

## Does kraft pulping have a future?

*Since it "got a life" more than a century ago, the kraft process has been on a marathon run, and prognostications for its future are positive.*

MARTIN MACLEOD

Few people seem to doubt that the kraft pulping sector will indeed have a sustained future, despite today's dismal business climate and increasing environmental regulations. The route forward is unlikely to be a single track, though. Most likely, it will have a large elemental chlorine-free (ECF) track, a smaller totally chlorine free (TCF) one, and a lot of confusion and creeping incrementalism from now to the end of the 1990s.

Lars-Åke Lindström, research vice president at Sunds Defibrator and host of the company's 10th technical seminar, held last fall near Porvoo, Finland, noted at the outset that even with severe business downturns, everything in the kraft pulping industry just keeps getting bigger—total production, the consolidation of smaller companies into much larger ones, the size of process units, and so forth.

Much of that may be true, but there's one thing that's decreasing dramatically—brownstock kappa number, especially of softwood pulp, which has gone from the traditional 30ish in the mid-1980s and earlier to mid-teens in the most advanced systems today. One such operation—Enocell—is described in the accompanying story.

### A view across the decades

Nils Hartler (KTH), recent Wallenberg Prize co-winner, lent prestige and a decades-long perspective to the gathering. In the 1950s, he said, kraft pulping was an art and was treated as a simple and insensitive process. Then, in the 1960s, ideas of yield enhancement (polysulfide), raw material control (chip thickness), better impregnation, and continuous cooking began to make inroads. The 1970s saw the advent of anthraquinone as a catalyst and the beginning of serious process control of kraft pulping. In the 1980s, batch pulping experienced a revival with low-energy liquor-displacement techniques, and modified kraft cooking went from research to commercial practice.

On the horizon, according to Hartler, are these prospects:

- Improved impregnation, with still tighter control of chip thickness and wood quality.

Sunds seminar speakers, from left, included Karl-Ewert Lidman, Lars Sjödin, Martin MacLeod, Lars Näsman, Lars-Åke Lindström, Hannu Korhonen, Nils Hartler, Per-Åke Färnstrand, and Panu Tikka.



- Better understanding of reactions between black liquor and wood. Also, perhaps, the use of both high- and low-sulfidity white liquors in a digester system.
- Increasing segregation of wood types (e.g., juvenile from mature), and pulp fiber fractionation by stiffness.
- Perhaps even better pulp yield and strength via genetics, with more cellulose and less lignin in designer trees. (They'll have to retain enough lignin so that they don't fall over, of course.)

### **Selling fiber walls and TCF pulp**

"What's the biggest challenge in kraft pulping? To go lower in kappa number while maintaining strength, beatability, bleachability, and yield. How many mills accomplish more than 30% further delignification below 30 kappa? Not many, due to problems of production, recovery capacity, and pulp quality."

So said Panu Tikka of SciTech Service Oy, Finland, who suggested that residual lignin is man-made; that is, we create it with the pulping chemistry we use. He postulated that we may be creating lignin-carbohydrate complexes, and perhaps even making lignin-like aromatic material from hemicelluloses when cooking conditions are extreme.

Tikka urged researchers and pulping professionals to be more specific in references to "selectivity." "Do you mean carbohydrate/lignin balance, or viscosity/kappa ratio, or strength versus kappa number, or what?"

In on-going research, the biggest barrier to a better understanding of kraft pulping is at the level of microfibrils and fiber walls—more so than at either the molecular level or in paper-making performance. "We're probably dealing with chemical physics here," said Tikka, "and we shouldn't forget that fiber walls are the pulp maker's real product."

TCF pulp often appears to be all the rage (and the market!) in Europe, and several companies whose dominant market is western Europe have joined the TCF bandwagon. Södra Cell is one example, and Karl-Ewert Lidman of Södra's Värö softwood kraft mill was there to explain the company's strategy.

Starting in 1991 with the hydrogen peroxide route to TCF production (at brightness levels in the low 70s), Södra ramped up to brightnesses in the mid-80s at the beginning of 1993, and expects to get to 90% in 1994. Now the company considers TCF pulp more profitable than ECF. "But to make good TCF pulp, you must start at the woodyard and work all the way along the fiber line," Lidman declared.

At Södra, the sign of the Z is prominent, meaning zero chlorine compounds in bleaching. In 1993, two-thirds of the mill's output will be Z-pulp. Collectively, the three Södra mills lead the world of TCF production.

