Well; it’s already the second week of November, where has this year gone?

I just got back from the fall conference three weeks ago at Reliant Center in Houston. The sixth edition of the “Web-Based HMI Panel” and the fifth edition of the Ethernet I/O panel came off quite well with nearly full rooms.

Well, there’s only four months until the 2007 PUPID scholarship deadline. Please, get the word out that we have two $1000 scholarships to give away. If you know of any deserving student, urge them to go to the PUPID website look at last years scholarship winners, fill out the application and email it to Mike Waller. Let’s not miss the chance to give away some of our scholarship endowment money. Spread the word

At this year’s ISA Fall Conference, at the ISA Joint A&T/I&S Luncheon on Tuesday PUPID received half of the Communications Award sharing it with the Power Industry Division

PUPID membership is slowly dwindling, it is now at 510 members. How can we get back to the 1996 membership level of around 1900 members?

I want to challenge ALL OF YOU to send me a couple of paragraphs telling me what you are doing in your part of the world. You can send me either some good news about some new and fun project you’ve been working on lately OR simply vent your frustrations with the state of the world (I’ll make your quotes anonymous if you want!)

The 2007 Spring Symposium will be with the TAPPI Papermaking and Process Control, Electrical & Information Divisions (PCE&I) and PIMA and will be March 12 – 16 at the Hyatt Regency Jacksonville Riverfront Hotel in Jacksonville, Florida. Mark it on your calendars.

Well, I’ll sign off now until next time; keep watching the PUPID website for upcoming attractions!
**Tuning Tip: Is This Cycling Normal?**

You observe on the screen that a temperature (PV) is cycling. Is this normal or is there something wrong? Is it noise, disturbance or something else?

In process control, cycling is abnormal and should be eliminated since oscillations have negative effects. (They increase energy costs, disturb other parts of the process, reduce quality, reduce equipment life, etc.)

**Noise or disturbance**

In a control loop, the controller uses the error between SP (set point) and PV (process variable) to manipulate CO (controller output) to bring back PV to SP. The settling time for a control loop is the time needed to bring back PV to SP (usually we consider the time it takes to reach 95% of the change). This settling time depends on the process and the controller tuning parameters.

If the loop is tuned sluggishly, the settling time is long and the error needed to bring back PV to SP is large. If the loop is tuned aggressively, the settling time is smaller and the error needed to bring back PV to SP is smaller, but temporary cycling could occur (damped oscillations).

If oscillations (or repetitive phenomenon) occur at a period that is shorter than the settling time, the controller is not able to fight them; in that case, we call them noise. Otherwise, they are disturbances.

To reduce or remove disturbances, we have to find their origin and eliminate them, or at least change the rate. For example, if a solenoid valve is used to reverse the flow in a heat exchanger that reduces fouling, the rate should be adjusted to reduce its impact on other loops. If a reservoir level is controlled by using hi and low limits and this cycling induces oscillations in the process, one should consider replacing the On-Off scheme by a controller and a modulating valve (or variable speed drive).

To reduce or remove noise, we also have to pinpoint its origin. If the noise cannot be eliminated, we must add a filter on the PV in order to reduce the impact of this noise on the controller output and its propagation to other loops.

**Loops without oscillations**

In processes in which all loops are optimized, all PVs should present normal statistical distributions, have a flat power spectral density, and an autocorrelation plot remaining within confidence limits after settling time. There should be no cycling or white noise (all frequencies are equally distributed).

**Rules of thumb:**

For example, if a temperature loop has a dead time of 1 minute, the filter time constant should be around 12 seconds and the settling time should be around 10 minutes. An oscillation that has a period of 1 or 2 minutes will be noise, while an oscillation that has a period of 30 minutes will be a disturbance.

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**Calendar of Events**

Get a quick overview of the ISA PUPID events for 2006 by going to the Calendar at: [http://www.isa.org/~pupid/2006_PUPID_Calendar.htm](http://www.isa.org/~pupid/2006_PUPID_Calendar.htm)

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**Paperweek 2007 - ExFor 2007**

February 5 - 9, 2007

Palais Des Congrès

Montreal, QC Canada

[http://www.paptac.ca/english/am/paperweek.htm](http://www.paptac.ca/english/am/paperweek.htm)

**PIMA/TAPPI Papermakers Conference 2007**

March 12 - 16, 2007

Hyatt Regency Jacksonville Riverfront Hotel

Jacksonville, Florida


**61st Appita Annual Conference and Exhibition & International Paper Physics Conference**

co-sponsored by PAPTAC (Canada) and TAPPI (USA)

Gold Coast Convention & Exhibition Centre

Broadbeach Queensland

6 – 10 May, 2007

[http://www.APPITA.com](http://www.APPITA.com)

**53rd Pulp & Paper Industry Conference 2007**

June 24 - 28, 2007

Williamsburg Lodge

Williamsburg, VA

[http://www.pulppaper.org](http://www.pulppaper.org)

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**The 3rd International Paper Industry Expo Guangzhou**

Guangzhou Jinhan Exhibition Center

Guangning People’s Government

July 25-27, 2006


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**ISA President’s Fall Meeting**

**Houston, TX**

**September 29 - October 1, 2007**

Come meet your leaders & get involved!

**ISA Expo 2007**

**Reliant Center, Houston, TX**

**October 2 - 4, 2007**

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**Upcoming ISA Conferences & Exhibitions**

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### ISA Pulp & Paper Industry Division 2006 Calendar

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You can see the online calendar at [http://www.isa.org/~pupid/2006_PUPID_Calendar.htm](http://www.isa.org/~pupid/2006_PUPID_Calendar.htm)
Welcome to the 14 NEW ISA Pulp & Paper Industry Division Members since August 2006

Welcome to New PUPID Members

Brian F. Greenwood
Ms. Lentia Vieira Alves
Marcelo Conelha Silva
Tiago P Campos Santos
Jose Mateus Theodoro Ropes
Tiago Carneiro Araujo
Robert A. Stevens
Alfredo Faz
Omar Riquelme
Keith R. Kersten
Ronnie Ruffo
Leonardo Borques Reis
Eduardo Espindola Batista Aguiar
Don Burns

ISA Pulp & Paper Industry Division Scholarships

Did you go to any of these schools that belong to the Pulp and Paper Education and Research Alliance (PPERA)? If you did (or if you know and/or work with any students currently attending one of these schools or you just root for one of them on Fall Saturday afternoons), then remind the students to apply for the ISA Pulp & Paper Industry Division Scholarships. We will award up to two $1000 scholarships per year ASSUMING we get the applicants (we had NO applicants for the last two years).

Members

• Auburn University at http://www.eng.auburn.edu/center/pnp/pnp.htm
• Georgia Institute of Technology at http://www.chemse.gatech.edu/Research/pulpapaper.htm
• Institute of Paper Science and Technology at http://www.ipst.gatech.edu/
• Miami University at http://www.sas.muohio.edu/pps/
• North Carolina State University at http://www.cfr.ncsu.edu/wps/
• State University of New York at http://www.esf.edu/faculty/ose/
• University of Maine at http://www.umecheme.maine.edu/
• University of Minnesota at http://www.che.umn.edu/
• University of Washington at http://www.cfr.washington.edu/
• University of Wisconsin - Stevens Point at http://www.uwsp.edu/papersci/
• Western Michigan University at http://www.wmich.edu/opp/

Applicants need to start the process now since they need three references and an official transcript in addition to the application (that can be found on the PUPID website at http://www.isa.org/~pupid/PUPID_Scholarship_Application_Form.pdf). The application needs to arrive no later than February 28.

Go to http://www.isa.org/~pupid/PUPID_Scholarship_Bulletin.html to get the information!
PRODUCT SHOWCASE:

Analytical Measurements Protect Recovery Furnace and Boiler in a Pulp and Paper Mill

By: Dave Joseph Senior Industry Manager
Emerson Process Management, Rosemount Analytical
Doug Simmers Worldwide Product Manager
Emerson Process Management, Rosemount Process

Recovery Boiler operations can be improved considerably by using continuous analytical measurements. The information they collect can be used to optimize black liquor conversion and energy extraction in the furnace without compromising safety and reliability of boiler tubes and other components. The Recovery Furnace oxidizes concentrated black liquor, thereby generating feedstock for green liquor and the rest of the Kraft process, and simultaneously producing steam for millwide use. The furnace is optimized by controlling excess combustion air levels to maximize smelt recovery, prevent corrosion, and maximize steam production. The boiler is optimized for longevity by monitoring the quality of water used to produce steam. This also protects the boiler tubes against corrosion and pitting due to harmful mineral deposits. Effective analytical measurements can assist in optimizing these operations. Additionally, accurate analysis of both combustion flue gases and boiler water can be used to prevent explosive conditions.

Furnace Operations While traditional natural gas or oil burner arrangements may be used for boiler start-up, the black liquor reaction is exothermic, and once started, it is self-sustaining. The black liquor is viscous, and great care is exercised to maintain at least a 50-60% solids content. The liquor is injected from above through oscillating nozzles, and forms a molten bed in the bottom of the furnace. Fuel control is comparatively poor, and fuel/air ratio control is difficult. Partially pyrolyzed liquor can form localized pockets of explosive gases, so reliable gas analysis is
important to not only maintain efficiency and optimize conversion, but also to prevent explosions. In-situ zirconium oxide oxygen sensing technology works well in this application. Typically, the heated sensor is placed onto the end of a probe that is 3-9 feet long, minimizing problems involved with filter plugging, since there is no sample transport required. It should be noted that since the sensor is heated to approximately 1500° F, the sensing cell will burn any combustible components in the flue gases, and read the remaining O2. Excursions of high CO or other combustible components will result in a depleted O2 reading, so a low O2 alarm should be utilized in the DCS control system for optimum control.

