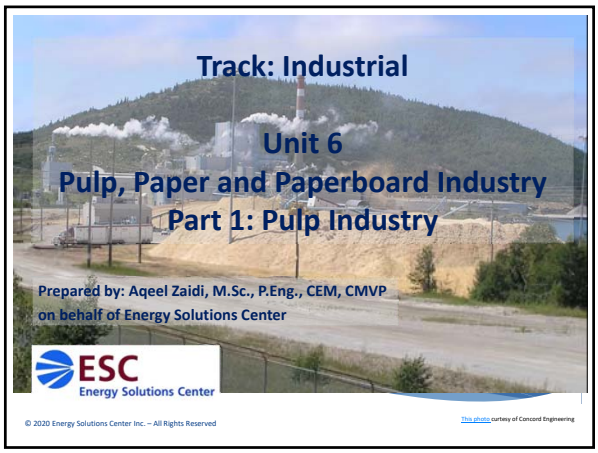

1

Topics

- Industry classification
- Market overview and industry trend
- Pulp making process
- Pulp drying
- Natural gas use in an integrated pulp and paper mill
- Boilers used in pulp mills
- CHP (Cogeneration) for pulp and paper mills
- Resources
- Common terminologies used in the pulp and paper industry

2

Industry Classification

Pulp, Paper and Paperboard Industry

Pulp
- Virgin Pulp
- Recycled Pulp
- On-site Consumption
- Market pulp

Paper
- Newsprint
- Printing & Writing
- Tissue
- Towel
- Napkins
- Bags
- Specialty

Paperboard
- Linerboard
- Corrugating Medium
- Boxboard
- Tubes
- Roofing Felt

3

Market Overview

- Paper and forest-product industry as a whole is growing, although at a slower pace
- Packaging products like paperboard is growing along with tissue paper (no alternative like ***e-tissue*** in-sight to replace this product) so the tissue market will continue to grow globally
- Pulp demand for hygiene products is growing
- New application of pulp for textile applications is growing slowly
  - Some old mothballed pulp mills are being converted to produce fiber for textile industry
- Wood construction is replacing steel and cement slowly to address global warming issues caused by Greenhouse gas emissions attributed to steel and cement industry

 4

4

Global Paper and Paperboard Industry Continues to Grow

Source: Pulp, paper, and packaging in the next decade: Transformational change, by Peter Berg and Oskar Lingqvist of McKinsey & Company, 2019

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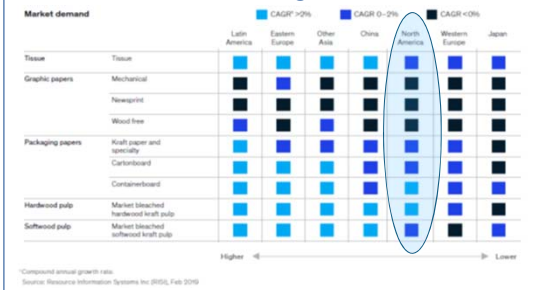
Growth Prospects Vary Among Segments and Regions



Source: Pulp, paper, and packaging in the next decade: Transformational change, by Peter Berg and Oskar Lingqvist of McKinsey & Company, 2019

 6

6

Industry Trends

- Newsprint and coated and uncoated paper will continue to face severe decline
- Newsprint machine will continue to be converted to packaging and board paper
- This trend has been going on in North America since late 90's due to collapse of Newsprint market
- Recent concerns over plastic use could create opportunities for paper based products *e.g. plastic straws replaced by paper straws*
- E-Commerce will drive demand growth for the packaging paperboard products
- Capacity constraints for pulp supply will keep this segment healthy
- The paper and forest industry will evolve in the coming decades to meet the growing demand of bio-fuels, biogas, decarbonization of fossil fuels, environmental concerns over the use of plastics and energy intensive products like steel and cement etc.
- These factor will impact how natural gas use in the industry

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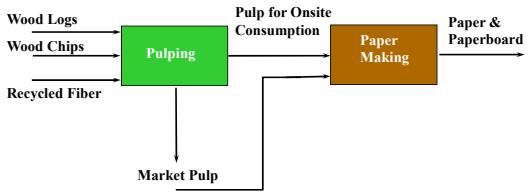
Pulp and Paper Making Process