"Read my tie," Lidman might have said. It had Zs all over it.

Representing Sunds, Lars Sjödin offered a clear message: the

bleachability of SuperBatch pulps certainly equals or exceeds that of conventional kraft pulps, whatever their parentage in wood or pulping equipment. This holds true at any kappa level, all the way down to the low teens.

### **American views and electronic challenges**

Across the Atlantic, the North American kraft industry represents a wide spectrum of mills and more than half of the world's kraft pulp output. Although there are some real differences between the industry in Canada and that in the United States, there is a shared conundrum of why the rush toward TCF pulp seems to have outrun the scientific (i.e., environmental) reasons for going in that direction. Looking at capital and manufacturing costs, and the marketplace, managers question the rationale for going TCF. The idea of system closure in kraft mills is better accepted, although many scientific and engineering challenges must be resolved.

Rainer Häggblom, of Pöyry Consulting, looked at how information technologies are likely to affect the market for printing papers.

"The world's paper consumption has grown steadily since the early 80s," Häggblom stated, "but in relative growth rate, paper is losing market share to electronic media." The concept of an electronic superhighway that's emerging in the United States has the potential to switch advertising and office technology away from paper. In countries not yet heavily industrialized, there's also a good chance of "jump-staging" right across the paper office into the electronic one.

Remember, said Häggblom, that users of printing papers are in the communications business. They'll choose their own "best media." Publishers are giving lots of consideration to CD-ROM and CVI products in place of paper ones.

But stick around. Despite our current travails, the venerable kraft process will remain the world's No. 1 pulping process for many years to come, mills will become much tighter environmentally and economically, and market prices might even increase. How about US\$ 499.95 per ton in the year 2000 (not adjusted for inflation, of course)? ■

**MacLeod is the director of Paprican's Information Services Division, a 1993 TAPPI Fellow, and a part-time freelance writer.**

# Enocell mill a showcase for TCF/ECF production

*Enopine: 175,000 tpy; Enobirch: 340,000 tpy. Enoquestions?*

No question about its size—it's big. And it has the first true SuperBatch cooking plant, using 10 300 m<sup>3</sup> stainless steel digesters, four for pine and six for birch. The two parallel fiber lines have medium-consistency oxygen delignification systems and DEoDD (or QPPP) bleach plants. A new Valmet/Flakt/Sunds pulp dryer completes the hardwood line, while a renovated machine handles pine pulp.

Enocell, Finland's newest, biggest kraft mill at Uimaharju in northern Karelia, is designed to make ECF and TCF pulps from both wood sources. Pulp quality was a crucial factor from the beginning of the project—uniformity, cleanliness, and superior physical properties were essential for Enso Gutzeit's paper and board makers and for customers beyond.

Environmental compatibility was a watchword too. After almost a year's operations, the mill's AOX load is around 0.1 kg/a.d. ton of pulp, and BOD is about 0.5 kg/a.d. ton. These levels owe a lot to SuperBatch cooking to low kappas: softwood at 15–18/ECF grade, 10–12/TCF; hardwood at 13–15/ECF, 10–12/TCF. Pulp strength delivery is in the 90s, a real bonus for TCF production. ECF brightnesses are 90+, and TCF figures are around 83/pine and 87/birch.

For effluent treatment, the mill has a cooling tower and a 30,000 m<sup>3</sup> equalization pond, then an 80,000 m<sup>3</sup> activated sludge treatment plant (one day), three secondary clarifiers, and a three-day ecological pond before discharge.

Special features at Enocell include spring-hung piping all through the SuperBatch plant (to accommodate piping expansions and contractions and preserve gasket integrity), pumped discharge of the digesters (two digesters per pump), brownstock washers driven hydraulically from both ends, and titanium D-stage towers. Cooking is run by the SuperBatch Administrator system, which in turn controls the DCS.

The Enocell pulp mill in Uimaharju, Finland



Hot liquor accumulators in front of the SuperBatch digester plant



Displacement presses for post-oxygen washing



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## ENVIRONMENTAL DATA ANALYSES

### **Statistical procedures for addressing nondetect results in environmental analyses**

Steven W. Hinton

NCASI, Tufts University

Data sets of chemical concentrations that contain observations which are less than the analytical chemistry limit of detection (LOD) value are becoming increasingly common as regulatory agencies and dischargers strive to reduce the concentrations of trace organic contaminants in treated effluent. Observations quantified as <LOD or nondetect arise when the compound being measured is either absent or exists at such low concentrations that the analytical result is judged unreliable. This data censoring can occur for a variety of reasons including noncompliance with quality control/quality assurance criteria, such as low signal-to-noise ratio or poor spike recovery.

