COST OF RETROFIT OF EXISTING DEMINERALIZERS WITH PACK BEDS

By Peter Meyers. Presented at the 1997 International Water Conference

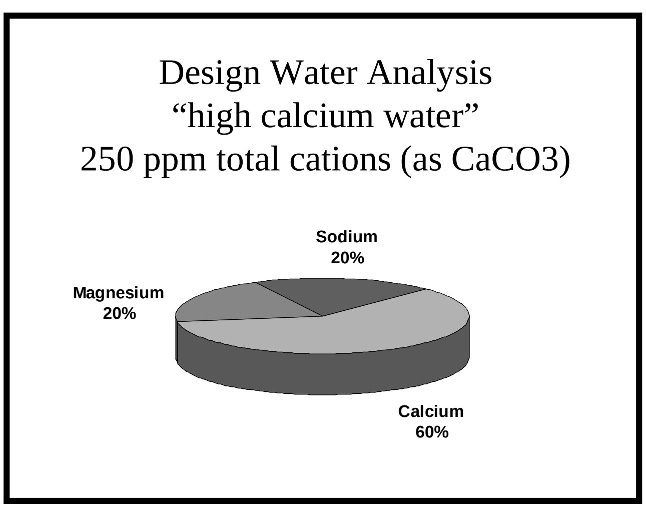
Introduction

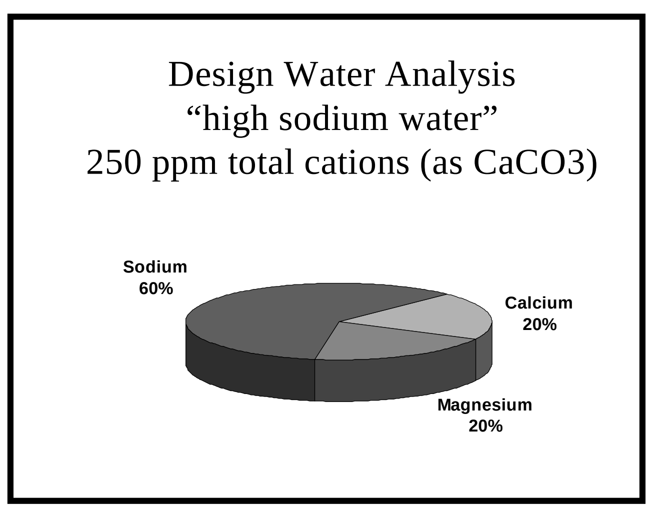
As the state of the art for new ion exchange systems improves in the United States, it is becoming quite clear that most of the large make up demineralizer of early vintage are woefully inefficient compared to modern technology. In addition, there are very few new large make-up demineralizers being built in the United States. This has caused a change in emphasis for many equipment suppliers.

Instead of concentrating on new equipment, equipment suppliers are looking for opportunities to modify existing systems and improve their performance. As the utility industry is deregulated, it is becoming increasingly necessary for public utilities to operate efficiently, and to re-examine their subsystems, such as the make up water treatment equipment. Where capital costs can be rapidly recovered by operating cost savings, most utilities are very receptive to upgrades and retrofits of their water treatment systems.

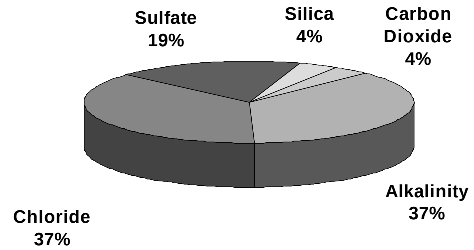
During the last several years, several papers have been given about opportunities to convert conventional demineralizers into packed bed countercurrent demineralizers. To date, few such projects have been undertaken. This is not surprising, as the complexity of converting a co-flow system into a packed bed (or other countercurrent design) can make such a project a major undertaking. It is also sometimes difficult to quantify costs and potential savings in a way that will convince management to approve of the capital expense.

This paper explores some of the complexities and costs associated with the conversion of a co-flow demineralizer into a packed bed, or other countercurrent design. Other less complex options for improving demineralizer performance and reducing operating cost are also presented. We hope that the ideas and cost structures presented will help to promote improvements in older water treatment systems. Since no two systems are ever identical (even exact duplicates never truly are), individual economics must be calculated for every system. However, the co-flow scenarios covered in this paper are representative of a fairly efficient, minimally sized system, such that savings possible with various modifications are minimal. Thus most real world cases should show more savings and faster pay backs.





