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ULTRAFILTRATION APPLICATIONS IN THE TEXTILE INDUSTRY

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INTRODUCTION

Ultrafiltration is a relatively low pressure membrane separation process through which an effluent stream is separated into two fractions - a concentrate fraction containing the bulk of macromolecules and suspended solids and a more dilute or permeate fraction. Capable of removing materials down to approximately 20 angstroms, ultrafilters are able to concentrate oils, waxes, latex, polymers, and certain dyestuffs such as indigo from textile wastewaters. Caustic salts, and detergents generally pass through the membrane.

For some applications the objective of ultrafiltration may be nothing more than volume reduction for subsequent waste treatment. In others, however, the objective is to recycle the concentrate fraction and/or the permeate fraction. From a financial standpoint, the recycle of either fraction not only reduces waste treatment costs, but often generates a significant return on investment through reduced chemical costs.

WARP SIZE RECOVERY

One such textile application is warp size recovery. The ever increasing production of synthetic fabrics and blends on high speed weaving machines requires the warp (lengthwise) yarns to possess high strength and abrasion resistance to reduce yarn breaks and loom stops. Lubricity is also desired to reduce wear of loom parts.

Toward this end, textile manufacturers apply synthetic sizing agents and waxes to the warp yarns in a slasher prior to weaving. Warp yarns are first dipped into hot solutions of sizing materials such as PVA, CMC, or WD. Add-on is controlled by regulating squeeze roll pressure, yarn speed, and size concentration. The yarns are then dried and forwarded to weaving. The fabric must then be washed to remove the size prior to further finishing.

While clearly jsutified by improved product quality and weaving efficiency, size use is both expensive and troublesome as they typically cost more than $1.00 per pound and their effluents are difficult to treat. Ultrafiltration offers an economical alternative to this expensive and wasteful practice.

The desize effluent can be separated into two recyclable streams. The concentrate stream contains the size, oils, and waxes which can be reapplied to warp yarns. The permeate stream consists essentially of hot water and detergent which can be returned to the washer. Waste treatment is virtually eliminated and substantial chemical, water, and energy savings are realized.

Gaston County has installed eight such systems recycling millions of pounds of size annually. PVA recovery installations require no further treatment beyond ultrafiltration. The concentrate includes both PVA and wax and may be used "as is" or in blends with virgin size. Eastman WD size recovery installations typically require further separation via centrifuge to remove excess waxes. Weaving efficiencies with recycled size equal that with virgin size. Both labor and energy savings are realized as compared to the "cooking" and bath preparation steps required for virgin size.

MEMBRANE PERFORMANCE

Size recovery applications require the utilization of membranes which are tolerant of lint and particulate matter, with wide pH ranges, and temperatures near 100°C.

Gaston County selected a 6 mm I.D. porous carbon support tube to which an inert and inorganic membrane is applied. Approximately 1000 tubes are assembled in a shell and tube configuration referred to as a module. Two modules are combined with a recirculation pump to form what is known as a LOOP. (Figure 1).

The de-size effluent is circulated through the inside of the tubes. Water and detergent permeate the membrane to the shell-side of the module leaving a more concentrated size solution in the loop.

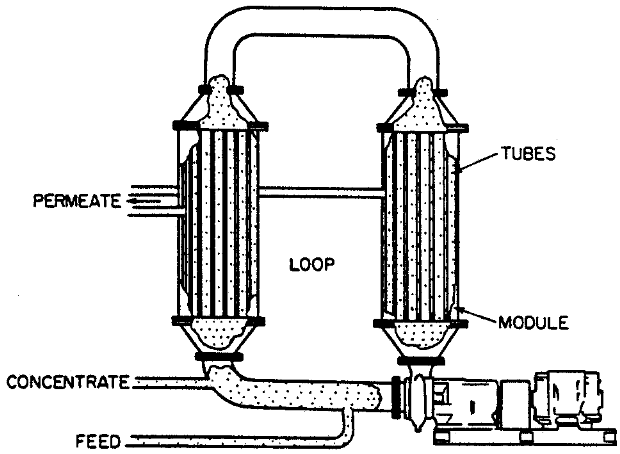

Figure 1. Typical membrane configuration for ultrafiltration.

The mode of filtration embodied is known as cross-flow filtration in which the effluent is circulated across or parallel to the membrane surface. Compared to the more common through-flow filtration in which an ever increasing layer of filtered material builds up on the surface requiring frequent cleaning or replacement, cross-flow filters tend to be self-cleaning as subsequent flows reduce the accumulation.

The rate at which water and low molecular weight species permeate the membrane is known as the flux rate and is normally expressed in gallons per square foot of surface area per day (GFD). Analagos to a D.C. electric circuit in which the current is proportional to the potential divided by the resistance, the permeate rate is similarly related to the pressure drop across the membrane divided by the sum total of resistances to flow (Figure 2).

Permeate flux usually increases linearly with increasing potential or available pressure drop. Gaston County loops are ASME code designed for 150 psig operation.

