CONTINUOUS DUST MEASUREMENT AS AN INDICATION OF SOOTBLOWING PERFORMANCE IN A RECOVERY BOILER

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ABSTRACT

In this paper, a new method is introduced for continuously measuring the amount and composition of dust (K, Cl) in the flue gas of recovery boilers. This system makes a tool for various real time observations of fine dust behavior. In this study, the dust analyzer was demonstrated to measure sootblowing performance at one recovery boiler. The sootblowing sequence and the frequency of each sootblower-pair could be detected as variations in the total dust concentration.

The amount of sootblown fine dust was 9 to 28% of the total amount of precipitator dust due to dust composition, boiler cleanability and operating conditions. The internal precipitator dust recycle varied from 93 to 220 tons/d being 5.3-9.5% of the boiler load (tons BLS/d). Also, interesting variations were observed in potassium and chloride content of the dust removed from surfaces during sootblowing.

This continuous dust measuring system makes a tool for studying the effectiveness of various sootblowing strategies. The required operating time and frequency of individual sootblowers in the boiler bank and economizer regions can be studied and optimized. It is possible to resolve the effects of operational variations on the amount of precipitator dust recycle. Furthermore, a major benefit of the described on-line measuring system of dust is that the responses can be seen immediately, and the outputs can be connected to the process control system of a mill, together with other process variables.

INTRODUCTION

Fouling and plugging problems in recovery boilers are related to the amount and composition of the flue gas dust. It is known that the composition of dust in the flue gas depends mainly on the composition of the fired black liquor. But also, the operating conditions of the boiler have a great effect on the dust composition and behavior, e.g., by lowering the pH of the dust and causing sticky dust which deposits easily on the heat transfer surfaces of the boiler. These deposits are harmful in many respects: they can cause fouling and plugging of the flue gas duct, so that the need for extra water washes and unexpected shutdowns increases; they can reduce boiler efficiency by lowering heat transfer through boiler tubes; and they can lead to severe corrosion of boiler tubes. /1/

Usually, these deposits are removed from the surfaces by continuous sootblowing in the recovery boiler. Sootblowers periodically blast the deposits with high-pressure steam. The ability to remove the deposits depends on many factors, including their location in the upper furnace, their thickness and mechanical strength, and variations in the deposit chemistry depending on the location. /1, 2/ Furthermore, the sootblowing sequence and frequency affect the efficiency of deposit removal. During the past decade, several attempts have been made to optimize sootblowing, and also a number of patents are issued /3, 4, 5/. Currently, the most popular way to optimize sootblowing is to apply practical experience of pressure drop measurements in the flue gas duct, and control the flue gas temperature. In practice, there are one or two sootblowing strategies in use, and individual modifications are made to these programs as needed. Effective deposit removal is very important for preventing plugging as well as ensuring high thermal efficiency of the boiler. Therefore, optimizing sootblowing operations will maximize both deposit removal efficiency and steam savings. The current systems for optimizing sootblowing and monitoring fouling and plugging are not sufficient, and the need for new inventions is apparent. /6, 7, 8, 9/

In this paper, a new method for continuously measuring dust concentrations in the flue gas is introduced. Its response to rapid changes in boiler dynamics is briefly described, and the results of monitoring sootblowing performance with this on-line measurement system are presented. Finally, new ideas for monitoring and optimizing sootblowing operation are discussed.

METHODS AND EXPERIMENTAL

Measurement system description

A recently developed on-line recovery boiler dust analyzer was demonstrated to measure dust amounts and composition in a full-scale recovery boiler. This novel on-line dust analyzer operates by dissolving the flue gas dust sample in water and analyzing the flowing water sample potentiometrically for ion concentrations.