Design Water Analysis
270 ppm total anions (as CaCO3)



Economic Factors used for Operating Cost Analysis

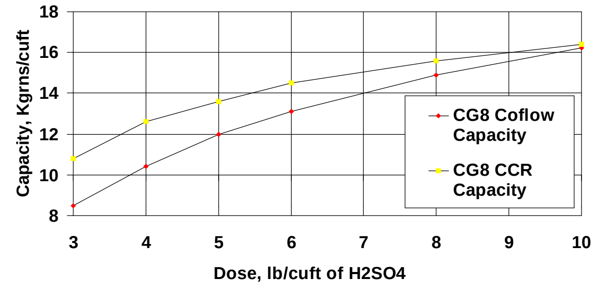
- Acid (lb of 100% H_2SO_4) $0.06
- Caustic (lb of 100 % NaOH) $0.14
- Power (kwhr) $0.10
- Cost of Water (1000 gallons) $1.00
- Mobile DI (1000 grains removed) $1.00
- Cation Resin (cuft 8% gel) $40.00
- Anion Resin (cuft Type 1 Porous) $150.00

Part I. - Conversion Of A Co-flow System To a Packed Bed

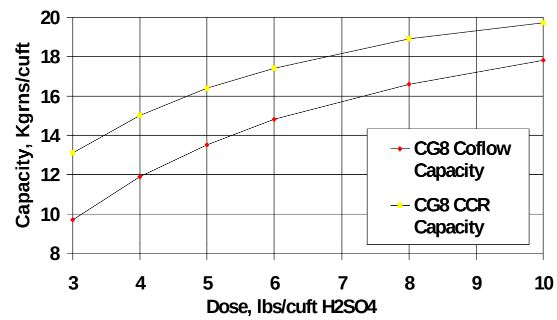
In order to make a comparison, it is necessary to have a base to compare against. We have created hypothetical co-flow systems to use as examples for comparison. The co-flow examples used are for a relatively short cycling system (6 to 8 hours per service cycle), that is operated relatively efficiently (for a co-flow design). Larger tanks and deeper resin beds will make a countercurrent system modification less attractive due to higher capital costs to complete the modification. However, many co-flow systems are not even relatively efficient. Modifications of poorly designed and operated co-flow systems will have extremely rapid paybacks.

The savings possible with countercurrent regeneration over co-flow are only partially due to inherently higher capacity at equivalent chemical doses. Another, bigger savings is realized because it is possible to operate countercurrently regenerated

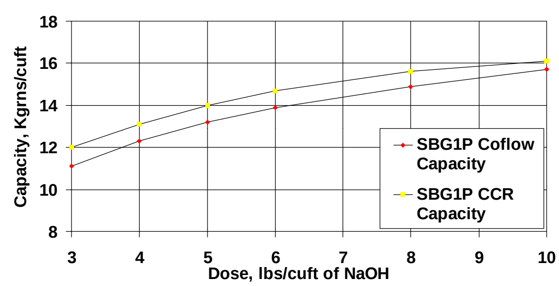
Cation Capacity Comparison High Calcium Water



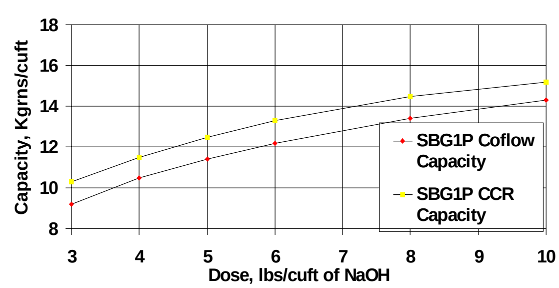
Cation Capacity Comparison High Sodium Water



Anion Capacity Comparison No Degasification



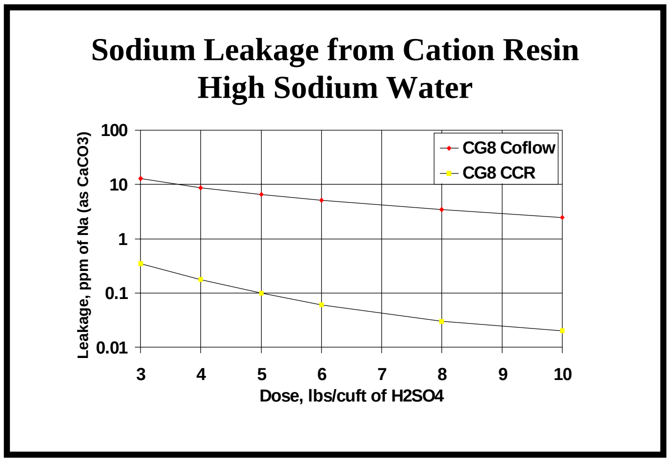
Anion Capacity Comparison With Degasification

