Design Considerations for Condensate Polishing Off-Site Regeneration

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ABSTRACT: In recent years, the use of off-site regeneration for existing deep bed Condensate Polishing Plants as well as Greenfield Plants is being given greater consideration for a multitude of reasons to be explained in this paper. The off-site regeneration may be for a temporary or long-term period. The challenges of a retrofit design that converts an existing condensate polishing plant with on-site regeneration to off-site regeneration and that of a new CPP plant that is specifically designed for off-site regeneration system can differ. Both designs require careful attention be given to the unique requirements associated with each approach. The concept of external regeneration must place equal emphasis on the design of the system and the contract for the off-site regeneration service. The ability of the condensate polisher to produce the specified effluent water quality cannot be achieved unless both are in harmony. In this paper, we will discuss the design requirements for both the existing and Greenfield Plants considerations along with the resin movement and conditioning outside the condensate polishing system.

Introduction

Condensate polishing plants (CPP) have been traditionally applied for the treatment of condensed steam from turbines and process use. This paper will address deep bed ion exchange CPP and its application in the power industry for once through steam generators (OTSG), critical and supercritical steam generators, boiling water reactors (BWR) and pressurized water reactors (PWR). While a CPP is primarily an ion exchange system designed to remove ionized contaminants, it also acts as a filter removing corrosion products commonly referred to as crud. Both impurities can enter into the condensate system through a variety of sources during either normal operation or start-ups/restarts. By removing the various contaminants, the CPP will enable the Plant to start-up faster, operate with minor condenser leaks, reduce the frequency of routine cleanings, increase on-line time, and maintain the desired system chemistry. This reduces corrosion and deposits in the system, ultimately lowering operating costs and reducing staffing and extending Plant life.

Once the deep bed CPP has exhausted its ion removal capacity of dissolved ionic contaminants to the point it is incapable of producing the desired effluent condensate quality, the resin must be regenerated. The CPP must also be removed from service if the pressure loss across the polisher due to crud removal has reached the specified maximum pressure loss. In either case the resin is removed from the polisher vessel to an external regeneration system for regeneration or physical cleaning of the resin. Traditionally, the external regeneration system has been an integral part of the CPP and located on-site within the power plant. In recent years, off-site regeneration has been given greater consideration as an alternate solution. This alternate solution is the topic of this paper. For the purpose of simplicity, this discussion will assume a naked mixed bed condensate polisher (MBP) whereas a few of the existing CPPs include a cation polisher (CP) ahead of the MBP.

Drivers for Off-Site Regeneration

The use of off-site regeneration can be applied not only for newly planned power plants but also for existing plants. Both have different and unique drivers, but their objectives are the same: the conversion of the exhausted ion exchange resin to a condition capable of meeting the specified effluent water quality the CPP and the elimination of resin fouling that can impair the resins' ability to produce the water quality associated with the utility's system chemistry.

Many of the existing CPPs are quite old dating back to the 1960's and 1970's. These plants have provided many years of reliable service producing the water quality that was specified by the manufacturers of the steam generators at that point in time. However, these plants have reached the end of their useful life and have become unreliable, placing a heavy demand on the operators and in some cases posing a safety risk. In most cases, they are incapable of producing the condensate quality that is currently specified and are incompatible with the new system chemistries now being practiced. This could include the desire of some Plants to try and operate in the ammonium form. These existing CPPs must be replaced with a CPP that is capable of producing the new standards or look to another option, that being new polishers with off-site regeneration. In most cases, it is virtually impossible to find space within an existing plant to locate a new CPP. There is also the issue of trying to install a new plant or modifying an existing one during an outage or while the plant is in operation. In some cases, where possible, the plant modification can simply be the abandonment of the on-site regeneration system while using the existing polisher vessels.

The motivation for incorporating off-site regeneration of resin from new polishers can be quite different from dealing with an existing CPP. The drivers can be as simple as a reduction in the capital investment but generally it is a combination of factors that include: (1) reducing operating personnel or operator involvement, (2) reducing the type and quantity of the chemicals that must be stored on-site, (3) eliminating wastewater treatment and discharge, (4) eliminating the need for periodic chemical cleaning of the resin to restore kinetic performance, (5) eliminating the uncertainty in predicting resin life and resin replacement, (6) reducing the size of the building required to house the on-site regeneration facility, and (7) reduction in capital investment.

