

Softening in steam boiler applications

Removing hardness minerals will provide optimum efficacy, efficiency and reduce operating costs.

By Mario C. Uy

Minerals such as calcium and magnesium that are found naturally in water are detrimental to certain applications like steam boilers since they will precipitate and deposit on heat transfer surfaces. Acting as an insulator, the deposit reduces heat transfer efficiency.

If the deposition is severe, it could cause the steam boiler to fail, shutting down the plant production or other similar consequences. Severe deposition has also been known to cause fire and boiler explosion.

The latter poses a liability issue and

an even great threat to the safety of the employees and the community. Insurance companies and local governments have been known to condemn boilers due to severe deposition.

In short, hardness minerals can cost dearly, so they should be mitigated. One mitigation method is via softening.

The best method is to remove most of the hardness mechanically, then to treat any residual hardness chemically.

Such a combination has proven to be the best mitigation method in terms of optimum efficacy, efficiency and operating cost.

Softener sizing

The most widely used mechanical softening equipment is a water softener. There are many factors to consider in choosing a softener, but the most important one is to specify the right size.

If the softener is undersized, the water flow will be restricted and the pressure after the softener will drop considerably.

If the softener is oversized, the water will only flow through a portion of the bed, causing a channeling effect. The resin in the water path will expire while the rest will be partially unused, resulting in short throughput, frequent regen-

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Figure 1:
Efficiency loss from scale build-up

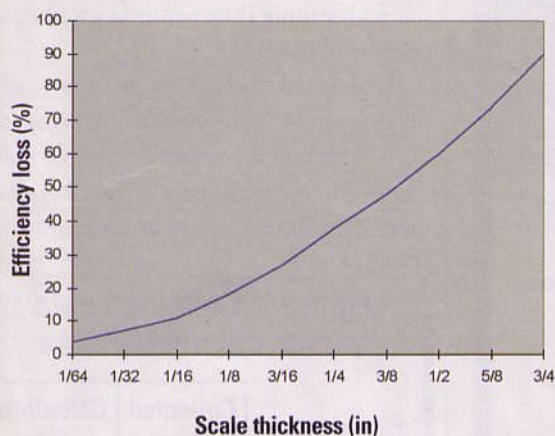


Figure 2: Single unit versus multiple unit softener

	Single unit	Multiple units
Supply of soft water	Supply of soft water is disrupted during regeneration	Continuous, uninterrupted supply of soft water
Peak flow	Requires a larger unit to meet peak flow	Smaller units can be combined to meet peak demand
Service disruption during repair	Supply of soft water is disrupted during repair	When only one unit is down, the remaining unit(s) can still supply soft water
Variable flow	Can handle a narrow range of flow rate	Can handle a wider range of flow rate; some units can be placed on stand-by during low flow and be placed back in service during high flow

eration, possible hardness leakage and excessive salt usage.

More choices

Other factors to consider in choosing a softener are:

- Single unit or multiple units
- Time or volume initiated regeneration

A design plan

Designing the right softener for a steam boiler application should start with a plant survey, collecting data such as water usage, flow rates and hours of operation, etc. However, some of this data may not be available, so they need to be derived by calculations.

See Figure 3 (page 60) for a sample exercise showing how to do so, for a 200 horsepower (Hp) steam boiler, running at 80 percent load, 24 hours a day, 80 percent condensate return, assuming an even and consistent flow rate and using make-up water with 9 grains per gallons of hardness.

Behind the calculations

Below are the bases, formulas and rules of thumb used for the above calculations.

- 1 boiler Hp = 34.5 lbs steam/hr
- Steam rate = Boiler Hp x 34.5
- 1 gal = 8.33 lbs
- Feedwater rate = Steam rate x (cycles/(cycles-1))
- Blowdown rate = Steam

rate/(cycles-1)

- Make-up rate = Steam loss rate + blowdown rate
- 1 ft³ of resin => 30,000 grain hardness @15 lbs salt/ft³

• 1 ft³ of resin => 25,000 grain hardness @10 lbs salt/ft³

• 1 ft³ of resin => 20,000 grain hardness @5 lbs salt/ft³

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- Minimum flow required => 0.5 gpm per ft³ of resin
- Maximum flow required => 10 gpm per ft³ of resin

(As water boils, its minerals are increasingly concentrated. Cycles of concentration is a measurement of how many times the minerals have concentrated in the boiler water compared to

Figure 3: Collected data versus calculated data

	Collected data	Calculated data
Hp design	200	
% load	80%	
Hp actual		160
Steam rate, actual, lbs/hr		5,520
% condensate return	80%	
Steam loss rate, lbs/hr		1,104
Cycles	10	
Feedwater rate, lbs/hr		6,133
Blowdown rate, lbs/hr		613
Make-up rate, lbs/hr		1,717
Make-up rate, gal/hr		206
Make-up rate, gal/day		4,944
Make-up rate, gpm		3.43
Hardness level, gpg	9	
Hardness level, gpd		44,496
Resin, ft ³ (1 regeneration/day @ 10 lbs salt/ft ³) (or 2 ft ³)		1.78

the feedwater. In essence, cycles = boiler water minerals/feedwater minerals.

The easiest, quickest and most popular, but not the most accurate, measurement of minerals is TDS. It is important to know the cycles because it determines the blowdown rate, and as such, the make-up rate — crucial information for softener sizing.)

An alternating system

Considering the critical nature of a steam boiler application, the right softener for this example should be an alternating (dual) softener system to ensure a continuous supply of soft water. The calculation shows that we need 2 ft³ of resin per tank.

To produce sufficient throughput for the day, the salt setting should be at least 10 lbs/ft³. At this setting and under ideal conditions, each tank can process 5,555 gallons of water before expiring, which is more than a day's demand of 4,944 gallons, calculated as follows:

$25,000 \text{ grain/ft}^3 \times 2 \text{ ft}^3 \times 9 \text{ grain/1 gal} = 5,555 \text{ gallons}$

Because each tank can supply greater than a day's demand, it would be cost efficient to choose a volume initiated regeneration (VIR) to make use of the full capacity. Furthermore, in real situations, boiler load is always changing, as is the make-up rate. In which case, a VIR is even better since it will adjust to the changing water usage, while a time initiated regeneration (TIR) will not.

Testing

The softener should be tested for hardness in parts per million (ppm), not in grains per gallon (gpg). There are 17.1 ppm to 1 gpg.

Since the ideal goal for a steam boiler application is zero hardness, the ppm method is preferred. Initially, the softener should be tested enough to ensure soft water production throughout its service cycle.

Depending on the test results, the regeneration settings may have to be readjusted to account for actual conditions.

Thereafter, the softener still has to be tested regularly as a redundant check against any mechanical failure on the softener.

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