High-solids black liquor combustion

Tampella's Super Combustion system

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A system capable of firing black liquor at 80% dry-solids content is in commercial operation and has total operator acceptance.

A Super Combustion system capable of firing black liquor at 80% dry-solids content was tested at the Rosenlew Aittaluoto kraft pulp mill in Pori, Finland. This mill produces 80,000 tons/year of unbleached sulfate pulp. The pulp mill's boiler is illustrated in **Fig. 1**. Splash-plate-type liquor guns are situated on the boiler's front and rear walls. Boiler steam capacity is 18 kg/s (142,860 lb/h) of 32-bar (435 psig) steam at 410°C (770°F).

The Super Combustion system was tested with 100% of the mill's black liquor flow, and the test facility was designed accordingly. Thus, the results received from the boiler correspond to the behavior of the furnace at the higher solids content. **Table I** shows the schedule of boiler tests.

Firing equipment

Figure 2 illustrates the flow of black liquor from the evaporation plant to the boiler. The system's main components—a super concentrator and a flash tank—are located between a standard salt-cake mixing tank and the recovery furnace. The liquor flowing from the multiple-effect evaporator to the mixing tank has a solids content of 62–65%. The rest of the system operates at 75–85% solids content, depending on the set value for firing.

Steam is fed into the falling-film tube-type super concentrator at a pressure of 10 bar (145 psig).* In the test plant there is also an evaporator unit to produce clean steam. The super concentrator and the evaporator are of identical construction. All of the equipment used in the system is commercially available.

The original liquor system was retained and was also available for liquor firing. This arrangement made it possible to use the high-solids liquor system to evaporate part of the liquor flow to an extremely high concentration (84%) and then study subsequent fouling of the evaporator tubes.

Two viscometers were used during the test. One of these was a Bendix model 1800; the other was built into the liquor return-flow pipe. The viscosity recorded by the latter device was calculated from the pressure drops of a measuring length of pipe. The results from the two viscometers correspond to each other.

Test results

The information in this report is based on test runs and on typical daily results from the pulp mill.

Chemical recovery

The smelt reduction rate during the reference test (test A) was 96%. At higher concentrations, the reduction rate was increased by 1–2%, as seen in **Fig. 3**. Maximum values measured during a one-year period exceeded 99%.

The SO_2 in the flue gas at the 62% dry-solids level is between 100 ppm and 400 ppm. At 62% solids content, the SO_2 content typically varies quickly, indicating changes in the firing conditions. When the dry-solids content of black liquor exceeds 75%, the SO_2 level immediately drops below 30 ppm and usually stays near the zero level, as seen in **Fig. 4**.

Fly ash is recovered by an electrostatic precipitator. Furnace behavior is evident in the percentage of Na_2CO_3 in the ash. Results are depicted in **Fig. 5**. Ash samples were collected from the electrostatic precipitator during tests A, B, and C. During test C (80% dry solids), the CO_3 values increased over time, and ash fouled the tubes during this test. During test B (75% dry solids), which was conducted the following day, sootblowing and gas blowing loosened the layer of ash, and the CO_3 values increased before finally dropping to a lower level. These results correspond to other measurements taken in Finland at 70% dry solids. Higher concentrations of liquor can change the characteristics of the ash, which in turn can affect the behavior of ash in the electrostatic precipitator.

The H_2S level in the flue gas was tested separately. **Figure 6** shows that the H_2S level was essentially zero when the excess O_2 in the flue gas was at the target value. The excess O_2 in the tested boiler should not be less than 2% (wet). At 62% black liquor concentration, the H_2S level was significantly higher, even when excess O_2 was 4%.

