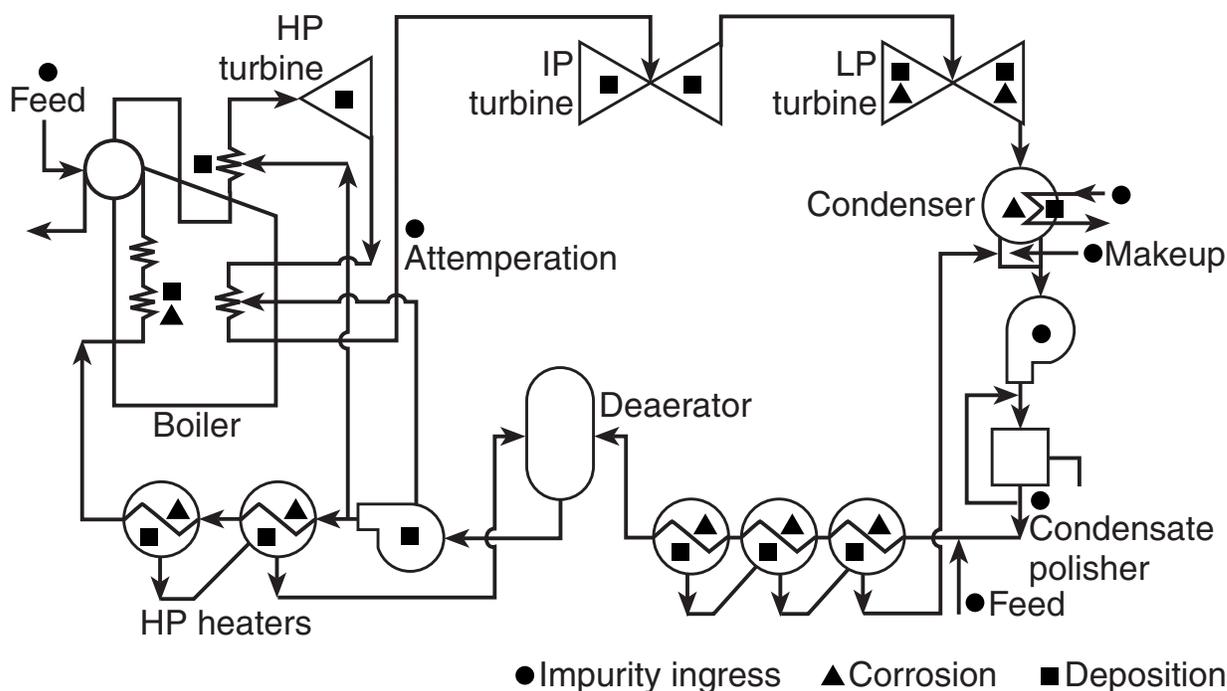


Guideline for Off-site Regeneration of Condensate Polishing Resins



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Technical Report



Guideline for Off-site Regeneration of Condensate Polishing Resins

1001502

Final Report, June 2001

EPRI Project Manager
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REPORT SUMMARY

Successful condensate polishing maintains control of ionic and particulate impurity transport in the fossil plant and allows the unit to operate more reliably. This report will assist utilities in reducing the overall cost of condensate polishing by the use of off-site regeneration of the resins.

Background

EPRI's fossil plant guidelines for cycle chemistry provide direction and guidance on selecting and optimizing water and steam chemistry for fossil plants. Since the optimum condensate and feedwater treatments are central to ensuring plant component availability and reliability, the chemistry parameters have been and are continuing to be tightened. Consistent industry guidelines for condensate polishing (EPRI report TR-104422) assist utilities in achieving these limits. However, condensate polishing is not employed in enough fossil plants. Condensate polishing would allow the use of more effective and less troublesome treatment regimes, such as all-volatile treatment (AVT) and oxygenated treatment (OT). A fresh look at the whole condensate polishing area was required specifically to reduce the overall cost of polishing.

Objective

To provide comprehensive guidelines for the evaluation and implementation of off-site regeneration of condensate polishing resins.

Approach

EPRI assembled an international team of condensate polishing specialists to investigate alternatives to the standard axial flow deep bed and powdered resin condensate polishers. The team indicated two avenues should be followed: off-site regeneration of resins and radial flow polishing. Radial flow has been addressed in a separate study (EPRI Report 1001409). In the off-site regeneration study, the project team interviewed potential off-site regeneration contractors to determine possible design interface and cost information. They next developed life-cycle costs for system procurement, installation, and operation. Finally, they developed the guideline, which was reviewed with the international team.

Results

The guideline provides information to assist utilities in evaluating the use of off-site regeneration for new or retrofit situations. Detailed cost comparisons are provided, which show that capital costs could be reduced by 25% and that total life cycle costs of off-site regeneration are economical if regeneration frequency is limited. Information is also included for procurement of the appropriate equipment and services for implementation of condensate polishing with off-site regeneration services. A sample off-site regeneration specification is provided.

EPRI Perspective

The off-site regeneration technology forms an important part of EPRI's aim to develop advanced and cheaper condensate polishing systems for the industry. In a parallel effort, EPRI is researching radial flow polishing systems. Here the increased surface area and thus flow capacity is obtained by increasing the axial dimensions of a vessel rather than the diameter, an approach which offers significant capital savings. In the next phases of the overall condensate polishing work, EPRI will be demonstrating the off-site regeneration technology and testing a scaled radial flow vessel in a power plant. Combining the off-site regeneration with radial flow has the potential to reduce the overall polishing costs further.

Keywords

Water chemistry

Condensate polishing

Feedwater

Boiler water

Resins

Regeneration

ABSTRACT

Condensate polishing can be an important part of any utility steam cycle. The cost of equipment, installation, and operation has impeded greater usage of condensate polishing by utilities. In the past, typical utility systems, have included complex regeneration systems. These systems contribute substantially to equipment and installation cost. In addition, regeneration has traditionally required the use of strong regenerant chemicals. The use of these chemicals has safety and environmental impacts on plant operation.

Regeneration of condensate polishing resins by an off-site contractor can reduce capital and installation cost as well as minimize safety and environmental impacts. Condensate polisher effluent quality can be improved and station manpower requirements can be reduced by the use of off-site regeneration. As a part of a project to investigate ways to reduce the cost of condensate polishing, guidelines are developed for utilities to use an off-site contractor to provide regeneration services for condensate polishing resins.

Chapter 1 describes Guideline goals. These goals were to devise off-site regeneration procedures that were simple to use and provide adequate assurance of satisfactory resin regeneration levels and satisfactory resin purity. Factors evaluated included the technical feasibility, advantages and disadvantages, and desirability of off-site regeneration of condensate polishing resins.

Chapter 2 describes evaluation of the plant and the determination of features that would be desirable for use with off-site regeneration. Performance of the existing unit, targets for future operation, and important choices for specific plant implementation are described.

Chapter 3 describes specific systems and guidance for plant implementation of the selected system and system features. Conceptual diagrams of several possible choices for systems are included. A roadmap for evaluation and implementation is provided.

Chapter 4 provides detailed operating guidelines including both internal operating parameters as well as testing guidelines for delivered resin quality. Quality control of off-site contractors operations is important. Tests and recommendations for quality control are also provided in these guidelines.

Chapter 5 develops the economics of off-site regeneration and compares economics with on-site regeneration. New units and retrofit units are compared. Economic comparison showed capital costs reduced by 25% and total life cycle costs of off-site regeneration to be economical if regeneration frequency is limited. The sensitivity to evaluation parameters is considered. Total life cycle cost for off-site regeneration is more sensitive to regeneration frequency and also relatively to contractor charges.

Appendix A includes a sample off-site regeneration specification. Appendix B includes extensive resin testing information, including important accept/reject and quality control testing for contractor delivered resins. Appendix C contains a listing of economic factors used in the Guideline.

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MISSION AND GOALS

1.1 Introduction

It is prudent for the management of fossil power stations to maximize plant availability by minimizing corrosion and deposition, through the use of condensate polishing,. At the same time there are growing pressures to reduce operating costs. This often means reducing staffing levels while trying to meet increasingly severe environmental constraints.

Most, if not all, types of fossil power stations can benefit by using condensate polishing. The benefits derived from the use of condensate polishing have been quantified and discussed in earlier EPRI documents (1). The use of off-site regeneration can be beneficial for a new installation where it is desired to avoid the capital cost, operating cost, construction impact, and operating impact of on-site regeneration facilities. The use of off-site regeneration may also be beneficial for retrofitting existing units that already have regeneration facilities.

The use of condensate polishing, while offering substantial water chemistry benefits, is costly, both from the capital costs of the polishing equipment and from the operating costs for regenerants and maintenance. Polishing does increase the workload on station staff, because it is another piece of plant equipment to be maintained, serviced, and monitored. Additionally, there are safety implications from the storage and use of regenerants, such as concentrated sulfuric or hydrochloric acid and caustic soda, as well as the additional discharges of spent regenerants and the effort needed to ensure compliance with environmental legislation. External regeneration of a mixed bed is a complicated operational sequence, especially when a high degree of regeneration is required.

The alternative of using specialized contractors to collect exhausted condensate polishing resins and to return regenerated resins of a guaranteed quality could become attractive provided that such a service can be shown to be both reliable and economical. The costs for regeneration equipment and controls for new installations, the need for storage and use of regenerant chemicals, the disposal of regeneration wastes, and a portion of the plant owner's monitoring and maintenance costs can be used to offset the cost of the contractor's service. This approach is already used by one major utility in the United States. These guidelines are intended to advise other potential users of the anticipated benefits of off-site regeneration and anticipated situations required for greatest benefit, to suggest means to evaluate the economics of off-site regeneration, and to roadmap to successful implementation of off-site regeneration.

1.2 Objectives

The main objective of developing guidelines for off-site regeneration of condensate polishing resins for fossil power stations is to allow plants to evaluate the potential benefits and if proven beneficial to implement condensate polishing using off-site regeneration. Other objectives are summarized below:

1. To reduce the cost of condensate polishing in order to increase its use on fossil power stations of all designs. The use of condensate polishing will allow more effective yet simpler forms of treatment of the steam/water circuit that will improve availability and result in more economic power generation.
2. To simplify the operation of condensate polishing plants by transferring the responsibility for the control and regeneration of resins and the associated disposal of effluents to off-site contractors. This may improve the performance of polishing plants where on-site regeneration has proven difficult because of equipment or staffing problems.
3. To facilitate improved operation of condensate polishers in the ammonium form on those stations where conditions are suitable for operating in this economical mode. Ammonium form operation can be used satisfactorily if resins are regenerated to a very high level to achieve the required purity. Many fossil stations lack the equipment and/or the trained staff to reduce impurity levels on the resins to the required levels. Contractors should be required to guarantee that resins prepared by them comply with the appropriate specifications.

1.3 Advantages

The following advantages are expected:

1. **Reduced Workload.** The workload on power station operators can be reduced by eliminating the time involved in the regeneration of exhausted resins, frequent resin quality monitoring, training, resin purchase and storage, handling and surveillance of bulk regenerant chemicals, and the handling, monitoring and disposal of waste regenerants and the associated effort to ensure compliance with permitting.
2. **Elimination of On-Site Regeneration Facilities.** The elimination of the need to provide an on-site regeneration plant for condensate polishing resins should result in significant capital savings for new condensate polishing systems. The savings will vary from plant to plant and will need to be evaluated on a case-by-case basis.
3. **Reduction or Elimination of the Need for Stocks of Bulk Chemicals.** For new installations, regenerant storage facilities for the condensate polisher can be eliminated. For existing facilities, operating and maintenance costs for regenerant facilities can be eliminated. There may also be a significant saving in insurance costs associated with the risks of hazardous chemicals handling.

4. **Improved Regenerated Resin Quality.** Difficulties associated with resin regeneration can lead to reduced polished water quality. Resins properly regenerated by specialty contractors, and supplied to a guaranteed specification, offer the promise of consistently high quality resin for polishing. Similarly, problems arising from the use of resins in poor physical or chemical condition should be minimized, as the responsibility for control of resin quality could also pass to the contractor.
5. **Elimination of Polishing Plant Effluents.** The use of contractor regeneration services will reduce or eliminate the need for stations to collect, check, and adjust wastewater chemical conditions such as pH. The discharge of exhausted regenerants and the associated rinse water resulting from regenerations of polisher resins will be eliminated or significantly reduced. The effort needed to ensure compliance with environmental regulatory requirements would also be reduced.
6. **Ammonium Form Operation.** Fossil power stations operate their steam/water circuits at relatively high pH in order to minimize corrosion product transport and deposition. The operation of condensate polishers in the H-OH form at high pH levels places significant demands on plant operators because of the short service runs and frequent bed regenerations. As will be shown later, off-site regeneration is much less economical for polishers operated in this manner. Ammonium form operation allows significantly longer runs and is more economical for off-site regeneration. In the absence of condenser leaks or frequent start-ups, service runs can be extended from a few days to two months. Because of a number of factors, most related to resin quality and resin purity, ammonium form operation has achieved variable success. Ion exchange resins could be regenerated to the required levels by a contractor, thus allowing stations to realize the economic benefit of ammonium form operation. This would save money as a result of the frequency of regeneration.

1.4 Drawbacks

Experience in the off-site regeneration of ion exchange resins used in condensate polishing plants is very limited. Some confidence can be gained from the obvious and growing success that such contractors are enjoying in providing make-up water to power stations and other industries. These services originally provided high quality makeup water for short periods of time using mobile equipment. In some instances the temporary makeup services have evolved to contractors assuming total responsibility for the continuous supply of make-up water. Nevertheless, concerns have been expressed over the proposed further extension to cover regeneration of condensate polishing resins. Drawbacks of these operations include :

1. **Operating Costs.** The cost of a contractor providing an off-site regeneration service is evaluated in detail in subsequent chapters and will vary from station to station. The question that must be addressed is whether there will be a net benefit to the station. This will require an individual assessment for each situation. A roadmap for conducting such an assessment is included later in these Guidelines. Actual costs will always be station specific but can be expected to fall if off-site regeneration services become more commonly used and the economies of scale and competition have their expected effects. Plants operating in the ammonium form should show a benefit at all times if they are substantially free of leaks and if they experience infrequent startups.

Mission and Goals

2. **Dependency Upon Contractors.** To install a condensate polishing plant on a power station without providing a regeneration plant makes the operation of the plant dependent upon outside contractors. This is not very different from the operation of many other vital station activities that are also dependent on a continuous and reliable supply of consumables. It is intended that a reliable service should be ensured by means of the contract between the utility and the contractor. Potential contractors are already involved in the supply of make-water services and are well aware of the importance of the continuity of supply. Structuring an appropriate contract and allowing for competition and flexibility of suppliers are considered important factors in minimizing concerns about dependency upon contractors.
3. **Reduced Control over Resin Supplies.** Condensate polishing plants must have the flexibility to respond to plant situations such as start-ups and, even more importantly, condenser leaks. Such events inevitably load impurities onto the resins and so lead to a more rapid exhaustion of the beds affected. Concern exists for the situations in which the rate of delivery of freshly regenerated resin by the contractor could fail to keep pace with peak demands. Under some circumstances, even the most efficient contractor could still encounter problems, for example bad weather or road conditions that would prevent a timely re-supply. The coincidence of contaminant intrusion and bad weather could lead to adverse water quality conditions. This could require a forced outage of the station. Review of previous plant experience and appropriate selection of on-site storage of reserves of regenerated resins or other backup plan, appropriate for each plant circumstance, is recommended to overcome this concern.
4. **Split Responsibility for Performance Guarantees.** For new systems, the service vessel supplier can only be responsible for uniform flow distribution and completeness of transfer for the equipment they supply. The resin contractor can be responsible for resin performance provided they have uniform flow distribution and complete transfer of resin from the resin storage tanks. This could be avoided if equipment supplier and resin contractor are the same entity.

1.5 References

1. *Condensate Polishing Guidelines*, EPRI, Palo Alto, CA: 1996. TR-104422.

2

PLANT EVALUATION

Plant evaluation is important whether a new condensate polishing system is being considered or whether modification of an existing system is the goal. A detailed review of plant features and operation is necessary in order to select the most appropriate items for the evaluation and to select the most appropriate features for the implementation of condensate polishing system. The performance of the existing plant features and operations also needs to be reviewed for improvement opportunities. Following the evaluation, goals for the improvements need to be established so that the most appropriate alternatives for the specific plant or group of plants are selected for implementation.

2.1 Performance Review

Plants should already have established their own customized water quality programs. EPRI has published guidelines for a variety of programs to suit virtually every type of plant and program. The water chemistry records for the plant should be reviewed to compare the performance of the plant's equipment and procedures against the established program and to identify opportunities for improvement of plant performance and water quality. Any expected changes in plant operations such as changing to cycling duty or significant increase in the restart frequency, will also need to be considered.

Water Quality Requirements. A plant planning to use condensate polishing must first consider what polished condensate quality it needs to attain. The various EPRI Guidelines give advice covering most designs of boilers and water treatments. These guidelines, as they apply to condensate, are summarized in Table 2-1.

**Table 2-1
EPRI Normal Limits For Polished Condensate**

Type of Boiler	Treatment	Normal Impurity Limits in Condensate		
		Sodium, ppb ($\mu\text{g}/\text{kg}$)	Cation Conductivity, $\mu\text{S}/\text{cm}$	Silica, ppb ($\mu\text{g}/\text{kg}$)
Once-Through	OT	< 3	< 0.15	< 10
	AVT	< 3	< 0.20	< 10
Drum Without Reheat	Phosphate	< 10	< 0.25	< 20
	Equilibrium Phosphate	< 6	< 0.25	< 20
	AVT	< 6	< 0.25	< 10
Drum With Reheat	Phosphate	< 5	< 0.20	< 10
	Equilibrium Phosphate	< 3	< 0.20	< 10
	AVT	< 3	< 0.20	< 10
	Sodium Hydroxide	< 5	< 0.20	< 10

These limits are not particularly challenging and are significantly higher than what can reasonably be achieved by a competently managed cycle using condensate polishing even if it is being operated under adverse conditions (such as high pH and operation beyond ammonia break). Polishers operating in the conventional H-OH form can, and some consistently do, attain sodium levels in polished water two or even three orders of magnitude below the guideline values for fossil plants. However, such performance requires special attention to resin condition and regeneration.

2.1.1 Water Chemistry Records

Water chemistry records must be reviewed to determine how well the goals and chemistry parameters are being met with the current plant equipment and operations. For the case where full flow condensate polishing is being considered, the frequency of condenser leaks and other impurity ingress incidents are of particular importance for either case of polisher addition or regeneration retrofit. Some plants suffer severe condensate contamination problems at start-up and this together with the projected frequency of start-ups must also be considered. The assessment should take into account the condition and experience with plant components, such as the condenser tubes. The goal of this review is to anticipate the potential benefits of a polisher addition as well as to predict the likely rate of regeneration of condensate polishing resin charges. The mode of operation of the polishing plant must also be taken into account. Table 2-1 shows that there are some minor differences between the impurity limits in polished water, but

even the lowest of these are significantly higher than what can realistically be expected to be produced by any deep bed polishing plant. Therefore, the water chemistry program selected for use on the boiler should not influence the design of the polishing plant and the demands made with respect to resin regeneration services.

2.2 Plant Design

Important aspects of the plant design need to be reviewed before retrofitting a new polisher to an existing unit or converting an existing polisher to use off-site regeneration. For the former case, the interfaces and requirements imposed by the condensate system and space and support utilities for the new equipment are the primary concerns. For both cases, the interfaces between the resin trucks and the service or storage vessels are important considerations. In the simpler regeneration retrofit case, the existing design of the regeneration system needs close review to determine how best to interface with the existing regeneration vessels.

Changes in plant configuration or operation such as re-powering, retrofits for cogeneration, or changes to cycling or two-shifting operation are important changes which would benefit by the use of an effective condensate polishing system.

2.2.1 Plant Design for New Installation

A new retrofit installation of a condensate polishing system is a significant undertaking and should start with a thorough study of the existing plant facilities to locate the optimum interfaces with the existing plant. Important requirements are listed below.

1. Space for service vessels
2. Interconnections with condensate system
3. Bypass valve use and location
4. Waste connections
5. Water and air supplies
6. Bulk storage tank locations
7. Control panel locations
8. Piping corridors
9. Resin loading and unloading station(s)
10. Power supplies.

Functional items need to be gathered from the plant review including maximum polished condensate flow rate and condensate system design pressure. A hydraulic evaluation of the condensate system will need to be performed to determine whether sufficient condensate pumping capacity exists to overcome the head loss caused by the addition of the service vessels. If pumping capacity is insufficient, locations and power supplies for booster pumps would also need to be determined.

2.2.2 Plant Design for Off-site Regeneration Retrofit

Retrofit of existing systems to be able to use off-site regeneration is simpler than the entire system addition but still requires careful review, evaluation, and attention to existing features. As described in Chapter 3, a typical retrofit is envisioned to continue to use the existing cation regeneration tank and existing resin storage tank as a part of the new system. This typical retrofit assumes a conventional system using three external regeneration vessels with mixed resin first routed to the cation regeneration tank. Because many plants may have other types of systems, these other systems would require different interconnections to achieve the same goals as the typical system retrofit. Capabilities of the existing regeneration system, which are still desired when implementing off-site regeneration, are listed below.

1. Resin cleaning and backwashing.
2. Resin mixing.
3. Resin transfer to and from the service vessels.
4. New resin charge preparation.
5. Resin sampling, rinsing, and testing.
6. Regenerated resin storage

The need for additional storage of resin is a reliability issue that is addressed more fully in the next chapter. If the need for such storage is expected, appropriate locations should be considered during the plant design review activities. When retrofitting a plant that has existing regeneration facilities, the use of those facilities as a backup to off-site regeneration instead of bulk storage could also be considered although the ability to keep chemical equipment operable without frequent use may be troublesome.

2.3 Design of Condensate Polishing Plant

Three main designs of deep bed polishing plants are in use worldwide, with the naked mixed bed being the most common in the United States. In Europe, the cation-mixed bed is widely used with separate bed plants preferred by some German power stations and now being adopted in a few other countries. The actual design of a plant and its operation will obviously affect the pattern of resin usage and hence the cost of any off-site services. When used in the conventional H-OH mode, and in the absence of contaminant in-leakage, beds will be removed from service on ammonia break and with the anion resin still largely in the useful OH form. However, as shown in Chapter 5, hydrogen cycle operation is expected to be uneconomical for most foreseeable circumstances unless the plant operates at a relatively low pH (around 8.0). In most instances, stations using cation-mixed bed plants or separate bed plants and operating in the hydrogen cycle need only to regenerate the lead cation bed. The mixed bed, or the anion bed in the case of a separate bed design, can be regenerated on a frequency that station experience shows to be appropriate. Thus, the design of the existing condensate polishing plant will affect the economics of off-site regeneration as will its mode of operation.

