CONTROLLING BLACK LIQUOR “VISCOITY” TO IMPROVE RECOVERY BOILER PERFORMANCE

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Abstract: A liquor property monitoring system was developed for the recovery boiler at Irving Pulp and Paper to indirectly measure the “viscosity” of as-fired black liquor. The system is based on the amperage registered by the black liquor circulating pump. The information is used to control the char bed and firing conditions in the lower furnace. The system has been working well. It helps stabilize liquor properties, control the char bed, and greatly improve boiler operation and thermal performance.

The viscosity of as-fired black liquor is an important physical property that affects the spray characteristics of the liquid and particle size and shape in recovery boilers [1]. It depends greatly on liquor solids content, temperature and residual alkali content [2]. Highly viscous black liquor does not flow well, it produces coarse spray droplets and results in larger and higher char beds. Low-viscosity black liquor, on the other hand, tends to produce small char beds and fine sprays that can be readily entrained in the flue gas to form carryover and deposits in the upper furnace.

While important, there is presently no reliable means for monitoring viscosity on-line in order to effectively control the liquor sprays and stabilize the char bed. Char bed is typically controlled by manually adjusting primary and/or secondary air flow rates and/or the liquor temperature.

A black liquor property monitoring system was developed for the recovery boiler at Irving Pulp and Paper (IPP), Saint John, New Brunswick mill to indirectly measure the black liquor viscosity. This was part of the mill’s efforts to optimize recovery boiler operation in order to improve boiler thermal efficiency and to minimize boiler downtimes caused by plugging and primary air port tube cracking. The system has been working well since its development in late 2003. It helps stabilize the liquor property and the char bed size when there is a change in residual alkali or in wood species. It also helps reduce smelt carryover, minimize incidents of tube temperature excursions around primary air ports that caused tube cracking and corrosion [3], and improve the boiler operation and thermal performance.

This paper discusses the operational problems experienced in the IPP recovery boiler that led to the development of the black liquor property monitoring system, the principle of the system, and how it has been used to improve the boiler performance.

EXPERIENCE AT IPP

Recovery Boiler Upgrade History

The recovery boiler at IPP is a 1970 Babcock & Wilcox UK boiler originally designed to burn 1100 metric t/d (2.4 million lbs/d) of as-fired black liquor dry solids (BLds) and to produce 360,000 lbs/hr (165,000 kg/hr) steam. Rated at 410°C (775°F) and 62 bars (900 psig). The boiler underwent a major retrofit in 1991 to increase the firing capacity to 1470 metric t/d (3.25 million lbs/d) BLds. Subsequent upgrades include installation of a new tertiary air system, a high solids crystallizer and a saltcake purge system, precipitator upgrade and steam drum internals replacement [4].

These upgrades made it possible for the mill to increase the as-fired black liquor solids content from 68% to 72% in 1996 and to 74% in 1997, as well as to increase the boiler firing load substantially. By 2000, the boiler was firing 1680 metric t/d (3.7 million lbs/day) of BLds at a solids content as high as 76%, and producing 249,000 kg/hr (550,000 lbs/hr) steam.

Primary Air Port Tube Cracking and Corrosion

In late 1990s and early 2000s, the boiler experienced severe primary air port cracking and widespread membrane bar wastage problems. A systematic investigation was conducted to examine the main cause(s) of the problems and to devise possible means to alleviate them [3]. The investigation revealed that the severity of tube cracking and corrosion was strongly related to the frequency and the magnitude of tube temperature excursions at the air ports in the south-east (rear-left) corner of the boiler, Fig. 1.

The thermal activity near the air ports at that time varied widely from day to day. Figure 2 shows temperature variations registered by crown thermocouples at various primary air ports for two extreme days: “good” (June 6, 2000) and “bad” (June 30, 2000). On the good day, the thermal activity near the primary air ports was relatively calm, and little temperature spiking was observed. On the “bad” day, on the other hand, not only the frequency of temperature spikes increased markedly, but also the magnitude of spiking increased, particularly at air ports on the south and east walls of the boiler. At air ports on the north (front) side (N22 and N65) and at one on the west (rear) side (W17), no temperature spikes were observed. The thermal activity was consistent with the experience that the cracking problem was much more severe on the south.
(rear) and east (left) walls than on the north (front) and west (right) walls.

The cracking problems were subsequently alleviated by lowering the black liquor solids content from 76% to 70% and by operating at a higher primary air flow rate to keep the char bed away from the air ports [3]. These operational changes significantly reduced tube temperature excursions, as shown in Fig. 3. The monthly averaged number of temperature spikes that occurred above 370°C (700°F) in a day on tubes #S22 and #E67 in the south-east (rear-left) corner decreased markedly from over 50 spikes/day to less than 20 spikes/day after the primary air flow was increased and the black liquor solids content was lowered in December 2000.

