Track: Industrial

Unit 7
Pulp, Paper and Paperboard Industry
Part 2: Paper Industry

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on behalf of Energy Solutions Center

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This photo curtesy of Concord Engineering

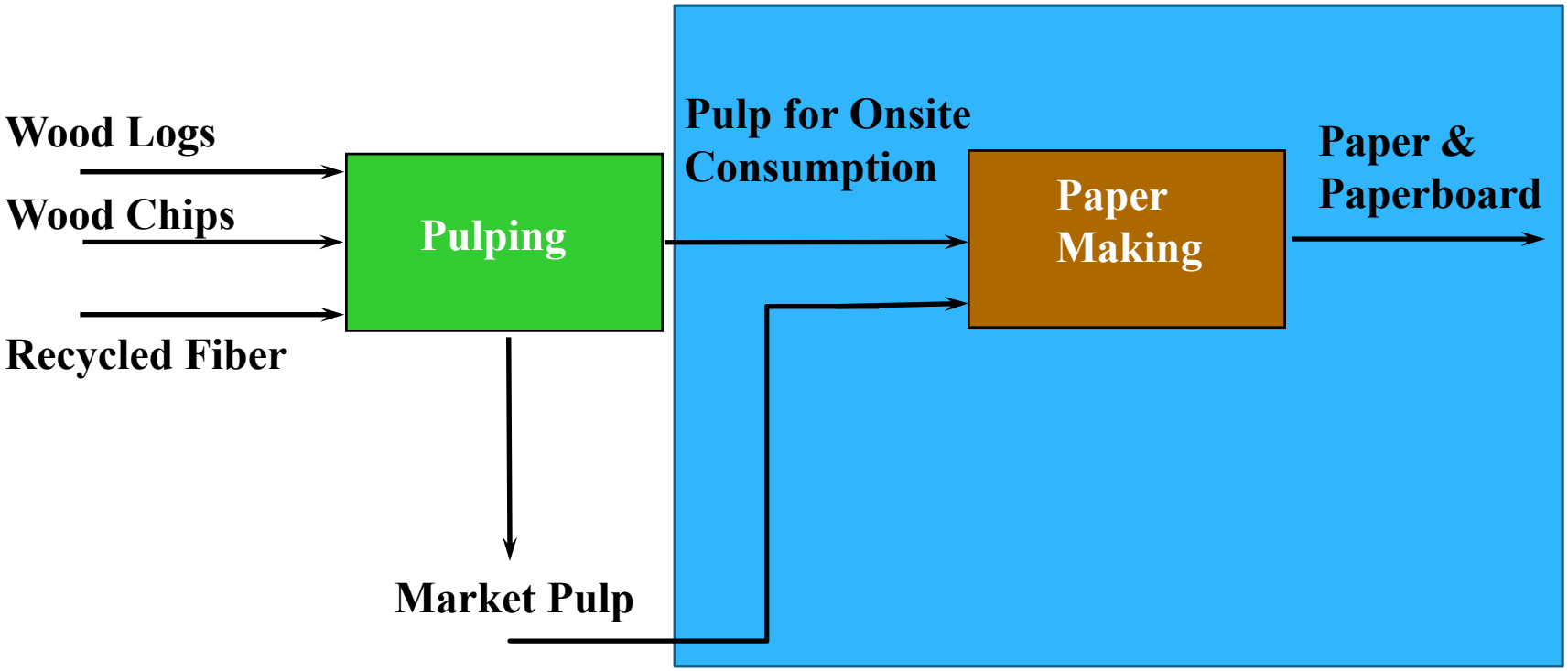
Recap of Part 1 – Pulp Making

- Market Overview and Industry Trend
  - Demand for tissue paper and packaging products will continue to grow
- Pulp Making Process
  - Four methods of pulp making
- Pulp Drying
  - Two types of pulp dryers
- Natural Gas Use In An Integrated Pulp and Paper Mill
- Boilers Used in Pulp Mills
  - Three types of boilers commonly used in pulp and paper mills
- CHP (Cogeneration) For Pulp and Paper Mills

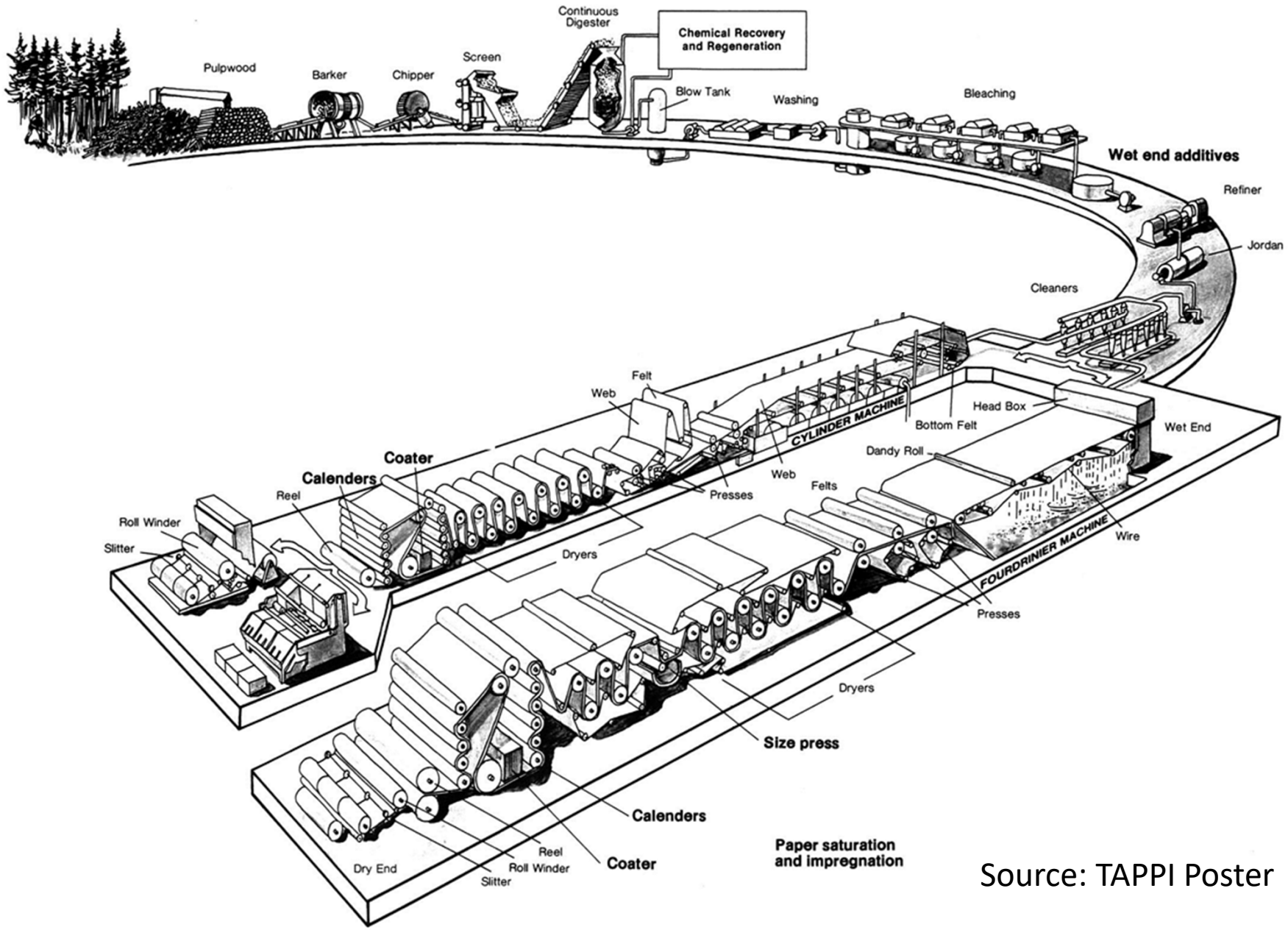
Part 2 Topics

- Brief Overview of Pulp and paper making Process
- Industry Classification
- Paper making
- Paperboard making
- Tissue paper making
- Resources
- Common Terminologies Used In The Pulp and Paper Industry

Pulp and Paper Making Process



From Tree Logs ⟹ Pulp ⟹ Paper



Source: TAPPI Poster

Industry Classification

Pulp, Paper and Paperboard Industry

Pulp

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

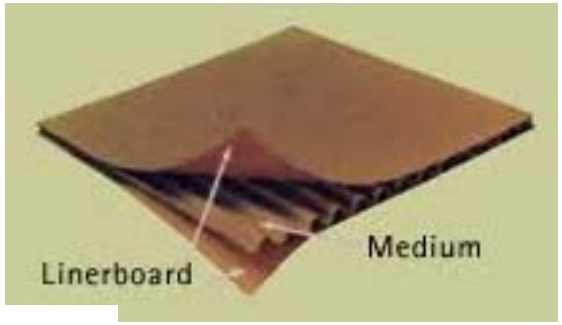
Paper

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

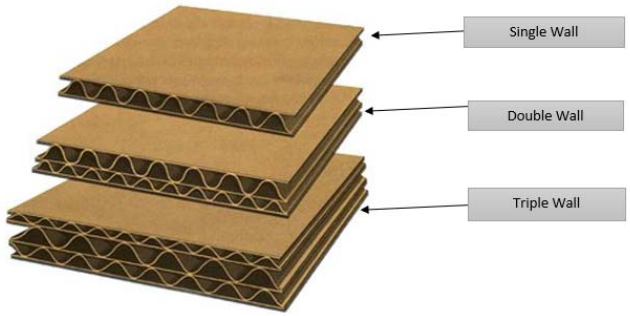
Paperboard

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

Paperboard



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



Paper/Paperboard Making

- Nicolas Louise Robert invented the papermaking machine in 1798
- The first modern paper machine was made in Britain by Henry and Sealy Fourdrinier (Fourdrinier brothers) in 1804
- Since then, the Fourdrinier Paper Machine is the most common paper machine
- The machines design has evolved over time to increase the speed and production, but the basic concept of paper making remains the same
    - New machines are much faster and wider than the older machine

