BOILERS

REDUCING FUEL COSTS IN A STEAM-GENERATING SYSTEM

With rising fuel and electrical costs, energy savings and water conservation are more important to a facility's economics than ever before. Energy costs typically account for as much as 60% of a facility's overhead, and the largest energy consumer is often the steam generating plant. Therefore, economics demand that attention must be focused on ways of improving the overall efficiency of the steam-generating equipment. This article will review methods of reducing fuel cost by minimizing boiler water blowdown rates. The article will also review calculations to determine fuel costs at current, versus proposed blowdown rates, as well as present an example of how to directly calculate fuel savings.

Boiler Blowdown

Every boiler has limits of how concentrated the boiler water can become until problems such as scale or carryover occur. A quantity of water (boiler blowdown) must continuously or periodically be removed from the boiler to regulate the concentration of impurities. There are typically two types of boiler water blowdown: bottom and surface. Bottom blowdown is a manual operation designed to remove sludge, particulates, and/or any solids settled out of the boiler water. Surface blowdown is typically a continuous discharge of dissolved solids that accumulate at the boiler water surface. The discharged boiler water has a significant heat value that is not being used to produce steam. If the amount of blowdown can be reduced, fuel, energy, water, and treatment chemicals will be conserved.

One way of evaluating boiler blowdown reduction is as an increase in the number of times the feedwater can concentrate in the boiler (commonly referred to as *cycles of concentration* or *cycles*). Since boiler blowdown (BD) is expressed as a percentage of the total feedwater (and is calculated as the reciprocal of the number of times the feedwater can be concentrated), the more the feedwater can cycle in the boiler, the less blowdown is needed. This is illustrated in Equation 1.

$$BD = 1 \div \text{Cycles} \qquad \text{Eq. 1}$$

Where:
BD = blowdown
Cycles = cycles of concentration

Equation example. If the feedwater can be cycled 10 times, the blowdown rate is 1 ÷ 10 = 0.10, or 10%. If the cycles can be increased to 20, the blowdown rate is 1 ÷ 20 = 0.5, or 5.0%. In this example, we have increased the percentage of feedwater converted to steam from 90% to 95%. This correlates to substantial fuel and water savings.

Minimizing Boiler Blowdown Rates

Automatic blowdown control. One of the easiest methods of reducing boiler blowdown is by the installation of an automatic blowdown control system. The advantage of automated blowdown control versus manual blowdown control is that the volume of water discharged from the system is precisely correlated to the dissolved solids present. This approach contrasts with manual blowdown control where it is extremely difficult to optimize the blowdown rate.

An automated blowdown control system achieves optimum control of the boiler water chemistry. Boiler water discharge is directly correlated to the amount of total dissolved solids (TDS) by using conductivity probes. Conductivity is a reliable indicator of dissolved ions in the boiler water, with increasing conductivity equivalent to increasing TDS. The conductivity reading is compared to the programmed set-point of a conductivity controller, thereby activating the blowdown valve. The automated blowdown control system maximizes the level of solids maintained in the boiler and this directly translates to efficient boiler operation. This is illustrated in Figure 1. In the figure, *A* = the average

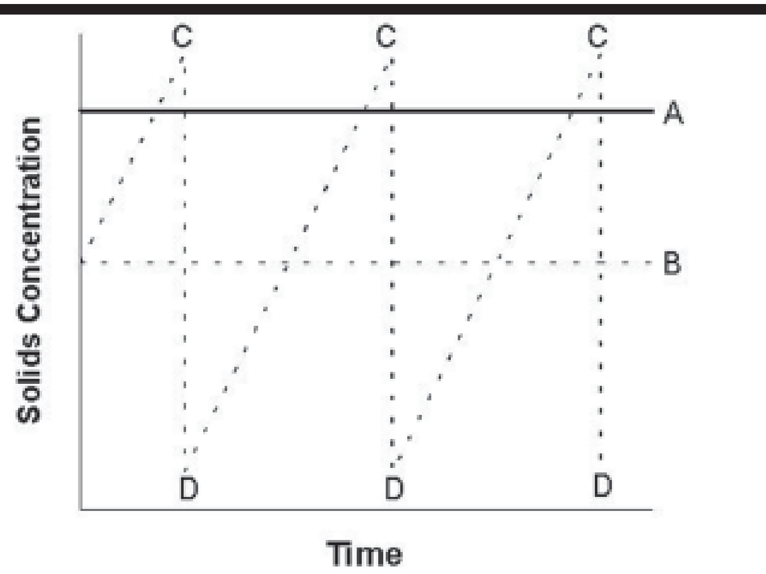

Figure 1. Tracking of manual versus automatic blowdown.

