Deaerated feedwater is pumped into a boiler, converted to steam, travels through the steam distribution system to do work, changes phase from gas to a liquid, and forms condensate. If the condensate return system is not functioning or the condensate is contaminated, it may end up being dumped down the drain instead of being returned to the boiler system. Sending condensate down the drain is the equivalent to pouring money down the drain because condensate can be a source of high purity, high temperature makeup water for the boiler system. Being able to calculate the dollar value of condensate can help justify condensate recovery projects such as polishers, pump repairs, new piping, and upgrades.

**Condensate Value**

The value of condensate can be broken down into the following categories:

- Water cost
- Sewer cost
- Fuel cost
- Chemical cost
- Pretreatment costs
- Blowdown cost

**Calculation**

As a basis for both current and future condensate recovery projects and ideas, it is recommended to come up with a condensate value based upon 1,000 gallons (e.g., $16.81/1,000 gallons condensate). This serves two purposes:

1. Condensate recovery values can easily be calculated. For example, if a condensate receiver pump is broken and it is estimated that 1,000,000 gallons/year of condensate (or 1.9 gpm) is being dumped down the drain at a condensate value of $16.81/1,000 gallons, the value of this wasted condensate is $16,810/year. This could pay for the pump repair.

2. It puts the condensate value into conceptual terms. The answer will be in dollars and cents and applied to a volume that most people can easily visualize.
**Water & Sewer Cost**

Water and sewer costs are typically easy to come by in a facility. If well water is being used, take into account the pumping costs. Water and sewer costs are typically reported in 1,000 gallon increments. If not, convert the cost to dollars per 1,000 gallons. (Note: The density of water is 8.335 lb/gallon, and there are 7.481 gallons/cubic foot.) If condensate is being dumped down the drain, then sewer costs are certainly a part of the condensate value. The following example and all subsequent examples are interrelated to demonstrate a typical calculation of condensate value, one step at a time.

**Example:**

Water cost = $1.50/1,000 gallons; Sewer cost = $3.00/1,000 gallons

Condensate Value for 1,000 gallons

\[
= (\frac{1.50}{1,000 \text{ gallons}} + \frac{3.00}{1,000 \text{ gallons}}) \times 1,000 \\
= $4.50 \text{ per 1,000 gallons of condensate recovered}
\]

**Fuel Cost**

Condensate that is not returned to the boiler system must be replaced with makeup water. Fuel cost is based upon the amount of energy it takes to heat makeup water up to the temperature of the unrecovered condensate. It takes 1 BTU to raise 1 pound of water by 1° F. To determine how many BTU’s are required to heat 1 pound of makeup water to the condensate temperature, simply subtract the makeup temperature from the condensate temperature. To base the value on 1,000 gallons of condensate as recommended previously, multiply the BTU/lb calculated by 8,335 pounds. (Note: 1,000 gallons of water weighs 8,335 pounds.) This is the theoretical amount of energy required to heat the makeup water.

**Example:**

Condensate Temperature = 200° F, Makeup Temperature = 55° F,

\[
\text{BTU/lb required } = 200^\circ \text{ F} - 55^\circ \text{ F} \\
= 145 \text{ BTU/lb}
\]

\[
\text{Theoretical Heat Energy Required } = 145 \text{ BTU/lb } \times 8,335 \text{ lb/1,000 gallons} \\
= 1,208,575 \text{ BTU/1,000 gallons of recovered condensate}
\]

Boiler efficiency must not be forgotten though. Not all the energy available in the fuel is transferred to the water to make steam. Some energy is lost out the exhaust stack with the combustion gases, some is lost as radiated heat,
and some is lost with blowdown. If the boiler efficiency of converting the energy content of fuel into steam is not known, a conservative estimate of 80% (or 0.80) can be used. Divide the BTU/lb required that was just calculated by the boiler efficiency as a fraction. This is the actual amount of energy required to heat the makeup water.

**Example:** Heat Energy Actually Required = 1,208,575 BTU/1,000 gallons ÷ 0.80 = 1,510,719 BTU/1,000 gallons of recovered condensate

To calculate the amount of fuel needed, divide the energy required by the fuel energy value. Then multiply the fuel required by the cost of the fuel. Table 1 lists the fuel energy content of common fuels.