Resistance to flux is offered by the carbon tube, the

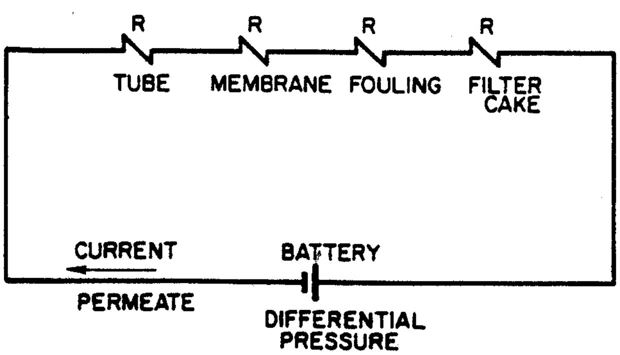

Figure 2. Permeate rate depends upon the sum of the resistance to flow.

membrane, fouling, and boundary layer filter cake or gel formation. Resistance of the tube and membrane are fixed by their selection. Fouling resistance gradually increases with time as iron, calcium, size or wax accumulates on the membrane. Periodic cleaning every 3 to 6 months is recommended using caustic soda, peroxide, and sometimes mild acid. The filter cake or gel layer resistance is determined by the materials being recovered, their concentration, and the circulation rate through the tubes. Resistance is reduced and flux rate enhanced by lower viscosity, lower concentration, higher temperature, and higher circulation rate. Minimum filter cake resistance is achieved in the loops by operation at approximately 100°C with a circulation rate of 1400 GPM.

RECOVERY AND YIELD

Approximately 96% of the size in the effluent is recovered by the ultrafilter. However, when one combines other losses such as loom shedding, de-size washer ineffiency, etc. with the 96% recovery efficiency, net recovery or yield is reduced to approximately 80% to 85%.

CONTROL MODES

The two major control modes are the batch and continous modes. Selection of the best control mode depends upon the flux curve and system size. In the true batch control mode, permeate is continuously removed while the loop concentrate is returned to the feed tank. This control mode yields the highest average flux and provides maximum benefit for small systems with sharply declining flux curves. The disadvantage is that multiple feed tanks are needed to reduce down time between cycles as one tank is discharged and refilled.

In the continuous control mode, the concentration level(s) in the loop(s) remains constant with time. Permeate is continuously withdrawn as in batch control. However, only concentrate at the desired final concentrate is allowed to discharge. The average permeate flux is below that of batch control. However, this deficiency is minimal in multi-loop installations and is justified by elimination of multiple feed tanks.

PVA RECOVERY

Now to take a closer look at a specific example. Let's assume a textile manufacturer annually applies approximately 2.5 million pounds of Dupont T-66 PVA in a 10% solution to polyester/cotton warp yarns. The woven fabric is de-sized in a three shift, 5 day per week operation yielding an average effluent of 60 GPM at 180°F and containing 1.2% PVA by weight.

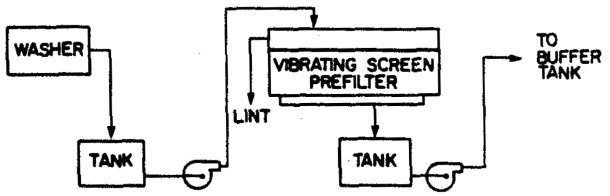

Figure 3. Desize effluent is treated to remove lint, etc., and stored in a high volume buffer tank.

With an approximate cost of $1.00/lb. of PVA, it is realized that this "wastewater" is worth 10 cents per gallon and that an ultrafiltration system would recover 2 million pounds of PVA annually.

A 12 loop ultrafiltration system is proposed. The desize effluent is collected at the washers and transferred to a 100 and 150 mesh vibrating screen prefilter for removal of lint and other large particulate matter. The effluent is then transferred to a volume buffer tank with a 4-8 hour holding capacity to allow independent operation of the washers and the ultrafiltration system. (Figure 3). A 25,000 gallon tank is selected and provided with a direct steam injection sparger to maintain the 160°F temperature needed to prevent bacterial growth. The effluent is overfed to the system at constant pressure via a pressurization and bypass control valve. (Figure 4).

The twelve loops would be arranged in two parallel six stage systems. The concentration of the final stage is monitored by a refractometer which prohibits the discharge of cencentrate until the desired 10% level required for slashing is achieved. The effluent is stage-wise concentrated such that the concentration in each successive stage is higher than in the previous stage. The average loop concentration is therefore considerably less than the 10% product level required and the capacity is markedly higher than if a single stage system had been designed.

