Tubular Membranes Rely on Turbulence for Maximum Performance

At Duraflow, we produce a product called a Tubular Membrane to filter particles out of water.

Our membrane tubes remove particles greater in size than 0.05 microns to 0.1 microns, which includes things like dust, bacterial, dyes, pigments, colloidal metal particles and more. To get a better idea of how and why this system can help companies produce a higher volume of clean, usable water, we wanted to take this opportunity to dissect a Tubular Membrane and explain how it works.

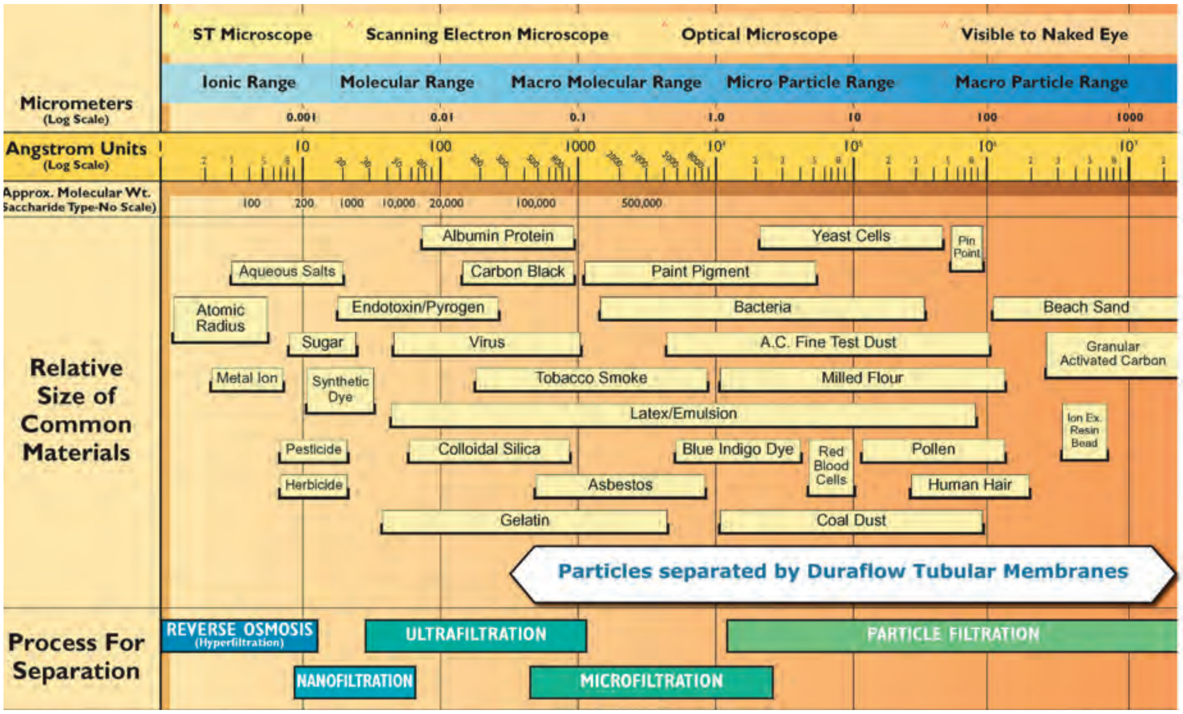


Diagram by Dave Norman

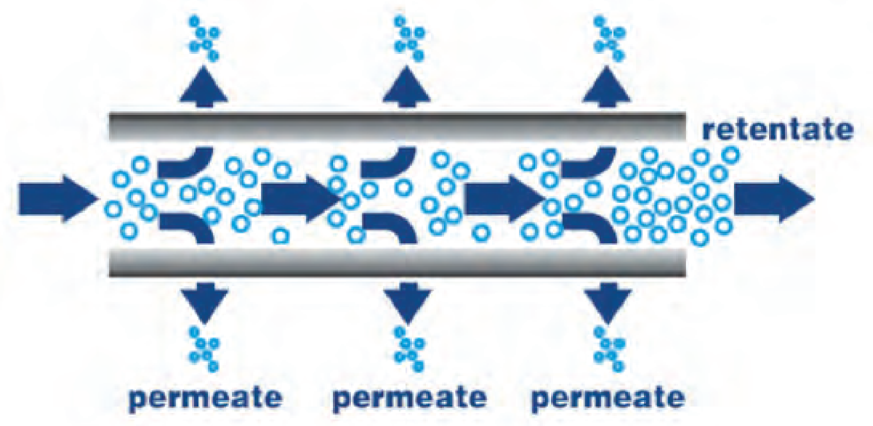
How it's Made

A Tubular Membrane is a filter that is produced in the shape of a hollow tube with the porous surface on the inside of the tube. Tubular Membranes can come in a wide range of sizes, from the diameter of a drinking straw — 1/4 inch (6 mm) — all the way up to the equivalent diameter of a garden hose, and everything in between. Through exhaustive testing and fluid dynamic engineering analysis, we have determined that the most efficient size tubular membrane has a tube diameter of one inch (25.4 mm). This configuration has the lowest pressure loss per linear foot at the required turbulent velocity. This allows for the maximum number of tubes in a series, which yields the maximum amount of filtration for each kilowatt (KW) of energy used.

An inside view of a Duraflow Tubular Membrane

To start, we create a support tube out of sintering plastic particles, that is uniformly porous both radially and length wise — water running through it will uniformly come out in all directions. Then, a fluorinated polymer called PVDF is used to form a membrane on the inside of the support tube. This material is extremely inert to chemical attack, meaning it won't break down when exposed to oxidizers or acids during membrane cleaning or when water that has chemical components filters through it. This membrane material is coated on to the inside of the tube as a liquid, and then the polymer is cured to create the final Tubular Membrane, one inch in diameter and six-foot-long.

The curing process causes the membrane to form small pores in the surface. This allows water to pass through the wall of the tubular membrane, while particles that are larger than the pores are rejected and filtered out. If these particles were to stick to the surface of the membrane on the inside of the support tube and accumulate as a layer, then the filtration rate of water would decrease very rapidly over time. So the tube is operated in a turbulent fluid dynamic condition, meaning water containing particles is pumped into the Tubular Membrane, pressure forces the water through the side wall membrane and the particles are rejected. They continue to be carried down-stream by the remaining turbulent water flow and exit the membrane tube. This describes the concentrating effect that occurs with the particles.



How a Tubular Membrane works to filter particles.

