STEAM MANAGEMENT INC.
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*Steam Management*
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# PULP & PAPER MILL BOILER BLOWDOWN
# ENERGY AND WATER SAVINGS OPPORTUNITY

## PART 1 – GENERAL

### 1.01 BACKGROUND

This paper is meant to give a background into the potential energy and water savings methods associated with steam plant blowdown. While we give a broad overview of legacy and new methods of implementing such methods, the desired outcome would be for Steam Management, Inc. to work with you in a collaborative relationship to find the solutions that best fit your needs.

### 1.02 INTRODUCTION

Performance of the boiler, like efficiency and evaporation ratio, reduces with time due to poor combustion, heat exchange surface fouling, and poor operation and maintenance. Deterioration of fuel quality and water quality can also lead to poor performance. Efficiency testing helps us to find out how far the boiler efficiency drifts away from the optimal efficiency. Any observed abnormal deviations can be investigated to pinpoint problems that require corrective action, hence it is necessary to find out the current level of efficiency for performance evaluation. This is a pre-requisite for energy and water conservation action. The steam plant and piping distribution systems' energy efficiency depend on the system design, operation, and maintenance.

This paper focuses on the opportunities to capture wasted heat lost in the boiler blowdown system, and provides a real-world example, taken from a successfully executed SMI project. There are two types of boiler blowdown; bottom blowdown, and surface (aka continuous) blowdown. Bottom blowdown is concerned with opening valves on the mud drum to briefly blow out sludge that has accumulated in the boiler water. Bottom blowdown energy losses are typically minimal, as this is typically only done once per shift, for a few minutes at a time. Generally, it is also more difficult to capture heat from bottom blowdown for other processes, due to its intermittent nature.

Heat recovery opportunities on blowdown systems typically center around surface blowdown, as this is a continuous flow from the boiler, and typically ranges from 2-8% of the boiler steam production. We have seen boilers in the field operating as high as 20% on boiler blowdown, although this typically would indicate poor water treatment upstream of the boiler.

## 1.03 WHY BLOWDOWN THE BOILER?

A. As a boiler generates steam, any impurities which are in the boiler feedwater, and which do not boil off with the steam will concentrate in the boiler water.

B. Surface blowdown is water intentionally and continuously wasted from the boiler to avoid concentrations of impurities left behind during the continuing evaporation of steam. The water flows out of the boiler due to the steam pressure within the boiler.

C. As the dissolved solids become more and more concentrated, the steam bubbles tend to become more stable, failing to burst as they reach the water surface of the boiler. The boiler reaches a point (depending on boiler pressure, size, and steam load) where a substantial part of the steam space in the boiler becomes filled with bubbles or froth. This is commonly known as "boiler foaming." When boiler foam builds up within the steam space, it can leave the boiler and enter the steam system. This is known as "carry-over", or "priming."

D. Carry-over is undesirable, not only because the steam is excessively wet as it leaves the boiler, but it also carries high levels of dissolved and perhaps suspended solids. These solids can lead to deposits of crystals in the steam distribution system contaminating control valves, heat exchangers and steam traps.

E. Foaming can be caused by high levels of suspended solids, high alkalinity, or contamination by oils and fats. However, typically a high Total Dissolved Solids (TDS) level is the culprit. Careful control of boiler water TDS level together with attention to these other factors should ensure that the risks of foaming and carryover are minimized.

F. Table 1 provides guidelines by ABMA and ASME for controlling boiler water and steam quality.

**TABLE 1 RECOMMENDED ABMA & ASME BOILER WATER LIMITS**

| | DRUM OPERATING PRESSURE (PSIG) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0-300 | 301-450 | 451-600 | 601-750 | 751-900 | 901-1000 | 1001-1500 | 1501-2000 |
| **STEAM** | | | | | | | | |
| TDS max (ppm) | 0.2-1.0 | 0.2-1.0 | 0.2-1.0 | 0.1-0.5 | 0.1-0.5 | 0.1-0.5 | 0.1 | 0.1 |
| **BOILER WATER** | | | | | | | | |
| TDS max (ppm) | 700-3500 | 600-3000 | 500-2500 | 200-1000 | 150-750 | 125-625 | 100 | 50 |
| ALK max (ppm) | 350 | 300 | 250 | 200 | 150 | 100 | Not specified | Not specified |
| TSS max (ppm) | 15 | 10 | 8 | 3 | 2 | 1 | 1 | n / a |
| Conductivity max (µmho/cm) | 1100-5400 | 900-4600 | 800-3800 | 300-1500 | 200-1200 | 200-1000 | 150 | 80 |
| Silica max (ppm $Si0_2$) | 150 | 90 | 40 | 30 | 20 | 8 | 2 | 1 |

