Root Cause Identification and Elimination of Problems in Soot Blowers of Chemical Recovery Boilers

M.Gowshikan[1], S.Ganesh Kumar[2], H.Surjith[3]
[123]*Dept. of Mechanical engineering, Sns College of engineering, Coimbatore, India*

ABSTRACT: *The chemical recovery boiler utilizes the black liquor which is the waste liquid coming out from pulp in paper industries. Soot blower is one of the major components required to clean the sediments deposited on boiler tubes which affects the heat transfer. Several issues like steam leakage, lance tube bending, ash deposition on lance tube and corrosion are frequently reported among the 28 soot blowers of SPB Ltd. In this project, the problems that occurring in soot blowers identified and analyzed. The problems are eliminated by the changing of material from stainless steel (310) to magnesium alloy (AZ91D). Solutions for corrosion, ash deposition and steam leakage are given for proper functioning of the soot blowers in the chemical recovery boiler.*

Keywords *- Chemical recovery boiler, Soot blowers, Lance tube, nozzle,*

1 INTRODUCTION

1.1 Chemical recovery boiler

Recovery boiler is the part of Kraft process of pulping where chemicals for white liquor are recovered and reformed from black liquor, which contains lignin from previously processed wood. The black liquor is burned, generating heat, which is used in the process and in making electricity, much as in a conventional steam power plant. The invention of the recovery boiler by G.H.

The Chemical recovery Boiler at SPB Ltd is a Single Drum, Finned Tube, Top-supported, Natural Circulation, drainable water tube boiler. The recovery boiler has two main functions. On one hand, it generates steam from the heat energy liberated upon combustion of the organic constituents of black liquor burned in the boiler, whereby the recovery boiler serves as a steam boiler.

On the other hand, the chemicals from pulp digesting - sulphur and sodium are recovered from the black liquor, the recovery boiler then serving as a chemical reactor. This double function makes the design of a recovery boiler rather complex and the operation of such a boiler much more complicated than that of, for instance, a power plant boiler burning conventional fuels in the boiler.

When viewing the recovery boiler as a chemical reactor, its construction is quite unique. In the recovery boiler furnace, to a great extent in the same space and at the same time, a number of entirely separate physiochemical processes take place.

1.2 Soot blowers

The combustion of black liquor causes buildup of combustion deposits (soot, ash and slag) on the boiler's heat transfer surfaces. Combustion deposits generally decrease the boiler's efficiency, particularly by reducing heat transfer. When the combustion deposits accumulate on the boiler tubes, the heat transfer efficiency of the tubes decreases, this in turn decreases the boiler efficiency. To maintain a high level of boiler efficiency, the heat transfer surfaces are periodically cleaned by directing a cleaning medium, e.g., air, steam, water or mixtures thereof, against the surfaces upon which the deposits have accumulated. To avoid or eliminate the negative effects of soot and slag buildup on boiler efficiency, the boiler heat transfer surfaces would need to be essentially free of deposits at all times.

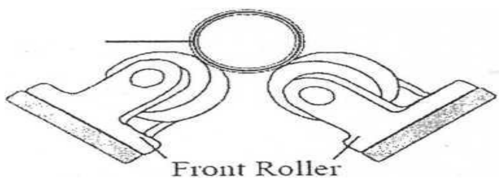

Fig. 1. Lance tube arrangements

Maintaining this level of cleanliness would require virtually continuous cleaning. However, this is not practical under actual operating conditions because cleaning is costly and creates wear and tear on boiler surfaces. Injecting the cleaning medium also, reduces the boiler's efficiency and prematurely damages heat transfer surfaces, particularly if they are over-cleaned. Boiler surface and water wall damage resulting from soot blowing is costly because correction may require an unscheduled shut down.

Therefore, it is important that these surfaces not be cleaned unnecessarily or excessively. Boiler cleanliness must be balanced against cleaning costs. Accordingly, boilers must be typically maintained reasonable, but less than ideal boiler cleanliness levels.

2 EXPERIMENTAL PROCEDURE

Soot blower is a device which is designed to blast soot and ash away from the walls of a furnace or similar piece of equipment. Soot blowers operate at set intervals, with a cleaning cycle that can vary in length, depending on the device and the size of the equipment which needs to be cleaned. Soot blowers function to keep combustion particles from sticking to boiler tube banks within the boiler tower.