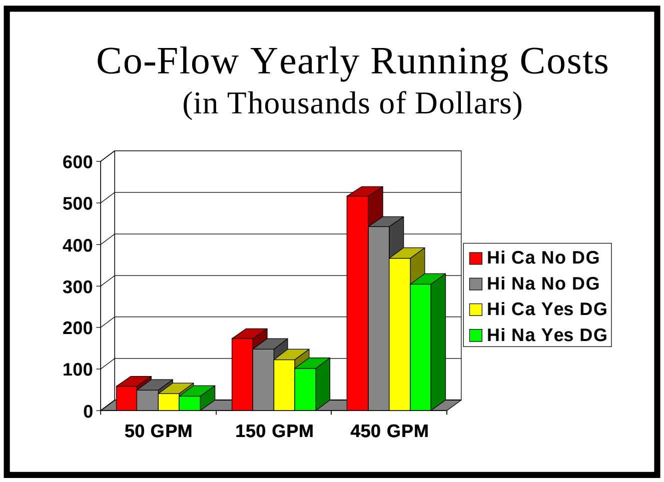


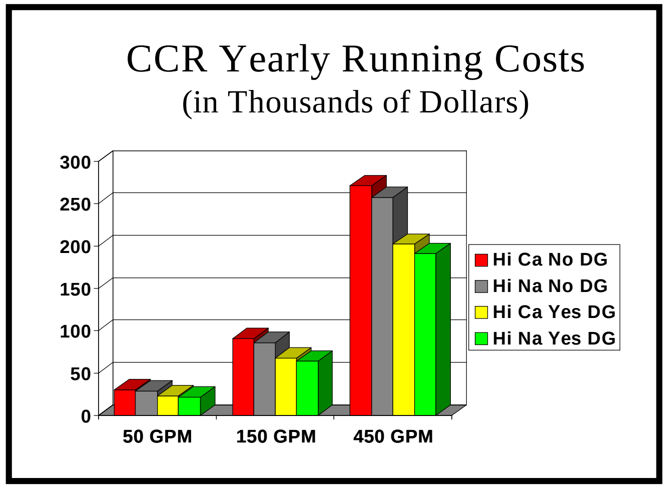
systems at lower chemical doses without incurring unacceptably high leakage.

Countercurrently regenerated systems (particularly packed beds), also produce less waste water. This is not only saves on water costs, but also produces a small but significant improvement in the percentage of net water produced per gross flow.

Countercurrently regenerated systems produce significantly better water quality than co-flow systems. This is primarily due to lower sodium leakage from the cation exchanger. This has been the most common reasons for choosing countercurrent systems in the USA.







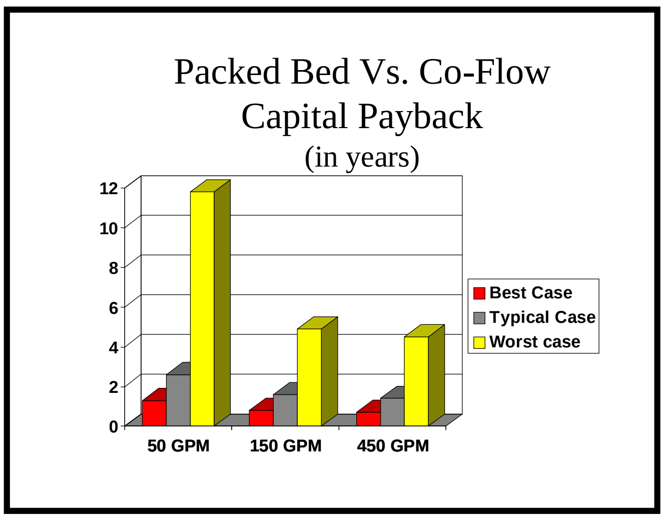
Whether the up-flow or down-flow service design is chosen, the modification is more involved than adding resin to fill the tanks with resin. As a bare minimum, the upper distributor, the regenerant piping, and the wastewater piping have to be modified to accommodate the difference in regeneration technique. The volume of resin is then increased to fill the tank. Is this all that is required?