<table>
<thead>
<tr>
<th>Table 1: Fuel Energy Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
</tr>
<tr>
<td>Coal – Anthracite</td>
</tr>
<tr>
<td>Coal – Bituminous</td>
</tr>
<tr>
<td>Coal – Sub-bituminous</td>
</tr>
<tr>
<td>Coal – Lignite</td>
</tr>
<tr>
<td>No. 2 Burner Fuel Oil</td>
</tr>
<tr>
<td>No. 4 Heavy Fuel Oil</td>
</tr>
<tr>
<td>No. 5 Heavy Fuel Oil</td>
</tr>
<tr>
<td>No. 6 Heavy Fuel Oil 2.7% Sulfur</td>
</tr>
<tr>
<td>No. 6 Heavy Fuel Oil 0.3% Sulfur</td>
</tr>
</tbody>
</table>

**Example:** From Table 1, natural gas has a fuel energy value of 1,000 BTU/cubic foot.

Cost of Natural Gas = $6.00/1,000 cubic feet

Fuel Required = (1,510,719 BTU/1,000 gallons) ÷ 1,000 BTU/cubic foot
= 1,511 cubic feet/1,000 gallons of recovered condensate.

Fuel Cost = (1,511 cubic feet/1,000 gallons) * $6.00/1,000 cubic foot
= $9.07/1,000 gallons of recovered condensate
Chemical Cost

Condensate line treatments such as neutralizing amines are the primary chemicals found in condensate. Filming amines are also used, but since they are typically non-volatile chemicals, they are not recycled back into the steam lines when the condensate is recovered and essentially add zero value. With the concentration and unit price of the treatment chemical, the chemical cost can be calculated.

Example: 5 ppm morpholine; 5 ppm DEAE; 12.5 ppm total product dosage (40% morpholine and 40% DEAE) at a cost of $1.50/lb

\[ \text{Pounds Required} = \left( \frac{\text{ppm desired}}{100} \right) \times \left( \frac{\text{volume}}{1,000} \right) = \left( \frac{12.5 \text{ ppm}}{120} \right) \times \left( \frac{1,000 \text{ gal}}{1,000} \right) = 0.1 \text{ lb} \]

\[ \text{Chemical Cost} = 0.1 \text{ lb} \times \$1.50/\text{lb} = \$0.15 \text{ per 1,000 gallons of recovered condensate} \]

Pretreatment Cost

It takes pretreatment equipment to produce water of high enough quality to replace the condensate that is not being recovered. Boiler systems may have water softeners, dealkalizers, reverse osmosis, deionization, etc. Each of these treatment schemes has a cost associated with every gallon of water produced. This cost should be calculated so the value of recovered condensate can be determined.

Example: A boiler system uses a water softener to remove hardness from makeup water.

\[ \text{Makeup Total Hardness} = 146 \text{ ppm} \]
\[ = \frac{146 \text{ ppm}}{17.1} = 8.54 \text{ grains/gallon} \]

\[ \text{Regeneration Salt Dosage} = 12 \text{ lb/cubic foot resin} \]

\[ \text{Regeneration Capacity} = 25,000 \text{ grains/cubic foot resin} \]

\[ \text{Salt Cost} = \$0.06/\text{lb} \]

1,000 gallons of water has 1,000 * 8.54 grains/gallon = 8,540 grains of hardness

If it takes 12 lb of salt to achieve 25,000 grains of regenerated capacity per cubic foot resin, then it takes (8,540/25,000) * 12 lb = 4.10 lb salt for 1,000 gallons of water.

\[ \text{Salt Cost} = 4.10 \text{ lb} \times (\$0.06/\text{lb}) = \$0.25 \text{ per 1,000 gallons condensate recovered} \]
Rule of thumb: Softener regeneration requires approximately 60 gallons/cubic foot resin.

If it takes 1 cubic foot of regenerated resin to remove 25,000 grains of hardness, then it takes \((8,540/25,000) \times 1\) cubic foot = 0.34 cubic feet of resin to soften 1,000 gallons of water.

- Water Required = \((60 \text{ gallons/cubic foot resin}) \times (0.34 \text{ cubic feet resin}) = 20.4 \text{ gallons}\)
- Water & Sewer Cost = \((20.4 \text{ gallons}) \times ($1.50/1,000 \text{ gallons} + $3.00/1,000 \text{ gallons}) = $0.09\)
- Total Regeneration Cost = $0.25 + $0.09 = $0.34 to replace 1,000 gallons of condensate

**Blowdown Cost**

If all that is desired is the direct value of each gallon of condensate, this has now been achieved. This alone may be enough to justify the cost to recover the condensate.

