

Development of Correct Feedwater Treatment

A review of factors important to good design of a system for treating and conditioning steam generator feedwater and circulating water cycles for a 1,000 ton per day ammonia plant.

L.C. Webb
Black & Veatch
Kansas City, Mo.

Correct design of feedwater treatment systems and circulating water cycles for steam generating plants necessitates careful attention to all variables, including materials of constructions and temperature and pressure conditions, but especially water quality control.

This article will review some current practices in this field, with discussion centering on quality control of feedwater, condensate polishing systems, and makeup water systems for steam cycles. First, it will be useful to cover some of the basic principles. For the sake of hypothesis, the first discussion will be on water quality control in a steam cycle that includes steam turbines.

The steam turbine may be the drive for a large device such as a compressor, or it may drive an electric generator. In any case, steam of high purity must be available to minimize loss in turbine efficiency. The second objective is to control the corrosive or scale-forming tendencies of fluids in the cycle.

Figure 1 is a simplified diagram of a steam cycle for a plant capable of producing 1,000 ton/day of ammonia. The substantial water losses with this system result in a high rate of makeup. Studies are underway which hopefully will produce the technology needed to recover a much larger fraction of the condensate.

Table 1 lists desired values for the makeup water, the condensate and feedwater, and the steam. The dissolved oxygen value of 20 micrograms per liter given for the makeup water is obtainable only if a degasification step is employed in the makeup system. Vacuum degasification as part of a demineralization system is recommended, and in most instances justified, on the basis of the savings thus realized in demineralized water storage and piping systems. Because every effort will be made in this hypothesis to remove dissolved oxygen in the steam cycle, through deaeration and chemical feed, it is important that the introduction of dissolved oxygen to the steam cycle be minimized. The characteristics given in Table 1 for the condensate and feedwater system assume that condensate polishing equipment is available.

The quality of steam indicated is a listing of maximum desirable values, although there could be some argument in favor of allowing a maximum cation conductivity of 1.0 micromho. There is no doubt that the better the steam quality, the better the turbine capability is maintained.

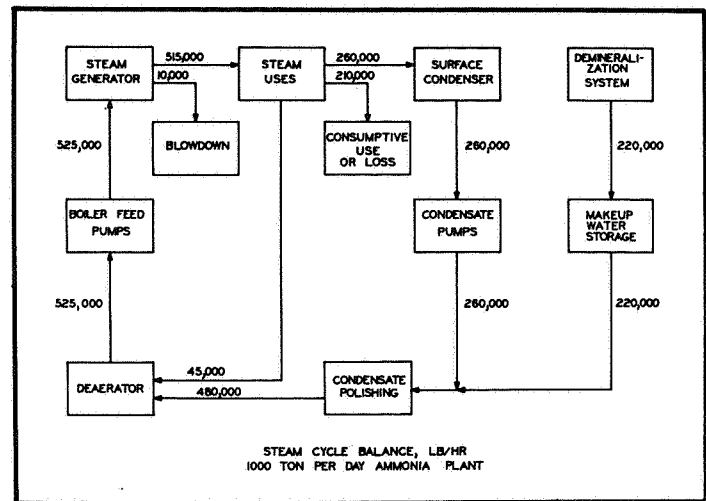


Figure 1. Steam cycle balance, lb./hr., 1,000-ton/day ammonia plant.

Table 1. Desired characteristics of water quality

	mg./l.	micromhos
Makeup to steam generator—		
turbine-condenser cycle:		
Total dissolved solids	0.05	
Silica	0.01	
Dissolved oxygen	0.02	
Condensate-feedwater		
(after condensate polishing):		
Total dissolved solids	0.025	
Silica	0.005	
Iron	0.005	
Sodium	0.005	
Hydrazine, condensate	0.030	
Hydrazine, feedwater	0.010	
Cation conductivity		0.5
Steam:		
Silica	0.020	
Dissolved oxygen	0.000	
Cation conductivity		0.5

Table 2. Water quality limits for condensate, feedwater, and steam

	Cycle copper-free	Cycle contains copper
pH	9.6	8.9
Specific conductance, micromhos	10	2
Ammonia, mg./l.	2	0.2

Table 2 indicates water quality limits for the condensate, feedwater and steam. Note that for a copper-free steam cycle a free-ammonia residual of approximately 2.0 mg./l. is recommended. Based on this ammonia level, the pH will be on the order of 9.6 and specific conductance at approximately 10 micromhos. Under these conditions, corrosion of ferrous metals in the cycle will be minimized.

If the cycle contains copper or copper alloys in any degree, the free-ammonia residual must be restricted to minimize ammonia attack on the copper alloys. If the cycle does contain copper, protection of ferrous metal components will be compromised because the cycle will operate at an approximate pH of from 8.8 to 9.0.

Figure 2 illustrates the relation of free-ammonia residual, specific conductance, and pH in high quality water systems. Empirical results have shown that the use of specific conductance to control the rate of ammonia feed is quite reliable and preferred over control by pH. In fact, the use

