An EconoPure™ White Paper

EconoPure™
Water Systems

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Point of Use/Point of Entry Treatment with LFNano™

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September 8, 2012

EconoPure™ Water Systems

EconoPure™ Water Systems designs and manufactures highly economical, scalable, low-fouling membrane systems. The Company leverages the proprietary low-fouling nanofiltration ("LFNano™") system consisting of a unique membrane element that is designed to avoid particulate fouling, biofouling and scaling. As the name suggests, the LFNano™ utilizes proven nanofiltration (NF) membrane technology and applies proprietary processes to enhance performance and decrease cost (both capital and operating). The LFNano™ requires much less pre-treatment and little or no process chemicals as compared to typical membrane systems. It provides the exceptional quality treatment associated with membranes, without the bother of extensive pretreatment systems.

Introduction

Treating water at the point where it is used or where it enters a building has become the standard in developing regions where publicly provided water is less than pure. Wealthier customers will treat the entire flow entering their homes (POE) and less affluent customers will treat just what is used for consumption or cooking (POU). These smaller treatment systems must be very flexible as water quality can be variable and simple to use as small systems generally suffer from poor operation and maintenance economics. EconoPure™ Water Systems has developed a simple treatment system that requires little operator attention and produces excellent water quality from most all source waters.

Problem Statement

High quality water treatment does not scale down well. The unit capital cost and the unit operating cost for these systems rises sharply as the system size gets small. As an example the Water Research Foundation published a cost study for various water treatment processes. The study covered larger systems but they highlighted the problem with downsizing water treatment processes.

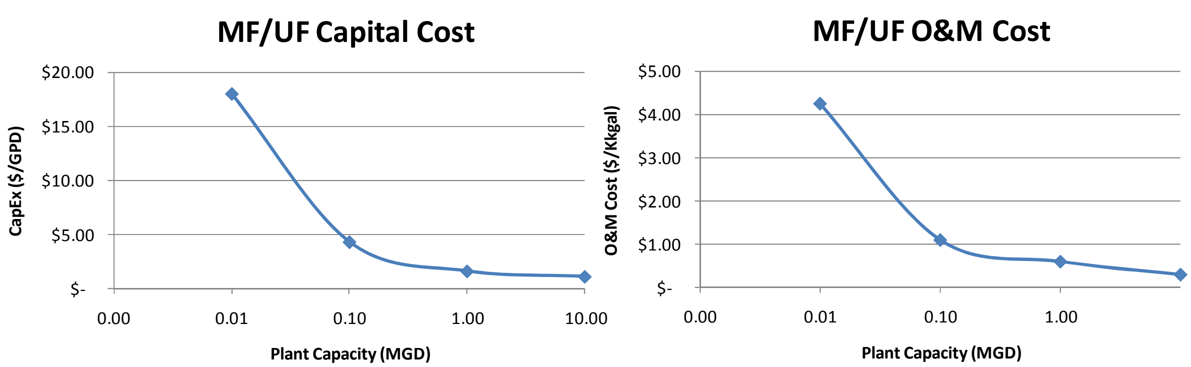

Figure 1 – Cost v. Capacity for MF/UF Treatment

Figure 1 shows the results of the unit costs of a microfiltration (MF) or ultrafiltration (UF) treatment process. Both the capital cost and the operation and maintenance costs rise precipitously at low output levels. This study also excluded operating labor which would skew the small plants unit cost even more. Though this study examined MF and UF membranes systems a similar cost curve for other technologies exists. A simple process is required to keep the unit cost down on the small end of the capacity scale. The LFNano™ from EconoPure™ provides that simple option.

Existing Options

Typically water treatment systems for POE/POU utilize wasteful and less effective cartridge filters. Some better systems employ reverse osmosis (RO) membranes to get the highest quality possible. However, existing RO membrane systems require removal of virtually all suspended matter ahead of the membrane step or they will clog (foul) quickly. Removing much suspended matter is simple and cheap but getting to the levels required by osmotic membranes is complex and costly. Figure 2 below shows (notionally) the relative costs for removing *much* suspended matter and *virtually all* suspended matter.