**Example:** Total Condensate Value = $4.50 + $9.07 + $0.15 + $0.34 = $14.06 per 1,000 gallons

However, returning more condensate back to the boiler system can have the additional benefit of improving feedwater quality, increasing the number of boiler cycles of concentration, and reducing the amount of blowdown. Blowdown savings are a real, quantifiable savings that can be factored into the overall condensate value as well. Costs included in the value of blowdown are water, sewer, fuel, chemicals, and pretreatment. These are very similar to the costs directly associated with the condensate. Blowdown savings require more complex calculations that require iterations that cannot be adequately detailed in this article. Instead, an example will be evaluated to show how much value blowdown savings can add. Table 2 shows the effects that recovering 1,000 gallons of condensate can have on a typical boiler system at various percent blowdowns and percent condensate recoveries. As Table 2 and the following example show, blowdown savings may be worth the time and effort it takes to calculate.

**Example:** Using the system described in Table 2, if the system currently has 50% condensate return and is running at 5% blowdown, 105 gallons of blowdown (BD) is saved by returning 1,000 gallons of condensate to the system.

System Parameters: Boiler Pressure = 150 psig; Boiler Efficiency = 80% = 0.80;
BD Enthalpy = 338.47 BTU/lb;  
Makeup Conductivity = 400 mmhos;  
Condensate Conductivity = 10 mmhos;  
Makeup Temperature = 55° F;  
Boiler Chemical = $0.84/lb at 160 ppm dosage; Boiler Liquid Sulfite = $0.45/lb at 110 ppm total dosage; assume the same water, sewer, pretreatment, and fuel costs used in previous examples

BD Water Cost = 105 gallons * ($1.50/1,000 gallons) = $0.16
BD Sewer Cost = 105 gallons * ($3.00/1,000 gallons) = $0.32
Pretreatment Cost = 105 gallons * ($0.34/1,000 gallons from previous example) = $0.04
Fuel Cost = (338.47 BTU/lb – (55-32)BTU/lb)*(105 gal)*(8.335 lb/gal)*(1/0.80) *(1 cubic foot/1,000 BTU)*($6.00/1,000 cubic foot) = $2.07
Boiler Chemical Cost = (160 ppm/120)*(105 gallons/1,000)*($0.84/lb) = $0.12
Boiler Liquid Sulfite Cost = (110 ppm/120)*(105 gallons/1,000)*($0.45/lb) = $0.04

Total BD Savings = $0.16 + $0.32 + $0.04 + $2.07 + $0.12 + $0.04 = $2.75 savings as a result of recovering 1,000 gallons of condensate

Summary
As has been shown in this article, the value of condensate can be quite substantial when all the effects of unrecovered condensate are taken into consideration.

Example:  
Total Condensate Value = $4.50 + $9.07 + $0.15 + $0.34 + $0.16 + $0.32 + $0.04 + $2.07 + $0.12 + $0.04 = $16.81 per 1,000 gallons of condensate

Figure 1 illustrates the impact each component of the total condensate value calculated in the previous examples. Fuel is the largest contributor at 54%, followed by sewer at 18%, and then blowdown. Blowdown savings were 16% of the total condensate value further showing the impact that recovering condensate can have on the overall boiler system.
Figure 2 shows the breakdown of savings for the blowdown alone. As expected, fuel was the major contributor at 75%, followed by sewer at 12%. Condensate is a very valuable resource that is designed to be recovered and used back in the boiler system. When pumps break, condensate lines leak, contamination occurs, or condensate return systems break down, often times an easy solution is to dump the condensate to a drain. This is the equivalent to pouring money down the drain that may quickly justify the expense it takes to recover the condensate once again.
Table 2: Gallons of Boiler Blowdown Saved per 1,000 Gallons of Condensate Recovered

**System Parameters:** 100,000 lb/hr Boiler; MU=400 $\mu$mhos
Condensate = 10 $\mu$mhos; Boiler Efficiency = 80%

<table>
<thead>
<tr>
<th>Current Percent Condensate Return (based on feedwater)</th>
<th>Current Percent Blowdown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
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<tr>
<td>0%</td>
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<td>80%</td>
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