Old and New Paper Machines

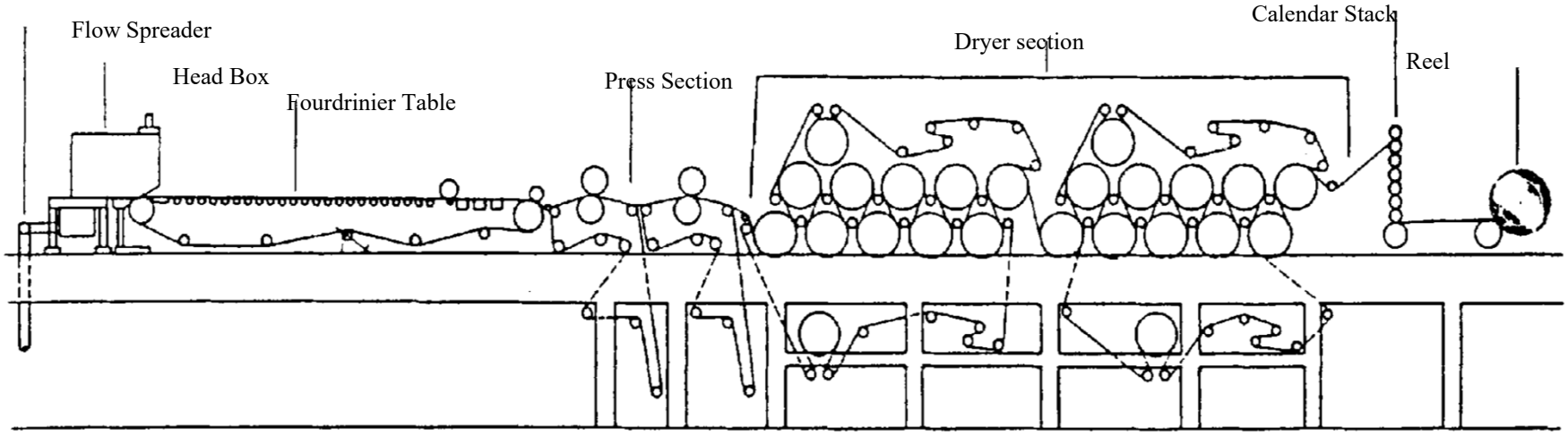
http://www.canammachinery.com/PM3/default.cfm

http://www.abb.com/cawp/seitp202/2e66f68dc8294228c1257654002c86bc.aspx

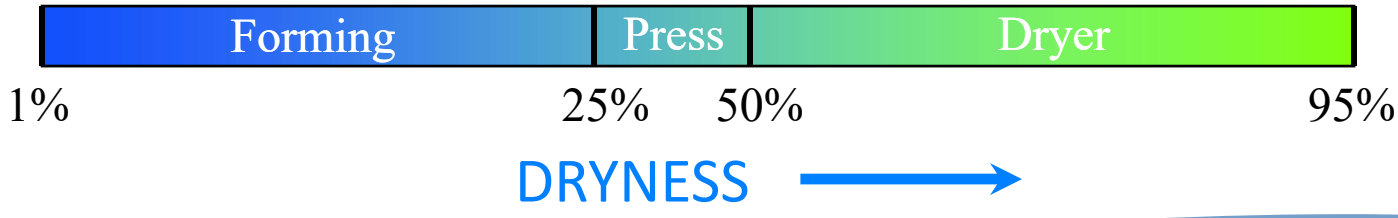
New Machine

- 1000 ton/day
- 100 km/hr (62 mi/hr)
- 10 m (33 ft) wide
- 100 m (330 ft) long
- $250,000,000++

Paper Making
Fourdrinier paper machine



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



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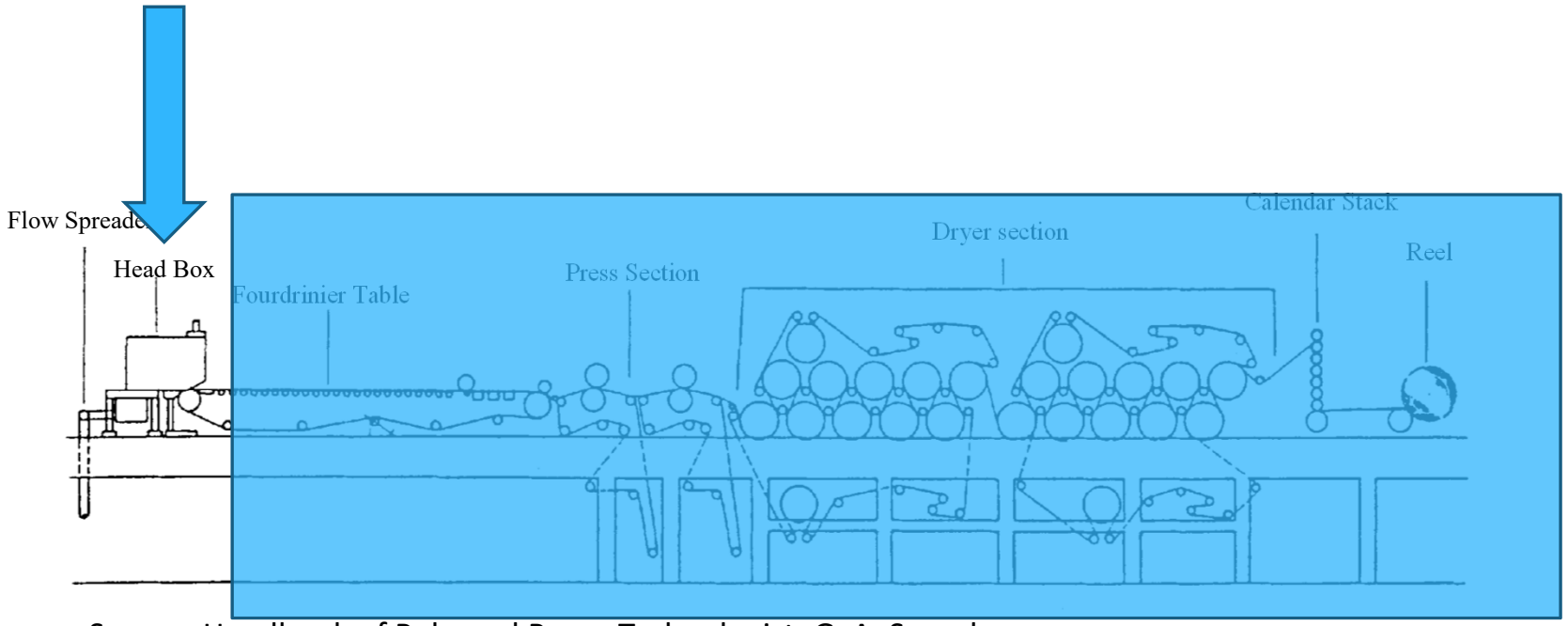
Head Box



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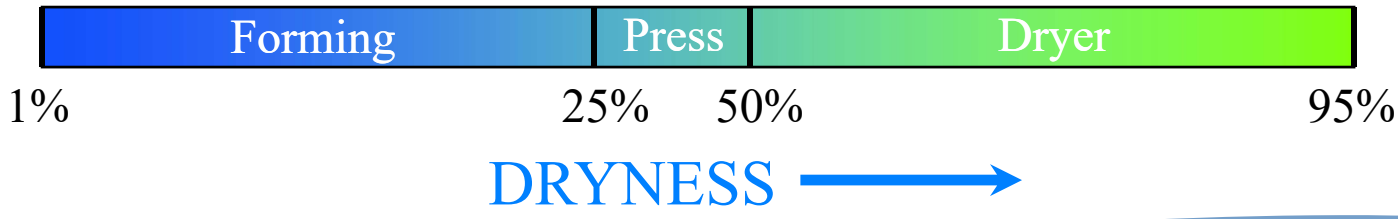

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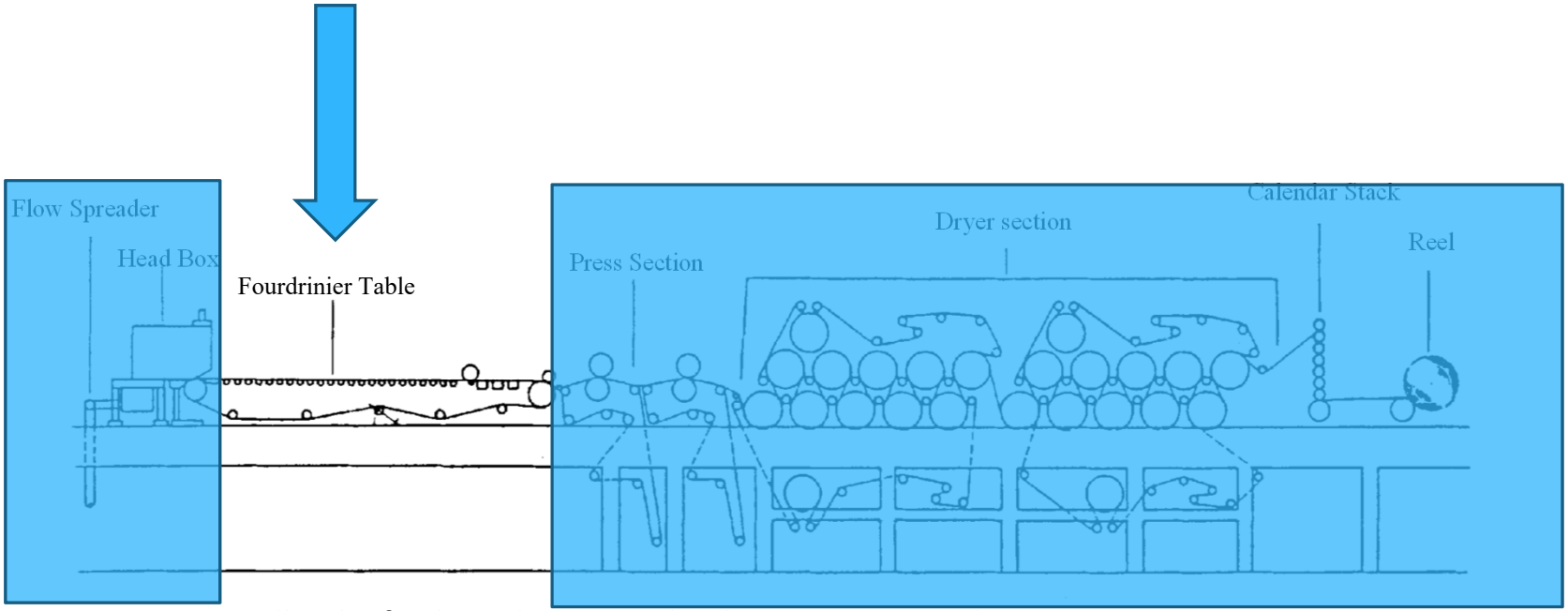
Head Box

http://www.papermachine.com/deckle.htm

- Purpose is to deliver a uniform slurry to the forming wire to form a paper sheet
- The pressurized flowbox spreads the slurry evenly through a slice on to a moving endless belt of wire cloth

Source: Valmet

Forming Section



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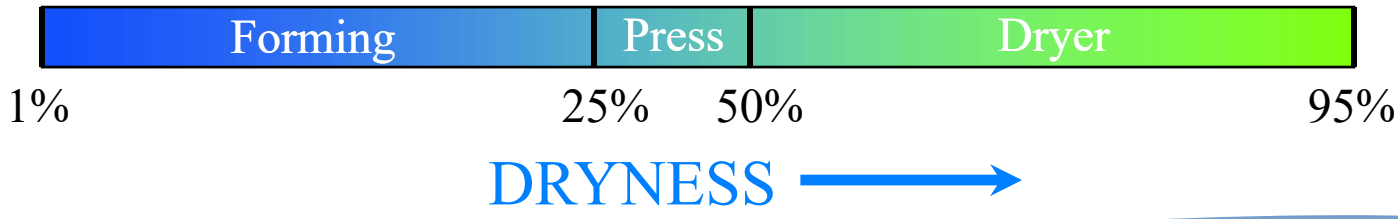

