CSIRO
DIVISION OF WOOL TECHNOLOGY
GEELONG LABORATORY

Membrane Filtration of Wool Scouring Effluents

A new membrane filtration system called V-SEP (Vibratory Shear Enhanced Processing) was tested on several wool scouring liquors and rinse waters. The system, by creating a rapid torsional shearing action on the membrane surface, was able to prevent a significant build up of solids (wool wax and dirt) on the surface and in the pores. As a result, the unit was able to operate continuously without decay in flux rates (apart from an initial drop) and without the need for back-flushing or regular cleaning. Filtrate rates of 50 l/hm^2 for a 20% total solids concentrate and 150 l/hm^2 for rinse water were obtained which were, respectively, five and two times higher than the rates obtained from a conventional crossflow system.

C. SKOURTIS
C.A. BILLOWS

February 1994

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION

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INTRODUCTION

Previous investigations[1,2] have shown that micro/ultra filtration is a simple, reliable and effective method of producing clear waste waters free of grease (wool wax) and suspended solids. The problem so far has been the fouling of membranes, either on the surface, in the pores or both. The gradual drop in the filtrate rates with time means that the system has to be shut down on a regular basis and the membranes cleaned with chemicals, leading to significant operating and maintenance costs. Also, some systems are suitable for treating low viscosity effluents such as rinse waters but not for concentrating strongflow liquors. The system investigated in this report is a new process developed by New Logic in Emeryville California and was designed to solve the problem of membrane fouling. As suggested in the V-SEP name (Vibratory shear Enhanced Processing) the system works by creating intense shear waves on the surface of a vibrating (torsional motion) membrane leaf filter element. The feed slurry remains nearly stationary moving between parallel membrane leaf elements, which move in a rapid vibratory motion tangent to the face of the membranes. The theory is that the shear waves produced by the membrane's vibrations causes solids and foulants to be repelled and liquid to flow to the membrane pores unhindered. Because the shear force is not produced by the bulk flow, very high solids concentrations can be achieved.

OBJECTIVES

The material of this report is based on the following three objectives:

I. To determine whether the V-SEP membrane filtration unit can treat wool scouring rinse water and strongflow liquors at high solids concentrations and with effective solids removal.

II. To test the ability of the V-SEP system to resist fouling and attain filtration rates higher than those of crossflow systems, as stated by the manufacturer.

III. To determine the cost effectiveness of the V-SEP system compared to present treatment methods by DCF rate of return calculations.

EXPERIMENTAL

The apparatus is illustrated in Figure 1. Strongflow liquor or rinse water was pumped from the feed tank (1) via a high-pressure pump (2), through the V-SEP filtration unit (3) and back to the feed tank. The filtrate was directed via the three way valve (4), either back to the feed tank for constant solids tests or to drain if operated in concentration mode. Feed rate was controlled by frequency speed control on the pump and the exit pressure (6) controlled by a needle valve (7) from 0 to 250 psig.

Liquor was kept at the desired temperature by an electric heating coil (8) submerged into the feed tank and temperature monitored by a thermocouple indicator (9). The degree of oscillation or amplitude of vibration of the membrane tested was adjusted by frequency control on the V-SEP unit front panel according to the manufacturers manual.

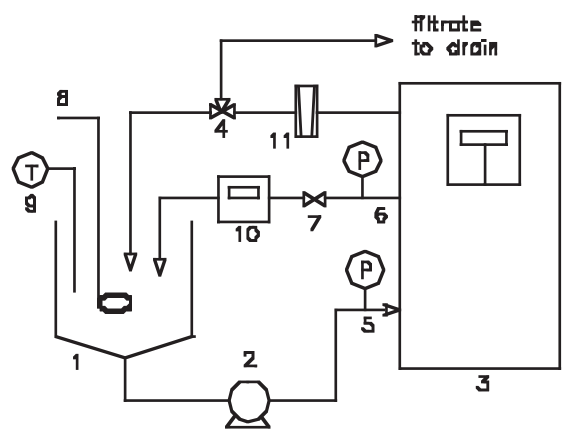


Figure 1. Diagram of experimental apparatus

1. Feed and recirculation tank
2. Feed pump, Hydracell triple diaphragm
3. V-SEP series L test unit, membrane area: 0.5 sq ft
4. Three way valve for filtrate flow direction
5. Liquor inlet pressure gauge
6. Liquor outlet pressure gauge
7. Valve for adjusting filtration pressure
8. Electric heating coil
9. Thermocouple temperature indicator
10. Magnetic flow meter for recirculation flow
11. Variable area flow meter for filtrate flow

RESULTS

Figure 2 is a plot of filtrate rates against recirculation liquor total solids concentration for several effluent streams using a 0.075µm polypropylene membrane. Results are shown adjusted to 25 °C using water viscosity charts to enable comparison between trials. Tables 1 & 2 summarise the analytical results for solids removal obtained for several strongflow liquors and rinse waters. Figure 3 shows the results obtained for a concentrated strongflow liquor (18% TS) operating in constant solids mode for a period of approximately ten hours. Trials were also conducted using Kynar, Teflon and polypropylene membranes supplied with the V-SEP unit, however the results are not presented here as the polypropylene membrane was significantly superior in both flux rates and fouling resistance.

