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# Increasing Yield and Quality of Low-Temperature, Low-Alkali Kraft Cooks with Microwave Pretreatment

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**Industry Partners:**

D. Parent, Communications and Power Industries

G. Marrs, Weyerhaeuser

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# Technology Description

- In wood pulping, ~50% of the chemicals and energy drive the reaction.
- Microwave pretreatment can decrease the chemicals and H-Factor required to pulp hard or soft wood by breaking the cellular microstructures which control permeability in wood.

**Project Goal:** Evaluate and develop at scales to prototype, a microwave pretreatment technology that can:

- Decrease H-factor and pulping chemicals by ~20%,
- Meet industry requirements for yield, quality, and safe/environmentally sound operation,
- Show attractive economics and energy balances.

**Project team demonstrated 40% chemical and H-Factor decreases.**

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## Microwave Pretreatment Could Save Energy In:

- Conventional alkaline pulp mills (Kraft and soda-AQ).
    - ~140 Mills
    - ~160,000 ADT/day
  - Could be introduced at mill scale ~2010-2015, earlier for oversized chips.
  - An initial mill trial, using an existing prototype scale applicator with a leased generator, could be started in FY2007 or early FY2008.
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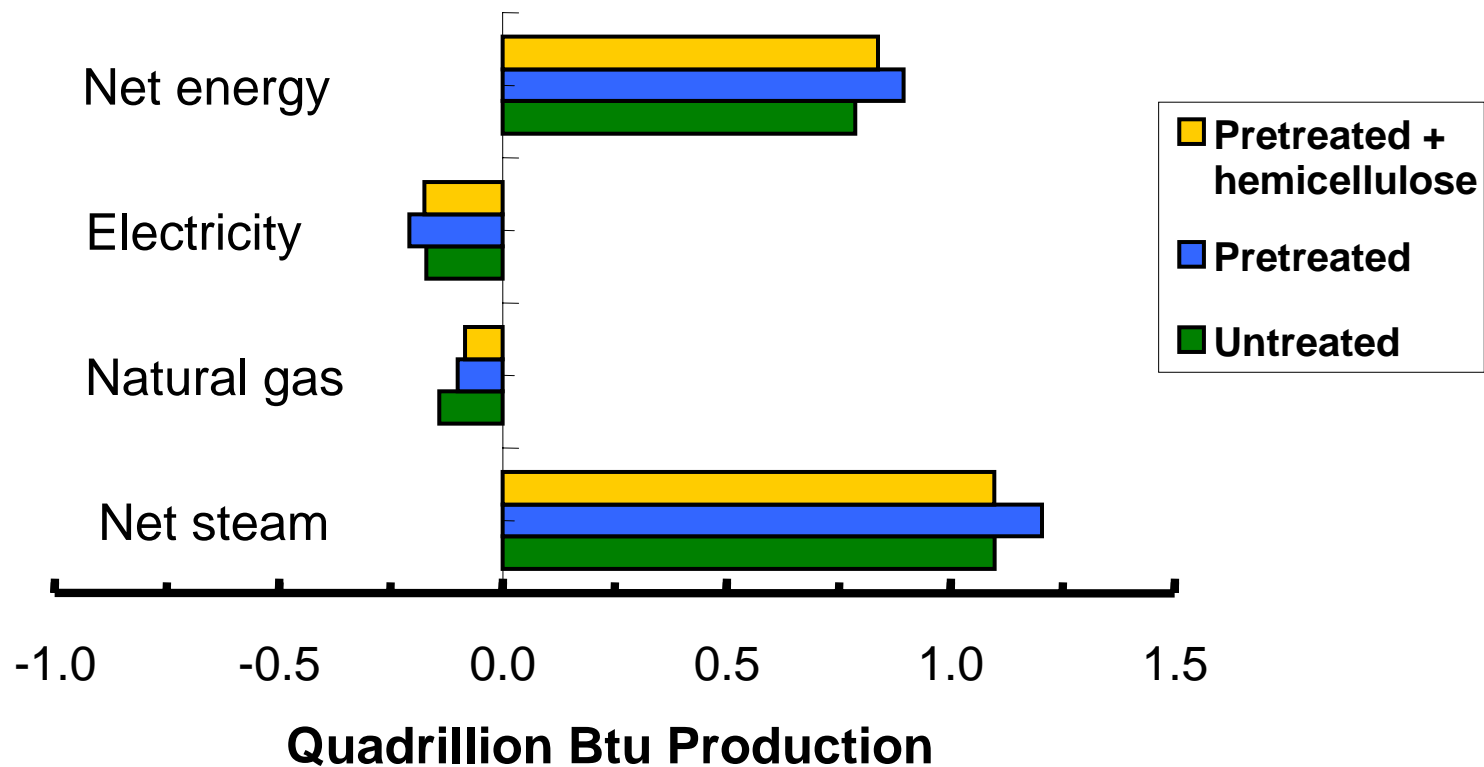
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# Energy Savings