Common benefits for both existing and new CPPs could include the freeing-up of operating personal time. While the regeneration of a MBP is highly automated, it does not completely eliminate operator involvement. To ensure a successful regeneration, periodic operator involvement is required to ensure the various steps in a regeneration have been successfully completed. Some examples of operator intervention are; (1) confirmation of resin removal and loading was successful, (2) complete flushing of resin transfer lines, (3) verification of chemical consumption, extended regenerations due to plant upsets, etc. Off-site regeneration can minimize the need for on-site storage of chemicals and fix the chemical costs associated with resin regeneration, reduce maintenance and repair for the regeneration systems, and reduce the volume of demineralized water required to support the regeneration. It is even possible to transfer the ownership of the resin to the service company providing the off-site regeneration.

The replacement/upgrade of an existing CPP requires a considerable amount of time to evaluate the benefits of trying to reuse any part of the existing system and to plan its implementation. There is also the issue of where to locate the new system. Does one demolish the old system to accommodate space for the new one or try to locate the new system within the plant so it can be installed without interrupting the operation of the Plant? Finally, there is a timing issue since any upgrade of the existing CPP is not something that can be done in a 30-day outage. Even if a complete new CPP is selected for an existing plant, the temporary availability of off-site regeneration during the installation of new equipment and the demolition of existing equipment can play an important role.

CPP Requirements to Support Off-Site Regeneration

The minimum requirements of a new off-site regenerated CPP would be the addition of a MBP. This plant could be designed for continuous full flow operation or partial flow operation, processing a portion of the condensate flow and/or bypassing a portion of the full flow at various times during its operation. The system should take into consideration the need or benefits of resin storage tanks on-site for fresh or exhausted resins and to facilitate the movement of the resin.

The MBP using off-site regeneration would be identical to the MBP using on-site external regeneration. The MBP should have internals that would ensure the uniform distribution of flow. The inlet distributor should prevent the movement of the resin and maintain a uniform bed depth to maximize the capacity of the resin and minimize its attrition. The internals should be designed to facilitate the complete removal of the exhausted resin (99.9%). Finally, the MBP should include provisions for remixing the resin bed in the event there is cation and anion resin separation during the movement of the resin. This feature can also be used to level the bed after a fresh charge of resin has been sluiced into the MBP.

The value of having a fresh resin storage tank (FRST) and a spent resin storage tank (SRST) will depend heavily upon the proximity of the service center that will be used for the off-site regeneration and that provider's ability to respond to a call for fresh resin. In most cases, a fresh resin storage tank will be provided. Similarly, a spent resin storage tank sized for either one or multiple beds will be driven by the same factors that dictate the need for the fresh resin storage tank. These vessels should have similar resin removal efficiencies of the MBP to ensure uniform management of the resin within the system.

The various vessels should be positioned to make the movement of the resin to and from the resin transfer trucks simple for the plant operators or the technicians of the resin service company. The trucks that will be used to deliver fresh resin and remove the exhausted resin can also have an impact upon resin movement. These trucks may have pressure limitations (as low as 10 psig) depending upon their construction. Some trucks can come equipped with provisions to provide motive air for the transfer of the fresh resin to the CPP. In general, demineralized water and air should be made available for the movement of the resin.

Implementation of Off-Site Regeneration for an Existing Plant

As one would expect, the conversion from an on-site external regeneration facility to an off-site regeneration facility would be more complex than the design of an off-site regeneration system for a new power plant. As most of the older CPP plants were designed and built to less demanding specifications than current systems, it is unlikely the existing MBPs or the vessels in the external regeneration system would have value. However, it is worth considering because there could be capital cost savings by reusing existing equipment or space constraints could dictate the need for reuse.