A passive hastelloy filter (diffuser) protects the sensing cell from particulate matter, and can endure the high temperatures and corrosive attack inside the recovery boiler. The buildup of salt cake on this in-situ filter (diffusion element) can pose a problem over time, reducing the speed of measurement response. The best way of diagnosing a plugged diffuser is a flow test with calibration gas. This can be done on-line, but the boiler operator should be notified so that any control loop can be placed into manual for safety considerations. Use bottled calibration gas with a different O2 value than the normal operating range (for instance, 8% O2). Once the O2 readings have stabilized at the bottled gas value, remove the cal gas, and note the time it takes to return to the normal process value.

With a new diffuser, the reading should begin to return within 3-5 seconds (Tinitial). The reading should return all the way back to the normal process value within 30 seconds or so (Tfinal). A badly plugged diffuser may take 30 seconds to reach Tinitial, and a minute or more to reach Tfinal. Besides delaying the normal speed of response, a plugged diffuser can cause a shifted reading if the probe is calibrated with a plugged diffuser. Care should be taken to prevent flowing too much cal gas to the sensor, pressurizing the cell during the calibration procedure. Set the calibration gas flow to specification only when installing a new diffuser. As the diffuser plugs, a lower flow rate will be noted, but never increase the flow rate back up as this will mask the problem.

The buildup of salt cake deposits is a unique problem associated with recovery boilers. This can be can be minimized by periodically back-purging with instrument air down the calibration gas line inside the probe. The back-purge can physically remove some material, and it also burns off any combustible components in the heated sensing cell and diffuser. Frequency and duration of this burn-off procedure is highly variable from furnace to furnace, and depends greatly on how the boiler is being operated.

SO2 and other sulfurous components can shorten the life of a ZrO2 sensing cell by attacking the platinum electrode that generates the O2 measurement signal. This condition is further aggravated by furnace operation with O2 levels below 1%. Rosemount’s Oxymitter product utilizes a “calibration recommended” diagnostic which will notify technicians when the sensing cell should be recalibrated. Sulfur-resistant cells increase cell life considerably in recovery boiler service.

**Boiler Operations** Protecting the boiler side of the recovery area requires verifying that the steam produced in the boiler is not contaminated by potentially corrosive chemicals, dissolved oxygen, or high levels of dissolved solids. pH, conductivity, and trace dissolved oxygen are three very common online measurements that can easily be installed for this purpose. These measurements are common to all large scale industrial boilers.

Boiler water is usually treated with chemicals to produce an optimum pH in the 8-9 range, which tends to minimize corrosion and scaling. Excursions above or below this range usually indicate a process leak in a heat exchanger tube. Continued operation in this mode can lead to widespread corrosion and expensive tube replacements. pH measurement of condensate can be problematic due to low ionic strength in the sample, but sensors designed for high purity measurement such as the model 320HP provide a stable signal by controlling both sample
flow and reference flow rates. The steam produced in the boiler is used to preheat and concentrate the black liquor in multiple effect evaporators before combustion in the furnace. The condensed steam provides an opportunity to monitor the purity of the boiler water and specifically check for black liquor leaks into the condensate. Black liquor is both highly alkaline and highly conductive, so it is easily detected by pH and/or conductivity measurements. Retractable conductivity sensors can be installed upstream and downstream of potential leak sources.

The Black Liquor Recovery Boiler Advisory Committee (BLRBAC) recommends “The installation of a conductivity sensor with alarm at an individual spout outlet or at a common point in the vacuum cooling water system can be helpful in the early detection of a spout leak, since the initial stages of a spout leak could allow small amounts of smelt to leak into the spout, slightly contaminating the purity of the cooling water prior to the leak becoming large enough to “break” the vacuum or siphon interrupting cooling water flow to the affected spout.”

Conductivity is an excellent leak detection method because it can indicate the presence of any ions in the condensate. It can quickly indicate a spout leak or indicate a slow buildup of solids over time. Boiler water is reused many times and can build up contaminants from several sources that eventually cause scaling or other damage to metal surfaces. Localized scale prevents heat conduction in the boiler tubes, leading to overcompensation and localized overheating. This is a costly and potentially dangerous activity as overheating may lead to leaks. A localized area of heat stress results, which is more easily corroded from the furnace side. A hole develops, and the steam explodes. Stainless clad boiler tubes are used to reduce heat stress failures and conductivity is continuously measured to prevent the accumulation of scale.

Water treatment chemicals add to the conductivity of water, so some data interpretation may be necessary to determine if harmful levels of ions are present. A condensate monitoring system with reboiler can be used to isolate the contribution of salt ions from the water treatment chemicals and dissolved gasses that may be present. Flow through conductivity cells can also be used separately to monitor general condensate purity. Dissolved oxygen is also a major cause of metal corrosion and is removed using a deaerator and/or injection of an oxygen scavenger chemical. Boiler water must be treated to reduce dissolved oxygen from ambient parts per million (ppm) levels to 50 parts per billion (ppb) or lower. Measurement of trace dissolved oxygen in the ppb range specifically verifies oxygen removal. Amperometric sensors use the current generated by the diffusion of oxygen across a semi-permeable membrane as an indication of the concentration in the solution. One model uses a patented technique for eliminating background

**Editor’s Note:**
This paper was originally published on the Pulp & Paper Online website at [http://www.pulpandpaperonline.com/](http://www.pulpandpaperonline.com/)
Where’s The Action? Who’s doin’ anything?

IP To Sell Pine Bluff Mill To CHH Affiliate
10/18/2006

Pine Bluff, AR - International Paper (IP) has reportedly agreed to sell its Pine Bluff, AR, mill to Rank Group Australia, an affiliate of Carter Holt Harvey of New Zealand. According to the Pine Bluff Commercial, the actual sales agreement has not yet been negotiated and the sales price has not been determined. Employees were informed of the company’s plans last Friday, October 13, the newspaper reported. The sale of the mill is part of a restructuring plan announced by IP in July 2005.

The Pine Bluff mill produces approximately 1,000 tpd of bleached board used for beverage cartons, supplying one-third of the world’s gable-top board market and 48% of the domestic liquid packaging market. The mill, which also produces coated publications papers, operates two paper machines, four extruders, one off-machine coater, and two supercalendars. It has some 1,100 employees.

SOURCE: TAPPI

National Gypsum Announces Major Paper Expansion
10/19/2006

Charlotte, NC - National Gypsum Company, a manufacturer of gypsum wallboard, announced recently it plans to more than triple paper manufacturing capacity at its Oxford, AL plant. The expansion will include installing a state-of-the-art paper machine with a tentative startup in late-2009. The company said that it will invest approximately $115M in the project, bringing employment at the plant to 93.

The company also announced wallboard capacity expansions with new high-speed plants near Charlotte, NC, and Phoenix, AZ. The additional paper capacity will be needed to support these expansions. While the building is erected and the machine installed, National Gypsum will continue to produce paper on its existing equipment in Alabama.

The new three-ply paper fourdrinier machine will use state-of-the-art technology to produce a strong, yet light-weight sheet of paper. With the technology, less fiber is used to produce the sheet and, because of the reduced weight, the company can ship more paper per truck to its wallboard plants. The machine allows for efficient production of 54-inch paper as well as 48-inch paper. This project builds on the company's previous fourdrinier paper-making experience at its Pryor, OK plant.

National Gypsum operates four paper mills, recycling 100 percent waste paper to produce the facing paper for its gypsum wallboard. The company is believed to be one of the largest waste paper recyclers in the nation.

SOURCE: National Gypsum Company
Caraustar Closes Reading Paperboard Mill In Pennsylvania
10/18/2006
Sinking Spring, PA - Caraustar Industries has closed its Reading Paperboard mill in Sinking Spring, PA. The Reading mill is a recycled, uncoated paperboard facility with a capacity of 16,000 short tpy. Caraustar expects to consolidate all of the mill's production into other existing company locations, which it says will increase company-wide mill capacity utilization.

The closure of the Reading mill, Caraustar notes, reflects the company's previously announced plans to achieve greater cost efficiencies throughout its system and better utilize capacity. Associated with this mill closure, the company will record a pre-tax charge of approximately $1.9M, of which approximately $1.2M will be non-cash. This rationalization is expected to generate an estimated $1.6M in annual pre-tax savings. The closure of the Reading mill will affect approximately 26 salaried and hourly employees. Caraustar says it will provide a comprehensive program of separation pay, benefits coverage, and job assistance to affected employees to facilitate their transition to alternate employment.

SOURCE: TAPPI

Tseshahnt Nation Buys Surplus Port Alberni Land From Catalyst Paper
10/19/2006
Port Alberni, BC - Catalyst Paper has finalized an agreement for the sale of 120 hectares (297 acres) of surplus company property into Vancouver Island's Tseshahnt First Nation. The transaction will close on December 1. The land is located next to the Tseshahnt reserve and is part of the Somass River delta. It includes 1.4 kilometers of riverfront and is in the agricultural land reserve. Catalyst used the property to grow poplar and retains a right-of-way for a water pipeline to its Port Alberni mill.

The $2M sale is part of an ongoing rationalization of property holdings that in the past year has resulted in the divestiture of six parcels of Catalyst land considered non-core to business operations. "When the Tseshahnt approached us with an offer to purchase this property, we saw it as a good opportunity to support aboriginal business initiatives in the Alberni Valley as the region evolves economically," said Russell Horner, Catalyst president and CEO. "At the same time, we are receiving a fair market price for land we no longer require and that makes good sense for our business."