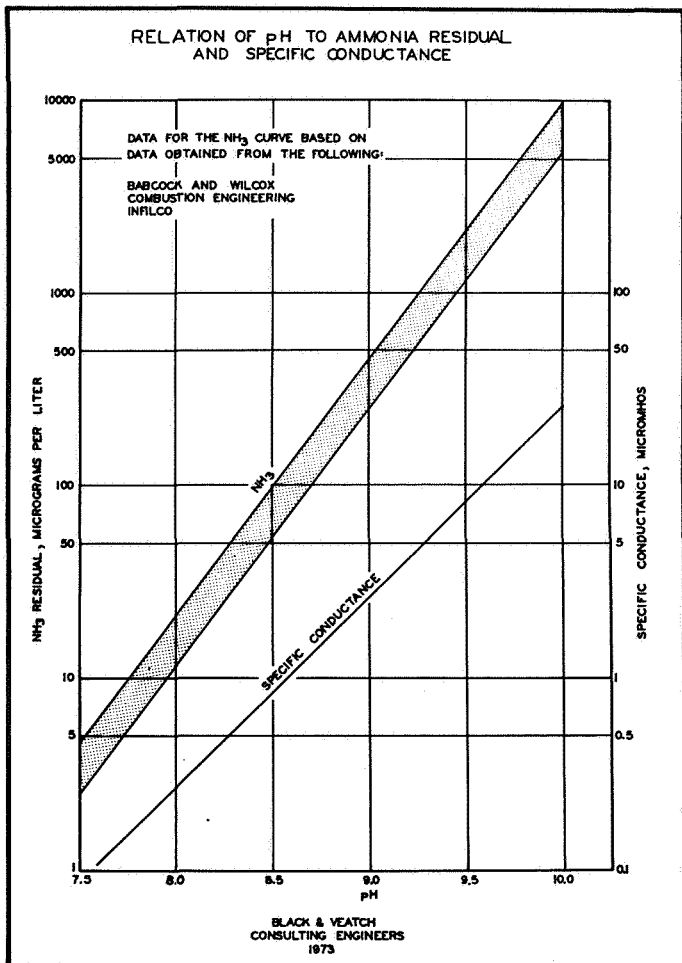


Figure 2. Relation of pH to ammonia residual and specific conductance.

Table 3. Water quality control for boiler water in a 1,500-lb./sq.in. gauge steam generator

	No-Solids	Low-Solids
Silica, mg./l.	0.3 to 0.5	0.3 to 0.5
Silica, Maximum mg./l.	1.0	1.0
P alkalinity, mg./l.	—	5 to 10
Hardness	0	0
Chlorides	0	0
Phosphate, mg./l.	0	2 to 4
Hydrazine, mg./l. (max.)	0.1	0.1
Specific conductance, micromhos	—	15 to 30
Specific conductance, micromhos max.	—	50

of pH for control purposes has generally been accepted in our designs only when there have been no alternatives.

Quality control for boiler water in a 1,500-lb./sq. in. gauge steam generator is suggested by the limits given in Table 3. The values under the column headed "Low-Solids" are the most frequently applied and represent what now may be considered standard operating procedure. The type of steam generator employed will certainly influence the water chemistry recommended. With proper control of both makeup water quality and the effects of leakage of undesirable material into the steam cycle through use of condensate polishing, it may be feasible to employ the "No-Solids" approach. In the no-solids treatment, volatile chemicals, ammonia and hydrazine, are fed to the conden-

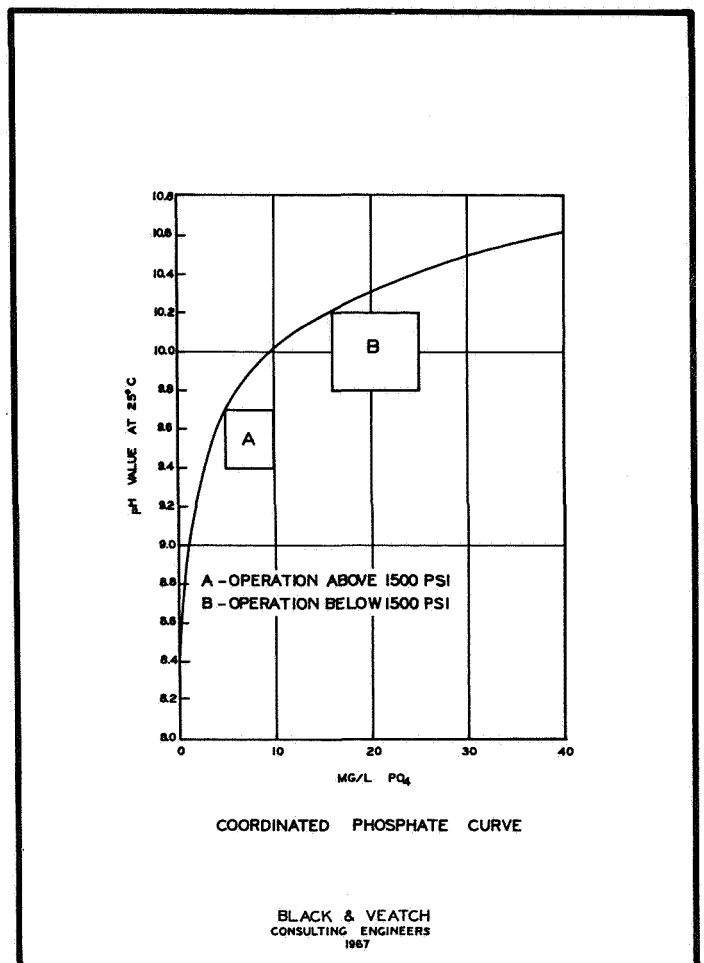


Figure 3. Coordinated phosphate curve.