The MBP could be reused if the features described above are present in the existing unit. While effective resin removal should have been a feature that the original MBP should have possessed, there was not as much emphasis on this requirement so many MBP internals did not achieve this objective. In some cases modifications to the existing operational program including the addition of an air assist could improve this shortcoming.

Perhaps the major issue is the inability to remix in the MBP. As the underdrains in the older MBPs were sized to accommodate the condensate flow only for collection at high hydraulic loadings, they have a very large open area to minimize pressure loss. Therefore, when the same underdrain is required to act as an air distributor, there is insufficient backpressure to provide the needed air distribution.

Another factor to consider is the newer resin manufacturing techniques have resulted in the production of cation and anion resins that enhance their separation properties. While this can be a benefit for minimizing cross contamination of cation and anion resin, it promotes the separation of the resin when they are transferred. Off-site regeneration will typically mean the transfer of the resin at the off-site regeneration facility, the transfer of the resin to the fresh resin tank at the Plant and the transfer of the resin from the fresh resin storage tank to the MBP.

The older MBPs did not take into consideration the corrosive nature of the MBP effluent due to the absence of conditioning chemicals (ammonia, ETA, etc) that minimize the corrosion of the carbon steel downstream of the condensate polisher. Therefore, there could be some incentive to replace the existing MBP to eliminate this shortcoming. The logistics of the MBP location to the location of the delivery/receiving trucks must also be considered to ensure complete removal and loading of the ion exchange resins. Should the existing MBP address these issues, and it is in good physical condition with special attention given to the lining, there is no reason the existing MBP could not be reused.

The number of MBPs will vary depending upon the condensate flow rate and the desire to maximize the on-site fresh resin capacity. It is generally accepted that the most desirable design would be one that minimizes the number of MBPs as it offers the lowest capital cost and minimizes the number of MBP regenerations. This would typically translate into either two (2) 100% capacity MBPs or three (3) 50% MBPs. In addition, the fresh resin storage tank would also contain a fully regenerated resin charge. Therefore, the on-site resin capacity would be equivalent to either three or four full resin charges. Some installations do not include a standby MBP so a portion of the condensate flow would be bypassed during resin transfers to and from the MBP. There is also the case where the installation only has provisions for a partial flow CPP so the CPP is sized accordingly.

The only value of the existing on-site external regeneration system could be to possibly reuse some of the regeneration vessels as fresh or exhausted resin storage vessels. These vessels would also have to address many of the concerns listed above. As there were a wide variety of external regeneration system designs by companies that no longer exist, there would be no uniformity in the vessel designs. A CPP plant could have been as simple as a two tank design, with a single regeneration tank and a resin storage tank. At the other end of the spectrum would be a four tank system consisting of a resin separation/cation regeneration tank, an anion regeneration tank, a resin mix and storage tank and an interface tank. Provided the same issues that apply to the MBP were adequately addressed, it is conceivable some of the existing on-site regeneration vessels could be used as either a fresh resin or an exhausted resin storage tank.

Concerning on-site utilities, there should be adequate high pressure air to facilitate resin transfer (~60 psig) and low pressure air for remixing the fresh resin in the MBP (~7.5 psig). It would be necessary to have demineralized water available to sluice the fresh resin from the truck to the MBP or fresh resin storage tank (~60 psig) as well as the exhausted resin from the MBP to the truck. Provisions should also be provided for the disposal of the sluice water including the sluice water of the exhausted resin which could contain high levels of metal oxides, or crud.

There are also some hardware requirements that are important in monitoring complete resin movement and maintaining the proper resin inventories. Sight windows in the various vessels are necessary to ensure the resins are completely removed from the vessels and the fresh resin volume is correct. It is also beneficial to have sight windows in the resin movement lines to ensure the lines are completely flushed free of resin. Finally, there should be pressure protection when there is a crossover between the high pressure demands of the MBP and the balance of the system.