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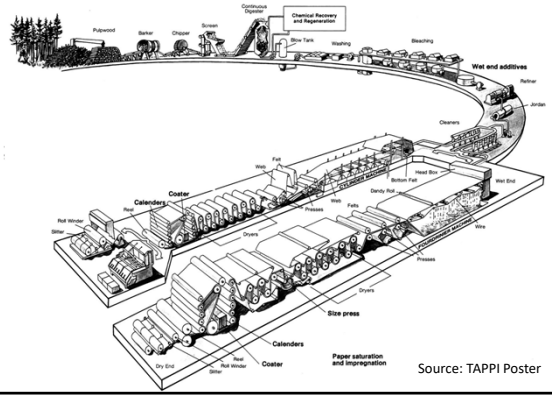
From Tree Logs ⟹ Pulp ⟹ Paper

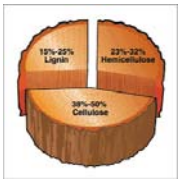


Source: TAPPI Poster

9

Pulping

- The pulping process starts with breaking bonds within the wood structure to reduce wood into individual fibers.
- Wood structure is composed of three main components:
  - Cellulose: Good fiber (50%)
  - Hemicellulose: Chemical impurity that comprises 25 to 35 percent of the dry weight of wood residues
  - Lignin: Holds together the cellulose and hemicellulose components. Lignin constitutes about 15 to 25 percent of the weight of woody biomass
- Two types of pulps:
  - Softwood: evergreen trees e.g. pine, cedar, fir, spruce
  - Hardwood: Trees that drop leaves in Fall e.g. birch, maple, oak, walnut



Wood Composition
P. Daniel Cassidy
Sarah F. Ashton
Univ. of Georgia

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Pulp Making Methods

1. **Mechanical Pulping**
2. **Chemical Pulping**
3. **Semi-chemical** (a combination of mechanical and chemical)
4. **Recycled Fiber Pulping**

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1. Mechanical Pulping

- Uses mechanical abrasion to separate cellulose fibers which are held together by lignin
- Three types:
  1. Stene Groundwood (SGW)
  2. Refiner Mechanical Pulping (RMP)
  3. Thermomechanical Pulping (TMP)

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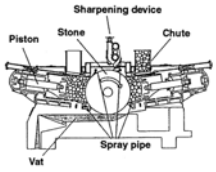
Types of Mechanical Pulping

1. Stone Groundwood (SGW):
   - Wet wood logs are pressed against a large stone rotating at high speed
   - Old method, replaced with RMP or TMP



http://www.fibrelab.ubc.ca/files/2013/01/Topic-3.1-Mechanical-Pulping-SGW.pdf

 13

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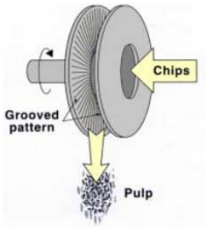
Types of Mechanical Pulping

2. Refiner Mechanical Pulp (RMP)
   - Instead of wood logs, wood chips are used
   - Instead of grindstone, uses metal discs called refiner plates
3. Thermomechanical Pulping (TMP):
   - Two stage process:
     - Wood chips are heated by steam which softens the lignin thus separating the individual fiber
     - Heated chips are pumped in between two high speed rotating discs, called refiners
   - Softening of chips with steam significantly reduces energy consumption
   - Decreases damage to the fiber



The principle of refiner mechanical pulping (Tienvieri et al., 1999).

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Advantages and Disadvantages of Mechanical Pulping

- Advantages
  - produces higher yields up to 95% since lignin is not removed from fiber.
  - One tonne of wood (2200 lb) produces about 2100 lb of pulp
  - Used for low grade paper such as newsprint, catalogues that require less strength
- Disadvantages
  - low strength, low age resistance
  - Newspaper turns yellow over time due to the presence of lignin in the paper

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2. Chemical Pulping

- Uses chemicals to reduce wood chips into cellulose fibers
- Wood chips are cooked with chemicals under high pressure
- Chemicals dissolve lignin that holds fibers together
- During cooking process, about half of the wood (lignin) is dissolved into what is called "black liquor"
- Black liquor is burned in a boiler called "Recovery Boiler" to recover chemicals while producing steam and electricity for the mill, For this reason, chemical pulp mills are net energy producers.
- The cooked pulp is then washed and screened to achieve a more uniform quality

