

RO Is a Key Part of GE's Total Solutions for Improving Steam Plant Operations

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Would your plant benefit from improved steam purity, improved condensate corrosion control, reduced boiler blowdown and/or reduced ion exchange vessel regenerant usage? If so, treating the makeup to the boiler feedwater with a reverse osmosis (RO) system may provide these benefits.

Most boiler makeup water is treated either by sodium zeolite softening or some form of demineralization using ion exchange. Systems using sodium zeolite softened makeup water often suffer from contaminated steam, condensate system corrosion and high energy costs due to high boiler blowdown rates. Systems using demineralized water often have high regenerant costs and may become capacity limited when raw water dissolved solids levels increase. In addition, demineralizers require the handling and disposal of acidic and caustic solutions.

Improved Steam Purity –Producing steam of satisfactory purity is of critical importance for safe and efficient plant operations.

Steam contaminants form deposits in superheaters, control valves and turbines, which cause superheater overheating failures and reduce both turbine capacity and efficiency. In plants where steam is injected directly into the process, steam of inadequate purity can contaminate the product or foul system catalysts.

Often overlooked are the safety hazards caused by contaminated steam. Deposits resulting from the contaminated steam may cause control valves to malfunction leading to catastrophic turbine failure. Caustic contamination of steam has also caused disastrous failures of expansion joints and steam lines.

In short, using contaminated steam can increase operating costs, reduce production and become a safety hazard.



Figure 1 – Boiler water carryover formed deposits in this superheater tube and caused tube failure from overheating.

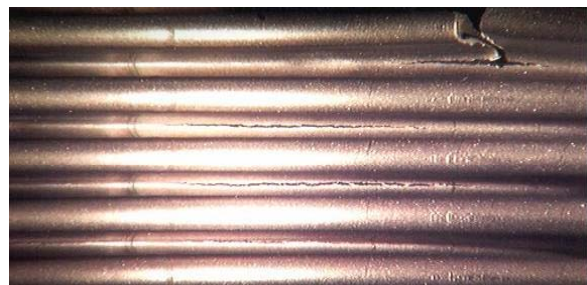


Figure 2 - Steam contaminated by caustic caused this steam line expansion joint to fail.



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Steam contamination in softened water makeup systems can often be reduced by the addition of an antifoam, such as GE Water & Process Technologies OptiSpense* ADJ575. In those instances where feeding antifoam does not produce the desired steam purity, treating the makeup water with an RO system can reduce steam contamination.

Usually, water tube boilers are guaranteed to have no more boiler water in the steam from carryover than that listed in column three of Table 1. Since dissolved solids in the boiler water contribute to steam contamination, reducing the dissolved solids by treating the makeup water with RO reduces the potential for dissolved solids in the steam. At a minimum, the dissolved solids contamination of the steam generated is reduced in proportion to the reduction in the dissolved solids in the boiler water.

Table 1: American boiler manufacturers normal guarantee of the maximum amount of boiler water that will be in the steam produced by a boiler.¹ Maximum boiler water alkalinity is usually specified to be less than 20% of boiler water solids.

Drum Pressure (psig)	Maximum Dissolved Solids In Boiler Water	Maximum % Moisture In Steam
0 -300	3500	0.03
301-450	3000	0.03
451-600	2500	0.04
601-750	1000	0.05
751-900	750	0.06
901-1000	625	0.07
1001-1800	100	0.10

In situations where high boiler water dissolved solids produce foaming, the improvement in steam purity is even greater than predicted by a simple comparison to the reduction in boiler water dissolved solids. This is because lower dissolved solids reduce the tendency for boiler water foaming.

Adding an RO system to plants with high sodium or silica leakage from the demineralizer plant can also significantly improve steam purity. This is most pronounced in plants that inject boiler feedwater for steam attemperation or desuperheating. This is a common and sometimes overlooked source of steam contamination.²

Overall, implementing RO treatment of boiler makeup water can substantially improve steam pu-

urity and often eliminate steam system fouling and corrosion problems.

Example 1 – A United States Midwest oil refinery provided their boilers with boiler feedwater consisting of 50% to 75% hot lime-hot zeolite softened makeup water and 25% to 50% condensate return. The boilers produce steam at 600, 450, 220 and 125 psig. The maximum boiler blowdown water conductivity limits in this refinery are 3000 μ S/cm for the 600 psig boilers and 5000 μ S/cm for the 450 psig and lower pressure boilers. Blowdown from the boilers goes to 50 psig flash tanks that vent steam to the refinery's low-pressure header and discharge the liquid to waste.

Raw water is obtained from a canal that is subject to contamination from run-off of adjacent roadways. Conductivity of the canal water, which is normally about 1000 μ S/cm, increases to 2000 μ S/cm due to salt contamination from the run-off in the winter months. During these times, it was impossible to blow down the boilers enough to keep boiler water conductivity within the specified limits. Despite feeding boiler water antifoam, unacceptable levels of boiler water carryover occurred during these episodes.

