

**High Permeability Crossflow Filtration Systems for Low Cost,
Minimum Size Liquid Waste Volume Reduction Equipment
Compared and Contrasted with Evaporation as a Final Separation Treatment -- 9550**

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ABSTRACT

A standard method of liquid waste volume reduction is the use of crossflow filter systems, which use the mechanism of keeping the accumulating solids from the waste stream in suspension in a recirculating loop at a velocity high enough to keep the solids in the stream suspended, whilst allowing clean liquid to permeate at a much lower velocity through permeable filter tubes.

Such systems provide remarkably fine liquid/solids separation typically these systems use low permeability materials that exhibit inherent, very fine filtration ratings when directly challenged. The penalties imposed by the use of such materials include high trans-membrane differential pressures, large recirculation ratios (and therefore heavy pump power requirements) and very low flow densities through the filter tubes. All of these things result in large size and high cost, both in capital and running terms.

By using smaller diameter, high permeability filter tubes, trans-membrane differential can be reduced to a minimum, so high flow densities are achieved (controlled by throttling the permeate instead of throttling the recirculating loop as in the case of low permeability tubes), resulting in fewer tubes which translates into smaller recirculation rates, smaller size and lower cost.

At the extremes, low permeability tube systems have, in tests, demonstrated a need for recirculation ratios as high as 1000:1, whereas, actual operating experience with high permeability tubes has shown recirculation rate of 2.4:1 with “no detectable solids or activity” can be achieved.

The economic balance between the use of crossflow systems and evaporation (with filtered vapour removal, prior to condensation) is affected by the possibilities presented by high permeability crossflow systems.

The paper will present actual operating experience of both low and high permeability systems, with separation performance data, recirculation ratios and physical size being noted.

Additionally, an economic comparison between crossflow volume reduction systems (which will include consideration of the final treatment of the thickened sludge from crossflow systems) and evaporation (which will include the cleanliness of the resultant condensed liquid and a review of the possible condition of the evaporator output) will be presented.

INTRODUCTION

In the late 1980s and early 1990s, a UK nuclear fuel producer collaborated with Microfiltrex (then a part of the Fairey Group of Companies, now a division of the Porvair Filtration Group) to find a solution to the problem of solids carryover in its final grinding coolant recirculation.

By definition, final polish particles will be extremely fine (possibly of single microns and smaller) and of a variety of shapes. The sheer quantity of solids present obviated the use of dead-end type, disposable cartridge filters, and it has been proven time and again in practice that whilst great claims are made for back flushing type liquid filters, they rarely if ever live up to their promise and are notoriously fickle to flow changes in conditions.

Centrifuges were considered as a viable solution, but their size, cost, energy consumption and high level need for regular maintenance militated against their selection. That left crossflow filters as the most practical solution, except that, at that time, the most effective crossflow systems in use, used very low permeability filter tubes (typically made from sintered metal powders) which were often as much as 15 mm (3/4") in diameter.

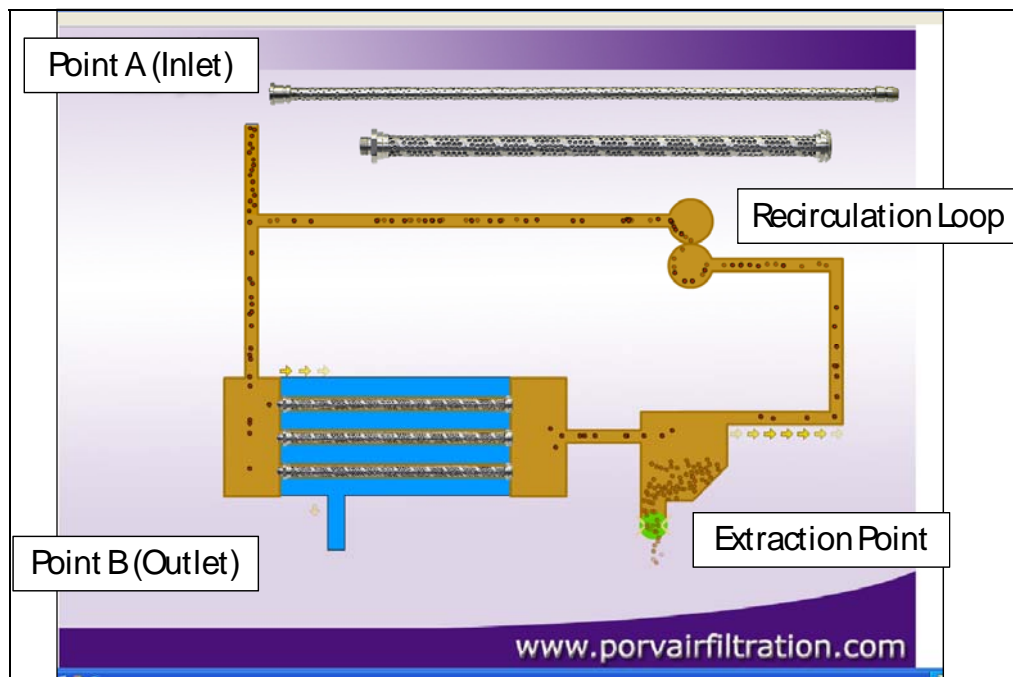


Fig. 1. Simplified schematic of a typical crossflow filter.