The Tseshahnt are one of 14 nations that make up the Nuu chah nulth Tribal Council. According to Tseshahnt Chief Councilor Les Sam, this marks the largest land purchase by the Tseshahnt to date. "The transaction clearly indicates the benefits of First Nations working together with industry on initiatives that benefit both of us," he added. "This acquisition will help meet the needs of future Tseshahnt governments in addressing community and business development opportunities."

Catalyst, headquartered in Vancouver, BC, produces mechanical printing papers in North America, as well as market kraft pulp. It has five mills with a combined annual capacity of 2.4 million metric tons, and employs 3,800 people.

SOURCE: Catalyst Paper
Hercules Celebrates 75th Anniversary Of Research Center
10/19/2006

Wilmington, DE - Hercules Incorporated celebrated the 75th Anniversary of the Hercules Research Center and the dedication of its Paper Applications Laboratory, the newest addition to the research campus, on October 4. Several state and local officials were in attendance, including Governor Ruth Ann Minner and Senator Tom Carper.

In his remarks, Hercules CEO Craig Rogerson recognized the invaluable contribution that research—and the people who led those efforts—made to the success of Hercules over its 94 years of existence and continues to contribute today and in the future. “For almost a century, Hercules men and women have been developing and improving products through systematic research in chemistry…Today, as we dedicate the Paper Applications building, we renew our commitment to the creative research and development of many more new and useful products.”

Governor Minner, who had met with Company leaders in June, 2005 to discuss their plans for the Research Center, thanked Hercules for its leadership in research and development and for contributing patents to the State’s technology initiative.

Senator Carper reflected that 75 years ago when the Research Center began was a “tough time for the country as it headed into the Great Depression.” He congratulated Hercules on its longevity, its world class workforce, and its commitment to investing in research, development and innovation.

After the ribbon cutting ceremony, guests went on tours of the new paper facility and other buildings on site, followed by a luncheon. In the afternoon, technology presentations were conducted by research leaders from Hercules Aqualon and Paper Technologies businesses. The Paper Applications Laboratory is a part of the initial phase of the Research Center revitalization project. It is a state-of-the-art customer applications facility that houses pilot papermaking and paper testing functions.

SOURCE: Hercules Incorporated
ANDRITZ TO DELIVER CORE SYSTEMS FOR MILL EXPANSION

Andritz has received an order from Sappi Saiccor to supply the bleaching, evaporation, and pulp drying systems for the mill in Umkomaas, near Durban. With this investment, the capacity of the mill will be increased from 600,000 to approximately 800,000 t/a of bleached viscose pulp. The pulp is utilized in a wide range of products (textiles, food, chemicals, and plastics).

The order is for the basic and detail engineering, supply of equipment, mechanical erection, supervision, start-up, and training. Start-up of the plant is scheduled for February 2008, and the order value is approximately 100 MEUR.

Andritz says the new bleach plant represents state-of-the-art process technology providing the best washing efficiency while minimizing chemical consumption. The pulp drying line (working width: 4 m) is based on the very successful high-capacity Twin Wire former, which is operating in pulp mills worldwide. In addition, Andritz Küsters, one of the world’s leading suppliers of roll and calendering technologies, will supply a calender to produce the uniform pulp sheet properties which are important for dissolving pulp.

The six-effect, 370 t/h evaporation plant Andritz will supply Saiccor is an advanced sulphite liquor evaporator, with special emphasis on the production of clean reusable condensates. It is equipped with a stripper and a methanol recovery unit for the cleaning of condensates and other specific features required by the sulphite process.

SIEMENS TO SUPPLY 46 MW INDUSTRIAL STEAM SURBINE-GENERATOR SET

Siemens Power Generation Industrial Applications will supply a new steam turbine-generator set to the Sappi Saiccor pulp mill in Umkomaas. The SST-PAC 400 backpressure turbine-generator will supply the mill with electricity and process steam for pulp production.

The scope of supply includes a back-pressure steam turbine generator set, type SST-PAC 400. The turbine-generator is rated at 46 MW. The unit is scheduled for delivery in September 2007 and will start commercial operation in February 2008. "This order is another step towards further strengthening our leading position in co-generation projects in the South African pulp and paper industry" says John Hazakis, director for Siemens Power Generation - New Equipment Sales.

Factors contributing to the contract award were the company's comprehensive experience in the pulp and paper industry, the versatility of the turbine offered, the high efficiency, proven technology and robust construction. The turbine is flexible for different operating loads and provides optimum supply of steam to the processes. The turbine-generator set will be integrated into the mill's overall process and fulfill its complex requirements in terms of process heat and electrical demand for the new energy recovery project.

The turbine will be manufactured at the Siemens industrial turbine factory in Goerlitz, Germany. The erection will be performed by local erection personnel from Siemens Mechanical Services in Wadeville, who will also provide the back-up support and after sales service.
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Did you know that there is a Pulp and Paper Merit Badge in the Boy Scouts?

Well, there is. So do a good deed and help a teenager in your community to get this merit badge on his way to becoming an Eagle Scout.

Boy Scout Merit Badge Requirements

PULP AND PAPER

1. Tell the history of papermaking. Describe the part paper products play in our culture and economy.
2. List the trees which are the major sources of papermaking fibers
   a. Tell what other uses are made of the trees and of the forest land owned by the pulp and paper industry.
   b. Describe ways the industry plants, grows, and harvests trees.
3. Describe two ways of getting fibers from wood.
   a. What are the major differences?
   b. Why are some pulps bleached? Describe this process.
4. Describe how paper is made. Make a sheet of paper by hand using the process described.
5. What is coated paper and why is it coated? Describe the major uses for different kinds of coated paper. In what other ways are papers changed by chemical or mechanical means to make new uses possible?
6. Make a list of fifteen pulp or paper products in your home. Show samples of ten such products.
7. Do one:
   a. Visit a pulp mill. Describe how they convert wood to cellulose fibers.
   b. Visit a paper mill and get a sample of the paper. Describe the processes used for making this paper. Tell how it will be used.
   c. Visit a container plant or box plant. Describe how the product was made.
   d. Visit a printer or newspaper plant to learn how they use paper. Describe the visit. Explain why particular types of paper were used.
8. Describe six of the major jobs in the pulp and paper industry.

BSA Advancement ID#: 91
Source: Boy Scout Requirements, #33215, revised 2004

Go to [http://www.meritbadge.com/mb/091.htm](http://www.meritbadge.com/mb/091.htm) for more information
ADVANCED SOOTBLOWING STRATEGY USING SMARTSOOTBLOWER

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ABSTRACT

The position of the sootblower nozzle with respect to the leading edge of the boiler bank has been known to have a great impact on the ability of the jet to exert force on deposits [1]. Smart Sootblower has been developed to increase the cleaning performance of the jet by positioning the nozzles such that to minimize the jet interaction with the boiler tubes. It is equipped with dual motors that independently control the transversing and rotating motion of the lance. Unlike conventional sootblowers, it cleans the boiler heat exchanger tube surfaces with full knowledge on where the sootblower nozzles are positioned with respect to the boiler banks and full control on the helix movement of the lance. Current advancement in fouling measurement system has enabled us to locate the area where the deposit is accumulating. With the help of these detection systems, Smart Sootblower can be used to target and adjust cleaning intensity based on fouling condition, thus maximizing sootblowing effectiveness, minimizing sootblower steam consumption and preventing sootblower induced tube erosion.

INTRODUCTION

Control of fireside deposit buildup in kraft recovery boilers is attained by sootblowers, which periodically blast deposits off the tube surfaces with high pressure superheated steam jets. Results of laboratory experiments and numerical modeling showed that the position of sootblower nozzles with respect to the leading edge of the tube bank plays an important role in maximizing the jet impact pressure on the deposits [2].

As the jet exits from the nozzle and flows downstream, it decelerates due to the jet mixing with the surrounding quiescent air. The flow of a sootblower jet can be characterized into three different velocity regions: potential core, supersonic, and subsonic regions (Figure 1). The potential core is the jet region where the Mach number of the jet is the same as that of the jet exit Mach number ($M_{exit}$). The velocity of the jet in the supersonic region is between Mach number 1 and $M_{exit}$, while in the subsonic region, the jet Mach number is below 1. Among all of these regions, the
jet potential core is the region where the jet flows at the fastest speed.

The position of the nozzle with respect to the leading edge of the tube passage (offset) controls the intensity of the jet-tube interaction. Offset is defined as the distance between the jet centerline and the tube surface as depicted in Figure 1. As the offset is decreased, the intensity of the jet-tube interaction increases and the subsonic, supersonic, and finally the potential core portion of the jet will hit the front end of the tube. A shock wave will be formed at the entrance of the bank if the portion of the jet that hits the front tube flows at a speed greater than a speed of sound (Mach > 1 - supersonic and potential core regions). The greater the jet Mach number, the stronger the shock wave will be. The formation of this shock wave will disturb the jet flow and, depending on the strength of the shock wave, decrease the ability of the jet to penetrate deep into the passage of the bank and exert force on deposits.

Figures 2 shows the results of CFDLIB, a Computational Fluid Dynamics code developed at Los Alamos US Department of Energy, simulations of a sootblower jet propagating between two platens with offsets 0 (no offset), 0.5, and 1 inches [1].

As seen in Figure 2, the jet is highly disturbed when the nozzle is positioned at no offset. In this case, the jet potential core is in direct collision with the front edge of Platen-1 and a strong shock wave is formed at the entrance of the platen. At offset = 0.5”, the supersonic portion of the jet hits the front edge of Platen-1, while at offset 1”, the subsonic region interacts with the tube surfaces. The shock wave that is formed as the result of positioning the nozzle at offset 0.5” is weaker than that at no offset. This is due to the fact that at offset 0.5”, the speed of the jet as it hits the platen is slower than the jet speed at no offset. When the subsonic portion of the jet hits the platen (offset 1”), no shock wave is formed and as the result, the jet is able to penetrate deeper into the tube passage and impact the deposits directly without much interference from the tube.