ABMA-Amercian Boiler Manufacturer's Association
ASME-Amercian Society of Mechanical Engineers

## PART 2 – BOILER BLOWDOWN CONTROL

### 2.01 MANUAL BLOWDOWN:

The simplest method of reducing the boiler water contamination is to take a boiler water sample, measure the TDS, and if higher than recommended for the boiler manufacturer's recommended operating criteria, blowdown the water to some point well below the recommended maximum value. This is usually done once each shift by the boiler operator. The boiler TDS gradually rises between blowdowns. A typical arrangement would be to open the valve at, for example, 3,000 ppm, then close the valve at say minus 20% less or 2,400 ppm. This type of blowdown results in the highest energy and water usage since it requires operating the boiler on average well below the recommended TDS level.

### 2.02 CONTINUOUS BLOWDOWN:

The continuous method is an improvement to the manual blowdown where a blowdown throttling valve is used to control the TDS level. Continuous blowdown valves are special valves that have stages to reduce the problem of erosion that results in damage and subsequent failure to shut off. The valves are also marked with reference values, to document the operating points of the valve and aid in adjustments. The continuous blow down valve position is usually set manually at a predetermined open position to maintain a maximum TDS level. This position is periodically adjusted by the boiler operator based on historical data and by periodically sampling boiler water and measuring TDS to ensure the maximum TDS level does not get exceeded. This is an improvement over the manual blowdown method, but changes in boiler demand due to process or heating load swing levels are not accounted for. This method also results in higher than necessary energy losses since operators are required to overshoot the blowdown flow rate to ensure acceptable TDS levels.

### 2.03 CLOSED LOOP DIGITALLY CONTROLLED BLOWDOWN:

This method continuously measures the boiler water conductivity, which corresponds to dissolved solids, compares it with a set point, and modulates a blowdown control valve if the TDS level is too high. Different types are available, and selection depends on the boiler type, boiler pressure, and blowdown flow requirements. The benefits of the closed loop system are labor savings of automation, tighter control of boiler TDS, and energy and water savings.

## PART 3 – POTENTIAL WATER AND ENERGY RECOVERY

A. Since boiler blowdown water is at a high temperature and pressure, it represents a considerable loss of energy and water. The degree of loss is determined by the operating pressure, and blowdown flow requirements.

B. The plants' supply water quality will determine the degree of treatment and cost associated with makeup water to replace losses from the steam system. Table 1 provides guidelines by ABMA and ASME for controlling boiler water and steam quality. Quality ranges from unsoftened city supplied or private well systems, to softened water (which is a recommended minimal source for steam boilers, to RO or DI make up water). As the quality of the makeup water decreases, the amount of blowdown required increases to maintain the proper boiler water TDS.

C. Code requirements, environmental constraints, and sewer material limits typically require the blowdown water to be cooled before it can be discharged to the sewer system. A typical acceptable maximum is 140°F. This is typically done by discharging the blowdown to a flash tank with the flashed steam being vented to atmosphere, reducing the blowdown to 212°F. The remaining liquid is cooled with plant water before being discharged to drain.

D. The hot high-pressure blowdown water will flash steam when entering a low-pressure vessel for heat recovery. This low-pressure steam can be recovered and used for heating the deaerator. Deaerators are used for two main reasons, one, to remove oxygen from the boiler feedwater, and two, to help preheat the water before being sent to the boiler. The recovered flash steam from the blowdown will offset the deaerator steam consumption. The remaining hot condensate from the vessel can then be sent through a plate type heat exchanger and used to pre-heat the boiler makeup water. Thereby, saving the cooling water required to cool the condensate to below the Code requirement and the energy to pre-heat the makeup water.

