Boiler Pretreatment Matrix

System	Effect on Water	Control Tests	Service Checkpoints	Design Flow	Ease of Operation	Comments
Sodium Zeolite Softener	• Replaces some cations: Ca, Mg, Fe, Ba, and Sr for Na. • Small increases in conductivity and TDS.	• Total Hardness: for influent = 50 ppm as $CaCO_3$, effluent = 0.1 • Influent of 500 ppm yields 1.0 ppm and influent of 1000 ppm yields 2.0 ppm	• Check influent and effluent for total hardness - test during service cycle and at end of a service cycle. • Check after all valves to detect hard water bypass leaks. • Check & record unit capacity between regenerations.	2-4 gpm/ft^3 2-14 gpm/ft^2	• Simple to automate and operate. Testing and monitoring also easy.	• High TDS & hardness waters have higher levels of leakage. • Effluent hardness in also influenced by the amount of salt used during regenerations. • Uses strong acid cation resin.
Sodium Chloride Dealkalizer	• Replaces some anions: HCO_3, SO_4, NO_3, for Cl. • Alkalinity reduction is about 90%. • It can significantly increase chloride, conductivity & TDS.	• Total Alkalinity: Regenerate when effluent alkalinity is >10 - 20% of the influent alkalinity.	• Check influent and effluent for total alkalinity. • Test during service cycle and at the end of a service cycle. • Check after all valves to check for any makeup water bypass leak. • Check and record unit processing capacity between regenerations.	2-4 gpm/ft^3 2-14 gpm/ft^2	• Simple to automate and operate. Testing and monitoring also easy.	• Must be proceeded by softening. • Capacity is affected by total exchangeable anions. • High influent chlorides reduces alkalinity reduction. • Higher capacity obtained when caustic is used along with salt. • Uses strong base anion resin. • Adding a small amount of caustic to regenerant brine enhances alkalinity removal.
Acid Dealkalization / Decarbonater	• Reduces alkalinity by injecting a strong acid such as sulfuric or hydrochloric acid. • Sodium zeolite softening in front of a process is common to obtain hardness reduction.	• Typically drop pH to <4.3 or to free mineral acidity (FMA) point. • Bicarbonates and carbonates are converted to carbonic acid. • Water is passed over a decarbonater to strip off carbon dioxide. NaOH is added back to raise pH and is controlled by a pH controller.	• Check pH after acid addition to achieve <4.3 pH & 0 alkalinity. • Check for CO_2 after decarbonater and before pH adjustment - should be < 10 ppm. • Test pH after NaOH addition for desired pH	Flow design will be based upon the in-line static mixer for the acid and the design limitations of the decarbonater.	• A relatively low cost alternative for highly alkaline waters. •The operation is relatively easy to operate with a good setup, but requires acid & caustic handling – and upsets can be very damaging to downstream piping and boilers.	• Excellent monitoring equipment is needed with frequent manual checks to avoid problems.
Weak Acid Ion Exchange	• Replaces hardness associated w/alkalinity with hydrogen ion – and thereby reducing HCO_3.	• Hardness in effluent should equal the influent non-carbonate hardness. • When alkalinity in the effluent exceeds 10% of the influent alkalinity the unit should be regenerated.	• Test for influent and effluent for total alkalinity & hardness. • Check after all valves to detect makeup water bypass leaks. • Check and record unit processing capacity between regenerations.	1-3 gpm/ft^3 2-8 gpm/ft^2	• Simple to automate and operate. Testing & monitoring also easy. • HCl or H_2SO_4 acid used to regenerate, so there may be need for pH neutralization of the regenerate.	• A decarbonater is commonly used after the weak acid vessel to release the carbon dioxide created. • Weak acid units are very efficient in the use of acid, around 90%. • Could be used with a cooling tower to take advantage of pH depression.
Split Stream Softening	• Lowers hardness, alkalinity, and TDS. • The alkalinity reduction is dependent upon how much water is directed to the sodium regenerated SAC unit and how much is direct to the acid regenerated SAC unit.	• Total Hardness: 0-1 ppm • Hydrogen unit alkalinity = 0, or operate with FMA. • Total alkalinity of blend: desired level below that of influent alkalinity. • Check CO_2 after decarbonater for blended water <10 ppm	• Same as for sodium zeolite softeners.	2-4 gpm/ft^3 2-14 gpm/ft^2	• Requires control to maintain the proper blend to achieve desired alkalinity.	• Applicable for high hardness and high alkalinity water.