The Duraflow family of Tubular Membrane modules in a variety of sizes.

The final step in the product creation process is to glue multiple tubes inside a single plastic housing to create a module. There are membrane modules available inside 4, 6 or 8 inch diameter PVC water pipes (containing 4, 5, 10 , 14, 19 or 24 tube models).

A total filtration system is created by installing as many as 12 to 24 of these modules in series. They are installed in series to utilize the energy (hydraulic pressure) remaining after the water has flown through the first module, which is then used to feed to the second module, and then third, etcetera to maximize the efficiency of a system. The number of modules used varies based on the volume of water that needs to be produced — we work backward, determining how much volume the system as a whole needs to produce each day, and then we use the number of modules with the correct number of membrane tubes in series to create what is called a module train and if needed, use more than one parallel train to ensure that target can be successfully achieved.

The Filtration System

Once the system is created, it's time to put it to work. The first step in the process is the preparation of the water to be filtered to make sure the components to be filtered are in a particle form > 0.05 microns. Tubular Membranes work using a crossflow-filtration method. This means that the water containing the particles that need to be filtered out is moving parallel to the membrane surface. As it passes through the tubes, clean water passes through the membrane side-wall, which will catch the particles, preventing them from being in the filtrate. The clean water flows out of the filtrate ports on the modules and into the holding tanks. The turbulent crossflow keeps the particles from adhering to the membrane surface and allows them to flow out the ends of the membrane tubes. After all the pressure has been utilized, this reject flow is recycled back to the feed tank where the particles concentrate to 5% TSS before harvesting the solids, typically, using a filter press.

One important thing to note here: colloidal particles and dissolved chemical ions like salt, sugar, organic chemicals or viruses will still pass through the Duraflow membranes and will be included in the permeate liquid the system produces. This is why our Tubular Membrane system is designed to be used in conjunction with a Reverse Osmosis (RO) filtration system, which will continue to filter out the ionic and colloidal species producing better than city water quality for use in the manufacturing process. The objective with the Tubular Membrane is to remove things like dissolved heavy metals, hardness, silica, oil and COD from the water, which are all compounds than can foul (gum up) an RO system much faster. This Tubular Membrane system allows engineers to produce a higher volume of clean, usable water without needing to invest in additional RO units.