This paper describes commonly used methods for estimating the mean and standard deviation of a parent population from censored data sets and evaluates the methods for bias and root mean square error characteristics.

One method had superior predictive capability overall, particularly when applied to real-world data sets. For the mean and standard deviation estimators, the author finds that method to be at least 2.5–1.2 times less biased, respectively, than those of the EPA recommended methodology.

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## SOLID WASTE MANAGEMENT

### **Alternative management of pulp and paper industry solid wastes**

Paul S. Wiegand and Jay P. Unwin  
NCASI

In recent years, the pulp and paper industry has decreased its reliance upon landfills as a means of managing solid wastes. Meanwhile, the use of land application, burning and incineration, and other unconventional waste-management alternatives has increased proportionally. Both land application and burning and incineration have been the subject of considerable research, and there is much practical experience with these alternatives. But research on other waste management alternatives is less focused and is not as widely available. This paper emphasizes the management of paper-industry wastes by unconventional methods.

The authors present more than 30 sludge management alternatives, several of which have recently received considerable attention. Alternative management techniques for lime grit, green liquor dregs, wood ash, and bark are also discussed.

The paper provides a general resource for evaluating the potential applicability of various, unconventional pulp and paper industry solid-waste management alternatives.

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## DEPOSIT CONTROL

### **Biofilms and dispersants: a less-toxic approach to deposit control**

Linda R. Robertson and  
Nicole R. Taylor  
Nalco Chemical Co.

Paper mills have long relied on biocides to control microbial deposits within acceptable limits. Recent interest in less-toxic approaches to deposit control has made the use of dispersants an attractive adjunct to standard biocide treatment programs.

The activity of dispersants on deposits is poorly understood, largely because of the difficulty in measuring their efficacy. Biocides are evaluated by measuring kill or inhibition. There is no comparable benchmark for evaluating the activity of nontoxic dispersants.

Conventional wisdom has held that dispersants act as "biopenetrants," either opening the biofilm deposits to allow ingress of biocides or triggering a sloughing process. Research from Europe suggests that lignosulfonate dispersants can prevent formation of bacterial deposits, possibly allowing mills to eliminate the use of toxic deposit-control agents.

This article describes laboratory efforts to study the effects of nonionic and lignosulfonate dispersants on *in vitro* cultures of pure biofilms and biofilms containing calcium carbonate. The authors also report the encouraging results of a low-toxicity mill trial with a nonionic dispersant.

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## AKD SIZING

### **AKD sizing mechanism: a more definitive description**

Kyle J. Bottorff  
Hercules Inc.

Many paper grades, because of their end use, are sized to enable them to resist the penetration of aqueous-based liquids. Paper made under neutral and alkaline conditions is most often sized using alkylketene dimer (AKD)-based dispersions. A full understanding of the mechanism by which AKD sizes paper is necessary to allow the papermaker to size a variety of grades effectively and efficiently. The work reported here shows definitively that

1. AKD reacts with cellulose to form covalent bonds under papermaking conditions
2. The initial hydrolysis products resulting from the direct action of AKD and water or base contribute very little toward sizing, and are present in the paper at low levels at most
3. The AKD associated with calcium carbonate fillers degrades to the nonsizing stearone at rates dependent on time, temperature, AKD concentration, fillers surface area, and filler calcium hydroxide content. AKD associated with low-surface-area, low-calcium-hydroxide-content filler shows no signs of degradation.

The results of this work show that AKD sizing efficiency can be optimized by controlling the papermaking chemistry to maximize AKD reaction with the pulp and minimize AKD reaction with water, base, and filler.

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## WEEPING VISUALIZATION

### **Weeping in blade coating, part 2**

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and Koichi Takamura  
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Philip C. Clark  
and James L. Vodnick  
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This second of two papers on visualization of the weeping phenomenon in blade coating of paper focuses on SEM and X-ray analysis of microtome-sectioned weeps. Weeping is a localized bleeding of the coating suspension into millimeter-scale wet deposits called "weeps" that appear and grow on the outer surface of a blade. They often grow, detach, and land on the coated sheet where they can cause gross surface imperfections.

