Resistance issues – Field notes

Resolving EDI resistance issues is a complex matter because there are so many factors that can affect module resistance. These can be broadly described as reversible and irreversible problems with, of course, reversible problems being the preference. A book could easily be written to cover each and every scenario. Getting 'back to basics', the notes below describe the common issues that I have come across in the field.

1. As difficult as it is to solve resistance problems, it is as difficult to predict what the 'normal' operating module resistance should be. Every site is different and the factors that affect the start-up resistance include feed water temperature, feed water composition, conductivities of the feed, dilute and concentrate, % recovery, and even the module construction, (batch to batch variations of resin and membranes). It is extremely import to monitor the voltage, current and temperature during commissioning <u>and</u> after the module has equilibrated, as this provides a 'baseline' for the module(s) resistance, so enabling any trends in resistance to be followed. As mentioned below, the resistance of identical module types can vary, but once constructed the module resistance should be constant. All of the other factors affecting resistance can vary, certainly on a seasonal basis, but often on a daily basis. It is therefore important to record resistance on a daily basis to monitor any trends.
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2. As mentioned above, modules takes time to equilibrate, perhaps as much as one or two weeks after installation. This is generally because the resin slowly equilibrates with the ionic composition of the feed water. When modules are delivered they will be partly, if not fully, regenerated. Thus the resin will be mainly in the H+/ OH- form, the remaining resin will be in the Na+/Cl- form. Both of these forms are very conductive. Typical feed water to an installed system will contain alkalinity, carbon dioxide and silica. This will partially convert the resin to the less conductive bicarbonate, carbonate and silicate forms. Thus the module resistance will vary depending what form the resin is in, which is dependent on the feed water composition.

3. Some module to module variation in resistance is expected and may be due to batch to batch variations in the resin and ion exchange membranes, tolerances of the materials, (spacers, etc), and the overall torque, (or tightness), of the module. In a multi-modular system with no independent flow valves, pressure drop is important. Flow will of course take preference to the lower differential pressure, (DP), and if the feed water is below specification, the module(s) with the highest flow, (lower DP), will likely exhibit the higher resistance.

4. Temperature greatly affects resistance and should be recorded along with the voltage and current data. A gradual increase in resistance could simply be due to the feed water getting colder, for instance in the winter months. Resistance should therefore be normalized in accordance with the following equation; R@25°C = (RT°C)(TCF), where TCF = (0.02)(T°C) + 0.5

5. In most cases resistance will not affect product water quality. At a pre-set current, increased resistance would just result in operation at higher voltage. Reduced quality occurs when the voltage reaches the maximum for the power supply. Then, as resistance continues to increase, the current reduces, and this will eventually result in poor performance.

6. Common issues that gives rise to increased resistance are scaling (usually hardness, occasionally silica), and / or organic fouling. Hardness scaling and organic fouling issues <u>usually</u> respond well to cleaning, so can be considered as reversible. However the longer the modules are left operating with poor feed water, the harder it is to clean the modules and return them to an acceptable resistance.

7. Water hammer, or operation at substantially higher dilute over concentrate pressure, (or vice-versa), can cause damage and lead to increase module resistance. Water hammer can 'compress' the resin in the spacers and create a void area with little or no resin, thus increasing resistance. This type of damage is often permanent. If the dilute pressure is substantially higher than the concentrate pressure, (or vise-versa), this can 'push' the

membranes away from the resin, which causes less resin / resin and resin / membrane contact, and thus increases resistance. Most EDI devices are concentrate filled, which supports both sides of the membranes, and reducing the pressure difference between dilute and concentrate will generally return the module to normal resistance.

8. Resin, (and ion exchange membrane), oxidation symptoms are usually a small increase in module resistance and a high DP in the dilute, and sometimes the concentrate compartments. Resin oxidation is generally due to chlorine in the feed water, but sometimes inappropriate cleaning and sanitization regimes can lead to oxidative damage. Unfortunately resin oxidation is irreversible.

9. Module exhaustion can also contribute to higher than expected resistance. When resins exhaust they contract, and as a result there is less resin / resin and resin / membrane contact, which again increases the module resistance. If the resin exhaustion is due to high feed water CO_2, (which is removed as a carbonate), then the resin converts almost totally to the less conductive carbonate form, which also increases resistance. Sufficient current must be applied to the module to keep the resin in the regenerated form.

