# Papermaking
# Forming

Pulp and Paper Centre,
Department of Mechanical Engineering,
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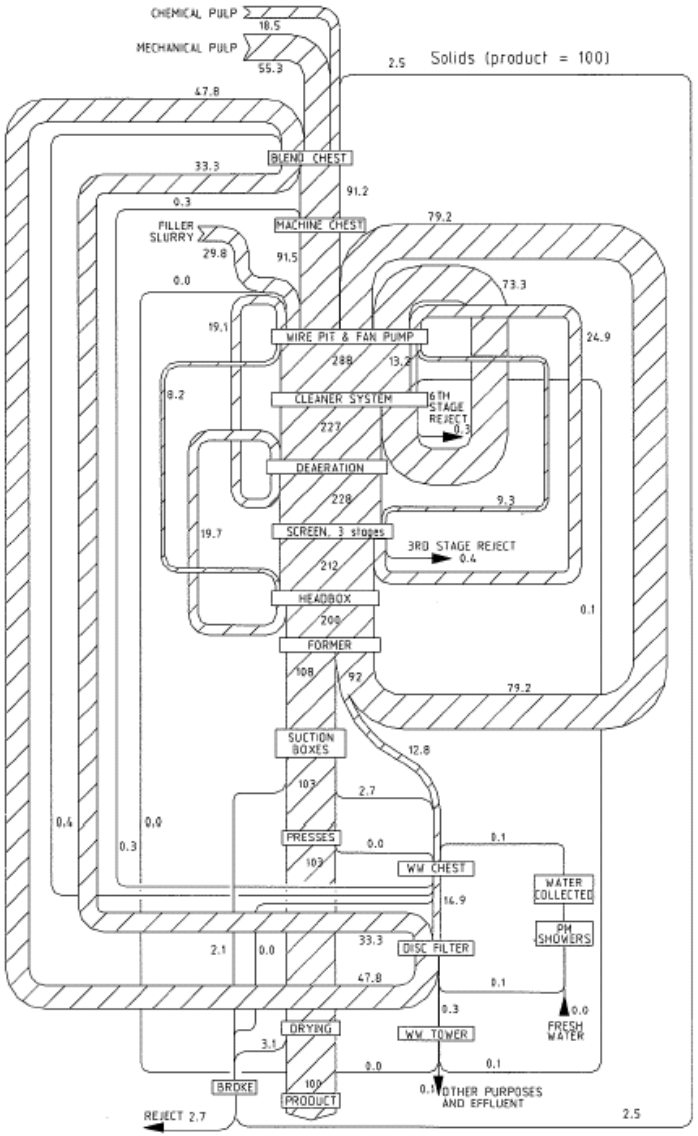
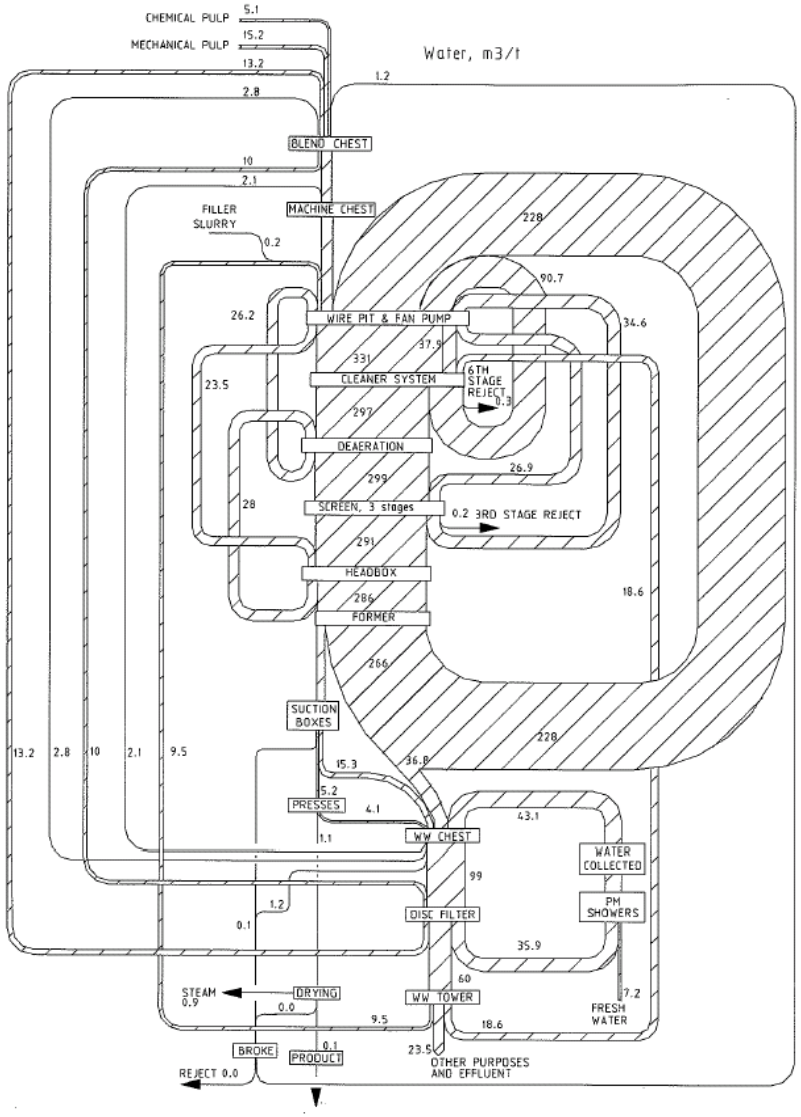
# Material Balance – Pulp and Water