- Two main energy savings:
    - Lower chemical use = lower lime kiln natural gas
    - Lower H-factor = higher throughput
  - Assuming 55 million tons per year of chemical pulp and evaporator held to base case, annual energy savings are ~ 110 trillion Btu (~2 million Btu/ADT).
    - Natural gas for the lime kiln is decreased by 40 trillion Btu (~40 billion ft<sup>3</sup>)
    - Assuming a petroleum price of \$60/bbl, annual energy savings are ~ \$3 billion.
  - Increasing mill throughput (lower H-factor, chemicals) will permit the forest products industry to move production to more efficient mills.
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# Comparison of Energy Consumption and Production

National energy impact, three cases, 55 million ADT/yr.



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## Other Benefits

- Natural gas used to recycle pulping chemicals will decrease in proportion to chemicals.
  - Larger or more diverse chip sizes can be pulped.
  - Hemicellulose stripping from black liquor could permit evaporator limited systems to produce substantially more pulp at a higher (~2 - 5%, wood basis) yield.
  - Better black liquor concentration
    - Lower pulping chemicals
    - Pre-evaporation hemicellulose stripping could permit ~ 80% solids, lowering both emissions and energy per ton of pulp.
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# Reductions in H-Factor and Pulping Chemicals Could Help Meet Forest Products Industry Roadmap Goals

- Microwave pretreatment could decrease chemical and H-factor required to pulp wood by ~40%. These reductions impact a number of roadmap areas.
  - Lower chemicals
    - Reductions in chemicals = reductions in lime kiln and causticizing (Breakthrough Manufacturing Technologies)
    - Lime kiln is the major consumer of natural gas (Reduced Energy for Causticizing)
    - Lower inorganics could permit higher black liquor solids concentrations in some mills (Reduced Energy for Black Liquor Concentration)
  - Lower H-Factor
    - Reduce energy required to pulp wood chips (Breakthrough Manufacturing Technologies).
  - Hemicellulose separation from black liquor could reduce viscosity and increase solids (Reduced Energy, Black Liquor Concentration)
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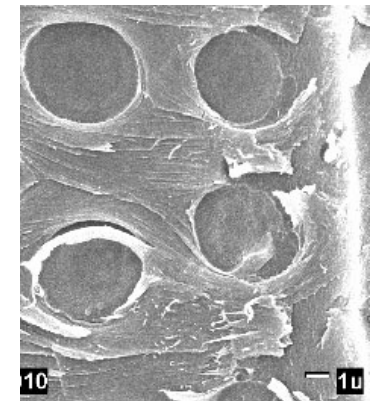
# Sequential Project Strategy

- The strategy which underlies the project is to develop and demonstrate the use of microwave pretreatment technology at increasing scale and with increasing emphasis on integration of this technology into pulp mills.
  - This project has moved systematically through several stages:
    - Proof-of-concept: Can microwave pretreatment be used to decrease chemicals and energy required to pulp hardwoods?
    - Processing chips: Can softwood and hardwood chips, the feedstock for most domestic pulp mills, be pretreated?
    - Prototype applicator: Working with Communications and Power Industries, can we develop a prototype applicator which will permit their development of turnkey systems for the forest products industry?
    - Mill integration: Econometric calculations for matched untreated and treated cooks showed that H-factor and chemical reductions could permit up to 20% additional mill throughput.
  - At each stage, barriers to use were identified and technical solutions developed.
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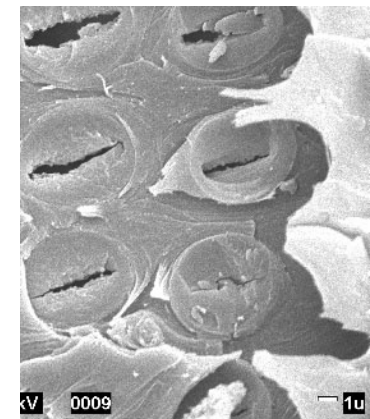
# Proof-of-Concept: Can Microwave Pretreatment Decrease Chemicals and Energy Required to Pulp Hardwoods?