10. An unusual effect has occasionally been noted in the field. Operation at high or maximum current will not damage a module, but operation at very high current, (very low current efficiency), disproportionate to the feed water challenge, can encourage hardness scaling. The explanation of this effect is complex, but basically operation at high current can cause excessive water splitting, which in turn could give large pH variations inside a module. I have seen this effect, (called over-polarisation), a few times with older generation 'thin-cell' devices. However, the predominant symptom is reduced performance, where the acid and caustic 'swamp' the dilute compartments. Thick cell devices do not generally exhibit this phenomenon. I have seen a few cases where I have reduced current and produced better quality water, thus have considered this as over-polarisation. High pH variations will I'm sure result in an increased risk of scaling.

11. When considering feed water quality, water analysis measured 'mid-run' does not always reflect what the module has been challenged with during start-up. By far the most problematic area in a stop-start system design is the RO flush. It is well known that the first few minutes of RO permeate is relative poor, in terms of conductivity. What is sometimes forgotten is that conductivity is a measurement of ionic contamination. Weakly ionized material, (such as silica), and organics, can be present during the first few minutes of RO operation which can lead to fouling issues in an EDI. I would go as far as to say that an RO flush is a prerequisite for warranty. My personal recommendation would be to flush the RO permeate on a conductivity basis, followed by a further 3-5 minute flush before the permeate is directed to the EDI skid.

So, we have a list of possibilities that can cause increased resistance. How can we identify which one has caused the problem? Firstly, I would state that in many cases a combination of several effects will be responsible. There are examples where just one is the problem – a softener failure, or SMBS dosing failure, for instance will cause scaling and oxidative damage respectively.

Routine monitoring and analysis is of course important. Many Engineers ignore CO_2 measurements which is a critical parameter to calculate the current required to optimize performance and prevent resin exhaustion. Organic measurements are also usually ignored because of the cost of TOC meters – and yes, organic fouling does occur post RO ! An adequate RO flush, as discussed, is a requirement. A particularly annoying thing, which can often disguise the problem, is when various analytical data is recorded as zero. In all cases the limit of detection should be stated. For instance the feed water specifications for chlorine and iron are very low, <0.02 and <0.01ppm respectively. Recording zero ppm will not necessarily highlight an issue.

The symptoms associated with the resistance issue are also important. Flow rates, DP measurements, (dilute and concentrate), recovery, and concentrate conductivity will all help an experienced troubleshooter to diagnose a problem.

In most cases, where the cause of increased resistance is unidentified, a good start would be a multi-chemical clean. If the resistance returns to 'normal', then at least it can be assumed that the cause is reversible. This fact will rule out a number of causes. The cleaning itself may also indicate the problem – colour throw for instance can indicate iron fouling and organic fouling. Analysis of the cleaning chemicals can also assist, although finding a laboratory capable of analyzing trace elements in an acid or caustic matrix is often difficult.

Antiscalants and biocides are often used in the pretreatment prior to the EDI. It is impractical for EDI manufacturers to approve various types of water treatment chemicals used in a plant, and their compatibility with EDI technology. To do this they would have to carry out test work on every proprietary additive, at various concentrations. The most important factor regarding any additives used pre-EDI is that they are fully rejected by the RO, and the RO flush is designed to ensure a more than adequate flush.

Again, there are many proprietary RO cleaning chemicals used in typical RO / EDI based systems which cannot be approved by the EDI manufacturer without test work. However, it is noted that several caustic cleaning agents used for RO cleaning contain EDTA. This has been known to cause problems if it comes in contact with ion exchange resins and membranes. As a complexing agent it tends to bind to IX resins and membranes and is very difficult to remove. Every precaution should be taken to avoid any contact of EDTA with the EDI modules. The RO should be fully rinsed after cleaning and any filters that have been in contact with the cleaning chemical should be disposed of before reconnecting the RO / EDI system.

Finally, as an addendum; most manufacturers of EDI devices QC their modules prior to shipping. In addition, manufacturing faults are rare. This therefore points to two mains reasons for resistance issues; feed water and system design. System design issues are relatively simple to diagnose, often by the P&ID's. Feed water issues are usually far more difficult and often it is a case of ruling out other causes, to identify the true cause. This is time consuming and will affect production. Therefore an effective routine cleaning regime is generally used when the resistance increases to the 'action' limit.

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