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Separate Bed Demineralizers	• SAC resin replaces all cations for hydrogen ion. • Lowers pH by converting all salts to their acid form. • SBA resin replaces anions with OH ion resulting in low conductivity • Final effluent generally <15 µS.	• Total hardness = 0-0.1 ppm. • pH: 5-7.5 • Conductivity: <15 µS/cm • Silica: <0.2 ppm	• Check for sodium leakage in the effluent. • Check for leaking valves of raw water into effluent. • When sulfuric acid is used for regeneration a two step addition may be required to avoid calcium sulfate precipitation on the resin. • Check and record unit processing capacity between regenerations.	• SAC: 1-4 gpm/ft^3 2-14 gpm/ft^2 • SBA: 1-4 gpm/ft^3 2-14 gpm/ft^2	• Moderately easy to operate. More difficult and more operator time if manual regenerations are required. • For silica rejection a heated caustic may be used. • Final pH neutralization may be required.	• A decarbonater may be used between the cation unit and the anion unit to remove CO_2 to reduce load on the anion unit. • Does not remove colloidal silica, only reactive silica.
Mixed Bed Demineralizers	• SAC and SBA resin mixed together in the same vessel. The close proximity yields higher purity water. • Conductivity < 0.25 µS.	• Conductivity: 0.05-0.25 µS/cm • Resistivity: 4-18 MΩ-cm. • Silica: 0.01- 0.05 ppm • pH: 7	• Check influent and effluent conductivity/ resistivity and silica. • Check and record unit processing capacity between regenerations.	5-8 gpm/ft^3 10-20 gpm/ft^2	• Moderately complex to operate, but more simple when automated.	•Does not remove colloidal silica, only reactive silica. • Silica will break through first accompanied by a temporary drop in conductivity.
Continuous Deionization (Not Reversal)	• Used as a polishing step, it can get resistivity to 16 MΩ-cm. • Often based on water qualities levels of 16 MΩ-cm can be guaranteed, some values to18 MΩ-cm	• Conductivity: 0.05-0.25 µS/cm. • Resistivity: 4-18 MΩ-cm. • Silica: 0.01- 0.05 ppm • Need to monitor inlet total hardness, very low levels will result in scaling • ΔP on concentrate loop for scale buildup	• Amp draw monitoring vs. Quality • Concentrate loop ΔP • Stack unit flow • Temp	• Typically 7.5-15 gpm per stack (on EDI system) can get as high as 20 gpm on some designs • Low flow range is due to sufficient supply of water flow to cool preventing overheat. • Typical max temp 30-35°C	• Typically very hands off with proper pretreatment, neglecting pretreatment targets will cause you pain and reduced quality/flow with higher cleaning frequency. • With adequate pretreatment cleaning frequency can be every 6 months if not longer.	•Only remove ionizable material, colloidal silica not removed. • Very sensitive to hardness. • If supply water is very pure, may require brine injection on concentrate loop to help with amp draw • Should install protection cartridge filter upstream to prevent debris or solids from getting to unit, as they can not be backwashed.
Reverse Osmosis	• Rejects up to 99.9% dissolved solids, all suspended solids, and most organic compounds >70 molecular weight. • Does not reject dissolved gases. • Two pass RO can get dissolved solids to <1 ppm when the first pass feedwater is <1000 ppm. • Removes colloidal silica.	• Control tests set for each machine: feedwater characteristics and the membrane used. • Test results are used to determine when to clean membranes or to replace them. • Permeate conductivity, ΔP of each stage, normalized permeate flow. • For PA membranes, 0 ppm free chlorine.	• Test FW free chlorine, conductivity & pH. • Test, Log & Determine: feed pressure, the intermediate stage pressure/s, permeate conductivity, % salt rejection, normalized permeate flow, the ΔP's for each stage.	• Depends upon application, design and membranes used. • Flux rate: 5-8 gfd for wastewater, 8-14 for surface water, 14-18 for well water, 20-30 for second pass using permeate. • Typical % Recovery is 75%, meaning 75% of the feedwater leaves as permeate and 25% as reject or concentrate.	• Can be relatively easy to operate and automate to operate with minimal operator attention. • Cleaning frequency is dependent upon design and feedwater quality. • Frequent cleaning requirement can complicate operation. • Cleanings are triggered by 10-15% change in pressure drop, normalized permeate flow, and percent salt rejection.	• The key to successful RO applications is proper design, adequate pretreatment to yield acceptable feedwater characteristics of low good SDI, and proper monitoring followed by timely and efficient cleanings. • Pretreatment such as dechlorination and filtration may be required upstream of RO. Can be preceded by softener or, for some applications, followed by a softener.
Hot Process/ Anthracite Filter/Hot Zeolite	• Hot process reduces hardness, alkalinity, iron, manganese, silica & TDS. • When followed by a hot zeolite, final hardness is <1 ppm.	• After filters for hot process effluent, tests depend upon what chemicals are used. • If both lime & soda ash are used: • 2P-M = 5-10 ppm; • M-H = 30-50 ppm; • Hardness and Total Acidified Hardness - Hot Zeolite Softener: <1 ppm. • Sludge blanket level is controlled.	• Test total acidified hardness before and after anthracite filters to test for carryover. • Sample hot process vessels at different levels to control sludge blanket level.	• Depends upon application and design.	• Complicated and generally requires high operator attention. • Not good for intermittent operation.	• Control becomes much more difficult with changing makeup water characteristics and flow fluctuations. • Coagulants can enhance operation (e.g., sodium aluminate, polymers).