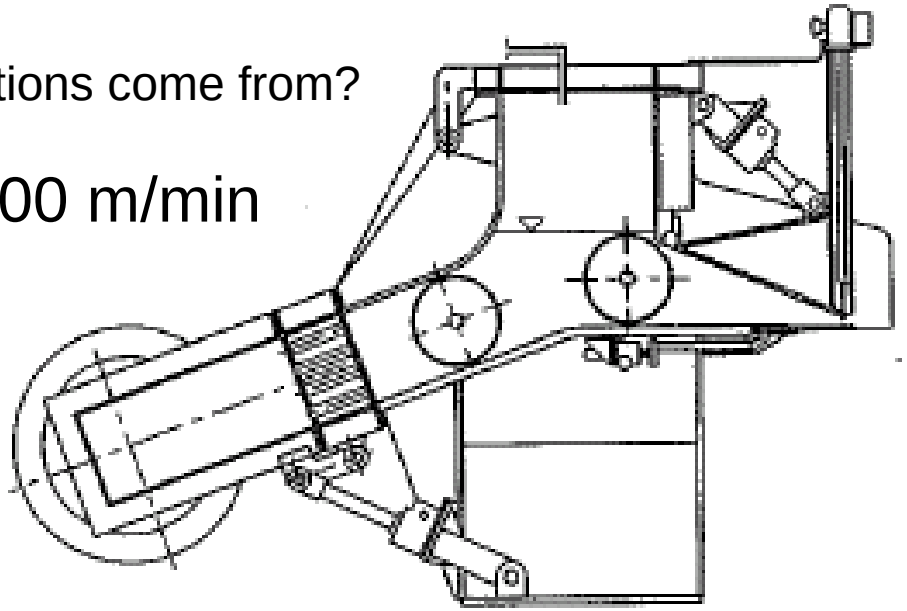



# Headbox

- Objective:
  - Distributes stock across wire
  - Flow straightening
  - Create controlled turbulence for Floc dispersion
  - Stock acceleration to wire speed (hence tapered).