2.3.1 Plant Records

Plant records should be reviewed to identify frequent maintenance requirements and failure frequency of power plant components. These records can be used to identify opportunities for improvement and can also serve as the basis for economic justification of the retrofit, if required.

For plants without polishers, records need to be reviewed to identify water purity related failures or inefficiencies that can be reduced or eliminated by condensate polishing. Turbine deposits or failures and boiler tube deposits or failures, main cycle deposition or corrosion records should be reviewed to determine root causes.

For the simpler retrofit case where off-site regeneration is expected to substitute for on-site regeneration, records of bad regenerations, regeneration equipment problems, and regenerant consumption can be sources of economic justification.

It is important to identify condenser leakage events. The incidence and magnitude of condenser leaks and other impurity ingress incidents will affect the run length of polisher beds and hence the economics of adopting off-site regeneration. The causes of these impurity ingress incidents should be reviewed and predictions made as to the extent of future problems. In making these predictions, the possible benefits of any remedial work, such as condenser tube replacement should be taken into account.

For power stations planning to install condensate polishing, a review of the incidence of corrosion problems affecting the steam/water circuit would be useful in making a general case for polishing. Many of these corrosion problems can be attributed to the presence and/or concentration of ionic impurities with some corrosion mechanisms being assisted by crud deposits. Condensate polishers will reduce levels of both ionic impurities and particulate impurities and should reduce the scale of future problems.

2.3.2 Plant Operations

The review of plant records also needs to include a review of plant operations to provide a complete picture. Future expectations for plant operation should be factored into the overall evaluation along with the plant history. Future changes in operations, such as increases in cycling operation or increased startups and shutdowns, will provide greater justification for the installation of polishing systems.

The approach to operating a polishing plant in the H-OH mode and employing conventional on-site regeneration will usually follow one of two courses.

- Operating the plant to a conservative throughput, established by experience assuming a consistent quality of regenerated resin, and then removing the bed for regeneration before ammonia breakthrough occurs, or
- Operating the plant to a predetermined specific conductivity point, often $0.1\mu\text{ S/cm}$ (effectively the ammonia break-point), or alternatively, to a sodium endpoint, such as, 1 ppb Na.

In either case, limits for cation conductivity should also be observed, although there is rarely a problem unless contaminant in-leakage is present or the resin was improperly regenerated or rinsed.

Both of the above options will remain open to any station employing off-site regeneration. However, because of the economics, hydrogen cycle operation will likely be limited. Because of the operating economics, contractor regenerated resins will need to be prepared to a very high quality to allow ammonia form operation. This will allow extended production runs of a bed hence reducing the regeneration costs. Regardless of the endpoint adopted, exhausted resins will be hydraulically removed in the normal way and transferred to storage tanks to await collection. For plants that use mixed beds and have mixed regenerated resins supplied by the contractor, the appropriate volumes of mixed resins must be hydraulically transported to the service vessel. If the service vessel has re-mixing capability, fluidization of the bed during transfer is not a significant problem. If there is no re-mixing capability in the service vessel, then the transfer must be accomplished without allowing the mixed bed to separate.

On stations employing contractor regeneration of polishing resins, separate procedures will have to be established to control the loading of exhausted mixed resins into the contractor's transport and for the receipt of the regenerated cation and anion resins. In all of the above cases operating instructions must be framed to ensure the thorough removal of exhausted resins from the service vessel, with 99.9% removal being the target. In most cases, stations will demand the return of ready prepared charges of mixed bed resins containing the appropriate volumes and ratios of cation and anion resins that are ready to be directly loaded into service vessels. Procedures to govern the use of "ready to load" mixed beds will be simpler, but still need to be clearly identified.

2.3.3 Deficiencies

When considering the adoption of off-site regeneration of polisher resins, problems with the existing equipment must be taken into account and the impact upon the use and cost of contractor services must be estimated. For example, the design of some service vessels, and particularly the water distribution and collection, gives rise to poor flow patterns leading to inefficient use of the resins. This problem is indicated by inferior polished water quality and apparent low operating capacity. These and other existing problems must be kept in mind when making the decision to rely on off-site services. Such a deficiency will not be improved by contracting with someone else for regeneration services. Other deficiencies like those with regeneration vessels or regenerant handling components also will need to be considered. Avoiding expensive repairs to regeneration equipment may help justify the conversion to off-site regeneration.

2.4 Targets for Off-site Regeneration

Obviously, there are significant differences between off-site regeneration and on-site regeneration. On-site regeneration is done on demand and has a turnaround of six to twenty four hours and deals with a minimum number of resin charges. Off-site regeneration will have a longer turnaround time and will likely result in the need to use more than the minimum number of resin charges. In order to have off-site regeneration provide the same level of flexibility and

response, storage of additional resin charges is anticipated. The cost of both storage and the additional resin charges will need to be factored into the off-site contractor's cost. Consequently, cost has to be balanced with the desired level of flexibility and responsiveness. In order to make a rational decision as to how much flexibility and responsiveness is required, it will be necessary to set performance targets for the system using off-site regeneration. Some of these targets will have unit availability as a basis. Other targets include effluent water quality, which also relates to resin and regeneration quality. Additionally, plant targets for boiler tube failure and equipment life are important considerations. Unit availability goals will also factor into any consideration of emergency supplies of resins.

2.4.1 Availability

Users of off-site regeneration services will expect efficient service from their supplier with exhausted resins being regularly collected and adequate supplies of regenerated resins being always available on site. Ideally, emergency supplies should be available at a few hours notice, but this may not be practical or economical. The selection and use of resin storage capability is addressed more thoroughly in the next chapter. Storage of regenerated resin is considered the appropriate method to provide the flexibility desired for unexpected and unplanned events such as condenser leakage and contaminant intrusion. The amount of storage required will also depend on the proximity of the off-site regeneration contractor's site and the contractor's ability to respond to emergency situations. Unit availability goals will provide guidance as to how important it is to keep a particular generating unit on-line regardless of the situation. Very high availability goals will indicate that it is very important and conservative amounts of storage need to be provided to assure that unit availability goals can be met. If a lower level of availability is acceptable, then some savings could be realized with lesser amounts of storage. This must be a matter of discussion and judgement as it clearly depends on local conditions.

Power stations employing off-site regeneration will, for economic reasons, tend to be those not exhausting resin beds quickly. A polishing plant of typical design, with 2x50% service vessels in service at any time and with bed lives of 10 days, will require two replacement mixed bed resin charges every 10 days. If the station holds bulk stocks of resins equivalent to three charges, and has a fourth charge in a stand-by service vessel, then this should give sufficient resin for about 20 days. Even if shorter bed lives are assumed, for example five days, then it would still have adequate resin for about 10 days. However, the definition of a reasonable supply period must depend on local considerations. These include the days in which it can realistically be expected that transport conditions will prevent resin collection and delivery and the probability of condenser leaks occurring. In the absence of steam/water circuit problems the service life of a resin bed can be extended by partially bypassing, by running to a sodium break, or by temporarily reducing the pH employed in the circuit. Obviously such bypass must be carefully monitored and preparations made to take prompt action should adverse water quality conditions occur.

2.4.2 Water Chemistry Targets

EPRI Normal Polished Condensate Limit

EPRI Guidelines for “normal operation” for polished condensate are summarized in Table 2-1. The guidelines vary slightly according to boiler design and the water treatment used with the most stringent being < 3 ppb sodium, < 10 ppb silica and < 0.15 $\mu\text{S}/\text{cm}$ cation conductivity. Most stations with condensate polishing operated either in the hydrogen cycle or in the amine form would be expected to operate well within these limits.

Hydrogen Cycle Operation Performance

Sodium levels of < 1 ppb should be readily achievable from any problem-free plant operating full flow deep bed condensate polishers with resins in the conventional H-OH mode. Sodium levels of less than 0.1 ppb have been achieved at one plant even when operating in the ammonium form, when much higher leakage is expected. Cation resins with about 47% of their active cation exchange sites in the sodium form and the remaining sites essentially in the hydrogen form will, theoretically, provide polished water containing 1.0 ppb sodium. This assumes that the sodium form sites are evenly distributed around the resin bed and are not all at the bottom of the bed. If 1.0 ppb sodium was adopted as the target, then this could be met using ineffectively regenerated resins containing very high levels of sodium. While EPRI Guideline values for polished condensate could still be achieved, the operating capacity of the cation resins would be almost one-half the desired capacity. Regeneration frequencies would then increase adversely affecting the economics of off-site regeneration and of course necessitating greater effort by operating staff. In addition to the nuisance this would cause, the production of a condensate (or cation resin) containing unnecessarily high levels of sodium can only be regarded as undesirable.

Resin regeneration specifications for cation resins to be used in the H^+ form should, therefore, be based on considerations such as the reasonably achievable residual impurity content and the resultant operating capacity imparted to the resin. Stations using off-site regeneration of resin for condensate polishing should specify that cation resin be regenerated so that less than 2% of its active exchange sites are in the sodium form. Such a target should be reasonably attainable with careful handling and conventional techniques. Such a resin should, theoretically at 25°C (77°F), yield a sodium leakage of about 0.02 ppb. Under service conditions, other effects such as temperature, resin fouling, and flow distribution all come into play so that the actual sodium leakage will inevitably be higher than simple calculations indicate.

Chloride levels at the condensate polisher outlet are not specified in any of the EPRI guidelines for fossil fired plants. Limits are, however, given for chloride in steam and are the same as those for sodium. Action and “normal” limits for chloride (and sulfate) in polished water can therefore be assumed to be the same as sodium, i.e. < 3 ppb. The same arguments can be applied to this value as for sodium with most, if not all stations aiming to produce water with a much lower impurity content. For some plants, 1 ppb is a reasonable target from the steam/water circuit corrosion chemistry viewpoint, but a much lower target is appropriate from the viewpoint of what can reasonably be expected in an H-OH form deep bed polishing plant. Chloride levels in

polished water are often determined by the kinetic response of the anion resin. At many power stations, kinetic response has been shown to be susceptible to rapid deterioration, often from fouling. This fouling allows a portion of the chloride contained in untreated condensate to pass through the bed. Kinetic leakage must be minimized by contractors constantly monitoring the kinetic response of the anion resins that they are supplying to ensure they meet agreed specifications. Specialized resin cleaning, surface treatment techniques, or replacement are possible options when kinetic response becomes impaired. It should be noted that cation resin exchange kinetics also impacts the overall kinetics of the mixed-bed polisher. Consequently, cation exchange kinetics should be tested prior to replacing anion resin that appears to be kinetically impaired.

From the viewpoint of resin regeneration, a target of 1 ppb chloride from a mixed bed polisher operated in the H-OH cycle provides little useful guidance with respect to acceptable resin impurity levels. This is because an anion resin containing over 80% chloride should, theoretically, still leak less than 1 ppb of the impurity when in service. Like the sodium form effluent guideline discussed above, such resin would have little capacity. Again, like the cation resin, the anion resin regeneration specification should be set on what is reasonably and economically achievable and will give an acceptable operating capacity. This is considered to be an anion resin containing less than 2% of its active exchange sites in the chloride form. Such a resin should, theoretically at 25°C (77°F), yield a chloride leakage of about 0.003 ppb. Under service conditions, other effects such as temperature, resin fouling, and flow distribution all come into play so that the actual chloride leakage will inevitably be higher than simple calculations indicate. Such low chloride levels may require two-component regeneration to remove chloride from the anion resin, should the resin receive significant levels of chloride.

The arguments for sulfate in polished water specifications are generally similar except that sulfate leakage is even more sensitive to the condition of the anion resin than is chloride. Thus the kinetic response of anion resins to the divalent sulfate ion is extremely sensitive to kinetic impairment effects like organic fouling. Both anion resin exchange kinetics for sulfate and weak base content must be monitored for the strongly basic anion resins used for condensate polishing. The condition of the anion resin, both kinetic and its weak base content, is critical in establishing effluent sulfate levels. The sulfate level on the regenerated resin should be controlled to a satisfactorily low level to ensure reasonable operating capacity. A limit of less than 2% of the exchange sites in the sulfate form is again suggested, if sulfate is not used as pretreatment or as a part of a two-component regeneration.

Some regeneration processes involve the deliberate sulfation of the anion resin to strip chloride or other contaminants or to enhance mixed bed separations. Following sulfate treatment, the anion resin is regenerated to the hydroxide form. If this process is used, some relaxation of the sulfate on resin value can be allowed. Experience shows that, because of the very high selectivity of strongly basic anion resins for sulfate, high sulfate on resin levels do not yield high sulfate leakage. If such treatment is used, the sulfate concentration requirement may be relaxed and may be allowed to increase to as high as 12 percent. An apparent disadvantage in accepting a regenerated anion resin containing over the arbitrary suggested level of 2% of its active sites in the sulfate form is the effective loss of useful capacity. In practice, however the useful capacity is actually higher following pretreatment with sulfate and regeneration with caustic as compared to regeneration with caustic alone.

Ammonium Form Operation

A number of fossil power stations operate their condensate polishers in the ammonium form and achieve very long run lengths which can result in significant operating economies. There are disadvantages of using resins in this mode. One of the problems is that ionic impurity leakage can be significantly higher when running in the ammonium form with reasonably regenerated resins and can be orders of magnitude higher with resins that were improperly regenerated. When polishers are operated in the ammonium form, extremely low levels of the impurities, namely sodium and chloride, must be achieved in order to obtain acceptable polished water quality. An additional complication is that leakage levels vary with pH so that regenerated resins that are suitable for one power station are not suitable for another station if its condensate is of a higher pH. For example, in the demanding case of a power station operating at pH 9.6, the cation resin would need to contain less than 0.08% sodium and the anion resin would need to contain less than 1.0% chloride in order to achieve a sodium and chloride leakage of <1 ppb. This represents an extremely high level of regeneration. However, experience shows that such regenerations are routinely achievable with modern separation and post regeneration techniques. Several stations have adopted these improved regeneration procedures and have satisfactorily operated at high pH (pH 9.5- 9.7) in the ammonium form for approaching 20 years. While the long run lengths achieved with ammonium form polishers make this kind of operation economically attractive, especially with off-site regeneration, it must again be stressed that ammonium form operation is not suitable for all power stations. For example, stations that experience condenser in-leakage would have to remove ammonium form polishers from service shortly after the leak to minimize contamination of the cycle. Stations with chronic condenser in-leakage may find that ammonium form operation is impractical.

2.4.3 Condensate Polishing Plant Resin Regeneration Targets

Resins for Polishers Operating in the Conventional H-OH Mode

As already discussed, resin regeneration specifications for the conventional mode of operation should be set not only on the desired quality of polished water but also on what is reasonable and economical to attain by accepted regeneration procedures. The aim must be not only to meet polished water quality targets but also to prepare resins that will give acceptable operating capacities when in service. Thus, for a polisher operating with resins in the H-OH form the percentage of the ion exchange sites on the cation in the sodium form should not exceed 2%. This level of sodium on the cation resin should yield a leakage of about 0.02 ppb at 25°C (77°F) in addition to sodium input from other leakage mechanisms or sources. It is proposed that for anion resins an arbitrary limit of less than 2% of the sites in the chloride and/or the sulfate form (unless sulfate pretreatment is used) should also be adopted. As discussed above, this limit is not necessarily based upon effluent quality but on the values which can reasonably be expected to be achieved by conventional regeneration processes. They should be regarded as being the limits of what is acceptable and effort should be made to regenerate resins to the highest standard reasonably and economically achievable. Problems associated with resin deterioration, such as kinetic impairment, are primarily of importance in controlling the leakage of anions and must be covered by resin quality specifications.

Resins for Polishers Operating in the Ammonium Form

As already discussed, operating a condensate polisher in the ammonium form is a very demanding mode of operation. To achieve polished water targets of 1 ppb sodium and chloride will require cation resins containing less than 0.08% sodium and anion resins containing less than 1.0% chloride. These values should be adopted as tentative regeneration targets. In practice, the behavior of ammonium form beds is more complex with initially a higher sodium leakage than simple calculations indicate leading to lower, steadily declining, steady state values.

Resins For Both H-OH and Ammonium Form Operation

If a power station wants the flexibility of operating its polishers past the ammonia break, to avoid high sodium throw during and just after the breakthrough period the resins employed should be regenerated to the standards suggested for use in the ammonium form

2.5 Select Alternatives

There are a number of important items to consider when planning for off-site regeneration of condensate polisher resin using contractor services. The most important ones are listed and discussed below. Since there are several alternatives available for each item, plants can customize the regeneration capabilities to meet their specific needs. During the evaluation phase these alternatives need to be carefully considered in order to obtain the most serviceable and economic implementation of off-site regeneration for the particular station circumstances.

- Bulk storage configuration and volume.
- Resin ownership.
- Reliability requirements.
- Condenser tube leakage operations.
- Spare vessels.
- Spare resin charges.

2.5.1 Bulk Storage Configuration and Volume Selection

The capability to regenerate resins as station operating circumstances dictate will be lost when regeneration is performed off-site. Thus, the use of off-site regeneration reduces some of the flexibility and control that is available with a conventional, on-site regenerated system. Bulk storage of resin is expected to be the method of choice to provide equivalent flexibility and control.

In order to determine the appropriate amount of storage for a particular circumstance, a station would first need to determine the amount of reserve capacity required and whether the station needs to continue operating under adverse cycle chemistry conditions such as condenser leakage. If condenser leakage operation is considered necessary, then hydrogen cycle operation may well

be required, which would require frequent bed replacement and result in the need for a large amount of storage. If a large amount of storage is considered, then there must be recognition that normal operation would likely result in relatively slow usage of the large amount of resin which is in storage. Because some deterioration of resin capacity may occur in bulk storage, very large storage may not be desirable, unless operating circumstances dictate the large storage requirement. The ability of the contractor to respond to urgent situations would also need to be considered. Because it is expected to be most economic to have delivery of a full truck of regenerated resin and removal of a full truck of spent resin, the minimum amount of storage would be that amount which allowed delivery and removal of the entire truck's capacity. For most instances this would be three to four resin charges since most trucks can hold about 600 cubic feet (17 m^3) of resin.

For both the retrofit and new station situations which were used to obtain input from prospective vendors, storage was based on a multiple of the resin volume in a delivery. For each situation where bulk storage was selected, a storage tank volume of 900 cubic feet (25 m^3) was selected. This would allow delivery when at least 600 cubic feet of empty space (17 m^3) were available, yet allows a reserve of 300 cubic feet (8.5 m^3), equivalent to about two spare charges. If the resin storage tank has an additional spare charge, this allows for three new charges, which would be sufficient for about four to five days of operation in the hydrogen cycle (assuming no load other than ammonia) for a drum unit operating at pH 9.2. The run length would be significantly longer for a unit on oxygenated treatment at lower pH. If it were desirable to operate for six to seven days without vendor support, it would be necessary to add about four resin charges plus a truckload volume to the total tank capacity.

Some plants that plan to allow operation in the ammonium cycle and that do not to operate with condenser leakage may choose not to add storage. They would need to specify that the vendor's truck be capable of segregating the new and used resin charges. Using this method, a station with four resin charges (3 vessels plus one resin charge stored in the regeneration vessels) totaling about 500 to 600 cubic feet (14 to 17 m^3) could transfer one resin charge at a time into one of the regeneration vessels and transfer an expended charge back to the truck. All four charges could be shuffled through the regeneration system vessels to the service vessels. While this operation would take a little longer to transfer the resins, it is expected that this could be done in a single day without significant extra cost for the delivery. A problem with this approach is the potential for contaminating newly regenerated resin with exhausted resin. To avoid this potential problem, careful control of the resin transfer process would be required. Vessels used to transfer or store an expended resin charge would need to be empty and clean before receiving a charge of regenerated resin. In addition, the frequency of these bulk transfers would have to be minimized in order to avoid making the process highly labor intensive.

Sample Resin Storage Calculations

The table below shows calculated results for storage requirements for a single system that has three, fifty percent capacity vessels (each containing 144 ft^3 (4.1 m^3)) and a fourth spare charge in the regeneration system. Storage requirements are calculated for three different run lengths; 1 day run lengths for hydrogen cycle operation at cycle pH of 9.6, 3 day run lengths for hydrogen cycle operation at pH 9.2, or 30 day run lengths for either hydrogen cycle operation at pH 8.0, or ammonium cycle operation. The minimum storage tank size was selected to be 1.5 times the

resin truck volume. This is selected to allow the most economic operation, that of taking complete truckloads of resin with each delivery. Also, the reserve capacity minimum was assumed to be a sufficient number of spare beds to operate at 100% load for one run length. (two bed for 50% capacity beds). Note that resin capacity listed below applies to two bulk storage tanks, one for fresh resin and one for used resin.

Run Length/ resin bed	One day			Three days			Thirty days		
	3	5	8	3	5	8	3	5	8
Reserve Capacity Req'd, days	3	5	8	3	5	8	3	5	8
No. of resin beds.	4	4	4	4	4	4	4	4	4
Resin volume/vessel	144	144	144	144	144	144	144	144	144
Truckload Resin Volume, ft ³ (m ³)	600 (17)	600 (17)	600 (17)	600 (17)	600 (17)	600 (17)	600 (17)	600 (17)	600 (17)
Reserve Resin Vol. Req'd, ft ³ (m ³)	2592 (73.4)	7200 (204)	18432 (522)	864 (24.5)	2400 (68.0)	6144 (174)	288 (8.16)	288 (8.16)	614 (17.4)
Resin Storage Req'd, ft ³ (m ³)	3192 (90.4)	7800 (221)	19032 (539)	1464 (41.5)	3000 (85.0)	6744 (191)	900 (25.5)	900 (25.5)	1214 (34.4)

As can be seen by analyzing the above results, it would not be practical to plan on off-site regeneration when operating at high pH in the hydrogen cycle because of the large reserve capacity which would be required. If a plant wanted to use off-site regeneration, appropriate reserve capacity could most practically be achieved by reducing the cycle pH, and/or converting to ammonia cycle operation. Because ammonium form polisher operation or OT at lower cycle pH values results in the minimum size storage tanks, one can once again conclude that these forms of operation may be most practical for implementation of off-site regeneration. As will be seen again later, off-site regeneration is not economical when operating in the hydrogen cycle at high pH for long periods of time.

Storage Configuration

As discussed previously, the minimum storage volume required for implementation of off-site regeneration may well be that no storage is required at all. A system operated in the ammonia cycle or using oxygenated treatment at lower cycle pH may be able to use only existing vessels and a spare charge in the regeneration system.