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2. Chemical Pulping

- Most chemical pulp is made by the sulphate process, also commonly known as Kraft pulp
- Kraft is a Swedish and German word for strength
- In Kraft pulping process, wood chips are cooked in a solution of Sodium Hydroxide (NaOH) and sodium sulfide Na_2S)
- The organic sulfide produces stinking smell, so any town with a pulp mill having rotten egg smell will have a kraft process. In the paper industry this smell is called "smell of money"
- The fact that sodium sulfate is used as a makeup chemical, the Kraft process is sometime called the "sulfate process"

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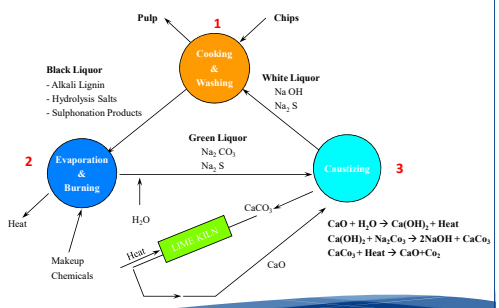
Liquor Cycle in Kraft Pulping



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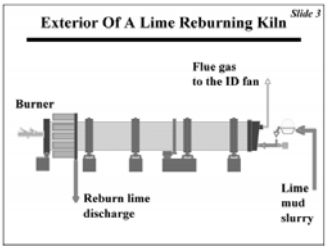
Natural Gas-fired Lime Kiln

- Wet lime mud is fed into the high end of the kiln. The kiln is sloped towards the front end where the gas burner is installed.
- The solids move counter current to the hot flue gases as the kiln rotates.
- Uses about *6-8 MMBtu/tonne of lime produced.*
- Biggest user of natural gas in a Kraft pulp mill
- Some mills also use Fluidized Bed instead of rotary lime kilns , but they are very few



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3. Semi-chemical Pulping

- Uses a combination of chemicals and mechanical pulping processes
- Wood chips are subjected to a mild chemical process to soften lignin, and then mechanical abrasion in refiners
- Yield is higher than chemical pulping due to higher lignin content and less than mechanical pulping since some lignin is dissolved

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Advantages and Disadvantages of Chemical Pulping

- Advantages
  - Produces high strength, smooth pulp since lignin is removed from fiber.
- Disadvantages
  - Yield is about 50%. One tonne (2200 lb) of wood produces about 1100 lb of pulp
  - Expensive

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4. Recycled Fiber Pulping

- Pulp is produced from recycled paper
- Main types of recycled papers:
  - Old Corrugated Cardboard (OCC)
  - Newsprint
  - Mixed paper
- Pulp is produced by:
  - Blending and dissolving recycled paper with water
  - Adding chemical and heat to help separate fibers
  - Removing contaminants

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Market Pulp

- When pulp made on site is not consumed on site for papermaking, it is dried before shipping to paper mills. This pulp is called "Market Pulp"
- Main purpose of drying is to reduce weight to reduce shipping cost

https://www.linkedin.com/pulse/pulp-drying-machine-overview-luciano-oliveira/

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How Market Pulp is Made?

- Wet pulp is converted into a sheet in the forming section. The pulp slurry is spread from the Headbox onto a moving high speed wire. The wet sheet is dewatered and pressed mechanically before being fed to the dryer. This proses is similar to how paper sheet is made. This will be discussed in more detail in Part 2 of this Track which deals with Paper making
- When the fiber web leaves the press section, the dryness is around 52%. The remaining water is evaporated in the Dryer.
- The wet sheet is dried by two types of drying:
  1. Air float drying (more common)
  2. Flash drying
- After the Dryer the fiber dryness will reach 90%.
- The continuous dried sheet is cut into smaller pieces to form bales for shipping

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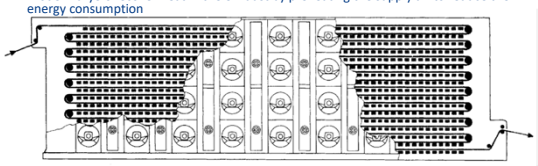
1. Air Float Pulp Dryer - FLAKT Pulp Dryer