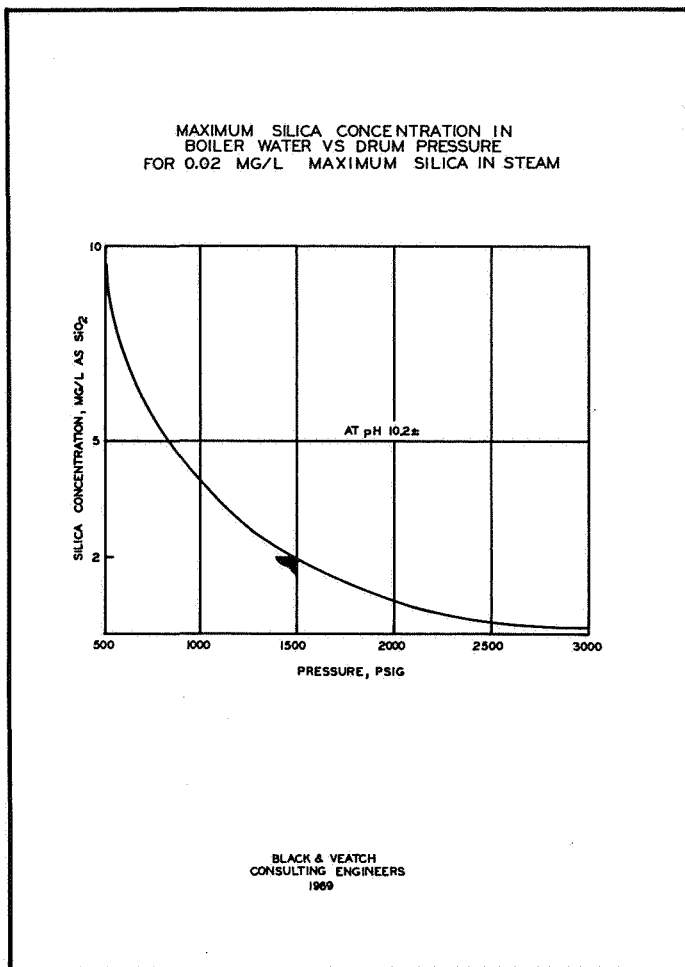


Figure 4. Maximum silica concentration in boiler feedwater vs. drum pressure for 0.02 mg./l. maximum silica in steam.

sate. In the low-solids treatment, sodium phosphate is fed to the boiler water, and ammonia and hydrazine are fed to the condensate.

Coordinated phosphate control is employed in some instances. Figure 3 shows the traditional curve for coordinated phosphate control. At 1,500 lb./sq. in. gauge, operation in Zone A or Zone B, or somewhere between, should meet the criteria set forth for coordinated phosphate control of boiler water. Another traditional curve is shown on Figure 4. Here the operating pressure of the steam generator versus silica concentration in the boiler water, when maintaining a maximum of 0.02 mg./l. SiO_2 in the steam, is plotted for a pH of approximately 10.2. This curve shows an allowable silica concentration of 2.0 mg./l. silica in the boiler water at an operating pressure of 1,500 lb./sq. in. gauge. It would appear that the maximum silica value at 1500 lb./sq. in. gauge is more appropriately 1.0 mg./l., as stated in Table 3.

Since silica volatilizes more easily at a lower pH it might be desirable in the case of no-solids treatment to maintain a maximum silica concentration below 1.0 mg./l., perhaps as low as 0.5. In the no-solids treatment, the pH of the boiler water may be below 9.0; thus the tendency for silica volatilization is increased by comparison to the higher pH realized with low solids or coordinated phosphate treatment.

Phosphate precipitation resulting from hardness in-

leakage to the steam generator may pose a greater problem with the bayonet tube boiler design sometimes employed than with the more conventional drum-type boiler. While the precipitated calcium phosphate does not have great scaling tendency, accumulation of the calcium phosphate in the bayonet tubes would probably impair circulation of boiler water within the steam generator.

There is no doubt that the use of high quality makeup water—that is, water low in total dissolved solids and silica, and preferably low in dissolved oxygen—improves the chances of maintaining proper operating conditions throughout the steam cycle. Furthermore, condensate polishing is an excellent aid in controlling the quality of all fluids contained in the cycle.

Possible sources of contaminants to the steam cycle include the makeup water itself, condenser tube leaks and turbine washing. Turbine washing may not be a particular problem where load to the turbine is essentially constant, as may be the case in an ammonia plant. Condensate polishing aids in the removal of dissolved solids from the cycle fluids and in the removal of corrosion products. The only other means of improving the cycle fluid quality is through boiler blowdown. In a properly operated and controlled steam cycle which incorporates condensate polishing, the blowdown should be a fraction of 1%.

Records from several gas-fired electric generating stations show makeup water routinely at 0.2%, or less, of the steam generated. Some generating station records show low makeup figures even though condensate polishing has not been used in the particular cycle studied.

Condensate polishing useful in maintaining fluid quality

Several types of condensate polishing systems have been employed to date. The simple filtration method shown in Figure 5 uses precoat filters with "Solkafloc." Properly designed into the cycle, these devices do an excellent job of removing corrosion products, but have no effect on dissolved solids.

Another of the devices sometimes employed is simple sodium cycle cation exchange, zeolite softening, as shown

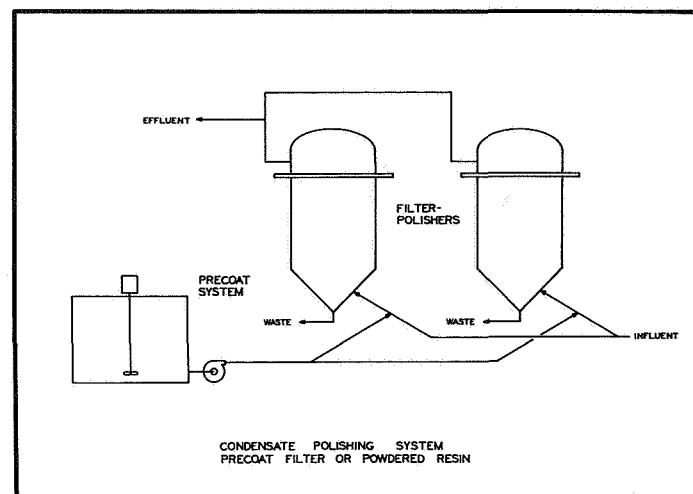


Figure 5. Condensate polishing system; precoat filter or powdered resin.