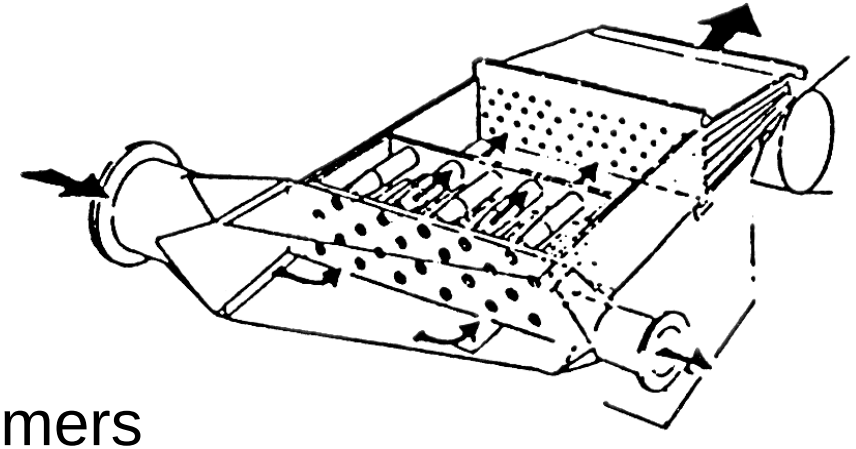
# Headbox Types

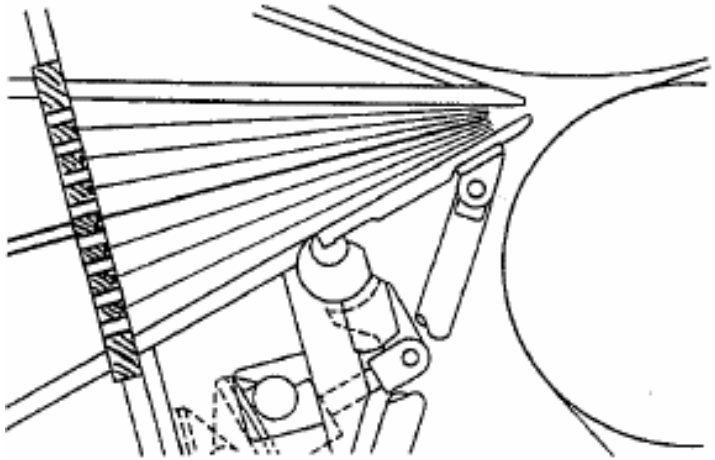
- Air-pad or air-cushion
- Have a free surface with pressurized air cushion
- Dampens pressure fluctuations
  - Where do pressure fluctuations come from?
- 10 inches of head for 500 m/min