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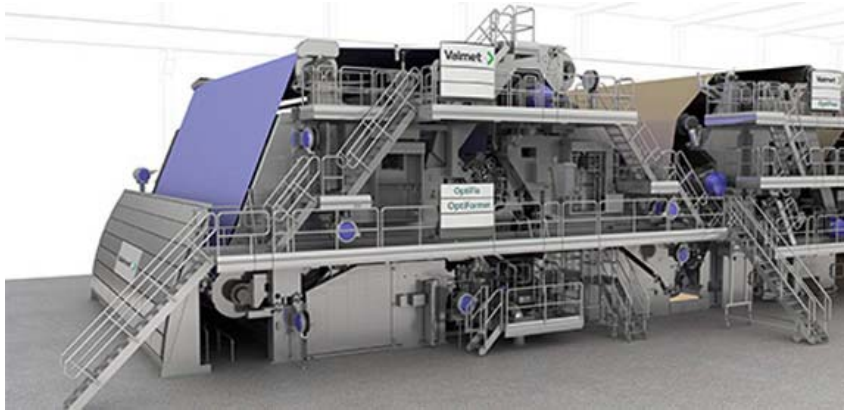
Forming Section



- That's where, the sheet is formed
- The sheet is formed on an endless moving table made of woven cloth fabric
- Water is drained by gravity and suction cups as the wet sheet moves on this table
- The conventional Fourdrinier forming section has evolved into various types to forming sections to handle high operating speed and product quality

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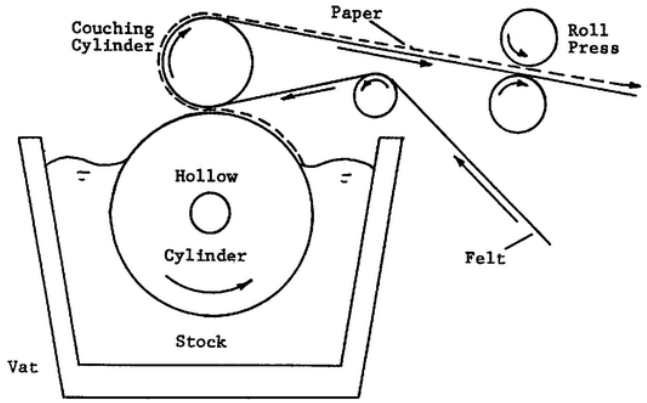
Types of Forming Sections



Source: Treament of paper Mill Whitewater

1. Fourdrinier Table
   - As discussed in last slide
2. Cylinder Mould with Vat
   - A horizontal cylinder with a wire or plastic cloth surface rotates in a vat of dilute paper stock.
   - As the cylinder rotates, the slurry flows onto the surface of the cylinder
   - The fiber layer is continuously transferred to a moving felt by means of soft couch roll.

Types of Sheets made by Forming Sections

1. Single ply

- Primarily for Paper
- Sometime for linerboard

2. Multiply

- Multiply sheets are used to make tissue and paperboard such as linerboard, corrugating medium and boxboard
- Why make a multiply sheet? To add strength

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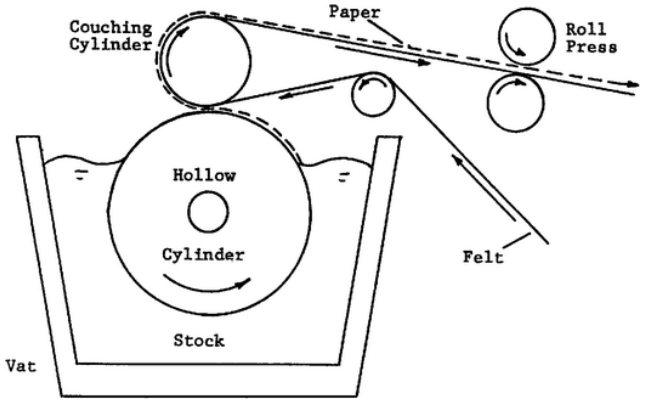
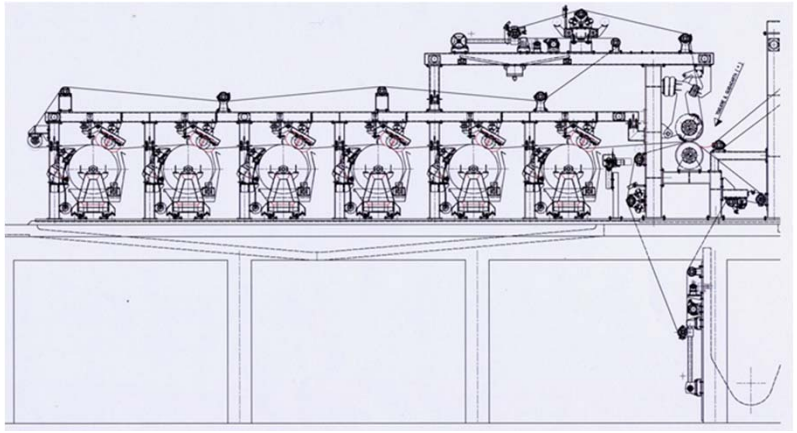
Single ply Forming Sections

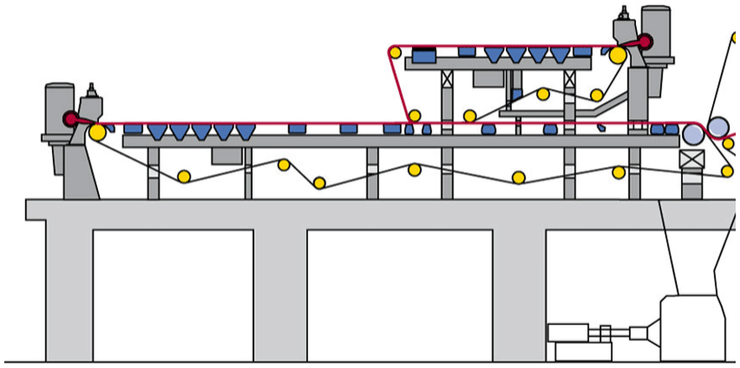
- As discussed in previous slides



Source: Treament of paper Mill Whitewater

Multiply Formers for Paperboard Making

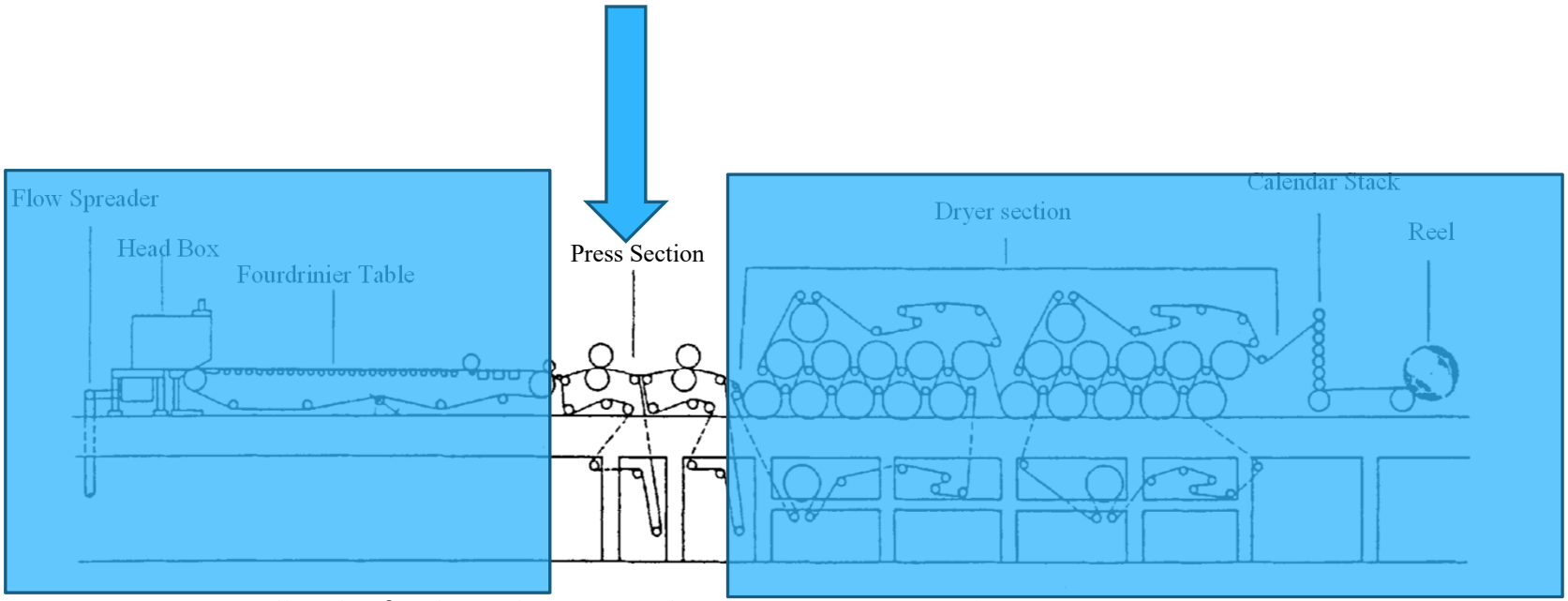




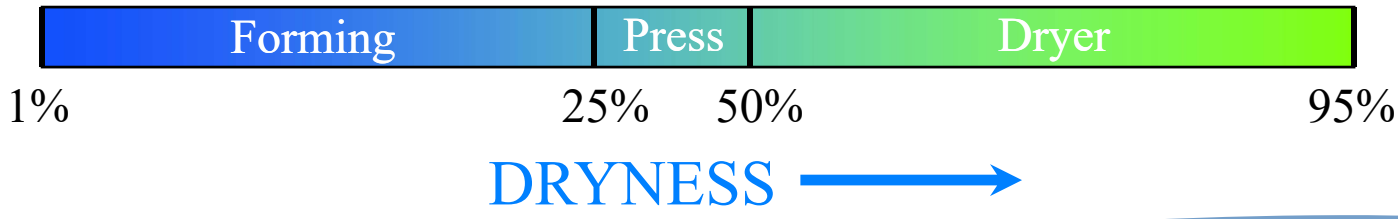
Two-ply Fourdrinier/hybrid forming section schematic (Multilayer machine, Voith)

- If multiply layer paperboard is desired, several vats and cylinders can be placed in series. The picture shows forming section for 6 ply sheet
- Multiple-Fourdrinier type forming sections are also used to make a paperboard sheet with multiple layers
  - Entire Fourdrinier section is mounted above a traditional Fourdrinier, called top formers