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TABLE A
Abbreviated Steam Table - Heat Content at Temp. and Pressure

Temp (°F)	*Heat of Liquid (Btu/lbs)*	*Gauge Pressure (psig)*	*Heat of Liquid (Btu/lb)*	*Gauge Pressure (psig)*	*Heat of Liquid (Btu/lb)*	*Gauge Pressure (psig)*	*Heat of Liquid (Btu/lb)*
60	28	50	267	125	325	200	362
70	38	55	272	130	328	210	366
80	48	60	277	135	331	220	370
90	59	65	282	140	333	230	399
100	70	70	287	145	336	240	403
Gauge Pressure (psig)	—	75	290	150	338	260	385
5	196	80	294	155	341	285	394
10	208	85	298	160	344	335	410
15	219	90	302	165	346	385	424
20	228	95	305	170	348	435	437
25	236	100	309	175	351	485	450
30	243	105	312	180	353	585	472
35	250	110	316	185	355	685	493
40	256	115	319	190	357	785	512
45	262	120	322	195	360	885	530

TABLE B
Approximate Btu Values and Conservative Costs

Fuel	*Btu Value/Unit*	*Costs/Unit*	*Cost/Btu*
#2 Oil	141,000 Btu/gal	\$0.50/gal	\$0.35/100,000 Btu
#6 Oil	152,000 Btu/gal	\$0.35/gal	\$0.23/100,000 Btu
Natural gas	1,000 Btu/ ft^3	\$0.0035/ft^3	\$0.35/100,000 Btu
Coal	12,000 Btu/lb	\$35/ton	\$0.15/100,000 Btu
Hog (dry)	8,500 Btu/lb	\$30/ton	\$0.18/100,000 Btu

concentration with automatic blowdown; *B* = the average concentration with intermittent blowdown; *C* = the highest concentration just before manual blowdown; and *D* = the lowest concentration just after manual blowdown.

Figure 1 graphically illustrates an example of tracking boiler water solids using manual blowdown techniques versus an automated blowdown system. In the graph, when boiler water solids concentrate to the upper limit, point *C*, a manual blowdown operation is performed (the upper limit of TDS is determined by the particular boiler and any steam purity/quality requirements). Manual blowdown immediately reduces the boiler water solids to a value well below the upper limit, point *D*. As the boiler continues to steam, the solids concentrate and the cycle repeats itself. The peaks and valleys of boiler water TDS, with manual blowdown, are plotted against time.

Line *B* represents the average solids concentration, over time, in a boiler with manual blowdown. Line *A* represents the average solids concentration, over time, in a boiler using an automated blowdown control system. With automated control, solids can be continually maintained near the upper limit at all times. The difference between Line *A* and Line *B* represents savings in energy, water, and chemical.

Improved feedwater quality. Simply stated; the better the quality (purity) of the feedwater, the more efficient the boiler can operate. The two most common methods of improving feedwater quality are to pretreat the makeup water and to increase the percentage of returned condensate.

Pretreatment. Improving the quality of the makeup water through pretreatment methods is a common, effective way of increasing the amount of times the feedwater can be cycled within the boiler. Whether the pretreatment is designed to remove total alkalinity (expressed as $CaCO_3$), silica (SiO_2), TDS, or calcium and magnesium hardness (suspended solids), several methods of removal are available.

Although beyond the scope of this article, common treatment methods of makeup water include: filtration, ultrafil-

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tration, lime-soda softening, ion exchange softening, anion exchange, dealkalization, decarbonation, evaporation, and reverse osmosis.

The makeup water quality, the steam boiler system, and the individual requirements for steam purity and steam quality determine the most effective method of pretreatment. By calculating which impurities limit the concentration of the feedwater in the boiler, we can determine what type of pretreatment will be the most cost effective.

Returned Condensate

In a properly operating steam generating system, returned steam condensate is essentially pure water. As more condensate is returned, the makeup water impurities are diluted, and the feedwater quality is proportionately improved. In a typical system, an increase in condensate return equals an increase in the cycles of concentration. As previously discussed, an increase in cycle of concentration means less boiler water blowdown, and hence, lower fuel costs, water, and treatment chemical savings.

Although the focus of this article is reducing boiler blowdown, an increase in steam condensate return has added benefits. First, condensate return equates to water conservation and directly reduces the makeup water demand. Not only does makeup water have a dollar value, but also the value goes up with pretreatment. Condensate return is a high quality water that does not require pretreatment (and is typically piped directly to the feedwater storage tank). Secondly, steam condensate is hot, and therefore carries a British thermal unit (Btu)/unit value. Returning condensate equates to returning energy to the boiler system. The more energy returned means less energy is required to create steam at any given pressure.

It should be noted that if the condensate return is not properly treated, its corrosive nature can result in detrimental levels of metals and metal oxides in the feedwater system.

Calculations

Demonstrating real energy and dollar savings by reducing boiler water blowdown is a simple process. The following calculations can be used to determine the fuel cost at the current blowdown rate vs. the fuel costs at the proposed blowdown rate. Figure 2 shows an example of a chart that could be used to examine heat loss and calculate potential savings. The following equations would be used to place data in the chart.