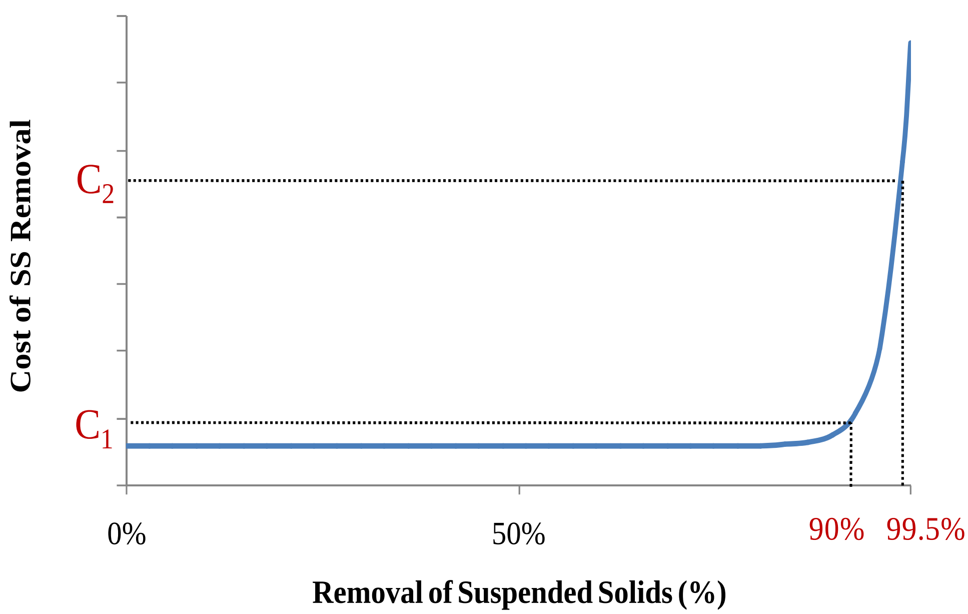

Figure 2 – Cost of Suspended Solids Removal (notional)

In Figure 2 the notional cost curve shows that removal of a lot of suspended solids from a source water is simple and inexpensive, shown as 90% removal and C_1 as the cost. Conversely most desalting steps require far more removal to operate efficiently. This is shown as 99.5% and C_2 as the cost, which is much higher than the cost (C_1) to remove 90% of the suspended matter. The LFNano™ from EconoPure™ can operate with far more suspended matter in the water than current membrane steps in most POE/POU applications. Also it will not require any process ahead of it. Traditional osmotic membrane systems today will either require an expensive pre-treatment step or the frequent (expensive) replacement of membrane elements.

Low-Fouling Nanofiltration (LFNano™)

The basis for the LFNano™ is the nanofiltration membrane or NF membrane. Figure 3 shows a range of physical separation technologies and what they can remove from the water. Most POE/POU systems go directly to reverse osmosis (RO) membranes which are excellent at cleaning up water but often are overkill and that can add significantly to cost. RO membranes are required only when very high salt removal is required. The NF will remove some salt, just not to the removal levels necessary for desalinating seawater and the like.