Approximately 7 GPM of 10% PVA concentrate would be discharged to a concentrate storage tank. An output flowmeter and controller are provided as

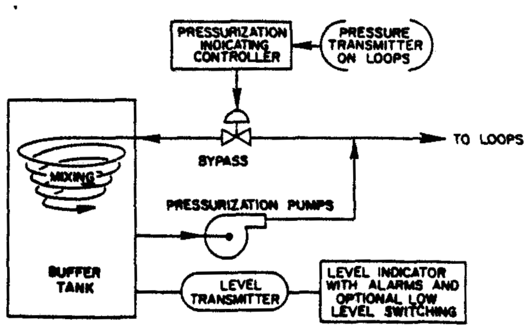

Figure 4. Effluent is overfed at constant pressure via a pressurization and bypass control valve.

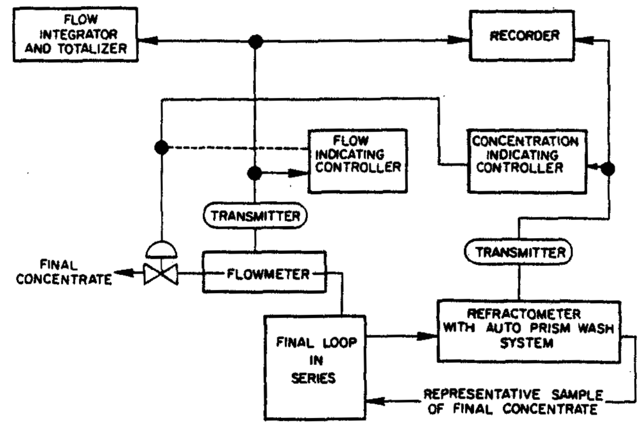

Figure 5. A central control panel provides all switches and controls functions.

back-up control for the refractometer. Concentration level is indicated and recorded. Concentrate flow is indicated, recorded, and totalized for system monitoring, efficiency reports, and inventory control. A central control panel provides all switches and control functions required for the system (Figure 5).

From the heated storage tank the concentrate is pumped either directly into the slasher room or to a tank truck for delivery to remote griege mills (Figure 6). Automatic batch delivery controls can be provided.

ECONOMICS

Principal equipment costs include the effluent transfer system loops, automatic controls, and miscellaneous valves and components. The cost of these items is estimated at $850,000. Installed costs can vary widely depending upon whether or not a new building must be constructed to house the system and the number of griege mill reuse locations. The cost of

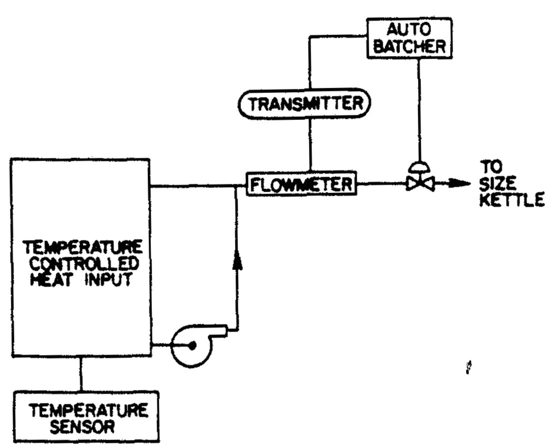

Figure 6. Concentrate is pumped either directly to the slasher room or a tank truck for remote delivery.

storage tanks and installation is estimated at 50% of the above for an installed cost of $1,275,000. This installed cost correlates to an investment of $0.64 per pound of PVA recovered annually.

Operating costs consist primarily of electrical power, labor, maintenance, transportation, and membrane replacement costs. The ultrafiltration system itself requires approximately 3/4 kwh per dry pound of PVA recovered. Transfer pumps, concentrate storage tank pumps, etc. will boost the total requirement to approximately 1 kwh/pound for a cost of $0.04/pound.

A full-time technician/operator is not required as automatic controls are provided. Operators are normally assigned additional duties, however, such as quality control, scheduling on shipments, and inventory control. Labor costs are estimated at $0.03/pound of PVA using 6,000 hours/year at $10.00/ hour.

MAINTENANCE COSTS ARE ESTIMATED AT $0.01/pound of PVA.

Transportation costs vary with the number of greige mill reuse locations and the distances involved. Using 4500 gallons per load, a 100 mile round trip, and a $1.50/mile cost of operating a tanker, the transportation cost is estimated $0.04/pound of PVA.

Membrane replacement costs are negligible. Loops installed 7 years ago are still in operation with the original tubes and membranes. The simple operating expense in this example totals up to $0.12 per dry pound of PVA recovered.

The principal savings from the system is realized from the PVA itself worth $1.00 per pound. Using this $1.00 per pound worth and the $0.12 recovery cost yields a net savings of $0.88/pound. Ignoring taxes and cash flow analyses, the savings of $0.88/pound will return the investment of $0.64/pound in 9 months.

Other savings not included in the above analysis include:

- Reduced cooking/slashing expense
- Reduced waste treatment cost
- Value of recycled permeate water and energy

The return on investment will vary with system size, warp size used, and other factors listed above. However, simple returns of less than 1 1/2 years are common.

We at Gaston County believe that warp size recovery is an excellent example of technology reducing our pollution problems while generating a profit rather than additional expense.

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