2.1 Principle

The basic principle of the soot blower is the cleaning of heating surfaces by multiple impacts of high pressure air, steam or water from nozzle orifice at end of the translating rotating tube nozzle jets penetrates the narrow openings in the boiler tube banks to blast.

The tubes must be kept clean to allow optimum boiler output and efficiency. A common application at oil, coal or multi-fuel source power plants is retractable or rotary soot blowers

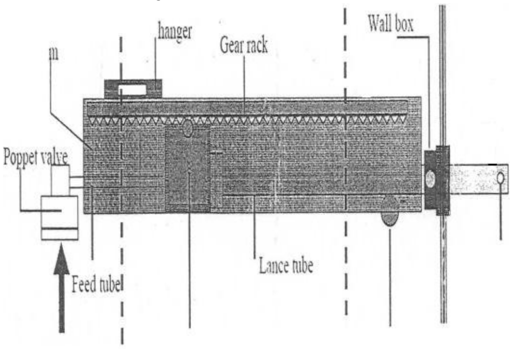

Fig. 2. Shoot blower major components

- A nozzle - especially selected for each application.
- A means to convey the nozzle-conveying mechanism includes the lance tube, carriage and drive motor.
- A means to supply blowing medium into the nozzle - poppet valve, feed tube, packing gland and lance tube.
- A means, to support and contain the lower component - a canopy type beam with a two-point suspension.
- Controls-integral components protected by the beam to control the blowing cycle and supply power to the drive motor.

2.1 Main parts

2.1.1 Lance tube

The lance tube is the main component that supplies the soot blower nozzles with high pressure steam and directs the jets toward the boiler tubes. During the cleaning process, the lance extends into the boiler and forms a structure similar to a cantilevered beam

2.1.2 Nozzle

The main function of a soot blower nozzle is to convert the high pressure steam inside the lance tube into a high- velocity jet. An ideal nozzle is defined as a nozzle that fully expands the blowing medium from the pressure inside the lance tube to the outside ambient pressure; thereby, converting them. iance pressure completely into velocity (100% efficiency). In order to fully expand the pressure inside the lance and accelerate the steam to a supersonic velocity, a convergent-divergent type of nozzle is used (Fig. 5). In the convergent section, the steam is accelerated to a speed of sound. The divergent section then accelerates it further to a supersonic velocity

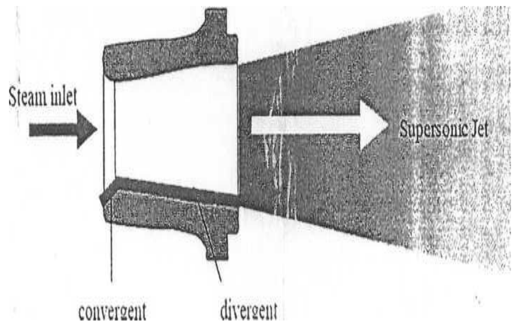

Fig. 3. Nozzle

2.1.3 Limit Switch

A limit switch is an electromechanical device that sends a signal transmission to the carriage when its mechanical leg is physically pushed by a lever arm.

There are two limit switches with one lever arm: one is mounted in the rest position and the other is mounted in the reverse position. The lever arm, which is used to trigger the switches, is attached to the carriage and travels together with it.

2.1.4 Wall box

The main function of a wall box is to prevent the hot flue gas, fume and carryover particles from escaping the boiler through the openings designed for soot blower operation.

This can be achieved by continuously supplying the wall box with pressurized air (seal air); hence creating an air wall that prevents the flue gas from leaking through the lance/wall sleeve gap.

3 PERFORMANCE GOALS

The industry management has established certain performance goals which need to be met in the recovery boiler. By keeping these goals as a scale of success for this project, we have progressed on the endeavor.

- Keep the cost of production of steam within Rs. 6/ton.
- Increase the power producing capacity of the plant to 10 MW/day.
- Maintain the steam production rate of the boiler at 70 tons/hour.

These are the benchmarks that will be used to define, track, and measure project success over time.

The difference in performance benchmarks reflects the inherent differences in the planning and execution of the project and hence need to be taken care.

2.1 Root cause analysis

The overall objective of this analysis was to identify and define the root causes impeding effective performance of the soot blowers. The specific objectives were:

- To identify a comprehensive list of issues and the root causes that negatively impact the performance soot blowers like nozzle damage, steam leakage, etc.