A close look reveals that there are many additional modifications that may be needed to fully implement the benefits of the design.

First, in modifying the vessel, it will probably be necessary to add additional structural supports, and possibly to remove the existing chemical distributor. It may also be necessary to modify the underdrain to accommodate the differences in flow between the chemical and service requirements. Furthermore, if there are view ports on the vessel, they will undoubtedly be in the wrong location, and it may be necessary to add additional view ports to accommodate the change in resin level. Packed beds are extremely sensitive to the amount of freeboard. Without appropriate view ports, it is almost impossible to verify that the correct amount of freeboard has been implemented. Unfortunately, this requires welding to the vessel shell, which then requires recertification of the tank, and repair of the rubber lining. This in turn, brings up the unfortunate possibility that the tank may not be able to be recertified.

In many cases there is too much freeboard to fill the tank with resin. Resin beds deeper than 8 feet (especially anion beds) can easily become resin crushers and are a risky proposition. If the tank has to be cut open and shortened, it is probably cheaper to buy a new tank specifically designed to be a packed bed. A new tank will require new face piping. This can increase the cost to where a new system makes more sense than a retrofit or where the capital expense is prohibitive. In cases where the vessel straight side is greater than 8 to 9 feet, it is worthwhile considering some other countercurrent design than a packed bed.

The piping will also have to be modified. As a bare minimum, the regenerant piping and rinse piping will have to be changed, or the service piping will have to be changed, as one or the other will be in the wrong position for countercurrent operation. Many larger industrial systems employ plastic lined pipe. This means extensive changes and possibly a complete new set of face piping for the tanks. Since most face piping assemblies are fitting to fitting, there may not be an easy way to modify the piping.



Changes to the face piping will most likely involve modifications to the inter connecting piping, and to the piping support structures. Anyone who has ever disassembled old flanged piping will understand the difficulties involved. Since most systems are painted, it is not an easy task to remove nuts and bolts, and it is extremely easy to damage plastic lined piping, particularly older piping, in which the liner has become brittle. A few systems may be fortunate enough to have been piped with stainless steel or possibly with plastic, and for these systems it is somewhat easier to rearrange the external piping.

The existing chemical dilution stations are most likely undersized for the flow rate requirements of a packed bed, particularly when the resin volume is increased. It may be possible to get by with less than optimum regeneration flows, but to take total advantage of the packed bed efficiency, one must consider replacing or modifying the existing dilution stations.

Almost all packed bed demineralizers are designed to operate as true trains. Many co-flow systems are set up for independent operation of individual cation and anion units.

This makes the modification far more complicated, as the full benefit of a countercurrent system is not realized unless the regeneration includes recirculation rinse. Systems that have a degasifier between the cation and anion units require significant additional piping and valving to accommodate the recycle function.

Up-flow service packed beds must employ rinse recycle and the cost of the recycle pump and associated piping and valving must be included in the overall modification. Down-flow packed beds can get by without recycle, but at a significant loss of efficiency, virtually doubling the wastewater produced. Later in this paper, we will show that a recycle pump will always have a favorable payback.

The control system for a packed bed is significantly different than that of a co-flow system. If the vintage demineralizer still employs electro-mechanical controls, it will probably be best to build a brand new control system, and throw the old one away. If the system employs a PLC, a programming modification will be required, and as the steps in the regeneration are significantly different. Either the graphic portion of the software, or the graphic display on the control panel will need to be overhauled. Of course, the resin will need to be changed out, or at least added to, as the resin volume will usually be significantly larger.

Resin manufacturers much prefer selling premium grade resin at high prices. Although, this is certainly not essential, there is no question that any system will operate better with a premium resin. As a resin supplier, we encourage everyone to spend more money for ion exchange resin.
It is necessary to consider how to manufacture DI water during the period of time when all of these modification are ongoing. It is not likely that extensive changes can be accommodated in a one or two week period. It is more likely that a one or two month period will be required to implement the design. It may be possible to get by modifying one train at a time, however, this will add to the capital cost. It may be necessary to hire a mobile water company to augment the demineralized water supply during the modifications. This cost, of course, should be included in the overall cost of the project.