For those stations which decide that they need more reserve capacity than that provided by the minimum storage case, there are several other options to consider. Regeneration contractors can provide the freshly regenerated resins in mixed form to a specific ratio or they can provide specific volumes of separated cation and anion resins. This latter case would require segregated storage at the plant for keeping the resins separated, and would also require measuring and mixing steps before use of a bed in service. These facilities would be more costly than simpler facilities that store pre-mixed resins. Keeping the resins separated does provide the opportunity for greater operating flexibility, that being the flexibility to use different resin ratios. The plant could choose to add additional cation resin for startups or additional anion resin for air in-

Plant Evaluation

leakage situations. With the greater flexibility also comes some potential for operational drawbacks. There would be more operating steps and thus more opportunity for operating error. It would be expected that plants opting for the simplicity of off-site regeneration would also logically want to select the simpler case of receiving mixed resins. However, some plants may select off-site regeneration to avoid the regulatory problems associated with storage and discharge of regenerant wastes. For those plants, the option for greater operational flexibility may be very important.

Storage of fresh resins requires isolation of the resins from the atmosphere to minimize adsorption by the resin. Without isolation, the anion fraction would adsorb carbon dioxide and other anions. However, the resulting reduction in capacity would be minimal if the resins were reasonably well isolated and not stored for extended periods of time. Another problem that occurs when resins are stored for long periods of time is the leaching of organics from the resins themselves. Sulfonates from the cation resin could foul the anion resin while organics from the anion could also foul the cation resin. Periodic rinsing of stored mixed-bed resins would reduce but not eliminate this potential problem. For stations where good exchange kinetics are of primary importance such as those stations with high sulfate levels in the circulating water that experience periodic condenser in-leakage, it would be better from a technical point of view to store the resins separately and rinse prior to mixing.

Storage of spent resin is simpler, because there only needs to be a tank to receive the exhausted mixed resin. Since the resin is exhausted there is no concern for resin contamination by atmosphere, so no need to blanket the storage tank with inert gas or to otherwise seal the storage tank.

Because ion exchange resins are corrosive to carbon steel, any bulk storage tanks will need to be made of corrosion resistant materials or lined with a corrosion resistant liner. The bulk tanks should be equipped with hopper or conical bottoms to allow complete transfer of properly mixed resins from the tank. Internal surfaces should be smooth to facilitate resin transfer and to keep resin from hiding inside the tank. The tanks will need to be protected from freezing by placing them in a space conditioned area or by use of insulation and heating.

It would be anticipated that plants that wish to use bulk storage to provide additional resin availability will want to use two separate tanks, one for fresh mixed resin and one for exhausted resin. Three tanks will be required if maintain separation of regenerated resin for bulk storage is desired. One tank would be used for storage of exhausted resin while the other two tanks would separately hold the stored cation and anion resins.

2.5.2 Resin Ownership

Resin ownership is an important issue to consider with off-site regeneration. Traditionally, plant owners have owned the resins used in condensate polishing. However, operators rarely owned more than one spare charge per unit. Further, resin charges are normally furnished initially with the equipment. The performance of the resin and equipment may well have been tied together with a performance warranty associated with effluent quality.

With off-site regeneration, much more resin will be needed. Sufficient resin will be needed to allow at least one truckload to be off-site for regeneration while at least one system full of resin charges are in service at the plant. If bulk storage is selected, significantly more resin may be needed to use off-site regeneration.

Regeneration vendors have indicated a willingness to supply the resin necessary for these operations. Because larger volumes of resins are required and because plant owners will not have much control over the resin when it is sent for regeneration, it seems reasonable that the vendor should be allowed to furnish the resin. Users will be concerned about the quality of resins to be furnished. Contracts with vendors should have sufficient controls in place to assure the quality of resins provided. This would require written contracts followed by surveillance of the resin quality. However, surveillance would be necessary to assure that capacity and purity of the resins were adequate, regardless of the ownership of the resins. The suggested surveillance is outlined later in this guideline.

Users will need to recognize that the regeneration contractors may also need to perform resin surveillance to assure that the plant owner has not improperly used the resin. Plant accidents that could result in damage to the resins need to be considered by both parties. Resin damage due to oil or other organics, or by excessive temperature exposure are among the accidents to be considered. The expected life of the resin should be enumerated in the contract so that both parties are aware of expectations. Should the plant owner wish to continue with plant ownership of the resin, similar concerns about the treatment of the resin while in the regeneration contractor's custody should be considered. Resin owners should consider excessive physical damage, osmotic shock, contamination with other resin, as well as losses due to traffic or industrial accidents.

Premium quality resins with specific characteristics are normally recommended for condensate polishing applications. The justification for the use of premium quality resins will continue to exist with off-site regeneration, so these recommendations for the use of premium quality resins would continue with off-site regeneration. The off-site vendor should be willing to supply such resins for plant use.

2.5.3 Reliability Requirements

Generating unit reliability requirements will need to be factored into the selection of the options used for implementation for condensate polishing. Operation with contaminant ingress during condenser tube leakage as well as the need for spare vessels and spare resin charges are important reliability considerations.

2.5.4 Condenser Tube Leakage Operations

Operation with condenser tube leakage should be carefully considered whether a plant is using off-site regeneration or on-site regeneration. With condenser tube leakage, once leakage is identified, the most desirable action is to shut down the unit and fix the leak. There are circumstances when it may seem commercially desirable or necessary to continue operation with condenser tube leakage. Such continued operation should only be considered if the leakage is

sufficiently small so that the condensate polishing system is capable of completely removing all of the contaminants and there is assurance that water chemistry limits will not be exceeded. Damage from contaminant ingress can be very expensive and quickly overcome any apparent economic advantage of continued operation for a few days.

As shown later in the examination of the economics of off-site regeneration, regeneration costs are more expensive when performed by an off-site contractor. However, eliminating the regeneration equipment and therefore eliminating the cost of such equipment can offset the higher cost of contractor regeneration. Operation with condenser leakage causes more frequent regeneration of the resin to be required because of the higher rate of exhaustion of the resin by the contaminants from the leakage. Extensive operation during condenser leakage periods will be significantly more expensive with off-site regeneration than with on-site regeneration. Each station will want to look at their own specific situation, but implementation of off-site regeneration will make operations during condenser leakage even less desirable than such operations would be with use of on-site regeneration.

2.5.5 Spare Vessels

Spare condensate polisher vessels are a desirable feature to provide the greatest operating flexibility to fully polish a unit's condensate continuously. However, a spare vessel does add to the cost of a system. While desirable, a spare vessel may be less justifiable for a plant using off-site regeneration, if that plant has chosen to add bulk resin storage capability. Such a plant would have the capability of transferring fresh resin from storage to service vessels fairly quickly from storage, at least within an hour. Plants which are considering polishing for improvement of availability, but do not necessarily need full time polishing (such as drum units), may consider opting for fewer service vessels and the associated cost savings. For plants that operate or plan to operate in the ammonium form, a spare service vessel also allows for rapid control of cycle pH, i.e., high cycle pH can be reduced by putting a hydrogen form bed in the spare polisher vessel in service for a short period of time.

2.5.6 Spare Resin Charges

Plants with existing regeneration systems will most likely have a spare resin charge associated with the regeneration system. This charge should be considered an extension of bulk storage, and in the case of the minimum storage system, is the only storage used. Plants installing new condensate polishing systems, which use off-site regeneration, will likely not want to use a single spare resin charge. They will instead want to have a vessel for cleaning, backwashing, and mixing of resins. Additional resin charges should be stored with bulk storage that would be sized based upon criteria discussed earlier in this chapter.

A unique case would exist when a new plant chooses to store only a single spare resin charge. In this case, a single resin storage tank could be added to contain a single charge of resin. No spent resin tankage would be needed in this case, since the cleaning, backwashing, and mixing tank could be used to hold an exhausted resin charge, and the resin storage tank would be available to receive the first charge of resin from the contractor's transport.

3

PLANT IMPLEMENTATION

In the previous chapter, the options to be considered were discussed, and the reasons for the various selections were enumerated. Based on these discussions and analysis performed for each station, the appropriate options should be chosen and the overall methods of implementation selected. At this point, plant modifications need to be undertaken, procedures should be revised, and training should be accomplished.

3.1 Plant Modifications

Plant modifications will vary depending upon whether an existing plant is being modified or a new condensate polisher is being installed.

3.1.1 Existing Plant

For the existing plant, modifications should be fairly simple and would consist mostly of revising the existing resin transfer systems to interface with service contractor delivery vehicles and/or with new bulk storage tanks. The extent of the modifications needed will depend on the original design of the system. It may be desirable to consult with the original equipment supplier for support during the detailed design of the resin transfer modifications. It will certainly be necessary to consult with potential regeneration contractors. The latter can be done in advance of a competitive bidding process or following selection of a contractor.

Resin Transfer Systems

Resin transfer systems will require modification for plant implementation of off-site regeneration for retrofit systems.

Retrofit Systems Without Bulk Storage

Resin transfer system modifications will be required for plants with existing systems that the plants wish to retrofit to use off-site regeneration. Obviously, the extent of the modifications necessary will depend on the type of existing system. For the typical three-vessel external regeneration system, the normal resin transfer process routes a bed to be regenerated to the cation regeneration vessel (CRT), and routes regenerated resin from the resin storage tank (RST) to the service vessel. The simplest resin transfer system modification would continue to use these existing resin transfer processes. Such a system, without the use of bulk storage is shown in Figure 3-1.

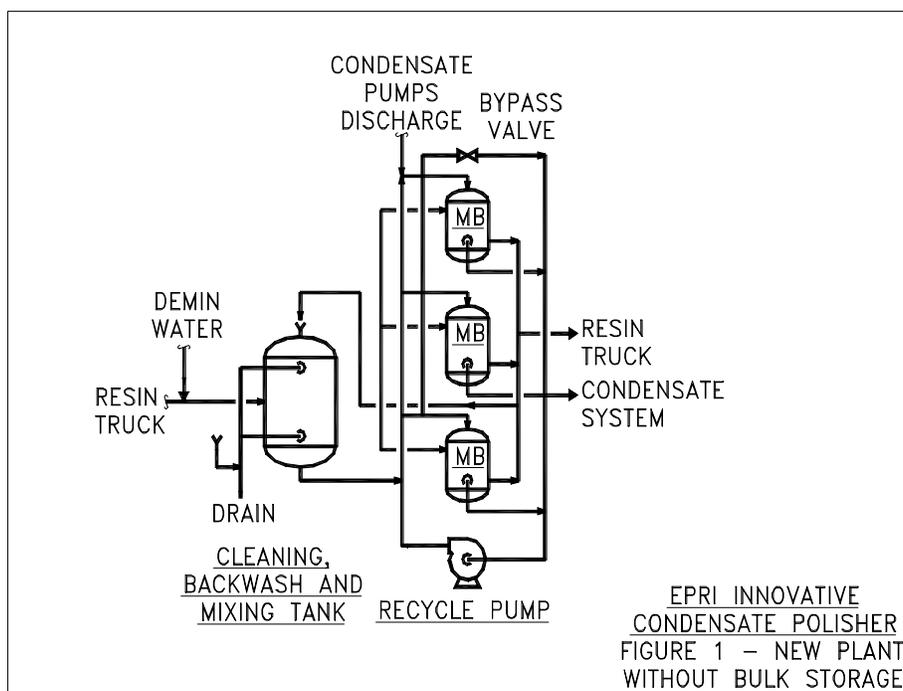


Figure 3-1
Retrofit Systems without Bulk Storage

Interconnections with the contractor's delivery truck are shown for freshly regenerated resin to the RST and for spent resin from the CRT. The RST is used for fresh resin because it would have the most direct path back to the service vessel and also because the RST would have capabilities to mix the resin. It will probably be desirable to remix the resin prior to transfer to the service vessel. The CRT is used for the exhausted resin, again, because it would be the most direct path from the service vessels back to the contractor's truck, which used existing resin transfer piping. CRT vessels usually also have air scrub and backwash capabilities which may still be useful to the plant. For startups, when resin tends to get dirty fairly quickly, it would be useful to use the air scrub and backwash capability. If this capability is desirable, a transfer line from the CRT to the RST would also be needed to remix the cleaned resin and return it to a service vessel. Such a line probably already exists and was formerly used to transfer regenerated cation resin to the RST. Plants may want to check to see if control modifications are required to allow the transfer lines use following resin cleaning.

Resin Sluice Piping

Resin sluice piping will need to be installed to sluice resin to and from storage facilities. Piping should be corrosion resistant material, either lined steel pipe or stainless steel pipe. At least 3-inch nominal (80 mm) diameter pipe should be used to facilitate resin transfer within reasonable times. Valves used will need to be full port valves such as ball or plug valves in order to minimize locations for resin settling. Pipe routing should be as direct as practical and low points or dead ends, which could trap resins, should be avoided. Long lines should also be avoided if

practical. If they cannot be avoided, be sure to plan on sufficient flush water to assure that resin is not left in the lines.

Retrofit Plants With Bulk Storage

Figure 3-2 shows resin routing setup that could be used with bulk storage tanks. Resin transfers between the former regeneration vessels and service vessels would still be the same and the reasoning for the transfers would also still be the same. Bulk storage would be used for receiving freshly delivered resin and also for providing spent resin to the contractor's truck for return to the off-site regeneration facilities. The RST would be used to receive resin from the bulk resin storage tank, again to allow for mixing of the resin from the bulk storage tank. The CRT would interface with the spent resin storage tank. Sizing considerations for bulk storage was provided in Section 2. Design considerations for bulk storage tanks are provided later in this Section.

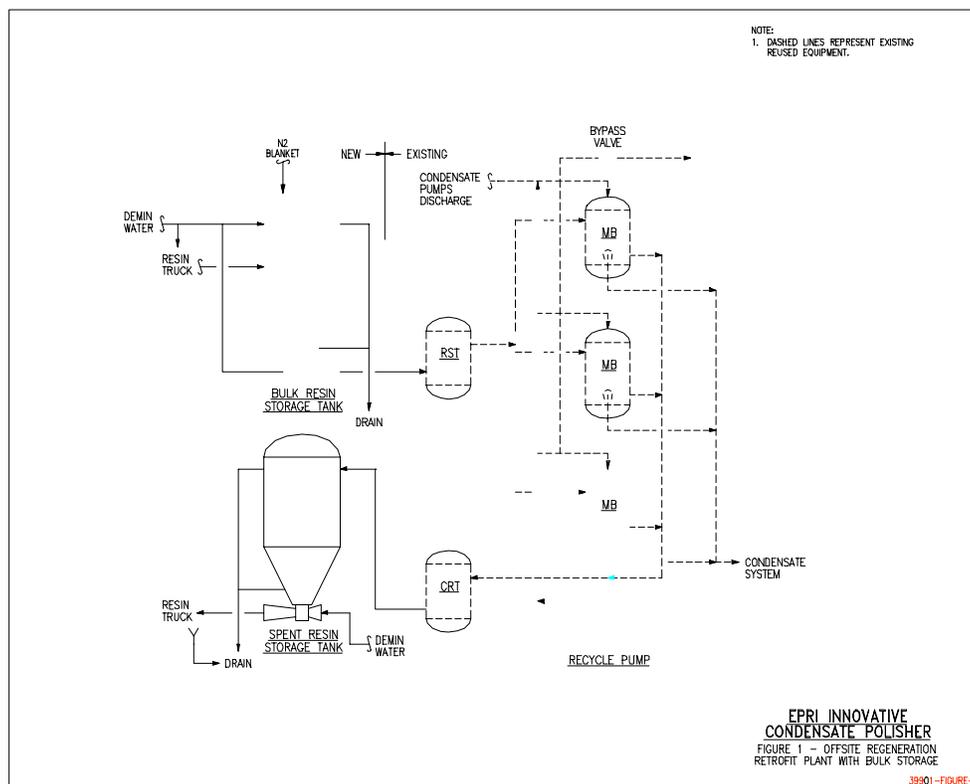


Figure 3-2
Retrofit Plant with Bulk Storage

3.1.2 New Plant

New installations of condensate polishing systems that use only off-site regeneration will have some different considerations than those that are retrofitting existing polishing systems for off-site regeneration. A system for a new installation is shown in Figure 3-3 for systems without bulk storage.

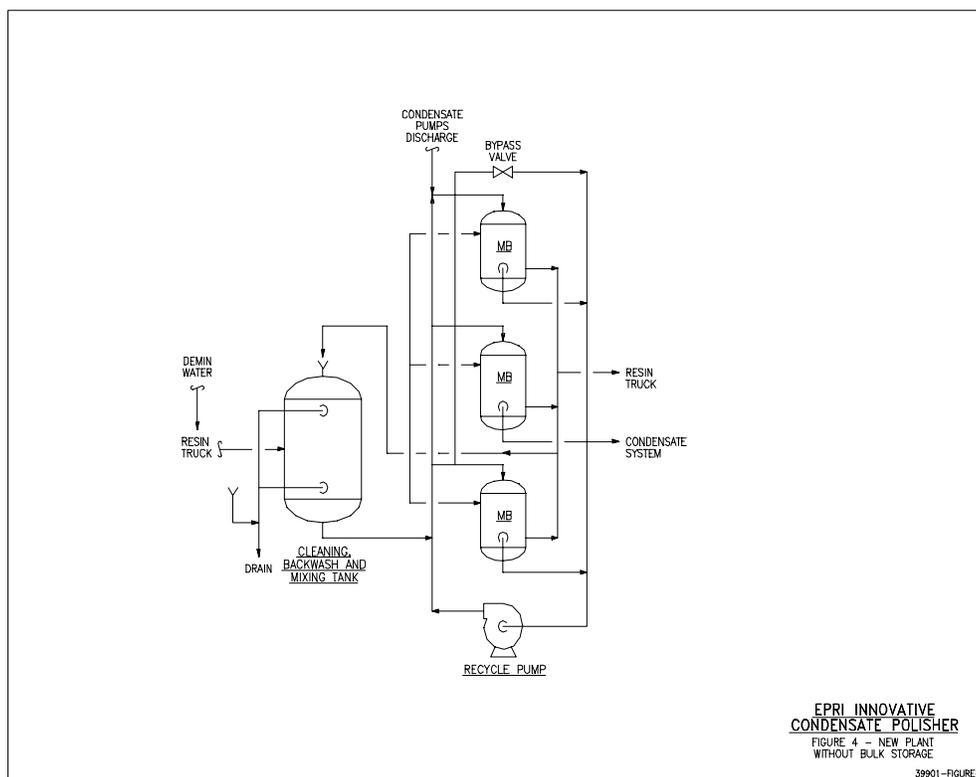


Figure 3-3
New Plant without Bulk Storage

Service Vessels

The sizing, number, and design of service vessels for systems using off-site regeneration are essentially the same as the design for use with an on-site regeneration system. This information was discussed extensively in the Condensate Polisher Guidelines (1).

One different consideration would be the selection of spare vessels. Because off-site regeneration is being used, it is assumed that minimizing the cost of equipment and installation is a primary consideration. Therefore, as previously discussed, the use of a spare service vessel should be carefully considered. When using off-site regeneration, the presence of extra resin charges can offset the need for a spare vessel. Transfer of a new resin charge to a service vessel should only take about an hour or so. Depending on the type of generating unit being considered, it may be acceptable to reduce the extent of polishing used for such a short period.

Delivery Interface

Resin Cleaning Facilities

While not mandatory for a new system, a means of cleaning and backwashing resins is desirable and should be considered. This will provide a cost-effective method of cleaning resins that are used for unit startups. A tank with an empty volume is also convenient to have for maintenance operations. Such a tank allows space for a resin batch to be sluiced when maintenance is necessary on a service vessel or service vessel valve. Also an empty tank can be useful in resin transfer operations and can serve as a place to inspect and sample the resin. Such a tank will also provide mixing capabilities and backwashing capabilities if new resins are to be placed into service at the station.

3.2 Bulk Tanks

Bulk storage tanks are used to store fresh resin and spent resin between resin deliveries as well as storing reserve resin. The volumes required for storage depend on each station's individual operating circumstance and were discussed in Section 2.

Bulk tanks receive fresh resins from the off-site regeneration contractor or store used resin for return to the contractor. It would be desirable for fresh resin tanks to have some sort of atmospheric isolation to minimize the degradation of fresh resin while in storage. Nitrogen blanketing is a satisfactory method for providing such isolation; however, this may impose pressure requirements on the storage tank that would not be required without nitrogen blanketing. If resin is to be used fairly quickly, it may be possible that the slight capacity deterioration would be as acceptable as the higher capital and operating cost that is imposed by nitrogen blanketing. Sealing of tank vents could also be used to minimize resin degradation in storage.

Bulk tanks will need to be of a corrosion resistant material because the resins are corrosive to carbon steel materials. Plastic or lined steel tanks would be acceptable. The off-site regeneration contractor would probably be willing to supply bulk storage tanks.

The means to sluice the proper volume and resin ratio from the tanks will be required. Storing and transferring mixed resin from a bulk storage tank presents two problems. Both the total volume of resin as well as the cation to anion resin ratio must be properly controlled. Verification of the resin ratio is more difficult to measure and assure. Volume control can be accomplished by use of several level switches, a level transmitter, or by weight or load cells. The capability to monitor tank level should also be provided to assist with keeping track of resin inventory.

If weight or load cells are used to determine when sufficient resin and water has left the bulk storage tank, then care would need to be taken to ensure that the water to resin mixture remained relatively constant during the transfer period. In order to maintain a mixed-bed condition when transferring resin out of the bulk storage tank, the resin in the vessel must not be permitted to completely fluidize. Consequently, transfer must be accomplished with both water and air. Both

Plant Implementation

are needed to maintain the bed as a compressed mass at the same time enough water is supplied to avoid resin-plugging problems. If cation and anion resins are stored separately, the primary focus is on transferring the correct volume of resin to the appropriate location (storage tank, spare vessel, mixing tank, etc.). Regardless of the method selected, careful coordination between the equipment, installation, and regeneration contractor is needed to achieve a workable installation.

Tanks will need to be insulated in colder climates where freezing could occur. Heat tracing may also be required. A screened drain, to drain only water will be required as well as a drain to remove resin for tank maintenance. Manways for inspection and resin sluice connections are required. Pressure relief and vent/overflow connections will also be needed as dictated by design.

Figure 3-4 is a typical schematic diagram showing connections for a new station that would use bulk storage.