Poor Thermal Efficiency and Plugging

However, operating at about 70% solids (down from 76%) and at high primary air flow rates not only resulted in at least 2% reduction in steam production capacity of the boiler, but also in excessive carryover and deposit buildup in the superheater region. The boiler also experienced more frequent plugging during this period, reducing further its efficiency and availability. As a result, efforts were made by the mill to devise ways to operate the boiler at the original black liquor solids content of 74-76% to increase boiler thermal efficiency and minimize boiler fouling/plugging, with no or minimum tube temperature excursions.

The Challenge

Since black liquor viscosity increases exponentially as the solids content exceeds 70%, with the existing equipment, it was a challenge to operate the boiler at a solids content around 74 to 76%, and yet keep the viscosity (or fluidity) at a level that was as controllable as at 70% solids. A black liquor heat treatment process was investigated, but this proved uneconomical due to high capital costs and increased alkali usage. Raising the black liquor temperature was another possibility, but this was constrained by the availability of low pressure steam, 3.4 bar (50 psig), used in the indirect liquor heater, which did not allow the liquor temperature to exceed 118°C (245°F). Consequently, during the 2002 mill outage, the mill installed a 10 bar (150 psig) steam line for the liquor heater, making it possible for the liquor to be heated up to 123°C (255°F).

While there was no problem in heating the black liquor up to a desired temperature with 10 bar (150 psig) steam, it was difficult to control the liquor viscosity to maintain constant liquid sprays, because of the extreme temperature-dependence of black liquor viscosity. The difficulty is particularly compounded when there were constant changes in residual alkali and in wood species, which are known to have great effects on liquor viscosity. Birch liquor, for instance, is much less viscous than maple or other types of softwood liquors, Table I.

**BLACK LIQUOR VISCOSITY CONTROL SYSTEM**

**Description**

A home-made black liquor viscosity control system was developed for the recovery boiler in 2003 to indirectly measure and control the black liquor “viscosity” on-line. As shown in Fig. 4, the control system is incorporated into the existing indirect liquor heater control loop. It consists of a new in-line ammeter (II) installed on the black liquor circulation pump and a new amperage controller (IC) for continuously monitoring the amperage and controlling it at an amperage set point. The output from the amperage controller (IC) is cascaded back to the existing cascade loop which consists of a tem-
perature controller (TC) and a pressure controller (PC). The steam pressure entering the indirect liquor heater is then adjusted to bring the temperature of the liquor at the heater exit up to a desired temperature. In essence, the system measures the pump amperage, compares this amperage value with its set point, and then regulates the 10 bar (150 psig) steam pressure to increase (or decrease) the liquor temperature so that a constant amperage on the pump can be maintained.

Strong black liquor is pumped from the liquor storage tank through an indirect liquor heater at a rate of about 210 l/s (3300 USGPM). When firing at full load, the liquor flow rate to the boiler is about 21 l/s (325 USGPM) with the rest being recycled back to the pump suction. Since about 90% of the total liquor flow is circulated, and only a minor adjustment, less than 1 l/s (15 USGPM), is typically made during normal operation, the circulating liquor load on the pump can be considered constant. Any changes in amperage would indicate changes in viscosity brought on by changes in solids content, residual alkali, and/or by wood species.

Testing

Thus, with this system, the liquor “viscosity” can be indicated by the amperage load (or power consumption) of the liquor circulation pump. Higher amperage indicates a more viscous liquor, and hence, a need to increase the liquor temperature, while a lower amperage implies that the liquor is more fluid, the liquor temperature needs to be decreased to keep the amperage value within a desirable range.

Before the black liquor viscosity control system was developed, the operator would make manual set-point changes in liquor temperature based on visual observations of the furnace bed. These set-point changes would be in response to seeing the bed grow or shrink. A growing bed would result in increased thermal activity (temperature excursions) registered by thermocouples near primarily air ports. A shrinking bed would mean more liquors being entrained, resulting in increased carryover and superheater tube fouling.

After the system was implemented, tests were performed at lower solids to examine if the system was robust. Test results show that the system worked better than expected. The control of liquor flow, temperature, “viscosity” and sprays was easier than before, and the char bed appeared to be more stable with fewer set-point changes.

The system was subsequently tested at higher liquor solids contents. The liquor solids were increased over a period of approximately four weeks and the liquor temperature was allowed to increase to 133°C (272°F). The test results also show that the system worked well under high solids and high temperature conditions; and it could handle process swings and respond well to changes in wood species.

Operation

Figure 5 shows an example of how the control system works when there is a change in black liquor viscosity as a result of changing the wood species pulped in the digester from maple to birch.
Since the birch black liquor viscosity is about a quarter of that of maple at 70% solids and 110°C (230°F), Table I, in the past, such a change would have resulted in rapid char bed shrinking due to fin-
er sprays of the liquor, and this could have led to massive fouling and plugging in the upper furnace. With the control system in place, however, these problems can be sig-
nificantly minimized.

Figure 5A shows the fiber length of the pulp collected from brownstock washers and the amperage registered by the liquor circulating pump over an 18-hour period on November 20-21, 2005. When the pulping in the digester was switched from maple (short fiber) to birch (longer fiber) at around 6 PM, it took several hours for the liquor from brownstock washers to reach the boiler.