The “best case” compares the highest co-flow running cost compared to the minimum packed bed capital requirement. The “typical case” is twice the best case. The “worst case” compares the lowest co-flow running cost to the highest packed bed capital cost. The question of resin maintenance and backwash tanks have been left for last as his has been the subject of some controversy at previous conferences. Suffice it to say that without a maintenance tank, there is no way to completely backwash or clean the resin. If the resin gets dirty or fouled, it will be necessary to replace it or to seek an out of tank method of cleaning. If the vessel internals ever need to be repaired or inspected, the lack of a maintenance tank will complicate the procedure. This is not an insurmountable problem, but is a big nuisance when access to the vessel is required. If it were my system, I would insist on a backwash tank.

When the retrofit is completed, the packed bed countercurrent demineralizer system will save approximately 50% of the chemicals used for regeneration. Depending on which economic factors used in the comparison, the packed bed will pay for itself in something between one and three years. Depending on the suitability of the existing tanks and piping, the conversion may be a major undertaking and a significant capital investment.

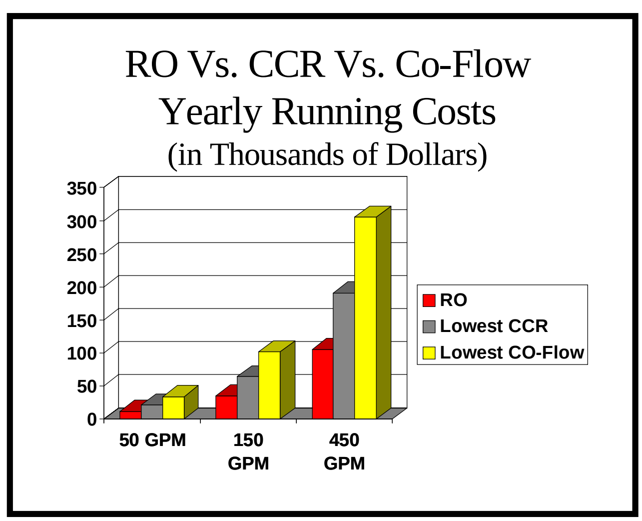
Part II - Why Not RO?

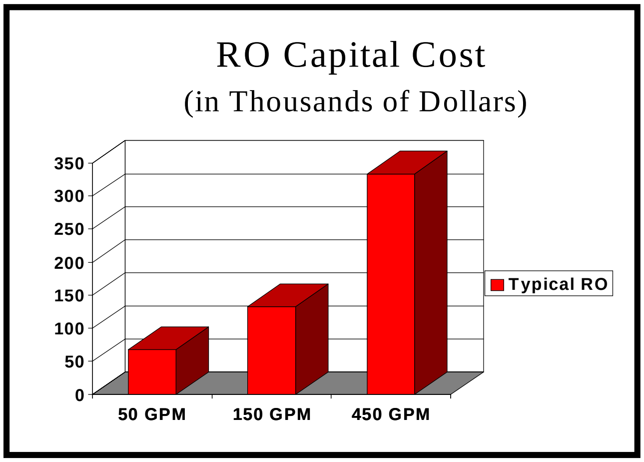
A far simpler answer to the problems associated with improving the efficiency of an existing co-flow system, is to install reverse osmosis up front as pretreatment. This design modification has been implemented at scores of installations around the country because of its rapid pay back, and relative ease of installation.

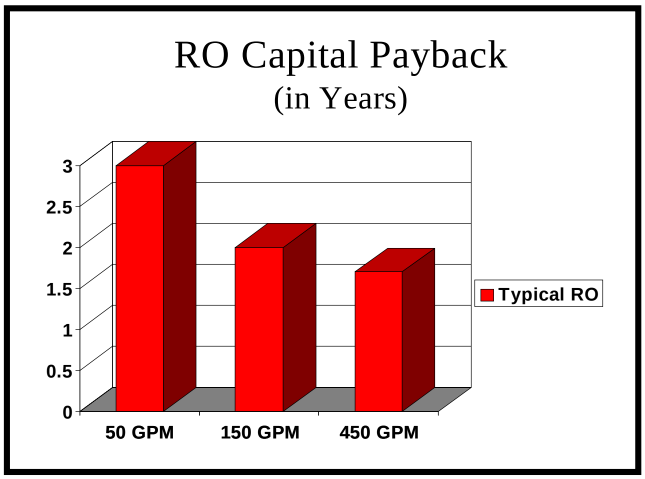
The breakpoint for an economic pay back adding an RO system to the front end of an inefficient co-flow DI system is probably in the neighborhood of 100 to 150 ppm total dissolved solids. At higher TDS, the economics pay back can be very short. It should be noted that RO Systems have been installed in front of countercurrent demineralizers including packed beds in order to reduce chemical usage.