Solids laden liquid is fed into the system at point A. Clean liquid (at the same flow rate) is extracted at point B. In between is the filter itself and the recirculation system; Fluid is recirculated in the recirculation loop accumulating the solids being fed in at the inlet to the system until they reach a sufficient concentration to warrant extraction. The extracted solids, in the form of a sludge, can then be further processed. In some systems the amount of liquid retained in the sludge is a function of the water necessary to allow cementation (allowing dry cement to added to the sludge and mixed), so the output (not the cleaned effluent, but the solids bearing sludge) can be considered as fully processed at the point of extraction. However, for other final conditioning routes, further drying may be necessary so that, for instance, the produced solids are suitable for immobilisation by vitrification. Typically, these further drying processes are thermal, often at elevated vacuum to reduce the heat input required to provoke evaporation. Such thermal processes may exhibit an additional advantage however. Anecdotal test results on simulated liquid waste dried in under vacuum, evaporating the liquid fraction and then recondensing it downstream of a fine filter, suggest that the condensate was effectively activity free.

Microfiltrex low permeability crossflow tubes not only have a permeability some tens of times higher than the typically used (especially sintered powder) tubes, but, as they are fabricated and not pressed in moulds, can be produced in diameters as low as 9 mm (3/8"). This is important as crossflow filters depend for their efficiency on the velocity at which the solids are carried around the system. The velocity in the tubes must be high enough that the largest particles are held in suspension (so that, by definition, the smallest particles – the normal challenge in filtration – are also held in suspension) and do not challenge the filtration media. For the same number of filter tubes of the same permeability, the smaller diameter reduces the rate at which the fluid must be pumped round system, reducing energy costs.



Fig 2. Typical, fabricated high permeability crossflow tubes with various end connections.

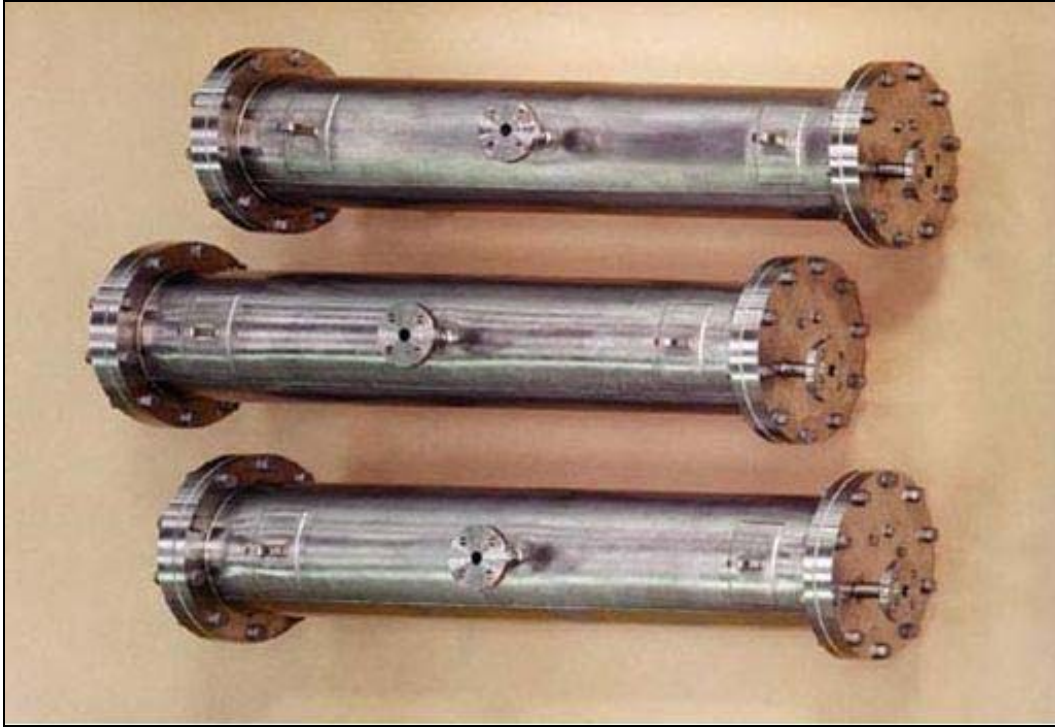


Fig. 3. 1 M³/hr output fuel grinding coolant crossflow filter modules. Approximate overall length is 50", diameter is approximately 10".

However, as secondary function is also at play. The permeability of the tube itself. Low permeability tubes require a significant DP across them (the 'Trans membrane Differential') to drive the clean liquid permeate through them.