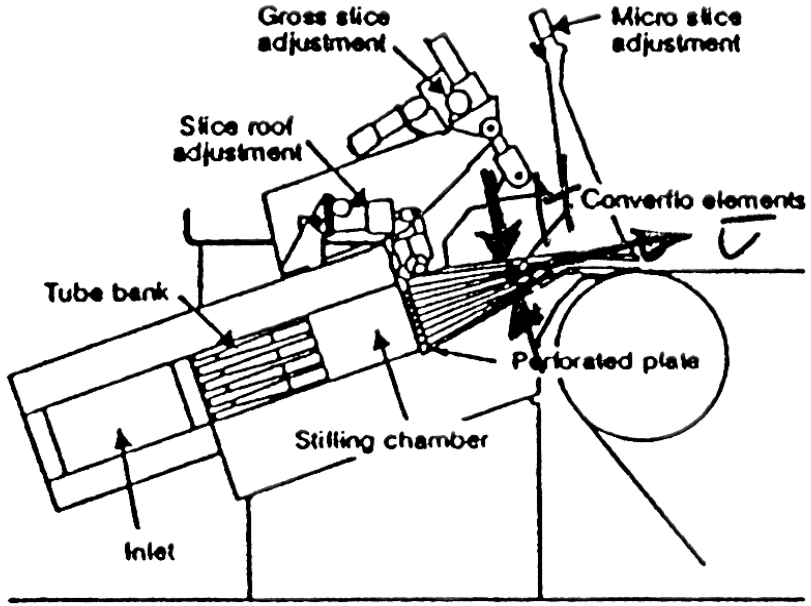


# Headbox Types

- Hydraulic headbox
- Faster machines
- Small ***slice*** for twin wire formers

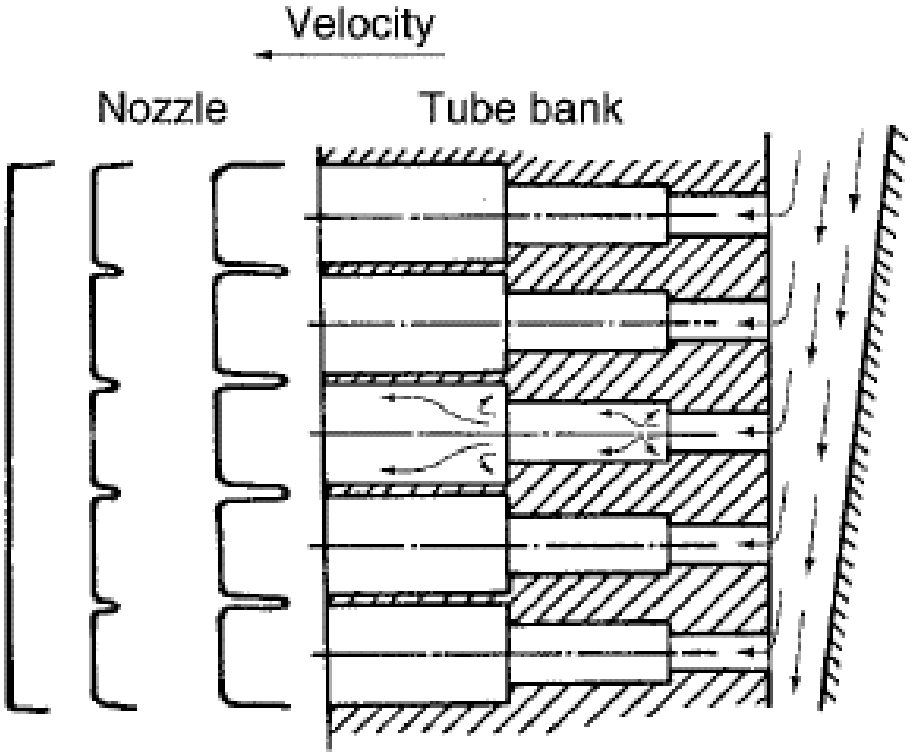






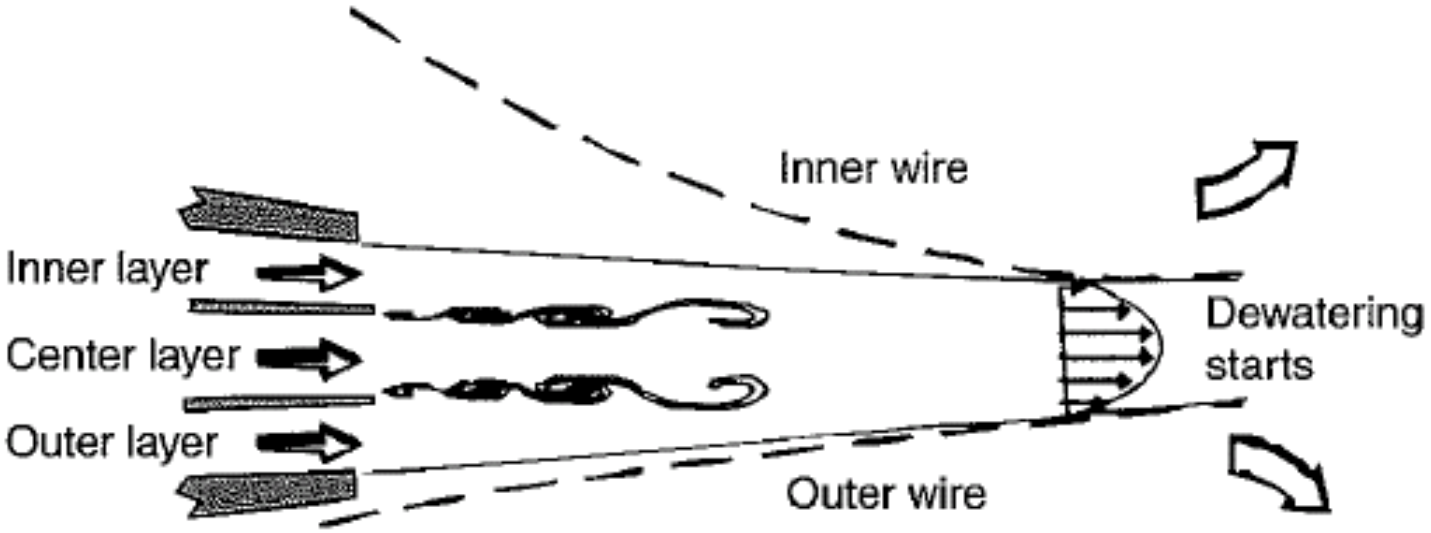
# Tube Bank

- Flow straightener