The dust sampling technique differs from the conventional approach. The dust-laden flue gas flow is extracted isokinetically and continuously into a sampling probe. Then the readily soluble salts are dissolved in ion exchanged water right at the mouth of the probe. The extracted flue gas sample moves towards the analyzer as a plug-flow in the sampling line (gas/water plugs). In the analyzer, the gas flow is separated from the water flow, and the sodium (Na^+), potassium (K^+) and chloride (Cl^-) ion concentrations in the sample solution are measured with ion selective electrodes (ISE). The gas flow and the sample water flow are measured, and the software of the device calculates the total dust concentrations (g/Nm^3, dry) in the flue gas and the potassium and chloride concentrations (weight-%) in the dust. This technique effectively prevents plugging of the sampling probe and makes the on-line sampling and continuous measurement possible. / 10, 11 / The operating principle of the analyzer is shown in **Figure 1**.

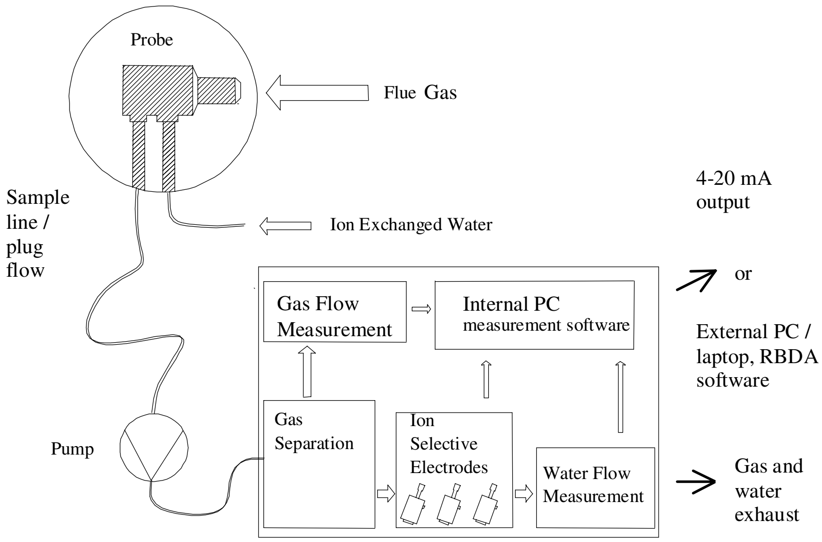

Figure 1. Operating principle of the on-line dust analyzer (RBD-analyzer).

This measurement system was shown to be very sensitive to rapid changes, both in the total dust concentration and in dust composition during transient changes in boiler operation. One example of these transient tests is shown in **Figure 2**. In this experiment the dry solids content of the as-fired black liquor was decreased from 73% to 59% dry solids by mixing some weaker liquor in the strong black liquor. After this transient the dry solids of black liquor were returned to the normal level. This rapid change was clearly reflected in lower dust concentration in the flue gases and in higher potassium content and lower chloride content in the dust. The dust measurements were performed upstream from an electrostatic precipitator where the dust concentration in flue gas was high.

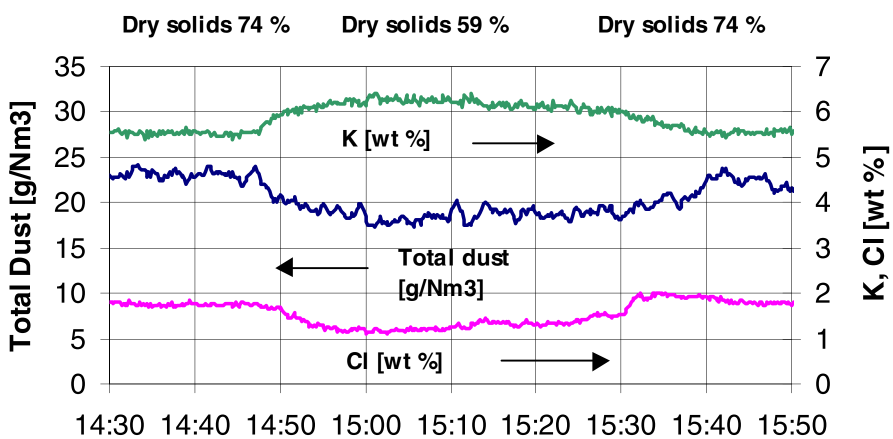

Figure 2. Example of a rapid change in the amount of dust and composition measured on-line. The dry solids content of the black liquor was reduced instantly from 73% to 59% BLS, which had the shown effect on dust formation. Sootblowing was not operating during this transient change in boiler operation.