Implementation of Off-Site Regeneration at a New Plant

Naturally, the design of an off-site regenerated CPP would be simpler to implement at a new Power Plant. The plant could be laid out to facilitate the movement and storage of the ion exchange resin. In some cases, when the proximity of the service company's off-site external regeneration plant is sufficiently close, it could be possible to completely eliminate both the fresh resin and exhausted resin tanks. The fresh resin could simply be sluiced from the delivery truck to the MBP and the exhausted resin could also be transferred directly from the exhausted MBP to the resin truck. This design would take away some of the flexibility of the CPP but might be acceptable if there would be no meaningful delay in the recharging of the MBP. However, if a Plant would want the ability to immediately recharge a MBP it would be necessary to have on-site fresh and exhausted resin storage.

For the situation where on-site storage of the fresh and exhausted resin are required, the capacity of these storage tanks could vary. For the exhausted resin tank, it could be sized for a single or multiple bed capacity. The resins from multiple MBP could be mixed without concern for ensuring each bed is isolated. The same would not be true for the fresh resin tank. It would be necessary to store the exact volume of fresh resin for each polisher to maintain consistency in resin inventory. Therefore multiple tanks with each tank having a single MBP resin charge or a multi-compartmented fresh resin storage tank would be required. It would also require delivery trucks with multiple compartments to be cost effective.

The air and water requirements along with the hardware requirements that are discussed above would also apply for a new CPP.

Resin Selection and System Chemistry

The use of off-site regeneration can expand the ion exchange resin selection but it could also impose some restrictions on the operation of the MBP. An on-site regeneration system provides benefits beyond the simple conversion of the cation and anion resins to their regenerated condition and the removal of crud.

Virtually all the new CPPs utilize uniform bead ion exchange resins as opposed to Gaussian resin size distribution. These resins can enhance the separation efficiency of the cation and anion resin necessary to minimize cross contamination. The resin will also display enhanced flow characteristics including a reduction in the pressure loss of the polisher when operated at the design flow rate that is typically 50 GPM/ft^2. It should be recognized uniform bead resin does not completely eliminate the need to conduct a backwashing of the resin prior to placement of the resin in the MBP. There is still value in conducting a thorough backwash of the resin after it is removed from the shipping container to remove a portion of the resin that is smaller than the specified bead size. As there will be no external regeneration system, the backwashing of the new resin in an on-site regeneration system is not possible. This means the resin would have to be properly conditioned before the resin is shipped to the jobsite.

During the start-up and commissioning of the Plant, the CPP ion exchange resins will be regenerated several times before the MBP is placed in service for the acceptance test and normal operation. These regenerations act as a form of resin cleanup prior to the placement of the Plant into service to minimize TOC throw and eliminate some smaller resin beads. If this resin conditioning step is not conducted, it may be necessary to select the appropriate resin and conduct off-site resin cleanup.

While the plant is normally designed with a specific ratio of cation to anion resin, this ratio can be changed with virtually no impact on the CPP when off-site regeneration of the resin is selected. Many on-site regeneration systems can limit if not prevent a change in the resin ratio once the plant has been designed and built.

The types of ion exchange resins can vary depending upon the type of plant (nuclear, fossil, or solar) and its system chemistry. With off-site regeneration of the polisher resin, the Plant has the flexibility to operate in the H/OH cycle or the ammonia cycle to suit the Plant's system chemistry. The use of higher cross-linked cation resins is another option that Plants may consider.

Attachment A offers a description of a typical cation and anion resin that would be used in a CPP.

Minimum Requirements of the Off-Site Regeneration System

As a minimum, the off-site regeneration system should be able to perform all the functions of a system had it been designed for on-site regeneration. However, it would be beneficial if the off-site regeneration system could perform additional resin conditioning services to enhance the performance of the CPP. In the case of retro-fitting off-site regeneration where the existing MBP or any of the other equipment is utilized, the Power Plant must accept any shortcomings that the use of existing equipment may have.

The first step in any mixed bed regeneration is the separation of the cation and anion resin. Ideally, the cross contamination after separation should be minimal. Cross contamination is a key factor when the Power Plant has any intention of operating past the ammonia break. Under this circumstance, the cross contamination of cation to anion resin should be approximately 0.1%. While the cross contamination of anion in cation is not that critical if sulfuric acid is used to regenerate the cation resin, it should be in the range of 0.1 - 0.5%.