In part 2, the authors report results of SEM and X-ray microanalysis of air-dried, microtome-sectioned weeps with resolutions down to 0.005  $\mu\text{m}$ . The sectioned weeps showed excess numbers of calcium carbonate lumps and rafts of clay booklets up to 36  $\mu\text{m}$  across in the trunks of the weeps where they attached to the blade. This indicates trunks may partly grow by blockage of large clay booklets and calcium carbonate lumps.

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## METALIZED FILM COATING

### **Characterization of vapor deposited aluminum coatings on oriented polypropylene films**

Martin J. Fay  
and Thomas D. Allston  
Mobil Chemical

Metalization can significantly enhance the barrier properties of polymer films used in packaging. The metal coating provides an effective light barrier, which is important for foods that spoil more quickly when exposed to light. Metalization can also significantly enhance a film's barrier to oxygen and water transmission. This aspect is critical for extending the shelf life of packaged foods.

In theory, a defect-free coating of aluminum should provide an almost complete barrier to oxygen and water transmission. But in practice, this expectation is not fulfilled. Poorly metalized films may be only moderately better barriers than unmetalized films, suggesting a significant number of defects can exist in the aluminum coating.

This paper describes a number of analytical techniques that can be used to examine the structure of vapor-deposited aluminum on corona-treated polypropylene. These measurements will add to the understanding of the structure of the aluminum coating and how the structure might affect its barrier properties.

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LABORATORY NOTEBOOK

**Purpose and proper maintenance of a laboratory notebook**

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and Science

The laboratory notebook provides a means for keeping one's thoughts, ideas, and data in an orderly and safe fashion. Often thoughts are arranged in a better fashion when they are entered into a notebook. When writing something down, one may think of other ideas, other data that should be collected, or additional experiments that should be performed.

While most countries recognize the inventor as being the one who is the "first to file," the United States still designates the inventor as the one who is the "first to invent." It is imperative, therefore, that the inventor be able to establish the date on which a particular invention was first conceived. When maintained properly, the laboratory notebook will provide such proof to the U.S. Patent and Trademark Office and to the courts.

Sixteen recommendations, with detailed reasons, are given for using and maintaining a legally acceptable notebook. Caution is stressed for filing for a patent within one year of the date the product or process is first used, sold, or mentioned in any publication. Otherwise, the individual or company may lose all rights to an idea if a patent is not applied for at the proper time.

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FABRIC CLEANING

**A new approach to fabric cleaning for nonwoven machines**

Joseph A. Bolton  
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Effectively cleaning and dewatering forming or conveying fabrics without causing streaks in nonwoven webs has been a problem for years. Laboratory and field trials suggest that the most effective method of cleaning fabrics contaminated with fiber and resins is the use of spray nozzles with high-pressure hot water. A continuous fabric cleaning system is desirable for maintaining optimum production and product quality on nonwoven machines.

Early systems used a stationary shower with fan spray nozzles. Later systems used a high-pressure oscillating or alternating needle jet and fan spray shower. A suction pipe and airknife were added to remove both water and fibers from the fabric.

A recent improvement involves replacing the high-pressure oscillating multiple-needle jet-nozzle shower with a slow-speed, programmable single-nozzle high-pressure shower. It offers continuous cleaning and full coverage due to its programmable speed adjustment. The single nozzle reduces the amount of shower water required and thus cuts down on streaking. The airknife and suction pipe are still used in the new system.

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**Ultrasonic characterization  
of forming fabrics**

Pierre H. Brodeur  
and Eddie L. Lewis Jr.

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and Technology

High-speed forming and the increased use of recycled fibers are imposing more stringent expectations on the design and performance of forming fabrics. The authors explored nondestructive ultrasonic testing techniques as a means to characterize stiffness properties of forming fabrics.

Two dry-contact ultrasonic methods were first tested to determine stiffness properties along the machine direction (MD), cross direction (CD), and thickness direction (ZD). A wet-coupling ultrasonic technique was then used to evaluate the ZD apparent stiffness of specimens immersed in water. Results gathered from four fabrics indicated that the MD extensional stiffness was systematically higher than the CD extensional stiffness, as expected from MD tension requirements. Among other findings, excellent agreement between the MD extensional stiffness and MD elastic modulus for a monolayer fabric suggested that ultrasonic measurements may be a good predictor of tensile-testing data. Also, ZD stiffness parameters determined under dry-contact conditions could not be correlated to existing fabric properties.