As the birch liquor finally reached the boiler at around 4 AM, the pump amper-
age decreased, indicating a decrease in liquor viscosity. The control system detected the change and responded to it by reg-
ulating the steam pressure to the indirect liquor heater to decrease the liquor temper-

erature in order to maintain the pump amperage within the desired point-range, Fig. 3B.

As can be seen from pump amperage curves, only a minor change was made to the amperage set-point by the operator in response to the change in bed size, as observed on the char bed camera.

Thus, with the control system, it is pos-
sible to make changes in wood species without experiencing problems associated with rapid change in bed size, such as high thermal activity and primary air port tube cracking, and/or fouling and plug-
ging in the upper boiler.

Figure 6 shows the weekly solids content (based on manual tests) of the as-fired black liquor from January 2000 to September 2004. Prior to 2001, the solids to the boiler averaged at 74 to 76%. The boiler experienced high thermal activity in the lower furnace and primary air port tube cracking, as discussed in previous sections, Figs. 2 and 3. During the two-
year period of 2001 and 2002, the liquor solids were lowered to 71-73%; the ther-
mal activity decreased, Fig. 3, with subse-
quent inspections finding no cracking at the primary air ports.

Since the implementation of the vis-
cosity control system in early 2003, the liquor solids content has been consistent-
ly operated between 73 and 75% and occasionally higher than 76%, except for a few months in early 2004, when the liquor solids were significantly lowered due to evaporator capacity issues, Fig. 6. Since that time, the solids content has been controlled at 75-75%

Effect on Char Bed
Prior to lowering black liquor solids in 2001, the char bed was large, as seen via infrared cameras. Once the liquor solids were lowered, the bed size was reduced to a more historical size. With the control system in place, higher solids can be achieved and the char bed became more stable and bed size remains in control.

As part of maintaining good operation, operators still have to keep an eye on the bed size and shape. Should the bed be seen as growing, a small decrease in amperage set point is required to reduce the size by making the liquor more fluid and the sprays finer. Conversely, a slight increase in amperage set point is required when the char bed is seen as getting smaller.

The boiler operator, at the beginning of his shift, will outline on the bed moni-
tor screen the shape of the char bed, Fig. 7. This serves as a reference for him to
decide whether the bed is growing or shrinking throughout that day.

Effect on Thermal Activity
The mill continuously monitors the ther-
mal activity in the lower furnace by count-

ing the number of times the tube temper-

erature rises (or spikes) above 371°C (700°F) and above 482°C (900°F). As shown in Fig. 8, prior to the initial lower-
ing of the solids target in early 2001, the average number of spikes over 371°C (700°F) per month for the two most active thermocouples E67 and S22, Fig. 1, was about 2300. After the lowering of solids to 71 to 74% in 2001 and 2002, the number of spikes reduced to about 200.

Since the implementation of the con-
trol system in early 2003, the solids con-
tent has been increased to 73-76%, but the number of spikes remains about the same, 240 spikes/month. A similar trend was also found for the number of spikes above 482°C (900°F). The results clearly show that the viscosity control system has helped keep the thermal activity low.

On each subsequent inspection dur-
ing annual shutdown, no cracking at the primary airports has been found. The mill has gained enough confidence that there will be no more cracking problems; and consequently, has extended the length of time between major mill shutdowns and corrosion/plugging inspections from 12 months to 18 months.

Effect on Fouling and Plugging
Initially the mill was concerned that con-
tinuous adjustment to the liquor temper-

erature may contribute to increased fouling and plugging in the upper furnace. The experience, however, shows that there was no discernable difference in fouling and plugging conditions before and after the viscosity control system was put in place.

CONCLUSIONS
A liquor viscosity monitoring and control system was implemented for the recovery boiler at Irving Pulp and Paper to indi-
rectly measure the "viscosity" of as-fired black liquor. The system is based on the amperage registered by the black liquor circulation pump. The information is used to control liquor sprays, char bed size and firing conditions in the lower fur-

nace. The control system has been work-
ing well since its initial installation in early 2003. It helps stabilize liquor properties, make char bed control easier and significantly improve boiler thermal performance.

LITERATURE
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Résumé: Nous avons élaboré un système de surveillance des propriétés de la liqueur pour la chaudière de récupération de Les Pâtes et Papier Irving afin de mesurer indirectement la « vis-
cosité » de la liqueur noire en combustion. Le système est basé sur l’intensité en ampères enregis-
trée par la pompe de circulation de la liqueur noire. Les données sont utilisées pour contrôler le
lit de charbon et les conditions d’allumage dans la chambre de combustion inférieure. Le système fonctionne bien. Il aide à stabiliser les propriétés de la liqueur et à contrôler le lit de charbon, et il a permis d’améliorer le fonctionnement et la performance thermique de la chaudière.

Reference: MCCABE, E.D., MOTT, D., SAVOY, D., TRAN, H. Controlling black liquor "viscos-

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