DISCUSSION

a) Strongflow liquors

The strongflow liquors treated were easily concentrated to 25% total solids with no pumping or filtering problems. Further concentrating could have been achieved but was limited by the sludge volume. As shown in Figure 2 the filtrate rates were found to linearly decrease with increasing total solids concentration and the relationship to be essentially independent of liquor type. In contrast, results obtained from a crossflow system[1] showed much lower filtrate rates (at the same temperature) and a rapid drop in the lower concentration range. Maximum attainable concentration for the crossflow system was only 18% TS and at one-fifth the filtrate rate of the V-SEP system at the same concentration. Temperature effects were significant with a rise from 25 to 50^{0}C giving a 60% increase in flux rate. Solids removal was very good with rejection factors (Table 1) in the range 87.9-99% for grease, dirt, TS and COD and 2-10 % for suint (water solubles).

b) Rinse waters

In this trial about 40 litres of rinse water at 0.1% total solids was concentrated down to about 12 litres giving a final total solids concentration of 0.3%. The results for solids removal shown in Table 2 show that an average rejection of 89% was obtained for grease and dirt while only 8% was obtained for suint. Average COD rejection was 26%. Flux vs concentration results plotted in Figure 3 were found to lie essentially on the same line drawn for the strongflow liquors showing that the total solids figure is a good indicator of the expected filtrate or flux rates. The V-SEP flux rates for rinse waters (low TS) was almost double the rates obtained with the cross-flow system on similar liquors.

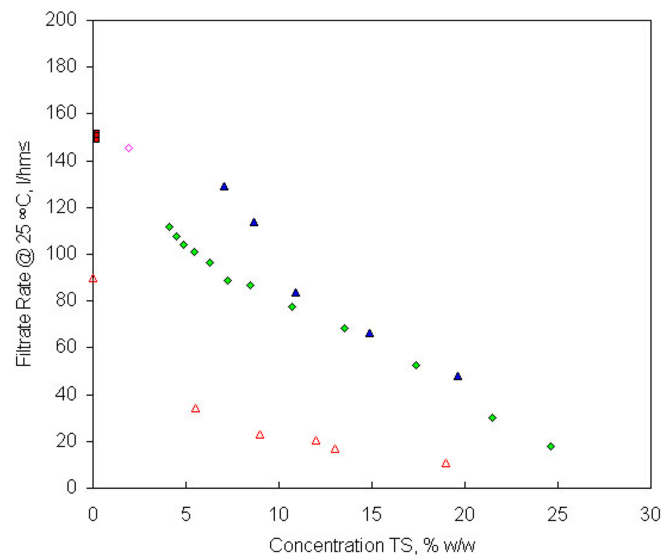


Figure 2. Plot of filtrate rates against recirculation liquor total solids concentration for different effluent streams.

A.Results obtained by the V-SEP system on various scouring liquors of differing compositions. Adj. To 25°C
B.Actual results from A obtained at 50 °C.
C.Results[1] obtained from a Dorr-Oliver crossflow system with Iopor XP24 membranes at 25 °C.

Table 1. Summary of strongflow liquor filtration results

COMPONENT	FEED CONC% w/w	FILTRATE % w/w
GREASE	12.0%	0.23 %
SUINT	2.3%	2.3 %
DIRT	10%	0.15%
TOTAL SOL.	24.3%	2.4%
COD	330,000 ppm	43,000 ppm

Table 2. Summary of rinse water filtration results

COMPONENT	FEED CONC% w/w	FILTRATE % w/w
GREASE	0.04%	0.01 %
SUINT	0.12%	0.11 %
DIRT	0.13%	0.00 %
TOTAL SOL.	0.29%	0.12 %
COD	330,000 ppm	43,000 ppm

c) Membrane fouling

The results of the ten-hour trial operating at 18% total solids (Fig. 3) showed that the filtrate rates remained essentially constant over that period. Examination of the membrane under an electron microscope (Fig. 4) after the trial revealed that no plugging of the pores had occurred. Rather, a thin amorphous layer of solids (dirt, protein, scale and grease) had formed on the surface, which appeared in most areas to have pealed away leaving the clean membrane This was evident by the fracture line in Figure 4. The results suggest that after an initial flux decay with a clean membrane, there is an equilibrium established where the rate of deposition of solids on the membrane equals the rate of solids removal as the membrane vibrates. With cleaner effluent this equilibrium takes longer to achieve.