High permeability tubes do not require these levels of driving force. Indeed, the fundamental difference in operating crossflow systems with high permeability tubes compared with those using low permeability tubes is that the system has to be choked at the clean permeate outlet with HP tubes, in order to prevent at the flow dewatering in the tubes and blocking them immediately upon start up, as opposed the LP tube system which requires the system to be choked downstream of the filter bundle in order to maximise the driving force across the filter medium and delivering clean permeate.

The combination of low trans membrane differential, reducing the flow area required to achieve the required permeate rate and reduced transverse area on the smaller tube, allowing for fewer tubes and a shorter filter path to be employed, saves both cost, space and energy.

OPERATING REGIME

Two primary considerations need to be borne in mind when considering the applicability of high permeability crossflow tube. The first is the consequence of tube blockage, leading to a dead end (blind) effect across the tube. Challenged with a direct pressure head, high permeability crossflow tubes will not offer the 0.2 or 0.5 micron absolute rating claimed by low permeability tubes. Typically, high permeability tubes are depth type media, but with a sufficiently fine matrix that they exhibit an extremely tortuous path to penetrating particles. High permeability tubes tend to be more surface type media, but

their very thin section and coarse supporting substrate, coupled with the very thin section of the surface control layer offer very little resistance to particles passing through the medium if the transverse velocity is slowed or stopped, or the trans membrane differential is increased dramatically (both of which phenomena will occur if the tubes in the filter dewater the recirculation loop rapidly and block). Another paper presented in this session looks at the challenges presented by the declogging of crossflow filter systems once they are blocked or blinded. In the present case, however, the concern being addressed is not to how to solve the problem of the blocked filter, but to mitigate its consequence – the passage of particles through the medium and into the clean stream. This is simply solved. In many process filtration applications (particular high temperature, gaseous applications, the use of secondary protective filters (or ‘fuses’ in the jargon) installed downstream of the main filters. Typically these are much smaller than the process filters and much coarser. Their job is to stop the solids passing the failed filter elements and to blind quickly. In the case of crossflow filters, though, a better option is to have a guard filter with a 0.2 or 0.5 micron efficiency that, under normal circumstance, would never see any solids. If a tube blocks or starts to bypass for any other reason, the dirt holding capacity of these very fine filter is so low that they will block virtually immediately, giving an almost immediate DP alarm of the failure, allowing mitigation to take over, but preventing absolutely any contamination downstream.

The second consideration which needs to be taken into account is the operating method for the high permeability crossflow filter tube. It differs diametrically from that used for the low permeability, conventional tube. By definition, low permeability media require high motive forces to pass fluids across them. In crossflow filtration terms this equates to the trans membrane differential. In conventional systems, a trans membrane differential capable of driving liquid through the medium is achieved by throttling the recirculation flow after the filter tube module. Throttling this flow against the recirculation pump results in a backup pressure in/across the tubes, but also requires additional motive force given to the inflowing solids laden fluid flow.

The high permeability crossflow tube obviates this problem, as the trans membrane differential must be kept to a minimum, requiring the clean permeate, not the recirculation flow, to be throttled. The consequence of this is two fold. First, a smaller filtration area is required as flow density through the tubes can be maximised (indeed, needs to be restrained), which means in effect fewer tubes, and fewer tubes means less recirculation volume is required to maintain suspension velocity in the tubes that the user does need, so recirculation pump rates are reduced. Add to that a final benefit, that of the fabricated tube having a typically smaller diameter as compared with the isostatically or mould formed tube, and this flow/velocity advantage is further developed.

CONCLUSION

Industrial use has proved that high permeability/lower absolute efficiency crossflow tubes fabricated to small diameters from sintered metal fibre have exhibited very low recirculation rates, when compared with low permeability/high absolute efficiency tubes pressed from sintered metal powder or other materials.

Lower recirculation rates, in the recirculation loop, result in smaller size, lower cost, and considerable energy savings.

The issue of particulate breakthrough at the lower efficiency tube material, either by blockage or failure of the tube can be addressed by the use of very high efficiency guard filters installed immediately at the permeate discharge. Since, in normal service, the guard filter should never actually see particulate, then it should be a life of plant item. However in the event of a failure, it will protect the downstream system and

provide an almost immediate indication of failure of the crossflow unit. as it will blind and its DP increase rapidly. DP can be monitored and used as an alarm signal.

That being the case, it is suggested that such guard filters should, anyway, be installed on the outlet of critical crossflow systems to provide just this service. Should that suggestion be taken up, then, the main argument against high permeability, crossflow systems, that they have low absolute efficiency in a dead-end situation, is obviated.

Careful design, installation and operation of high permeability crossflow systems with appropriate breakthrough protection can reduce the size capital cost and running cost of dewatering systems, but may not be the optimum solution to applications where the dryness of the final solids needs be more than a flowing sludge. In that case thermal evaporation (probably at some elevated vacuum and lowered temperature) will provide the dryness fraction required in the solids, whilst, possibly, providing an inactive condensate stream.