The effectiveness of minimizing cross contamination is complicated when the full bed volume of a MBP is not separated in a single step. As most off-site regeneration systems do not have a separation vessel adequately sized to separate a single MBP vessel, the separation will have to be conducted in multiple steps with smaller volumes.

The resin separation techniques can vary depending upon the capabilities of the service organization. In general there are three choices; the use of hydraulic/density separation, the use of chemical separation, and the use of mechanical screening/hydraulic separation. Each has its own advantages and disadvantages but the option of choice should be one that will enable the service company to guarantee the required performance of the CPP.

The off-site regeneration system should have provisions for mechanically cleaning the resins both prior to and after the chemical regeneration.

The off-site regeneration system should use sulfuric acid to regenerate the cation resin. While this may appear to be obvious, the designs of many off-site regeneration systems are based upon the use of hydrochloric acid and not sulfuric acid. This is because HCl is easier to use (no calcium sulfate precipitation issues), it offers higher cation capacity, it produces a higher quality product water quality, and it produces less waste water. Ideally, both acids should be available because it would be desirable to have the ability to use HCl to assist in the removal of iron fouling from the cation resin. The anion resin should utilize heated caustic and demineralized water for caustic dilution. As the regeneration vessels for both the cation and anion resins may not be large enough to handle a complete MBP resin charge, care must be taken to ensure the repeatability of each regeneration.

It is critical that the final stored regenerated resin volume be equal to that of a MBP charge so the resin inventory remains in balance.

In the event there is a requirement to convert the cation resin to the ammonia form and not the hydrogen form, the regeneration system should have the ability to use ammonium hydroxide rinse. This can be an issue for some off-site regeneration facilities due to discharge permitting of the ammonia. This could also be true for other cleaning chemicals should they be required.

Examples of both cation and anion resins before and after regenerations are provided in Attachment B (cation resin) and Attachment C (anion resin). The data includes pre and post regeneration for resins utilized in a Power Plant operated in the NH_4/OH form during start-up as well resins utilized in a Power Plant operated in the H/OH form during normal operation.

The final remix and rinse must be conducted for the MBP resin charge at the off-site regeneration facility to ensure there will be no problem once the resin is returned to the MBP.

Regeneration Services

The performance of a CPP is controlled by two factors; the hydraulic/mechanical design of the MBP and the ability to effectively regenerate/condition the resin. Just as these two factors cannot be isolated from each other, the responsibility for each of these two factors should not be separated. This fact is critical for off-site regeneration with a new CPP or for a retrofit of a existing CPP with a new MBP. It is important to have the performance acceptance test be conducted with the responsibility for the design and the responsibility of the resin regeneration be placed with a single organization. If the responsibility for these two functions is separated, one always runs the risk of having “finger pointing” in the event the performance of the CPP does not achieve its required objectives.
The design of a CPP for a new Power Plant is normally the responsibility of a third party Engineering Company. This company will be responsible to demonstrate the CPP is capable of meeting the stated performance objectives. It is virtually impossible for the acceptance test to be conducted unless a service company has been engaged to regenerate/condition the resin during startup and commissioning. It should be noted the performance test will be run under the most favorable conditions (relatively clean system and unimpaired resin) making it highly probable the test will be successful. It would be prudent to make the selection of the service organization that would provide this service over a minimum of one year of plant operation. As this contract would be considered an operating contract and not an integral part of the Plant’s design, the Power Company should be engaged in the selection of the service organization responsible for the regeneration/conditioning of the resin.

The number of service organizations that can provide off-site regeneration of the resin to satisfy the requirements above is surprisingly limited. The logistics of the Power Plant and that of the service organization can also have an impact on the number of service companies that are capable of providing the service. Transportation can also influence the decision of the service company as it relates to facilities capabilities as well as economic considerations. In addition, there is the question of transportation risk associated with weather or other environmental considerations. Therefore, an analysis of the service organizations should be given careful consideration when making the selection of the service organization.