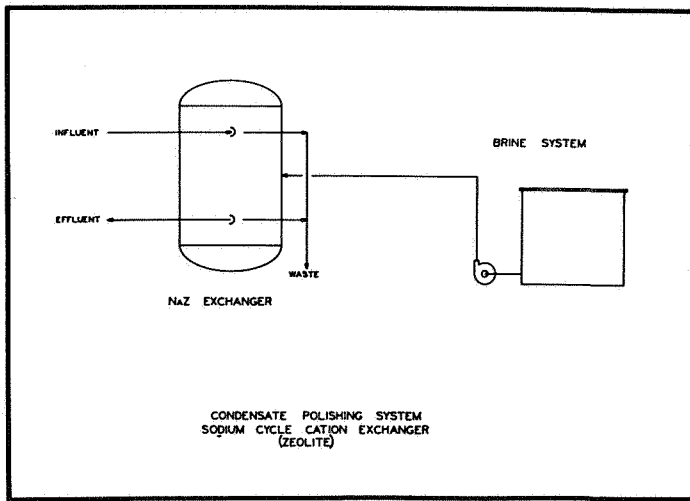


Figure 6. Condensate polishing system; sodium cycle cation exchanger (zeolite).

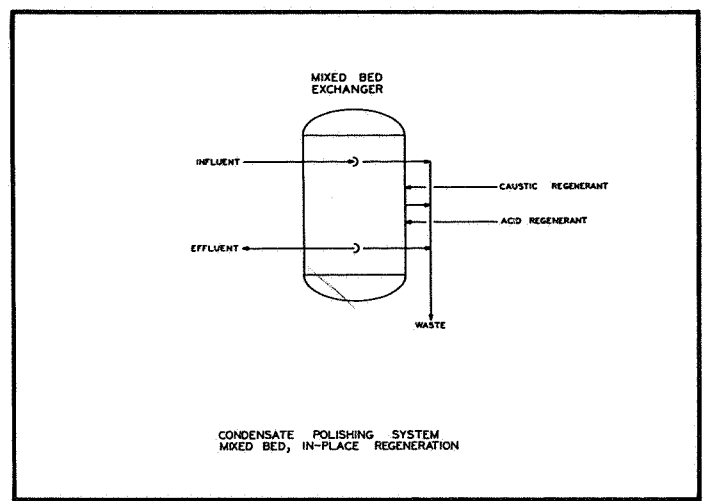


Figure 8. Condensate polishing system; mixed-bed, in-place regeneration.

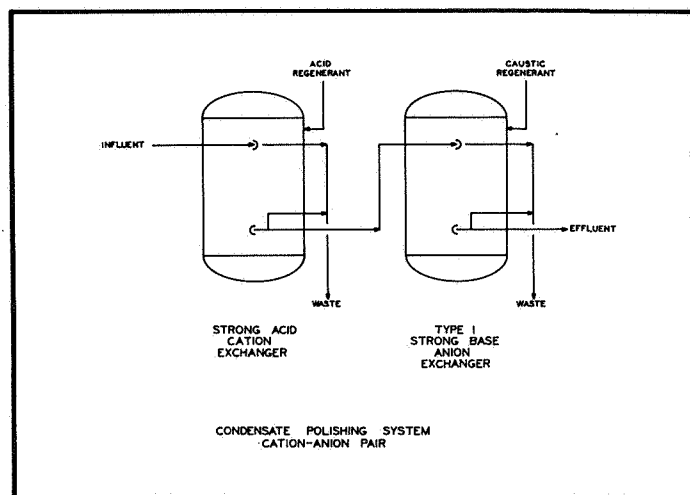


Figure 7. Condensate polishing system; cation-anion pair.

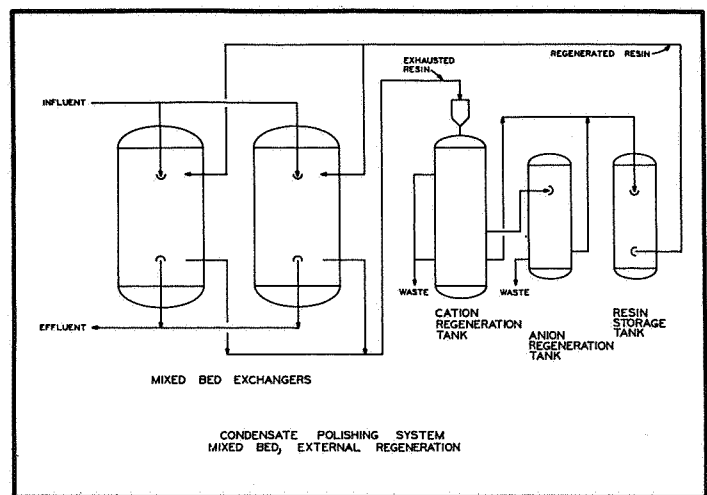


Figure 9. Condensate polishing system; mixed-bed, external regeneration.

in Figure 6. This system reduces hardness, calcium and magnesium, and serves as a low-efficiency filter for suspended solids.

Figure 7 illustrates a two-bed polishing system consisting of a strong acid cation, strong base anion exchanger pair. Also shown in Figure 5 is a system which uses powdered resin. These condensate polishing systems consist essentially of a precoat filter, with a mixture of cation and anion resin in powdered form used as the precoat. Although these devices are excellent filters, their ion exchange is somewhat limited because the precoat is only about 1/4-in. inch thick; consequently, little resin is actually available. Powdered resins have quite a high exchange capacity per pound of resin. The powdered resin is disposed of and replaced upon realization of exhaustion from the ion exchange standpoint or excessive pressure drop.