Press Section



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



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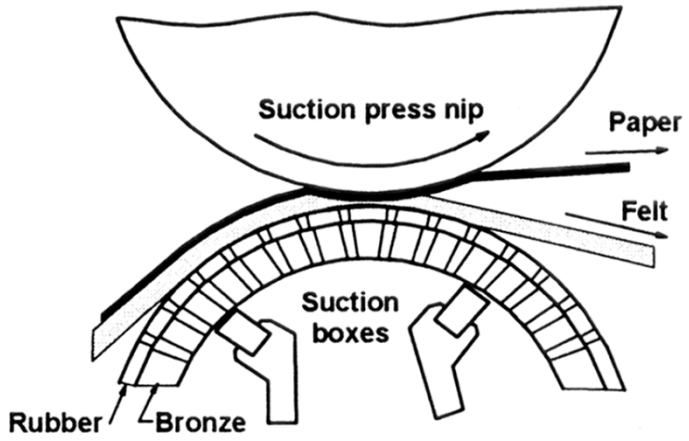
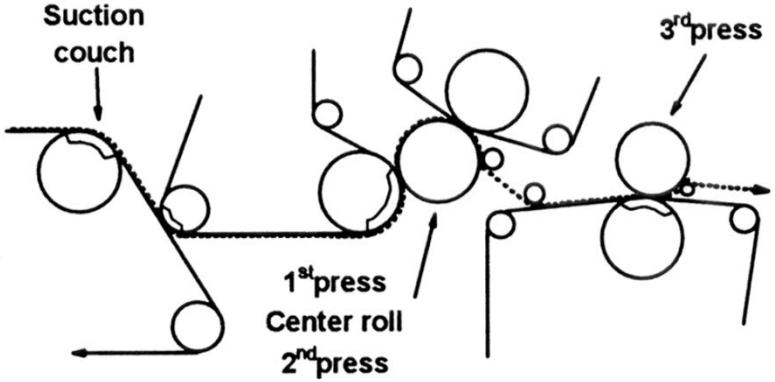
Press Section





- The purpose of the press section is:
  1. Remove water mechanically from the web
  2. Consolidate the web by bringing fibers into close contact
- In a simple press, the paper web is squeezed between a solid roll and a felt supported by a perforated roll. The water is expelled into the felt and then into the holes of the perforated roll.
- Generally three or four presses are used in a paper machine, also called nips (3 nips in the picture)
- The sheet is dried to about to 50% dryness coming out of the press section

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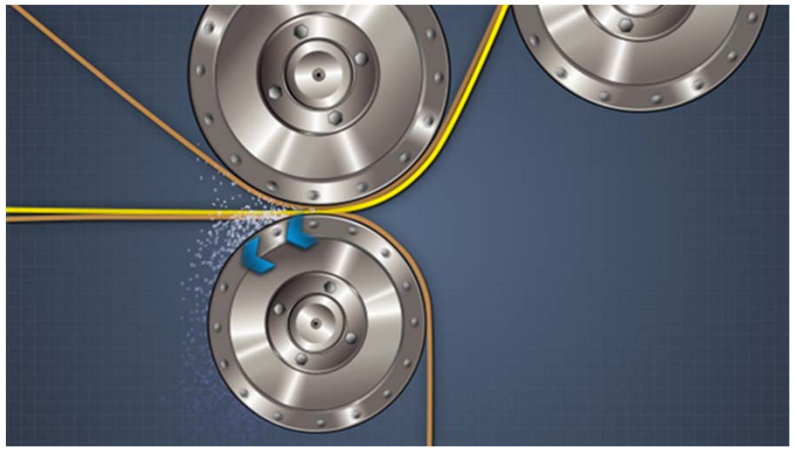
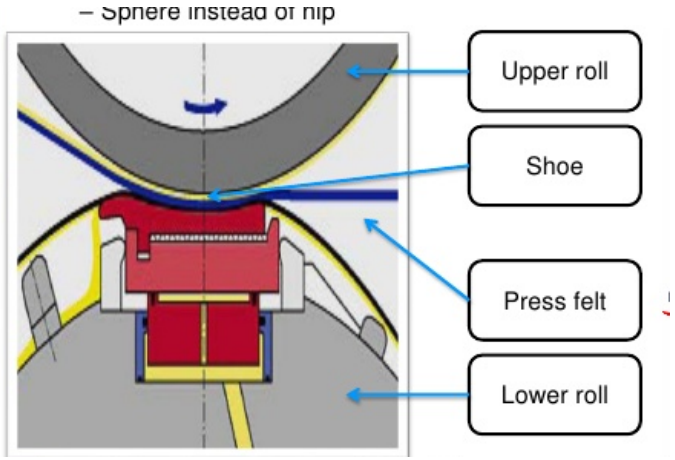
Types of Presses



https://www.convergencetraining.com/Images/Courses/RP-Image_03.jpg



- Types of Presses
  1. Roll Nip Press
  2. Extended Nip Press (ENP) also called Shoe Press
- ENP removes more water than a nip press
- A 1% reduction in sheet moisture entering drying section reduces dryer steam consumption of 4%

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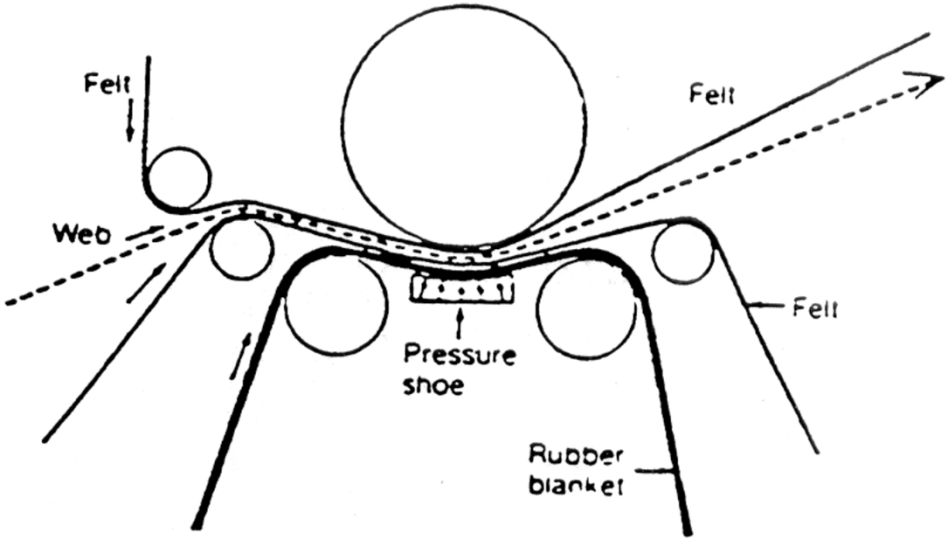
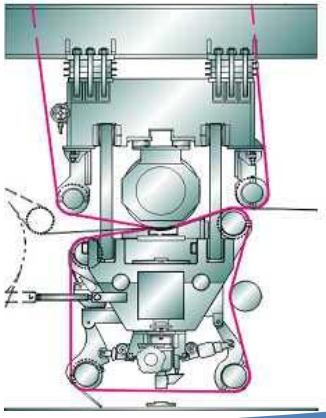
Extended Nip (Shoe) Press



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

ENP



Source: Valmet

- Extended Nip is used to increase the dwell time and contact area in the press
- The press is usually double felted with one felt against the top roll and the other passing through the nip surrounding the shoe and its supporting beam.
- With the increased dwell time of these presses a dryness of around 55% can be reached.
- Combination of shoe presses with other presses or using two shoe presses is becoming a common trend, delivering significant steam saving or speed increases

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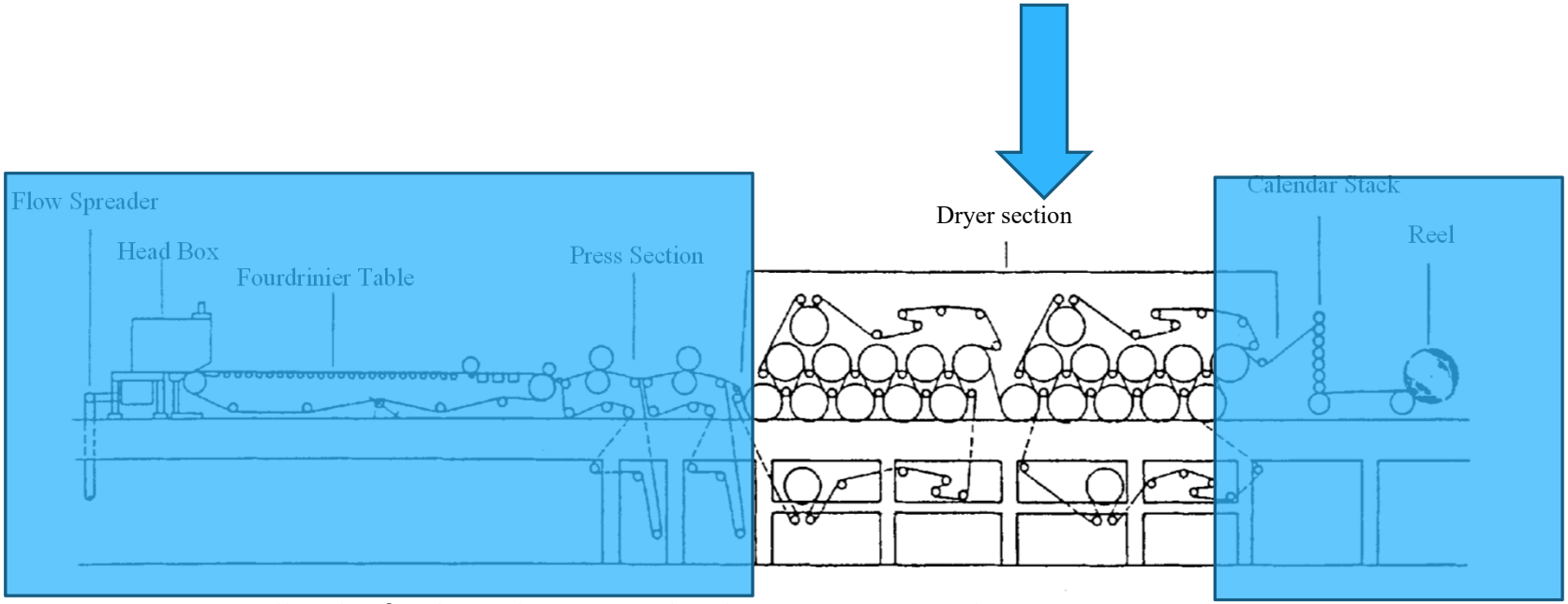
Dryer Section



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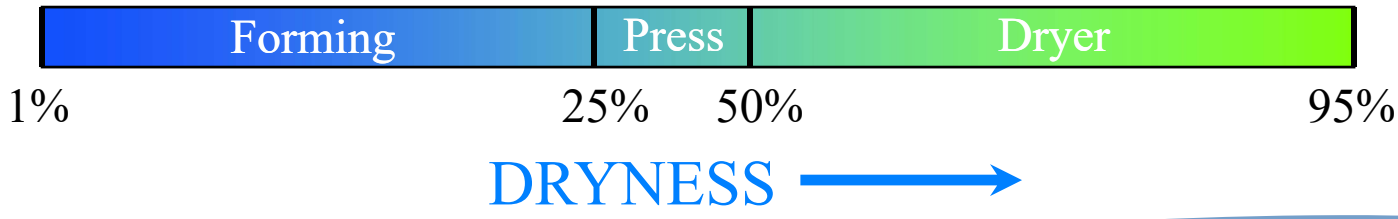