Since it is critical to ensure the regeneration/conditioning of the resins has met its objectives, there should be laboratory support to analyze the effectiveness of the regeneration/conditioning. This could also involve the ability to run kinetic tests in the event the objective of the regeneration/conditioning has not been successful. Cross contamination measurement and resin conversion are some other factors that must be evaluated. The increased use of amines and dispersants can result in kinetic impairment so periodic cleaning of the resin may be necessary. The treatment of the resin to restore the resin to acceptable performance may also require chemicals that may have to be discharged into municipal sewer lines. Therefore the Plant's existing permits could be affected.

The service organization should have an adequate fleet of resin transportation trucks. Multi-compartmented trucks are the most efficient from an economic point of view as they would permit the handling of the fresh resin and exhausted resin in a single trip. Trucks equipped with air transfer systems will simplify the plant requirements if the air pressure is adequate to move the resin over the distance between the tanks and the trucks.

The service organization also plays an important role during the startup and commissioning of the Power Plant. Assuming the resin purchased with the CPP is used during the startup, the resin will be used to clean up the system, primarily the removal of iron oxides (crud). The MBP resin will have to be removed from service to thoroughly remove crud and regenerate the resin. After the startup and commissioning of the Plant, the resin will have to be once again cleaned and regenerated prior to the performance testing. As an alternative, the service organization may provide resin of a lesser quality to be used during the startup and commissioning to avoid the use of the resin that was purchased with the CPP.

Finally, the service organization must have the ability to keep the MBP resin segregated from the other resins that are processed at their regeneration facility. Due to the high purity demands of the CPP their resins must not be contaminated by resin used for general industry. This could include the storage of a resin interface volume that would be used to achieve the desired minimal cross contamination. It could also involve the storage of a resin "float" to provide the necessary assurance of on-time delivery of freshly regenerated resin.
The service organization should have a backup plan (alternate site) to meet the CPPs plants need in the even the plant that had been selected to perform the resin conditioning is unavailable. Since the service organization is an integral part of the Power Plants operation, there should be an assurance this organization will be there to provide the required services.

Designs That Should be Given Future Consideration

This presentation deals with the use of a conventional MBP for condensate treatment. There are a few Plants in the USA that also incorporate a cation polisher (CP) ahead of the MBP, such as the San Onofre Nuclear Generating Station. One of the advantages of the CP is the reduction in cationic loading and crud on the MBP thereby permitting the MBP to operate for an extended period of time. The other advantages have been enumerated in previous papers. With this approach it would be logical to have provisions for the simple regeneration of the CP on site.