Mixed-bed ion exchange is often employed for condensate polishing. With this method, the mixture of cation and anion resins provides good filtration characteristics and effective ion exchange for dissolved solids. Mixed-bed exchangers may be regenerated in place, as shown in Figure 8, or externally regenerated, as shown in Figure 9. External

regeneration facilities may be rather expensive yet justified in the case of large condensate flows.

For copper-free cycles where the free-ammonia residual is on the order of 2 mg./l., ammonia-form cation resin may be employed. For powdered resin systems, the cation fraction of the resin is purchased in ammonia form. In mixed-bed polishing systems, the cation resin is either exhausted in place or ammonia regeneration follows acid regeneration of the cation resin. For systems containing copper where the ammonia residual in the steam cycle is at a relatively low level, operation of cation resins past the ammonia breakthrough point may not be justified. Ammonia removed from the steam cycle by the mixed-bed polishing system is contained in the spent regenerant wastes. Whether the cation resin is regenerated at the point of ammonia breakthrough, or the regeneration takes place after prolonged use of the resin in ammonia form, the quantity of ammonia discharged to waste is the same because the cation resin has a specific capacity with respect to ammonia of approximately 30 kg./cu. ft. It should also be pointed out that the ammonia feed to the cycle, for proper control of cycle chemistry, is only that amount lost

in the condensate polishing system plus the relatively minor losses which occur in the air removal system of the surface condenser, and through venting. All consumptive steam or condensate uses do, of course, contribute to the need for ammonia feed.

Control limits are recommended

To summarize the recommended control measures for the steam cycle; the condensate-feedwater and steam in a copper-free system should have a pH of approximately 9.6 with an ammonia residual of approximately 2 mg./l. and a specific conductance of approximately 10 micromhos. The chemical feed point for hydrazine and ammonia should immediately follow the condensate polishing system. Low-solids treatment requires that small quantities of sodium phosphate to be fed to the boiler water. For this purpose, trisodium phosphate is preferred rather than monosodium or disodium phosphate and caustic. If the silica in the boiler can be maintained at a very low level, then no-solids treatment may be employed where only the ammonia and hydrazine are fed to the discharge of the condensate polishing system. Mixed-bed condensate polishing systems serve quite well as an aid in maintaining control of steam cycle chemistry and may be operated past the ammonia breakthrough point without compromising the results obtained.

Where the cycles are not copper-free, greater corrosion rates will be encountered with the ferrous metal system components, because the pH of the system must be maintained at or below 9.0 to minimize ammonia-caused deterioration of copper alloys. Condensate polishing for removal of corrosion products is perhaps even more important with a steam cycle containing copper alloys than with a copper-free system.

The hydrazine feed for both the copper-free cycle and the steam cycle containing copper alloys is essentially at the same level. Hydrazine residual on the order of 10 to 20 $\mu\text{g./l.}$ should be present at the inlet to the steam generator. Just downstream of the hydrazine feedpoint, the residual may be between 20 and 40 $\mu\text{g./l.}$ Loss of hydrazine through the deaerator is negligible. The advantage gained by feeding the hydrazine to the condensate is that some passivation occurs even at the lower temperatures and that the fluid thus conditioned can react at any time with traces of dissolved oxygen which may be present.

Water treatment system must fit specific situation

The system provided to treat the water supply to the necessary high purity levels should be carefully studied for each specific design situation. Polishing of the effluent from a demineralization system, or from a flash evaporator, is recommended. A demineralization process frequently employed to provide makeup water involves a primary cation exchanger, primary anion exchanger, and a mixed-bed exchanger. The anion exchanger normally employs a strong base resin although it may employ a layered bed with a weak or intermediate base resin on top and strong base resin on the bottom.

In some instances a **simple three-bed system** comprised

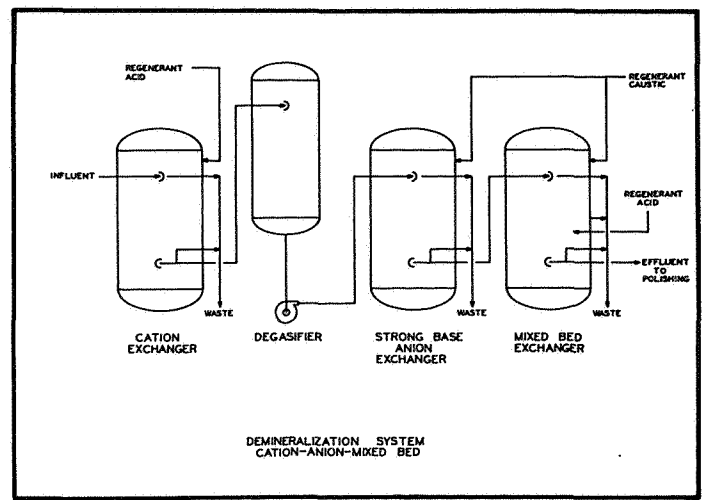


Figure 10. Demineralization system; cation-anion-mixed bed.