Heat Loss Study		
Current	*Data*	*Proposed*
1.	Boiler Water Cycles	
2.	% Blowdown	
3.	Feedwater (lb)	
4.	Blowdown (lb)	
5.	Fuel Costs ($)	
Fuel Savings = Current Fuel Cost - Proposed Fuel Cost = $____		

Figure 2. Chart for determining heat loss and fuel costs.

#1: Boiler water cycles of concentration. Use either actual as determined by: Boiler Water Chlorides ÷ Feedwater Chlorides, or a theoretical maximum as determined by the specific boiler the feedwater quality.

#2: % BD. Equation 2 illustrates how to calculate the blowdown percentage.

$$\% BD = 1 \div Cycles \qquad \text{Eq. 2}$$

#3: Feedwater (FW). Equation 3 shows how to calculate the feedwater data.

$$FW = Steam \div (1 - \%BD) \qquad \text{Eq. 3}$$

Where:
Steam = steam generated in pounds (lb)
%BD = percent blowdown, as a decimal

#4: Blowdown. Equation 4 shows how to calculate the amount of blowdown.

$$BD = FW - Steam \qquad \text{Eq. 4}$$

#5: Fuel costs (FC). Equation 5 illustrates calculating the fuel cost.

$$FC (\$) = [BD(H_{bd}) \div H_f (\%Eff)] \times C_f \qquad \text{Eq. 5}$$

Where:
BD = blowdown
H_{bd} = heat content of blowdown, see Table A or steam tables
H_f = heat value of fuel (Btu/unit), see Table B
%Eff = boiler efficiency
C_f = cost of fuel, see Table B

Directly Calculating Savings:

The following example demonstrates a simple way to calculate fuel savings by decreasing the boiler water blowdown.

Steam load: 1,000,000 lb/day
Boiler efficiency: 80%
Boiler Pressure: 125 pounds per square inch gauge (psig) (from Table A, the total heat content of the boiler water = 325 Btu/lb)
Fuel: Natural gas (from Table B, heat content = 1,000 Btu per cubic foot [ft^3], cost = \$0.0035/ ft^3)

Potential savings. One may calculate the potential fuel savings that can be achieved if the percentage of returned condensate can be increased to achieve an increase in boiler water cycles (of concentration) from 10 to 20 using Equations 6 and 7.

$$\text{BD at 10 cycles} = 1 \div 10 \text{ or } 10\% \qquad \text{Eq. 6}$$

$$\text{BD at 20 cycles} = 1 \div 20 \text{ or } 5.0\% \qquad \text{Eq. 7}$$

First, calculate the actual blowdown and feedwater requirements with Equation 8.

$$FW = Steam \div (1 - \%BD) \qquad \text{Eq. 8}$$

Where:
FW = feedwater requirements (lb)
Steam = steam generated (lb)
%BD = percent blowdown, as a decimal

The calculation shows the following:

1. At 10% blowdown, FW = 1,000,000 lb ÷ (1 - 0.1) = 1,000,000 lb ÷ 0.90 = 1,111,110 lb

2. At 5% blowdown, FW = 1,000,000 lb ÷ (1 - 0.05) = 1,000,000 lb ÷ 0.95 = 1,052,632 lb

The difference in feedwater requirements represents blowdown reduction as follows:

1,111,110 lb - 1,052,632 lb = 58,478 lb in blowdown reduction.

Next, the reduction in blowdown can be converted to actual fuel savings, as seen in Equation 9.

$[BD_r (H_{bd}) \div H_f (\%Eff)] \times C_f$ = Savings in Fuel Costs ($) Eq. 9

Where:
BD_r = blowdown reduction
H_{bd} = heat content of blowdown (Table A or from steam tables)
H_f = heat value of fuel (Table B or Btu/unit)
%Eff = boiler efficiency
C_f = cost of fuel

Using the data from Equation 9, one can derive the following calculation:

[58,478 lb (325 Btu/lb) ÷ 1,000 Btu/ ft^3 (0.80)] x \$0.0035/ ft^3 = [19,005,350 ÷ 800] x 0.0035 = \$83.15/day, or more than \$30,000 dollars a year in fuel savings.

Summary

We have just demonstrated, using very conservative fuel costs and steaming rates, that by simply increasing the boiler water cycles of concentration from 10 to 20, a savings of \$30,000/year in fuel can be achieved. In fact, if water and treatment chemical savings are also factored in, even more savings can be realized. In conclusion, if energy accounts for as much as 60% of a facilities overhead, and the largest energy consumer is the steam generating plant, then now is the time to implement measures to reduce boiler water blowdown. How much can you save?■

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Key words: BLOWDOWN, BOILERS, ECONOMICS, STEAM, TREATMENT CHEMICALS