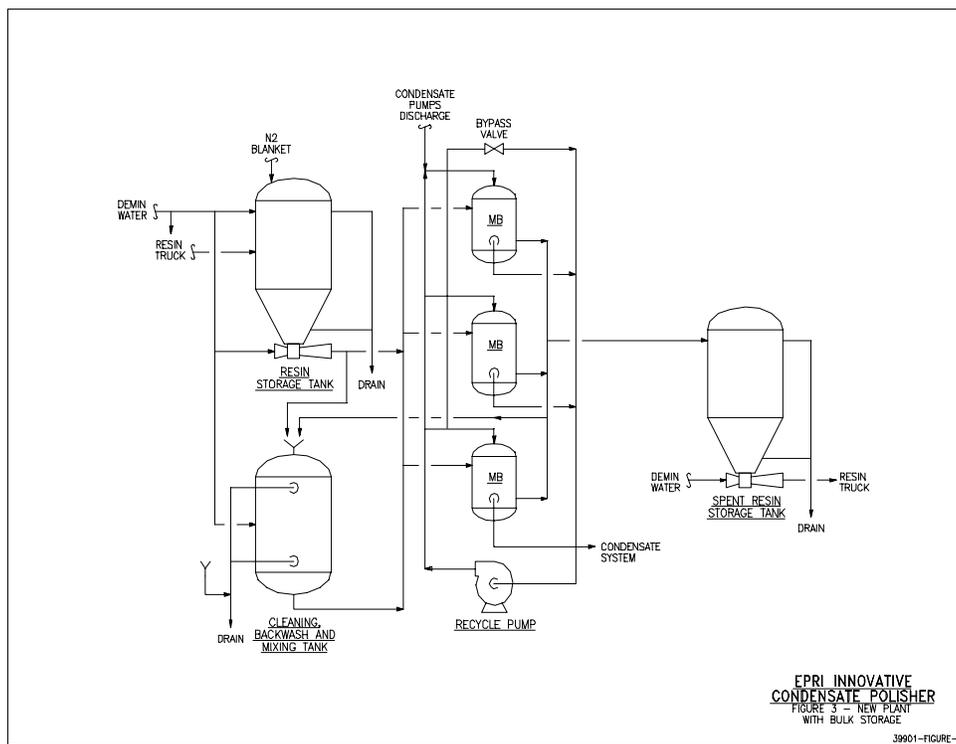


Figure 3-4
New Unit with Bulk Storage

3.3 Mixing Facilities

Resin mixing can be done both in the service vessel as well as in external support vessels.

3.3.1 Service Vessel Mixing

Because of concerns for resin separation during resin transfers, resin mixing capabilities within each service vessel are suggested. Such capabilities may not be easily retrofitted to existing vessels, but should be easily obtained for new service vessels. One concern will arise with the interconnection of a low pressure system (such as air) with a high pressure system (condensate system). Designs must include proper measures for protection of lower pressure systems.

3.3.2 External vessel Mixing

Resin mixing capabilities are routinely included in external support vessels for on-site regenerated systems. These capabilities are needed to remix resins following separation for regeneration. Such capabilities could be helpful with off-site regeneration to assure that resin has not separated in transport and to mix new resins.

3.4 Contractor Support Facilities

Contractors need ready access to the delivery and pickup points. Trucks are full sized semi-trailers, which may be up to 60 feet long, 8ft wide, and 14 ft. tall (18 m long, 2.4 m wide, and 4.3 m tall). These trucks will require minimum roadway widths of 10 feet (3.0 m) and a minimum turning radius of 52 ft (16 m) at the centerline of the roadway. Resin sluice line connections need to be routed to such a location. If resin storage vessels are a long distance from the truck connections, a common sluice line can be provided to be most economical. Means of controlling resin delivery processes need to be considered. While it would be most desirable to have remote controls at the delivery point, communication with the control location and delivery location would need to be provided at a minimum.

Contractors will need a supply of high purity water for resin sluicing to and from plant facilities. Additionally, drain facilities to dispose of excess water from truck tanks prior to departure will be needed. The volume and pressure requirements for sluice water as well as flow rates for wastewater should be coordinated with contractors. A nominal three-inch (80 mm) sluice water supply line and a nominal six-inch (150 mm) drain should be adequate.

3.4.1 Sampling Resin

It will be desirable to build in the capability to sample resins delivered by the contractor. Such provisions should be included in the resin delivery station. Sample valves on transfer lines or simple provisions to take core samples should be provided.

3.5 Procurement of Off-site Services

Once decisions have been made regarding the general methods of implementation of off-site regeneration, steps need to be taken to initiate detailed design and to obtain the services of a vendor. There are several ways to proceed. Currently, off-site suppliers are willing and even eager to supply the plant equipment and even assist with the physical plant changes that are required such as construction. This would allow the utility to have a single point of contact and responsibility for the entire retrofit. Utilities may wish to consider using separate contracts for the equipment supply and for future regeneration services supply.

Utilities could continue with traditional methods and obtain equipment separately from the service vendors. This would involve performing detailed design either with utility engineers, through an A/E, or with the support of an equipment supplier. The utility would separately obtain the services of an off-site regeneration contractor and equipment supplier. The utility or its designated project manager would coordinate between the two parties. One advantage of such an approach is the independence between the equipment and the service contractor. This independence would make it simpler to change regeneration contractors in the future and may allow the utility to achieve more competitive pricing for regeneration services.

3.6 Roadmap

A roadmap for the overall conversion process is shown in Figure 3-5. The overall conversion is fairly simple and straightforward following justification of the use of off-site regeneration. The process shown is pretty typical for a plant retrofit project.

The economic justification process is discussed in detail in Section 5. Once polishing is justified and the decision is made to go forward with a retrofit, a conceptual design should be performed. This conceptual design would confirm the general decisions made during the economic evaluation and confirm that locations are satisfactory for equipment. Preliminary piping routings should be performed. The conceptual design should be documented and the documents reviewed by management, engineering, and operations personnel.

Following confirmation of the conceptual design, detailed design should proceed to develop the drawings, lists, and documents necessary to describe the necessary physical changes. Once detailed design has been completed to sufficient detail, procurement may begin. As described earlier, procurement can be performed by the utility or its selected designee or by the off-site service contractor. Equipment, construction services, and regeneration services would all need to be obtained.

In parallel with construction and prior to commissioning, revision of operating documentation and complete training of operating personnel should take place. Following completion of commissioning, the benefits of condensate polishing will be available to the station, with the economy of contractor regeneration.

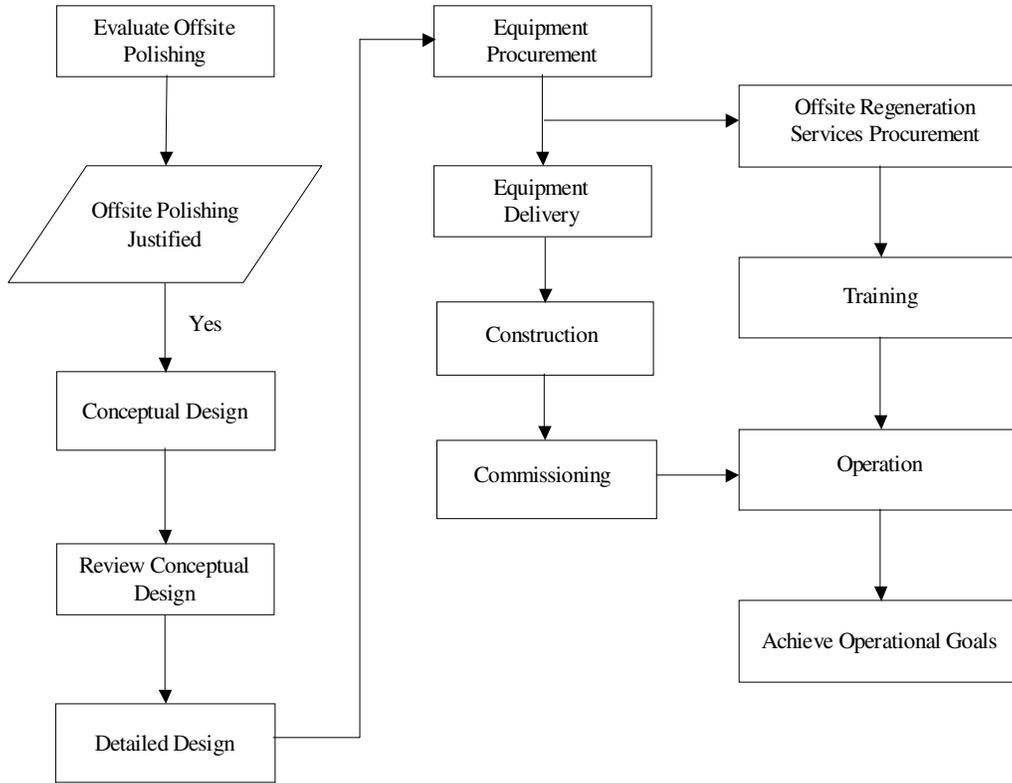


Figure 3-5
Off-site Regeneration Roadmap

3.7 References

1. *Condensate Polishing Guidelines*, EPRI, Palo Alto, CA: 1996. TR-104422.

4

OPERATING GUIDELINES

4.1 Introduction

To a great extent, optimum operation of condensate polishers depends on the quality and degree of resin regeneration. In turn, the minimum standards required for appropriate cation and anion resin regeneration depends on a variety of operating conditions. A summary of the major operating conditions of concern is listed below.

- Condensate pH.
- Operating mode.
 - H-OH only.
 - Operation past amine breakthrough.
- Frequency and severity of contaminant intrusion.
- Circulating water TDS.
- Other contaminants in circulating water (e.g., polymers used for scaling and corrosion control, organics, biocides, etc.).
- Frequency of startups.
- Flow through polishers.
 - Flow rate.
 - Uniformity of flow.
- Polisher bed depth.
- Design of service vessel.
- Polishing system design.
 - Naked mixed-bed.
 - Cation/mixed-bed.
 - Separate beds.

Low condensate pH (< 8.8) normally allows adequately long polisher run lengths even with polishers operated in the H-OH mode (14 to 30 days or more). For condensate pH in the 9.5 – 9.6 range, H-OH operation typically provides run lengths of only 3 to 4 days. Unless operation past ammonia breakthrough is feasible when condensate pH is in the 9.5 – 9.6 range, off-site

Operating Guidelines

regeneration will not usually be practical. Based on economics and operatability, off-site regeneration will probably be practical when average polisher run lengths exceed 10 days.

Although ammonium form operation has been successfully practiced for a long time in plants both overseas and in the United States, it does require resins to be regenerated to high standards, that is with very limited sodium and chloride residuals. While very limited residual chloride levels on the anion resin can be achieved through appropriate chemical pretreatment such as stripping with sulfate or carbonate/bicarbonate, low sodium residuals also require good separation and in some cases additional treatment such as resin-on-resin or ammonia rinse of the anion resin following regeneration. Where a need for high condensate pH and issues such as environmental regulations are both present, the plant may find off-site regeneration and operation beyond ammonia breakthrough the most satisfactory alternative.

4.2 Effluent Quality Targets

There are three major components to condensate polisher operation. They are as follows:

1. In-service operation.
2. Resin transfer.
3. Regeneration and conditioning of the exhausted resin.

Since the third component (resin regeneration and conditioning) is critical to the first (plant operation and performance), turning over responsibility for resin regeneration to a third party is a serious matter.

A power station that contemplates the use of off-site regeneration must first determine the quality of polished condensate needed. Table 4-1 provides a summary of “normal” levels of impurities in polished condensate that may be referred to for an indication of upper limits. In general, the limits provided in the table are considerably higher than those normally achieved at plants with well-operated condensate polisher systems.

**Table 4-1
Polariser Effluent Quality Targets (Normal Operation)**

Effluent Contaminant	HOH Operation Only (Naked Mixed Beds or Separate Two Bed System)	HOH Operation and Occasional Operation Past Ammonium Break (Naked Mixed Beds or Separate Two Bed System)	HOH Operation and Long Run Lengths in Ammonia Form (Naked Mixed Beds or Separate Two Bed System)	HOH Operation Only (Cation/Mixed-Bed or Separate Three Bed System)
Sodium	< 0.3 ppb	< 0.5 ppb	< 1.0 ppb	< 0.2 ppb
Chloride	< 0.5 ppb	<0.5 ppb	< 1.0 ppb	< 0.5 ppb
Sulfate	< 0.5 ppb average	< 0.5 ppb average	< 0.5 ppb average	< 0.5 ppb average

When polisher resin is sent to an off-site regeneration facility (a regeneration specialist), there is no reason that the quality of separation and regeneration should be any less than can be accomplished on-site by plant personnel. Table 4-2 provides some examples of processes that can be used to improve separation and regeneration. There are several additional processes not listed, as well as equipment that both clean and separate mixed-bed resin at the same time. Suppliers that are anxious to service their customers can use many of the listed processes or their own in-house process to achieve adequate mixed bed resin separation. It is important to initially establish the criteria for the quality of off-site regeneration.

**Table 4-2
Examples of Processes to Reduce Sodium from Mixed-Bed Polishers**

Process	Comments
Ammonia Wash	Ammonia rinse of anion resin following NaOH regeneration has been successfully used.
Ammonium Sulfate Density Separation	Ammonium sulfate density separation is a density separation process that does not rely on particle size for separation. Particle size can be optimized for kinetics without sacrificing separation. Also “cleans” resin and strips chloride from anion resin.
Cation/Mixed-Bed	Hydrogen form lead cation bed removes ammonia upstream of the mixed bed resulting in reduced sodium out of mixed bed. Best results are obtained if the cation/mixed-bed design is combined with good separation of mixed bed.
Bottom Transfer Regeneration System	Bottom draw-off of cation resin. Interface remains in transfer pipe or moved to separate “interface isolation vessel”. Significant improvement over standard separation.
Resin-on-Resin	Simple, successful, and cost-effective procedure that reduces sodium release. This process can be used in conjunction with other processes for additional improvement.
Caustic Floatation Regeneration Process	Following hydraulic separation of the mixed-bed resin, the anion resin is floated in caustic while the cation resin drops to the bottom. When combined with the Bottom Transfer Regeneration System which reduces the amount of cation resin entrained in the anion resin, there is significant improvement over standard separation.
Uniform Particle Size Resin	Facilitates good hydraulic separation, but does not address fines.

Table 4-3 provides a summary of polisher effluent quality targets during a minor to moderate condenser leak (less than 8 hours duration) with circulating water having a reasonable distribution of sodium, chloride and sulfate (in other words, not extremely high in sulfate). Effluent quality targets under condenser in-leakage conditions may have to be slightly adjusted for some difficult circulating waters in order to achieve reasonable resin life. (Anion kinetic performance tends to decrease with age.) Tables 4-2 and 4-3 are provided as guidelines that combine protection for the steam cycle system and reasonable requirements for the vendor supplying off-site regeneration services.

**Table 4-3
Polisher Effluent Quality Targets (During Minor to Moderate Condenser In-leakage)**

Effluent Contaminant	HOH Operation Only (Naked Mixed Beds or Separate Two Bed System)	HOH Operation and Occasional Operation Past Ammonium Break (Naked Mixed Beds or Separate Two Bed System)	HOH Operation and Long Run Lengths in Ammonia Form (Naked Mixed Beds or Separate Two Bed System)	HOH Operation Only (Cation/Mixed-Bed or Separate Three Bed System)
Sodium	< 0.4 ppb	< 0.6 ppb	< 1.1 ppb	< 0.3 ppb
Chloride	< 0.7 ppb	<0.7 ppb	< 1.3 ppb	< 0.7 ppb
Sulfate	< 2.0 ppb average	< 2.0 ppb average	< 2.0 ppb average	< 2.0 ppb average

4.3 Resin Quality Targets

When a fossil-fueled power plant purchases new anion and cation resin for use in its condensate polishing system, the typical resin specifications provided to the resin supplier include parameters such as whole perfect beads, water retention capacity, particle size distribution, friability, and percentage of cation resin in the hydrogen form. Residual sodium on the cation resin may be required and reported on either a dry basis or as a percent of total sites. If the anion resin is purchased in the hydroxide form, percent OH may be required as well as target values for residual chloride and sulfate. When purchased in the carbonate/bicarbonate form, target values for residual chloride and sulfate on the anion resin may or may not be included in the specification.

Few specifications include anion or cation resin kinetics or leachable total organic carbon (TOC) or any guarantees of useful life even under specified operating conditions. Consequently, it is difficult to expect suppliers of off-site regeneration services to meet more stringent resin quality specifications than the original resin supplier was asked to meet. Therefore, the first issue to address is the initial quality of the resin purchased for use in condensate polishing whether the end user or the supplier owns it.

If the supplier of off-site regeneration services also owns the resin and is required to meet reasonable but stringent regenerated resin quality targets, it will be in the supplier's interest, as well as in the end-user's interest, to supply quality resin. Under these circumstances, the parameters of concern to the end-user (power plant operator, steam supplier, etc.) relate to operational factors rather than to useful resin life. Specifications for regenerated resin should, therefore, target meaningful operational parameters, i.e. those parameters that affect or have the potential to affect in-service polisher performance. Table 4-4 provides a summary of target values for the quality of regenerated resin. These target values are easily attainable with reasonable care and a good regeneration system.

Table 4-4
Summary of Target Values for Regenerated Resin

Parameter	Cation Resin	Anion Resin
Cl Residual on the Resin		< 2 % ¹ , < 1% ²
Na Residual on the Resin	< 2 % ¹ , < 0.08% ²	
SO ₄ Residual on the Resin		< 2 % ³
Mass Transfer Coefficient ⁴	> 85 % of new resin value	> 75 % of new resin value
Leachable TOC	< 5 ppm using Edison test ⁵ < 2 ppm using PPL test ⁵	< 35 ppm using Edison test ⁵ < 20 ppm using PPL test ⁵
Iron Fouling	< 5 ppm	< 5 ppm

¹ This target applies to resins being operated only in the H-OH mode.

² This value will permit operation past ammonium breakthrough when the influent pH is < 9.6. Some relaxation of these targets may be allowed for operation at consistently lower pH levels.

³ This target applies for operation in both the H-OH mode and in the Ammonium Form. When sulfate is used as a pretreatment or intermediate step, a higher degree of conversion of the anion resin to the OH form is achieved than with OH regeneration alone partially offsetting the higher residual sulfate and the resulting reduction of available capacity. Sulfate residuals of < 12% are acceptable when sulfate is used as an intermediate or pretreatment chemical.

⁴ % Removal may be used in place of Mass Transfer Coefficient

⁵ Test methods for TOC leachables and other parameters are provided in Appendix B

Other issues that may arise with vendor owned resin, such as vendor involvement in plant operation or their placement of restrictions that could affect plant operation, should be addressed in the regeneration services contract. Just as turbine manufacturers provide a warranty for their product that has conditions about steam quality specifications being met, so can a similar warranty be negotiated with contractors that supply off-site regeneration services and own the condensate polishing resin. However, since most of the impact on resin life occurs during regeneration, it is important to only hold the end user responsible for maintaining reasonable conditions typical of normal operation. Normal operating conditions include a reasonable flow rate through the polishers appropriate for system design, periodic unit startups (4–6 per month on the average), condensate temperature not exceeding 160° F (70 °C) for an extended period, reasonable condensate oxygen levels, and no incursions of oil or oily products.

The vendor and the end-user should negotiate appropriate compensation when any special conditions that may impact resin life or regeneration requirements are present, such as the use of alternate amines. However, reasonable quality limits on regenerated resin should not be penalized with significantly higher cost. Although it is to be expected that the off-site regenerators will be initially reluctant to offer more than basic services or to commit to quality targets for resin regeneration without trying to tie the limits to higher prices, the potential for new and continuing business should encourage the marketplace.

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A different situation exists when the resin is owned by the end user. In most cases, resin attrition during regeneration or transfer is less of a concern to the supplier than when he owns the resin. On the other hand, the end-user is more concerned about resin life when he (rather than the contractor) owns the resin because the cost of replacement resin will be his problem. Consequently, ownership of the resin by the end-user means establishing a reasonable level of resin attrition in conjunction with the target resin quality values. Responsibility for resin replacement for losses exceeding the agreed upon target level needs to be identified in the resin regeneration contract. The issues of knowing and maintaining resin inventory levels are discussed later in this chapter.

4.4 Surveillance

Operation and surveillance of polishing systems is much the same whether off-site regeneration or on-site regeneration is used. A good program to oversee the performance of the system is required for satisfactory operation. Effluent guidelines (such as those provided in Tables 4-2 and 4-3) should be established to be met under both normal operating conditions and during a minor to moderate condenser leak. Maintaining records of all cycle chemistry parameters as well as operating conditions is essential. Individual polisher effluent quality during a condenser leak is valuable data to indicate whether kinetic impairment is a problem. The data must be accompanied by other parameters such as flow rate through the polisher, condensate temperature, and pH.

This information base is most often properly recorded if an operator or operating supervisor has been designated with primary responsibility for seeing that appropriate surveillance and recording is routinely done. Additional activities with off-site regeneration would include assurance that the supplier quality control activities are identified and that the procedures are being followed. Knowledge and good records can prevent misunderstandings.

On-site personnel should be trained to appropriately assist the vendor when deliveries and/or resin pickups are being made. Routine deliveries of regenerated resin and pickups of exhausted resin should be coordinated so as to minimize travel time and charges and assure an adequate supply of regenerated resin is on hand to meet emergency situations. Thorough receipt inspection procedures should be established, logs maintained, and records reviewed. The quantities and apparent condition of the resin should be noted and recorded.

Management must ensure that individuals or departments assigned responsibility for certain tasks are given the opportunity and encouragement to follow through. Collecting samples of regenerated resin for periodic quality control testing is an example. The samples may be collected by on-site personnel or provided by the vendor when regenerated resin is delivered. Suggested quality targets for regenerated resin are provided in Table 4-4. Establishing and implementing a reasonable testing schedule is at least as important as the targets themselves and should be a management objective.

In summary, surveillance requires a written program and interested personnel to record chemistry and operational data.

4.4.1 Testing

Since it is the vendor's responsibility to provide resins that meet physical and kinetics specifications and the appropriate degree of regeneration, internal quality control checks should be part of their normal regime for off-site regeneration. However, additional testing is normally required to verify that resins are consistently being regenerated to the desired degree and that they are (remain) in good physical and kinetic condition to ensure protection of the equipment for which the condensate polishers were installed. Periodic checks to determine the quality of regeneration (for example, chloride and sodium capacities) and resin kinetics should be performed. Responsibility to perform this testing must be identified. The vendor can be assigned prime responsibility for resin testing. If this option is chosen, the end-user is recommended to carry out, or cause to be carried out by independent laboratories, its own periodic quality control checks.