The preliminary results reported in this paper indicate that ultrasonic characterization of forming fabrics is a promising technique.

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**Real-time quality analysis  
of newsprint paper machines**

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and Brad B. Bardwell,  
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More than 20 different tests may be used to determine newsprint quality, but much of the data are not examined or analyzed in real time. So, when quality disturbances occur, most of the data are analyzed well after the fact, when large amounts of off-quality paper have already been produced.

Factor network analysis has been used to analyze newsprint quality data. This technique allows an experienced papermaker to determine the underlying causes of paper quality variations. Factor network analysis transforms qualitative patterns, such as fiber orientation and fiber bonding, into quantitative variables that can be plotted and tracked over time.

A real-time paper quality analysis system has been developed and tested under mill conditions to detect sensor miscalibrations and random test errors as well as determine the sources of paper quality disturbances. Operating personnel can more efficiently control product quality in real time rather than performing post-mortem analyses of off-quality paper. The results are reduced product variability for the customer and an increased understanding of the process for the mill.

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NEWSPRINT TRIALS

**The *Dagbladet* full-scale printing trials, part 2**

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and Bent Foyen  
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Print quality is easily recognized but difficult to measure. Until we learn more about which features correspond to a visually appealing print, image-analysis measurements of print quality will have to be validated by visual judgments, which remains the best way to ensure reliable results.

This report shows that models based on image-analysis measurements reliably predicted subjective evaluations of print quality in evenness in the solid print, evenness in halftones, and print sharpness. Image analysis did not successfully predict scores for evenness in gloss.

The article describes the 12 image-analysis parameters that were measured and recounts the model-building process.

The results are based on printed samples from 19 of the 27 full-scale printing trials during production of *Dagbladet*, a daily newspaper printed in four colors. Results for linting behavior and roll/web performance will be published separately in upcoming issues of *Tappi Journal*.

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PRINT MOTTLE

**Formation and consolidation of a coating layer and the effect on offset-print mottle**

Gunnar Engström  
Swedish Pulp and Paper Research  
Institute (STFI)

Print mottle on coated papers can be a serious quality problem. The consensus is that mottle is caused by binder migration from the wet coating layer to the surface during overly intense drying. This belief is based on the results of various stain tests, which are poor predictors of offset mottle.

The author's review of the most recent literature on the subject of paper-related causes of print mottle shows that the problem is more complicated than simple binder migration.

The key factors affecting mottle are the distribution of binder at the coating surface and the distribution of porosity throughout the coating layer. Both factors, in turn, are governed by the mass distribution of the coating layer. A coating layer that is evenly distributed atop the base sheet is less likely to experience print mottle. Calendering of a nonuniform coating layer can exacerbate the problem by compressing the coating layer unevenly, thus further distorting the porosity distribution.

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### **Comparison of enzyme-enhanced with conventional deinking of xerographic and laser-printed paper**

Thomas W. Jeffries, John H. Klunness, Marguerite S. Sykes, and Kathleen R. Rutledge—Cropsey  
USDA Forest Service

Office recovered papers are a rapidly growing, inexpensive source of high-quality paper fiber for recycling mills. Microbial enzymes are particularly effective at removing inks from office papers printed with laser and xerographic toners, which are among the most difficult contaminants to remove. The enzymes can be much more effective and less expensive than conventional deinking chemicals, and they do not create wastewater treatment problems.

The authors' work examined seven commercial enzymes with cellulase activity, xylanase activity, or a combination of both applied to paper stock in the pulper at optimum conditions. In terms of deinking efficiency, most enzyme preparations performed better than the conventional chemical methods.

Successful development of enzyme-enhanced deinking technology could be beneficial for papermakers, wet-end chemical suppliers, and enzyme manufacturers. Further development is needed to better understand the basic mechanisms involved and to optimize performance.

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### **A method for measuring the mass of nondispersible ink**

Ken N. Law, Z. H. Jiang, and Jacques L. Valade  
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The number and size of ink particles, but not the mass or concentration of ink, in recovered paper stock can be efficiently determined by image-analyzing techniques. The authors have developed a rapid and accurate method that can be used to measure the mass of toner ink in recovered paper stock.