During this study, it was observed that the sootblowing sequence of the boiler could be seen clearly from these continuous dust measurement data when the boiler was operating using its normal continuous sootblowing sequence. This phenomenon is illustrated in **Figure 3**. Also in these tests, the probe of the dust analyzer was situated in the end of the flue gas channel upstream from electrostatic precipitators.

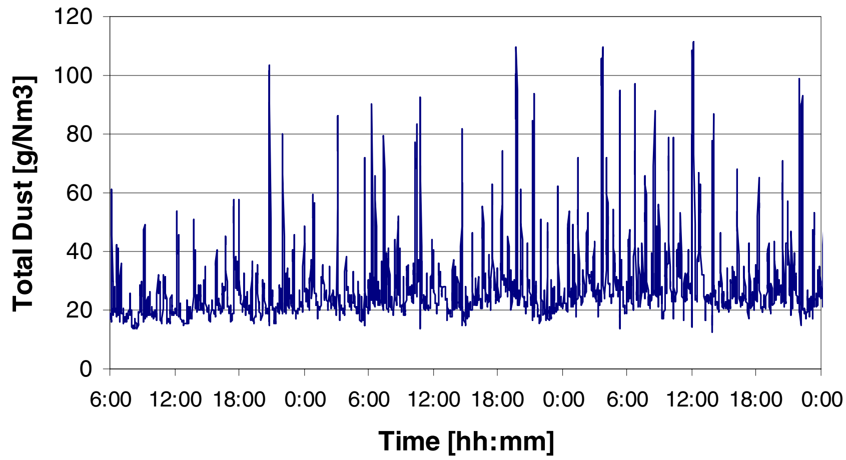

Figure 3. The concentration of the total dust in the flue gas [g/Nm^3] upstream from an electrostatic precipitator - peaks are caused by sootblowing.

Description of the boiler

The measurements concerning the sootblowing performance were performed in a kraft recovery boiler firing mainly hardwood (more than 2/3); the period of softwood being only few days at the time. The maximum load of this boiler is 2100-2300 tons BLS/d, the steam production being 71kg/s, 480°C, 80 bar.

In this recovery boiler, sootblowing is operating continuously in different parts of the upper furnace. A typical sootblowing strategy is shown in **Figure 4**. Operators change manually the sootblowing sequence if, e.g., pressure drop in some parts of the flue gas duct becomes too high.

During the measurements, the information of the sootblowing sequence was collected to the process data collection system of the mill. The one complete cycle of the sootblowing sequence takes about 24-25 hour. The frequency of each sootblower is individual depending on their location in the boiler. In this boiler, the boiler bank and first economizer are sootblown more frequently due to fouling and plugging experiences in these regions. The sootblowers are introduced into the boiler as pairs; every third minute a new sootblower starts, the operating time being six minutes for each sootblower.

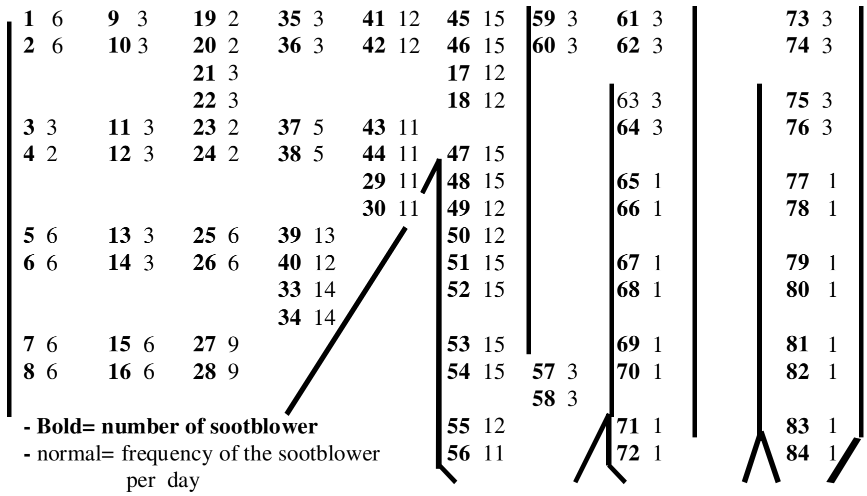

Figure 4. Typical sootblowing strategy of this recovery boiler, about 500 sootblower operations per day.