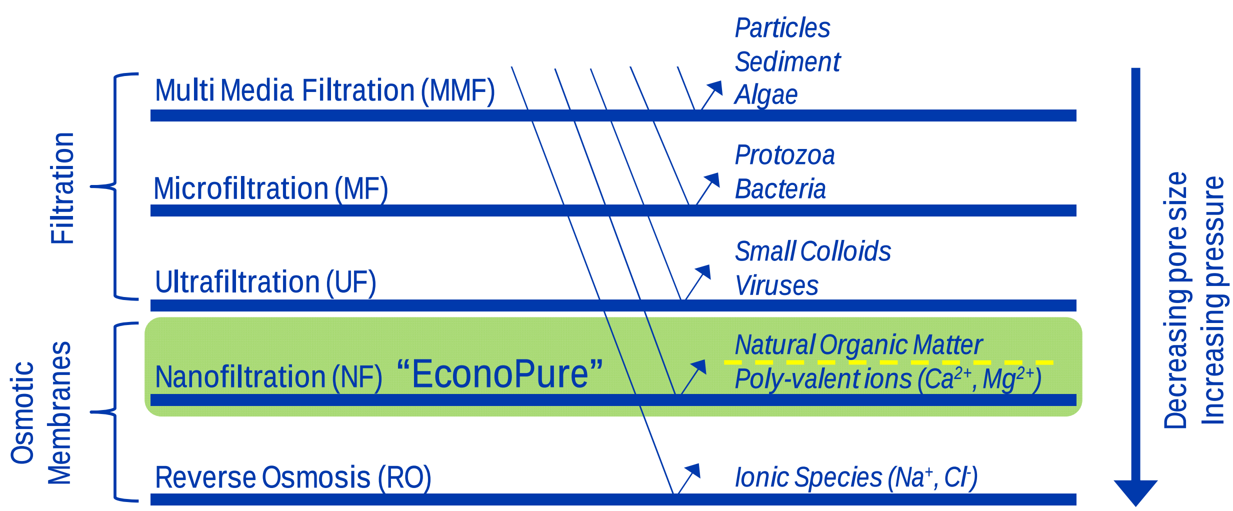

Figure 3 – Physical Separation Media Chart

Virtually all source waters require the removal of every contaminant in Figure 3 above the yellow dashed line and very few require removal of those below the line. With NF treatment the water achieves a high removal of natural organic matter without the high cost/pressure required for RO membranes. The LFNano™ avoids the fouling that occurs on traditional membrane systems making for a low maintenance, simple system

Fouling Avoidance

The LFNano™ avoids fouling in several ways. First, it has a unique spiral membrane design that creates consistent velocity past the membrane. This consistent velocity does not allow dead spots (low velocity) to occur where contaminants can deposit and grow. The unique membrane element from EconoPure™ has a parallel channel feed spacer eliminating the traditional cross-woven spacer that leads to low-flow spots and subsequent fouling.

Second, the LFNano™ benefits from a particulate coating on top of the membrane. The addition of particles to the membrane element is counter-intuitive as membrane systems strive to eliminate particles from the feed water. However, the LFNano™ can handle the suspended solids and the coating is comprised of high surface area particles such as diatomaceous earth or bentonite or zeolite. This thin coating (though many times the thickness of the active membrane) on the membrane can create a surface area above the membrane that is 700 to 1,200 times the surface area of the membrane. Tiny particles (called colloids) will adhere to the particles rather than imbed into the membrane. This keeps the fouling on the particles, which are easily removed, and away from the membrane. Figure 4 shows a schematic of this with microscopic view of the high-surface area particles on the membrane.

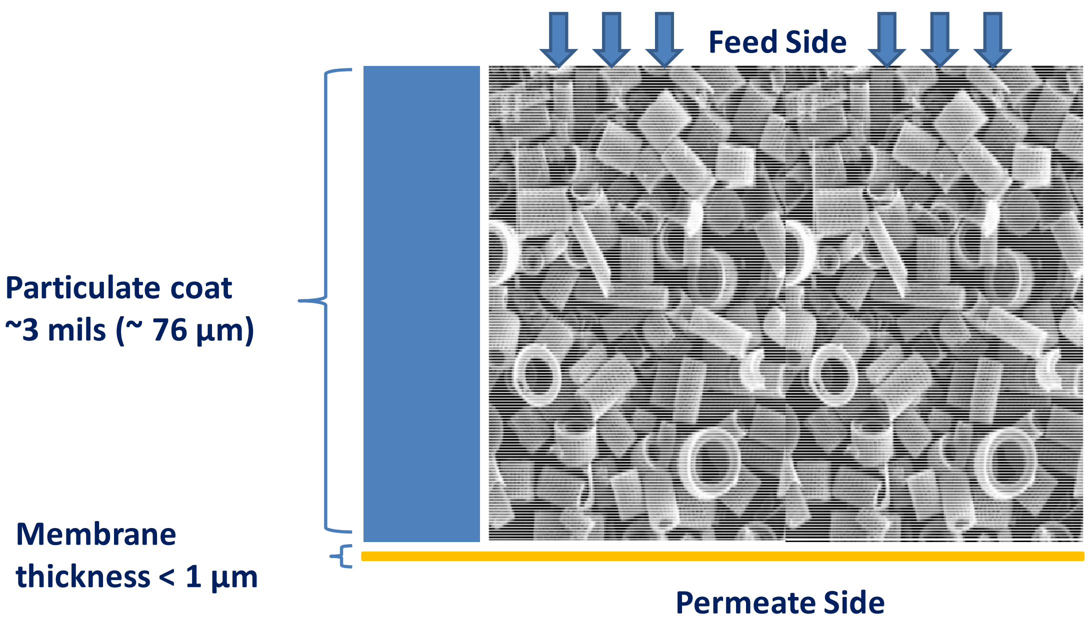

Figure 4 – Membrane with Coating

The smallest particles are trapped in the coating of these anti-fouling particles. Certainly the anti-fouling particles eventually get plugged themselves but that takes quite a bit longer than blocking the thin membrane surface. This slow rate of fouling as compared to the unprotected membrane creates the desired result.