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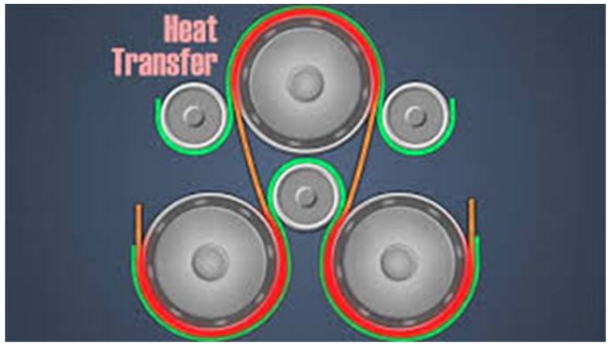
Dryer Section



https://www.convergencetraining.com/paper-machine-drying.html

http://www.glvcastiron.com/foundry-service/

- The dryer section consists of series of internally steam heated cast-iron rotating cylinders,
- Heat is transferred to the wet web from the heated cylinder as the web passes on the outer surface of the cylinder
- The web is held firmly against steam cylinders by means of fabric drier felts.
- As the web passes from one drier to another, both sides are pressed against the heated surface of the drier

Dryer Section (Continued)

- The steam gets condense inside the dryer cylinder and the condensate is removed from by means of syphons together with blow through steam
- Large Amount of Steam is used to Evaporate Water from the Paper
- The evaporated water comes out of the dryer section as big “plume” of cloud (sometime people think it’s the smoke coming out of the paper mills)

Steam Cylinders - Paper/Paperboard

- Hot Surface Drying: Conduction
- No. Of Steam Cylinders: 40 to 100+
- Cylinder Diameter: 4 to 6 ft (Most are 5 ft)
- Water Evaporation: 1 lb of water evaporated per lb of product
- Large Space: as big as a football field
- High Capital Cost: Millions of dollars
- New Trends: Smaller section

Theoretical Steam Heat Requirements for Cylinder Dryers

	Input Energy (Btu/lb of Water Evaporated)
Sheet Heating (warmup section)	86
Evaporation	988
Blow Through Steam	20 - 200
Air Heating	180 - 301
Total	**1274 - 1575**

Steam Cylinders in a Dryer Section

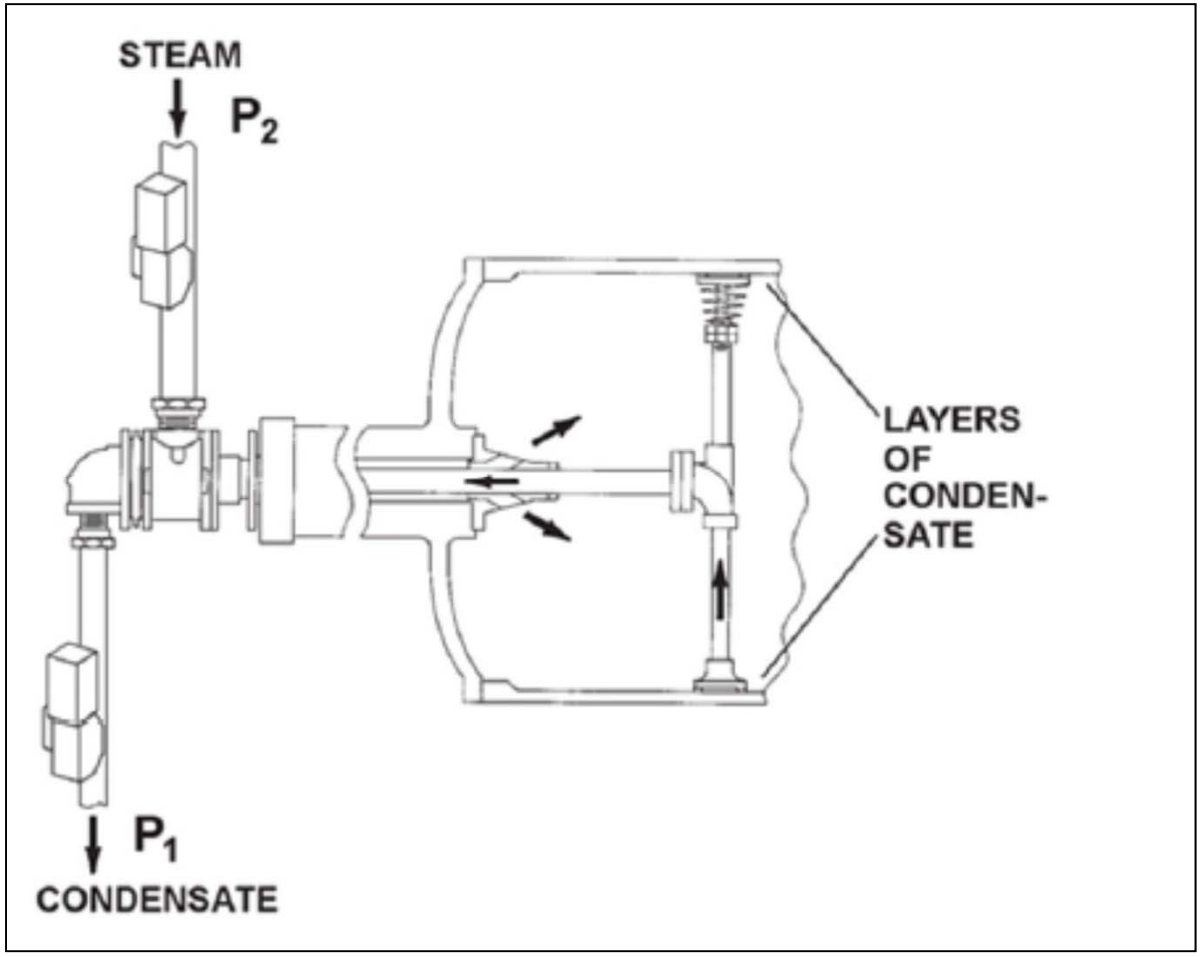
http://www.khalsaenggworks.com/dryer-section-667641.html

http://www.glv.com/paper/dryersection/CompleteDryerSections/CompleteDryerSections

Steam and Condensate System

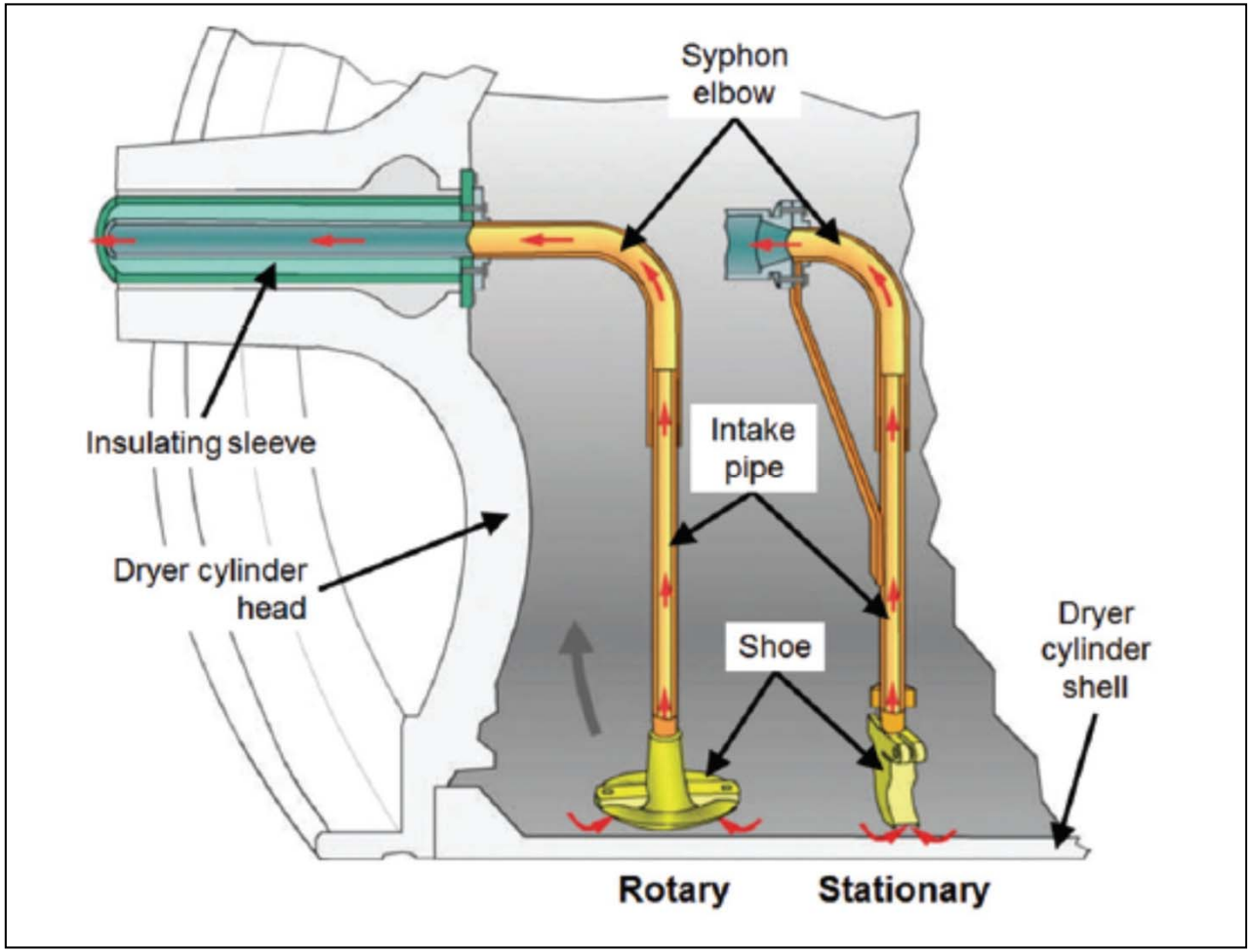
- Purpose of steam and condensate system is to provide steam for drying and remove condensate
- Steam is supplied to various sections of dryer cylinders that are maintained at different pressures and temperatures, gradually increasing from wet end to dry end from 160 F to 365 F
- Steam condenses as the latent heat is released to dry the sheet
- Condensate is removed by syphons, which could be stationary or rotary. A small percentage of steam supplied to dryer never condenses and leaves dryer mixed with condensate as “blow-through” steam
- The blow-through could be 10%-20% of total steam
- Condensate and blow-through steam are collected in a tank called “separator” since it separates the blow-through and flash steam from condensate
- The condensate is collected in main condensate tank and pumped back to the boiler room