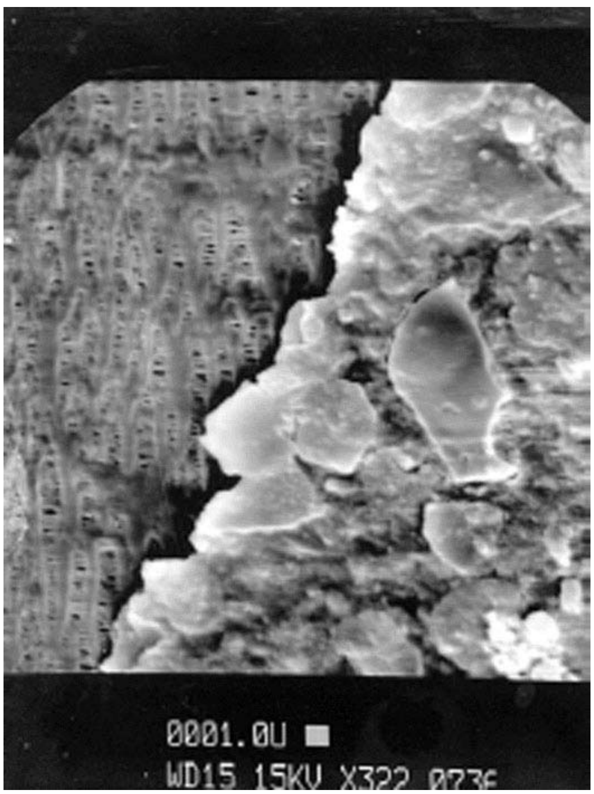
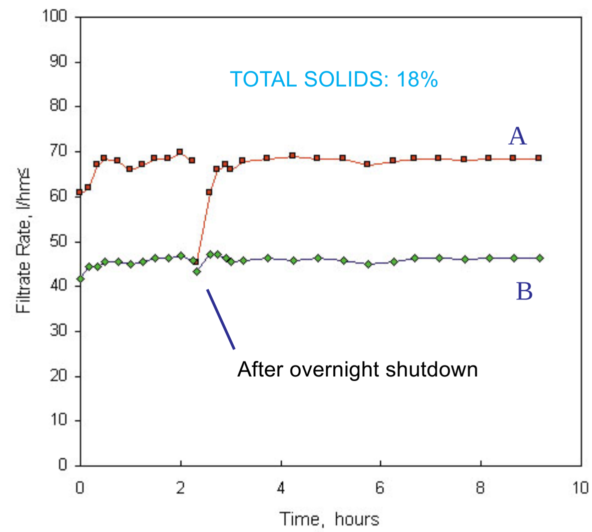


Figure 4. SEM photograph of a 0.075 µm polypropylene membrane after filtering strongflow liquors. Feed side showing fracture of a solids layer section leaving clean membrane. Scale: 3mm= 1µm



A. Actual filtrate rates obtained with a mean liquor temperature of 45°C
B. Filtrate rates from A corrected to 25 °C

Figure 3. Liquor constant solids test.

ECONOMICS

An economic analysis was made of using the V-SEP system in several different processes by the discounted cash flow method. Calculations were based on a conventional scouring line producing 4200 litres per hour of strongflow effluent at about 5 % total solids and using the V-SEP unit to produce a sludge of 25% TS. Descriptions of the processes and results of the analysis are presented below. Note that the results of the economic analysis are dependent on the assumptions that are listed in the Appendix. Table 3 is a summary of the results obtained from the economic analysis calculations using the DCF method over a ten year period.

(1) Sludge incineration

In this process the filtrate is disposed of and the sludge incinerated in one of two ways; (a) incineration in an external incinerator at a charge of 4 cents per kg or (b) incineration in an in-house incinerator with a cost of $350 000 plus $20 000 pa operating cost. The ash produced is disposed of in the same manner as conventional sludge as in (a).

(2) Acid treatment process

This process requires heating the sludge to 95^{0}C and centrifuging in a disc centrifuge to recover wool wax (60-65%) followed by acidification to about pH4 with sulphuric acid. Decanting the liquor produces an aqueous phase containing mainly suint and a sludge phase which are both disposed of in the sewer. The economics of this process is highly dependent on the sale of recovered wool wax which is of a lower grade than that recovered by the primary centrifuge. Figure 5 shows pay back periods for this process as a function of crude wax selling cost.