In order to increase the effectiveness of a sootblower to remove deposits and to minimize sootblower induced-tube-erosion, it is important that the nozzles are positioned in such a way that the jets propagate as close as possible to the tube surfaces without creating a shock wave at the entrance of the tube banks. This can be achieved by preventing direct collision between the potential core or the supersonic portions of the jet with the leading edge of the tube. An advanced dual motor sootblower (SmartSootblower) has been developed to meet the demand to fully control the sootblower lance movement and the position of the nozzles. It was designed with dual motors that independently control the traversing and rotating motion of the lance tube. With this capability, the sootblower can be operated with a full knowledge on where the nozzles are positioned with respect to the boiler banks and full control on the helix movement of the lance. Hence, jet-tube interaction can be minimized and targeted cleaning can be achieved. This paper discusses the problems associated with the current conventional sootblowing strategy and how the SmartSootblower can be utilized to address those problems and provides advanced solutions.

**Figure 2.** Simulations of a sootblower jet propagating between two platens with (a) no offset, (b) 0.5”, (c) 1” offsets.
CONVENTIONAL SOOTBLOWING STRATEGY

Conventional sootblowers clean the heat exchanger tube surfaces with little or no knowledge of where the nozzles are positioned. Figure 3 shows a typical helical motion of a conventional sootblower. Since the transversing and rotating motions of the lance tube that forms the sootblower helical movement is controlled by a single motor, the position of the nozzles with respect to the boiler banks cannot be adjusted. Hence, targeted cleaning where the jet is directed toward the deposit with minimum amount of jet-tube interaction, cannot be achieved. The helical movement produced by this single motor also makes the sootblower cleans the entire tube surfaces with even intensity, resulting in over cleaning of some areas and under cleaning in others. Figure 4 illustrates a scenario where the downstream helical movement of the sootblower nozzle puts the jet in a direct collision with the leading edge of the tube bank (no offset). A strong shock wave will be formed in the first stroke (stroke I). This shock wave will prevent the jet to penetrate deep into the passage. Hence, any deposits that are sitting in the right side of the tube (shaded area in Figure 4) will not receive any significant force from the jet at the first stroke. In order for the deposit in the shaded area to receive significant force from this conventional sootblower, it has to grow in size so that it can be hit by the second stroke (stroke II). However, in many occasions especially in the superheater section of the boiler, allowing the deposit to grow in size may significantly reduce the possibility of that deposit to be removed by a sootblower. This is due to the fact that as the deposit grows in size, the deposit-tube contact area also increases, which in turn, increases the force required to remove the deposit. A strategy to progressively shift the helical movement of the lance has been proposed and applied in the field in the effort to improve the efficiency of conventional sootblowers (Figure 5). In this case, the sootblower will have a different helical motion every time it is run and will go back to its original helix after a certain amount of helical shift. The problem with this strategy is that the shift is usually very small and it requires hundreds of shifts before it returns back to its original helix. In the problem of Figure 4, the small shift in the sootblower helical movement may not give any significant benefits in the effort to deal with the deposit accumulation in the shaded area. This is due to the fact that the timing to remove the deposit is very important, where the deposit should not be allowed to grow excessively in size, whereas the time between this small shift (time between sootblower operations) is usually quite long, in the range of 2-5 hours. In other words, to exert a significant amount of force on deposits in the shaded area of Figure 4, the helix has to be
progressively shifted until the nozzle is positioned in such a way that the first stroke avoids the formation of a strong shock wave and allows the jet to penetrate further into the shaded area and directly target the deposit. However, since most of the shift applied to the sootblower is very small and the time between these small shifts is long, the deposit may grow excessively in size to the point that its adhesion strength is greater than the jet total momentum energy. In this case, the deposit will not be able to be removed by means of sootblower anymore.

Figure 5. Progressive helical movement of a conventional sootblower

Figure 6. Smart Sootblower stop & rotate strategy
ADVANCED SOOTBLOWING STRATEGY WITH SMART SOOTBLOWER

Unlike conventional sootblowers, SmartSootblower, which equipped with the capability to maneuver the transversing and rotating motions of its lance tube independently, can be programmed to position its nozzles such that as to minimize the jettube interaction. Figure 6 shows one of the cleaning strategies that can be utilized using this sootblower to target the deposit more effectively. In the clean area, the sootblower can be programmed to transverse the lance tube at a high speed and stop the transversing motion of the tube, while keeping the rotation speed constant (Stop & Rotate strategy), in the problematic area. It has been known that the plugging of recovery boiler superheater section begins with the deposit accumulation in the leading edge of the platens [3].

![Figure 6. Cleaning strategies using SmartSootblower](image)

**Figure 7. Plugging process of recovery boiler superheater section: A top view perspective**

Figure 7 illustrates the process of carryover deposition on the leading edge of superheater tubes, which leads to the plugging of the flue gas passage. Recent boiler observation using IR camera suggests that sootblowers operated in the windward section of the platens are ineffective to prevent the plugging of boiler superheater section (Figure 8).
This may be due to the fact that the sootblower in the windward section is only pushing the deposit against the tubes and no significant torque produced by the jet to remove the deposit. Smartsootblower can be utilized to combat the deposit bridging and plugging in the superheater or the entrance of generating bank. The best location for the sootblower to produce the highest torque will be in the leeward section of the platens. The nozzle can be positioned right in the middle of the platens, hence minimizing the jet-tube interaction, while implementing a Stop & Rotate strategy (Figure 9). With the help of fouling detection systems, Smartsootblower can also be run to target deposits in the fouling area and avoid over cleaning in the clean area.
in many occasions, has led to the plugging of this zone. The fouling monitoring system that was installed in this boiler shows a flat trend in deposit buildup for Zones 1, 2, and 4, while the trend for Zone 3 was downward and then consistently in upward direction. The use of conventional sootblowers to prevent the plugging of Zone 3 has resulted in over cleaning of Zones 1, 2, and 4 and the increase in sootblowing steam consumption. To address this problem, the Smartsootblower was installed and programmed to intensify the cleaning only on Zone 3 and speed up the transversing motion of the lance while the nozzles are in Zone 1, 2, and 4. The plugging of Zone 3 has been successfully prevented by the operation of a Smartsootblower in this area.

**SUMMARY**

To increase the effectiveness of a sootblower to remove deposits and to minimize sootblower induced-tube-erosion, it is important that the nozzles are positioned in such a way that the jets propagate as close as possible to the tube surfaces without creating a shock wave at the entrance of the tube banks. The Smartsootblower has been developed to meet the demand to fully control the sootblower lance movement and the position of the nozzles. It was designed with Smartsootblower that independently control the transversing and rotating motion of the lance tube. With this capability, the sootblower can be operated with a full knowledge on where the nozzles are positioned with respect to the boiler banks and full control on the helix movement of the lance. Hence, jet-tube interaction can be minimized and targeted cleaning can be achieved. With the help of fouling detection systems, Smartsootblower can also be run to target deposits in the fouling area and avoid over cleaning in the clean area.

**REFERENCES**

Investigation and Analysis of the Causes of Recovery Boiler Economizer Failures

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Clement Consulting Inc.  T.M. Grace
Company

ABSTRACT

Data on 346 recovery boiler economizers in the USA and Canada were analyzed to determine the relationship between economizer failures and design, construction, operating and maintenance practices. The analysis shows that an order of magnitude reduction in failure frequency is possible with the mini-header design. Guidelines for specification and construction of recovery boiler economizers and a reference for operating and maintenance practices detrimental to economizers were developed in the course of the study.

INTRODUCTION

The continuing incidence and adverse consequences of economizer pressure part failures prompted the American Forest & Paper Association’s (AF&PA) Recovery Boiler Committee to sponsor an investigation of economizer tube failures. The Committee recognized the need for an industry-wide effort to review economizer tube failures, and to collect and analyze available information on economizers. Although the root causes of some economizer pressure part failures are known, the information has not been widely disseminated, and there has been no systematic study of economizers. Economizer integrity is influenced by both design and operation. While economizer manufacturers have solved some of the problems connected with their own designs, there is currently no industry-wide forum or agency to define acceptable criteria for design, construction, performance, and operation of economizers. Objectives The overall objectives of this investigation were to understand the causes of recovery boiler economizer failures and to identify means for preventing their occurrence. Five specific objectives were met in the course of this study;

1. document and evaluate the industry experience,
2. categorize the types of failures that have occurred,
3. determine the correlation of failures with design and operating factors,
4. provide Guidelines for specification and construction of economizers, and
5. provide a reference for operating and maintenance practices impacting economizers.

This paper is an abridged version of the report prepared by the authors’ for the Recovery Boiler Committee [1].

DATA COMPILATION

Approach

Information on economizers was obtained from several sources:

- a Survey questionnaire was developed and sent to operating companies,
- lists of economizers contracted and placed in service for the years 1980 through 2004, along with design data were obtained from the major economizer manufacturers,
- BLRBAC reports for 1982 through mid-year 2005 were reviewed,
- detailed reports were obtained on a few selected cases, and
- follow-up discussions were held with manufacturers and operating companies.

Survey Questionnaire: The questionnaire was designed to provide information on economizer replacement, number of leaks and outage time attributed to repairs, and the reasons for replacement (if replaced). Limited information on the nature of failures experienced was also
sought. A response was received for 84 of the 182 recovery boilers operating in the USA according to the recent list maintained by BLRBAC and the AF&PA Recovery Boiler Committee [2]. We estimate that the response covers about one-half of the units currently in service, discounting about 20 that have no economizer, horizontal tube economizers, etc. We did not actively seek information on economizers on Canadian recovery boilers, but did use it when it was available.