## PART 4 – EXAMPLE

A. This example project is for a Specialty Paper Company Steam Plant with the following pre retrofit Operating Data:

1. 2 Boilers each 30,000 pounds per hours steam capacity
2. Boiler operating pressure 150 PSIG
3. Boiler water TDS manually controlled with TDS range of (1,800 to 2,200 ppm)
4. Feedwater TDS (100 ppm)

5. Average steam rate 15,290 pounds per hour

6. Makeup water temperature 50°F

7. Deaerator pressure 30 PSIG

8. Annual operating hours 8,760

9. Fuel cost: #6 Oil $1.33 per THERM

10. Steam plant annual fuel use 900,000 gallons

11. Boiler combustion efficiency 80.5%

12. Water cost $5.00 per 1,000 gallons

B. This example is to retrofit the steam plant with an automatically controlled closed loop digital blowdown control and blowdown heat and water recovery system. Estimated annual savings:

1. Total Annual Cost Savings: $43,750

2. Total Annual Energy Savings: 2,951 MMBTU.

3. Total Annual Fuel Oil Savings: 19,367 gallons.

4. Total Annual Water Savings: 899,205 gallons.

C. Calculations are attached.

## BLOWDOWN EFFICIENCY IMPROVEMENT AND HEAT RECOVERY:

**Performance Data:**

2 Boilers each 30,000 pounds per hour
Boiler operating pressure 150 psig
B=Boiler water TDS Manual Control (1840 average ppm)
F=Feedwater water TDS (100 ppm)
S=Average steam rate 366,915.5 lb/day
Tmw=Makeup Water Temperature 50 F = 510 R
Tsl = Sewer Temperature Limit 140 F = 600 R
Fuel Cost: #6 Oil $1.33 per Therm
Water Cost: $5/1,000 gallons
BE=Boiler Efficiency 80.5%
HR= Operating Hours = 8760 hr/year

$\$ := ¤$

$$S := \frac{366915.5}{24} \cdot \frac{lb}{hr} = 15288 \ \frac{lb}{hr}$$

$$T_{MW} := 50 \ °F = 510 \ R$$
$$T_{SL} := 140 \ °F = 600 \ R$$

$$FuelCost\$ := \frac{1.33 \ \$}{100000 \cdot Btu}$$

$$FuelHV := \frac{152400 \ Btu}{gal}$$

$$BE := 0.805$$
$$HR := 8760 \ hr$$

$$Water\$ := \frac{5 \ \$}{1000 \cdot gal}$$

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**Install Electronic Automatic Blowdown Control System:**

Existing Condition: Currently blowdown is controlled manually and is blowdown to as high as 2800 TDS maximum. This is done by periodically blowing down boiler to 1840 average TDS.
Proposed Modification: Install an electronic control system to automatically blowdown to more accurately track and maintain the setpoint of 2200 TDS. Savings would be in the ability to maintain the boiler TDS closer to the setpoint of 2200 and is estimated to provide an annual average increase in TDS of 360.

**Existing Blowdown:**

Blowdown Rate = (FxS)/(B-F)
F=Feed Water TDS (ppm)
S=Steam generation rate (lb/hr)
B=Required boiler water TDS (ppm)

$F := 100 \qquad B_{Exist} := 1840 \qquad S = 15288 \ \frac{lb}{hr}$

$$BD_{Exist} := \frac{F \cdot S}{B_{Exist} - F}$$

$$BD_{Exist} = 879 \ \frac{lb}{hr} \qquad PercBD_{Exist} := \frac{BD_{Exist}}{S} = 5.75\%$$

**Proposed Blowdown:**

Blowdown Rate = (FxS)/(B-F)
F=Feed Water TDS (ppm)
S=Steam generation rate (lb/hr)
B=Required boiler water TDS (ppm)

$F = 100 \qquad B_{Prop} := 2200 \qquad S = 15288 \ \frac{lb}{hr}$

$$BD_{Prop} := \frac{F \cdot S}{B_{Prop} - F}$$

$$BD_{Prop} = 728 \ \frac{lb}{hr} \qquad PercBD_{Prop} := \frac{BD_{Prop}}{S} = 4.76\%$$

Enthalpy of saturated liquid at 150psig:

$$SH := 338 \cdot \frac{Btu}{lb}$$

$$EnergySavings_{Control} := \frac{(879-728)}{BE} \cdot \frac{lb}{hr} \cdot 339 \cdot \frac{Btu}{lb} \cdot HR$$

$$EnergySavings_{Control} = 557038062\ Btu$$

$$EnergyCostSaved_{Control} := EnergySavings_{Control} \cdot FuelCost\$ = 7409\ \$$$ **$7,409**

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**<u>Install Blowdown Heat Recovery System:</u>**

<u>Existing Condition:</u> Currently the fuel oil from a back oil pressure control valve (back pressure) surplus oil not being used to the boiler burners goes through a blow down heat exchanger and then returns to the oil storage tanks.

<u>Proposed Modification:</u> All of the available blowdown heat is not being utilized in heating of the fuel oil being returned to the oil storage tanks. Also, this represents a risk of contaminating the fuel with water in the event the heat exchanger would leak. This proposal would be to remove the blowdown water to oil heat exchanger and install a new heat exchanger that would use the available heat in the blowdown water to preheat makeup water to the boiler.