- Using a small 915 MHz RF applicator, chemicals and H-factor used to pulp sycamore coppice could be reduced by up to 40% even for very large (100 mm X 100 mm) sections of coppice (Milestone 1.1 – 11/2001).
- A basic understanding of physical mechanisms (vessel cell and pit membrane breakage, increased wood permeability) was developed.
- Energy and mass balances, together with basic econometrics, indicated that the technology had the potential to meet industrial needs (Milestone 1.2 – 9/2001).

Untreated



Pretreated

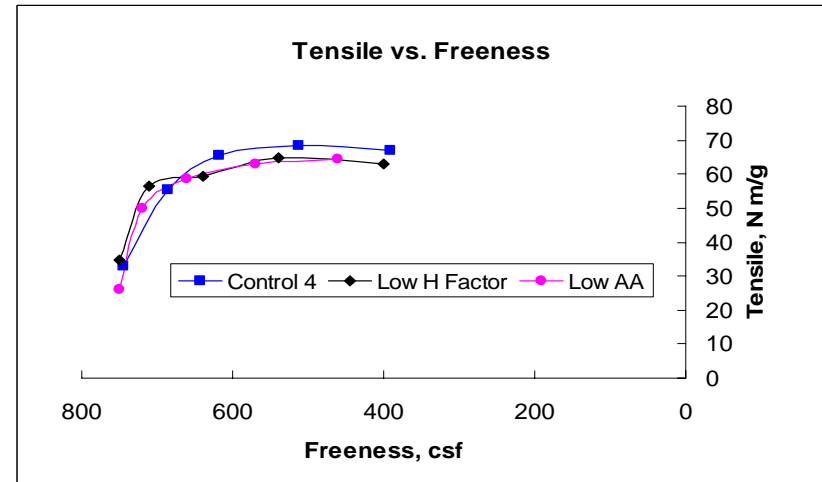
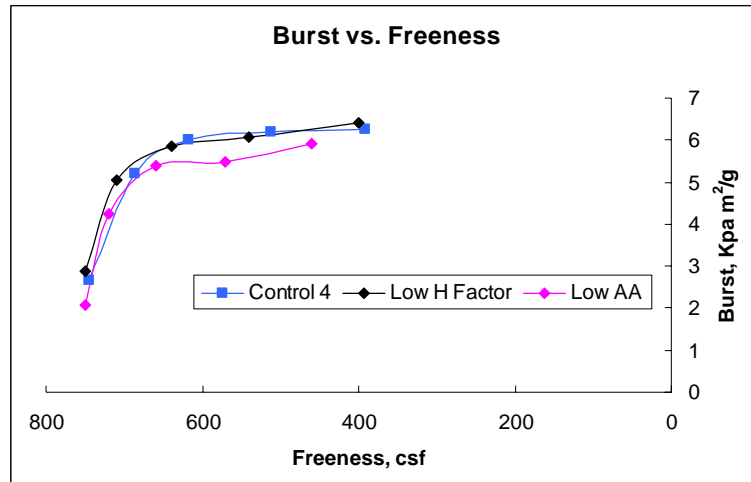


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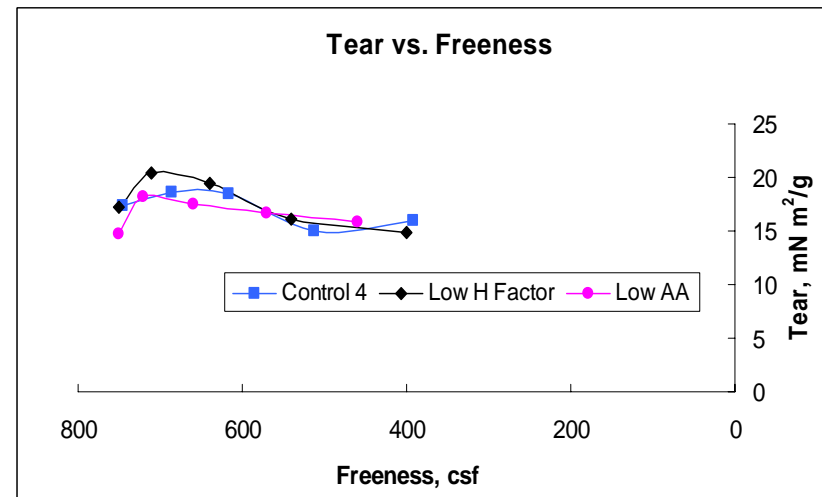
## Processing Chips: Can Chips Be Pretreated?

