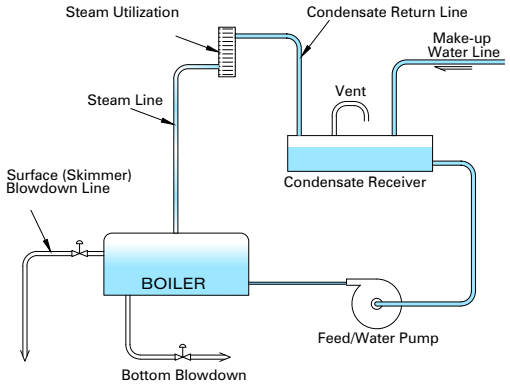
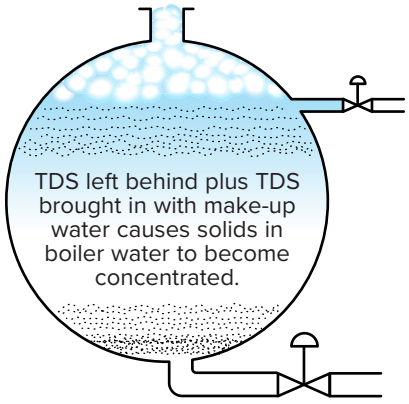
QUALITY WATER FOR STEAM BOILERS
STEAM PRODUCTION

Most boilers have several things in common. Usually at the bottom is a firebox or combustion chamber (furnace) where the cheapest or most available fuel is fed through a burner to form a flame. The burner is controlled automatically to pass only enough fuel to maintain a desired steam pressure. The flame or heat is directed and distributed to the heating surfaces which are usually tubes, flues or coils of fairly small diameter. In some designs the water flows through the tubes or coils and the heat is applied to the outside. These are called watertube boilers. In other boilers, the tubes or flues are immersed in the water and the heat passes through the inside of the tubes. These are fire-tube boilers. If the water is subjected to the heated gases more than once the boiler is a “two pass”, “three pass”, or “multiple pass” boiler.



The heated water or steam rises to the water surface, vaporizes, and is collected in one or more chambers or “drums”. The larger the drum capacity, the greater is the ability of the boiler to produce large, sudden demands of steam. At the top of the steam drum is an outlet or “steam header” from which the steam is piped to the points of use. At the top of the firebox is a metal or brick chimney or “stack” which carries away the combustion by-products and varying amounts of unused fuel. At the bottom of the boiler, and usually at the opposite end from the firebox, is an outlet valve called a “blowdown”. It is through this valve that most of the dirt, mud, sludge and other undesirable materials are purged from the boiler.



Attached to the boiler are a multitude of safety controls to relieve the pressure if it gets too high, to shut off the burner if the water gets too low or to automatically control the water level. A water column (sight glass) is provided so that the interior water level is visible to the operator.

EQUIVALENTS:
1 Boiler Hp hr = 4 gal of water evaporated per hr.
1 lb evaporation per hr = 0.12 gal evaporated per hr.
1 gal evaporation per hr = 8.34 lbs of water per hr.
1 Boiler Hp = 33.36 pounds of water per hr.

BOILER FEED WATER

The water for the boiler is usually stored in a “make-up” tank so that a sufficient volume of water is available for larger than usual demands. A constant level is maintained by a float valve similar in principle to the tank type toilet float control. A high pressure pump pulls the water from the make-up tank and pushes it into the boiler. Because most boilers operate at pressures higher than those of the water supply, the pump must raise the feed water pressure to somewhat above that of the boiler operating pressure.

Clean steam is pure water in the form of gas. When it is cooled and condensed, it is pure water and it is referred to as “condensate”. As it is condensed into water it contains considerable heat which can be utilized. It is nearly perfect boiler make-up or feed water since it has been stripped of dissolved minerals and foreign matter in the evaporation process.

Whenever possible, condensate is returned to the boiler and is collected in a tank called a “condensate receiver”. When condensate is recovered, the receiver may also perform the functions of the make-up tank. In some installations, condensate return may supply as much as 99% of the feed water and the higher the percentage of condensate the less water treatment is required. Other installations may use 100% make-up if, for various reasons, the condensate cannot be recovered, or if it is badly contaminated.

BOILER PRESSURES

The temperature and pressure at which a boiler operates have a definite relationship as shown in the following table:

BOILING POINT OF WATER AT VARIOUS PRESSURES

TEMPERATURE °F	TEMPERATURE °C	PRESSURE P.S.I
212	100	0
300	149	52
400	204	232
500	260	666
600	316	1529
700	371	3080
705	374	3200

At normal atmospheric pressure, water boils at 212° F (100° C); at higher pressures the boiling point increases, reaching a maximum of 705° F (374° C) at a pressure of 3200 pounds per square inch. Above this temperature water cannot exist as a liquid.