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Mixed Bed Condensate Polisher	• Removes ionic & suspended impurities. • Reduces MU water needs & saves energy since it is already heated.	• Conductivity: 0.05-0.25 µS/cm on mixed bed resin	• Resin level check & proper interface on regeneration; low water volume (just above resin) on air scour mix step to avoid rapid bed expansion and internal lateral damage, as well as promotes good mixing. • Resin sampling in high temp operation due to impact on anion resin life. • Check & record unit processing capacity between regenerations.	25-35 gpm/ft^2	• Focus on intended removal needs, many used as iron filters only, however this indicates possible treatment issues in condensate that are better addressed by treating cause not the effect. • Can operate as SAC resin only, using an amine regeneration media to avoid pH depression.	• Relatively difficult regeneration, prone to iron fouling. • Temperature limited, some resins degrade in the presence of oxygen at temperatures as low as 100°F. • There are many other types of condensate polishers such as iron filters, softeners, media filters, magnetic filters, etc.
Deaerator: Spray & Tray Types	• Removes dissolved gases such as oxygen, carbon dioxide, and hydrogen sulfide. • Raises water temperature.	• Dissolved oxygen: <7 ppb per Mfg. Specs for properly operating units (Chemetrics or Hach tests). May see 5-25 ppb for tray type & 20-40 ppb for spray type. • Indirect Testing: O_2 Scavenger residual + Scavenger usage DA Water Temp = 212 + 2*(DA psig) If scavenger usage steadily increases, to maintain boiler or FW residuals for no apparent reason (i.e., no change in steam load), then there may be issues with DA efficiency (broken nozzle, loss of trays, wrong operating temp or pressure). Also check condensate for oxygen.	• Monitor operating pressure & temp to make sure the DA is within manufacturer's operating specifications. • When testing for DO, sample at/after the storage tank. • Vent plume should be 2-3 feet high or with a 4-6 inch clear gap between the end of the vent pipe & beginning of the visible plume. • DA dome water temp should be within 4°F of the steam temp for the operating pressure; & the storage section should be within 5°F of the steam temp for the operating pressure.	• Depends upon style/type of DA. • Spray and Tray type DA's will have the spray nozzles and trays/fill located in a small chamber above the storage vessel. • Spray types tend to spray directly into the storage vessel.	• Easy to operate. • Should record operating temperature and pressure on a routine basis. • DA efficiencies should be determined for each account.	• Deaerators are typically elevated in boiler rooms to help create head pressure on pumps located lower. This allows hotter water to be pumped without vapor locking should some steam get into the pump. • Sometimes DA's are lined to help prevent corrosion. • Vent condensers can be used to improve DA efficiency. • Oxygen scavenger feed point is to the DA water storage section. • pH control may be required in FW tanks for high purity makeup applications.
Economizers	• A boiler economizer is a heat exchanger that heats feedwater, return water and/or other process fluid using hot stack gas from the boiler. • Capturing stack gas heat reduces fuel requirements for the boiler and equates to money savings as well as lower emissions due to the higher operating efficiency.	• Dissolved oxygen: 0 ppb • An oxygen scavenger residual is desired.	• Visual inspection during outages: check for cold end corrosion.	• There are various designs available depending on the manufacturer. • All are heat exchange vessels with flue gas on one side and FW/process fluid on the other.	• Relatively easy to operate.	• Cold end corrosion is an issue with these units. This occurs when temps drop to the acid dew point: 240-280°F, depending on sulfur content in stack gas. • Oxygen scavenger should be feed upstream w/a positive residual carried through the unit.

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Feedwater Heaters	• Preheating feedwater reduces the amount of energy needed to make steam and, thus reduces plant costs of operation. It also improves the thermodynamic efficiency of a system and helps to avoid thermal shock to the boiler metal when FW is introduced back into the steam cycle. • Used primarily in the power industry. • Typical FW heater designs are open or closed. A closed design is similar to a shell and tube heat exchanger, with turbine extraction steam and hot drains supplying the shell side and boiler FW on the tube side. An open design is a direct-contact heat exchange in which extracted steam is allowed to mix with the feedwater.	• Eddy current testing for corrosion. • Sulfite testing may be conducted to ensure adequate chemical deaeration.	• Monitor feedwater temperatures. • Visually inspect during outages.	• Depends upon the size and type of FW heater. • Typical closed design is similar to a shell and tube heat exchanger	• Units relatively easy to operate.	• Feedwater heaters are not a replacement for deaerators – that both heat the water and deaerate the water. • FW heaters primarily add heat to feedwater w/minimal mechanical deaeration taking place.