Equipment – Syphons



The dryer (rotary) syphon assembly, inside of the cylinder, with supply and inlet and outlet piping (source: Valmet)

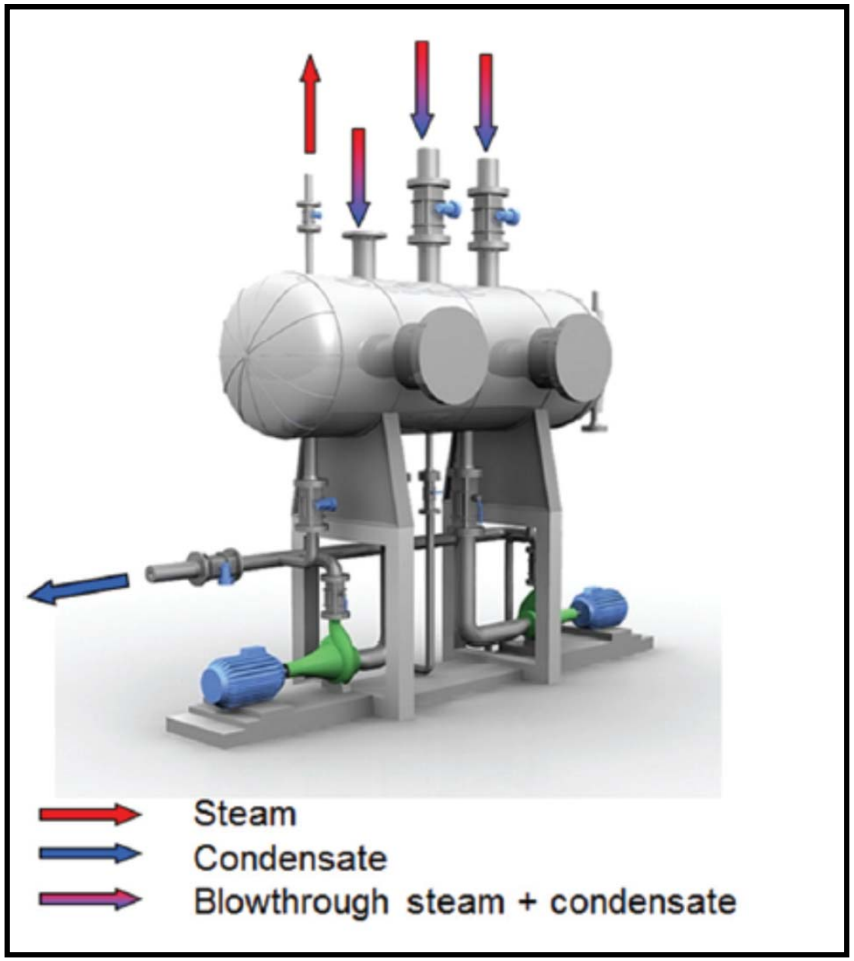
Rotary and Stationary Syphons



- As the name implies, rotary syphon (left) rotate with the cylinder and stationary syphon (right) stays stationary
- Both have pros and cons

(source: Valmet)

Equipment – Condensate Tank



(Source: Valmet)

- Steam and condensate from a section of a dryer flow to the condensate tank
- Blow-through steam and flash steam is either vented to atmosphere (not a good practice) or sent to a low pressure header, or a thermo-compressor

Dryer Hood

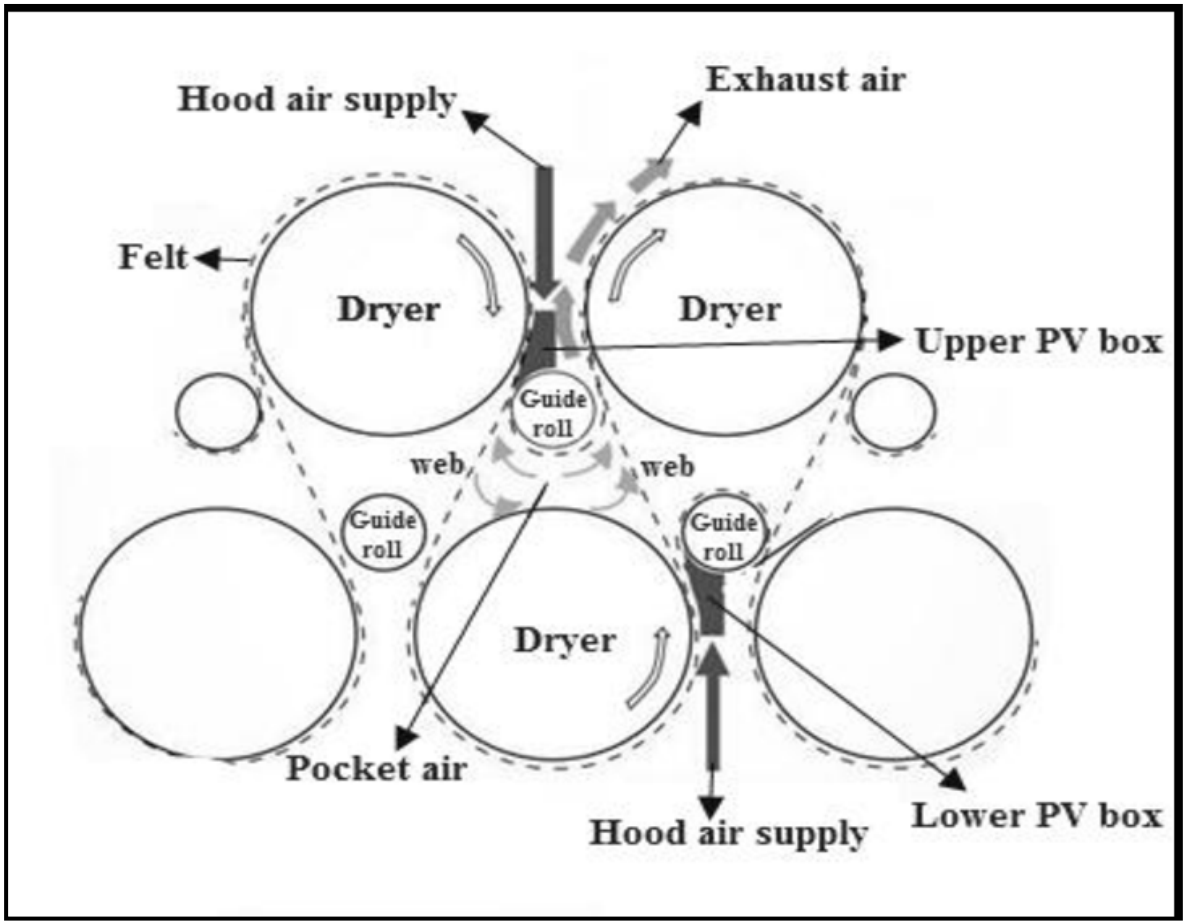
Source: http://www.enerquin.com/documents/EA-Product-Brochure.pdf

- Dryer hood is the enclosed space above the dryer cylinders, starting from the last press, where paper enters the dryer section to the reel where paper exits the dryer section
- Purpose of hood is to capture the moisture and to increase the driving force for evaporation
- The hood covers all dryer cylinders from press section to reel

Pocket Ventilation to Remove Moisture

- The dryer pocket is defined as the space in the dryer section between adjacent cylinders
- The moisture trapped in the pocket must be removed for efficient drying
- Purpose of pocket ventilation is to remove water vapours from around the web, to increase the driving force for evaporation
- A good hood and dryer ventilation is important to improve the energy efficiency of the drying process

Pocket Ventilation For Two Tier Dryer Section



- Dryer pocket is separated by paper web and felt. See "pocket air" label in the diagram
- Pocket ventilation air is supplied from the hood air supply system through a pocket ventilation duct
- The moisture laden air is exhausted to the exhaust duct

Source: Fig.3, Pocket Ventilation System in Dryer Section of Paper Machine by Pratik A. Chavan et.al., International Journal of Technology Enhancement and Emerging Engineering Research, Vol 3, 2015

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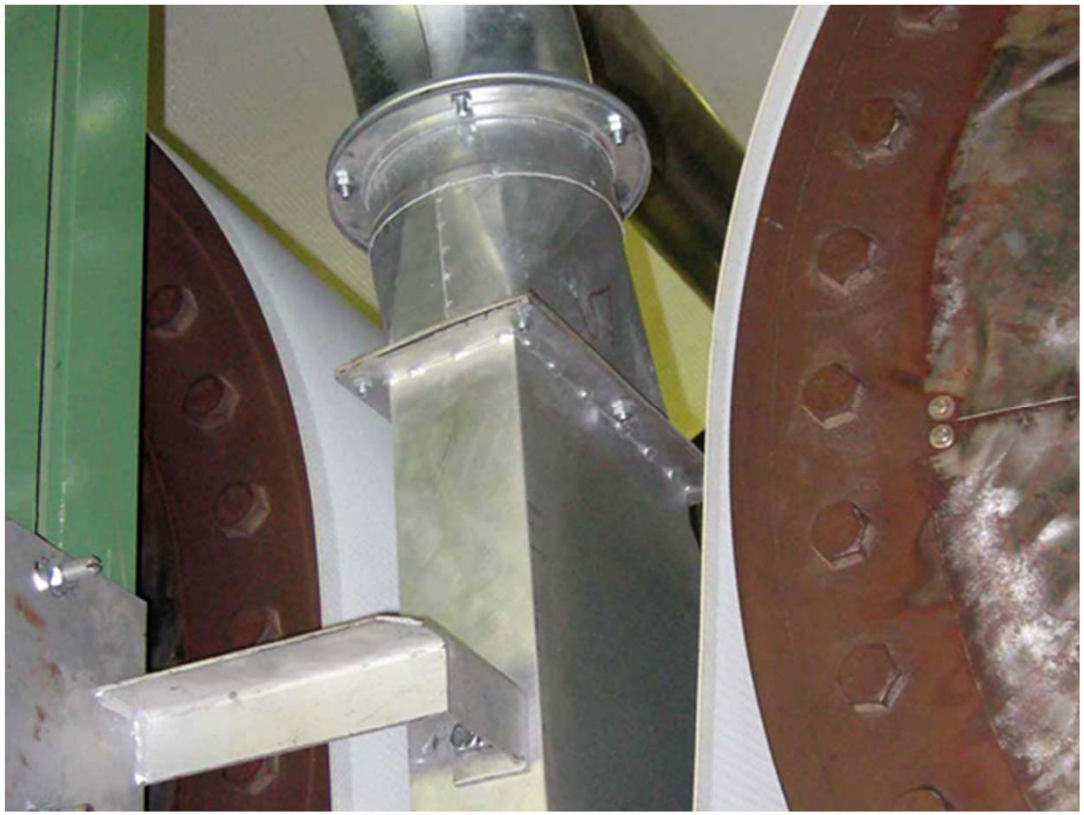
Pocket Ventilation For Two Tier Dryer Section