BOILER RATINGS

Boilers are rated by the amount of steam they can produce in a certain period of time at a certain temperature. The largest units produce 1,000,000 pounds of steam per hour. Boiler are rated at one horsepower for every 34.5 pounds of water it can evaporate per hour. Another definition is one horsepower for every 10 square feet of heating surface in a water-tube boiler or 12 square feet of heating surface in a fire-tube boiler.

SOFTENER SIZING

In the process of selecting a proper water softener for boiler feedwater treatment, several areas of sizing must be reviewed. This basically entails the need to obtain a water analysis, the boiler horsepower and information pertaining to the recovery of the steam. Each of these areas will be addressed prior to the process of actually selecting a softener.

WATER HARDNESS ANALYSIS

Hardness is made up of calcium and magnesium. Hardness within natural waters will vary considerably, depending upon the source from which water is obtained. Sections of the country that have limestone formations generally have a high hardness content in the water. Since surface waters are diluted by rainfall, well water in the same area will normally have a much higher hardness than surface water since the flow is underground over rock layers.

The degree of hardness at any location should never be assumed. Every effort should be made to obtain a water analysis at the site of installation. This will assure accuracy in your selection process.

In order to determine the size of a water softener, the first procedure in the selection process is to determine the amount of hardness. Many of the water analysis reports express total hardness in parts per million (PPM). The PPM expression must be converted to grains per gallon (GPG) in order to size a softener system. To convert the hardness expressed in PPM to GPG, divide PPM by 17.1.

EXAMPLE: A report of total hardness of 342 PPM is converted as follows; 342 PPM ÷ 17.1 = 20 GPG of hardness.

DETERMINING MAKE-UP VOLUME

In order to determine the amount of water used to feed a boiler, calculations are necessary to convert the rating of the boiler to the maximum amount of make-up in gallons. Boiler ratings are provided in several forms. However, all can be and should be converted to a common factor of horsepower. For each horsepower, a feed water volume of 4.25 gallons per hour is required. To convert other boiler ratings to horsepower, the following table should be referenced.

Boiler Ratings	Factors Used to Convert to Horsepower
Pounds of steam per hour	Divide by 34.5
BTU's	Divide by 33,475
Square foot area — water tube	Divide by 10
Square foot area — fire tube	Divide by 12

Upon determining the boiler horsepower rating, two additional factors must be known in order to obtain the net amount of make-up water required in a 24 hour period. The first of these is to determine the amount of condensate return to the boiler. The amount of the condensate returned to a boiler system is vital information in selecting a water softener. This information is generally known by the boiler operator or design engineer. The amount of condensate returned is subtracted from the maximum amount of boiler water make-up volume calculated from the horsepower rating. The net amount referred to is the variance between maximum make-up less the amount of condensate returned to the system.

A very accurate method in determining the net amount of makeup water per hour, or the percent of condensate returned, can be simply calculated on existing operations by comparing a water analysis of the water from the condensate receiver tank and the raw makeup water. In comparing these two waters one can be very accurate in the amount of condensate returned to the system.

EXAMPLE: A condensate receiver tank with a water containing 300 PPM of total dissolved solids (TDS) and a known factor of 600 PPM TDS in the raw water make-up supply would indicate a 50% condensate return. As described earlier in this publication, condensate is near perfect water (zero TDS) when it enters the condensate receiver. Therefore, when the raw water supply of 600 PPM TDS is diluted with 0 PPM TDS water at a one to one ratio, the result would be 300 PPM TDS or a dilution of 50% or a condensate return of 50%.

The final step in our gathering of data for our softener selection process is to obtain the number of hours in a day the boiler is operated. This is not only important in order to determine total make-up volume, it is also information required to determine the design of our softener system. A boiler operating 24 hours per day will require soft water at all times. Therefore, the design will require the use of two units. On systems operating 16 hours per day, the use of a single softener will meet the needs of the operation. Typically the time required to recharge a softener is less than three hours.

SOFTENER SELECTION

We are now ready to proceed with a typical approach to selecting a water softener. Information is first gathered on all of the aspects of the boiler system discussed in this section. A listing of all our design factors should first be assembled. The following represents a typical boiler plant from which we can calculate the demand for a softener.

(1) DETERMINE WATER HARDNESS

Analysis received or taken is in parts per million (PPM). Convert to grains per gallon (GPG).

342 ÷ 17.1 = 20 GPG.

(2) DETERMINE BOILER HORSEPOWER

Boiler rating is in pounds per hour of steam. Convert to Horsepower.

3,450 pounds per hour ÷ 34.5 = 100 H.P.

(3) DETERMINE MAXIMUM GALLONS PER HOUR MAKE-UP

Boiler rating is 100 horsepower.
Convert H.P. to gallons per hour make-up.

100 H.P. x 4.25 gallons per hour make-up.

(4) DETERMINE AMOUNT OF CONDENSATE RETURNED TO SYSTEM AND CALCULATE NET MAKE-UP REQUIREMENT

Make-up per hour is 425 gallons.
Condensate returned is 50% or 213 gallons per hour.