If the vendor owns the resin, it may be possible for the vendor to perform many of the tests. However, periodic quality control testing to determine the quality of regeneration (for example, sodium and chloride capacities) and resin kinetics should still be done by someone other than the vendor. If the resin is owned by the end user, kinetics testing is especially important to determine the useful life of the resin particularly if the circulating water has a high level of dissolved solids. Table 4-5 lists the resin analysis procedures provided in Appendix B and indicates the resin tests that are considered to be useful. Further discussion of the tests and their usefulness is provided in Appendix B.

**Table 4-5
Resin Analysis Procedures**

Method	Title
A	Perfect Bead Content
B	Resin Fines
C	Exchange Capacity of Hydroxide Form Anion Resin
D	Trace Metal Determination
E	Anion Resin Exchange Kinetics Assessment
F	Determination of Chloride, Sulfate, Sodium, Magnesium, and Calcium Impurities Exchanged on Bead Resin
G	Hydrogen Form Cation Resin Exchange Capacity
H	Ion Exchange Resin Organic Extractables

4.4.2 Administration

Recommendations relating to the administration of an off-site polisher resin regeneration program are important. For a program of this type to be successful, both technical and procurement personnel should be involved. Technical personnel must establish all of the relevant criteria and quality limits, and identify critical areas such as the quantity of on-site resin required and the frequency of routine deliveries. Commercial aspects of the contract are often better left to procurement personnel who are familiar with insurance requirements and legal protection. Once a contract is in place, routine pickup of exhausted resin and delivery of regenerated resin should follow procedures that were established in advance of the contract. However, because of the need for technical monitoring and quality control, administration of the program is probably best left to a technical employee involved in condensate polisher operation. An attitude of partnership between the vendor and the end-user can assure smooth operation.

Administration of an off-site regeneration program becomes more difficult if several plants are involved in the same contract in such a way that they may be competing with each other for service or emergency service. Such considerations may be factored into the conceptual aspects of implementation. For example, additional resin storage could be considered to avoid these kinds of problems when more than one plant is involved.

5

ECONOMICS OF OFF-SITE REGENERATION

5.1 Background

The economics of off-site polishing are important in selecting regeneration options and in justifying plant additions and changes. These economics were briefly discussed in Appendix E of the Condensate Polisher Guidelines (1). For the situations evaluated there, on-site regeneration is more expensive to purchase and install, but more cost effective to operate. For situations where regeneration is required infrequently, off-site regeneration can be cost effective. For these situations, elimination of the cost of the regeneration equipment more than offsets the higher regeneration costs of off-site regeneration.

Similar economic studies were performed for this guideline. A specification for obtaining off-site regeneration services was developed and transmitted to potential vendors. The specification solicited cost information as well as input on how best to accomplish off-site regeneration with the contractors. Comments on the specification were also solicited. A copy of the specification is included in Appendix A.

It was expected that vendor charges would be associated with and proportional to the costs the vendor incurred for providing these services. One such set of costs would be those associated with regeneration of the resins, and it was expected that this cost would be quoted on a per volume of resin treated basis. Such costs would be for regenerants and water used as well as wastewater disposal costs (if any). These costs would be expected to increase with increasing resin purity requirements that would necessitate the use of more regenerant per volume of resin regenerated. Costs such as transportation costs were expected to be established on a mileage basis. These costs were expected to increase or decrease based upon the distance between the regeneration contractor's facilities and the plant using the service. Other costs would be expected to be based on a batch basis, such as laboratory work associated with receiving and regenerating a batch of resin, labor for filling and emptying tankers, and the quality control requirements of those operations.

5.2 Contractor Supply Parameters

Potential contractors were asked for a variety of information, including cost estimates for performing off-site regeneration services. The following parameters were specified.

5.2.1 Regeneration Frequency

Information on both frequent regeneration operation (hydrogen cycle operation at high cycle pH) as well as less frequent regeneration operation (ammonia cycle operation at high pH or hydrogen cycle at moderate pH) information was of interest. Vendors' information was used to estimate annual charges for regeneration frequencies of the two different design cases: new units and retrofit units. Frequencies of 24 regenerations per year were used for the less frequent case based upon 30 day runs for the two fifty percent units. For frequent regeneration operation, the frequency of 146 regenerations per year was assumed for the two different design cases. In general, vendors responded that the frequency of regeneration did not matter in determining the overall price. Vendors generally gave a "per regeneration" pricing, although a few did indicate that a large volume of business would bring about a small reduction in regeneration cost. Hopefully, the maturation of this business will bring about greater levels of consideration for more frequent service users.

5.2.2 Distance from Regeneration Facilities

It was expected that the distance for transportation of resin would be a significant factor in the cost of off-site regeneration. A base distance of 100 miles (160 km) was used for cost estimates. Also, vendors were asked to supply differential cost information for providing service to more remote plants. In general, vendors indicated that transportation costs range from \$1.50/mile (\$0.93/km) to \$1.95/mile (\$1.21/km). There would be additional charges for trips over 300 miles (480 km), because of charges for an overnight stay by the driver.

5.2.3 Resin Regeneration Specifications

Resin specifications were supplied to off-site regeneration contractors. Vendors indicated that they were capable of meeting these specifications and in some instances capable of exceeding these specifications. There were several grades of resin regeneration offered in certain instances. It was originally envisioned that the better grades of regeneration could be used for operation beyond amine breakthrough and the poorer grades could be used for hydrogen cycle operation. However, the frequent regeneration which is associated with hydrogen cycle operation at high cycle pH has been found to be uneconomical, so any potential savings are not meaningful.

5.2.4 Resin Replacement Cost

This area may present challenges in the relationship between supplier and user. Both parties can make operating errors, which would decrease the normal resin life. The errors could go undetected, and could certainly go undetected by the both parties if only routine surveillance is used.

As previously described, the ownership of the resin can vary; either the polisher user or the regeneration contractor can own the resin. If the resin user continues to own the resin as has been traditional in the field of condensate polishing, there would be no need to establish a resin cost from the regeneration supplier. However, the contract could include the cost of resin replacement in the event that the regeneration contractor were to lose or damage the resin in

some sort of an accident. This could be included with other possibilities of supplier failure and have liquidated damages associated with such an incident.

In the case where the regeneration supplier owns the resin, the cost of resin replacement would be built into the fees paid for regeneration. The cost of replacement resin would be amortized over a reasonable replacement period. Replacement costs should be determined in advance, so that in the event that some sort of accident occurs where the resin user would be responsible for the replacement of the resin. The replacement should consider the useful life already expended. Therefore, the responsible party should be prepared to pay the pro-rata remaining useful life of the resin as a replacement cost. For this reason, requests for bid prices for resin replacement were included.

5.3 Economic Models

Economic evaluation is useful in determining the cost of using off-site regeneration. While many factors other than direct economics may influence the justification and decision to use off-site regeneration, the economics of the conversion and operation should be known to the end user.

5.3.1 Capital Costs

Capital costs are those costs that must be incurred for equipment and installation of equipment for the initial installation or retrofit prior to operation. For a new plant, condensate polishing equipment can be purchased without regeneration facilities. This saves a significant portion of the condensate polishing equipment cost. Additionally, certain facilities such as neutralization equipment, regenerant handling and preparation areas, and chemical collection systems can be eliminated. Retrofit systems would have these same benefits as well as the additional benefits which include lesser space requirements, simpler interfacing with existing plant equipment, and reduced licensing requirements

Two condensate polisher designs were used as examples: one to simulate a retrofit system and one to simulate a new system. Each of these designs were based on the example designs used in the Condensate Polisher Guidelines⁽¹⁾. Descriptions of each of these systems are provided below.

Retrofit Plant Equipment

The existing condensate polishing system includes mixed bed ion exchangers designed for removal of suspended as well as soluble contaminants from the condensate. The system consists of the following:

- Full-flow condensate polishing system, 4700 gpm (0.30 m³/s).
- Three 50% capacity, rubber-lined service vessels.
 - 2350 gpm (0.15 m³/s) capacity per vessel.
 - 525 psig (3.72 MPa) vessel design pressure.

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- 90 inch (2.29m) diameter by 54 inch (1.37m) side sheet.
- 36 inch (0.91 m) resin bed depth.
- 84 cubic feet (2.4 m³) of cation resin and 42 cubic feet (1.2 m³) of anion resin per vessel.
- Three vessel external regeneration system consisting of a cation regeneration tank, anion regeneration tank, and resin storage tank. All vessels are rubber-lined.
 - CRT: 66 inch (1.68 m) OD, 144 inch (3.66 m) SS
 - ART: 42 inch (1.07 m) OD, 144 inch (3.66 m) SS
 - RST: 66 inch (1.68 m) OD, 114 (2.9 m) inch SS
- Two bulk resin storage vessels consisting of a bulk resin storage tank and a bulk spent resin storage tank.
 - 120 inch (3.05 m) OD, 144 inch (3.66 m) SS
- Two 1100 gpm (0.069 m³/s) recycle pumps.
- Interconnecting piping and valves.
- Controls and instrumentation.

New Plant Equipment

The condensate polishing system includes mixed bed ion exchangers designed for removal of suspended as well as soluble contaminants from the condensate. The system consists of the following:

- Full-flow condensate polishing system, 6000 gpm (0.38 m³/s).
- Three 50% capacity, rubber-lined service vessels.
 - 3000 gpm (0.19 m³/s) capacity per vessel.
 - 720 psig (5.07 MPa) vessel design pressure.
 - 96 inch (2.44 m) diameter by 74 inch (1.88 m) side sheet.
 - 36 inch (0.91 m) resin bed depth.
 - 96 cubic feet (2.7 m³) of cation resin and 48 cubic feet (1.4 m³) of anion resin per vessel.
- Two bulk resin storage vessels consisting of a bulk resin storage tank and a bulk spent resin storage tank--120 inch (3.05 m) OD, 144 inch (3.56 m) SS
- Cleaning, Backwash, and Mixing Tank --72 inch (1.83 m) OD, 121 inch (3.07 m) SS.
- Two 1800 gpm (0.11 m³/s) recycle pumps.
- Interconnection piping and valves.
- Controls and instrumentation.

The Bulk Resin Storage Tank provides storage capacity for regenerated resin received from the Contractor's delivery vehicle. The Bulk Spent Resin Storage Tank provides storage capacity for spent resin waiting shipment for off-site regeneration. Resin is sluiced directly between the service vessels and the bulk storage tanks.

Capital Cost Results

The results from the capital cost analyses are presented below. Equipment costs for each type of system were determined from equipment supplier quotes. In addition to equipment costs, estimates were made for support facilities for each type of system. Support facilities include:

- Regenerant storage tanks.
- Building space.
- Neutralization facilities.
- Discharge facilities.
- Larger condensate pump motors.
- Condensate piping runs to and from the polisher.
- Polisher isolation valves and bypass control valve.
- Miscellaneous piping.
- Equipment pads.
- Power supplies, cable, motor control centers.
- Curbed areas, sumps, and trenches with protective coatings.
- Miscellaneous structural steel.

Equipment installation consists of the labor and material costs associated with installation of the polishing equipment and auxiliary facilities required for the new installation or retrofit. Indirect costs include engineering, allowance for funds used during construction, and administrative costs associated with installation of the new or retrofit equipment.

As seen in Table 5-1, elimination of regeneration equipment and supporting facilities can save about one fourth of a new installation and about one third of a retrofit installation. These savings are realized in each area of installed cost because less equipment is required, building space requirements are decreased, fewer support facilities are required, installation requirements are reduced, and indirects are reduced.

**Table 5-1
Cost Comparisons Between On-site and Off-site Regeneration**

Cost Parameter	New On-site	New Off-site	Retrofit On-site	Retrofit Off-site
	Cost, \$	Cost, \$	Cost, \$	Cost, \$
Polishing Equipment	\$ 1,800,000	\$ 1,400,000	\$ 1,600,000	\$ 1,200,000
Buildings and support facilities	\$ 270,000	\$ 140,000	\$ 500,000	\$ 290,000
Installation	\$ 520,000	\$ 370,000	\$ 770,000	\$ 540,000
Indirects	\$ 650,000	\$ 460,000	\$ 710,000	\$ 500,000
Total Installed Costs	\$ 3,200,000	\$ 2,400,000	\$ 3,600,000	\$ 2,500,000

5.3.2 Capital Cost Alternates

The base systems shown in Table 5-1 show costs for systems that do not contain bulk storage capabilities. Vendor quotes were also solicited for systems with 900 cubic foot (25 m³) bulk storage tanks. Two tanks are required, one for fresh resin, and one for spent resin. Systems showing bulk storage were shown in Figures 3-2 and 3-4. The advantage of bulk storage is the ability to have spare charges at the site available to deal with water chemistry needs without waiting for an off-site regeneration supplier delivery. There are two disadvantages, higher capital cost for the additional storage and greater resin cost, including greater operating cost for resin replacement. The capital cost comparisons are shown in Table 5-2 for the two off-site regeneration system cases.

**Table 5-2
The Capital Cost Comparisons for Two Off-site Regeneration System Cases**

	New Off-site	Retrofit Off-site
Cost Parameter	Cost, \$	Cost, \$
Polishing Equipment	\$ 1,500,000	\$ 1,300,000
Buildings and support facilities	\$ 150,000	\$ 320,000
Installation	\$ 400,000	\$ 600,000
Indirects	\$ 500,000	\$ 550,000
Total Installed Costs	\$ 2,600,000	\$ 2,800,000

As shown in Table 5-2 costs for the systems with bulk storage are greater than for the equivalent system without bulk storage. The justification for the increased costs would need to be based upon the expectation of greater benefit derived from the greater flexibility of the system with bulk storage. If the need for the greater flexibility provided by bulk storage is not evident from plant evaluations and installation justification, then the lower cost systems without bulk storage should be selected.

5.3.3 Operating Costs

Because of the different types of costs for off-site and on-site regeneration, it is necessary to assess total life cycle costs for the two different types of systems. Operating costs are a portion of the total life cycle cost comparison. Operating costs evaluated included those for regeneration chemicals, power consumption, cycle chemicals, staffing, maintenance, and resin replacement. Regeneration costs for off-site regeneration cases included contractor costs and water consumption for sluicing resins to and from the contractor's trucks. Regeneration costs for on-site regeneration included regenerant chemicals, water consumption and power costs. As seen earlier in the Condensate Polishing Guidelines⁽¹⁾, operation with more frequent regeneration, (such as hydrogen cycle at a high cycle pH) versus less frequent regeneration (such as oxygenated treatment at moderate cycle pH or ammonia cycle operation) has great impact on the economics of condensate polishing. Thus, operating economics for both hydrogen cycle regeneration and ammonia cycle were evaluated. Results of the annual operating costs for both hydrogen cycle and ammonia cycle are provided in the Tables 5-3 and 5-4, respectively.

**Table 5-3
Annual Hydrogen Cycle Operating Costs**

	New On-site \$1,000's	New Off-site \$1,000's	Retrofit On-site \$1,000's	Retrofit Off-site \$1,000's
Power Consumption	116	113	91	88
Regeneration Costs	23	321	20	286
Cycle Chemicals	2	2	2	2
Resins	9	17	8	15
Operation and Maintenance	49	25	49	25
Total	199	478	170	416

The above results clearly show the affect of the higher cost of operation for use of off-site regeneration. The comparison clearly shows that on-site regeneration is is much less costly from an operating cost standpoint when frequent regeneration of condensate polishing systems is practiced.

**Table 5-4
Annual Ammonia Cycle Operating Costs**

	New On-site, \$1,000's	New Off-site, \$1,000's	Retrofit On-site, \$1,000's	Retrofit Off-site, \$1,000's
Power Consumption	113	113	89	88
Regeneration Costs	4	53	3	48
Cycle Chemicals	1	1	1	1
Resins	9	17	7	15
Operation and Maintenance	25	19	25	19
Total	152	203	125	171

As shown in Table 5-4 for less frequent regeneration, such as ammonia cycle operation or operation at moderate condensate pH, on-site regeneration continues to be less costly from an operating cost standpoint. However, the difference is less dramatic and the cost of regeneration is less dominant in this operating cost tabulation.

5.3.4 Life Cycle Cost Comparisons

While capital costs favor an off-site regeneration system, operating costs favor an on-site regeneration system. To determine the most beneficial system economically, it will be necessary to determine life cycle costs for both types of systems. Capital costs for systems and installation will be amortized over the evaluation period in order to place the capital costs on an annual basis. Operating costs will be escalated over the evaluation period in recognition of the inflation in operating costs that are expected to occur. Because escalated future costs have a lesser economic impact than current day costs, present worth evaluations over the evaluation period will be necessary. Additionally, future costs will be levelized so that present day levelized costs can be presented. The economic and evaluation factors were used to develop the annual comparative costs for off-site and on-site regeneration. The listing of factors used in this analysis are contained in Appendix C

Comparative costs for each of the plans are presented in Tables 5-5 and 5-6, one for frequent regeneration and one for less frequent regeneration.

**Table 5-5
Comparative Annual Costs – Frequent Regeneration**

	New On-site, \$1,000's	New Off-site, \$1,000's	Retrofit On-site, \$1,000's	Retrofit Off-site, \$1,000's
Amortization	340	250	380	270
Levelized Operating Costs	340	810	290	710
Total Comparative Costs	680	1,100	670	980

As can be seen in Table 5-5, while off-site regeneration saves capital expenses, the high cost of regeneration on a frequent basis makes operating costs very high and causes total comparative costs to favor on-site regeneration. There may however, be certain instances where other factors might offset the high comparative costs of off-site regeneration. Certain licensing and operational factors could still cause off-site regeneration to be considered.

**Table 5-6
Comparative Annual Costs – Less Frequent Regeneration**

	New On-site, \$1,000's	New Off-site, \$1,000's	Retrofit On-site, \$1,000's	Retrofit Off-site, \$1,000's
Amortization	340	250	380	270
Levelized Operating Costs	260	260	210	290
Total	600	510	590	560

The comparative costs in Table 5-6 show that for less frequent regeneration cases, off-site regeneration is more economical than on-site regeneration. While operating costs are higher, these higher operating costs are offset by the lower amortization costs of off-site regeneration.

Because certain economic and operational factors affect the value of both amortization and levelized operating costs, a series of sensitivity analyses were performed to determine the sensitivity of the analysis to variation in the economic or operational factors.

5.3.5 Sensitivity Analysis

Total costs and levelized operating costs are sensitive to regeneration frequency. Thus, operating costs were developed for several regeneration frequencies. The results were plotted in Figure 5-1.

Economics of Off-site Regeneration

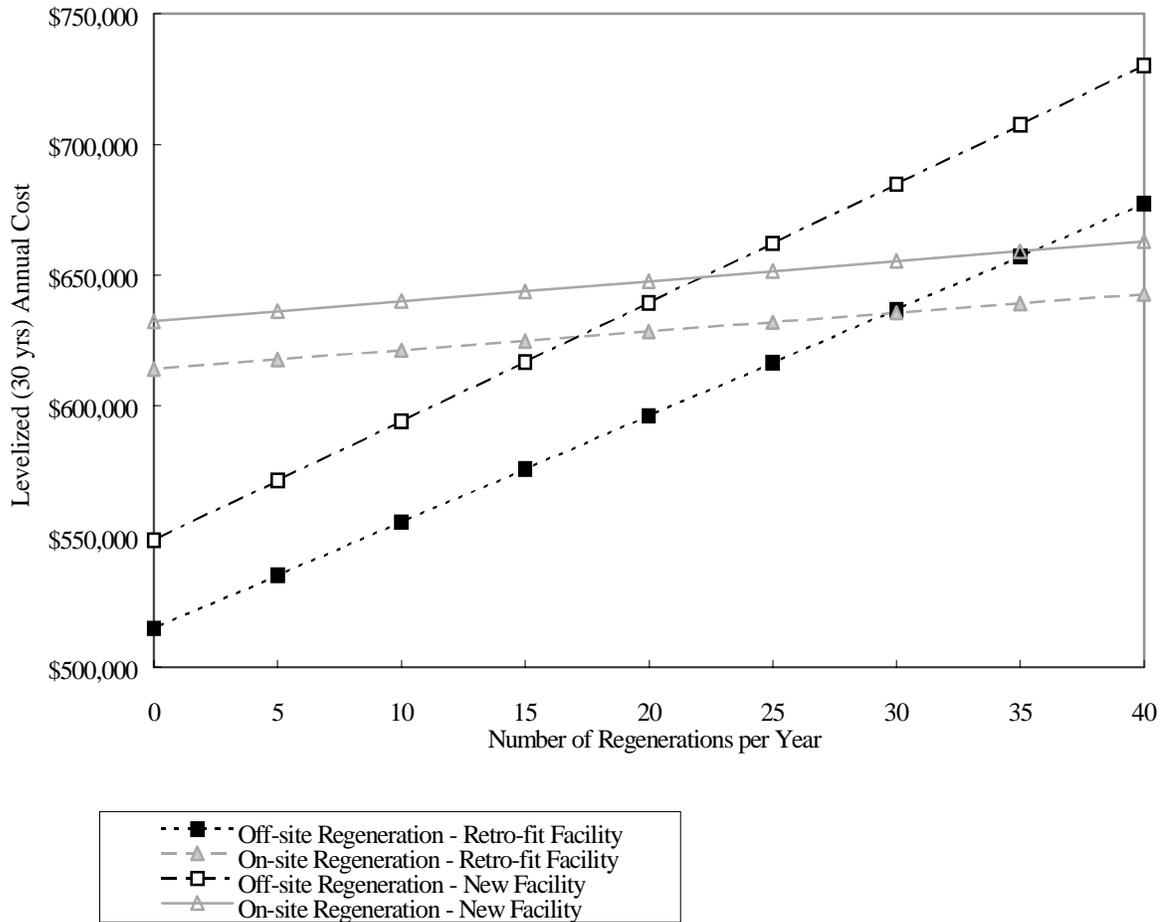


Figure 5-1
Sensitivity to Regeneration Frequency for On-site and Off-site Regeneration

For the economic parameters selected, the results indicate that off-site regeneration is more cost effective for new facilities at around 24 regenerations per year and for retrofit facilities at about 30 regenerations per year.

Comparison of the relative slopes of the curves for the two different types of regeneration system, off-site and on-site, show that total costs are relatively insensitive to the regeneration frequency for on-site regeneration systems and relatively sensitive to regeneration frequency for off-site regeneration.

Contractors provided costs for regeneration on both a resin volume basis as well as a charge for transportation of the resin. These two costs make up the primary costs for the contractor portion of off-site regeneration. The resin volume cost makes up about 80% of the total contractor charges. Thus, the sensitivity of this charge was evaluated and is shown in Figure 5-2.