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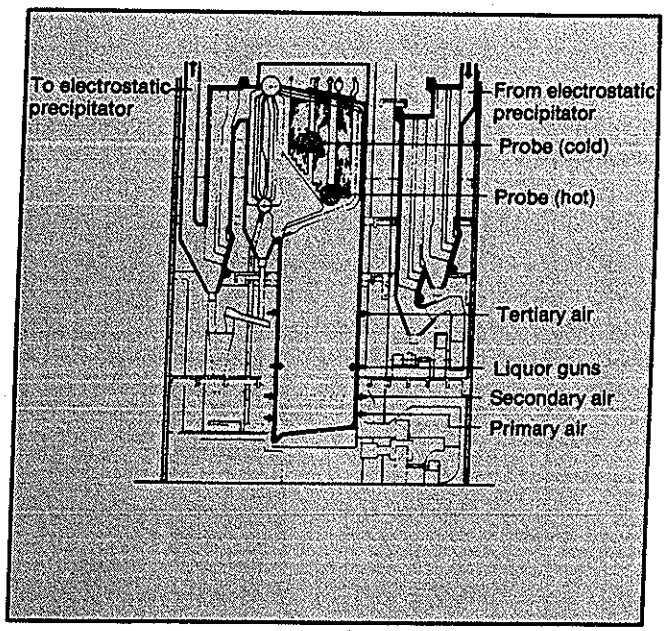
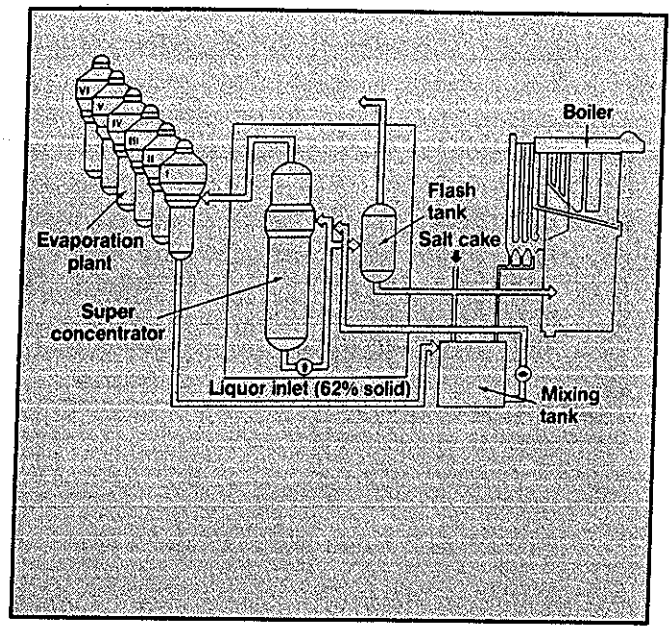
*Nurminen, K., "New technique in chemical recovery in pulp industry: concentration of black liquor to high solids content up to 80% or more before burning in recovery boiler," paper presented at The World Pulp and Paper Week, SPCI and Adforum, Stockholm, 1987.

1. Recovery boiler, 350 tons dry solids/day



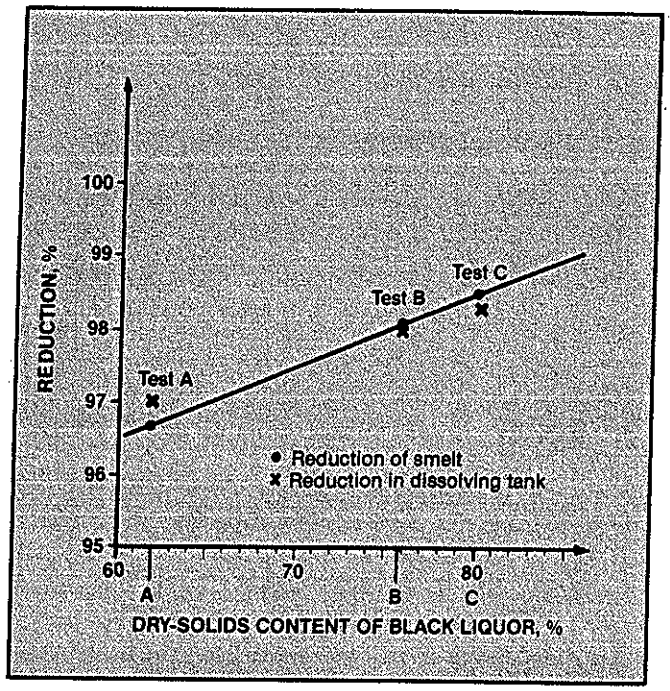
2. Flow of black liquor from the evaporation plant to the boiler



I. Schedule of boiler tests

Test identification	Test date	Liquor dry-solids content, %
A (benchmark tests)	10/21/86	62
B	10/23/86	75
C	10/22/86	80
H_2S/O_2 measurement	11/17/86	

3. Effect of black liquor dry solids on reduction of smelt



Energy balance

Table II shows the increase in steam production by the recovery boiler at higher solids contents. Auxiliary power demand was increased by 10–12 kW·h/ton of dry solids at 75–80% solids content. Most of this extra power is consumed by the super concentrator's pumps. Power consumption for sootblowing was reduced by 70% when the solids level was increased from 62% to 75–80%. Continuous sootblowing was necessary at the 62% level.