RESULTS AND DISCUSSION

In this study, the amount of the sootblown fine dust was calculated in different days using continuously measured dust concentrations and process information of the boiler. The average dust level without sootblowing was defined by first filtering out highest peaks, and then using median filtering (base level). / Figure 5a/ The average level of dust concentration without sootblowing was around 15 to 22 g/Nm^3 depending on the boiler operation.

By combining the measured dust concentrations and the sootblowing sequence it could be seen how individual sootblowers work and how much dust they remove from the boiler tubes **/Figures 5a** and **5b/**. Results show that momentary dust concentration in flue gas could be even three to six times higher than the dust concentration measured without sootblowing. In these measurements the sootblowers situated in the economizer area resulted the highest fine dust concentrations.

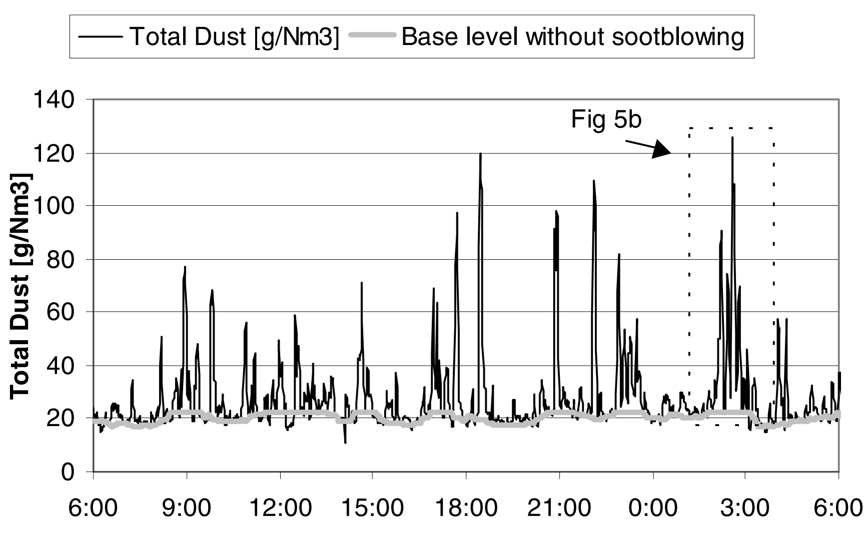

Figure 5a. An example of the total dust concentration during one sootblowing sequence. The gray line is an average dust level without sootblowing.