% Flash Steam = ((SH-SL)/H)*100
SH=Sensible heat in the condensate at the higher pressure before discharge
SL=Sensible heat in the condensate at the lower pressure to which discharge takes place
H=Latent heat in the steam at the lower pressure to which the condensate is discharged
Assuming the blowdown water is released to a flash steam system operating at 30 psig

$$SH = 338\ \frac{Btu}{lb} \qquad SL := 243 \cdot \frac{Btu}{lb} \qquad H := 929 \cdot \frac{Btu}{lb}$$

$$PercentFlashSteam := \left(\frac{SH-SL}{H}\right) = 10.23\%$$

Energy in flash steam (EFS):

$$EFS := PercentFlashSteam \cdot BD_{Prop} \cdot (H) \qquad EFS = 69161\ \frac{Btu}{hr}$$

Energy in condensate (EC):

$$EC := BD_{Prop} \cdot (1 - PercentFlashSteam) \cdot (SL) \qquad EC = 158815 \, \frac{Btu}{hr}$$

Energy Savings with blowdown heat exchanger efficiency of 95%:

$$EnergySavings_{BDHR} := \frac{EFS + (EC \cdot 0.95)}{BE} \cdot HR \qquad EnergySavings_{BDHR} = 2394419473 \, Btu$$

$$EnergyCostSaved_{BDHR} := EnergySavings_{BDHR} \cdot FuelCost\$$$

$$EnergyCostSaved_{BDHR} = 31846 \, \$$$ **$31,846**

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**Water Conserved:**

<u>Tempering Water Saved:</u>
To calculated the amount of tempering water saved we use the following relationship to solve for Mtempering, which is the flow of tempering water required in gpm, using the following relationship:

Tdrain * Mdrain = Ttempering * Mtempering + Tbddrain * Mbddrain

Mdrain = Mtempering + Mbddrain

Solving for Mtempering;

Mtempering = Mbddrain * (Tbddrain-Tdrain)/(Tdrain-Ttemp)

This is solved for the original blowdown case. Once the heat recovery unit is implemented, the heat exchanger drain temperature will be low enough so that tempering water is not required. Therefore, all current tempering water is saved.

$$BD_{Exist} = 878.63 \, \frac{lb}{hr} \qquad T_{BDExist} := 212 \, °F = 671.67 \, R$$

$$M_{BDDrain} := BD_{Exist} \cdot (1 - PercentFlashSteam) = 788.78 \, \frac{lb}{hr}$$

$$M_{tempering} := M_{BDDrain} \cdot \left( \frac{(T_{BDExist} - T_{SL})}{(T_{SL} - T_{MW})} \right) = 631.02 \, \frac{lb}{hr}$$

$$V_{tempering} := M_{tempering} \frac{1}{8.34} \frac{gal}{lb} \frac{hr}{60\ min} = 1.26 \frac{gal}{min}$$

$$V_{TempPerYear} := V_{tempering} \cdot 60 \frac{min}{hr} \cdot HR = 662802\ gal$$

<u>Makeup Water Saved:</u>
The amount of makeup water saved is equal to the reduction in blowdown flow plus the flash steam utilized with the new system.

$$M_{MUSaved} := BD_{Exist} - BD_{Prop} + BD_{Prop} \cdot (PercentFlashSteam) = 225.07 \frac{lb}{hr}$$

$$V_{MUSaved} := M_{MUSaved} \frac{1}{8.34} \frac{gal}{lb} \frac{hr}{60\ min} = 0.45 \frac{gal}{min}$$

$$V_{MUSavedPerYear} := V_{MUSaved} \cdot 60 \frac{min}{hr} \cdot HR = 236403\ gal$$

$$WaterSaved := V_{TempPerYear} + V_{MUSavedPerYear} = 899205\ gal$$

$$WaterCostSaved := WaterSaved \cdot Water\$ = 4496\ \$$$ **$4,496**

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**Summary:**

$$TotalCostSaved := EnergyCostSaved_{Control} + EnergyCostSaved_{BDHR} + WaterCostSaved = 43750\ \$$$

$$TotalEnergySaved := EnergySavings_{Control} + EnergySavings_{BDHR} = 2951457535\ Btu$$

$$FuelOilSaved := \frac{TotalEnergySaved}{FuelHV} = 19367\ gal$$

$$WaterSaved = 899205\ gal$$