Retrofitting an RO System is usually a straight forward proposition that does not require any modification to the existing demineralizer or interruption in operation. The RO System does not even need to be located close to the demineralizer. The major elements generally include enhanced prefiltration, booster pumps (at surprisingly low pressures compared to a few years ago), the membrane skids and a CIP (Clean In Place) System.

The biggest potential disadvantage of RO is primarily associated with the increase in waste water volume. It is also a necessity to provide







clean feedwater. However, the installation is very easy. RO systems can be "parachuted" into place, upstream of the demineralizer, without any downtime or major modifications necessary. The use of RO permeate as feedwater to any demineralizer will improve its operation, will increase the life of the resin and will provide better water quality particularly with respect to organics. These are hidden benefits associated with the use of RO beyond the savings of acids and caustics.
The benefits of RO in many cases can be realized without the necessity of capitalizing the project. There are many companies willing to finance the capital cost of the reverse osmosis system in exchange for a share of the operating cost savings or to provide trailer mounted RO Systems on a lease basis. Despite obvious advantages, RO has not been widely embraced by the utility industry. This is probably due to the perception that RO is a high maintenance unreliable process. This perception is no longer valid. RO is a mature industry. The requirements for successful design are well

Mobile RO Lease Cost
5 Year Commitment

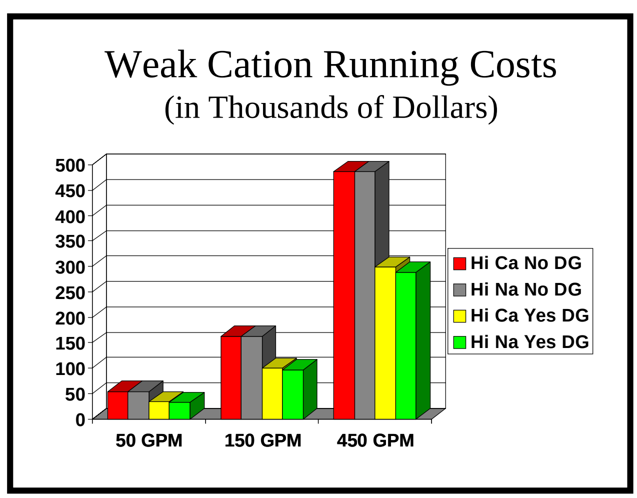
System Size	Lease Cost per Year
50 GPM	$45,000.00
150 GPM	$90,000.00
450 GPM	$270,000.00

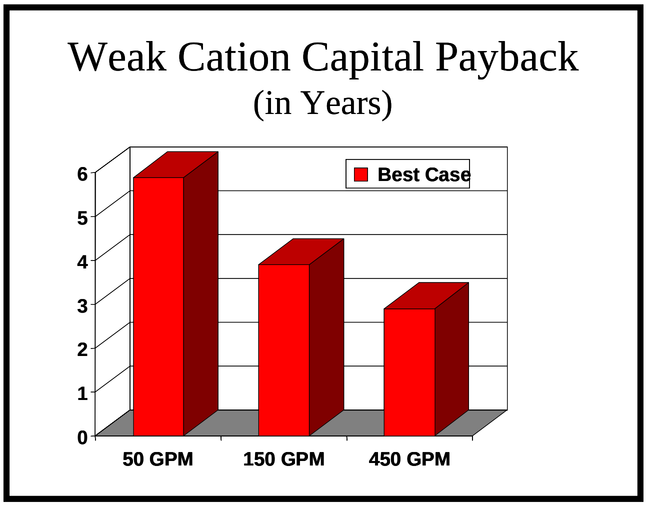
understood. Early failures should not be considered grounds for dismissing RO out of hand.

Finally, a comparison of RO versus CCR conversion costs shows that the minimum demineralizer conversion is much less expensive, but if other ancillary costs are considered, RO compares very favorably.