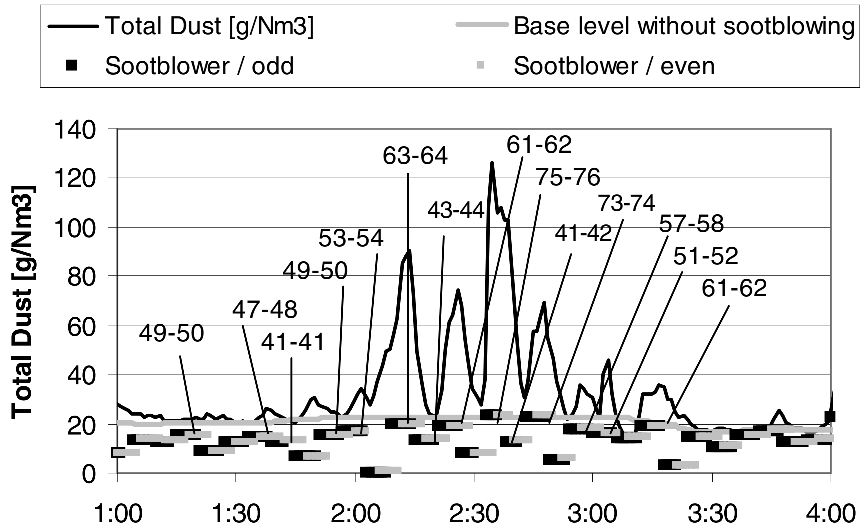

Figure 5b. Details from Figure 5a. Here the operating time of individual sootblowers can clearly be observed. Note that the sootblowers operate continuously as pairs (odd/even). The highest peaks in dust concentration are resulted from the economizer area.

It can be seen from the figure that sootblowers from boiler bank area resulted only small amount of fine dust in this measurement. There are two reasons why boiler bank sootblowers seemed to remove only small amount of fine dust from surfaces. One reason is that boiler bank sootblowers were operating even 12 to 15 times per day, compared to sootblowers in economizer area where the operating frequencies were 1 to 3 times per day. So this way the dust had less time to accumulate on surfaces between sootblowing in boiler bank area. Other reason is that a part of boiler bank deposits was already removed from flue gas to the ash hoppers of the boiler. This way a part of dust never reached the on-line analyzer, which was situated in the flue gas channel just before electrostatic precipitators.

Although, sootblowers in the superheater region were operating only 2-6 times per sootblowing sequence, they did not cause a similar increase in dust concentration as sootblowers from the economizer area. The dust deposited on superheaters is partially molten, and will break away as larger lumps, which fall back to the furnace and to the ash hoppers during sootblowing.

In these preliminary tests, also the potassium and chlorine contents of the sootblown dust were measured continuously with this dust analyzer. Potassium level in dust typically increased in sootblown dust. This can be easily observed particularly from the highest dust peaks resulting from the economizer area (**Figure 6a**). These measurements show that potassium concentration is higher in the dust deposited on surfaces that in the dust resulting directly from black liquor firing. It is interesting to study further whether this potassium enrichment on deposits is the same in different locations of the boiler. Also chlorine content in dust had variations due to sootblowing, but this variation was not as regular as with potassium. It was observed that sometimes chlorine concentration increased and sometimes decreased in the sootblown dust (**Figure 6b**).

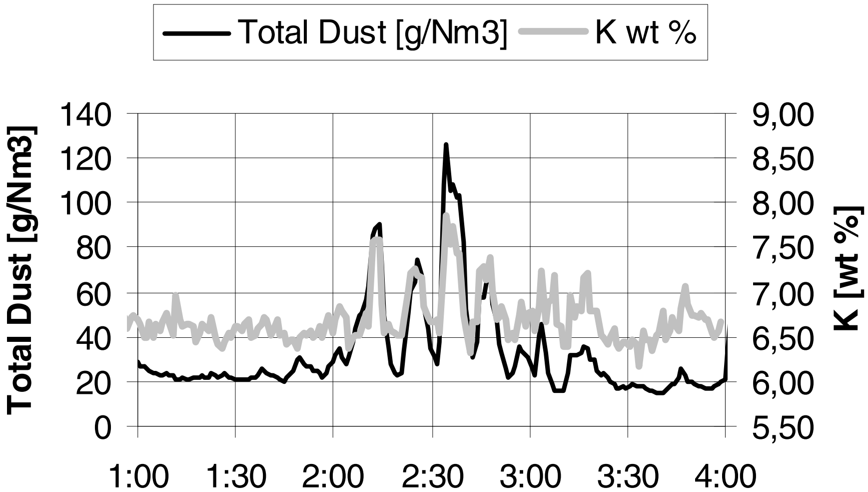

Figure 6a. Potassium concentration (K weight%) in dust during sootblowing. Here the potassium concentration increases in the dust sootblown from the economizer area.