Steam turbine fouling occurred from chronic boiler water carryover and turbine washes were required every few weeks. Additionally, the blowdown flash drums were ineffective for separating the water from the steam at the high boiler blowdown rates necessary when the high conductivity boiler makeup water was being used. Consequently, boiler blowdown water carried over from the flash tanks into the low pressure steam line creating the need for routine condensate flushing of this line to remove deposits.

In one instance, when operating a package boiler with the continuous blowdown valve wide open did not maintain the boiler water conductivity within range, the manual blowdown valve was left open to help reduce the boiler water conductivity. Operating with the manual blowdown valve continuously open reduced the water circulation in the generating tubes near the manual blowdown take-off, which caused the tubes to overheat, form blisters and rupture.

Installing an RO system to treat some of the softened makeup water proved successful. The RO permeate conductivity typically ranges from 15 to

30 $\mu\text{S}/\text{cm}$, a dramatic improvement compared to the softened water. Boiler blowdown rates have been reduced so they now vary from 2% to 10% of the boiler feedwater depending on the quantity of softened water that by-passes the RO system.

Energy savings from the lower blowdown rates are estimated to be over 250,000 million BTUs per year. Additionally, reducing (and soon eliminating) the need for turbine and condensate line washings increases plant reliability and improves safety. Due to these benefits, the refinery is evaluating the use of additional RO equipment to treat all of their boiler makeup water during future winters to further improve their steam plant performance.

Improved Condensate System Corrosion Control – Effective condensate system corrosion control enables reliable, energy efficient plant operation.

Condensate system corrosion causes equipment and piping failures. Costs increase as plant equipment and piping must be replaced more frequently. Often more costly are the losses of plant production and the ability to return valuable, high energy, high purity condensate to the boilers.

Poor condensate corrosion control increases the quantity of iron and copper corrosion products returned to the boiler feedwater with the condensate. Boiler deposits formed by these corrosion products increase the potential for boiler tube failures. In plants where the feedwater is used for steam at-temperation or desuperheating, corrosion products in the feedwater may form deposits in control valves and on turbine blades and cause solid particle erosion of turbine blades.

GE has a complete line of condensate system corrosion inhibitors, encompassing acid neutralizers (Steamate* NA), film formers (Steamate FM and Steamate NF) and metal passivators (Steamate PAS). In addition GE's unique proprietary condensate modeling ability (CMS)³ enables us to identify the best products, feed points and feedrates for complex steam-condensate systems.

Effective, economical treatment of condensate systems with high carbon dioxide content cannot always be achieved with chemicals alone. In these instances, the addition of RO equipment to remove alkalinity from the makeup water significantly reduces the potential for condensate system corrosion. Lower alkalinity in the makeup water

translates into lower carbon dioxide in the steam, the main contributor to most condensate system corrosion.

Example 2 - A U.S. Northeastern refinery uses sodium zeolite softened makeup as feedwater to their low-pressure boiler system. The boiler feedwater "M" alkalinity is 35 ppm. This alkalinity decomposes in the boiler releasing approximately 30 ppm of carbon dioxide into the steam. Untreated, condensate corrosion led to equipment and condensate return piping failures. Treatment has been initiated to control the corrosion, but treatment costs are high due to the large amount of amine required to neutralize the high level of carbonic acid formed by the dissolution of carbon dioxide into the condensate.

Installing an RO system to treat the boiler makeup water followed by removal of free carbon dioxide in a degassifier or deaerator will reduce the steam carbon dioxide in the steam to 1 or 2 ppm. This will reduce the cost of effective condensate corrosion control to less than 10% of the current cost (Figure 3). In addition, the reduction in boiler blowdown rates possible with reverse osmosis treated makeup water is projected to save 25,000 million BTU per year.

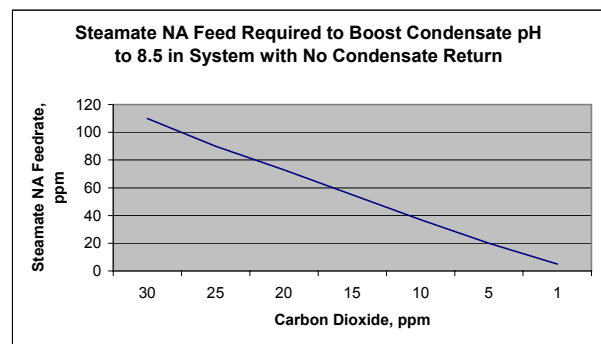


Figure 3 - Steamate NA feedrate is nearly proportional to the carbon dioxide content of the steam.

Reduced Boiler Blowdown – High boiler blowdown rates waste energy. In plants where efficient blowdown heat recovery equipment is not installed, the amount of additional fuel required to makeup for the energy wasted in boiler blowdown can be very costly – adding tens to hundreds of thousands of dollars per year to the fuel budget. Additionally, when large amounts of boiler energy are sent to sewer with the blowdown, steam produced by a boiler may be reduced, limiting plant steam produc-

tion. With fired boilers often steaming can be increased by burning more fuel, but waste heat boilers have a fixed heat input so the higher the blowdown rate the lower the steaming rate.