2.2 Approach and methodology

The approach for conducting the RCA on soot blower performance anomalies involved collecting data through document reviews and interviews with the engineers and operators working in the chemical recovery boiler. The data collected where then analyzed to identify the root causes for the problems being encountered in the soot blowers.

The methodology used to perform the RCA included the following steps:

Step 1 Define the Problem.

The smooth operation of the soot blower in the boiler is affected by various reasons as reported by the industry. Despite their efforts to curb them, the complete eradication of the instances remained a challenge.

Step 2 Gather Data and Evidence.

Data were gathered to document past shortcomings in performance. These data were predominantly gathered from reviewing documented reports that specifically addressed the repair works undertaken in the soot blowers.

The significance and value of the findings in many of these reports were still germane. They were reviewed for continued applicability.

The findings from these reports were validated and supplemented with interviews of people directly responsible for soot blowers in the boiler.

Step 3 Identify Issues that contribute to the problem

On the basis of the data gathered and reviewed through document reviews and interviews, the most significant issues that plague the soot blower performance were identified.

Step 4 Find the root causes

Once the common issues negatively affecting soot blower performance were found, a more thorough review of the top an issue was undertaken to determine the reasons why they continue. The RCA Lance rotational speed.

Methodologies commonly referred to as the "Ishikawa Diagram" and "Five- Whys" were used. The responses -obtained in the previous steps were structured to find out the root causes.

Step 5 Develop Recommended Solutions

Upon determining the underlying root causes, a series of possible solutions was analyzed in the form of corrective measures aimed at resolving these issues.

Step 6 Implement Recommended Solutions

Each corrective measure will be included in a comprehensive and integrated corrective action plan. The implementation of specific corrective measures will be evaluated and reported on a periodic basis.

Step 7 Observe and Measure Performance for Desired Outcome

Ensure the commitment and allocation of the necessary resources to continually measure performance against our performance goals. The contents of this report represent completed activity through the first five steps.

4 PROBLEMS IDENTIFIED

The various problems that are identified in 28 soot blowers of the chemical recovery boiler are listed below.

1. Bending of the lance tube
2. Steam leakage
3. Nozzle rupturing

4.1 Bending of Lance Tube

The bending of lance tube is the major problem in soot blowers, here the reason for the bending are,

- Bending due to external forces
- Material Weakness, improper balancing

4.2 Steam Leakage

The steam leakage in the soot blower is one of the minor problems due to the following reasons,