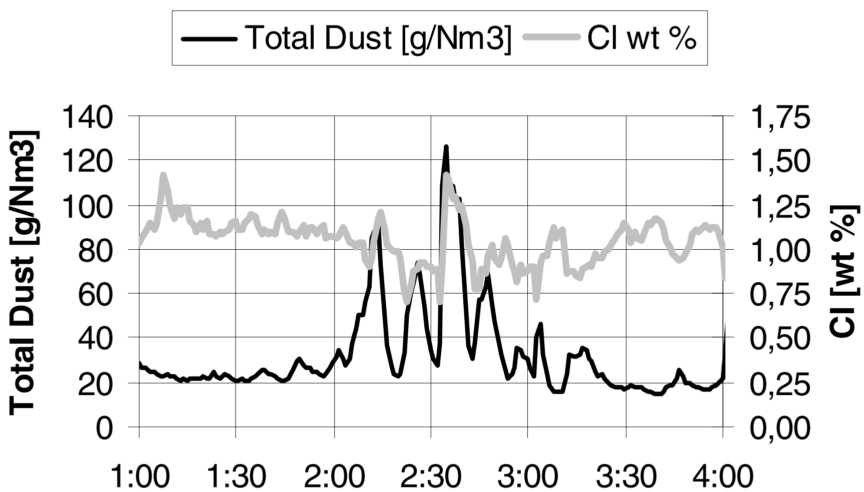

Figure 6b. Chlorine concentration (Cl weight%) in dust during sootblowing. The chlorine content in dust shows variation due to deposit location removed by sootblowing.

The efficiency of individual sootblowers or sootblower-pairs was also briefly studied. The efficiency of one sootblower –pair is defined here as the amount of deposited material removed during each sootblower operation (kg sootblown dust/ sootblower operation). In this example (**Figure 7a**), the amount of sootblown dust removed by the individual sootblower-pair (number 73-74) is plotted against the accumulation time of dust on surfaces before the sootblowing during one day. The accumulation time is the time between the previous sootblowing and the present one. This sootblower-pair (73-74) operates in the economizer area usually 3-4 times per one whole sootblowing sequence.

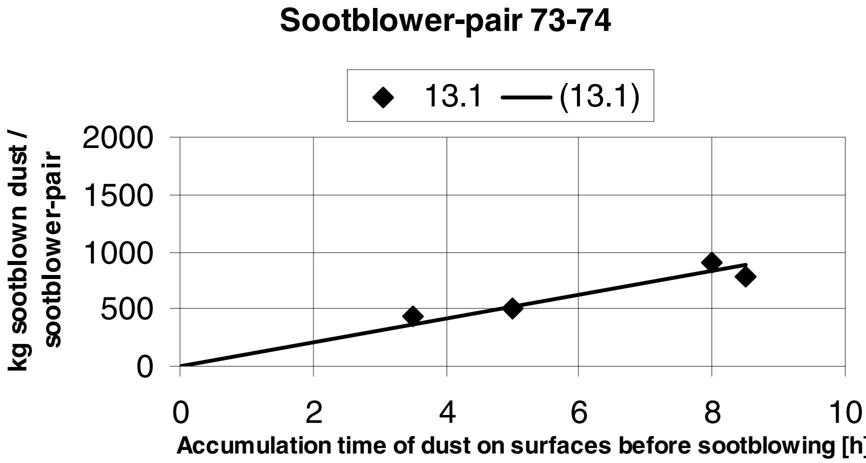

Figure 7a. The amount of sootblown dust (kg dust / sootblower operation) as a function of accumulation time of dust on surfaces before sootblowing.

One would expect that the longer the accumulation time is the more dust is sootblown from the surfaces of the boiler. This seems to be the trend also in Figure 7a. The longer the accumulation time is the more dust is removed from surfaces. However, the same analysis was made in different days, which is shown in **Figure 7b**. These results clearly show that there are great variations in the amount of sootblown dust, which cannot be explained with accumulation time. For example in eight hours frequency the sootblown dust varies from 500 to 1500 kg /sootblower operation as can be seen from the Figure 7b. These variations are strongly related to the composition of the dust and the flue gas and boiler operating conditions.

