INTRODUCTION

Deep bed condensate polishers are nominally limited to a temperature of 120 deg F because above that, the anion resins begin to degrade. Any degradation will be cumulative over time resulting in less and less overall capacity and shorter run lengths. When powdered resins runs are ended, the resin is discarded and replaced with fresh resins. This allows powdered resin units installed as condensate polishers or in other power plant applications to be operated at temperatures well in excess of 120 deg F.

BREAKDOWN OF ANION RESINS

Generally speaking, cation resins can withstand much higher temperature than anion (1). The difference is due to the fact that sulfonate or carboxylate functional groups of cation resins are more stable at high temperatures than the corresponding functional groups of anions.

Of the two general types of strong base resins, Type I has the higher permissible operating temperature. It has three methyl groups in its quaternary structure and the degradation is described by either of the following:

\[
[R-CH_2N(CH_3)_3]^+ \text{OH} \rightarrow R-CH_2-OH + N(CH_3)_3
\]

or

\[
R-CH_2-N(CH_3)_2 + CH_3OH
\]

The resin residue from the first is an alcohol with no significant exchange capacity and decomposes quickly to carbon dioxide and hydrogen. The other product is trimethylamine, which will be absorbed by the cation resin. A further result of the degradation is that a portion of the strong base sites will be converted to weak base sites and reduce the resins ability to remove silica. Thus in a operating mixed bed, there is corresponding loss for both cation and anion capacity although the cation can be regenerated. In addition, the longer a mix bed operates; more of the resin is converted to the salt form and the rate of degradation decreases.
CAPACITY LOSS MEASUREMENT

A review of the literature has found several papers estimating loss of capacity with high temperatures.

A study completed by Japan Organo Co. Ltd. (2) have shown that Type I hydroxide form anion resin loses about 20-30% of its exchange capacity after a year’s operation at 140 deg F. This loss becomes geometric with further increases in temperature (see Fig 1). Loss of capacity is rapid during the first 4 days or so and then follows a first order reaction.

A study completed by Baumann (1) fines that at 194°F a type 1 strong base resin (IRA-400-OH) will be experience an initial rapid lose of approximately 15% of its capacity in the first few days of operation and then decompose by a first order reaction to a 43 day half life.

A study by Simon (3) and presented in a paper by McGarvey (4) reported that Type 1 Strong base resin at 140°F lost 1.3% of its strong base capacity per month and the degradation rate doubled for each 18°F rise in temperature. This means that at 194°F the half-life is 43 days with agrees exactly with the Baumann findings.

A study presented by Ryan and Brown (5) concerning the application of Powdered Resin in Nuclear Cycles found that at 270°F feed water temperature and a simulated condenser leak contributing 930 ppb of chloride on the inlet, powdered resin produced < 50 ppb fro 4.5 hours of operation. They also reported finding that high temperatures (148°F to 286°F) did not adversely effect pressure drop of the precoat, did not cause high conductivity peaks, and did not affect insoluble ion exchange capacity.

EFFECT ON POWDERED RESIN PERFORMANCE

Most powdered resin units operate for about 2 to 4 weeks before the resins are sent to waste and new resins are applied. Hence, the degradation may be minimal even at temperatures that are relatively high. Figure 2 shows the percent loss of capacity at various temperatures for 2 and 4-week runs based on the Organo data.

In the condensate/feedwater stream, that polishers can be located not immediately after the condensate pumps but after passing through several heaters and can even pick up heater drains that are dumped into the feedwater cycle. In addition to picking up more corrosion products from the piping and heaters, drains that are not normally treated can be demineralized.

EXISTING DATA ON OPERATION OF RESINS AT HIGH TEMPERATURE

Probably the most extensive data on operation at high temperatures was contained in EPRI Report TR-103833 (6) conducted at Davis-Besse Nuclear Station that tested operation of a powdered resin unit at temperatures of 180 – 265 deg F. The test unit
was installed on the drain from a moisture separator and had an inlet heat exchanger that could be used to vary the temperature. The primary contaminant targeted by the installation was sodium. In addition to varying temperature, cation to anion ratio was changed as well as different types of resins.

Because of the concentration of total solids by the moisture separator, influent values for both cations and anions were well above those experienced in normal condensate polishing. Runs were terminated on high effluent sodium or on high effluent conductivity (breakthrough of anions).