- Chips are difficult to pretreat because of a short path length, a high likelihood of microwave arcing, and extractives.
  - In conjunction with Communications and Power Industries, a method for treating chips which minimized arcing (speed, evenness, airflow, etc.) was developed and verified.
  - This method permitted H-factor and chemical reductions of up to 40% in both softwood and hardwood chips with comparable kappa and yield.
    - Hardwood, concurrent ~ 40% H-factor and chemical reductions.
    - Softwood, concurrent ~ 30% reductions, ~ 40% single factor (Milestone 1.3 — 9/2002).
    - Oversized chips can also be microwave pretreated and added into untreated chips with satisfactory processing results.
  - Handsheet tests show comparable pulp mechanical properties (Milestone 2.2 — 9/2003) with a decrease in hemicellulose content (12.5% vs. 11.5%).
  - Review committee originally recommended log pretreatment studies in case chips could not be pretreated. These were dropped because chip pretreatment was successful.
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# Linerboard Handsheet Properties



- Burst and tear indices for pretreated samples were comparable.
- Tensile strength is slightly lower, probably due to reduction in hemicellulose content from 12.5% to 11.5%.



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# Prototype Applicator: Can an Effective Prototype Applicator be Developed?

- Applicator was developed to support projects working with logs, cants, lumber, and chips.
- Obtained using a partner-subsidized lease.
- Based on a system used in food preparation.
  - Capable of 24 hr. operation.
  - Reliable.
  - Large enough for a mill trial.
- Produces results which are comparable to those with smaller applicators (Milestones 2.3 – 3/2004, 2.4 – 9/2004).
- Communications and Power Industries will permit this project to use their applicator in a mutually agreed pulp mill trial.



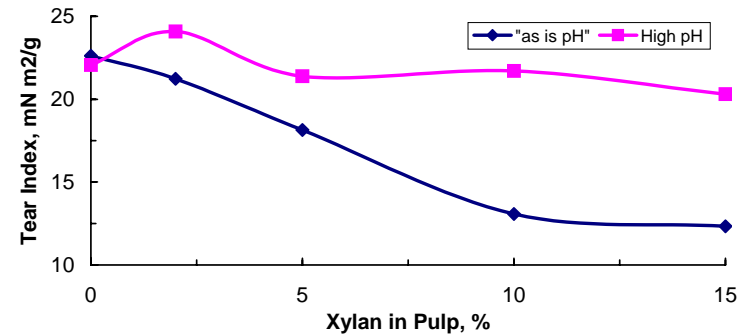
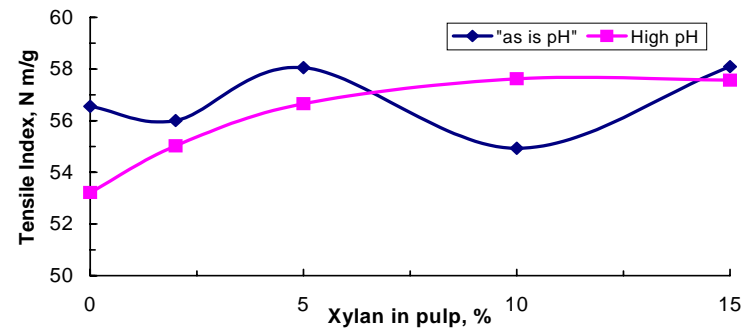
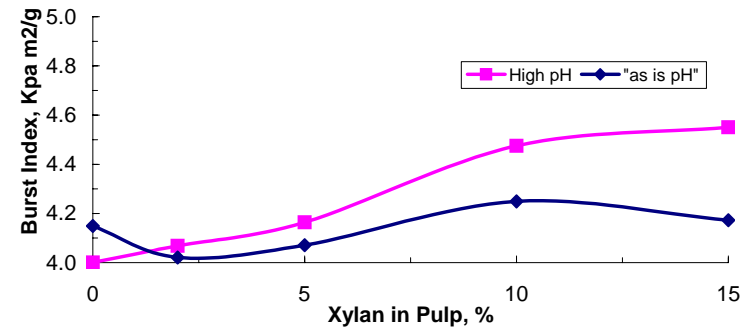
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## Mill Integration: Fitting Microwave Pretreatment into a Conventional Mill