Part III – Weak Acid Cation Pretreatment

Systems that have degasifiers, generally have unbalanced chemical doses. The addition of the degasifier significantly decreases the anion resin volume, and the volume of caustic needed. However, if the cation is a co-flow exchanger, it is probably so inefficient, that excess caustic is needed for neutralization, regardless of the anion requirements. In these cases, it is almost always cost effective to add a weak acid exchanger to the front end of the system. The weak acid resin absorbs the excess acid from the strong cation exchanger, so that less caustic is needed during



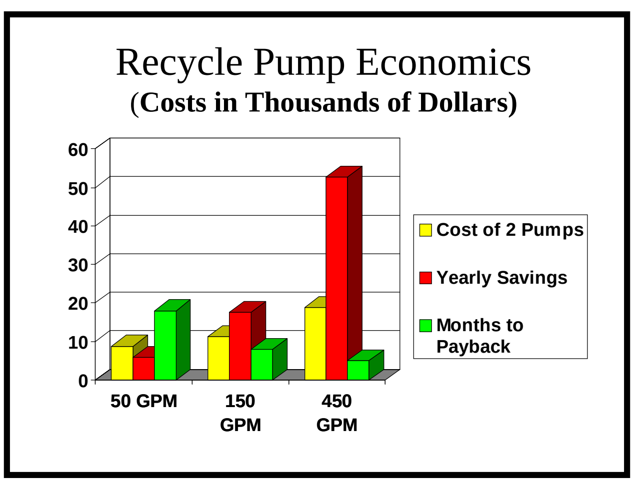


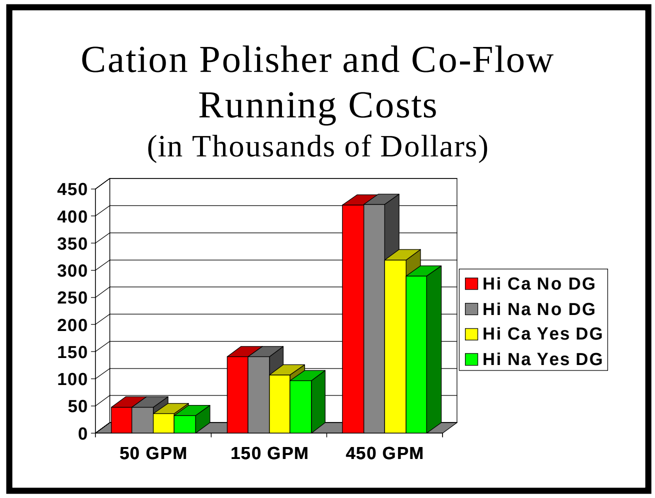
neutralization. The addition of a weak acid to the front end of the system can be implemented without major impact on the existing demineralizer. However, some piping modifications may be necessary, if the existing cation in that piping is unlined steel.

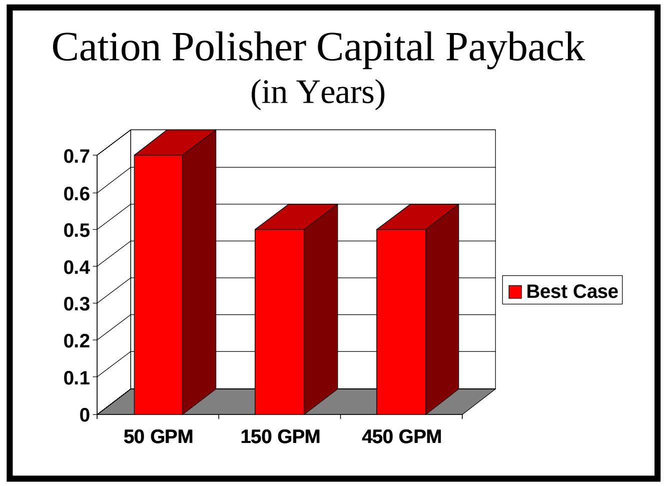
Part IV – Minor Retrofits

Major retrofits are not always easy to implement. The cost/benefit often must compete for capital with other projects. When the future of a power plant is uncertain, management is usually reluctant to fund any improvements that require significant capital expense.

There are still things that can be done to improve the overall efficiency of a co-flow demineralizer that do not involve major modifications. An obvious "no brainer' is to optimize the operation of the existing demineralizer. Significant savings are often possible







without any capital expense at all. Optimization starts by studying the existing operation, including the raw water, the regeneration sequence and the method of operation. Existing operation is compared to an "ideal" model to pinpoint areas where improvements can be made changes are made on a trial basis with the results compared to the existing operation. Positive changes are incorporated into the normal operating procedures. Such studies can often be performed with "in house" personnel or under the guidance of a reputable water consultant.