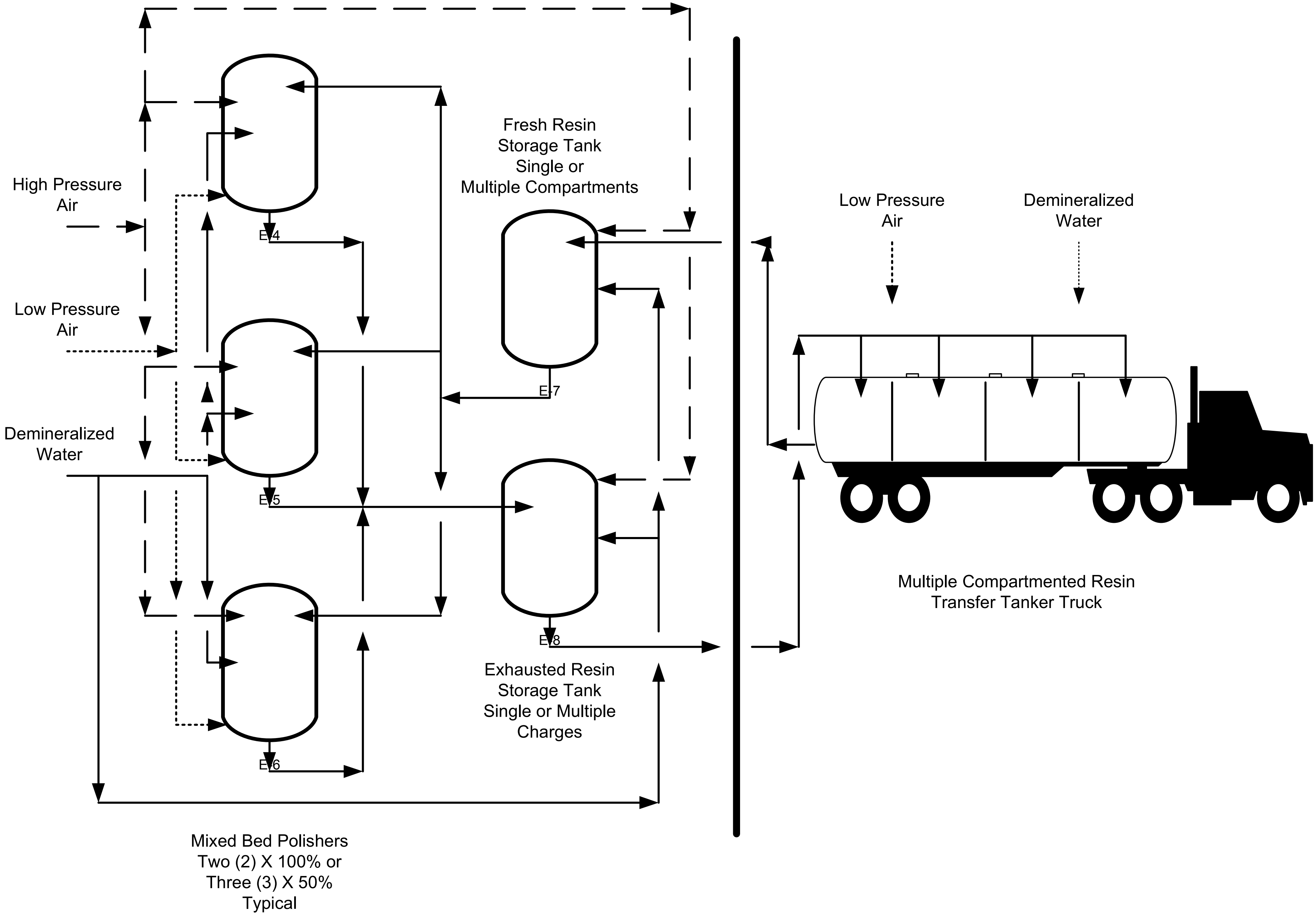
A second and more intriguing design consideration would be the use of an individual bed ion exchange CPP. This design would be appropriate for fossil and solar Power Plants. The CPP would consist of a cation bed, followed by an anion bed, and possibly a second cation bed. This design has been used in Power Plants outside the USA but is yet to have gained acceptance in the USA. However, this design was tested by EPRI in cooperation with Southern California Edison. This work was conducted at the Huntington Beach Generating Station, now owned by AES. The advantages of this design are self-evident. Since the cation and anion resins are never mixed, the regeneration system can be greatly simplified. There would be no need for resin separation and no concern over cross contamination. The resin beds could be independently regenerated/conditioned as required. There would be no concern over the need to maintain a uniform mixture of cation and anion resin.

Summary

The move toward off-site regeneration of deep bed condensate polishers will continue to grow. This growth will be driven by the need to replace the large number of existing CPPs and the desire to simplify the operation of new plants while minimizing the capital investment. In most cases in the USA, it is unlikely that a completely new CPP with on-site regeneration will be the preferred solution. This being the case the major issues that must be addressed are:

- The identification of off-site regeneration facilities that are logistically acceptable for the regeneration/servicing of the ion exchange resins whether it be for a new plant or a retrofit.
- The capabilities of the off-site regeneration system to accommodate servicing the resin beyond simple regeneration and its analytical capabilities to ensure the servicing had been performed correctly.
- The value in re-using existing equipment in the case of an existing system.
- The location of the MBP and its associated regeneration system within the Power Plant.
- The timing for the retirement of the existing CPP and the installation of the new one to minimize the impact on the operation of the existing Power Plant.