- Pretreated chips immersed in pulping liquor soak up significant amounts of pulping chemicals in a few minutes.
  - Calculations of volatiles production from chip pretreatment indicate no significant emissions. (Committee request).
  - Econometric calculations for matched untreated and treated cooks showed that H-factor and chemical reductions could permit ~20% higher pulp production in an existing batch mill.
  - This could be accomplished using:
    - Lower H-factor (400 vs. 800) and chemicals (12% AA vs. 16% AA) use and a slight reduction in liquor to wood ratio (3.2 vs. 3.6).
    - Hemicellulose stripping from black liquor for re-use in pulp.
    - Evaporation to higher concentration (80% solids vs. 70% solids).
    - Higher solids concentration decreases boiler emissions.
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# Black Liquor Hemicellulose Could Increase Yield

- In addition to pre-process extraction, hemicellulose can be directly precipitated from black liquor.
- Substantial amounts of hemicellulose precipitated from black liquor can be incorporated into handsheets.
  - Hemicellulose precipitation and recovery for use in pulp could:
  - Decrease black viscosity,
  - Improve yield, and
  - Increase maximum black liquor solids concentration.



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# Commercialization Potential

- Industrial microwave systems are used 24/7 in many industries.
  - Microwave pretreatment has a small physical footprint and could be retrofit into many existing chemical pulp mills.
  - Microwave pretreatment could lower the capital intensity of existing pulp mills because the capital cost of a microwave/RF system is ~\$25 million for a 1000 ADT mill (~3 to 4% that of the overall mill). But the mill could produce ~20% more pulp. (Payback < 2 years)
  - Microwave pretreatment decreases chemicals and energy required to produce pulp. This would be particularly useful in mills where pulp production is limited by boiler or chemical recycle capacity.
  - With hemicellulose stripping from black liquor, lowered pulping chemical use could permit production of ~ 80% solids liquor. This would lower emissions, a concern for some mills.
  - However, to be a commercial success, microwave pretreatment must also produce acceptable pulp, at an acceptable price, while meeting both internal and external regulations and commitments.
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# Commercialization Barriers

- Pulp mills are highly-integrated, high-throughput industrial plants which must produce:
    - From a variable feedstock,
    - A product which meets company and customer quality standards,
    - With acceptable economics and energy balances,
  - While meeting applicable requirements:
    - International, federal, state, and local standards for environmental, safety, operating, and emissions, and
    - Permitted frequency.
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# Basis for Commercialization Plan

- First installation designed to minimize risk and cost.
  - Two applications could show the potential of mill scale technology using small scale equipment:
    - Pretreatment of oversized chips
    - Pretreatment of feed to one digester in a small multi-digester batch mill
  - Calculations indicate that these could be accomplished using equipment near the size of our prototype applicator.
  - Larger leased applicators and generators could also be used.
  - These are typically small equipment which can be disassembled, moved, and re-assembled.
  - Our research team has members with experience and skill in arranging mill trials.
  - Our microwave partner, Communications and Power Industries, has performed similar trials to initiate commercialization of other technologies and has indicated that they favor a mill trial.
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## First Mill Trial

- Two small applications could show the potential of mill scale technology using small scale equipment:
    - Pretreatment of oversized chips
    - Installation to feed one digester in a multi-digester batch mill
  - Could be accomplished using our leased prototype applicator and a leased generator.
  - Our equipment can be disassembled, moved, and re-assembled.
  - Research team has members with experience and skill in arranging mill trials.
  - Communications and Power Industries, the dominant international equipment producer, has agreed to support an initial mill trial with equipment, staff, and modeling capabilities.
  - We are currently working to determine which mills are suitable and might be interested.
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# Project Partners

- A. Compere, W. Griffith, and T. White, Oak Ridge National Laboratory
    - Primary responsibility for project integration, reporting, and subcontracting. Work with Communications and Power Industries on microwave and process development, maintain and operate equipment. Select and pretreat wood samples.
  - D. Parent, Communications and Power Industries
    - World's leading designer/manufacturer of industrial scale microwave/RF equipment. Expect to commercialize and service microwave pretreatment equipment for Forest products. Advise on information needed to commercialize, discuss project results. Will be involved in any mill trials.
  - H. Jameel and other North Carolina State University faculty and staff
    - Perform pulping, bleaching, handsheet, and papermaking experiments/small production runs. Provides a mill simulation spreadsheet for project use. Equipment, expertise, and simulations to address a wide range of chemical and operational issues.
  - A. Fricke, Emeritus Professor, Florida State University.
    - Performs process econometric and mass balance calculations. Also provides pulping and separations expertise.
  - G. Marrs is currently our official Weyerhaeuser partner. We have also benefited from the the expertise of a number of Weyerhaeuser staff members during this project. They include:
    - Bill Fuller (original project partner, wood technology, retired) and
    - Bob Eckert, Peter Gorog, and Bruno Marcoccia (mill integration).
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