As might be expected, anion capacity was lower at high temperatures while cation capacity did not appear to be affected. However, when ratios were changed to include a greater portion of anion resin, there was a breakthrough of cations before anions.

This test unit was permanently installed and is operating today (see data from field installations below). Ratio of cation to anion is 1:1. Because inlet temperature is cooled by condensate, the unit is operating at 180 – 200 deg F. However, test conclusions state that there was no significant difference in performance at temperatures from 180 to 265. Annual cost savings from this installation was estimated at $450,000.

OPERATING PERFORMANCE

A survey was made of 4 powdered resin units actually operating at temperatures between 166 deg F and 239 deg F to determine how temperature was affecting performance. Results are shown in Figure 3.

Three installations are condensate polishers and the moisture separator drain unit discussed above is the fourth. The survey results are as follows:

The installation at New Brunswick Power is in a co-generation plant and treats return condensate from an adjacent paper mill. The primary purpose is removal of suspended solids particularly iron. Because of this, measurement of chemical constituents is not taken. The runs are terminated pressure drop rather than chemistry. The precoat material is a resin-fiber mix.

The unit at Eddystone Station 1 is a two-unit full flow condensate polisher located after the last LP heater and before the Deaerator. The normal operating temperature is 228°F. These units were retrofitted in the early 1960s into the condensate system specifically to remove copper from the condenser and LP heaters before it could carry over into the supercritical boiler and turbine systems. Today, sodium and silica are routinely monitored and the units are precoated based on chemistry and/or Δp.

The polisher at Davis-Besse has a severely reduced loading due to the moisture separator drain unit. Run lengths have been increased by a factor of at least 6 because a much smaller unit under concentrated influent loadings has removed system contaminants.
The David-Besse moisture separator drain demineralizer actually treats less than half of the total moisture separator drain flow. Its primary purpose is to remove sodium. Because the reactor is once-through, there is no blowdown unless these drains are sent to the condenser. The inlet temperature is controlled by a heat exchanger using condensate for cooling to recover the heat. The effluent is fed forward to the shell side of the #5 feed water heater.

None of these plants is appreciably affected by the temperature at which they operate.

**DESIGN CHANGES FOR POWDERED RESIN UNITS AT HIGH TEMPERATURE**

There is no design change required for the units until the temperature reaches 212 deg F except for assuring that the materials will withstand that temperature. Of primary concern are the septa which are often are wound fibers. Elements of polypropylene fibers are rated for 150 deg F maximum since above that temperature the fibers will begin to stretch. Fibers of Ryton are good up to 375 deg F. Septa made of stainless steel are good at any polishing temperature as long as the gaskets or seals are adequate for that temperature.

Of major design concern is the fact that, at temperatures approaching 212 deg F, the vessel contents will flash when backwash is initiated. Hence cool-down must be included. (See Figure 4) To do this, either a heat exchanger is placed in the recirculation loop or there is some method of adding cool water to the loop. Once the temperature is below 180 or 190 deg F, normal backwash can continue.

Similarly after precoat, to prevent shocking the vessel and the resin cake, a small bypass valve is added around the effluent to bleed in influent at a controlled rate.

**APPLICATIONS FOR HIGH TEMPERATURE POLISHING**

As mentioned earlier, operation at higher temperature in a conventional fossil or nuclear plant allows the unit to be placed closer to the boiler inlet. The Davis-Besse unit described in one of the installation reports treats moisture separator drains that have concentrated the contamination in the steam to an efficient removal level. The authors feel there is also a potential for treating blowdown and recovering the heat.

As combined cycle plants become more complex with multi-pressure HRSG’s and fuel gas heaters, there should be numerous potential applications for high temperature polishing. This should be particularly practical where blowdowns have concentrated the impurities into low flows that can be treated by small, inexpensive units. The heat from some of these blowdowns is already being recovered for fuel gas heating and rotor air-cooling.
CONCLUSIONS

While regenerable, whole bead resin deep bed units are limited to approximately 120 deg F, powdered resin units have no such restriction and can be used at much higher temperatures. Designers should examine applications that can result in not only better quality water but also savings from heat recovery, often offsetting the cost on the installation.

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