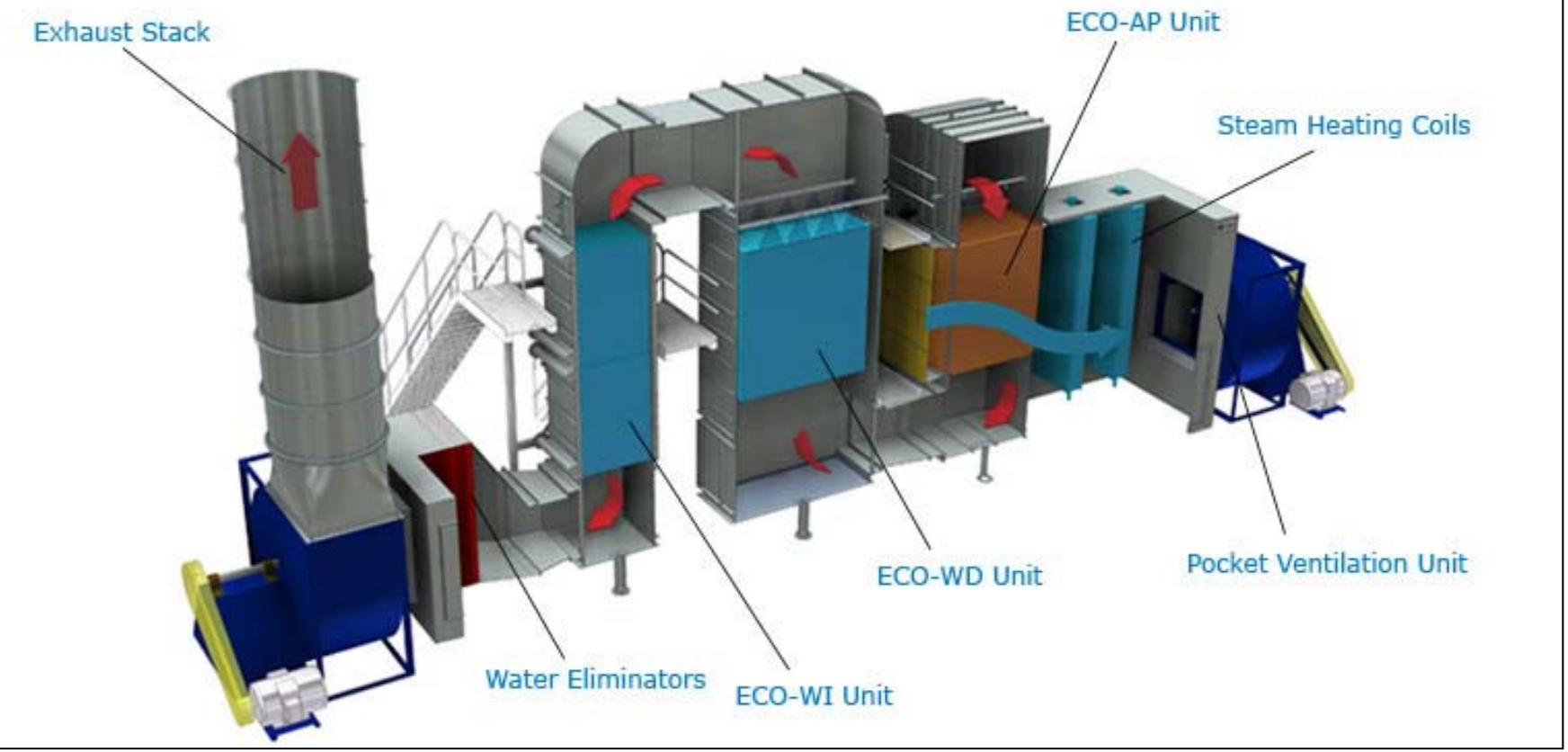
- Pocket Ventilation system has been designed to blow air in each lower and upper pocket. Air is preheated in Heat Recovery units and then raised to 110 - 120°C with steam coils and blown on the felts.

Source: https://kappahoods.it/el-salam-paper-mill/

Dryer Heat Recovery

- Most of the heat energy supplied to the dryer section ends up in the dryer exhaust stream
- The temperature of the exhaust air could be as high as 185 F
- Most machines has some type of HR system,
- Exhaust waste heat can be recovered at various stages with multiple heat exchangers
- In the first stage, air is heated via air/air heat exchanger to supply heated air for pocket ventilation or for machine room ventilation
- In the second stage, air/water heat exchanger heats water indirectly, like a feedwater economizer in boilers
- In the third stage, a direct contact type heat exchanger heats water where air is in direct contact with water. Also, called scrubber in the paper industry

Heat Recovery Stack of a Paper Machine



3rd Stage
- ECO-WI: Direct Air-to-Water Heat Recovery

2nd-stage
- ECO-WD: Indirect Air- to-Water Heat Recovery

1st-stage
- ECO-AP: Air-to-Air Heat Recovery

Source: http://www.enerquin.com/index.php

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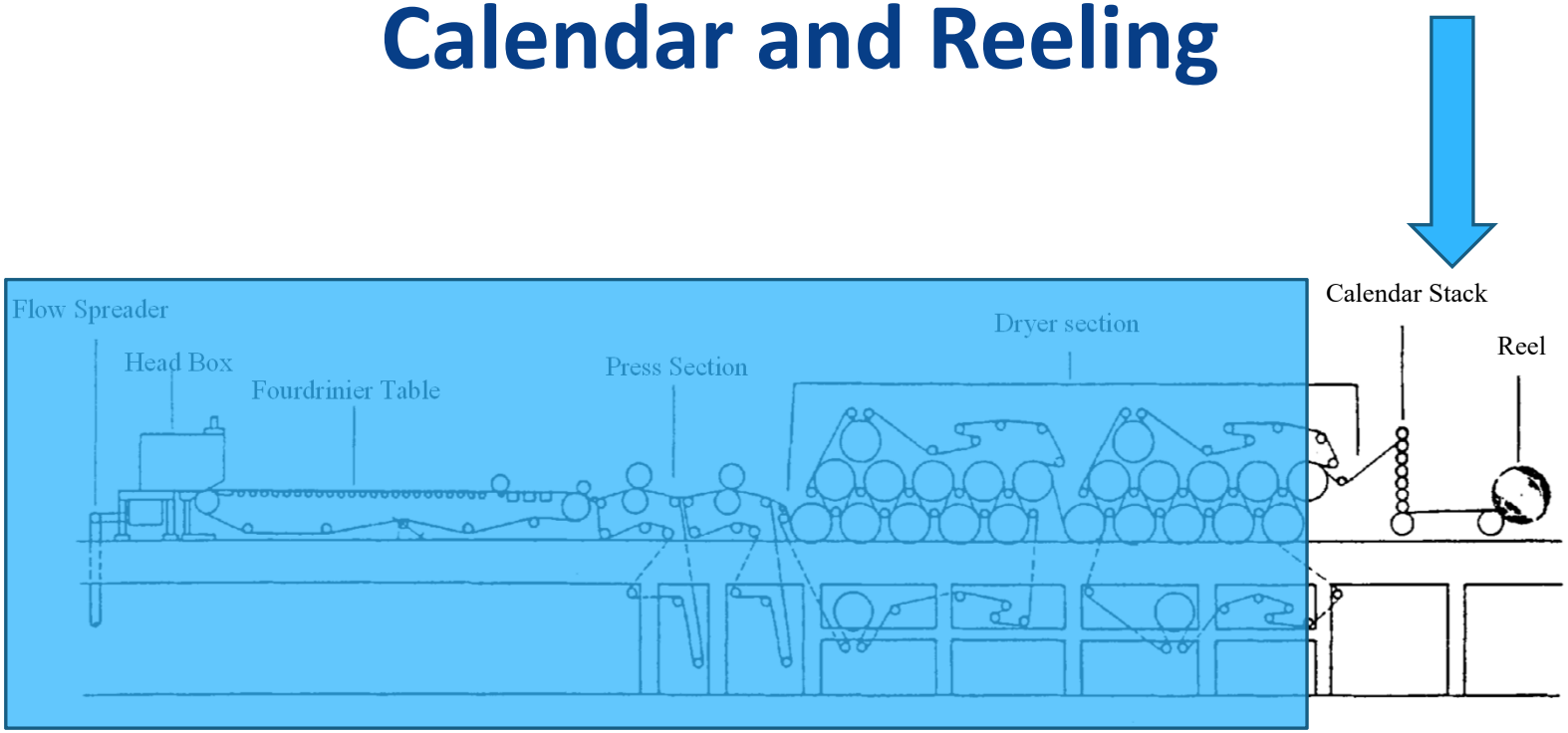
Heat Recovery Stack of a Paper Machine

Source: http://www.tip95.si/heat.asp

Calendar and Reeling



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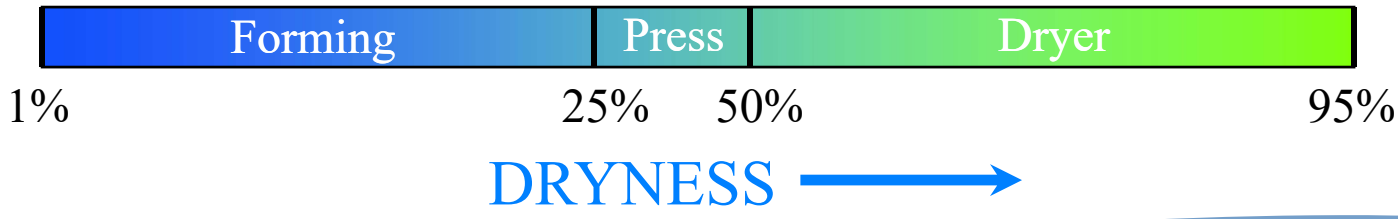