The quality of the information received from the questionnaires was mixed. There was generally good information on the number and nature of the economizers on a given unit (although there was sometimes confusion when an economizer was simply retubed in part or completely). The data on the number and outage time resulting from failures was inconsistent, with very little information on types of failures or root causes. For some economizers, it was indicated that no records exist at the mill.

Supplier Lists: The North American boiler suppliers each provided a list of economizers placed in service during the years 1980 through 2004, indicating the date when placed in service and, if relevant, the date removed from service. Key design information on these units was also requested. The data from the suppliers was quite comprehensive. These lists were considered to be an accurate record of every economizer placed in service after 1980. The supplier data provided a good basis for tracking designs and design changes. As was expected, the supplier data provided minimal information on the types of failures encountered.

BLRBAC Data: The BLRBAC incident reports proved to be the best source of information on the nature of economizer failures. The incident summaries in the BLRBAC meeting minutes for 1982 through mid-year 2005 provided relevant data on each reported economizer failure. It was very apparent that the BLRBAC data does not include all or most of the economizer failures experienced. It is difficult to estimate the extent that economizer incidents are underreported, but it is suspected that the reported incidents are less than half of the total.

Integration and Analysis of Data

The data from the questionnaires, suppliers and BLRBAC records were combined into one master spreadsheet. There is one row in the spreadsheet for each known economizer. The data was reviewed with suppliers and some operating companies and discrepancies resolved. Additional data obtained from some detailed reports and from supplier and operating sources was also incorporated. As information was compiled, it became apparent that a number of causes of failures showed up again and again. This served as a basis for defining failure categories. These categories in turn were used to sort the data to determine the frequency that certain types of failures occurred and to see if there were common factors that explained them. The data was also sorted by economizer manufacture, which provided a basis for beginning to understand the role of design in economizer failures. The detailed information available for the selected individual cases proved to be very helpful in helping to understand some of the key issues involved.

Limitations

The biggest deficiency in the available information on economizers is the lack of solid information on the number of economizer failures and the nature of these failures. Most of the information on failures came from the BLRBAC records supplemented by the few detailed reports on some cases. Relatively little information on failure numbers and causes was obtained from the questionnaires or from suppliers. In many cases the information does not exist. There are no records of past economizer problems at many mill sites. This lack of information has made it difficult if not impossible to determine the root cause in many cases. Another difficulty was the inability to ascertain operating conditions affecting the economizer. While it is known that certain conditions are detrimental, it is difficult to know the extent they exist in any given operation. It is even less clear how operating practices affect stress and fatigue cracking problems. These are only approachable on a case-by-case basis where detailed knowledge of the operating environment is available.

Master Spreadsheet

The master spreadsheet represented a total of 346 economizers, with 266 of them on recovery boilers located in the United States and 80 on recovery boilers located in Canada. In general, the study dealt only with economizers on
recovery boilers currently in service. Unless there was a pressing reason for including it, we excluded units at closed mills and recovery boilers that have been removed from service. There were a lot of blank entries in the spreadsheet. This simply represents a lack of information and has no other significance. The master spreadsheet was the starting point for all subsequent data analysis. The spreadsheet is voluminous and could not be included with this paper.

**Selected, Sorted Spreadsheets**

The compiled data for the 346 economizers was sorted into separate supplier-specific lists, each containing those economizers installed by one of the major recovery boiler manufacturers - Babcock & Wilcox, Alstom Power, Aker Kvaerner, and Andritz. The Aker Kvaerner economizers were further divided into Gotaverken units and Tampella units as well as post-merger Kvaerner units. For each supplier, the economizers were further sorted by date of installation, starting with the most recent ones. The lists for Babcock & Wilcox and Alstom Power combined the economizer lists for the USA and Canada operations of both companies. The supplier-specific spreadsheets were very useful for tracking the evolution in economizer designs and the correlation between design and economizer failures.

**ANALYSIS OF DATA**

**Types of Failures Encountered**

The information on the frequency and nature of economizer failures showed that they could be classified into a relatively small number of categories. These are:

- stress or fatigue cracks
- cracks in the tube-header attachment region
- cracks at fin terminations
- cracks at other locations
- handhole and radiography test plug seal weld leaks
- poor quality welds, in addition to those in preceding item
- external tube thinning
- internal corrosion or thinning
- mechanical damage
- leaks at rolled tube joints

The most widespread problem (encountered on the greatest number of economizers) was stress and fatigue cracks near or at the tube-header interface. This includes cracks at butt welds, where tubes were welded to extruded nipples on the forged header, and cracks at tube-header fillet welds. The tube-header attachment area is potentially subject to high thermal or mechanical stresses. There are indications that many of these cracks originate on the waterside, but the extent that waterside conditions play a role in these failures is unclear.

Stress cracks have also developed at fin terminations. The design of the fin attachment plays a critical role, with tapered fins and wrap-around welds apparently not subject to crack development. However, this does not appear to be the whole story. Some installations with square-end fins have not developed leaks.

Cracking problems were also encountered at other locations such as elbows and attachment welds. These were less widespread and more varied in nature. Most were confined to older-design economizers, but there were cases of pressure part failures associated with the feedwater piping manifold on mini-header economizers. These were generally a result of restricted expansion of piping.

Handhole seal weld leaks were quite common in older economizers with large diameter headers, where handholes are used to provide access to

![Figure 1: Handhole cap seal weld](image)
the interior of the header (Figure 1). The leaks were typically cracks or pinholes in the seal weld between the handhole cap and the header. There were also some leaks in header end plug seal welds; Figure 2 shows a typical hole to be sealed.

External tube thinning was fairly common and a factor, if not the primary cause, of many failures. One type is localized thinning of tubes caused by corrosion/erosion from moisture in sootblowing steam. Another form was “washing” (erosion/corrosion) from other leaks or from previous leaks. Many of this form were initiated at tube plugs used to repair previous leaks. The most common cause of economizer tube ruptures was washing from nearby smaller leaks. Some economizers experience general wastage from sulfuric acid or acidic sulfate corrosion, but this was not as widespread as expected. Part of this may be due to changes in recovery boiler firing practices that result in less \( \text{SO}_2 \) and excess \( \text{O}_2 \) in the flue gas. This problem may also be understated. General tube wastage appears to have been a factor in decisions to replace economizers, even if it did not actually lead to tube failures. Another problem was air infiltration through casing leaks which can lead to high local \( \text{O}_2 \) concentrations and lower gas temperatures and result in localized sulfuric acid dew point attack. Finally, there were a few cases of pitting as a result of water washing the boiler (and economizer).

Internal corrosion and thinning was a direct cause of a number of economizer failures and may be an underlying cause of many more. Specific types of problems include:

- flow accelerated corrosion where localized turbulence leads to rapid metal loss,
- corrosion fatigue (often called stress-assisted corrosion or SAC), most commonly at attachment welds,
- oxygen pitting, and
- under-deposit corrosion.

Waterside problems are undoubtedly understated, because they are not usually recognized unless the failure area is removed and analyzed.

There were a relatively small number of failures directly attributable to mechanical damage, mostly from tubes rubbing against something such as a sootblower lance, economizer casing, baffles, or vibration bars. This category does not include cracks induced by vibration fatigue. The final major cause of economizer failures was poor quality welds. This includes all types of welds:

- shop welds
- OEM field welds
- repair welds
- welds used to plug tubes.

Access to the weld area was a critical issue in obtaining good quality welds and this is influenced, in part, by economizer design. Inadequate welds underlie many of the other problems that occur. A poor weld may lie dormant for many years before it ultimately fails. Not all of the reported “poor quality welds” may have actually been so. Evidence on weld quality was often fragmentary and the phrase “weld problems” is sometimes a euphemism for cause unknown or undetermined.

As mentioned earlier, considerable difficulty was experienced in identifying the root causes of many failures because of a lack of information. In many cases the mill did only a cursory failure analysis or none at all. Even when a failure
analysis was done, the final report might not have been available when the BLRBAC report was made and so did not become public knowledge.

Operational Influences on Failures

It proved to be very difficult to get a quantitative handle on the effect of operating conditions on economizer failures. Information on general average operating conditions (such as operating pressure, loading, etc.), which was readily available, was of very limited value. More detailed operating data, that would be germane to economizer failures, was normally not available.

Some operating conditions or actions are clearly detrimental. These include:

- high SO\textsubscript{2} and O\textsubscript{2} which lead to sulfuric acid dew point corrosion and possible acidic sulfate corrosion,
- moisture in soot blowing steam, and
- frequent boiler ups and downs (as from boiler trips).

As a general rule, operating conditions that lead to a steaming economizer, especially intermittently, are detrimental to the economizer. There were a number of cases where cracking near the outlet of the hot economizer was associated with a steaming economizer.

Other operating variables that could potentially affect economizer integrity include:

- flue gas velocities,
- boiler loads and load variations,
- capacity increases,
- ash deposition plugging or partially plugging the economizer, generating bank, and superheater,
- startup and shutdown procedures,
- feedwater chemistry and boiler water quality upsets,
- oxygen in the feedwater,
- safety valves lifting and closing, and
- chill and blow procedures.

Information on these variables is generally lacking in the BLRBAC record and other sources of information available to this study. Determination of the effects of these variables is best done on a specific case basis.

One of the main tasks in the project was to provide a description of operating practices that are detrimental to economizer integrity. The procedure that was developed to prepare this reference listing was to use knowledge of failure mechanisms to obtain insight into operating practices that might contribute to failures and then review the tabulated information on the economizer failure incidents to seek confirmation that these practices were detrimental to economizer integrity. While compiling the listing, it became apparent that repair and maintenance practices were also significant factors in economizer failures and the listing was expanded to include repair practices and general maintenance. This document is an Appendix in the report to AF&PA but is not included as part of this paper.