Third, the LFNano™ benefits from a rest cycle that extends the performance and mitigates the effects of fouling. The rest cycle is an infrequent relaxing of the pressure difference on the membrane. This release of the differential on the membrane stops or slows the 'suction' pressure and allows the particulate coating to decompress and crack. This periodic decompression opens the outside of the coating that might be loaded with fine particulate. The particulate coat eventually becomes so full of contaminant particles that it must be cleaned off, but the interim rest cycles restore the flux considerably and flattens out the flux decline curve. Figure 5 shows some actual data from an LFNano™ system in operation. The chart shows the specific flux (measure of throughput) over time. The specific flux is a common measure of fouling as the contaminants block flow through and to the membrane. The downward slope indicates fouling, but the rest cycles partially restore the flux greatly flattening out the decline curve.

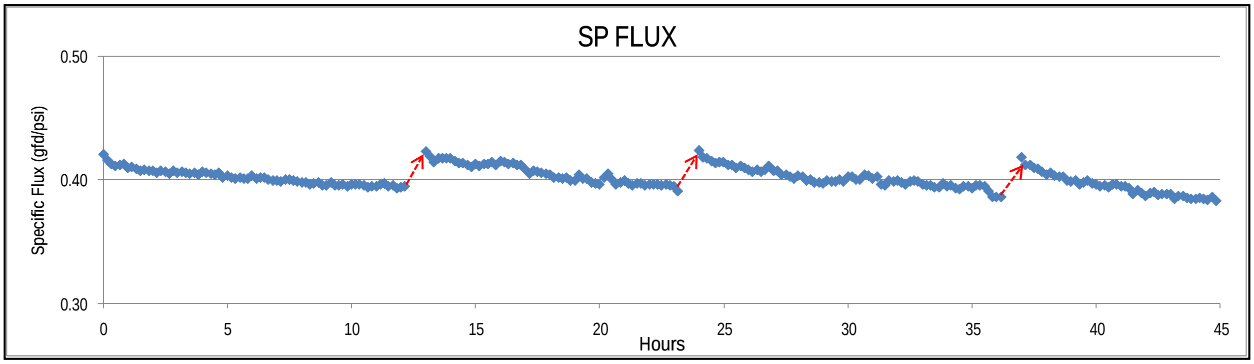

Figure 5 – LFNano™ Rest Cycle and Flux Restoration

The red arrows on Figure 5 show the effects of this rest cycle on the flux. Declining flux is how the fouling manifests itself and the restoration of the flux is the mitigation imparted by the LFNano™. The overall flux trend is still down (it is called the *Low* fouling nanofiltration not the *No* fouling NF) but far less so than without this system.

The rest cycle of the LFNano™ contrasts to the backwash cycle of a low-pressure filtration pre-treatment as a means of flux restoration. The ultrafiltration (UF) and microfiltration (MF) systems commonly used in drinking water treatment today require a frequent backwash cycle to maintain flux. This backwash cycle is a very mechanically complex process requiring seven (7) valves working together every 20 to 60 minutes. By contrast the LFNano™ rest cycle requires a single valve operated one to four times per day. The simplicity of controls and the reduction in maintenance is great. Figure 6 shows schematically the two processes with the automatic valves shown in red. Automatic valves represent moving parts and therefore potential points of failure.

Lastly, the LFNano™ benefits from a high, constant feed water velocity. The unique design allows the disconnection of recovery (ratio of permeate to feed flow) and velocity that plagues existing cross-flow membrane systems. The LFNano™ operator can choose the velocity to aid in keeping contaminant particles from fouling the membrane and still choose the recovery rate. This is something a once-through membrane system cannot achieve.