Typical Illustration of an Off-Site Regenerated Condensate Polishing Plant



ATTACHMENT A

TYPICAL STRONG ACID CATION RESIN

Chemical Properties

Functional Group	Sulfonic Acid
Cross-linkage	10%
Ionic Form (as shipped)	Hydrogen
Moisture Content	46 - 51% (H form)
Exchange Capacity	2.0 meq / ml minimum (H form)
Conversion to Hydrogen Form	99% minimum
Kinetics	> 17 megohm

Physical Properties

Particle Screen Sizing	
+ 16 Mesh	2% maximum
- 50 mesh	0.5% maximum
Friability	
Average	350 grams / bead minimum
% > 200 gm / bd	95
Whole Beads (%)	95% minimum

TYPICAL STRONG BASE ANION RESIN (TYPE 1)

Chemical Properties

Functional Group	Trimethylamine
Ionic Form (as shipped)	Hydroxide
Moisture Content	43 - 48% (Cl form)
Exchange Capacity	1.2 meq / ml minimum (OH form)
Conversion to Hydroxide Form	94% minimum
Impurities	
Chlorides	0.5% maximum
Sulfates	0.5% maximum
Carbonates	5% maximum
Kinetics	> 17 megohm

Physical Properties

Particle Screen Sizing	
+ 16 Mesh	5% maximum
- 50 mesh	0.5% maximum
Friability	
Average (gm / bd)	350 grams / bead minimum
% > 200 gm / bd	95
Whole Beads (%)	95% minimum

Attachment B

Mixed Bed Cation Resin Components

Start Up NH4/OH form Condensate Polishing Mixed Bed: Cation Resin Component

	Total Capacity (meq/mL)	Percent NH4	Percent H	Ca Content (mg/kg, wet)	Cu Content (mg/kg, wet)	Fe Content (mg/kg, wet)	Mg Content (mg/kg, wet)	Na Content (mg/kg, wet)	Zn Content (mg/kg, wet)
Initial Cation Resin				1564	3.3	10.9	284.7	5829	6.4
Processed Cation Resin	2.16	93%	7%	180	0.10	3.3	2.9	24.2	0.10

H/OH form Condensate Polishing Mixed Bed: Cation Resin Component

	Total Capacity (meq/mL)	Percent H	Percent Moisture	Ca Content (mg/kg, wet)	Cu Content (mg/kg, wet)	Fe Content (mg/kg, wet)	Mg Content (mg/kg, wet)	Na Content (mg/kg, wet)	Zn Content (mg/kg, wet)
Initial Cation Resin									
Processed Cation Resin	2.12	99.3%	48.6%	217	0.2	26.2	35.3	1.9	0.4

Attachment C

Mixed Bed Anion Resin Components

Start Up NH4/OH form Condensate Polishing Mixed Bed: Anion Resin Component

	Total Capacity	Salt Splitting Capacity	% OH	% CO3	% Cl	% SO4
	(meq/mL, OH Form)	(meq/mL, OH Form)				
Initial Anion Resin						
Processed Anion Resin	0.88	0.85	96.6%	1.9%	0.24%	0.07%

	Percent	Ca Content	Cu Content	Fe Content	Mg Content	Na Content	Zn Content
	Moisture	(mg/kg, wet)	(mg/kg, wet)	(mg/kg, wet)	(mg/kg, wet)	(mg/kg, wet)	(mg/kg, wet)
Initial Anion Resin		7.3	1.4	218.6	28.5	149.4	0.5
Processed Anion Resin	62.9%	2.6	0.3	97.5	0.5	BDL	0.3

H/OH form Condensate Polishing Mixed Bed: Anion Resin Component

	Total Capacity	Salt Splitting Capacity	% OH	% CO3	% Cl	% SO4
	(meq/mL, OH Form)	(meq/mL, OH Form)				
Initial Anion Resin						
Processed Anion Resin	1.24	1.21	92.7%	2.2%	0.01%	0.07%

	Percent	Ca Content	Cu Content	Fe Content	Mg Content	Na Content	Zn Content
	Moisture	(mg/kg, wet)	(mg/kg, wet)	(mg/kg, wet)	(mg/kg, wet)	(mg/kg, wet)	(mg/kg, wet)
Initial Anion Resin							
Processed Anion Resin	45.0%	0.6	BDL	34	1.5	38	BDL