- Failure of Seal
- Lance tube Erosion

4.3 Nozzle Rupturing

Nozzle rupturing occurs due to the following reasons

- Presence of minute particulates in the steam

- Friction between nozzle surface and steam

5 ANALYSIS OF MODELS

5.1 Model 1 (Inner diameter: 97mm, outer diameter: 101.7mm)

5.1.1 Material with maximum deformation of 0.078259m

Lance material: Mild stee

Nozzle section material: Stainless steel

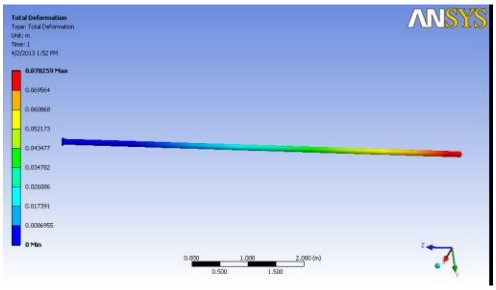

Fig. 4. Total deformation of stainless steel nozzle section under model 1

5.1.2 Material with maximum deformation of 0. 053114m

Lance material: Mild steel

Nozzle section material: Magnesium alloy

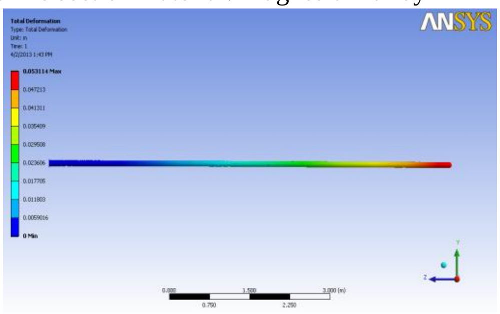

Fig. 5. Total deformation of magnesium alloy nozzle section under model 1

5.2 Model 2 (Inner diameter: 97mm, outer diameter: 105mm)

5.2.1 Material with maximum deformation of 0.11423m

Lance material: Mild steel

Nozzle section material: Stainless steel

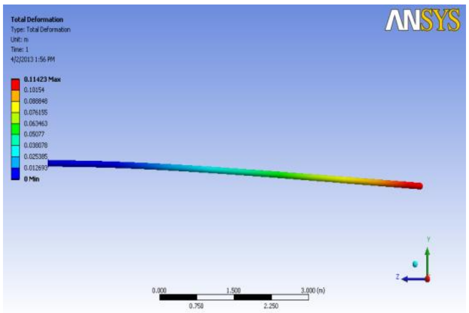

Fig. 6. Total deformation of stainless steel nozzle section under model 2

5.2.2 Material with maximum deformation of 0.077151m

Lance material: mild steel

Nozzle section material: magnesium alloy

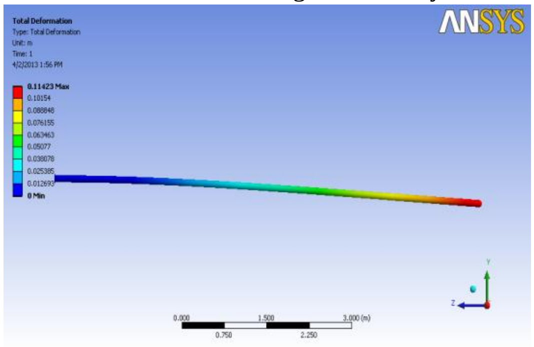

Fig. 7. Total deformation of magnesium alloy nozzle section under model 2

5.3 Model 3 (Inner diameter: 97mm, outer diameter: 107mm)

5.3.1 Material with maximum deformation of 0.078285m

Lance material: Mild steel

Nozzle section material: Stainless steel

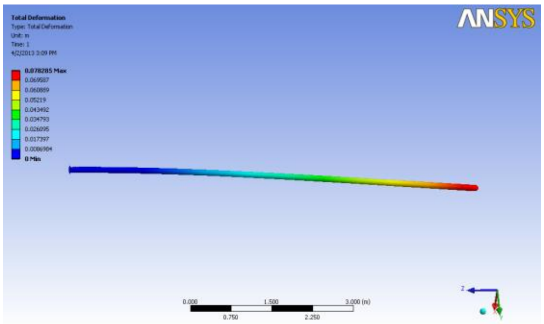

Fig. 8. Total deformation of stainless steel nozzle section under model 3

5.3.2 Material with maximum deformation of 0.035827m

Lance material: Mild steel

Nozzle section material: Magnesium alloy

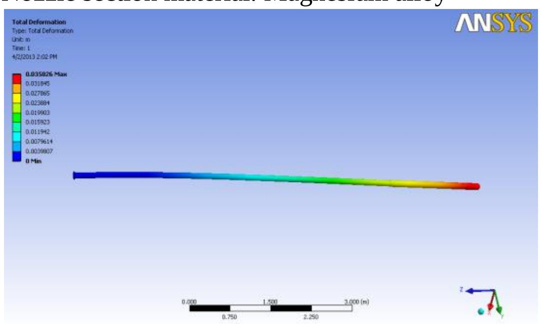

Fig. 9. Total deformation of magnesium alloy nozzle section under model 3

5.4 Model 4 (Inner diameter: 97mm, outer diameter: 108mm)

5.4.1 Material with maximum deformation of 0.10792m

Lance material: Mild steel
Nozzle section material: Stainless steel

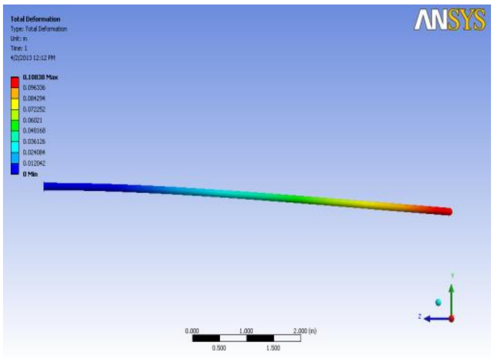

Fig. 10. Total deformation of stainless steel nozzle section under model 4

5.4.2 Material with maximum deformation of 0.073273m
Lance material: Mild steel
Nozzle section material: Magnesium alloy

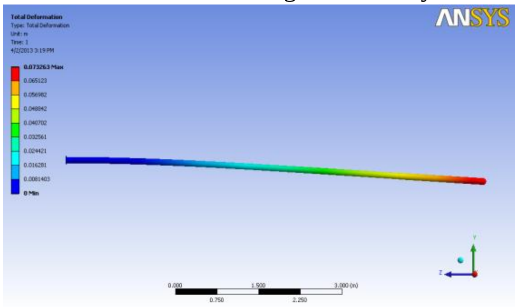

