer between backflushes to build up the same differential pressure, given the same flow rate, than a two dimensional screen.

During the filtration process, incoming fluid surrounds the cylindrical stack of compressed discs and passes through the groove passages to the interior of the cylinder. Particles are removed from the stream as described above. Once inside the cylinder, the filtered fluid passes from multiple parallel stacked disc cylinders into a common manifold and out of the filter unit.

The backflushing process can be fully automatic, triggered by differential pressure, timing interval or a combination of both. The filters use filtrate to clean each separate disc. Because of the sequential nature of the backflush cycle, the filtration process is never interrupted. Space does not allow the full description of this reliable backflushing process in this manuscript.

APPLICATIONS

Where nozzles can be impaired, energy consumption increased and heat transfer efficiencies drastically reduced by the presence of suspended particles, cooling tower applications are often addressed by disc filtration. Not only are solid particulates removed, but also algae and other organic materials. Over 150 disc filters have been in operation for at least seven years in side stream filtration cooling tower systems in Canada, France, Great Britain, Israel and Thailand. Normally, 6-15% of the flow rate is passed through the filter in a side stream setup. Over 70 disc filters have been used in full stream cooling tower applications for at least eight years worldwide. Not only is the removal of solid particles important for energy and thermodynamic reasons, but it also improves the effectiveness of chemical disinfection.

Disc filtration has been used in such industries as food and beverage, pulp and paper, mining, textile, chemical, pharmaceutical, electronic, refinery, power generation, municipal wastewater and aquaculture. In systems using water softeners, ion exchange or membrane technologies, disc pre-filtration reduces the load of large particles from the final water conditioning giving longer life to the system. Since disc filtration uniquely manages to separate both solid and organic particles from the fluid stream, often it can replace two existing systems in an industrial process.

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