A very simple modification is to add rinse recycle. Every co-flow system can benefit by using rinse recycle. The cost of adding a pump and piping is quickly paid for in savings of waste water and in the improvement of service run caused by the reduction in water rinsed to waste. Adding a rinse recycle pump is relatively easy to do. Although the potential savings are modest, the savings in cost benefits are very good. The potential saving is about one quarter to one third of the total waste water produced each cycle, and 1 to 5% increase in throughput during the service cycle. This is a change that every co-flow demineralizer should consider implementing, as the cost of the recycle pump is paid for in a few months.

Co-flow demineralizers operate inefficiently, primarily because they require very large chemical doses in order to produce satisfactory water quality.

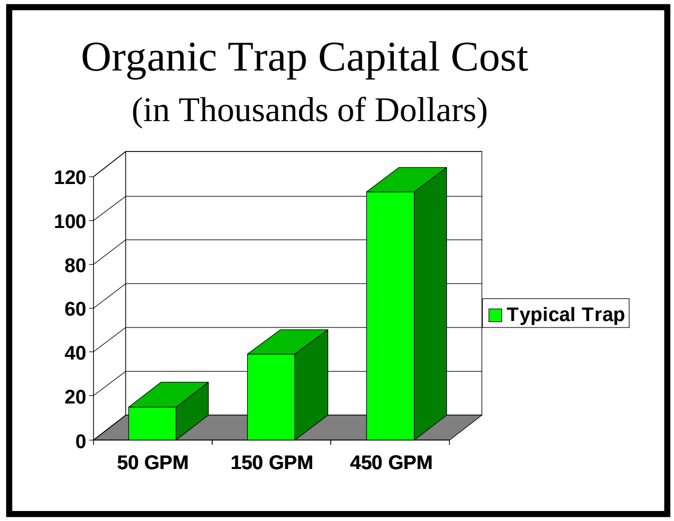
When a co-flow system is operated at low chemical doses, its efficiency is not much worse than that of a counter currently regenerated demineralizer. However, the leakage of ions from a co-flow system operated at low chemical doses would be intolerably high.

One potential answer to this, is to add a cation polisher to the back end of the co-flow train. The cation polisher absorbs the excess sodium leakage, and reduces conductivity to levels similar to that of countercurrent systems. The cation polisher can be a very small unit and can be operated independently from the co-flow system. This retrofit is relatively easy to implement, as it has very little impact on the operation of the existing system. Cation polishers are finding increasing favor with manufacturers of small systems, as in many cases they produce water quality equivalent to that of a mixed bed.

Another potential change to improve efficiency that does not involve equipment modifications, is to change the types of resin being used. It may be possible to improve the performance by changing to a type 2 anion resin, or vice versa, changing to an acrylic anion resin, providing the water supply and temperature can accommodate these types of resins. These resins have inherently better efficiency than Type I resins at times provide significant chemical savings.

In systems where organic fouling is the cause of long rinses and short thru-put, the opportunity to re-bed existing carbon filters with an organic scavenger resin can significantly improve operation. It may be necessary to add a brine regeneration system and chemical feed to remove chlorine, but the retrofit is relatively inexpensive and straight forward.

Another potential solution to co-flow inefficiency is to add a reclaim system for recovering and reusing a portion of the regenerant chemicals. The co-flow system then operates at a high equivalent chemical



dose with the last portion of the regenerant saved for use during the next regeneration cycle. On paper this approach looks very attractive. However, it is tricky and difficult to employ successfully, as the point at which the regenerant is good enough to reuse, is not easily measured. If the reclaimed portion is not chosen correctly, it can cause problems due to precipitation and fouling of the resin

Most co-flow systems have extremely large amounts of freeboard. This excess freeboard can sometimes be used to increase the resin volume. This design change may require relocating in the chemical distributor and adding screens to the upper distributor. The increased resin volume increases throughput more than linearly because deeper bed depths improve overall efficiency. An existing co-flow system can be modified to accommodate additional resin relatively easily. However, some of the same arguments about viewports and internal structural supports, mentioned earlier for packed beds, are relevant and may make this type of modification unattractive.

Closure

We hope that this presentation has provided useful suggestions for improving the efficiency of existing co-flow demineralizers. Whether the change is to a packed bed countercurrent design, to RO as pretreatment, or one of the lesser modifications, there is no doubt that many of the existing co-flow systems are inefficient dinosaurs, and that the cost of modifications can quickly be recovered by savings in chemicals. At the same time, it may be possible to take advantage of the opportunity to upgrade and improve the operation of older systems.

The saddest thing of all, is to see a new system being designed for a clean water using co-flow process technology that is now 40 years out of date.

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