Fig. 11. Total deformation of magnesium alloy nozzle section under model 4

***5.5* Model 5 (Inner diameter: 97mm, outer diameter: 110mm)**

5.5.1 Material with maximum deformation of 0.10792m
Lance material: Mild steel
Nozzle section material: Stainless steel

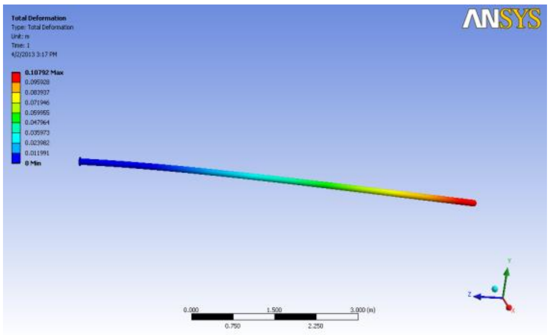

Fig. 12. Total deformation of stainless steel nozzle section under model 5

5.5.2 Material with maximum deformation of 0.073273m
Lance material: Mild steel
Nozzle section material: Magnesium alloy

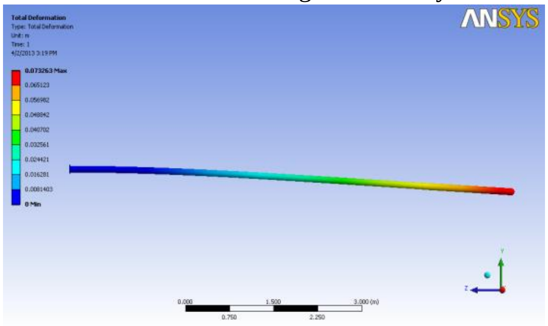

Fig. 13. Total deformation of magnesium alloy nozzle section under model 5

5 RESULTS

5.1 MODEL 1 (inner diameter=97mm,outer diameter=101.7mm)

TABLE 1 Comparison of results for model 1

5.2 MODEL 2 (inner diameter=97mm,outer diameter=105mm)

TABLE 2 Comparison of results for model 2

S. No	Lance tube material	Nozzle selection material	Deformation (meter)	Max. shear stress (Pascal)	Shear stress
1	Mild steel	Stainless steel	0.078823	$8.27e^{8}$	$3.7e^{8}$
2	Mild steel	Magnesium alloy	0.053144	$3.23e^{8}$	$2.4e^{8}$

5.3 MODEL 3 (inner diameter=97mm,outer diameter=107mm)

TABLE 3 Comparison of results for model 3

S. No	Lance tube material	Nozzle selection material	Deformation (meter)	Max. shear stress (Pascal)	Shear stress (Pascal)
1	Mild steel	Stainless steel	0.11423	$7.66e^{8}$	$2.337e^{8}$
2	Mild steel	Magnesium alloy	0.077151	$6.47e^{8}$	$2.787e^{8}$

S. No	Lance tube material	Nozzle selection material	Deformation (meter)	Max. shear stress (Pascal)	Shear stress (Pascal)
1	Mild steel	Stain less steel	0.078285	7.77e8	2.337 e8
2	Mild steel	Magnesium alloy	0.0358	7.47e8	2.787 e8

5.4 MODEL 4 (inner diameter=97mm,outer diameter=108mm)

TABLE 4 Comparison of results for model 4

S. No	Lance tube material	Nozzle selection material	Deformation (meter)	Max. shear stress (Pascal)	Shear stress (Pascal)
1	Mild steel	Stain less steel	0.10792	8.72e8	3.194 e8
2	Mild steel	Magnesium alloy	0.07273	5.27e8	2.829 e8

5.5 MODEL 5 (inner diameter=97mm,outer diameter=110mm)

TABLE 5 Comparison of results for model 5

S. No	Lance tube material	Nozzle selection material	Deformation (meter)	Max. shear stress	Shear stress
1	Mild steel	Stain less steel	0.10838	7.14e8	3.348 e8
2	Mild steel	Magnesium alloy	0.072474	4.73e8	2.852 e8

.