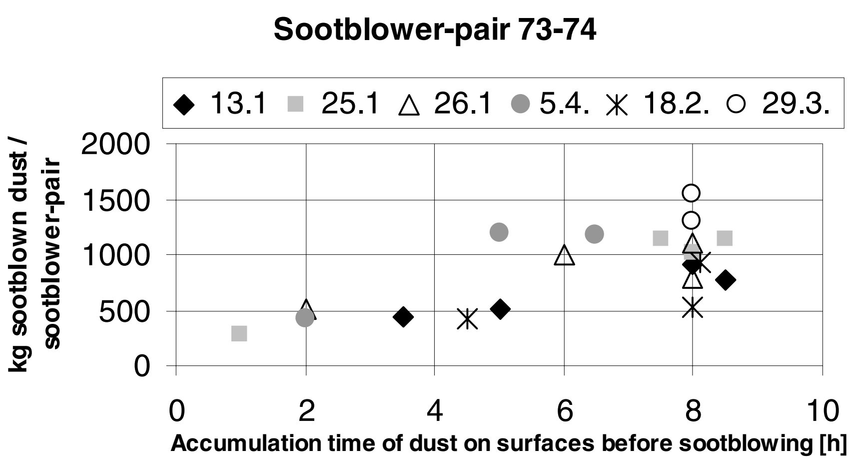

Figure 7b. The same analysis as shown in Figure 7a made in different days.

The total amount of precipitator dust

It is known that the total amount of internal dust recycling depends greatly on the boiler load (kg BLS/d). In this study, the total amount of recycled precipitator dust was calculated from measured dust concentrations and process information of the boiler. In calculated cases (**Figure 8a**), it varied between 93 to 220 tons/d being 5.3-9.5% of the boiler load (tons BLS / d). The liquor quality and the boiler load were also monitored in a course way as shown in Figure 8a. In all these cases except two cases (28.1 and 18.2) the average boiler load was about 2200 tons BLS/d (maximum load). In the cases 28.1 and 18.2 the average boiler load was 1800 tons BLS/d. The liquor quality (hardwood/softwood) and dry solids load of the boiler do not explain all the variations in the total amount of internal fine dust recycle. There are obviously some other operational parameters that have a great affect to the amount of sootblown dust and also, to the total amount of ESP catch.

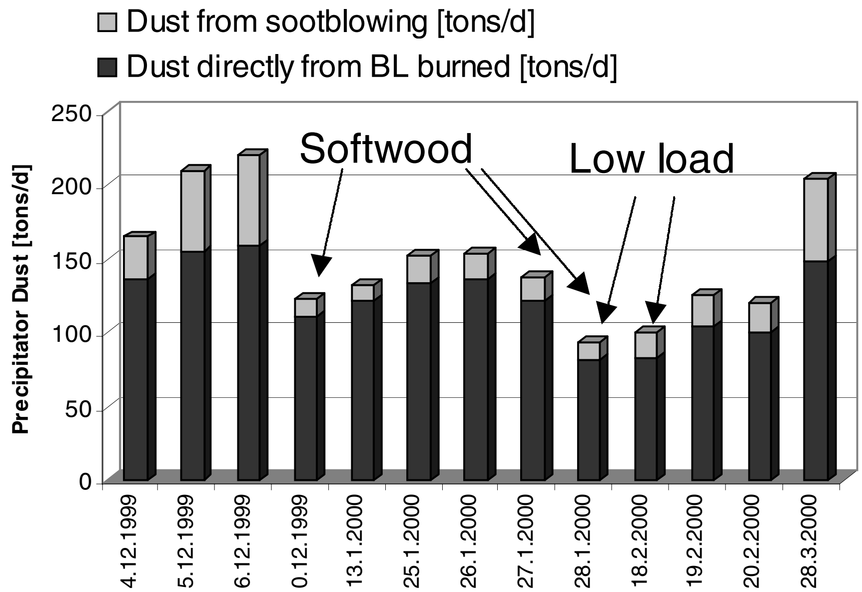

Figure 8a. The amount of dust per day [tons/day] resulting from sootblowing and directly from black liquor burned (= the total amount of precipitator dust). Softwood days are shown, other days Hardwood.