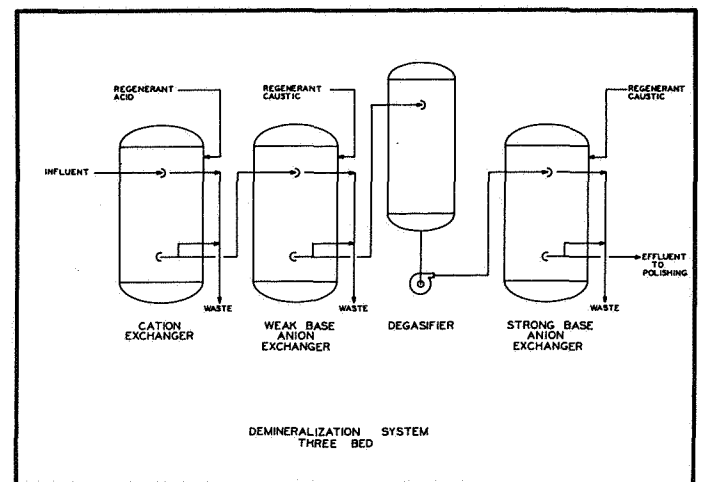


Figure 11. Demineralization system; three-bed.

of the cation exchanger, weak (intermediate) base anion exchanger, and a strong base anion exchanger might serve the purpose. A four-bed system consisting of two pairs of cation-anion exchangers in series will at times serve very well. In this system the primary anion exchanger is a weak or intermediate base resin, and the secondary anion exchanger is a strong base resin.

If degasification is employed in any of these systems, it should precede the first strong base anion exchange resin. For the cation-anion mixed-bed system, degasification will follow the cation exchanger, as shown in Figure 10. In the three-bed system shown in Figure 11, the cation and weak base anion exchangers are followed by the degasifier and then the strong base exchanger. For the four-bed system, the degasifier is located between the primary and secondary exchanger pairs, as shown in Figure 12. The degasifier may be of either the forced-draft or the vacuum type, and the vacuum degasifier may be either single or two-stage. The vacuum degasifier, as discussed previously, has the advantage of removing dissolved oxygen as well as carbon dioxide. The forced-draft degasifier removes carbon dioxide, reducing anion load, but saturates the water with dissolved oxygen.

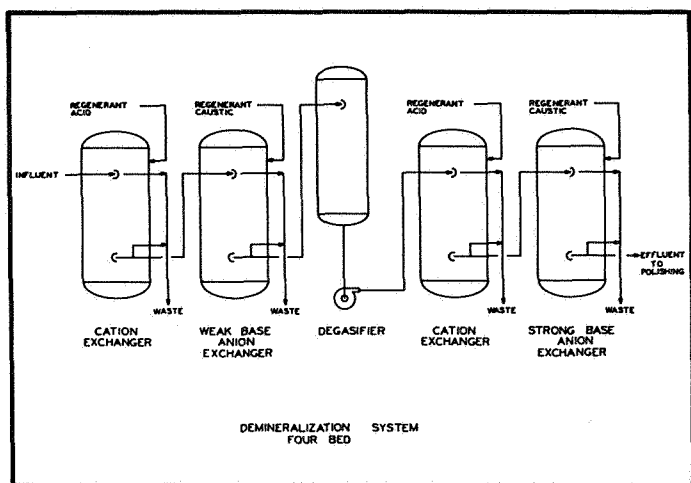


Figure 12. Demineralization system; four-bed.

The proper selection of the demineralization process is a matter of detailed study and evaluation for the particular project under design. Polishing is suggested regardless of the system selected. The polishing may be in the form of a cation-anion pair, the anion exchanger utilizing a strong base resin, or it may be in the form of a mixed-bed exchanger. For an overall cycle, such as the 1,000-ton/day ammonia plant cycle discussed earlier, the demineralization system effluent may be polished in conjunction with mixed-bed condensate polishing.

Once-through systems usually use chlorination

Circulating water systems used to cool surface condensers and auxiliary heat exchangers are not as easily defined as steam cycles. Once-through systems which are often utilized when a large volume of water is available are rarely treated in any manner other than with shock chlorination. The water source may be a cooling lake, sea water, or a river. Quantities of water involved are usually so large that it is impractical to consider treatment, other than chlorination, prior to introduction of the circulating water to the heat exchange devices.

A disadvantage with the cooling towers frequently employed as part of a circulating water system is the consumptive loss of large quantities of water through evaporation. The available ground or surface water may not require treatment prior to use as makeup to the cooling system, or the cost of treatment facilities may not be justified economically. In many cases, however, it is appropriate to provide treatment of the makeup water.

Cycles of concentration in a tower system are limited to maintain circulating water quality within certain control limits. Blowdown from such tower systems may pose a pollution control problem. One set of quality control limits for circulating water where the system includes a cooling tower is as follows: pH, 6.8 to 7.0; M alkalinity, 20 to 30 mg./l.; calcium hardness, 1000 mg./l. maximum; SiO_2 , 150 mg./l. maximum; $(\text{PO}_3)_x$, 6 to 10 mg./l. The chlorine residual at the return to the tower should not exceed 1.0 mg./l. as free available chlorine at the time shock chlorination occurs. Higher chlorine residuals would be detrimental to tower lumber.

The alkalinity, hence pH, is controlled through acid feed; with the acid feed in proportion to makeup water flow and the alkalinity content of the makeup water. The polyphosphate feed is in proportion to blowdown from the circulating water system. Shock chlorination is simply a timed function occurring perhaps 1 to 3 times daily for a period of from 15 to 30 minutes per cycle of chlorination. If ammonia is present in the circulating water, the chlorination system must be adjusted to compensate for the particular circumstances. A biocide, other than chlorine, may be required in addition to the chlorine.

In circulating water systems where high chlorides are a problem, chromates may be required as inhibitors. In some instances a dianodic corrosion inhibitor system providing a 35-mg./l. CrO_4 residual with a polyphosphate residual of 8 mg./l. as PO_4 has proven quite successful. The use of chromates as inhibitors does of course increase the potential pollution problem.

One major electric power company has been prohibited from using either phosphate or chromate inhibitors by regulatory authorities. The quality control limits established in this case are as follows: M alkalinity, 135 to 235 mg./l.; pH, 8.2 to 8.5; Rysnar stability index, 5.14 to 4.36; Langelier stability index, 1.53 to 2.07. In this example, a mechanical cleaning system is provided for the condenser and the auxiliary heat exchanger.