- Most Common Dryer to Produce Market Pulp
- The pulp web moves over the dryer decks via turning rolls at the end section
- Dryer Consists of Multiple Drying Decks
  One above the other (Eight or more Decks)
- Sheet is Supported by Air Jets
- Air is Heated by Steam.
- New Dryers offer direct gas firing for Air Heating, but not popular due to risk of fire
- Energy intensive, uses about **4.2 MMBtu of steam per ton of pulp**
- Modern dryers recover heat in the exhaust by preheating the supply air to reduce the energy consumption



Source: Handbook of Pulp and Paper Technologist by G. A. Smook

25

Pulp Drying - FLAKT Pulp Dryer

Source: http://bbcmb.org/content/news/files/Flakt-Dryer.pdf

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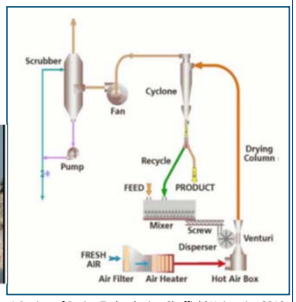
2. Flash Dryer

- Pulp is first pressed and fluffed and the injected (feed) into a stream of hot gases
- Wet pulp and hot gases flow upward in drying column
- The hot gases cause the moisture to "flash" into vapor
- Dried pulp is released as "Product"
- The pulp is compressed directly into a bale or into small pieces which are then formed into a bale

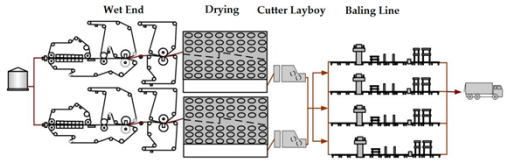


http://www.waggerydcell.se/the-flash-dryer-investment-has-increased-the-mills-capacity

A Review of Drying Technologies, Sheffield University, 2010.

27

Market Pulp Making – 2 Production Lines



https://www.linkedin.com/pulse/pulp-drying-machine-overview-luciano-oliveira/

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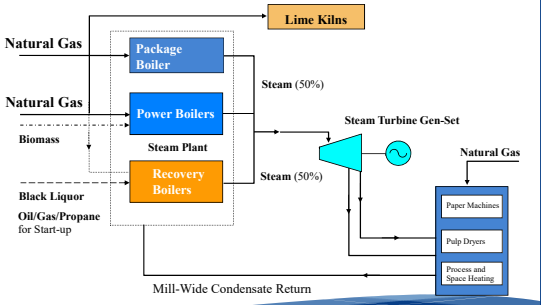
Natural Gas Use in an Integrated Pulp and Paper Mill



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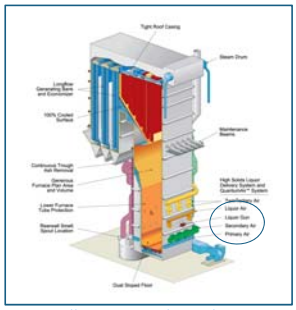
Recovery Boiler

- Fuels:
  - Black liquor
  - Natural gas/oil for start-up
- Concentrated black liquor and combustion air are introduced into the furnace (marked with the circle)
- Heat is recovered as steam for electricity generation and process heating
- Chemicals are recovered as smelt at the bottom
- Recovery boiler in a 1000 tonne per day of kraft pulp mill can produce 350,000 lb/hr steam and 25 – 35 MW of electricity



https://www.babcock.com/products/recovery-boiler

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Package Boiler

- Typically natural gas fired from 50,000 lbs/hr – 500,000 lbs/hr steam capacity
- Produce high pressure steam (500 psig)
- Could be dual fuel fired with natural gas and oil
- Generally equipped with heat recovery devices (Feed water economizer and/or air-preheater)
- High fuel-to-steam efficiency in the 83% range
- Could also burn digester gas

Courtesy: Clever Brooks

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Power Boiler

- Other Names: Hog Fuel, Woodwaste, Biomass, Refuse boiler
- Boiler Types: Grate (*stationary, traveling, inclined*), Suspension Firing, Fluidized Bed
- Primary Fuel: Woodwaste
- Secondary Fuel: Natural Gas / oil
- Woodwaste Heating Value: 8,800 Btu/lb bone dry
- Typical Moisture of WW: 50 – 60 %
- Boiler Efficiency: 55 – 70%
- Trend: Increase Woodwaste and Reduce natural gas
- Gas Industry's Role: Demonstrate Benefits of Gas Co-firing to Optimize Woodwaste Combustion