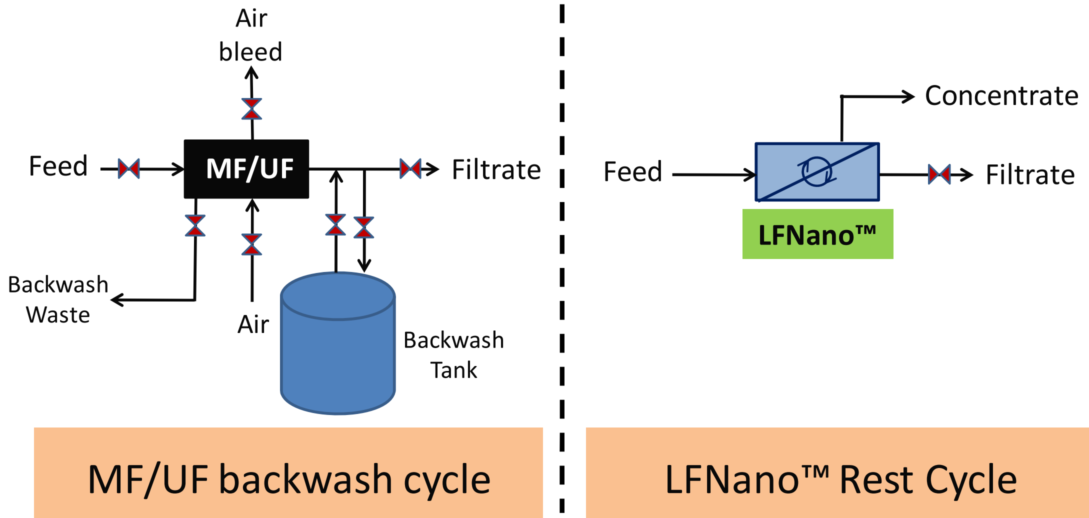

Figure 6 – Backwash Cycle vs. LFNano™ Rest Cycle

Water Quality

The water quality can be determined by the membrane selected. If the water is largely devoid of salt, a looser membrane will be adequate. If some salt removal is desired a tighter NF membrane can be used. If a lot of salt (like seawater) is to be treated, the 'loose' membrane is best to be used followed by a desalting RO membrane. The chart below shows the range of NF membranes available for the LFNano™.

Membrane	% $MgSO_4$ Rejection	% NaCl Rejection	Rejection Difference %
EPWS NF6A	99.5	90.0	9.5
EPWS NF5A	99.0	55.0	44.0
EPWS NF4A	98.5	35.0	63.5
EPWS NF3A	99.5	40.0	59.5
EPWS NF2A	99.5	46.0	53.5
EPWS NF1A	85.0	15.0	70.0

Chart 1 – Membrane Elements for LFNano™

Chart 1 shows the rejection of certain salts (NaCl and $MgSO_4$) to determine which is desirable for a given application. It is important to note that the rejection of salts even to low levels means the much larger organic molecules will be rejected completely resulting in an exceptionally clean water.

Energy
The LFNano™ can work at very low pressures saving energy as compared to traditional RO systems. Reverse osmosis treatment often takes out more than necessary from the source water. The pressure required to remove these additional minerals from the water is not insignificant.

BENEFITS
The benefits of the LFNano™ are summarized as such:

Benefit 1 - **Effective** – The nanofiltration membrane produces exceptional quality product water, removing nearly all contaminants to very high levels in one step. Alone, the NF membrane addresses all separation needs short of total desalting.

Benefit 2 - **Easy** – The low fouling nature of the LFNano™ system requires little or no pretreatment itself, minimal if any process chemicals and infrequent cleaning. The system is inherently flexible in adjusting to operational needs, flow demands and varying feed water quality. The system contains minimal valves and industry standard pumps. The result: a system that is easy to operate and easy to maintain.

Benefit 3 - **Economical** – The LFNano™ is the economical alternative to the high pressure, low output RO membrane systems on the market. The LFNano™ eliminates the need for extensive pretreatment, operational complexity, and frequent cleaning of current systems. Savings result from lower use of energy and chemicals and greatly reduced need for operator attention and skill.

The modular nature of the LFNano™ allows for custom-configurable systems to meet any requirement. Figure 7 shows a large POE system (for a large building or village) that treats approximately 20,000 gallons per day (3,300 liters per hour).