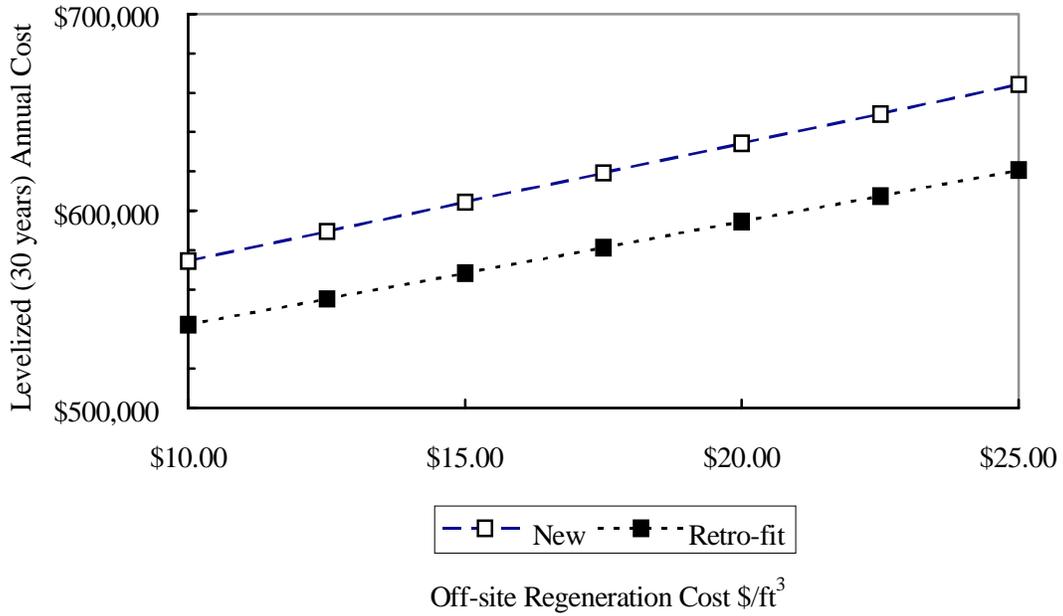


Figure 5-2
Sensitivity of Levelized Operating Cost to Resin Regeneration Cost for Ammonia Cycle Facilities

This curve again shows that annual costs are significantly affected by the off-site regeneration contractor's charges for regeneration services. This points out an area of potential cost improvement to make off-site regeneration more economical.

The period of amortization is another variable that may be important for retrofit situations. In Figure 5-3, variation in total annual cost with the period of amortization (or remaining period of operation) is shown.

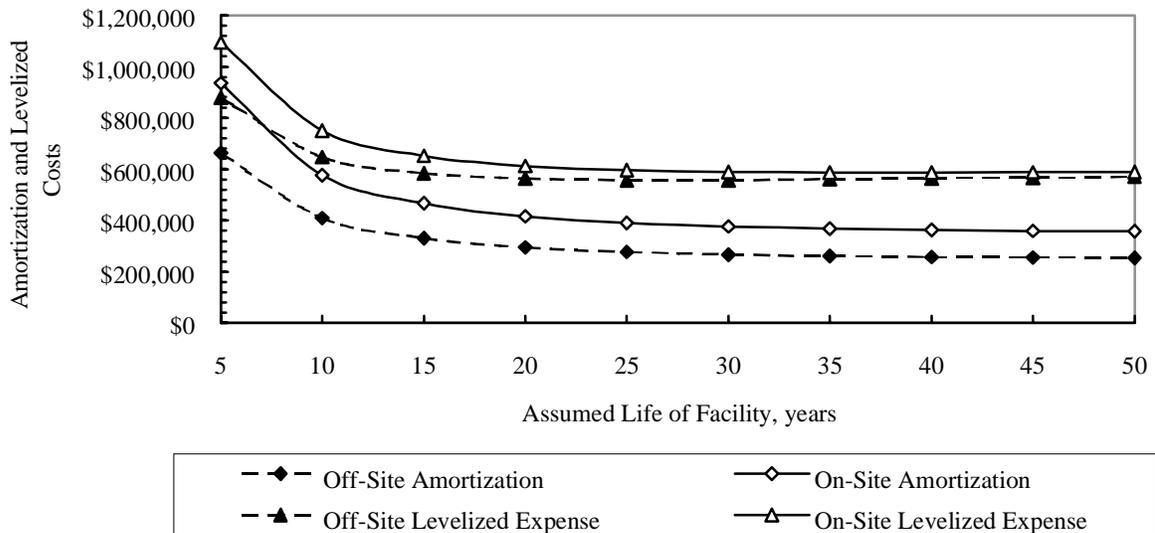


Figure 5-3
Sensitivity of Amortization and Levelized Costs to Assumed Life of Facility for Off-site and On-site Regeneration at a Retro-fit Facility (Ammonia Cycle)

Economics of Off-site Regeneration

As expected, short terms for amortization show higher annual costs for all alternatives. Also as expected, shorter facility life values more greatly favor the use of off-site regeneration. While longer facility life values result in more closely matched annual costs for both off-site and on-site regeneration systems, off-site regeneration continues to be more cost effective. Note that these curves are for infrequent regeneration conditions and frequency of regeneration more strongly controls the total annual cost than the period of amortization.

5.4 References

1. *Condensate Polishing Guidelines*, EPRI, Palo Alto, CA: 1996. TR-104422.

A

OFF-SITE REGENERATION SPECIFICATION

Section GR - General Requirements OFF-SITE REGENERATION SERVICES

Users: Explanatory text is provided in italics. Also see some text will be shown in [brackets]. The brackets enclose text which is optional, depending upon the options chosen, for example. hydrogen cycle operation or ammonia cycle operation or the brackets hold places for specific information like the owner and project name space below.

GR.1 GENERAL. This section covers the general description, scope of work, and supplementary requirements for furnishing off-site condensate polisher resin regeneration services as indicated under these specifications.

The services covered by these specifications will be incorporated in the [Insert owner's and project's name]. The project site is located [insert project site location description].

GR.2 WORK INCLUDED UNDER THESE SPECIFICATIONS. The work under these specifications shall, for the period of the agreement, include furnishing all equipment and materials for the off-site regeneration of condensate polisher resins in accordance with the specifications, drawings, and other contract documents, except as specifically excluded under **WORK NOT INCLUDED UNDER THESE SPECIFICATIONS.**

Major components of the work under these specifications for Off-site Regeneration Services are as follows:

Supply of freshly regenerated resins to, and removal of a like amount of exhausted resin from, the Owner's operating facility.

Transport of resin to and from the Owner's operating facility, including personnel and materials for the transfer of resins to/from the Owner's resin receiving facility.

Disposal of any liquid, solid, or chemical wastes produced off-site, except for resin transfer wastewater which results from transfer operations at the Owner's operating facility.

The above explanations and listings are intended to give a general definition of the scope of the work under these specifications, and shall not be construed to be an itemized listing of each element of the work required. The Contractor shall be responsible for successfully conducting off-site regenerations, and conforming in all respects to the details and requirements of the specifications, drawings, and other contract documents.

Off-site Regeneration Specification

GR.3 WORK NOT INCLUDED UNDER THESE SPECIFICATIONS. In addition to the work under this Contract, the following items of work will be furnished by the Owner:

Condensate polisher system, including service vessels [and resin storage vessels].

Demineralized water to a single connection at the boundary of the truck unloading area.

Rinse and transfer water disposal piping from a single connection at the boundary of the truck unloading area.

Regenerated resin piping to a single connection at the boundary of the truck unloading area.

Spent resin piping from a single connection at the boundary of the truck unloading area.

Operating personnel for the daily operation of the condensate polishing system.
Maintenance of the condensate polishing facilities, excluding personnel and materials for the periodic transfer of resins for off-site regeneration, will be furnished by the Owner.

GR.4 COORDINATION MEETINGS. Representatives of the Contractor shall attend a coordination meeting at a time and place selected by the Owner to discuss matters relative to the execution of this Contract. The Contractor's representatives shall attend additional meetings as required by the Owner thereafter to expedite the work.

GR.5 SUBMITTAL OF RESIN DATA. The Contractor will be required to submit information and engineering data in accordance with the requirements specified herein to assure compliance with the overall operation of the facility.

GR.6 SCHEDULE. The timely completion of resin deliveries and spent resin pickup is a basic consideration of the contract. It is necessary that the Contractor perform the activities shown on or before the dates indicated to avoid interruption in the operation of the facility.

<u>Activity</u>	<u>Schedule</u>
Contractor to deliver complete description of services to be provided and equipment to be utilized.	With proposal
Return signed Contract Agreement to be included in the Conformed Contract.	15 days after contract award
Initial delivery of regenerated resin	[Provide date]
Delivery of regenerated resin, and removal of spent resin.	_____ days after notification [Provide duration]

Section TS - Technical Specifications

OFF-SITE REGENERATION SERVICES

TS.1 GENERAL. This section covers the general description, design criteria, and performance requirements for off-site regeneration of condensate polisher resins. The services covered by these specifications will be used at [Insert name and location of facility].

TS.2 DESCRIPTION OF SERVICES. The Contractor shall provide off-site regeneration services for the condensate polisher system described herein. The Contractor shall be responsible for all aspects of off-site regeneration including the furnishing and delivery of regenerated resin delivery to the site's regenerated resin receiving facility and receipt of spent resin from the site's spent resin storage facility, resin transfers to/from delivery vehicles, resin regeneration at the Contractor's off-site facility, replacement of lost resin, and waste disposal at the Contractor's facilities.

The Owner will provide demineralized water to a single connection at the boundary of the resin truck unloading area, and rinse and sluice water disposal piping from a single connection at the boundary of the truck unloading area. The Owner will also provide operating and maintenance personnel for the daily operation of the condensate polishing system, excluding personnel and materials for the periodic transfer of resins to or from transport vessels for off-site regeneration.

Note: Some owners may wish to make existing condensate polisher resins available to Contractor, for a reduction in price. If so, such information should be included with text as follows. ["The owners existing resins are available for use by the Contractor. The Contractor may test the resins to assure their physical and chemical properties. Use of the owners resins does not relieve the Contractor from meeting any of the requirements of this specification." The Contractor shall provide a cost quote reduction for the first year of service. The owner shall have the option of accepting the reduction or retaining the resin for other uses. "]

The frequency of deliveries and regenerations will be highly dependent upon plant load and whether service runs are to be extended beyond the ammonia breakpoint. This plant is expected to operate in the [hydrogen or ammonia] cycle. For [hydrogen or ammonia] cycle operation, [146 or 24] regenerations per year are anticipated. Additional regenerations may be required based on the frequency of startups or minor condenser leaks. The Contractor shall base his proposal on the stated frequency of regeneration, with price adjustments to allow for more or less frequent regenerations.

TS.3 SYSTEM DESCRIPTION.

[Choose the appropriate description for the following section; Retrofit without storage vessels, Retrofit with storage vessels, or New facility with bulk storage vessels, New facility without storage vessels. Note that the storage vessels can contain more than one charge of resin. It is anticipated that the amount of storage desired may vary, depending upon how stations customize these systems to their specific needs. Thus, larger, smaller or multiple tankage could be envisioned.]

[Retrofit Plant with bulk storage tanks added]

The existing condensate polishing system includes mixed bed ion exchangers designed for removal of suspended as well as soluble contaminants from the condensate. The system consists of the following:

- Full-flow condensate polishing system, 4700 gpm (0.30 m³/s).
- Three 50% capacity, rubber-lined service vessels.
 - 2350 gpm (0.15 m³/s) capacity per vessel.
 - 525 psig (3.72 MPa) vessel design pressure.
 - 90 inch (2290 mm) diameter by 54 inch (1370 mm) side sheet.
 - 36 inch (910 mm) resin bed depth.
 - 84 cubic feet (2.4 m³) of cation resin and 42 cubic feet (1.2 m³) of anion resin per vessel.
- Three vessel external regeneration system consisting of a cation regeneration tank, anion regeneration tank, and resin storage tank. All vessels are rubber-lined.
 - CRT: 66 inch (1680 mm) OD, 144 inch (3660 mm) SS.
 - ART: 42 inch (1070 mm) OD, 144 (3660 mm) inch SS.
 - RST: 66 inch (1680 mm) OD, 114 (2900 mm) inch SS.
- Two bulk resin storage vessels consisting of a bulk resin storage tank and a bulk spent resin storage tank.
 - 120 inch (3050 mm) OD, 144 inch (3660 mm) SS.
- Two 1100 gpm (0.069 m³/s) recycle pumps.
- Interconnecting piping and valves.
- Controls and instrumentation.

The Bulk Resin Storage Tank provides storage capacity for regenerated resin received from the Contractor's delivery vehicle. The Bulk Spent Resin Storage Tank provides storage capacity for spent resin waiting shipment for off-site regeneration. The existing regeneration system has been modified to aid in the transfer of resin charges between the service vessels and the storage tanks. The Resin Storage Tank (RST) will accept resin transfers from the Bulk Resin Storage Tank. The Cation Regeneration Tank (CRT) has been modified to transfer resin to the Spent Resin Storage Tank. The attached flow diagram [Figure-1] illustrates the overall process.

[Retrofit Plant without bulk storage tanks added]

The existing condensate polishing system includes mixed bed ion exchangers designed for removal of suspended as well as soluble contaminants from the condensate. The system consists of the following:

- Full-flow condensate polishing system, 4700 gpm (0.30 m³/s).
- Three 50% capacity, rubber-lined service vessels.
 - 2350 gpm (0.15 m³/s) capacity per vessel.
 - 525 psig (3.72 MPa) vessel design pressure.
 - 90 inch (2290 mm) diameter by 54 inch (1370 mm) side sheet.
 - 36 inch (910 mm) resin bed depth.
 - 84 cubic feet (2.4 m³) of cation resin and 42 cubic feet (1.2 m³) of anion resin per vessel.
- Three vessel external regeneration system consisting of a cation regeneration tank, anion regeneration tank, and resin storage tank. All vessels are rubber-lined.
 - CRT: 66 inch (1680 mm) OD, 144 inch (3660 mm) SS.
 - ART: 42 inch (1070 mm) OD, 144 inch (3660 mm) SS.
 - RST: 66 inch (1680 mm) OD, 114 inch (2900 mm) SS.
- Two 1100 gpm (0.069 m³/s) recycle pumps.
- Acid and caustic dilution and feed system including pumps and water heater.
- Interconnecting piping and valves.
- Controls and instrumentation.

The existing regeneration system has been modified to aid in the transfer of resin charges between the Contractor's delivery vehicle and the service vessels. The Resin Storage Tank (RST) has been modified to accept resin transfers from the delivery vehicle. The Cation Regeneration Tank (CRT) has been modified to transfer resin to the delivery vehicle. Each tank will contain a single charge of resin. The existing transfer system will be used to sluice resin to and from the service vessels. The attached flow diagram [Figure-2] illustrates the overall process.

[New Plant with bulk storage tanks added]

The condensate polishing system includes mixed bed ion exchangers designed for removal of suspended as well as soluble contaminants from the condensate. The system consists of the following:

- Full-flow condensate polishing system, 6000 gpm (0.38 m³/s).
- Three 50% capacity, rubber-lined service vessels.
 - 3000 gpm (0.19 m³/s) capacity per vessel.
 - 720 psig (5.07 MPa) vessel design pressure.
 - 96 inch (2440 mm) diameter by 74 inch (1880 mm) side sheet.
 - 36 inch (910 mm) resin bed depth.
 - 96 cubic feet (2.7 m³) of cation resin and 48 cubic feet (1.4 m³) of anion resin per vessel.

Off-site Regeneration Specification

- Two bulk resin storage vessels consisting of a bulk resin storage tank and a bulk spent resin storage tank. (120 inch (3050 mm) OD, 144 inch (3660 mm) SS).
- Cleaning, Backwash, and Mixing Tank (72 inch (1830 mm) OD, 121 inch (3070 mm) SS).
- Two 1800 gpm (0.11 m³/s) recycle pumps.
- Interconnecting piping and valves.
- Controls and instrumentation.

The Bulk Resin Storage Tank provides storage capacity for regenerated resin received from the Contractor's delivery vehicle. The Bulk Spent Resin Storage Tank provides storage capacity for spent resin waiting shipment for off-site regeneration. Resin is sluiced directly between the service vessels and the bulk storage tanks. The attached flow diagram, [Figure-3], illustrates the overall process.

[New Plant without bulk storage tanks added]

The condensate polishing system includes mixed bed ion exchangers designed for removal of suspended as well as soluble contaminants from the condensate. The system consists of the following:

- Full-flow condensate polishing system, 6000 gpm (0.38m³/s).
- Three 50% capacity, rubber-lined service vessels.
 - 3000 gpm (0.19 m³/s) capacity per vessel.
 - 720 psig (5.07 MPa) vessel design pressure.
 - 96 inch (2440 mm) diameter by 74 inch (1880 mm) side sheet.
 - 36 inch (910 mm) resin bed depth.
 - 96 cubic feet (2.7 m³) of cation resin, and 48 cubic feet (1.4 m³) of anion resin, per vessel.
- Cleaning, Backwash, and Mixing Tank (72 inch (1830 mm) OD, 121 inch (3070 mm) SS).
- Two 1800 gpm (0.11 m³/s) recycle pumps.
- Interconnecting piping and valves.
- Controls and instrumentation.

Regenerated resin is sluiced directly, one vessel volume at a time, to the Resin Mixing and Cleaning Tank, which is normally empty. Spent resin is received directly from the service vessels. The Resin Mixing and Cleaning Tank prepares the regenerated resin and transfers it to the empty service vessel. The process proceeds batchwise until all regenerated resin is delivered and all spent resin is returned to the truck. The attached flow diagram [Figure 4] illustrates the overall process.

TS.4 DESIGN CRITERIA. The mixed bed resins and the off-site regeneration process shall be selected in accordance with the following requirements,

TS.4.1 Resin Requirements. The Contractor shall provide off-site regenerated resin which meets the following criteria:

Resin volumes, per service vessel [select applicable size, either retrofit or new]

	Retrofit	New
Cation	[90 ft ³] [(2.5 m ³)]	[96 ft ³] [(2.7 m ³)]
Anion	[51 ft ³] [(1.4 m ³)]	[48 ft ³] [(1.4 m ³)]

[Selection of gel resins are normally recommended, but MR type resins could be specified based upon a user preference]

Resin type	Homogenous Gel type
Cation	10 % cross-linked strong acid cation
Anion	strong base anion type I
Bead uniformity coefficient	1.1
Cation resin capacity	>2.1 meq/ml
Anion resin capacity	>1.1 meq/ml
Impurity Limits	
Regenerated cation resin	>90% in hydrogen form <10% in ammonium form <0.08% in sodium form (ammonia cycle operation) <2.0% in sodium form (hydrogen cycle operation)
Regenerated anion resin	>80% in hydroxide form <5% in carbonate/bicarbonate form <1% in chloride form (ammonia cycle operation) <2% in chloride form (hydrogen cycle operation) <2% in sulfate form <12% in sulfate form, (if sulfate used in regeneration process)
Allowable resin fines	<0.06 %
[Alternative resin fine limitation]	
Allowable resin fines	
Cation Resin	<1% smaller than 420 μm (40#)
Anion Resin	<0.2% smaller than 297 μm (50#)

Off-site Regeneration Specification

TS.4.2 Operating Conditions. The condensate polishing system will be operated under the following conditions:

Condensate temperature, F	
Maximum	140°F (60°C)
Minimum	90°F (32°C)
Allow pressure drop across resin bed	
Normal (clean condition)	10 psi (69 kPa)
Maximum	30 psi (207 kPa)
Operating cycle	[choose Hydrogen or Ammonium]

The conditions of operation are characterized by the following influent condensate analyses:

	<u>Normal Service</u>
Ammonia (NH ₃), ppb	800-1200
Iron (Fe), ppb	10
Copper (Cu), ppb	5
Silica (SiO ₂), ppb	20
Sodium (Na), ppb	5
Chloride (Cl), ppb	5

TS.5 PERFORMANCE GUARANTEE. The condensate polishing system shall be guaranteed for operation under the conditions set forth herein under DESIGN CRITERIA.

The Contractor furnished resin beds, operating under normal service conditions, shall be guaranteed to deliver polished condensate containing not more than the following concentrations of impurities:

	<u>Hydrogen-Hydroxide Form Resins</u>	<u>Ammonium-Hydroxide Form Resins</u>
Total iron (Fe), ppb	5	5
Total copper (Cu), ppb	2	2
Reactive silica (SiO ₂), ppb	5	5
Sodium (Na), ppb	0.1	1
Chloride (Cl), ppb	0.1	0.5
Specific conductance (μS/cm)	0.1	-
Cation conductivity (μS/cm)	0.1	0.1

TS.5.1 Quality Testing. The Owner will conduct quality tests on the freshly delivered regenerated resin. Each delivery will be measured with respect to total volume. Random deliveries will be sampled, and will undergo testing to verify conformance with the resin requirements established in subsection TS.4.1. Kinetic tests will be performed on random samples and quarterly samples to verify the kinetic performance of the regenerated resin. If any quality test yields negative results, an additional resin sample will be withdrawn and tested. If successive tests yield similar negative results, the Contractor will be notified immediately. The Owner will draw additional resin samples for the Contractor’s use in verifying the claim. The Contractor shall be required to take corrective action as specified in the following subsection.

TS.5.2 Corrective Actions. If a resin charge fails to meet performance requirements or fails to pass quality testing, the Contractor will be notified immediately. The Contractor shall take appropriate corrective action as follows.

Resin charges with inadequate capacity may remain in service as long as effluent quality is maintained. Compensation for reduced service run will be proportional to the reduction in service length and applied as a credit to the next delivery. An additional 20 percent reduction on the per bed charge will also be given to the operators to cover the additional expense of rinsing and transferring resin.

Resin charges that do not meet kinetics requirements shall be replaced as soon as possible. The Contractor will be notified as soon as the failure is known. Following notification, the vendor shall replace all affected resin within [3] days.

Resin charges which do not meet specifications and which would result in contamination of the steam cycle require immediate replacement with freshly regenerated resin or new resin at no additional charge to the Owner. If the Contractor fails to respond within [3] days, fresh resin may be obtained by alternate methods with the costs back-charged to the Contractor. The

Off-site Regeneration Specification

[Owner][Contractor] shall maintain a quantity of spare resin [on-site][at the Contractor's facility] for use in emergencies involving contaminated resins or late deliveries.

B

RESIN SAMPLING AND ANALYSIS PROCEDURES

Resin sampling and analysis procedures are presented in this appendix to provide end- users with general information and, for some procedures, a choice between simple, quick pass/fail tests and more rigorous analysis. A list of current ASTM standards relating to ion exchange is also provided for reference purposes.