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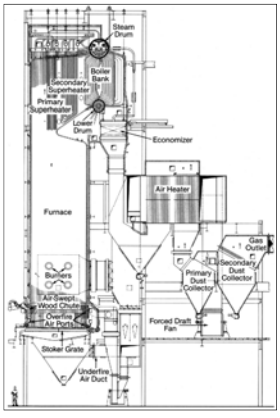
Wood-fired Power Boiler With Traveling Grate

Source: Babcock & Wilcox, Steam, its generation and use



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Combined Heat and Power (CHP) in Pulp and Paper Mills

- In the pulp and paper industry CHP is commonly referred to as Cogeneration
- The size and type of CHP system depends on several factors:
  - Type of mill
    - Integrated (pulp and paper) and non-integrated (pulp or paper)
      - Integrated mills are higher consumer of electricity and steam, over 100 MW of electricity and few hundred thousand lb per hour steam
      - Good candidate for large combined cycle CHP, using gas turbine, heat recovery steam generator (HRSG) and steam turbine
    - Recycled board mills and Tissue mills tend to need about 10 – 25 MW of electricity and about 50,000 - 100,000 lb/hr steam
      - Good candidate for small simple cycle CHP using gas turbine and HRSG
  - Type of pulping
    - Mechanical pulping require large amount of electricity (more than 100 MW)
    - Kraft pulp mills are one of the oldest application of CHP. Most pulp mills were built with a steam turbine due to availability of steam from the recovery boiler and wood waste boilers
    - Most pulp mills are net exporter of electricity
    - Kraft pulp mills typically produce 25 – 35 MW of electricity
  - Merchant plant (feeding to the grid, thermal host) or behind-the-fence

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Combined Heat and Power (CHP) in Pulp and Paper Mills

- Excellent candidates for CHP due to coincident electric and thermal load and 24/7 year round operation
- Size could vary from 5 MW to over 100 MW, depending upon the factors mentioned in the previous slide
- Since paper mills typically run 24/7 year round, any unscheduled downtimes are costly and cumbersome.
- Could take hours or days to get mill up and running from an unscheduled shut down
- CHP offers resiliency to the paper making operation
- Highly efficient CHP systems reduce energy costs for the mill and reduce GHG emissions

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Northland Power265 MW Merchant Plant located near Niagara Falls, Ontario

- Combined Cycle CHP: One170 MW gas turbine and one 95 MW steam turbine (foreground)
- Provides up to 350,000 lb per hour steam to adjacent Resolute Forest Products paper mill (background)
- Electricity output is fully contracted with the Ontario electricity system operator

https://www.northlandpower.com/What-We-Do/Operating-Assets/Thermal/Thorold.aspx

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Sonoco, Brantford Board Mill 3.9 MW CHP

- One 3.9 MW gas turbine with HRSG
- 55,000 lbs/hr steam
- In operation for more than 25 years

Courtesy: CEM Engineering

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Pulp and Paper Commonly Used Terminologies

- Pulp and Paper Industry speaks its own language
- Learn about these technologies to communicate effectively with pulp and paper customers

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Commonly Used Terminologies

- **Basis weight**: weight per unit area of paper
- **Black liqour**: A thick black liquid containing dissolved organic wood material (lignin) and residual alkali compounds
- **Bone dry**: no moisture
- **Break:** break of the paper web during manufacturing on the paper machine
- **Calendar stack:** Stack of rolls at the dry end of the paper machine to impart a finish to reduce roughness – similar to ironing of paper
- **Cross direction:** right angle to the direction of running a paper machine
- **Machine direction:** forward motion on the paper machine
- **Corrugating medium:** Lightweight board used for the fluted inner lies of corrugated box tock.
- **Corrugated board :** Paperboard made by utilizing a fluted medium "corrugating medium" sandwiched between two layers of line