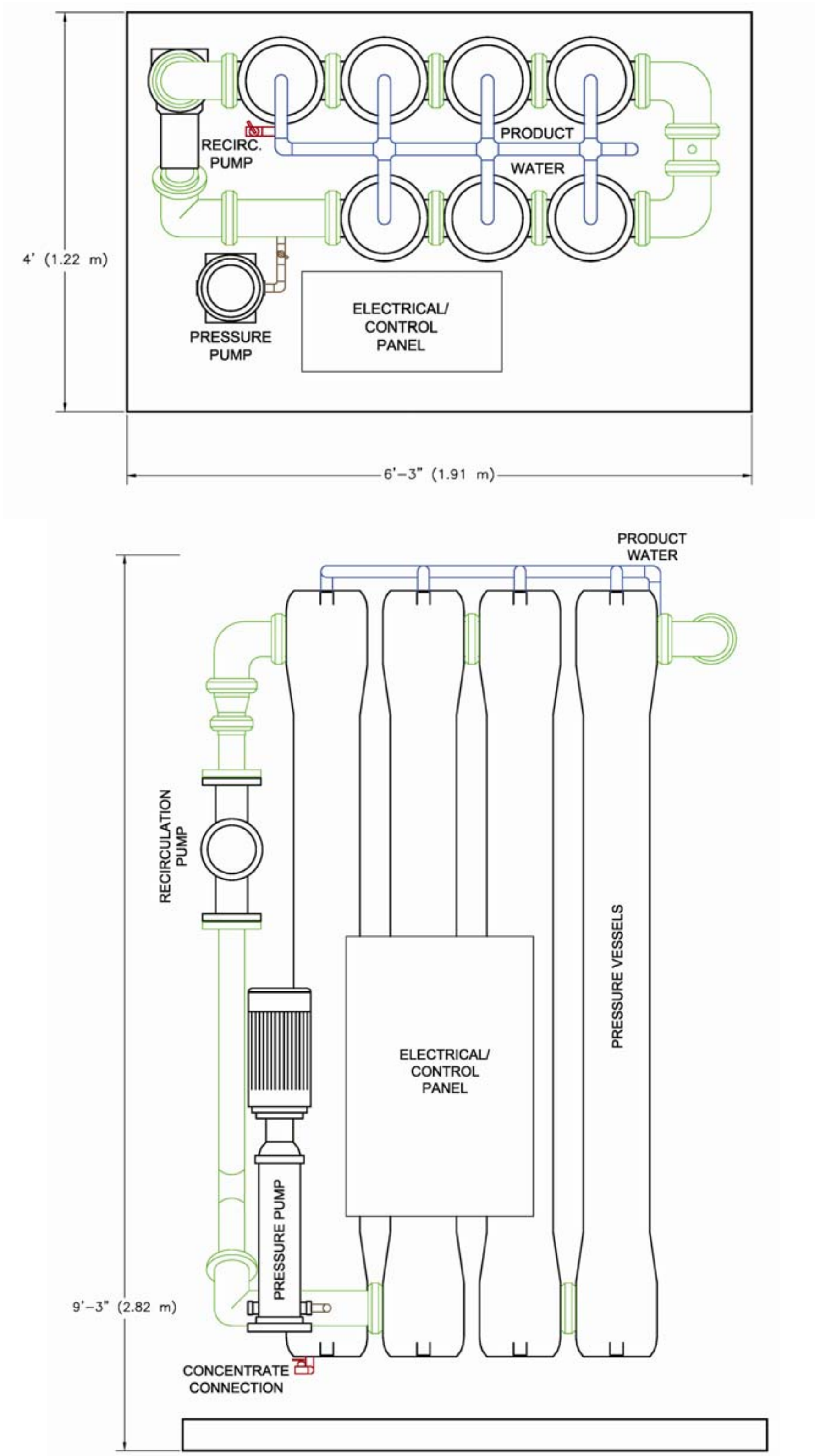

Figure 7 - Plan and Profile View of Seven-Vessel LFNano™ System

Summary

The LFNano™ by EconoPure™ Water Systems is an ideal solution for POU/POE applications. The NF membrane is the best possible separation medium short of desalting as it removes 'everything but the salt' allowing high quality product water without the destabilizing effects and flat taste of distilled water. In summary, the LFNano™ gives the following benefits for Point of Use (POU) and Point of Entry (POE) applications:

- Lower lifecycle cost and high level of drinking water treatment
- Lower energy use
- Lower chemical use
- Simpler operation allowing less operator skill and attention
- Compact size
- Can accommodate highly variable source waters with little adjustment

"The next great water technology company will be the one that finds a solution to membrane fouling."

Christopher Gasson
Editor, Global Water Intelligence
October, 2010