The concept employed dictates that the circulating water be maintained at conditions which tend slightly to scale formation. The acid feed is increased for a period of a few hours to bring the pH down to a point which will descale the system. A pH somewhat below 6.0 may be required for a period of from 4 to 8 hr., the descaling operation normally required about once a week. It is obvious that careful monitoring of terminal difference on heat exchange devices is essential. Frequency and duration of low pH descaling operations must be adjusted to suit actual operating conditions.

In summary, a circulating water system should be conditioned to minimize corrosion and scale formation and biological slimes and algae must be controlled to assure efficiency. Many of the proprietary compounds used in treatment of tower systems have, in some instances, been appropriate in every way. In the majority of cases non-proprietary chemicals fulfill systems requirements.

Conclusions

Each design problem should be resolved in light of all other design criteria. The proper design of treatment systems for steam cycles and circulating water cycles recognizes the need to meet appropriate water quality control limits in these cycles. The water quality control limits established must in turn recognize the specific needs of the system served. Materials of construction, as well as temperature and pressure conditions, influence decisions.

In every case, the proper study will consider alternative solutions, their advantages and disadvantages, and a decision made on the basis of the comparison. Steam generator-feedwater and circulating water cycles are important facets of overall plant design, and as such deserve careful consideration.

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DISCUSSION

GENE COMEAU—CFCA. Could you expand on the effect of ammonia on copper? I am familiar with a number of systems which had very high ammonia content and no apparent corrosion on admiralty. I have not found any specific references as to why this is possible. I assume it has something to do with pH. Can you enlighten me on this subject?

WEBB: Our experience has been that carrying a pH in excess of 9.0, where the free ammonia residual is higher than something on the order of 200 to 300 parts per billion, or micrograms per litre, we do have deterioration of copper alloys be they admiralty or 90-10 copper nickel or what have you. You must recognize that the basis for my paper is my experience in the electric power generation industry, where the general philosophy of design, construction and maintenance is somewhat different perhaps than you have in the process industries. We expect things to last for 30 years without having to do much to them. We cannot stand these 20 day outages you talk about in ammonia plants.

COMEAU: I was thinking specifically of cases where the ammonia was, say, 500 to 1000 parts per million. The pH may be 7.0 or 8.0. Would you say that that condition was corrosive to Admiralty?

WEBB: If your pH is 7.0 to 8.0 you do not have free ammonia in a high quality water system.

COMEAU: The pH could be low because the water also contained an anion such as carbonate or nitrate.

WEBB: If you are talking about, let's say, ammonium carbonate, I would not expect that material to be particularly reactive. My discussion related to free ammonia residuals.

COMEAU: In other words, it is not combined ammonia but free ammonia that attacks the copper tubing?

WEBB: That is correct.

J.M. BLANKEN—UKF—Holland: We operated one of our ammonia plants with about 500 ppm of ammonia for about three weeks. We feared very much that we would lose the aluminum brass vacuum condenser tubes and would develop a leak in the high heat flux reformed gas boiler. The copper content as analysed by the laboratory was about 0.5–1.2 ppm or about 100 times normal allowable. After operating like this for three weeks we inspected the vacuum condenser and chemically cleaned the reformed gas boiler and we didn't find anything serious.

R.S. TRESEDER, Consulting Corrosion Engineer: I'd like to comment further on the corrosion of copper and copper alloys in ammonia systems. It has been shown that corrosion of copper and copper alloys by ammonia solutions requires the presence of an oxidizing agent such as oxygen. Therefore, the absence of corrosion in some cases could be explained by the lack of oxygen.

P.A. RUZISKA, Exxon Chemical: I wonder what is normal treatment practice with plants having waste heat boilers using bayonet tube design where you can get deposition of calcium phosphate scale in the bottom of the tubes. Is it normal practice to use low solid treatment and hope for the best, or is it normal practice to go to no solids with condensate polishing, etc.?

WEBB: Phil, I am not sure what the "normal practice" is because I am not familiar with a large number of ammonia plants. The Kellogg design using the bayonet tube boiler is the system with which I am most familiar. It would definitely be our recommendation to employ nothing more than the low solids treatment, and I think consideration might be given to the no solids treatment since it appears to

me that any precipitation, such as calcium phosphate sludge, might impair the circulation in the tubes of a bayonet tube boiler. This may not be the case, but it appears logical to me that it could occur. Condensate polishing is very much essential to successful ammonia plant operation, in my opinion.

HAYS MAYO, Farmland Industries: Les, you list the limits of pH as 9.6 on copper free and 8.9 on systems containing copper. What is the increased penalty in corrosion that you pay for this difference between the two pH levels?

WEBB: Hays, I do not have specific figures to give you. Our records from various power plant operations would give us some index of this, but I do not have the figures in mind. The effects of the copper pickup you might have could be detrimental as this increases solids to your boiler if they are not taken out by condensate polishing. Soluble copper would, of course, be removed by condensate polishing through ion exchange and at least a portion of insoluble coppers would be removed through filtration by the polishers.

MAYO: I believe that failure of bayonet tube boilers is caused by corrosion on the inner surface of the scabbard tube. Analysis of scale taken near the failed areas shows a large percentage of Fe_3O_4 . Presenting or removing the scale is of primary importance in preventing failures.

WEBB: I have not seen analyses of the scales to which you refer which do contain copper and there are several of these boilers in systems where the surface condensers do contain admiralty tubes. I think it would be in order to ask the audience whether they have found any copper depositions.

TOM CARROLL, Amoco Oil: The one failure that we analyzed did not have copper. The scale was basically iron oxide. We normally control at a pH of 9.2 to 10.0. Our surface condensers have admiralty tubes. My question is what penalty are we paying for running it at this high pH with admiralty condensers?