425 - 213 = 212 net gallons make-up per hour.

(5) DETERMINE TOTAL DAILY MAKE-UP REQUIREMENTS

212 gallons net make-up per hour.
Boiler system operates 16 hours per day.

212 gallons per hr. x 16 hrs. = 3,392 gallons per operating day.

(6) DETERMINE TOTAL GRAINS OF HARDNESS TO BE REMOVED DAILY

3,392 gallons per day with a hardness of 20 grains per gallon.

3,392 gallons x 20 GPG = 67,840 grains of hardness needed to be removed daily.

The answer in our sixth step of 67,840 grains of hardness to be removed daily, brings us to our final approach in selecting a water softener. Due to the nature of the importance of obtaining soft water for the boiler feed water, we must allow for a margin of error in our sizing process. This margin is commonly 15%. Multiplication of the 67,840 grains per day by 1.15 results in a total removal demand of 78,016 grains per day needed to be removed.

COMPENSATED HARDNESS:

When sizing water conditioning equipment, the hardness should be based on compensated hardness. Compensated hardness takes into consideration minerals and other factors that will reduce the softening capacity of a softener.

These items cannot be picked up in a standard hardness test. To arrive at compensated hardness multiple the figure on the right by the hardness in grains per gallon.

YOUR TEST HARDNESS	MULTIPLY BY	COMPENSATED HARDNESS
1-20	1.1	=
21 - 40	1.2	=
41-70	1.3	=
71-100	1.4	=
101- Plus	1.5	=

ALWAYS DETERMINE BOTH (1) FLOW RATE AND (2) CAPACITY TOTAL IN GRAINS

CONTINUOUS HARDNESS LEAKAGE
in ppm as $CaCO_3$

	SALT DOSAGE PER CU. FT		
TDS*	6lbs	10lbs	12lbs
250	1.25	.6	.2
500	5	2.5	.8
750	12	6	1.75
1000	20	10	3
1500	45	23	7
2000	-	40	13
2500	-	-	20
3000	-	-	30

*Raw Water TDS as $CaCO_3$

TERMS DEFINED:

TERM	GRAINS PER GAL	MILLIGRAMS PER LITER
Soft	1.0 or less	17.0 or less
Slightly Hard	1. 0 to 3.5	17.1 to60
Moderately Hard	3.5 to 7.0	60 to 120
Hard	7.0 to 10.5	120 to 180
Very Hard	10.5 or over	180 or over

Use this chart to determine softener model /size for a given hardness and given number of people in household, the setting required for regeneration cycle, and optional meter setting (gallons). See note below chart for KEY to reading the chart.

Hardness (Grains per Gallon)	Number of People Using Softened Water in Household							
	1 75gal	2 150gal	3 225gal	4 300gal	5 375gal	6 450gal	7 525gal	8 600gal
1 - 5	15k 12 1700	15k 12 1600	15k 6 1500	15k 6 1500	15k 4 1400	30k 6 3500	30k 4 3400	30k 3 3300
6-10	15k 12 800	15k 4 750	15k 3 650	30k 4 1500	30k 4 1400	30k 3 1300	30k 3 1200	45k 4 2100
11-15	15k 6 500	15k 3 400	30k 4 950	30k 3 900	30k 3 800	45k 3 1300	45k 3 1200	45k 2 100
16-20	15k 4 375	15k 2 300	30k 3 675	45k 4 1100	45k 3 1000	45k 3 900	60k 3 1200	60k 2 1100
21-25	15k 4 250	30k 4 600	30k 3 500	45k 3 800	45k 2 700	60k 3 100	60k 2 900	90k 3 1600
26-30	30k 6 450	30k 3 400	45k 3 550	45k 2 500	60k 2 700	90k 3 1200	120k 3 1600	120k 3 1500
31-35	30k 6 400	30k 3 350	45k 3 550	60k 3 700	90k 4 1200	90k 3 1100	120k 3 1500	120k 3 1400
36-40	30k 4 400	45k 4 525	45k 2 450	60k 2 600	90k 3 975	120k 3 1350	120k 3 1200	- - -
41-45	45k 6 500	45k 3 400	60k 3 500	90k 3 900	90k 3 800	120k 3 100	- - -	- - -
46-50	45k 6 500	60k 4 600	90k 4 950	90k 3 850	120k 3 1100	- - -	- - -	- - -

KEY TO EACH HORIZONTAL SEGMENT OF CHART:
First line in row = Softener Size (THOUSANDS OF GRAINS) Model
Second line = Number of DAYS between regeneration cycle (where timer is installed)
Third line = Meter setting (GALLONS used between regeneration) where optional meter is installed.

Meter settings based on softener capacities at minimum brining (6 lbs / cu. ft.)