5.6 Acceptance of conditions

The analyzed model of lance tube must accept some of the parameters that are prevailing in the chemical recovery boiler and environment.

1. Temperature
2. Pressure
3. Bending Resistance

5.6.1 Temperature

The analyzed model withstands the prescribed blower design temperature of 420˚C.

Also the lance tube is analyzed for the steam temperature of 470˚C.

5.6.2 Pressure

The model accepts the working pressure of 87kg/cm^2.

5.6.3 Bending Resistance

The lance tube made of mild steel and nozzle section made of magnesium alloy proves to have deformation of 35.8mm and equivalent stress of $1.229*10^9$ Pascal.

5.7 Magnesium alloy composition

TABLE 3 Composition of magnesium alloy

Materials	Composition
Aluminum	8.3-9.7
Manganese	0.15-0.5
Zinc	0.35-1
Silicon	0.1
Copper	0.03
Nickel	0.002
Iron	0.005
Magnesium	Remaining

5.8 Properties of magnesium alloy

- Lightest of all structural metals 35%lighter than aluminium and 75%lighter than steel.
- Higher operating temperature with excellent stiffness and strength to weight ratio.

5.9 Ash deposition on lance tube

The ash produced as the result of combustion of the black liquor inside the chemical recovery boiler deposits on the outside wall of lance tube during the retraction the ash content were deposited on the lance tube.

This ash content over period of time would plug in the clearances provided between the lance tube and wall box. This deposited ash can is removed by providing compressed air blowing system.

By implementing the air blowing system near the wall box, the compressed air is blown over the surface during the retraction of the lance tube to remove the ash deposited over the lance tube. The ash deposited on the lance tube is one of the minor problems that are occurring in the soot blower; hence this problem does not affect the soot blower performance in major level.

5.10 Steam leakage

5.10.1 Reason for failure

The main reason for steam leakage between feed tube and lance tube is due to the nature of joint used between them. The sliding joint is the main reason for major steam leakage. The seal is provided between the feed tube and lance tube, which guides the moving lance tube with fixed feed tube.

The major cause for steam leakage is the failure of seal. Due to continuous sliding, the outer surface of the seal wears; it results in increase in the clearance between the inner surface of seal and outer surface of the seal.

The increased clearance paves the way for puffing of high pressurized steam outside the lance tube

5.10.2 Solution

The remedy for the problem is to replace the seal within prescribed life. Next the seal could be made of high wear resistant materials. The leakage problem can be minimized by changing the design of seal.

6 CONCLUSION

The efficient functioning of any equipment or machinery is guaranteed when it is installed in the industry and operated according to the design condition which was formulated after careful and prolonged examination of its performance. The problems that occur in soot blowers of chemical recovery boilers are analyzed and solutions are provided for elimination of problems that encounters the soot blowers.

The best solution is to replace the nozzle section made up of stainless steel (SS310) to magnesium alloy (AZ91D) and the outer diameter of the lance tube and nozzle section is increased from 101.6mm to106mm. This helps to reduce the deformation up to 55.12% from existing lance tube made of stainless steel. The deformation value by using the nozzle section made of magnesium alloy is 35mm.By replacing stainless steel section made of outer diameter 106mm by magnesium alloy, the material cost is saved. Remedial measures for steam leakage and ash deposition are given for efficient functioning of soot blowers of chemical recovery boiler.

REFERENCES

[1] Kent, Sandquist (1987) "Operational experience with single drum recovery boilers" in North America. Tappi 1987 Kraft Recovery Operations Seminar, Orlando, Fl, January 11–16.

[2] A.K. Varshneya. "Fundamentals of soot blowers" Gulf Professional Publishing, 1994 ISBN 0127149708.

[3] Hannu, Hänninen (1994)."Cracking and corrosion problems in black liquor recovery boilers" 30 Years Recovery Boiler Co-operation in Finland. International conference, Baltic sea, 24–26 May.

[4] Karl, Holmlund and Kari, Parviainen, (2000)."Evaporation of black liquor" Chapter 12 in Chemical Pulping, Book 6, series editors Johan Gullichsen and Carl-Johan Fogelholm. Finnish Paper Engineers' Association and TAPPI. ISBN 952-5216-06-3.