When off-site regeneration service includes the resin (the resin is owned and provided by the vendor/supplier), the end-user may want to perform only limited quality control testing to assure satisfactory in-service performance, reasonable run length, and adequate protection during periods of condenser in-leakage. Under these conditions, the primary tests of interest are ion exchange kinetics, degree of resin regeneration and level of contaminants remaining on the resin (for example the sodium capacity of cation resin and chloride and sulfate capacities of anion resin).

If the resin is owned by the end-user, the issue of reasonable resin life becomes important. Barring an in-service or start-up calamity such as prolonged exposure to high temperature, 60°C (140°F) or incursion of oil, etc., resin life is primarily determined by regeneration and resin conditioning/cleaning. Therefore, it is in the end-users interest to develop and maintain a reasonable resin quality control program to track resin condition. Monitoring exchange kinetics and the development of weak base sites on the anion resin are two important parameters to consider.

Appropriate resin sampling is extremely important. A poor sample may invalidate test results that took several hours of analysis time. Consequently, it is important to know what tests are to be run prior to sample collection. Core samples are required if bed utilization is to be determined while successive aliquots may be combined and used as a representative sample for tests such as ion exchange kinetics.

With off-site resin regeneration, the end-user may request samples from the vendor or collect his own samples. For sampling of containers or fixed resin beds, refer to ASTM –2687. If resin samples are to be taken from transfer lines during a transfer, the resins should first be air-mixed. Multiple aliquots should then be taken during transfer. However, for manual sampling through a sample valve, a slurry volume equal to the sample line dead volume must be discarded before each aliquot is collected. Following sample collection, combine all of the aliquots and mix thoroughly prior to analysis.

The analysis methods provided in this appendix are listed in the following table. The methods are not all encompassing, there may be alternate approaches for each analysis. In addition, a list of the current ASTM standards relating to ion exchange is also provided.

Resin Sampling and Analysis Procedures

Resin Analysis Procedures

Method	Title
A	Perfect Bead Content
B	Resin Fines
C	Exchange Capacity of Hydroxide Form Anion Resin
D	Trace Metal Determination
E	Anion Resin Exchange Kinetics Assessment
F	Determination of Chloride, Sulfate, Sodium, Magnesium, and Calcium Impurities Exchanged on Bead Resin
G	Hydrogen Form Cation Resin Exchange Capacity
H	Ion Exchange Resin Organic Extractables

ASTM Standards for Ion-Exchange Materials

D-1782-78 (1985)	Operating Performance, Particulate Cation-Exchange Materials Sodium Cycle Hydrogen Cycle
D-2187-94	Physical and Chemical Properties Pretreatment Water Retention Capacity Backwashed and Settled Density Particle Size Distribution Salt-Splitting Capacity Total Capacity, Cation-Exchange Resins Percent Regeneration, Hydrogen-Form Cation-Exchange Resins Total and Salt-Splitting Capacity, Anion Exchange Resins Percent Regeneration, Anion Resins Ionic Chloride Content, Anion Exchange Resins Carbonate Content, Anion-Exchange Resins Sulfate Content, Anion Exchange Resins Total Anion Capacity
D-2687-84 (1990)	Sampling
	Single and Multiple Package Lots Fixed-Bed Ion Exchange Equipment, Unrestricted Headroom Fixed-Bed Ion Exchange Equipment, Restricted Headroom
D-3087-78 (1986)	Operating Performance, Anion Exchange Materials for Strong Acid Removal
D-3375-84	Column Capacity, Mixed-Bed Ion Exchange Materials
D-5042-90	Organic Fouling of Particulate Anion Exchange Resins

Method A: Perfect Bead Content

Principle: A sample of ion-exchange resin is spread on a glass grid and visually inspected with the aid of a microscope. Each square of the grid contains approximately 100 beads. Cracked and fragmented beads in the five squares of the grid are counted and subtracted from the calculated number of particles in the five squares to obtain the number of perfect beads. The results are reported as percent perfect beads.

Procedure

1. Place a portion of the sample in a petri dish with a grid of approximately ¼ inch (0.64 cm) squares. Arrange the beads so that they are closely packed and single layered.
2. Set the microscope at 15x. Under this magnification, approximately 100-150 beads are visible in the microscope field.
3. Select a square and calculate the number of particles it contains by multiplying the number across by the number down. (If there are fragments, estimate the number of whole beads the fragment would yield and use this number in determining both the total number of beads and the number of imperfect beads.)
4. Within the same square, count the number of imperfect beads (i.e., cracked, pocked, or fragmented).

Repeat steps 3 and 4 four times.

Note: As an alternative, 15 cm qualitative filter paper and 30x magnification (20-50 beads visible in the field) may also be used.

Calculations:

$$\% \text{ Perfect Beads} = \frac{\text{Average number of perfect beads}}{\text{Total number of beads}} \times 100\% = \frac{A-B}{A} \times 100\%$$

where:

A = total number of beads

B = number of imperfect beads

Method B: Resin Fines

Introduction

The distribution of bead sizes in a resin sample can be determined by passing the sample through a series of stacked sieves and measuring the volume of resin retained on each screen. With the widespread use of uniform particle sized resin for condensate polishing, testing for particle size distribution is no longer as prevalent as it once was. However, the need to determine the percent of resin fines (one portion of the size distribution test) is still very important. Resin particles that pass through a U. S. Sieve # 50 and are retained on a U. S. Sieve # 325 are considered to be fines. Because the size of a resin bead is a function of the ionic form, certain standards were established. All cation resin was converted to the sodium form while strong base anion resin was measured in the chloride form.

When using the following procedure for determination of resin fines, it is suggested that the resins be converted to the recommended form. However, it is not essential to do so if the test is to be used for QC testing and all parties have agreed to test in the regenerated form.

References

Method E in this Appendix contains a table showing the relationship between U. S. Standards Mesh Screen Numbers (U. S. Sieve #'s) and the size of the openings in millimeters.

Procedure

1. Run the tests on the resin as received. Do not backwash the sample prior to analysis.
2. Condition the cation resin as follows unless it has been agreed to run the tests on regenerated resin as received.

Add 16 g of sodium chloride and 150 ml of deionized water to a 250 ml beaker.

Place a 50 ml core sample of the cation resin in the 250 ml beaker.

Stir the mixture for 5 minutes and allow to sit for 30 minutes before using the resin.

3. Condition the strong base anion resin unless it has been agreed to run the tests on regenerated resin as received.

Add 16 g of sodium chloride and 150 ml of deionized water to a 250 ml beaker.

Place a 50 ml core sample of the anion resin in the 250 ml beaker.

Stir the mixture for 5 minutes and allow to sit for 30 minutes before using the resin.

Resin Sampling and Analysis Procedures

4. Stack a # 50 U. S. Standard Mesh Screen on top of a # 325 screen. (Note: If determination of particle size distribution is desired, assemble a set of U. S. Standard Mesh Screens in the following order, top to bottom: 16, 20, 30, 40, 50 and 325.)
5. Place the sample of resin on the top screen (50-mesh for fines testing and 16-mesh for particle size distribution.)
6. Wash the resin on the top screen with a stream of deionized water for at least 5 minutes.
7. Remove the top pie screen and invert it over a glass pie pan. Use a stream of deionized water to flush the resin from the screen. Use a brush as necessary to remove the resin particles stuck in the mesh.
8. Rinse the resin from the pie plate into a plastic Imhoff cone. Allow the resin to settle for at least 5 minutes and determine the volume of resin in the cone.

Repeat the last 3 steps for each succeeding screen if doing particle size distribution. However, **UNDER NO CIRCUMSTANCES SHOULD ANY KIND OF BRUSH BE USED TO REMOVE RESIN FROM THE 325-MESH SCREEN.**

Calculations

$$\text{Resin retained on screen (\%)} = \frac{\text{Resin retained on screen (ml)}}{\text{Total resin (ml)}} \times 100$$

$$\text{Total resin (ml)} = \text{sum of } V_i$$

Where,

V_i = volume of resin (ml) retained on each screen

$$\text{Fines (\%)} = \frac{\text{Resin retained on \# 325 screen (ml)}}{\text{Total resin (ml)}} \times 100$$

Method C: Exchange Capacity of Hydroxide-Form Anion Resin

Reference: The alternate procedure outlined below is provided by Edison International. ASTM Standard D-2187, Methods H and M can be used to determine total and salt splitting capacity of anion resins.

Application: This procedure outlines a method for estimating the salt splitting capacity (SSC) and weak base capacity (WBC) of anion exchange resin.

Principle: Salt splitting capacity is measured by exhausting the **hydroxide-form** anion resin with sodium chloride; the total equivalents of hydroxide ion in the effluent is a measure of the salt splitting capacity. To determine weak base capacity, the resin, in which the strong base sites have been converted to the chloride form by treatment with sodium chloride, is exhausted with a precisely measured amount of hydrochloric acid. The difference between the equivalents of hydrochloric acid entering the resin and the equivalents found in the effluent is the weak base capacity of the resin.

Reagents:

Hydrochloric Acid, 1 N
 Sodium Hydroxide, 1 N
 Sodium Chloride, 1M
 Sodium Hydroxide, 0.50 N (standardized)
 Hydrochloric Acid, 0.10 N (standardized)
 Hydrochloric Acid, 0.20 equivalent/kg (standardized)

The reagent must be standardized with the same 0.5 N sodium hydroxide titrant used in the weak base capacity measurement.

Accurately weigh 40 g of hydrochloric acid into an Erlenmeyer flask. A top loading balance having a resolution of 0.01 g is adequate for the measurement.

Titrate (25 ml buret) with 0.5 N sodium hydroxide to a pH of 7.0.

Calculate the acid concentration.

$$\text{HCl (equiv/kg)} = \frac{V_{\text{NaOH}} \text{ (ml)} \times N_{\text{NaOH}} \text{ (equiv/L)}}{W_{\text{t}_{\text{HCl}}} \text{ (g)}}$$

If necessary, adjust the hydrochloric acid so that its concentration is between 0.20 and 0.21 equivalents/kg.

Resin Sampling and Analysis Procedures

Procedure:

1. Place a core sample containing between 20 and 30 ml of wet, backwashed resin in a beaker. Add 200 ml of 1N hydrochloric acid and stir the acid/resin mixture. If an appreciable fraction of the exchange sites are in the carbonate form, bubbles of carbon dioxide gas will be released in this step.
2. After the evolution of gas is complete, transfer the resin to a 20 mm i.d. fritted-disc chromatography column. Place 300 ml of 1 N hydrochloric acid in a separatory funnel and attach the funnel to the top of the column. Allow the acid to flow through the bed at about 5 ml/min (60 minutes contact time).
3. Rinse the resin with 500 ml of deionized water at about 30 ml/min.
4. Place 1000 ml of 1 N sodium hydroxide in the separatory funnel and regenerate the resin by passing the solution through the bed at about 11 ml/min (90 minutes contact time). If air bubbles appear in the bed, dislodge them by stirring the resin with a glass stirring rod.
5. After the regeneration is complete, rinse the resin with 500 ml of deionized water at about 30 ml/min. Collect the last 50 ml of rinse water effluent and titrate it with 0.01 N hydrochloric acid (Note 1) to a pH =7.0 endpoint. If the resin is weak base anion resin measure the volume at this point. Quantitatively transfer the resin to a 50 ml plastic graduated cylinder. Tap and settle the resin and note the volume. Return the resin (quantitatively) to the chromatography column.

This step describes the measurement of salt splitting capacity.

6. Drain the resin water to bed level (Note 2). Place 1000 ml of 1N sodium chloride in the separatory funnel, attach the funnel to the top of the column, and allow the solution to percolate through the column at about 11 ml/min (90 minutes contact time). Periodically inspect the column for air bubbles and if they are present, dislodge them by stirring the bed with a glass stirring rod. Collect the effluent in a 1-liter volumetric flask and discontinue the flow when 1.0 liter has been collected. Stopper the flask and mix thoroughly. Withdraw a 25 ml aliquot, transfer to an Erlenmeyer flask and titrate with 0.10 N hydrochloric acid to a pH of 7.0. If 25.0 ml does not produce a favorable titration volume, repeat the titration with the appropriate volume (Note 3).

This step describes the measurement of the weak base capacity of a weak base resin.

7. Drain any liquid in the column to bed level. Place 900 g (use 0.1 g top loading balance) 0.2 equiv/kg hydrochloric acid in the separatory funnel. Attach the funnel to the top of the column and allow the acid to flow through the bed at about 6 ml/min (150 minutes contact time). Collect the effluent in a 1.0 liter volumetric flask. If air bubbles appear in the column, dislodge them by stirring the resin with a stirring rod. Rinse the separatory funnel and the column thoroughly with deionized water and allow these rinses to pass through the resin bed and into the volumetric flask. Adjust the final effluent volume to 1.0 liter. Stopper the flask and mix well. Pipet 250 ml of the effluent into an Erlenmeyer flask, and titrate to a pH of 7.0 with 0.50 N sodium hydroxide. If necessary, adjust the sample size to produce optimum volumetric accuracy in the buret.

This step describes the measurement of the weak base capacity of a strong base anion resin.

8. Drain any liquid in the column to bed level. Place 400 g (use 0.1g top loading balance) of 0.2 equiv/kg hydrochloric acid in the separatory funnel and attach the funnel to the top of the column. Allow the acid to flow through the bed at about 3 ml/min (~ 130 minutes contact time) and collect the effluent in a 500 ml volumetric flask. If air bubbles appear in the column, dislodge them by stirring with a stirring rod. Rinse the separatory funnel and the column thoroughly with deionized water and allow the rinses to pass through the resin bed and into the volumetric flask. Adjust the final volume to 500 ml. Stopper the flask and mix well. Pipet 50.0 ml of the effluent into an Erlenmeyer flask and titrate with 0.50 N sodium hydroxide (25 ml buret) to a pH of 7.0. If necessary, adjust the sample size to produce optimum volumetric accuracy in the buret.
9. If the resin is a strong base anion, measure the resin volume at this point. Quantitatively transfer the resin to a 50 ml plastic graduated cylinder. Tap and settle the resin and note the volume.

Perform the analysis in parallel on two separate resin samples.

Resin Sampling and Analysis Procedures

Calculations:

$$\text{SSC (meq/ml)} = \frac{(V_{\text{HCl}})(N_{\text{HCl}})(1000\text{ml})}{(V_{\text{Resin}})(V_{\text{Aliquot}})}$$

where:

- V_{HCl} = Volume of hydrochloric acid titrant, ml
- N_{HCl} = Normality of hydrochloric acid titrant, equiv/l
- V_{Resin} = Resin volume, ml
- V_{Aliquot} = Volume of effluent taken for analysis, ml

$$\text{WBC (meq/ml)} = \frac{(M_{\text{R}})(C_{\text{R}}) - (V_{\text{NaOH}})(N_{\text{NaOH}}) \left(\frac{V_{\text{Flask}}}{V_{\text{Aliquot}}} \right)}{V_{\text{Resin}}}$$

Where:

- M_{R} = Mass of hydrochloric acid, g
- C_{R} = Concentration of hydrochloric acid, equiv/kg
- V_{NaOH} = Volume of sodium hydroxide titrant, ml
- N_{NaOH} = Normality of sodium hydroxide titrant, equiv/l
- V_{Flask} = Volume of flask used for collecting the effluent, ml
- V_{Aliquot} = Volume of effluent taken for analysis, ml
- V_{Resin} = Resin volume, ml

Notes:

Prepare 0.01 N hydrochloric acid by diluting 1 ml of 0.1 N hydrochloric with 9 ml of deionized water.

Begin the salt splitting capacity measurement immediately after the rinse. A delay of more than ten minutes may require that the bed be rinsed again.

If weak base capacity and salt-splitting capacity cannot be measured on the same day, the resin should be rinsed with at least 500 ml of deionized water before it is allowed to stand overnight.

Method D: Trace Metal Determination

Principle: The trace metal contaminants in ion exchange resins are quantified by ashing a known weight of as-received resin, dissolving the residue in acid and analyzing for specific metals by atomic absorption or plasma emission spectrophotometry. Results are reported in parts per million on a dry weight basis.

Reagents:

Sulfuric Acid, concentrated spectrograde

Hydrochloric Acid, concentrated spectrograde

Hydrochloric Acid (1+1)

Add 1 volume of concentrated HCl to 1 volume of deionized water and mix thoroughly.

Potassium Chloride Crystals, reagent grade

Deionized Water

Sample Preparation:

1. Weigh a 10 g sample of the as-received resin. Transfer sample to a clean 100 ml platinum dish. Dry the sample on a hot plate until free flowing.

Note: Do not add sulfuric acid directly to the as-received resin sample without drying. The sulfuric acid will react with the water in the pores of the resin and on heating a “popcorn” effect will occur resulting in loss of sample from the dish.

2. Moisten one sample with a few drops of concentrated sulfuric acid. Transfer the platinum dish to a high temperature burner and carefully heat without spattering until charring occurs.
3. Ignite the sample until it is free of carbon. If carbonaceous residue remains, moisten the ash with several drops of concentrated sulfuric acid and repeat the process until only a light colored residue remains.
4. Cool and dissolve the ash with 10 ml of 1 + 1 HCl, warming the solution if necessary to dissolve the ash.
5. Quantitatively transfer the solution to a 100 ml volumetric flask. Dilute to volume with deionized water and mix well. This is solution “A”.
6. For Cu and Fe evaluation, pipet 20 ml of solution “A” into a 100 ml volumetric flask. Dilute to volume with deionized water and mix well. Dilution factor is 500.
7. For Na evaluation, pipet 10 ml of solution “A” into a 100 ml volumetric flask. Add 0.05 g of KCl crystals to the flask. Dilute to volume with deionized water and mix well. Dilution factor is 1000.

Resin Sampling and Analysis Procedures

Reagent Blanks: Prepare reagent blanks in similar manner, omitting the sample. Blanks should include all the reagents used in the ashing and dilution steps.

Procedure:

1. Determine the iron concentration in accordance with Method A of ASTM D1068.
2. Determine the copper concentration in accordance with Method A of ASTM D1688.
3. Determine the sodium concentration in accordance with ASTM D4191.

Calculations:

$$\text{Metal, ppm (dry basis)} = \frac{(\text{Test soln. Conc., mg/l} - \text{Blank}) (\text{Dil. Factor, ml})}{(\text{Sample Weight, g}) (\text{Solids Fraction})}$$

Where:

Solids Fraction = the reciprocal of the water retention capacity

Method E: The Assessment of Anion Resin Exchange Kinetic Performance

Selection of Test Procedures

The ability of strongly acidic cation exchange resins and strongly basic anion exchange resins to rapidly remove ionic impurities from water allows them to be used in beds operating at high water flow velocities. This ability is critically important in condensate polishing as condensate flows on modern thermal power stations are very large. Resins or processes operating at lower flow rates would demand the use of larger plants so affecting the whole economics of condensate polishing. However, it is known that the kinetics of ion exchange of both anion and cation resins can deteriorate from several causes such as iron or organic fouling (broadly referred to as “resin fouling”). Although anion resins are more often seen to be affected, cation resins sometimes also show kinetic impairment that significantly impacts both anion and cation exchange kinetics. Consequently, fouling of either mixed-bed component significantly reduces the ability to rapidly remove influent contaminants.

In view of the importance of resin kinetics to condensate polishing it was useful when Harries and Ray identified a simple resin characteristic that could be used for assessing the potential speed of reaction of a resin and for following its in-service deterioration¹. Prior to this development various workers had used test methods that employed the challenging of columns of mixed resins, under flowing conditions, and comparing their ion exchange behaviour with that of reference resins. The Harries and Ray method was aimed at measuring the speed of transport of an ion across the static layer of water that most models of the ion exchange process assume to be present around each resin bead. Transport of ions through the bulk water outside of this boundary layer is presumed to be fast as is the transport of resins within the resin bead once an ion has crossed the boundary water layer. It is, therefore, the transport of an ion across this boundary layer, and any layers of foreign matter deposited on the bead surface when in service, that is regarded as the rate determining step. The determination of a “mass transfer coefficient” involves the use of an apparatus generally simulating polishing plant conditions. The technique can be used for testing anion resins combined with a reference cation resin or cation resin combined with a reference anion resin. The “mass transfer coefficient” so determined is not a constant but relates to the behaviour of the resin under test towards a specific ion and under the certain defined conditions of the test. Sulphate is normally employed as the anion to be exchanged when testing for anion kinetic behaviour and sodium when testing for cation resin kinetics.

The early work of Harries and Ray provided a technique by which Mass Transfer Coefficients could be measured and that was also useful for research into ion exchange processes. The work was extended by other workers in an attempt to simplify the procedure and because it was realised that kinetics within a mixed bed were strongly influenced by the behaviour of both the active resins². Thus, anion resin kinetics are influenced by the behaviour of the cation resin. The “referee” cation resin used in the determination of MTC values by the above process is actually a selected sample of a cation resin in overall sound good condition, often a virtually new resin. The results obtained will not be the same as those that would be achieved if the anion resin had been tested in a mixed bed with a used and possibly fouled cation resin. The criticism then becomes that the results of the Harries/McNulty type MTC tests do not provide a useful

indication of the likely kinetic behaviour of the anion resin when in service with a used cation resin. Cutler in 1996 and 1997 published the results of detailed tests carried out to explore these various effects^{3,4}.

The subject of kinetic testing of ion exchange resins is obviously complex but sight must not be lost of the importance of regular, in-service testing of resins. The original Harries and Ray procedure is time consuming but is obviously useful for checking the kinetic quality of new resins as is that of McNulty. It is to be noted that these procedures give similar, but not identical, results⁵. They are also valuable for comparing the kinetic condition of anion resins in different charges as they are carried out under standard conditions against a “referee” cation resin. Between laboratory comparisons should also be possible—again assuming standard conditions and the same referee cation resin. These procedures are fully described in the literature and are currently being used by a number of specialist laboratories.

In the context of off-site regeneration resins it has already been suggested in Section 4.4 that the contractor should assume the basic responsibility of periodically monitoring the kinetic performance of any resins being regenerated. They may well decide to use one of the full methods, such as those mentioned above and using “referee” cation resins, possibly supplemented by the simpler EPRI test and/or by tests employing both the anion and cation resins sampled from actual mixed beds. The choice of test procedure becomes their responsibility as does the frequency of testing with a minimum of once/year external checks by an impartial laboratory being suggested. Formal MTC tests are, without doubt, time consuming and contractors may decide to use a simplified procedure for routine control purposes. The monitoring and control of the kinetic condition of both anion and cation resins is important and acceptable ways must be found by contractors to maintain surveillance over this resin characteristic.