Economizer Design Evolution and Influence on Failures

The early black liquor recovery boilers did not have economizers. The flue gas passed from the boiler generating bank directly into a direct contact evaporator, or DCE. In the DCE, the hot flue gas was brought into direct contact with the liquor to cool the gas by evaporating water from the liquor while simultaneously raising the solids concentration to a value that could be burned in the furnace. There are low pressure recovery boilers operating today in this manner.

As the industry sought to improve energy efficiency, boiler operating pressures increased and the ability improved oxeff multiple effect evaporation systems to deliver higher concentrations for feed to the DCE. The net result was that an economizer had to be interposed to reduce the flue gas temperature from the value leaving the generating bank to the temperature required at the DCE inlet to achieve the desired solids concentration increase. These economizers were generally small and of various configurations ranging from...
vertical tubes fixed between two small drums like a generating bank to horizontal, continuous tube economizers such as those used for utility boilers. One type of drum economizer was assembled by expanding the tubes to lock them into grooved tube seats in the 24 inch diameter drums followed by internally seal welding the tubes to the drum in order to withstand stresses imposed by feedwater flow and temperature upsets. There are recovery boilers in operation today with both of these designs.

A major change in North American design occurred around 1970 when environmental concerns with pulp mill odor led to the elimination of the direct contact evaporator (DCE) on new units and some older units requiring that all liquor concentrating be done external to the recovery boiler. The economizer heat transfer surface had to be increased substantially to cool the flue gas to a temperature that was acceptable for the electrostatic precipitator operation. Different approaches were used to make effective use of the water cooled surface required for cooling the gas. Economizers became much longer vertically. Cross-flow baffling was incorporated to take advantage of the superior heat transfer of gas flowing across the tubes as compared to gas flowing parallel to the tubes in long flow. Fin surface was added on the front and rear sides of the tubes to increase the heat capture of each individual tube. The first generation of these large, “low odor” economizers utilized an arrangement of tubes bent and welded into horizontal headers in a radial array. Header length was in the order of 10 feet and a complete installation used multiple, suspended modules to achieve the total heat transfer surface requirement.

Cross-flow gradually gave way to “long flow” with the experience that the latter was less susceptible to ash buildup and plugging. The “long flow” economizer maintained an arrangement of flue gas entering the upper end of the module at a gas inlet in the vertical plane, turning 90 degrees, flowing down the module parallel to the tubes and turning 90 degrees at the bottom to discharge through a vertical plane opposite the inlet side. Figure 3 shows a large header, finned tube, long flow economizer module.

The next significant design advance for reduced installed cost and increased reliability was brought to North America from Sweden in the late 1980’s. The “mini-header” or “bottle header” concept of fitting each row of tubes with a small diameter header and shop-assembling these individual sheets or platens into an economizer has proved to be more reliable than the prior generation of economizers that welded tubes radially into headers of greater than 6 inch diameter. This relative reliability is validated by the available data. Figure 4 shows mini-header assemblies of five platens being prepared for shipment.
The lists of installations made available by the suppliers provided the information in Table I:

Table I – New Installations of Economizers Contracted on North American Recovery Boilers 1980-2004

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Installed in USA</th>
<th>Installed in Canada</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alstom Power - Ottawa</td>
<td>6</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Alstom Power - Windsor</td>
<td>16</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Andritz</td>
<td>19</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Babcock &amp; Wilcox - Cambridge</td>
<td>0</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Babcock &amp; Wilcox – Barberton</td>
<td>59</td>
<td>0</td>
<td>59</td>
</tr>
<tr>
<td>Aker Kvaerner *</td>
<td>37</td>
<td>5</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>137</td>
<td>54</td>
<td>191</td>
</tr>
</tbody>
</table>

* Includes Gotaverken and Tampella designs

The suppliers’ lists were of critical importance for identifying the economizer design type and arrangement that corresponded with the economizer histories provided in the Survey Questionnaire forms submitted by operators. Some of the boilers had as many as three economizers in operation after 1980.

Aker Kvaerner (including installations by Kvaerner Power, Gotaverken and Tampella)

Gotaverken in 1984 placed in service its first recovery boiler in the USA. Tampella started up its first recovery boiler in 1991. In about 1996, the two companies merged to form Aker Kvaerner. The investigators segregated the pre-merger boilers to study separately the Gotaverken design marketed by Kvaerner and the Finnish design marketed by Tampella. Post 1996 boiler contracts are identified as “Kvaerner”. All of the economizers are the mini-header design. The most significant differentiation between the Gotaverken and the Tampella configurations is that the former employs horizontal lower headers and the latter has lower headers at an approximate inclination of 80°. The distribution for USA installations was as follows:

Table III – Economizer Distribution by Design Source

<table>
<thead>
<tr>
<th>Design Source</th>
<th>Installed Economizers</th>
<th>Reports received from Mills</th>
<th>Mills reporting Zero Leaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gotaverken</td>
<td>10</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Tampella</td>
<td>14</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Kvaerner-post 1996</td>
<td>13</td>
<td>5</td>
<td>6*</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>21</td>
<td>12</td>
</tr>
</tbody>
</table>

* Includes two boilers in one mill that faithfully reported leaks before replacing the economizers, and no reports subsequently. Investigators have assumed no leaks with replacement economizers.
The economizers designed and manufactured by Gotaverken/Tampella/Kvaerner are known to have used various design details for connecting the tubes to the headers. Headers have varied in diameter and have incorporated different methods of tube attachment. In some cases, the header nipples are extruded from the wall metal of the forged header and the tube is butt welded to this very short nipple. Others employ a machined seating surface on the header outside wall into which the tube end is fitted and seal welded. There have been several designs for this machined surface. Two of these are a machined socket and a flat surface. There is believed to be a correlation between economizer failures and the design of the connection for at least one Gotaverken installation, but it would require more information of this detail on each economizer to confirm this.

The Aker Kvaerner leak experience can be summarized as follows:

Gotaverken Design—three installations reported leaks as follows:

1. 3 leaks in 1st year; no further leaks in 13 years.
2. 3 leaks 4 to 5 years after startup attributed to fabrication errors; since that time have operated leak free for 15 years.
3. 25 outages for economizer leaks over about 8 years; most are associated with the tube attachment to the header. It is believed tubes are welded to a flat surface machined on the headers.

Tampella Design—leaks generally small in number; mostly at fin terminations and tube-header connections. Two installations supplied had a large number of leaks.

1. Failures tallied 288 hours (12 days) of forced downtime over a period of 6 years. Principally at butt weld of tube to extruded nozzles on forged feedwater inlet headers.
2. Failures associated with fin terminations on tubes that were at the feedwater outlet of the hot section of the economizer.

In addition, four of the boilers have reported stress failures at the weld connection of tubes to the pipe cap that is welded on the upper end of the inclined headers. These tubes are in the first row that is formed into a flue gas baffle by either welding together the ends of fins on the tubes or membrane instead of fins. The majority of fins are on tubes in the banks that are oriented at 90° to those fins in the baffle. The type of failure is shown by the Figure 5 photograph. In one case, the first leak from a crack (internally initiated) occurred eight years after startup.

Aker Kvaerner—Only one of the reports for installations after 1996 indicated downtime resulting from economizer leaks. The one installation reported a single leak in 8 years.

Babcock and Wilcox

Babcock & Wilcox changed their economizer design about 1990. Prior to this, the majority of economizer modules were manufactured in the shop with 10.75 inch OD header pipe into which were radially welded six tubes per row along a header length of up to approximately ten feet. Each tube fitted into a machined socket seat on the header face and the tube was fillet welded to the preheated header wall. Each header was built with two inspection handholes into which a cap would be seal welded. The end of the header was formed using a flat end plate in the center of which was welded an “end plug” for radiography.

Figure 5 – Failure at inclined header
The first Babcock & Wilcox mini-header economizer started up in 1989 and 19 were placed in service in the USA through 2004. The data in the spreadsheet shows:

- 9 had zero leaks
- 3 had never submitted an incident report to BLRBAC nor did they complete a Survey Form. The available information was provided by the supplier
- 3 reported cracks in the tube to header welds
- 1 reported a pinhole leak at a defect in an ERW tube weld
- 1 reported failure of a chelant injection quill where chelant corroded the water feed line
- 1 reported flow turbulence thinning the inlet header creating a hole in a fillet weld
- 1 reported the occurrence of leaks, but did not report a cause for leaks

The operator of two economizers where BLRBAC records show leaks have occurred stated in the Survey Form that both had zero leaks. Both boilers had cracks in 3 tubes at the same location, that is, the weld of tubes to upper header of the hot section of economizer, specifically, tubes in the first row receiving gas from the generating section. The investigators surmise that the stress cause was fixed and no further problems encountered, and the incident forgotten.

Of these 19 mini-header economizers, 47% have a confirmed history of zero leaks. Adding the two who reported no leaks on the Survey Form, the number would be 58%. In contrast, the approximately 50 economizers with large headers built prior to evolution of the mini-header design had less than 5% with zero leaks. In about one-half of these economizers, leaks at handhole seal welds and header end plugs were a major cause of outages for repair.

Andritz (includes installations by Ahlstrom)

Andritz listed 19 economizer installations in the USA. Survey forms were received on 11 installations, of which 10 indicated the leak history and one was just starting up. The economizer in startup mode was disregarded. Several of the early economizers used headers nominally 8.625” OD, but around 1990, the design transitioned to applying mini-headers with all headers in a horizontal orientation. Two of the ten reported “zero” leaks; of the two, one was reported to be fabricated with 8.625” OD headers and one with mini-headers. The reported large header size is questionable and the economizer may have mini-headers. Leaks occurred on both large and mini-header economizers. However, the information received indicates the number of leaks for each type to have been small. The majority of leaks were associated with the arrangement of supply pipes between the feedwater inlet manifold pipe and the individual mini-headers. The manifold pipe penetrates the hopper casing with a seal arrangement. In some cases, the pipe is continuous and passes through the casing on both side of the boiler.