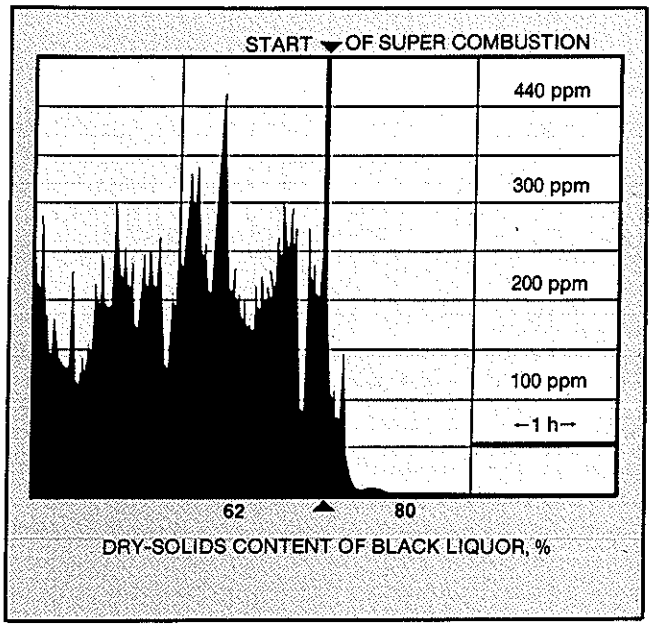
Availability of the Super Combustion system

The mill's recovery boiler has been in operation for 1.5 years since installation of the Super Combustion system. The unplanned downtime for the the Super Combustion system has been only 1%. The super concentrator must be washed occasionally, and the flash tank serves as a storage tank during this washing period. The flash tank at the test plant is not large enough for the entire washing period, but it can be designed in the future for that purpose. After taking the washing periods into account, availability of the Super Combustion system has been as high as 93%.

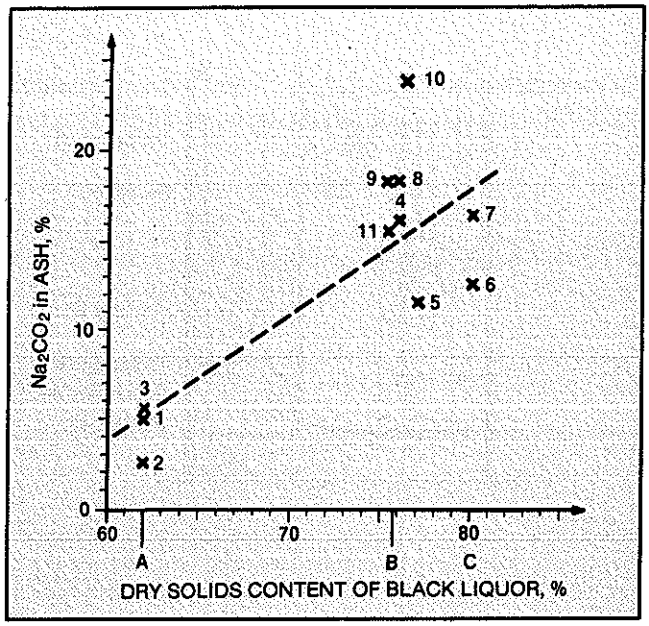
Boiler availability has improved since the installation of the Super Combustion system. Before installation of the high-solids liquor system, the boiler had to be cleaned every five weeks. Sootblowing consumed about 8% of total steam flow. As of September 1987, sootblowing has been reduced to approximately 25% of its former level, and there has been no need for cleaning.

The behavior of the ash deposits can be seen by following the trends in the flue-gas pressure drops. When using 62% solids, the pressure drops increase; after changing over to 80% dry solids, the pressure drops slowly begin to decline. The recovery operators have also noticed that the ash deposits are looser than before, and the deposits are easier to remove. Furthermore, even with the reduced sootblowing, the temperature of the economizer exit gas is approximately 20°C (36°F) less than before. Mill operators are reporting less interruptions or disturbances in the operation of the electrostatic precipitator, and they have noted the improved ability of the electrostatic precipitator to withstand tension.