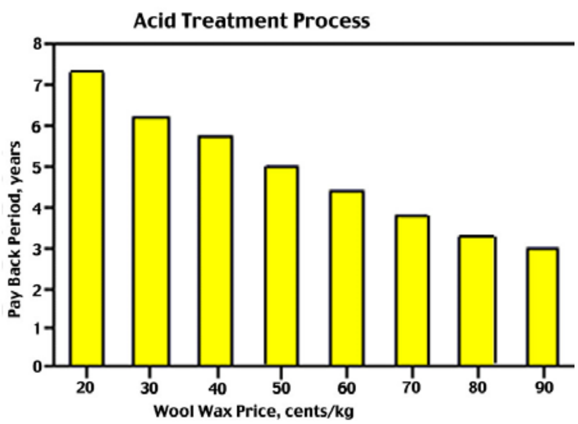


Figure 5. Effect of crude wool wax price on the pay back period for the acid treatment process of sludge produced by V-SEP filtration.

(3) Rinse water treatment

In this process rinse water is filtered and recycled while the solids are continuously collected and concentrated in the recycle stream of the V-SEP unit. Savings are made in water usage cost and volume disposal charges.

Figure 6. New Logic's patented V-SEP membrane filtration system.

Process	Savings $1000/yr	CDF %return	Payback, yrs
Incineration In-house	151	6.7	7
Sludge/Acid	151	16.4	6
Rinsewater	86	8	4.5
Incineration External	92	5.55	8

Table 3. Summary of V-SEP economic analysis as at Feb .1994

CONCLUSION

The V-SEP microfiltration system is a simple and reliable means of treating strongflow and rinse-water scouring effluents. The vibration mechanism designed to prevent membrane fouling was effective over a wide range of solids concentrations with no noticeable drop in flux rates when operating for long periods at constant solids concentration. Filtrate rates were significantly higher than those obtained by a conventional cross-flow system (up to five times higher) and with the added benefit of not requiring back-flushing or regular cleaning. At the time of writing this report, the best economic outlook for the V-SEP process unit appears to be either in the rinse water treatment or sludge/acid treatment process where an income is made from the recovery and sale of wool wax. Pay back periods, however are likely to be shorter in the future as effluent disposal cost increase and new ones introduced.

ACKNOWLEGMENTS

This work was performed under a grant from the Wool Research and Development Corporation whose assistance is gratefully acknowledged. The author would also like to thank Mrs R. Connolly for her assistance with the analytical work.

REFERENCES

1. Pearson A.J.C. et al.; "Ultrafiltration of Wool Scouring Effluents."
2. Anna E.Wildegger-Gaissmaier.; "Application of Crossflow-Microfiltration on Scouring Rinse Water."

APPENDIX
V-SEP Process Economic Evaluation Assumptions

07-Feb-94

ECO 2

Disposal Charges	
Volume, ¢/kl	28.7
Suspended Solids, ¢/kg	15.1
BOD, ¢/kg	30.7
Sludge incineration*, ¢/kg	3
Sludge land fill*, ¢/kg	4.65

*Estimate. Includes transport

Production	
Operating hours pa	5520
Strong-flow rate*, l/h	4200
Rinse water rate, l/h	10395

*Includes decanter feed

Other	
V-SEP capital cost*	240,365
Other capital costs	20000
Labour cost pa per man	24000
Add. man hours/shift	1
Sulphuric acid 98%, $/l	0.69
Lime (CaO) cost, $/kg	0.26
Grease recovery, % w/w	60
Low grade wool wax, $/kg	0.4
Wool wax transport, $/kg	0.24
Company tax rate, %	39
Depreciation rate, %	13.33

* One series I units, 1300 sq.ft each.

Analysis	Strong**	Rinse
Grease	2	0.04
Suint	1.3	0.01
Dirt	2	0.04
BOD* ppm	19755	538
V-SEP filtrate BOD*	3305 ppm	
V-SEP sludge TS	30 %	
Avg. effluent TS †	5.3 %	

* Calculated † Not including rinse water

** Combines decanter effluent and strong flow effluent

Utilities	
Electricity, ¢/kwh	7.89
Water, $/kl	0.45
Gas, $/GJ	4.13

Power Usage	kW
Disc centrifuge	11.8
V-SEP vibration motor*	8.0
V-SEP pump*	6.0

In house incineration option	
Capital cost*	350000
Ash disposal cost, ¢/kg	4
Operating costs*, pa	20000

* Estimates