One boiler operated leak-free for 15 years before experiencing a series of failures. Six failures occurred in ten months; the majority were associated with the manifold piping feeding water to the inlet of the hot economizer bank. One report is very specific in designating the problem to be expansion of the seal arrangement where the feedwater piping penetrates the economizer casing. The casing at gas temperature expands downward more than the tube elements at feedwater temperature.

Alstom Power (includes installations by ABB and Combustion Engineering)

Forty-two (42) economizers supplied by Alstom Power or its predecessors, CE and ABB, were operating for some period of time in North America for 1980 through 2004. Twenty-nine (29) were at USA installations. The majority of these use headers ranging in size from 12.75 inches to 20 inches OD; three were constructed using a mini-header design.

Of these 42 economizers, 28 are included on the Alstom Power list of economizers placed in service from 1980 through 2004. Further breaking down these 28, there are 19 for which there is some leak data in the Surveys or BLRBAC files. These 19 include the three of mini-header construction. One of the 19, a 27.25 foot long economizer with 18 inch OD headers, is indicated by the operator to have not suffered any leaks over a period of about 20 years. One of the mini-
header economizers has not had any problems since it was installed in 1999.

The failures for the other 17 breakdown as follows:

- 10 with cracks at the tube to header weld connection. One of these then operated for 20 years after repair without further leaks
- 5 with handhole seal weld cracks or pinholes in RT plug welds
- 1 with internal oxygen pitting
- 1 with internal thinning from turbulence generated by a flow orifice
- 1 crack at a square fin termination
- 1 hole rubbed by a baffle
- 1 from external corrosion from condensate in sootblower
- 1 where feedwater supply tubes are rolled into the steam drum

Some units experienced more than one type of problem.

Two of the economizers constructed using mini-headers have had cracks leading to leaks. The first was a relatively short economizer of 36 feet-7 inches length that reported two cracks in the extruded nipples at an upper header suspected to be the result of a stuck sootblower setting up vibration fatigue. The second installation was longer at 60 feet. In this second installation, four cracks in the first 10 weeks of operation were attributed to flow induced, low cycle fatigue in the side-to-side direction. The failures were typically circumferential cracks on both sides of the tube at the extruded nipples of both upper and lower mini-headers in the hot economizer section. The BLRBAC record indicates that a replacement economizer with less flexible tubes eliminated the problem.

Reports are available for many of the remaining economizers. A high number of leaks that occurred in these older economizers are attributed to cracks at the fin termination and cracks or pinholes in the tube to header welds.

General

The role of the fin termination design is believed to be well understood through experience and stress analysis by various parties. The original designs by several manufacturers used a ‘square cut’ end on the fin (flat bar end cut off at 90° to the bar length) and the fin to tube weld was terminated short of the end of the fin. The result was an area of high stress that caused cracks and tube failure. Failures due to the fin termination were first reported in 1980 [3]. The successful solution to minimize stress level was to taper the end of the fin down to a short height at the end, and to extend the fin to tube weld to wrap around the end of the fin. The BLRBAC Incident Reports have not shown the fin termination to be a cause of failure for the newer, mini-header economizers with the exception of one supplier. Tampella continued to apply fins with square-cut ends into the early 1990’s and a number of economizer tube leaks were attributed to this design. There is no record of any failures where the fin termination has been tapered and the weld wrapped around the end of the fin.

The post-1990 mini-header design eliminated the need for handholes and end plugs. The economizer consisted of a number of sheets, or platens, suspended across the boiler width to form a bank of tubes. Each sheet consists of a parallel row of finned tubes connected at each end to a straight, small diameter header pipe. Each tube is welded into a machined seat similar to that used for the earlier headers.

The shop assembly of sheets provided a superior opportunity for quality control of shop welding because of the improved accessibility of the weld area. The efficacy of this approach appears to be demonstrated by the large number of installations reporting zero leaks for the platen design. The downside is that access for installing a tube plug to isolate a failed tube is limited and frequently requires installing plugs in the header inlet and outlet nozzles to isolate the complete platen.
The investigators have some concern that the longer economizers will have an increased susceptibility to vibration fatigue failures. The relatively short length of operating time for the few reports received for economizers in this category are insufficient to draw any conclusions. For the four (4) cases where reports were received, all had failures that were not necessarily related to tube length, as follows:

- 1 had a fatigue crack at the supply tube to header weld and a defect in the weld of the tube to upper header
- 2 had cracks at fin terminations
- 1 had cracks at fin terminations and cracks in cold economizer inlet tube to header welds

Only one of the above exceeded 80 feet in length. No reports were obtained for the several other economizers exceeding 80 feet. One started up in 1989 and the others in 2001 or later.

Design Provides Increased Reliability

The statistics support a large order of magnitude improvement in economizer reliability with the mini-header design. Consider the year 1990 for the advent of the mini-header economizer design and its wide industry acceptance. The economizers that were a part of this study installed during the 15 year period 1990 through 2004 were responsible for 148 leaks. However, three economizers accounted for 70% of these leaks. These three economizers are known to have contributed 103 leaks, with the other 45 leaks distributed among approximately 70 other mini-header economizers installed during the 15 years.

The survey results for the economizers installed before 1990 indicate many more leaks. As there is very little information before 1980, the leak data essentially represents the 10 year period 1980 to 1990 during which about 62 economizers were installed. Close to 300 leaks are identified on the Survey Form for economizers where a specific number of leaks were reported. A number of Survey Forms submitted used terms of “some” or “many” and others reported terms like “2/month”. Taking a conservative estimate of 400 for pre-1990 leaks, the 62 economizers incurred 6.5 leaks/economizer over 10 years, or 0.65 leaks/operating year. About one-half of these were attributed to handhole seal weld leaks and radiography hole plug leaks.

By comparison for the 15 years of 1990 through 2004, and disregarding the three economizers responsible for 70% of the leaks, 70 economizers were responsible for 45 leaks. This equates to 0.64 leaks per economizer over a term of 15 years, or about 0.04 leaks/operating year. The 15 year period since inception and acceptance of the miniheader design concept has seen a reduction in leaks by a factor of 15. Even if the leak estimate is doubled to 0.08 leaks per economizer operating year to allow for unreported incidents, the net result is still an order of magnitude reduction in failure frequency.

Though not a rigid statistical analysis, the data clearly shows the superior reliability of the mini-header design. The differences in experience are so striking that even if arguments are made about details of the data interpretation, the results could be radically changed and still be significant. The leak history data available for 62 mini-header economizers shows that about 40% have not had a leak. From these results it can be concluded that a properly designed and manufactured economizer using mini-headers can be reliable.

STATE OF ECONOMIZERS

The evolution and industry acceptance of the mini-header or bottle header design has resulted in an economizer design being supplied today that has already significantly reduced downtime caused by economizer pressure part failures. The design has characteristics that can be exploited to further reduce the failures and increase availability of the equipment. A considerable number of these economizers in operation are successful and leak free. A very high proportion of the known reported leaks have occurred in three economizer installations. In addition, the operating experience with the mini-header economizer has exposed some aspects of design to be avoided or that can be improved with an objective of achieving zero leaks in every installation.

The most important ingredient for achieving the objective will be “discipline”. The supplier must have the discipline to resist cheapening the design. And the user must have the discipline for hands-on involvement in all phases of procurement and production. All economizers are not built equal. The “devil is in the detail!!” Reviewing the history of the three economizers mentioned above, the design details that are the source of the failures would probably been different.
had a knowledgeable user advocate been involved in a review process of the supplier’s engineering and manufacturing. For example, it was known in 1980 that square cut ends on fins could cause a high stress and tube failure, yet the supplier delivered and the operating company purchased an economizer with this design in 1992.

Each supplier has used their experience to provide a design and manufacturing for the improved reliability of the mini-header product. Each is committed to delivering a quality product. The products have differences, but there are many similarities. In each there are some details that could be altered to improve the product.

However, one practice the investigators are aware of is that of decreasing cost at the expense of quality, which is a sure road to installing an inferior product. One manifestation is the pricing practice of the supplier offering quality assurance as a price option, or, the purchaser requesting a take-out option. For example, radiography of butt welds, stress relief of tube-to-header welds, tapered fin terminations, etc. In fact, one supplier went so far as to state that “the economizer would be manufactured to the ASME Code unless the prospective purchaser stated specific NDT requirements in their specification when requesting a quotation.” The ASME Code does not require the NDT that is very important to the control of quality in manufacturing.

CONCLUSIONS

Experience shows that economizers can be operated for over 20 years without experiencing tube leaks if it is properly designed, constructed, operated, and maintained. All four parts of this quadripartite are critical. If an economizer is not designed or constructed properly, it will tend to have frequent failures, even if properly operated or maintained. Conversely, poor operating or maintenance practices can lead to failures in the best economizers.

Design evolution has had a very important influence on economizer reliability. There has been a significant reduction in the frequency of economizer leaks since the adoption of the mini-header design by the suppliers circa 1990. A very small number of economizers have been responsible for most of the reported leaks with the miniheader design. Excluding these few units, the failure frequency for mini-header design economizers is currently about 0.04 leaks per economizer operating year. In contrast, the frequency in older designs (in which tubes were welded to large pipe headers) was about 0.65 leaks per economizer operating year. About one-half of these were attributed to handhole seal weld leaks and radiography hole plug leaks, which are eliminated in the mini-header design. This experience represents an order of magnitude reduction in failure frequency with the mini-header design.