This method consisted of three main successive steps. First, the stock was treated with nitric acid (4 N) to reduce the ash content. The treated stock was then delignified using a mixture of potassium permanganate (0.1 N) and sulfuric acid. Finally, the carbohydrates of the delignified stock were removed using 1 M cupriethylenediamine. The remainder of ink particles can be determined in the usual way. Repeated measurements of 0.50-g/m<sup>2</sup> toner ink-printed papers yielded a standard deviation of 0.02 and a repeatability of 0.029.

The test method is useful for measuring the initial toner ink concentration of recovered paper stocks.

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## STRENGTHENING

### **Caustic treatment of OCC for strength improvement during recycling**

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Sodium hydroxide soaking can greatly increase the strength of recycled paper. This study examined the caustic soaking parameters for a 100% recycle facility using a furnish of OCC to produce new linerboard. Optimum process parameters for soaking were 4 h in 2% sodium hydroxide at 52°C and 14% consistency. The pH of the sheet was as important as caustic soaking in OCC strength improvement. Adjustment of the pH to 5.5 resulted in a maximum strength increase of 11% over untreated pulp. With pH of 11, however, the short-span compression index increase was 22%

Using bench-scale equipment, the authors examined caustic concentration, soaking time, temperature, and consistency. They also studied several contaminants to understand the differences between pilot and mill-scale results. Salts and multivalent cations reduced the strength of the caustic treated pulps. Soaking towers were not necessary due to the low soaking time required.

The use of sodium hydroxide can reduce refining energy necessary to achieve strength. With an alkaline papermaking process, the increase in sheet strength will allow the use of increased OCC content without the use of strength aids such as starch.

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## EDGE CRUSH TEST

### **The effect of boxplant operations on corrugated board edge crush test**

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Institute of Paper Science  
and Technology

This project studied the quantitative effect of five selected boxplant process variables on both the average edge crush test (ECT) and the ECT variability of corrugated board, and its impact on the ability to achieve Alternate Item 222/Rule 41 ECT compliance. The process variables studied were crushing, single-facer cured bond strength, leaning flutes, high and low flutes, and pressure roll cutting.

The experimental corrugated board used in this study was produced on the Institute of Paper Science and Technology 14-in.-wide pilot corrugator at commercial speeds. The techniques used to change the levels of the process variables studied were the same conditions that would exist in a commercial boxplant.

The experimental results show that a lower single-face pin adhesion bond strength, a greater angle of leaning flutes, a greater percentage of high and low flutes, and crushing of the combined board all adversely affect average ECT. Moderate increases in the pressure-roll cutting of the linerboard improved the average ECT results.

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## CORRUGATOR SCHEDULING

### **Analysis of corrugator side trim**

Franklin H. Cloud

Industrial Engineering Consultant

When order item blanks for corrugated containers are first combined on the corrugator, it is necessary to leave an edge on each side of the combined rolls of paper. This is required because, as paper runs over the hot machine, it shrinks, has a certain amount of weave, and 100% alignment of the rolls is very difficult. This wasted edge, on each side of the combined board, is called the trim. The amount of corrugator side trim in a container plant is significant because, in most cases, it is the second largest item in controllable waste.

Cloud's paper examines and quantifies various aspects of side trim. It gives the results of a national company's 10-month study of its 23 corrugators of six different sizes, provides a chart of relative costs between roll stock sizes and inches of side trim, presents breakeven formulas for running excess trim vs. the cost of a size change, and discusses two different methods of sequencing runs.

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## CORRUGATED CONTAINER PRODUCTION

### **Standards and efficiencies for corrugated work centers**

Elliot S. Rohde

Elliot Rohde Associates Inc.

During the 1970s and 1980s, TAPPI conducted productivity surveys for the corrugated container industry. These surveys used simplified setup and run standards for the various work centers and reported efficiencies based on these simple and general standards. These standards did not reflect the increasingly complex parameters that exist in the corrugated industry, nor were they updated to reflect changes in the automation of these work centers and in the changed mix of work resulting from this development.

In the 1991 and 1992 surveys, comprehensive statistics were used, and time standards were discontinued.

Modern industrial engineering techniques involve the use of industrial engineering disciplines, statistical disciplines, and computer facilities in ways that were unknown decades ago. This paper describes these techniques, with a specific analysis of the flexo folder-gluer, which is a typical and vital work center in corrugated manufacture.

Modern standards enable the reader to continue to use statistical measures with which he or she is comfortable. And these standards enable the user to obtain a true reading of skill and effort performance that cannot be obtained with the statistical data alone.

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