The end-user, having opted to use off-site regeneration services so as to reduce the work-load on station staff, will probably be reluctant to undertake any kinetic control testing of incoming resins. As already stressed the use of resins in good kinetic condition is of vital importance because, in the absence of condenser leaks, there is usually little evidence of a problem existing. However, resins in poor kinetic condition can fail to function effectively when faced with a condenser leak leading to the unjustified complaint sometimes heard that the “resins suddenly failed”! It is, therefore, suggested that end-users should, themselves, periodically checks the kinetic condition of anion resins being delivered using the simple conductivity based EPRI procedure described below. The EPRI procedure also provides for a simple test of cation kinetics that could be used as needed.

References

1. R.R. Harries and N.J. Ray, *Effluent and Water Treatment Journal*, April 1984.
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4. F.M. Cutler, "Anion Kinetics Issues for Utility Practices", *Proceedings: Workshop on Condensate Polishing*, EPRI, Palo Alto, CA: 1998. TR-109568.
5. F. McCarthy and D. O'Connor, "Ammonium Form Operation of Condensate Polishing Plant for Long Periods in High pH Systems", *Proceedings of 53rd International Water Conference*, Engineers Society of Western Pennsylvania, 1992.

Quick Test for Anion Resin Exchange Kinetics Assessment Using EPRI Test Apparatus

Application

Since the standard kinetics tests normally take significant time to set up and perform, they have not been widely used for frequent or routine quality control testing at fossil plants. For plants contemplating the use of off-site regeneration, the ability to quickly check anion resin exchange kinetics would be very useful. Consequently, EPRI has put together a simple protocol and apparatus that enables the end user to routinely and cost effectively monitor anion exchange kinetics (and also cation exchange kinetics when desired).

Principle

An EPRI designed test apparatus provides the means to perform a simple and rapid test to determine anion or cation exchange kinetics in a field laboratory.

Summary

The challenge solution used is sulfuric acid, permitting a test column of anion resin rather than mixed-bed resin. An additional column for cation resin follows the test column. The design of the apparatus permits reversal of resins if testing of cation resin kinetics is desired. The second column is provided to remove sodium remaining after anion resin regeneration or chloride or sulfate remaining after cation resin regeneration so that this leakage is not confused with kinetic leakage. The apparatus is insulated to maintain constant temperature through the test columns and includes appropriate conductivity cells and flow indicators. The resin columns are calibrated so that measuring the volume of resin is automatically done when the columns are loaded. A reference chart correlating individual column effluent conductivity, differential conductivity, and exchange kinetics is also included.

Procedure Summary (details provided with test apparatus)

1. Collect representative resin samples or have the off-site regeneration vendor provide appropriate resin samples with each delivery of regenerated resin.
2. For anion exchange kinetics, transfer the regenerated anion resin to the test column.
3. Transfer regenerated cation resin to the trail column.

Resin Sampling and Analysis Procedures

4. Pump deionized water through test apparatus to verify connections are tight and conductivity cells are working.
5. Fill reservoir with 1500 ppb sulfuric acid challenge solution.
6. Pump challenge solution through test columns.
7. Record influent conductivity, test column effluent conductivity, trail column effluent conductivity, temperature, and flow rate.
8. With the help of reference charts provided with test apparatus, record calculated value for anion exchange kinetics.

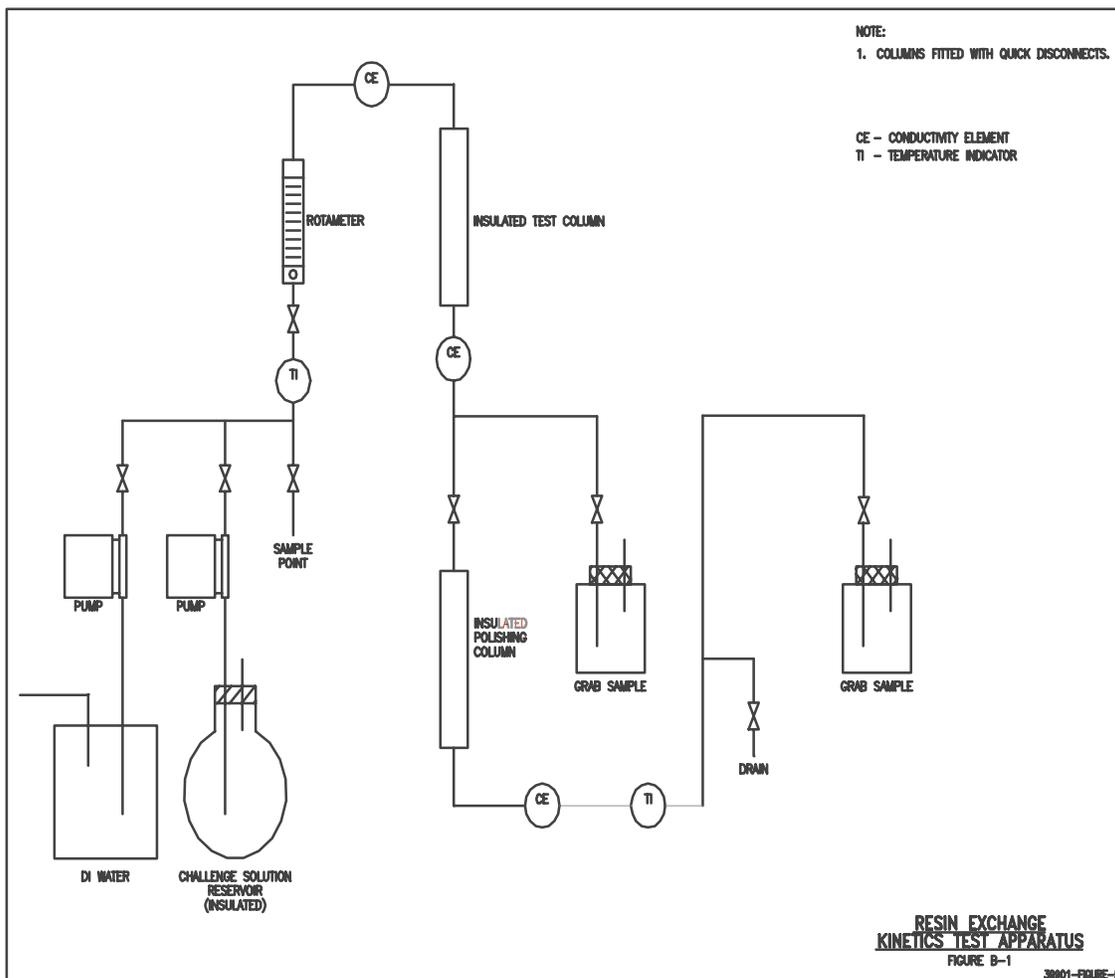


Figure B-1
Diagram of EPRI test apparatus for Quick Test for Anion Resin Exchange Kinetics Assessment

Method F: Determination of Chloride, Sulfate, Sodium, Magnesium, and Calcium Impurities Exchanged on Bead Resin

CHLORIDE AND SULFATE CONTENT OF ANION RESIN

Summary: A sample of anion exchange resin is treated with nitric acid, and the chloride and sulfate eluted by the acid are determined.

Reference: ASTM Standard D-4327, "Test Method for Anions in Water by Ion Chromatography."

Procedure:

1. Measure 15 to 20 ml of anion resin using a graduated cylinder and water.
2. Rinse the resin from the graduated cylinder into the elution column.
3. Pass deionized water through the column until the resin is packed and channeling has been eliminated. (Note: Do not allow liquid to drain below the top of the resin bed.)
4. Pass 200 ml of 1 N HNO₃ through the column at a rate of 5 to 10 ml/min. Collect the column effluent in a 200 ml volumetric flask.
5. Dilute the column effluent with deionized water by 20:1 and analyze the diluted sample using ASTM procedure D-4327 or a modified version of this procedure using a 0.05 ml sample loop with an AS-10 column and NaOH eluent. The combination of the 0.05 ml loop and the AS-10 column with NaOH eluent generally provides a good separation of the chloride and sulfate from the nitrate.
6. Convert the resin to the hydroxide form by passing 100 ml of 1.5 N NaOH through the column at a flow rate of 5-10 ml/min. Rinse the column with an equal volume of deionized water.
7. Quantitatively remove the resin from the column and determine the tapped-settled volume using a 25 ml Class A graduated cylinder.

Calculations:

Chloride or sulfate on the resin in meq/ml (C) is given by:

$$C = \frac{(\text{Conc. in column effluent, meq/ml})(200 \text{ ml})(20)}{(\text{Volume of resin, ml})}$$

Resin Sampling and Analysis Procedures

SODIUM, MAGNESIUM AND CALCIUM CONTENT OF CATION RESIN

Summary: A sample of cation exchange resin is treated with nitric acid and the eluted sodium, magnesium, and calcium in the acid are determined by atomic absorption analysis.

Reference: ASTM Standard D-4191, "Test Method for Sodium in Water by Atomic Absorption Spectrometry" for sodium and ASTM Standard D-511, "Test Methods for Calcium and Magnesium in Water" for calcium and magnesium.

Procedure:

1. Place 15 to 20 ml of wet swollen cation resin in a 25 ml graduated cylinder.
2. Rinse the resin from the graduated cylinder into the elution column.
3. Pass deionized water through the column until the resin is packed and channeling has been eliminated. (Note: Do not allow liquid to drain below the top of the resin bed.)
4. Pass 80 ml of 2 N HNO₃ through the column at a rate of 5 to 10 ml/min. Collect the column effluent in a 100 ml volumetric flask.
5. Dilute the column effluent to 100 ml with deionized water (ASTM procedure D-4191).
6. Analyze the column effluent for sodium by flame AA (ASTM Procedure D-4191) or plasma emission. Analyze the column effluent for calcium and/or magnesium by flame AA (ASEM Procedure 0-511) or plasma emission.
7. Rinse acid out of the column. Quantitatively remove the resin from the column and determine the tapped-settled volume using a 25 ml Class A graduated cylinder.

Calculations:

Sodium, magnesium, or calcium on the resin in meq/ml (C) is given by:

$$C = \frac{(\text{Conc. in column effluent, meq/ml})(100 \text{ ml})}{(\text{Volume of resin, ml})}$$

Method G: Hydrogen Form Cation Resin Exchange Capacity

Application: Hydrogen form, strong acid cation resin wet volume capacity determination.

Reference: ASTM Standard D-2187, Methods E, F, and G can be used to determine salt splitting capacity, total capacity, and percent regeneration of hydrogen form strong acid cation resin.

An alternate procedure provided by D. Ryan and published in EPRI's "Condensate Polishing Guidelines for PWR and BWR Plants – 1997 Revision" is provided below.

Remaining Capacity

1. Measure 10.0 ml as received cation resin in water using a 10 ml Class A graduated cylinder.
2. Set up column of resin and pass 4% Na₂SO₄ (0.29 M) through column at ~ 30 ml/min and collect exactly 1.0 liter of effluent. Mix effluent.
3. Titrate 100 ml aliquot of the eluent with standardized 0.10 N NaOH to pH 7.0. Record volume of titrant as V_A.

Total Regenerated Capacity

1. Using same column of resin, rinse column with 200 ml of deionized of water.
2. Regenerate resin with 1 liter of 4% HCl (1.12 M) at a flow of ~ 30ml/min.
3. Rinse column with 1 liter deionized water. Check eluent with pH paper to assure neutrality.
4. Pass 4% Na₂SO₄ solution through the column at ~ 30 ml/min and collect exactly 1 liter of the effluent. Mix effluent.
5. Titrate 100 ml aliquot of the eluent with standardized 0.10 N NaOH to pH 7. Record volume of titrant as B.

Calculation:

$$\text{Remaining Volumetric Capacity (meq/ml)} = \frac{(1000)(V_A)(N_{\text{NaOH}})}{(V_{\text{Aliquot}})(V_{\text{Resin}})}$$

$$\text{Remaining Regenerated Capacity (meq/ml)} = \frac{(1000)(V_B)(N_{\text{NaOH}})}{(V_{\text{Aliquot}})(V_{\text{Resin}})}$$

Where:

$$\begin{aligned} V_A \text{ or } V_B &= \text{ml of NaOH titrant} \\ N_{\text{NaOH}} &= \text{Normality of NaOH titrant, equiv/l} \\ V_{\text{Aliquot}} &= \text{ml of aliquot titrated} \\ V_{\text{Resin}} &= \text{ml of resin} \end{aligned}$$

Method H: Ion Exchange Resin Organic Extractables

Application: The amount of water-soluble organic extractables is determined for any ion-exchange resin.

Reference: ASTM Standard D-5042 can be used to determine ion exchange resin organic extractables. Alternate procedures provided by PP&L Susquehanna and Edison International's Water Technology Resources are outlined below.

Principle: A known volume of as-received resin (or quantitatively rinsed as-received resin) is contacted with deionized water at elevated temperature for 16 hours. The water is decanted off the resin and analyzed for TOC. The mg of TOC per liter of resin is calculated from the results.

Procedure:

1. Prepare resin for extractables test by rinsing. Note 1.
2. Add 100 ml of rinsed sample resin to 250 ml glass bottle which has been cleaned for TOC analysis. Note 2.
3. Add ultrapure water to give a total volume of 200 ml. Note 2.
4. Place in oven or water bath set for 60°C (140°F) and maintain temperature for 16 hours.
5. Decant leach water off and measure volume.
6. Determine TOC in leach water.

A bottle blank should be run alongside the sample. The blank bottle should be filled with the same water used for the sample.

Calculations:

$$\frac{\text{Mg TOC}}{\text{liter resin}} = \frac{(\text{TOC, ppb})(\text{leach water volume, ml})}{100,000}$$

Note 1:

During storage (especially of new resin or cation resin in the amine form), organic leachables from the ion exchange resins tend to accumulate. A portion of these extractable organics may be removed by simply rinsing the resin. Pre-rinsing new or regenerated resin before it goes into service is always a good idea unless there are no facilities to do so.

When testing resin for organic leachables, it is important to consider the purpose of the test before deciding on the optimum procedure. For example, when testing new resin, both "rinsable" and "extractable" organics are of concern. The volume of rinse water and the duration of contact time will affect the numerical results for "rinsable" organics as well as the results for organic leachables. While the actual volume of rinse water selected is not critical, consistent use of the same volume of rinse water for each test is critical in order for the plant

to be able to compare and trend data. Two procedures for “rinsable” organics are outlined below. The first procedure is provided by PP&L Susquehanna and the second one by Edison International’s Water Technology Resources. The chief difference is in the volume of rinse water selected.

TOTAL RINSABLE ORGANICS

Procedure 1:

1. Place 100 ml of as-received anion or cation resin in a clean beaker.
2. Fill beaker with 25°C (77°F) demineralized water to a total volume of 400 ml.
3. Using a magnetic stirrer, stir the resin/water mixture at a moderate speed for 15 minutes.
4. Filter resin/water mixture through filter paper that has been pre-rinsed with 500 ml of demineralized water. Collect and measure the water volume (V).
5. Determine ppm TOC.

$$\mu\text{g TOC/ml} = \frac{(\text{TOC, ppm})(V, \text{ml})}{100 \text{ ml resin}}$$

where: V, ml = volume of resin rinse water

Procedure 2:

1. Place 50 ml of as-received anion or cation resin in a clean beaker.
2. Fill beaker with 25°C (77°F) demineralized water to a total volume of 100 ml.
3. Using a magnetic stirrer, stir the resin/water mixture at a moderate speed for 15 minutes.
4. Filter resin/water mixture through filter paper that has been pre-rinsed with 500 ml of demineralized water. Collect and measure the water volume (V).
5. Determine ppm TOC.

$$\mu\text{g TOC/ml} = \frac{(\text{TOC, ppm})(V, \text{ml})}{50 \text{ ml resin}}$$

where: V, ml = volume of resin rinse water

Note 2:

The Edison test uses 50 ml of resin with the addition of deionized water to bring the total volume to 100 ml. Either cleaned TOC bottles or Erlenmeyer flasks are used during the 16 hour hot water soak in a hot water bath kept at 60°C (140°F). Many hundreds of leachable tests have been run at Edison under these conditions so that an extensive database for different resins has been accumulated. However, either test described above is valid. Again, the most important items for the user to remember are consistency and an understanding of the potential impact of using different volumes of water and different resin/water ratios.

Resin Sampling and Analysis Procedures

Arguments in favor of using a higher water to resin ratio include the potential for more leachables to be extracted under the test conditions. An argument for a lower (1:1) ratio of water to resin is that for low leachable resins, the more concentrated solution provides better test results.

C

ECONOMIC FACTORS

Table C-1
Input Values for New Plant

Item	2000 U.S. Dollars	
	New Mixed Bed Condensate Polisher (Hydrogen)	New Mixed Bed Condensate Polisher (Ammonia)
Total Condensate Flow, gpm	6000 (0.38 m ³ /s)	6000 (0.38 m ³ /s)
Generating Capacity, MW	440	440
Percent Capacity of Each Vessel	50%	50%
Number of Vessels	3	3
Normal Days/Regen or Precoat at 100% Load/Vessel	5	30
Regen or Precoat/Y - 100% Load	219.	24.3
66 Baumé Acid Used, lb/regen	1152 (523 kg/regen)	1152 (523 kg/regen)
66 Baumé Acid Cost, \$/lb	\$0.05 (\$0.11/kg)	\$0.05 (\$0.11/kg)
50% Caustic Used, lb/regen	480 (220 kg/regen)	480 (220 kg/regen)
50% Caustic Cost, \$/lb	\$0.20 (\$0.44/kg)	\$0.20 (\$0.44/kg)
Precoat Used, dry lb/precoat	0 (0 dry kg/precoat)	0 (0 dry kg/precoat)
Precoat Cost, \$/lb	\$0.00 (\$0.00/kg)	\$0.00 (\$0.00/kg)
Electrical Demand Rate, kW	531 on-site/514 off-site	517 on-site/514 off-site
Aux Electrical Usage Rate, \$/kWh	0.025	0.025

Economic Factors

Fixed Annual Labor Cost	\$8,000	\$8,000
Fixed Annual Maintenance Cost	\$10,000	\$10,000
Years per Resin Replacement	4	4
Cation Resin Volume/Vessel, ft ³	96 (2.7 m ³)	96 (2.7 m ³)
Cation Resin Cost, \$/ft ³	\$63.25 (\$2234/m ³)	\$63.25 (\$2234/m ³)
Anion Resin Volume/Vessel, ft ³	48 (1.4 m ³)	48 (1.4 m ³)
Anion Resin Cost, \$/ft ³	\$112.70 (\$3980/m ³)	\$112.70 (\$3980/m ³)
Total Condensate Flow Rate, gpm	6000 (0.38 m ³ /s)	6000 (0.38 m ³ /s)
Ammonia Feed, ppm	1.5	0.5
Ammonia Cost, \$/ton	\$110.00 (\$0.12/kg)	\$110.00 (\$0.12/kg)
Pump/Motor Efficiency	80%	80%

Item	2000 Dollars	
	Retrofit Mixed Bed Condensate Polisher (Hydrogen)	Retrofit Mixed Bed Condensate Polisher (Ammonia)
Total Condensate Flow, gpm	4700 (0.30 m ³ /s)	4700 (0.30 m ³ /s)
Generating Capacity, MW	360	360
Percent Capacity of Vessels	50%	50%
Number of Vessels	3	3
Normal Days/Regen or Precoat at 100% Load/Vessel	5	30
Regen or Precoat/Y - 100% Load	146	24.3
66 Baumé Acid Used, lb/regen	1008 (457 kg/regen)	1008 (457 kg/regen)
66 Baumé Acid Cost, \$/lb	\$0.05 (\$0.11/kg)	\$0.05 (\$0.11/kg)
50% Caustic Used, lb/regen	420 (191 kg/regen)	420 (191 kg/regen)
50% Caustic Cost, \$/lb	\$0.20 (\$0.44/kg)	\$0.20 (\$0.44/kg)
Precoat Used, dry lb/precoat	0 (0 dry kg/precoat)	0 (0 dry kg/precoat)
Precoat Cost, \$/lb	\$0.00 (\$0.00/kg)	\$0.00 (\$0.00/kg)
Electrical Demand Rate, kW	416 on-site/402 off-site	405 on-site/402 off-site
Aux Electrical Usage Rate, \$/kWh	\$0.025	\$0.025
Fixed Annual Labor Cost	\$8,000	\$8,000
Fixed Annual Maintenance Cost	\$10,000	\$10,000
Years per Resin Replacement	4	4
Total Cation Resin Volume, ft ³ /vessel	84 (2.4 m ³ /vessel)	84 (2.4 m ³ /vessel)

Economic Factors

Cation Resin Cost, \$/ft ³	\$63.25 (\$2234/m ³)	\$63.25 (\$2234/m ³)
Total Anion Resin Volume, ft ³	42 (1.2 m ³ /vessel)	42 (1.2 m ³ /vessel)
Anion Resin Cost, \$/ft ³	\$112.70 (\$3980/m ³)	\$112.70 (\$3980/m ³)
Total Condensate Flow Rate, gpm	4700 (0.30 m ³ /s)	4700 (0.30 m ³ /s)
Ammonia Feed, ppm	1.5	0.5
Ammonia Cost, \$/ton	\$110.00 (\$0.12/kg)	\$110.00 (\$0.12/kg)
Pump/Motor Efficiency	80%	80%
Demin Water Cost/1000 gal	\$2.00 (\$0.53/m ³)	\$2.00 (\$0.53/m ³)
Weighted Avg Cost of Capital	10%	10%

Year	O&M & Electrical Replacement Escalation	Future O&M & Electrical Replacement Costs	Present Worth Factor
2000	1.000	1.000	0.9052
2001	1.040	1.040	0.8194
2002	1.040	1.082	0.7417
2003	1.040	1.125	0.6714
2004	1.040	1.170	0.6078
2005	1.040	1.217	0.5502
2006	1.040	1.265	0.4980
2007	1.040	1.316	0.4508
2008	1.040	1.369	0.4081
2009	1.040	1.423	0.3694
2010	1.040	1.480	0.3344
2011	1.040	1.539	0.3027
2012	1.040	1.601	0.2740
2013	1.040	1.665	0.2480
2014	1.040	1.732	0.2245
2015	1.040	1.801	0.2032
2016	1.040	1.873	0.1840
2017	1.040	1.948	0.1665
2018	1.040	2.026	0.1508
2019	1.040	2.107	0.1365
2020	1.040	2.191	0.1235
2021	1.040	2.279	0.1118
2022	1.040	2.370	0.1012
2023	1.040	2.465	0.0916
2024	1.040	2.563	0.0829
2025	1.040	2.666	0.0751
2026	1.040	2.772	0.0680
2027	1.040	2.883	0.0615
2028	1.040	2.999	0.0557
2029	1.040	3.119	0.0504
		Sums	9.0683

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