On many economizers it was common to see a pattern of recurrent leaks in a given area that were directly connected with previous leaks in that area. These might take the form of a leak in a repair weld for a previous leak, a leak in the seal weld of a tube plug, or a leak in a thinned area where a previous leak sprayed on adjacent tubes. Lack of access for making effective repairs and doing proper inspections around failure sites is a critical factor in this regard.

The most serious problem in economizers today is cracks near the tube-to-header welds, most commonly at the feedwater inlet headers and the economizer discharge headers. These are strongly influenced by design factors and by original weld quality. External wastage is generally not a major problem in economizers, except in sootblower lanes when there is moisture in the sootblowing steam. The evolution of high-solids firing practices and low SO\textsubscript{2} operation has had a beneficial effect. Water quality is also important. However, except for the detrimental effect of dissolved O\textsubscript{2}, it has not been possible to reach conclusions about water quality variables as part of this study.

The suppliers are committed to delivering a quality product. They have made design improvements since 1990 with the economizers. The features that caused trouble in some economizers are no longer being marketed. The designs are converging in some respects. The largest impediment to success may be lapses in a NDT program to reduce cost.
ACKNOWLEDGMENT
This investigation was sponsored by the American Forest & Paper Association's Recovery Boiler Committee.

REFERENCES
2. List of Operating Recovery Boilers. This list is maintained current at the web site www.blrbac.org by the BLRBAC ESP Subcommittee
4.
LETTERS TO THE EDITOR

Send your comments on this newsletter to the ISA PUPID Technical Discussion Forum & “get something started”!

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<table>
<thead>
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<th>WORLD CORNERS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CANADA CORNER</strong></td>
</tr>
<tr>
<td>Nothing from anyone there this time!</td>
</tr>
<tr>
<td><strong>CENTRAL &amp; SOUTH AMERICAN CORNER</strong></td>
</tr>
<tr>
<td>Nothing from anyone there this time!</td>
</tr>
<tr>
<td><strong>FAR EAST CORNER</strong></td>
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<tr>
<td>Nothing from anyone there this time!</td>
</tr>
<tr>
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<tr>
<td>Nothing from anyone there this time!</td>
</tr>
<tr>
<td><strong>EUROPEAN CORNER</strong></td>
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<tr>
<td>Nothing from anyone there this time!</td>
</tr>
</tbody>
</table>
Remote Distributed Sensing

ABSTRACT

Measuring the water in the sheet at various locations between the forming section and the reel, with both fixed point and scanning measurements solves the problem of being blind to the true sources of variation in your process. Variations in water content and water removal rates change fiber swelling, web tensions and mechanical properties of the final product. When water is maintained at uniform distributions in the cross direction, and removed at optimal rates along the length of the machine, it can be run with lower draws, reducing tensions and shrinkage so that on-machine performance, converting and printing operations will run better.

This paper discusses a new architecture to facilitate an economical deployment of highly accurate sensors to measure the water removal in both the cross and machine directions. This approach to measuring water and its changes across and along the paper machine is shown to benefit the efficiency of production and the quality of that production.

INTRODUCTION

Though we do not like to admit it, the paper machine is really just the water removal stage of pulping. Almost the entire machine is devoted to the removal of water, changing the stock from about 99% water to just 5% water. The traditional approach has been to wait until the end of the process to see if you got it right, and the industry has done surprisingly well with this approach, making incremental changes over the past 40 years. To make further significant improvements, however, measurements are needed throughout the machine to determine more exactly the source of disturbances and more accurately control the actuators that have an impact on water content.

There are numerous elements to control water removal on the paper machine. Typically in the forming section you have foils, vacuum boxes and steam boxes, but you also have chemistry changes that affect drainage. In the press section you have press felts, press nips and steam boxes. Dryer sections have steam cylinders, dryer felts, air flows and re-wet showers. Each of these elements can be a source of error, but many of them can also be a source of compensation or correction.

MEASUREMENT ARCHITECTURE

Remote Distributed Sensing is a new architecture for the measurement of water removal on the paper machine. It consists of small, robust sensors that are placed throughout the process as depicted in figure 1 to measure near the source of variations. It is made possible by keeping sensitive electronics off process and creating a shared infrastructure that keeps the cost per sensor reasonable.

There are two key issues that are important to the success of a sensor. Can it fit where it needs to be, and will it survive in that location? As you find with good solutions, they usually have multiple benefits. The key to solving these two constraints is to place only the bare minimum in the hostile environment and remote everything else. This allows the sensor head packaging to be very small, and thus you can

Figure 1, Remote Distributed Sensing Family
locate the sensors in more places. It also removes the sensitive electronics from the hostile environment. There are several ways to do this, but one of the ways is to use fiber optics to deliver radiation to and collect it from the paper web.

ExPress moisture is an example of this architecture, as shown in figure 2. A sensor control cabinet (SCC) can be located on or near the back side of the machine where the IR rich source energy is created, manipulated and coupled into a delivery fiber. The fiber carries this energy to the correct location on the paper machine where the sensor head redirects it into the web. After scattering and interacting with the web, IR energy is emitted from the web and collected by the sensor head and coupled into another fiber optic cable. This then routes the infrared wavelengths with information about the water content of the paper to a set of high efficiency detectors back in the SCC. All of the digitization and other signal processing can then take place in this relatively tolerable environment and then communicated over a network to a computer system. A typical SCC can support half a dozen sensors.

The sensor head then remains quite simple, containing no active components, and having a very small form factor to allow it to be located where needed. This also provides a smaller area to keep clean, making the automated cleaning and standardization much simpler. This reduced size has additional benefits when talking about generating CD profiles.

The smaller a sensor is the less mass it has, therefore the smaller the structure needs to be to support it, and the faster it can start and stop. This then leads to a scanner infrastructure that is much smaller and simpler to allowing scanning an order of magnitude faster than traditional scanning systems. Figure 3 shows the cross section of an ExPress CD scanner installed immediately after the 3\textsuperscript{rd} nip in a tri-nip press, before the release point so that the profile can even be measured before threading the driers.

This unit is capable of scanning at 4 m/sec while generating 3 mm profile zones. Another benefit is that maintenance costs of the system are lower because the sensitive components are stressed less and are more readily accessible if maintenance is required.

**RDS FAMILY**

Infrared measurement techniques are generally valid from bone dry to a moisture content of some 80% (20% dry), depending upon the structure of the paper. Beyond that you need to look at other measurement physics to get a dependable measurement. Therefore ExPress moisture is good from about the end of the forming section all the way to the reel. In the forming section itself, however, there is also a need to understand the rate of water removal. For that there exists the commercially available SpectraFoil product. Here resistive field measurement technology is used. It is applicable for measuring water weight between the headbox and dryline in the forming section.

For coaters, where you are primarily interested in just the coating layer moisture, there is the GelView system to measure and control the rate of coating drying with visible light scattering off the coated surface. All of these systems are built upon the RDS architecture, leveraging the infrastructure, reducing the cost per measurement point and providing measurements at the source of variation, delivering rate of change information that has previously been unavailable, and
thus enabling a whole new sphere of control opportunities to generate more uniform paper. All of these sensors are focused around the measurement of water removal.

**BENEFITS**

For many years the industry has concentrated on cross direction profiles (CD), and for good reason. Huge improvements have been made in the quality and efficiency of papermaking with this focus. Due to the importance of CD measurements the machine direction (MD) variations have been assessed from the capabilities of the CD sensors. An inherent problem with this approach is that there are both MD and CD influences in the measurements that cannot be adequately removed by filtering alone.

As mentioned earlier, the small size enables faster scanning. With faster scanning there is less MD influence in the CD profile. Most MD oscillations that are likely to be aliased into a CD profile are in the order of 10s of seconds. Therefore if a full sheet can be scanned in just two or three seconds this aliasing issue will not appear.

Figures 4 and 5 are an excellent example of this point. A new ExPress Moisture scanner (figure 5) was installed which traversed at 2.0 m/sec. The traditional QCS scanner at the reel (figure 4) scanned at 0.25 m/sec. Due to the particular frequency of MD oscillations the reel scanner indicated that there were profile stability problems. In fact there were no stability issues in the profiles, just a profound MD oscillation. This issue also masked the CD streak that is clearly seen in figure 5.

There are certain points along the path of paper machine where the CD profile is of extreme importance. There are many other locations where the primary changes are in the machine direction variations. By combining together both the CD and MD measurements, the influences of one from the other can be further minimized.

Measuring early in the process can identify influences that might otherwise be misattributed to other areas on the machine. Figures 6 shows the influence of broke flow on the drainage in the forming section of the machine. Here we have a sensor located on the pickup felt of a fine paper machine. It is clear that the significant change in broke flow seen on the trend has a corresponding change on the % dry content as measured by the pickup felt location sensor.

A similar process phenomenon is seen in figure 7 where the ratio of dried pulp to never-dried pulp is changed, also affecting the drainage in the forming section. With a good measurement following the Couch, it is possible to quantify the effects of changes that take place on the machine, enabling the true economic impact to be calculated for these changes.

**CONCLUSIONS**

Separating the sensor head from its electronics has reduced the size of the on-machine sensors. It has also increased the robustness of the sensors, allowing them to be placed throughout the process and not just in open areas at the end of the process. This, in turn, places the sensors closer to the source of variation, reducing transport delay times, and more clearly identifying the source of problems by segmenting the machine.

Remote Distributed Sensing significantly improves the level of information available to the operators and control algorithms, allowing both open loop and closed loop improvements to be made to the machine, and therefore paper. With both faster scans and the combination of MD and CD sensors, aliasing issues can be minimized or eliminated. To date there are three products that benefit from this new architectural approach to measurement, providing moisture information from one end of the machine to the other.
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