WEBB: I would be glad to try and come up with some figures from our studies. We do have the good fortune to maintain clients for a long time and we do keep in close touch with our clients, reviewing their operating logs regularly. I would be able to determine what corrosion rates are for years back on many of the plants.

This brings up one point, and while I do not want to digress from your particular point of discussion, I do want to mention that careful consideration of monitoring of cycles and really knowing what is going on in the cycles is necessary. I am not finding adequate monitoring in the ammonia plants I have reviewed. While we perhaps would, in your opinion, go overboard a bit on a water quality control system for a major power station, which might cost \$250,000 just for the monitoring system, it is important that monitoring be done.

We have a fairly sizable generating unit that the company was happy to use in some experimentation, this being a 175 megawatt generating unit. We attempted pH at 10.0 and above, and all the way down to about 9.1. We monitored the corrosion rates in this copper free system. We found little in the way of help after we got up to a pH of about 9.6 to 9.7, a free ammonia residual of 2000 micrograms per liter.

MAYO: If data has been developed on corrosion rates versus pH, I have not seen this published. I do have some information from Betz which applied to corrosion rates in cooling water systems. This showed a curve of corrosion rates in mils per year versus pH; the curve is essentially flat for a pH for 6.5 and higher. I had assumed this as being the

same general shape for boiler waters, but certainly not drawn for boiler waters and not necessarily so.

There are some other problems associated with low pH. One of the papers mentioned that ammonia existed in effluent waters of about 2 parts per million. Using the mixed bed polisher to polish the condensate, removes ammonia up to a certain point, this ammonia showing up in your effluent stream. Using your curves, at a pH of 9.6 about 2.0 parts per million. In taking out 2 parts per million in the mixed bed polishers, we are taking a substantial percentage of the total ammonia that we are permitted in our effluent water. What I am really aiming at is what penalty do we pay, because we will sooner or later have to cope with the ammonia in the effluent water?

WEBB: Hays, I recognize the problem of ammonia in the waste waters. What I was trying to point out was that in condensate polishing where you have a mixed bed, such as you have at Lawrence and at Enid, you can operate the polisher past the point of ammonia breakthrough. You are only going to take out that ammonia from the steam cycle, the condensate, that you have the capacity for in the cation resins. After that point, the ammonia just comes on through the polisher and you do not have to feed as much ammonia to the steam cycle to compensate for ammonia lost from the system.

MAYO: We calculate the amount of ammonia that was to be taken out by the regenerant chemicals was a serious problem and as a result, we did reduce the pH in the boiler. How much does this hurt us?

WEBB: The pH of your boiler water when you are operating with a sodium phosphate chemical feed as well as ammonia and hydrazine feed to the condensate, doesn't have too much to do with ammonia in waste water effluents. The waste waters might contain some of the ammonia used in the protection of the preboiler system, the condensate and feedwater, and the steam, because the volatile chemicals come over with the steam. Whatever residual ammonia you are carrying in your condensate feedwater steam cycle that you are polishing, all that will end up in the waste water is that which is removed through ion exchange in cation resins.

That is the same quantity of ammonia whether you are operating at a pH of 9.0 or pH of 9.6 in your condensate-feedwater system, assuming that you do operate past the ammonia breakthrough on your polishers.

MAYO: I am going to have to think about that for awhile. There is another point that concerns me, having to do with coordinated phosphate treatment and the possibility of precipitation of solids in the bayonet tube boilers. It is my experience that precipitation does not occur in the tubes.

The velocity in the bottom of the bayonet tubes is sufficient to lift grains of sand for instance. Experimental work run on glass tubes shows this to be the case. We have one case where we know that solids did plug the tube, but composition of the solids indicates badly contaminated boiler water. Analysis of the solids showed the following:

Magnetic Iron Oxide as Fe_3O_4	23%
Basic Calcium Phosphate	64%
Magnesium Hydroxide	13%

In examining the boiler, the bayonet tube was pulled but the scabbard tube was not. A donut shaped deposit encircled the bayonet tube. It seems probable that the deposit formed on the scabbard tube caused overheating and failure. The deposit got large enough to cling to the bayonet tube and was pulled out of the scabbard tube when the bayonet was withdrawn.

We have experienced tube failure of 102C, Secondary waste heat boiler, which is a vertical fixed tube sheet boiler, with process gas inside the tubes, at the bottom tube sheet. The failure is probably caused by deposit of solids on the hot lower tube sheet with insulation of the tubes and resultant overheating. Appearance of the failed tube is similar to a beaver attack on a tree. The tube sheet deposit is largely iron oxide which again points up the problem of reducing corrosion in the boiler. Blowing down the boiler at regular intervals helps but does not eliminate the problem.

Let me make another point. We are running process condensate which has been stripped, through a carbon filter and back into the system comingling with the feed to the main unit. This work was initiated by Harvey Spangler at Ft. Dodge, Iowa.

At Lawrence we are running the same water to the cooling tower. We have found no problem with this, with the exception that you cannot maintain a free chlorine residual. The chlorine feed still is an effective biocide.

The recovery of stripped process condensate for reuse in the steam cycle is of economic importance.

WEBB: I must second your last comment. A far greater recovery of condensate than normally realized should be an important consideration.

Let me emphasize one point. The water chemistry control of the condensate-feedwater system, whether it be a copper free system with a pH of 9.6, a free ammonia residual of 2.0 milligrams per litre, or a system containing copper alloys with a pH of 8.9 and a free ammonia residual of 0.2 milligrams per litre, is almost independent of chemical control of the boiler water. Low solids treatment of the boiler water as shown in Table 3 may be used, regardless of the pH carried in the condensate-feedwater system. Thank you for your discussions.