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Commonly Used Terminologies

- **Linerboard:** a thin cardboard used for the flat facings of corrugated containerboard
- **Couch roll:** a large, hollow, perforated roll that removes water from the wet web as it leaves the wire and is guided onto the felt.
- **Doctor blades:** thin scraper to keep the roll clean and free from paper, pulp, dirt etc. Doctors are used on paper and board machines to remove excess water and contaminants from roll and cylinder surfaces, and to remove the sheet from these surfaces during sheet breaks and threading.
- **Dry end:** Part of the paper machine where the paper is dried and reeled

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Commonly Used Terminologies

- **Fourdrinier machine:** A papermaking machine invented by the Frenchman, Nicolas Louis Robert in 1798, developed in England by Brian Donkin for Henry and Sealy Fourdrinier, but not placed into operation until 1804.
- **Headbox:** It spreads the stock into a uniform rectangular flow at a uniform flowrate equal in width to the paper machine in the machine direction. Since this is the starting point of papermaking process, the design and operation of headbox is critical to a successful papermaking system.

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Commonly Used Terminologies

- **Hog fuel:** is an unrefined mix of coarse chips of bark and wood fiber. **Hog fuel** is any type of wood by product or waste that can be burned for **fuel** but can't be categorized as chips, shavings, bark, or sawdust.
- **Lignin:** is the complex polymers that give woody plants their structure, strength, and rigidness. Without the lignin, woody trees would simply flop over because they would not have the cellular structure that makes wood rigid. In simple terms, it holds wood fibers together.

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Commonly Used Terminologies

- **Market pulp:** Pulp sold as raw material
- **Nip (Roll) press**: In the nip press, the wet sheet is pressed by the line of contact of two rolls to remove water mechanically , therefore reducing the need for evaporation in the dryer section. The high pressure created at the nip point brings the sheets into intimate contact, and can squeeze out any bubbles or blisters that might cause a defective bond.
- **Show press:** In the shoe press, the line (nip) contact is increase by passing the sheet through a bigger contact area that allows to press the sheet to very high dryness level , therefore, reducing the need for evaporating drying . Depending on the grade and press configuration, a shoe press can create dryness values 2 to 5 points higher than typical roll press configurations while maintaining bulk Shoe presses are able to preserve sheet bulk while pressing to high dryness values.

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Commonly Used Terminologies

- **Size press:** Two rolls forming a nip which contains liquid starch. The nip pressure forces starch into the paper as it passes through the starch and nip
- **Recovery boiler:** Recovery boiler is a critical part of the Kraft pulping process where chemicals for white liquor are recovered and the black liquor is burned, generating steam that is used to generate electricity in a steam turbine.
- **Hardwood**: Wood comes from angiosperm — or flowering plants — trees are usually broad-leaved, such as alder, balsa, beech, hickory, mahogany, maple, oak, teak, and walnut.

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Commonly Used Terminologies

- **Softwood:** Wood comes from gymnosperm trees, which usually have needles and cones usually evergreen conifers, like pine, spruce. cedar, Douglas fir, juniper, redwood, and yew.
- **Pocket ventilation:** Dryer pocket is a space bounded between two adjacent steam cylinder. The main purpose of pocket ventilation system is to remove vapours from the dryer pocket
- **Wet end:** Portion of the machine between the headbox and the dryer section
- **Converting:** The converting process is the step in papermaking that takes the sheet as it comes off of the end of the paper machine and changes it into useable paper items. Through rewinding, cutting, creping, embossing, printing, coating and other process, the sheet is transformed into napkins, facial tissue, placemats, packaging, etc.

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Resources

- Handbook for Pulp and Paper Technologists by G.A. Smook
- Technical Association of Pulp and Paper Industry (TAPPI)
  - Courses
    - Introduction to Pulp and Paper Technologist
    - Practical Aspects of Pressing and Drying
    - How Paper is Made – CD
    - Paper Machine Design and Operation by Gunnar Gavelin
    - Check TAPPI website for other Publications
- US Department Of Energy
- Institute of Paper Science & Technology (IPST), Georgia Institute of Technology

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Resources

- US Environmental Protection Agency
- Pulp and Paper Technical Association of Canada (PAPTAC)
  - Technical Courses and Annual Conference
  - Directory
- Paprican – Energy Cost Reduction in the Pulp and Paper Industry
- Lockwood-Post Directory of the Pulp & Paper Mills
- SAPPI: South African Pulp and Paper Industries Limited

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Thank you …

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