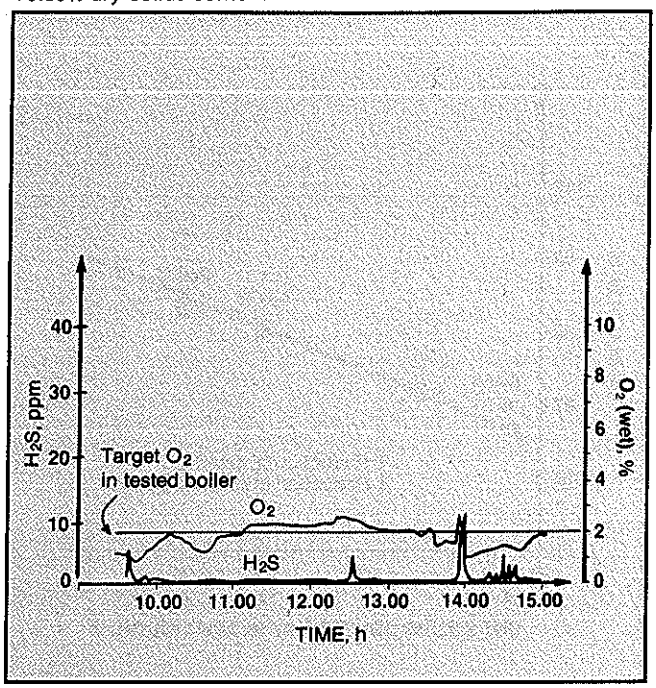
4. Sulfur emissions as a function of dry-solids content of black liquor



5. Na_2CO_3 content in fly ash. × marks the location of data points. The numbers at each data point identify the sequence of the results. Test A, 1.4. Test C, 5.8. Test B, 9.11



6. H_2S level in flue gas relative to O_2 concentration in flue gas at 75.80% dry-solids content



II. Steam production during tests

Test	Liquor dry-solids content, %	Heat recovery in the high-pressure steam, MJ/kg dry solids	Boiler efficiency, %
A	60.1	9.7	60.5
B	74.3	10.5	65.2
C	77.9	10.7	66.8

Conclusions

Temperature increase of char bed

Installation of the Super Combustion system led to a number of changes in the recovery furnace. Measurements taken during the test periods showed that the furnace temperature at the char bed had increased by 70°C (126°F). Generally, a 100°C (180°F) increase has been observed, and the smelt temperature is 40°C (72°F) higher. The difference in flue-gas color when burning 65% liquor and 80% liquor is apparent by simply looking through the inspection door at the screen level or in front of the superheater. At 80% solids content, the upper furnace in front of the superheater is completely dark. These findings, along with the increased carbonate content of the fly ash, are good indications concerning the temperature increase around the char-bed area in the lower part of the furnace.

Carryover decrease

The quantity of fly ash increased by 20–50% after the changeover to 80% concentration. When firing liquor with 62–65% solids content, the quantity of ash can vary greatly, from approximately 8 g/m³ to 18 g/m³, depending on furnace conditions. During the test, values of 10–18 g/m³ were measured. The increase in the quantity of fly ash was smaller than expected.

According to the probe measurement, the 62% run was better than usual in the boilers. Generally, the probe measurements show smaller deposits at the 80% concentration. The composition and quantity of fly ash, along with probe measurements, lead to the conclusion that the fume from the bed is increased and that the carryover is decreased when a 75–80% liquor is fired. This results in more favorable fly ash quality as far as surface fouling is concerned.

Equalized conditions

In reviewing the activities of the char bed, it can be seen that the droplets of liquor are heavier and fall downward. As the water content of the droplets decreases, the need for

drying disappears. The char bed is stable all the time and in every point. This was confirmed by viewing the char bed with a video camera and recording it on tape.

The authors believe that favorable conditions can be maintained in all areas of the furnace when firing liquors with dry-solids contents greater than 75%. Because drying no longer plays such an important role in furnace operation, the size of the droplets at the liquor guns is less important. This provides a greater margin for the operators to work in when there is fluctuation in liquor quality. According to the measurable results presented here, effective pyrolysis, reduction, and burning are taking place in the furnace.

Summary

A system for firing black liquor at 80% dry-solids content has now been in commercial operation for 1.5 years. Experience indicates that the system can provide the following advantages:

- An increase in the availability and controllability of the boiler through stable firing and nonsticky fly ash; a decrease in carryover; and an increase in fuming.
- A significant decrease in emissions, with the level of SO_2 close to zero and H_2S (total reduced sulfur) at zero.
- An increase of 9–12% in total system energy recovery.
- A 1% increase in green-liquor reduction.
- An increase of 8–10% in the solids throughput of the recovery boiler.

The Super Combustion system has demonstrated its ability to improve recovery boiler operation. The system also has received the total acceptance of the operators who have used it.