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Water treatment-related opportunities for energy conservation in a paper mill powerhouse

Scope

The purpose of this Technical Information Paper is to identify and optimize areas of energy use in the paper mill powerhouse system that relate to water and water treatment systems. Even as energy prices have fluctuated widely in recent years, it is always a good operating practice to review powerhouse operations in terms of the efficient use of energy. The three main areas of focus that will be addressed are:

- Paper Mill Condensate Management
- Blowdown Heat Recovery
- Blowdown Rate Adjustment

There are certainly other areas of potential energy savings in the paper mill powerhouse that are outside the scope of this TIP. Fuel selection, boiler fireside management and burner optimization are all major energy savings possibilities, but fall outside the scope of this effort. Also, the installation and maintenance of insulation on steam generating units and steam and water transfer piping lines can produce major savings, but are not addressed here.

Definitions

Condensate: For the purposes of this TIP, condensate will refer to the liquid phase created when powerhouse-generated steam is condensed. Process-related condensates, sometimes called dirty or foul condensates, are not within this definition and are not considered here.

Makeup (water): Makeup is the water added to condensate that combines to become boiler feedwater in the deaerator unit. Makeup water will typically be produced by an ion exchange or membrane-based process.

Blowdown: Blowdown is the intentional discharge of water from a boiler for the purpose of removing soluble or suspended contaminants. Blowdown can occur from various drums or headers of the boiler and can be continuous or intermittent, depending on the needs of the system.

Separators: Condensate separators are tanks positioned beneath or alongside the paper machine. Paper machine operation is optimized when a fraction of steam passes through the dryer cans without condensing; this is called “blow through steam.” It is in the separators where the blow through steam is separated from the condensate. The separated blow-through steam is recycled back to the dryer cans via repressurization or via cascading to a lower pressure section of the paper machine dryers. The liquid phase of condensate is routed to a storage tank for collection and return to the powerhouse. A paper machine may have from one to ten or more separators, depending on the size, age and design of the machine. They may also be called receivers or flash tanks by some, although the term flash tank does not really apply since the function of these tanks is primarily separation without significant flashing. So the term (condensate) separator is preferred, and used here.

TIP Category: Automatically Periodically Reviewed (Seven-year review)

Materials

No specific materials are required for use of this information. Application of this information may be enhanced by comparison to the relevant P&IDs (Process and Instrumentation Diagrams) for the specific system being considered. Also, mill-specific schematics, either from paper records or taken from control computers can be used to define the positioning and interconnection of various system components.

Safety precautions

Applying the information contained in this TIP will require work in the powerhouse and process areas of the paper mill. Therefore, all precautions for safe work as defined by the mill must be followed. These include, but are not restricted to:

- Exposure to hot surfaces and fluids
- Exposure to noisy environments
- Danger from moving and rotating equipment, such as pumps
- Danger from overhead equipment, such as cranes and paper roll moving equipment
- Some exposure to hazardous or noxious odors and gases
- Danger from slip, trip, and fall hazards
- Danger from intermittently operating equipment
- Danger from confined spaces

It is critical that all mill safety precautions be followed, and that operating crews are informed of work being done in their areas of responsibility.

Background

The consumption of energy by paper mills continues to lead that of other industrial segments. Even though the unit cost of energy may change, it is always worthwhile to give strong consideration to energy savings projects. A number of energy savings opportunities in the paper mill powerhouse are related to the water systems, and it is the focus of this paper to identify the largest and most practical opportunities for improved energy utilization.

There are a number of potential energy savings opportunities that are outside the scope of this paper that may represent just as significant or possibly larger savings opportunities. Fuel prices can often be negotiated, and there can be considerable risk avoidance in “locking in” energy prices for some time into the future. But should prices drop, those who have established fixed costs above prevailing market rates might be at a cost disadvantage to the rest of the industry. Optimizing burner operation, particularly in the case of residual fuel oil burning, can be a big savings potential not covered here. And lastly, this paper will not cover areas where considerable capital would have to be spent to achieve energy optimization. The target payout periods of most corporations are currently so demanding that even the most advantageous projects often fall short. So these will not be considered.

Paper mill condensate management

The return of condensed steam from various parts of the mill to the powerhouse for reuse as boiler feedwater is a practice that has been in place since the earliest days of boiler operation. Condensate retains considerable heat, which is a thermal benefit to the boiler cycle, and it can be as good in quality as the best makeup water that can be prepared. But if the condensate contains an unacceptable concentration of contaminants, it can be a serious detriment to boiler reliability. The contaminants can be the result of metal corrosion, with the metal oxides present as particles returning with the condensate flow. But the contaminants, particularly in a kraft mill, can also be highly ionic cooking liquors that are a serious threat to boiler operation. The goal is simple: return the maximum volume of good quality condensate to the powerhouse.

An engineering approach to managing paper mill condensate can be developed, with finite steps involved to verify good operating practices are being employed.