Calendering and Reeling

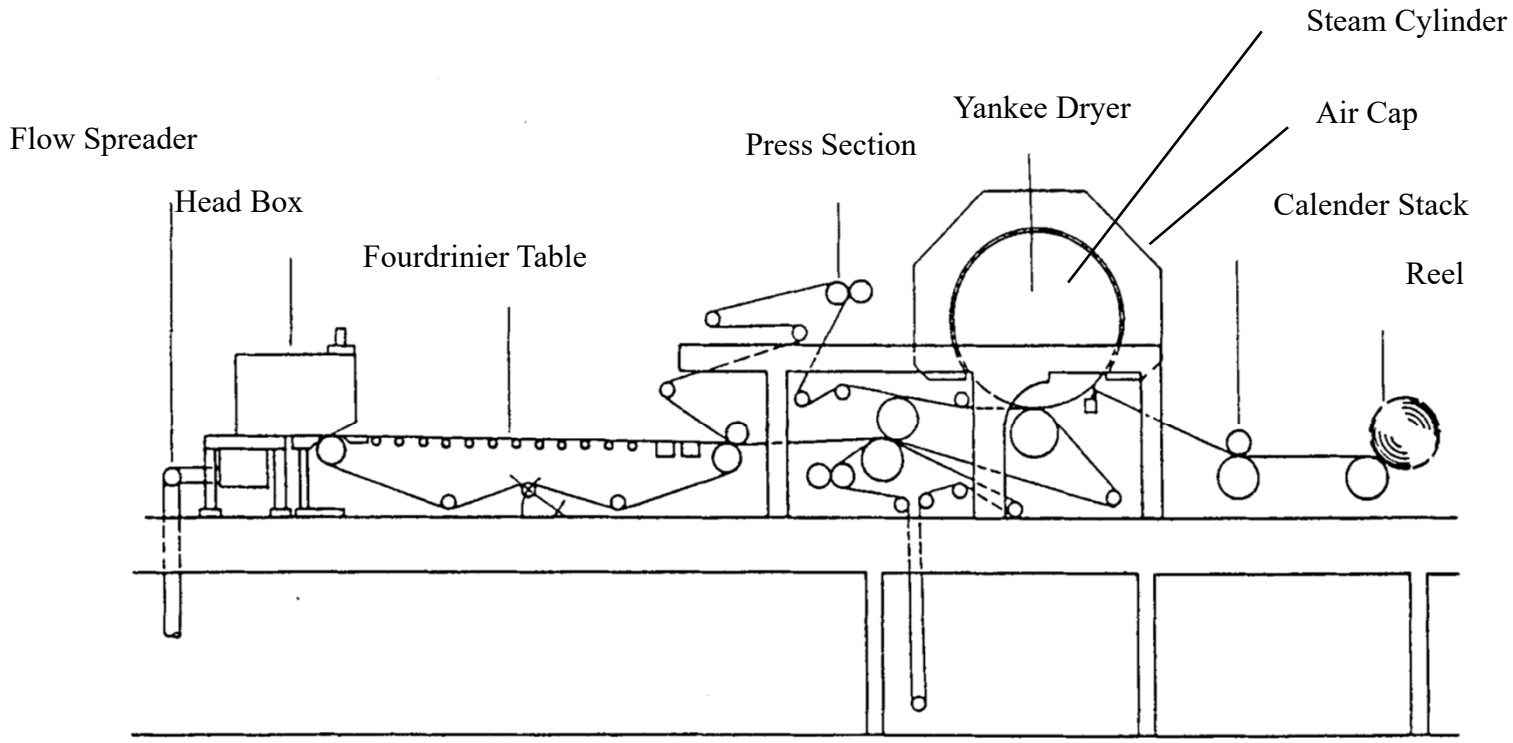
- Primary purpose of calendering is to improve surface properties and impart smoothness and gloss, could be analogous to ironing the paper
- Paper passes through nips formed by a set of iron rolls
- After drying and calendaring, the paper is wound up on reel spool, which are changed automatically every 60 – 90 minutes after reaching full diameter of paper roll

Paper roll on reel spool (source: Voith)

Tissue Paper Making

- Tissue machine looks very different than a typical paper or paperboard machine
- It has much smaller footprint
- The main reason is the size of dryer section
- The dryer section of a paper machine has more than 50 steam cylinders
- In the Tissue machine, typically there is only one very large diameter (16 – 25 ft in diameter) steam cylinders

Typical Tissue Machine

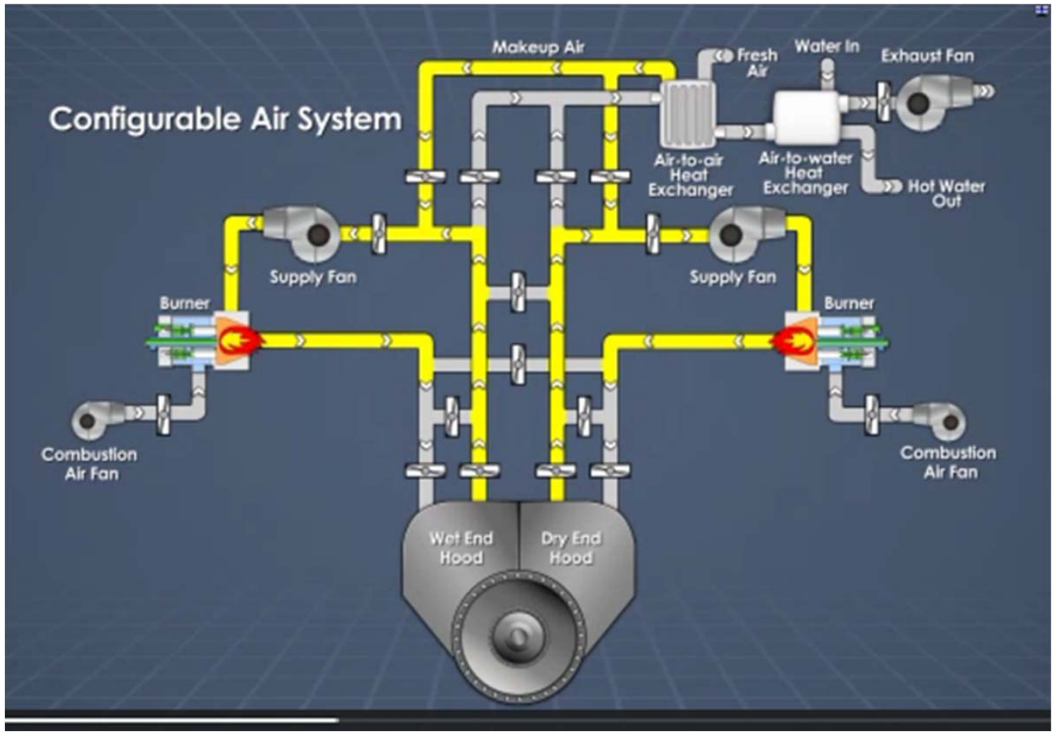


Source: Handbook of Pulp and Paper Technologist, G.A. Smook

Tissue Drying

- Since the tissue sheet is very fragile, it can not be produced on a conventional paper machine using large number of steam cylinders
- Instead, tissue is dried on a single large drying cylinder, 16 – 25 feet in diameter, often called a Yankee cylinder
- *Fun fact: The origin of the name Yankee is said to come from a Dutchman called Yonke who was working with the technology and when this technology was transferred to the US the name became Yankee*
- Energy for the tissue drying process is transferred from the steam inside the cylinder and heated air or combustion gases blowing at high velocities against the paper surface on the outside by

Yankee Hood



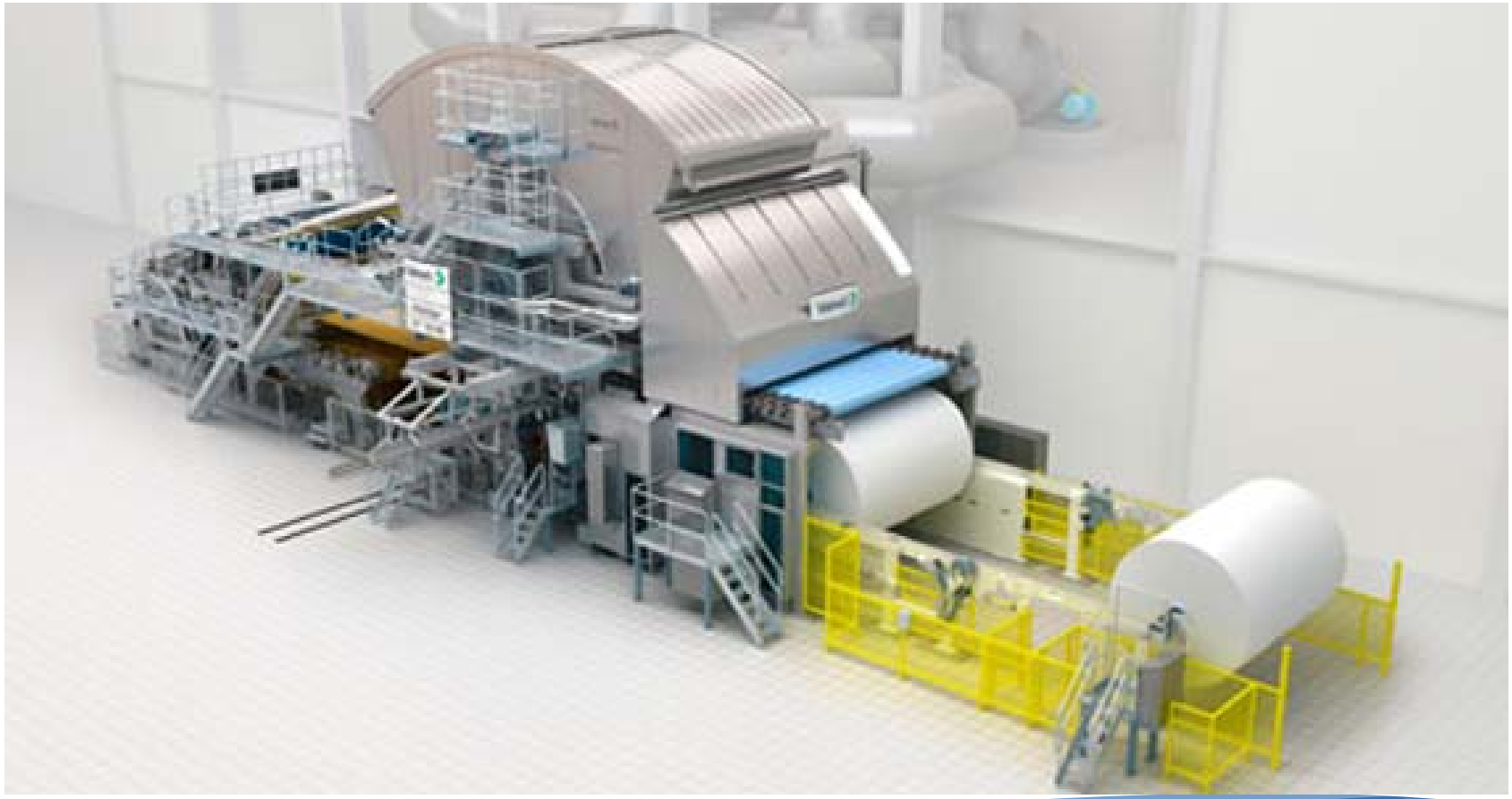
https://www.convergencetraining.com/yankee-hoods-and-air-systems.html

- The purpose of the hood is to supply hot air and remove evaporated water
- Dryer has two hoods:
  1. wet-end where wet sheet enters
  2. Dry-end where dry sheet leaves
- Hot air is produced by gas-fired burners
- Some exhaust air is recirculated via burner

Yankee Hood and Steam Cylinder

- https://www.paper-machine-papcel.com/products/tissue/yankee-drying-cylinders/

Large Capacity Tissue Machines 142 -333 tonnes/day (Valmet)



Summary

- Reviewed how paper is made on a paper machine
- Covered all components of a Fourdrinier type paper machine including heat recovery from the machine hood
- Covered all components of a tissue paper machine including Yankee dryer

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

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

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

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.

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.

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.

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.

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.

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

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

Thank you …