Adding RO equipment to systems previously treated with sodium zeolite softeners only, enables a plant to reduce blowdown by reducing the solids in the boiler makeup water. This reduction in boiler blowdown may save a substantial amount of fuel and, in certain circumstances, increase plant steam generating capacity.

Example 3 – A U.S. Mid-Atlantic refinery uses sodium zeolite softened makeup as feedwater to their 400 psig saturated steam waste heat boilers. Blowdown to control steam purity averages about 11 percent of boiler feedwater. Heat in the boiler blowdown water is partially recovered in a 35 psig flash tank, but the rest is sent to sewer.

Installing an RO system to treat the makeup water would enable the plant to reduce blowdown to approximately 2% of boiler feedwater. At the lower blowdown rate it is estimated that 400 psig steam production from these boilers will increase from 219,000 lbs/hr at 10.9% blowdown to 224,000 lbs/hr at 2% blowdown. This is an increase of 45 million pounds of 400 psig steam per year. Of course, there will be some loss of 35 psig steam generation from the blowdown flash tank at the lower blowdown rate but, the net energy savings is projected to be more than 30,000 million BTU per year. Figures 4 and 5 show the projected water and steam flows at both operating conditions.

Reduced Regenerant Usage – Acid and caustic regeneration and the resulting regenerant waste disposal are the most costly parts of preparing demineralized water for boiler makeup.

The higher the dissolved solids content of the supply water, the more acid and caustic regenerant required and the more waste to handle. Additionally, the improper handling of acid and caustic presents a safety issue and potential waste discharge violation.

Adding an RO system ahead of an existing demineralizer system will reduce the ionic loading on the demineralizer. The reduced ionic loading proportionately reduces the acid and caustic required for regeneration and consequently, the quantity of acid and caustic waste that must be handled. In many

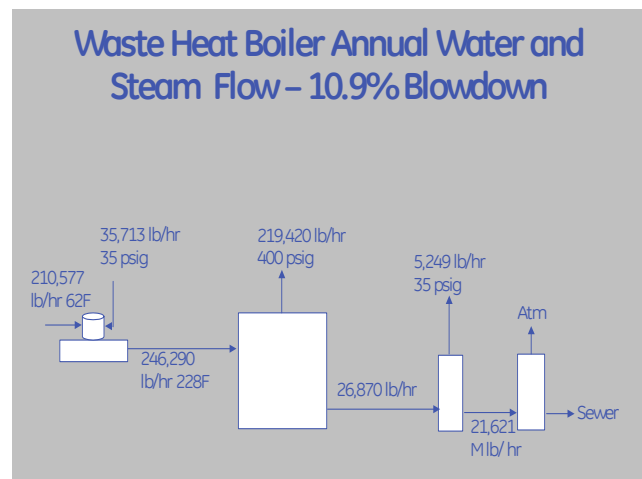


Figure 4 – Water and steam flows with sodium zeolite softened makeup water

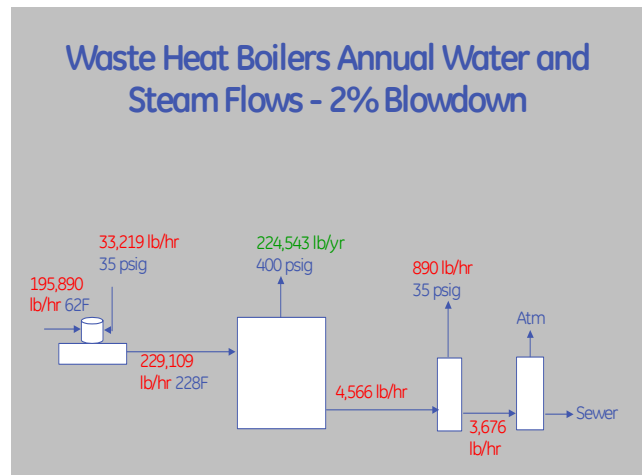


Figure 5 Water and steam flows with reverse osmosis treated makeup water.

systems RO pretreatment can reduce acid and caustic requirements for demineralizer regeneration by up to 90% to 95%.

For those plants with high purity boiler feedwater requirements that wish to completely eliminate the handling of acid and caustic for safety or environmental reasons, a 2-pass RO plus an electrodeionization system (EDI), where needed may meet the plant needs.

References:

¹"Boiler Water Limits and Achievable Steam Purity for Watertube Boilers," American Boiler Manufacturers Association, 4th edition, 1995, Table 1, Recommended Boiler Water Limits and Estimates of Carryover Limits that Can be Achieved.

²"A Practical Guide to Avoiding Steam Purity Problems in the Industrial Plant", ASME Research Report CRTD-Vol. 35, The American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017

³ Robinson, J.O., "New Computer Modeling System Improves Condensate Treatment", Corrosion Asia, Singapore, September 1994