The amount of sootblown fine dust was usually 9 to 17% of the total amount of precipitator dust (calculated per day, **Figure 8b**). In extreme cases the amount of sootblown dust could be even 25 to 28% of total recycled fine dust. Variations are due to boiler cleanability (the time since boiler has been water washed), the dust composition, and its stickiness, and the boiler operation. The amounts of fine dust resulting directly from black liquor firing or from sootblowing in different days are illustrated in Figures 8a and 8b.

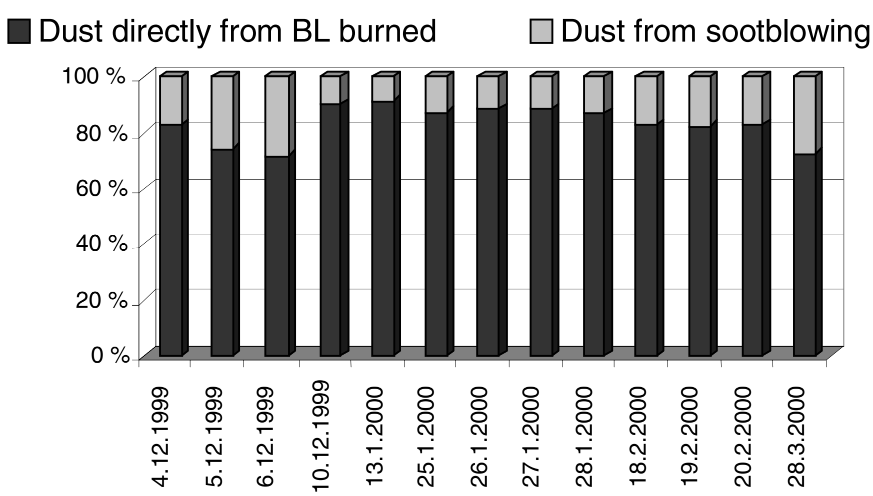

Figure 8b. Percentage of dust resulting from sootblowing and directly from black liquor burned.

SUMMARY AND CONCLUSIONS

A new method was introduced for continuously measuring the amount and composition (K, Cl) of dust in the flue gas of recovery boilers. This system gives a tool for various real time observations of fine dust behavior. The measurement method was shown to be very sensitive to rapid changes, both in total dust concentration and dust composition. It is a useful tool when studying chemical dynamics of a boiler, i.e., fume formation and composition under different boiler operating conditions.

In this study, the dust analyzer was demonstrated to measure sootblowing performance in one recovery boiler. The sootblowing sequence and the frequency of each sootblower-pair could be detected as variations in the total dust concentration. The results indicate that the amount of dust due to sootblowing can vary greatly based on boiler cleanability, dust composition and boiler operating conditions. The amount of sootblown fine dust was usually 9 to 17% of the total amount of recycled precipitator dust, although higher portions, even 28%, also occurred. Interesting variations were observed in potassium and chloride content of the dust removed from surfaces during sootblowing. The total amount of precipitator dust was 93 to 220 tons/d depending on the load of the boiler, the composition of sprayed black liquor, and other operating parameters. The recycled precipitator dust loading was calculated to be 5.3 to 9.5% of the boiler load (kg BLS /d).

Using this continuous dust measuring system the effectiveness of various sootblowing strategies can be studied. The required frequency and time of operation of individual sootblowers in the boiler bank and economizer regions can be studied and optimized. It is possible to resolve the effects of operational variations on the amount of precipitator dust recycle. Furthermore, the measured data can also help to identify fouling and plugging problems in the boiler bank and economizer regions. An on-line measurement of the amount and composition of internal dust recycle can be a useful tool to aid recovery boiler control.

A major benefit of the described on-line measuring system of dust is that the responses can be seen immediately, and the outputs can be connected to the process control system of a mill, together with other process variables.

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