Deionization Capacity Monitoring

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Introduction

Deionization has a long and respected history in pure water treatment. Since the 1940s, resins have been used to detain cations and anions to produce pure water. Despite many advances and new processes for water treatment, ion exchange resins remain by far the most common process to produce the purest waters.

In operation, deionization resins eventually reach exhaustion and need to be regenerated. The costs of regeneration, for acid, caustic, rinse water and labor are very substantial. Anything that can be done to extend run cycles, regenerate more efficiently or accurately determine the need for resin treatment or replacement can bring significant operating savings.[1]

Described here is a newly available and convenient method to more accurately predict resin exhaustion in the short term and to enable monitoring of changes in resin working capacity in the long term.

Detecting Resin Exhaustion

When exhaustion is reached, the resin begins to leak the most weakly held ions. Cation bed breakthrough is usually detected by sodium measurement or occasionally by conductivity ratio. Direct conductivity cannot be used because effluent of a cation exchanger is usually higher in conductivity than the feed, due to its highly conductive acid condition. Instead, the ratio of the conductivity of the effluent to the conductivity of the water about 15% from the end of bed is measured as illustrated in Figure 1, for a down-flow bed.[2] The ratio will be close to 1.0 during normal operation. It will deviate from 1 when leakage reaches the ‘in-bed’ point but not the outlet. The ‘in-bed’ conductivity sensor may actually be inserted into the bed, if screened from the resin or it may be in a representative sample stream brought out, as shown. In either case, it requires access through the vessel wall to an appropriate representative sampling point near the center. The effluent conductivity measurement can provide the conventional detection of final breakthrough.

Anion bed breakthrough is often detected by direct silica and/or conductivity measurement. An increase in either measurement usually indicates exhaustion although cation breakthrough upstream, if undetected, could also increase anion effluent conductivity.

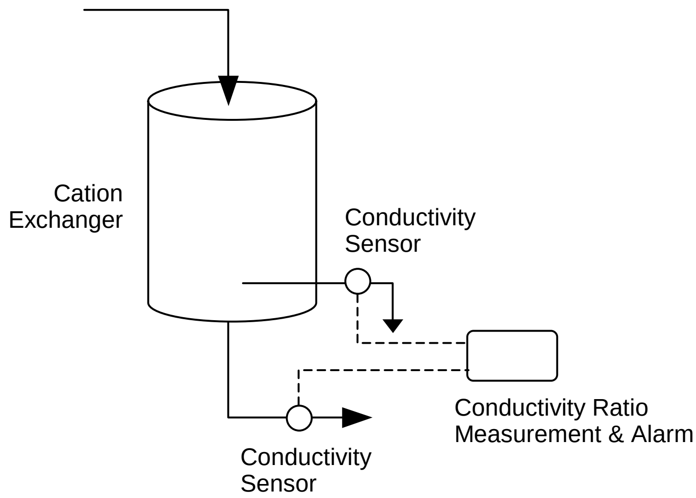

Figure 1 - Conductivity Ratio Detection of Cation Exchanger Exhaustion

Mixed bed breakthrough is almost always monitored by direct conductivity measurement. An accurate and precisely temperature compensated conductivity measurement provides a reliable, low cost, continuous means of detecting exhaustion.

All of these methods are very sensitive and reliable. However, they have a common disadvantage: with the exception of conductivity ratio, they detect exhaustion only after breakthrough. There is no advance warning. The process downstream begins receiving contamination at the same time the measurement detects it. In many situations it is desirable to predict when exhaustion will occur to allow coming off-line and regenerating beforehand.

Predicting Resin Exhaustion

Predicting resin exhaustion has a number of benefits. It can help avoid running to exhaustion during an inadequately staffed shift or weekend, allowing more reliable scheduling of operations. In some situations this can reduce overtime labor costs or wasted chemicals. With more confidence in the amount of exchange capacity remaining, it can allow running longer and can avoid premature regeneration. Early regeneration wastes time, system capacity, and most importantly, expensive acid and caustic used for regeneration plus more acid or caustic needed to neutralize the wastewater produced by the unneeded regenerations. Examples of these savings have been evaluated in other contexts.[1,3]

Without means for monitoring resin capacity remaining, it is much like running a car with a broken fuel gage. You must be constantly vigilant to avoid running out of gas and even then, there is no real assurance. Extra, pre-emptive stops for fuel are inevitable—just in case.

Common methods for predicting exhaustion have been based on elapsed time or totalized flow. If average flow is nearly constant over the run cycle, then a consistent run time before regeneration should be adequate, if the water composition is also constant. (Home water softeners routinely operate with a simple timer but only a small amount of wasted salt is at stake.) If the flow varies through the exchanger, then a total flow measurement can accurately account for this, but again, only if the feedwater composition is constant.