Determine the rate of condensate return

The first step, and one that should be employed periodically in monitoring mill operation, is that of determining the current rate of condensate returned to become boiler feedwater. This can be done in several ways, and the best way for an individual mill study depends on how the boiler makeup water is prepared. Those mills using sodium zeolite ion exchange softeners can be the simplest for which a fractional condensate return rate might be determined because there are species present in high enough concentrations to allow tracking and dilution calculations. An example follows:

Example Calculation of Fractional Condensate Return in a Softened Water System

Makeup water Chloride concentration = 40 ppm (40 mg/L)
Condensate Chloride concentration = 0 ppm (0 mg/L)
Boiler Feedwater Chloride Concentration = 15 ppm (15 mg/L)

Since feedwater is defined as the flow of makeup water and condensate, $X + Y = 1$

Where

X = the fractional makeup water flow.
 Y = the fractional condensate flow

The feedwater concentration of chloride is a weighted average of the combination of makeup water and condensate, so $40X + 0Y = 15$

Solving this equation $X = 15/40 = 0.375$

Going to the $X + Y = 1$ equation, $0.375 + Y = 1.000$. Solving $Y = 0.625$, or 62.5%.

In this case we can calculate the fractional condensate return as being 62.5% of feedwater flow. The only assumption we are making in this case is that the chloride concentration in the condensate is zero. This can be verified to some degree by using the same chloride titration test as was used to develop the makeup and feedwater concentrations.

The calculation method is best applied when the species measured is not reactive with any other constituents in the water, is not a treatment that would be added to the streams involved, and can be accurately detected at the concentration range present. So for this reason, molecules such as silica, hardness ions, sodium and sulfate would not be good candidates.

In the case of demineralized water systems, there are no convenient species in the water that are both non-reactive with other molecules present and also detectable in the concentrations at which they are present. In this case, we need to rely on flowmeter information to track system operation. Since condensate is hot and possibly flashing, and often not measured in total, it is typical practice to monitor makeup water and feedwater flows and use these values to calculate the condensate return rate by difference. Some adjustment of units may be required, since makeup water flow is most often recorded as gallons per minute, and feedwater is tracked in terms of pounds per hour. An example would be:

Example Calculation of Fractional Condensate Return in a Demineralized Water System

Feedwater Flow = 625,000 pounds per hour (284 Tonnes per hour)

Makeup water flow = 500 gallons per minute (1892 L/min)

Converting makeup water flow,

500 gal/min x 8.33 pounds/gal x 60 min/hr = 250,000 pounds per hour.

1892 L/min x 1 kg/L x 60 min/hr x 1 Tonne/1000 kg = 113.5 Tonnes/hr

Subtracting, condensate flow = feedwater flow – makeup flow

Condensate flow = 625,000 pounds per hour - 250,000 pounds per hour =

375,000 pounds per hour

= 284 Tonnes per hr – 113.5 Tonnes per hr = 170.5 Tonnes per hr

Condensate flow as a fraction of feedwater flow becomes:

% Condensate = 375,000 pounds per hour/625,000 pounds per hour = 0.60, or 60%

= 170.5 Tonnes per hr/284 Tonnes per hr = 0.60, or 60%

So the apparent condensate return rate under these conditions is 60% of feedwater flow.

It would be unwise to try to do this calculation too precisely, for example to two decimal point accuracy. Most mills will want to report their condensate rates at about 60%, and not be too much more precise than 5% increments. This is because the meter readings will vary minute to minute in normal plant operation, and depending on the current state of operation in the process units generating condensate, there might be too much variability to be any more precise than this.

Variables affecting percent condensate return

Once a mill site calculates its fractional condensate return (ideally this would be done over a period of several days and the results averaged to balance out process variability), a decision can be reached as to whether additional condensate is available. A common operating range is 50 – 70% condensate return in mills using the kraft pulping process. Recycled fiber mills can sometimes realize higher return rates, and tissue/towel mills seem to run at lower return rates. There are a number of variables responsible for the variations seen across the industry. These reasons include:

- *Steam applied directly onto the paper machine.* Some grades of paper benefit from the use of a steam box on the wet end of the paper machine to heat the fiber/water solution, to improve drainage due to the reduced viscosity of hotter water. Steam applied here is lost from the system as a source of condensate return.
- *Variable condensing turbine operation.* Mills may have the option of condensing more steam to increase turbine power output which will affect the fractional return.
- *Batch digester use.* The standard operating practice for batch digesters seen in the industry is for direct steam injection to heat the chips, and thus no condensate return is possible. A continuous digester often heats the liquor indirectly in a heat exchanger, so condensate return is possible. But these units must be closely monitored to prevent liquor contamination of the feedwater.
- *Air heating systems.* On a seasonal basis the mill may need to heat more or less air to better accept moisture from the sheet as it dries.
- *Draining separators.* The condensate receivers or separators under the paper machine are drained to the sewer from time to time. This practice, though sometimes necessary to enable production, can result in a significant loss of valuable condensate.
- *Dumping practices.* Machine condensate may contain particulate contaminants when the machine comes back up after a break or grade change, so the condensate might be intentionally dumped so that this metallic oxide loading is not returned to the boiler. The dumping period should be optimized, and the condensate flow should be returned to the powerhouse as soon as the quality is restored.