As the water passes through the Tubular Membranes, it is done so at a very specific pressure, known as the Transmembrane Pressure (TMP). To simplify, this is the amount of force the water needs to ensure the clean water passes through the pores, while the particles being filtered out are passed harmlessly down the tube and into the waste. The TMP is the difference between the pressure inside a Tubular Membrane and the pressure contained outside of the Tubular Membrane in the permeate collection piping. This is the driving force for filtration of the water. In a full system, you can have up to 20 tubes (or modules) in the series continuing to filter water as it moves through a module train. Each module has a different transmembrane pressure due to the frictional pressure loss that water undergoes as it flows down any pipe. Eventually you lose the required TMP for optimal filtration.

In a simple example, let's say we're pumping the water through the 1 inch diameter tubes at a rate of about 25 gallons per minute. This creates a velocity of liquid moving 2.8 meters per second through each Tubular Membrane filter. At this velocity, the water doesn't flow in a single straight line — it has turbulence, which forces the water and particles to continuously swirl around inside the tube. This is absolutely what we want to happen — to be effective, the system needs to have the water and particles all bumping into each other, forcing the liquid out through the pores, and forcing the filtered particles to continue moving through the tubes to the end of the system instead of depositing on the Tubular Membrane surface. Because this process is reproducible, it is now possible to predict the stable filtration rate that will result when a water stream containing particles is processed through our Tubular Membrane filter.

The end result is that the solution with the particles is up to 100 to 1000 times more concentrated than what it started at, and the filtered water is completely clear, with zero solids in it. It doesn't matter how murky or dirty the water going into the system might look; when it comes out of the Tubular Membrane process, it will look crystal clear and clean.

A Duraflow Tubular Membrane system installed and running.

There is an upper limit to the amount of solids you can push through the system before it becomes too thick and can't effectively pump through the Tubular Membranes. Think about the difference between a glass of juice and a milkshake — both of them have solids suspended in the liquid, but it is much harder to suck the milkshake through a straw than the juice. Ideally, the upper end of the concentration of solids to liquids in a solution being run through the Tubular Membrane process is about 5% solids to 95% water. That does not sound very concentrated but believe me it is really thick and dirty. See our video and see for yourself. Above that concentration, the flow of the water through the pipes is slowed and the velocity is reduced, which in turn allows the solids to cake up on the inside of the tubes, further slowing down the filtration rate of the water through the membrane side wall. But as long as the liquid to solid ratio remains in range, the system can continue operating indefinitely without issue. In a typical Tubular Membrane system application, unfiltered water with particles is fed to 20 Tubular Membranes connected in series from a tank with a pump, and 40% of the water is processed our as filtrate with no particles. The remaining 60% of the water containing all the concentrated particles is returned to that same feed tank. Over time the particles concentrate to the 5% level, and then must be removed for further processing. This mechanism for controlling the material balance will be discussed is greater detail in a subsequent article.

That being said, particles like oils, grease, chemical cleaners or bacteria can also impact the function of the membrane. These types of particles can form a slimy coating that will prevent water from passing through the membrane, that will cause the solid particles to adhere to the membrane surface, impacting the rate of filtration. The pumping velocity can be impacted by foam or viscosity as much as when mixture with too high a ratio of solids to liquids. One way to prevent this type of problem is by using a chemical pretreatment, which we'll address in depth in a future article in this series.

One of the biggest benefits to using Tubular Membranes as part of a larger filtration system is that it is incredibly predictable, and extremely reproducible. All particles bigger than 0.1 microns — that's 100% of those particles — will be filtered out of the system at a consistent flow rate and filter water quality, which then allows engineers to design an RO treatment process based on knowing the exact quality of the incoming brine, which in turn allows them to get maximum efficiency out of the RO system as well. Utilizing turbulence in a Tubular Membrane system results in a predictable, reliable and consistent water-production system that can then be used for a wide range of manufacturing processes.

About Us

Duraflow, which is headquartered in Tewksbury, Mass., manufactures Tubular Microfiltration Membrane products specifically designed for the harsh industrial environment. They are used for many industrial filtration applications because they can tolerate high levels of suspended solids, are easy to clean, have amazing chemical resistance and last a very long time. Our global infrastructure and uncompromising commitment to product quality and development has earned Duraflow its reputation for supplying world-class membrane technology around the world. Duraflow is an ISO 9001-2015 Certified Company.

Founded by Joseph Lander and William Matheson in 2003, the filters were created to satisfy the fast-growing global wastewater recycle demand. Duraflow works closely with its customers to provide consultation and support in analyzing project objectives and presenting the most practical, cost-effective solution to meet short- and long-term requirements.
Find out more.

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