In the broken fuel gage analogy, using total flow as the criteria for regeneration is like using the odometer of the car to monitor mileage between refueling stops. It can be used successfully. However, if the driving involves mountainous terrain, strong headwinds or long waits in traffic jams, the odometer mileage will not correlate well with the amount of fuel consumed. Likewise, if the water composition changes for any reason, then a total flow measurement will not be a good predictor of the optimum time to regenerate.

In today's environment of scarcer water supplies we are resorting to using multiple sources, recycling and reclaiming water used previously and using variable pretreatment processes ahead of deionization. As a result, variable composition in DI feedwater is becoming the rule rather than the exception. There really is a need to account for the varying ionic load on a DI bed due to both flowrate and composition.

This need has been recognized and even implemented using a combination of instruments which seems somewhat cumbersome by today's standards.[4,5] Recently, Thornton has been able to provide this capability in a standard compact multiparameter (flow and conductivity as well as other parameters) measuring instrument as its DI-Cap™ deionization capacity monitoring algorithm. It is expected this type of capability will become a standard requirement for water treatment with variable water supplies.

Figure 2 illustrates how this method works. Feed conductivity is measured and converted to TDS (total dissolved solids) using an adjustable conversion factor and algorithm. This non-linear algorithm corrects both for the conductivity of the water itself (needed in pure water ranges) and for the decreasing activity coefficient of ions at higher concentrations. Flowrate is also measured and multiplied by the TDS value. The product of these is integrated over time to produce a measure of ionic load entering the DI column as illustrated by Equation 1. With appropriate conversions, the readout can be in grains or ppm-gallons as calcium carbonate or as equivalents.

$$\text{Grains} = \int \text{Flow} \times \text{TDS} \qquad (1)$$

With this system, an accounting is made for both variable flow and variable water composition to give the best available estimate of ion loading. Display, output signals, setpoints and relays can be assigned to this computed parameter to enable continuous monitoring and control. The total grains measurement can be reset manually or by a remote contact closure at the beginning of a new run. The instrument has additional channels that allow it to measure, alarm and provide output signal for effluent conductivity, as shown, and still have room for other measurements.

Back to the car analogy, deionization capacity monitoring is like having a car odometer's estimate of gas consumption continuously corrected for driving conditions. Unfortunately, there is not yet a way to have a direct DI capacity level gage on a bed.

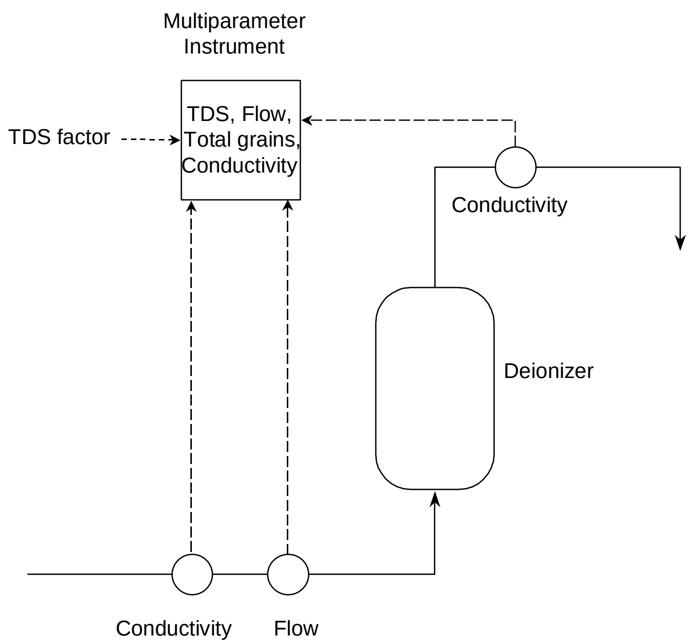

Figure 2 - Deionization Capacity Monitoring

Assessing Resin Health

Perhaps a more valuable use for deionization capacity monitoring is to monitor resin bed working capacity over the long term to warn of capacity loss. Lowered working capacity can be due to incomplete regeneration, loss of resin, channeling, fouling with organics or silica, etc. which leaves many areas to examine when a problem occurs. If a DI bed is run to exhaustion as detected by effluent conductivity or other means and the total grains for each run cycle are logged, a good historical record of performance can be developed. This record will be much more useful than a record of just total gallons since it will be corrected for changing feedwater composition.

With this system, even slight deterioration in performance can be detected and corrective action taken before major loss of efficiency. This represents a real improvement in DI system troubleshooting since the first loss of capacity will be more visible and will allow more timely diagnosing of the problem. Problems that continue undetected become harder to pinpoint and more damage and inefficient operation can result.

Conclusion

It is anticipated that deionization capacity monitoring will provide a significant contribution to the efficient operation and troubleshooting of large DI systems. Whether deionizing raw water, reverse osmosis permeate, or condensate with deep beds, most systems will benefit from this new water treatment monitoring tool.

References

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