- Sudden expansion creates turbulence to disrupt flocs



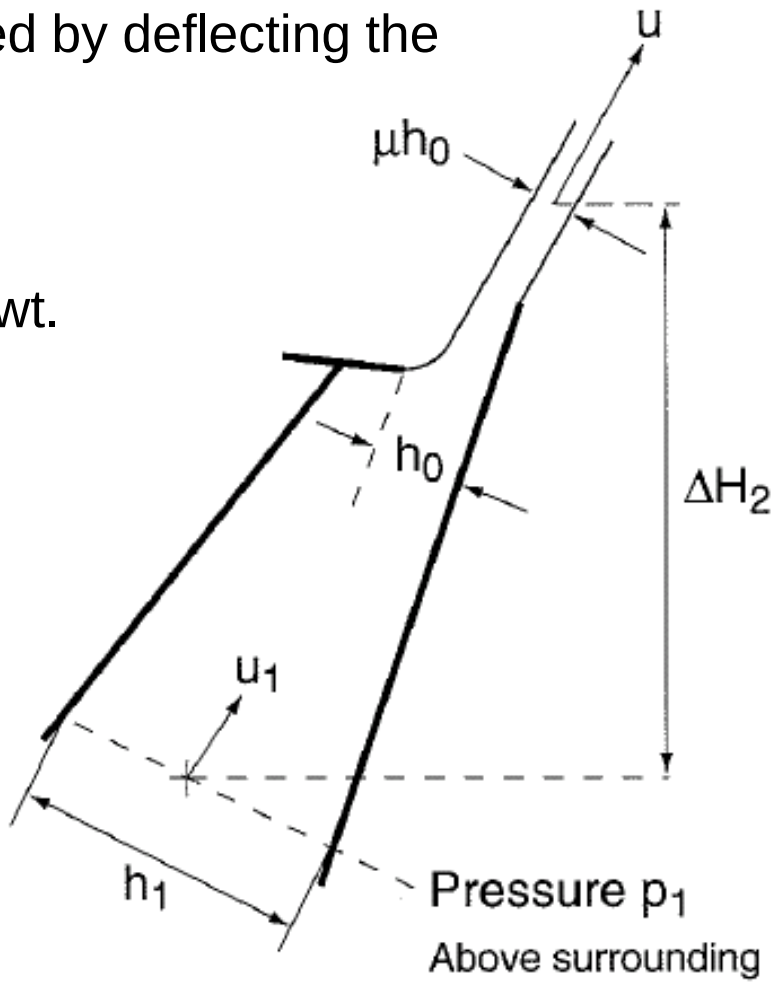
# Headbox types

- Multi-layer headbox
  - Primarily used for liner board grades
  - Smooth pulp on outside … Bulky stiff pulp on inside.
  - Sepa

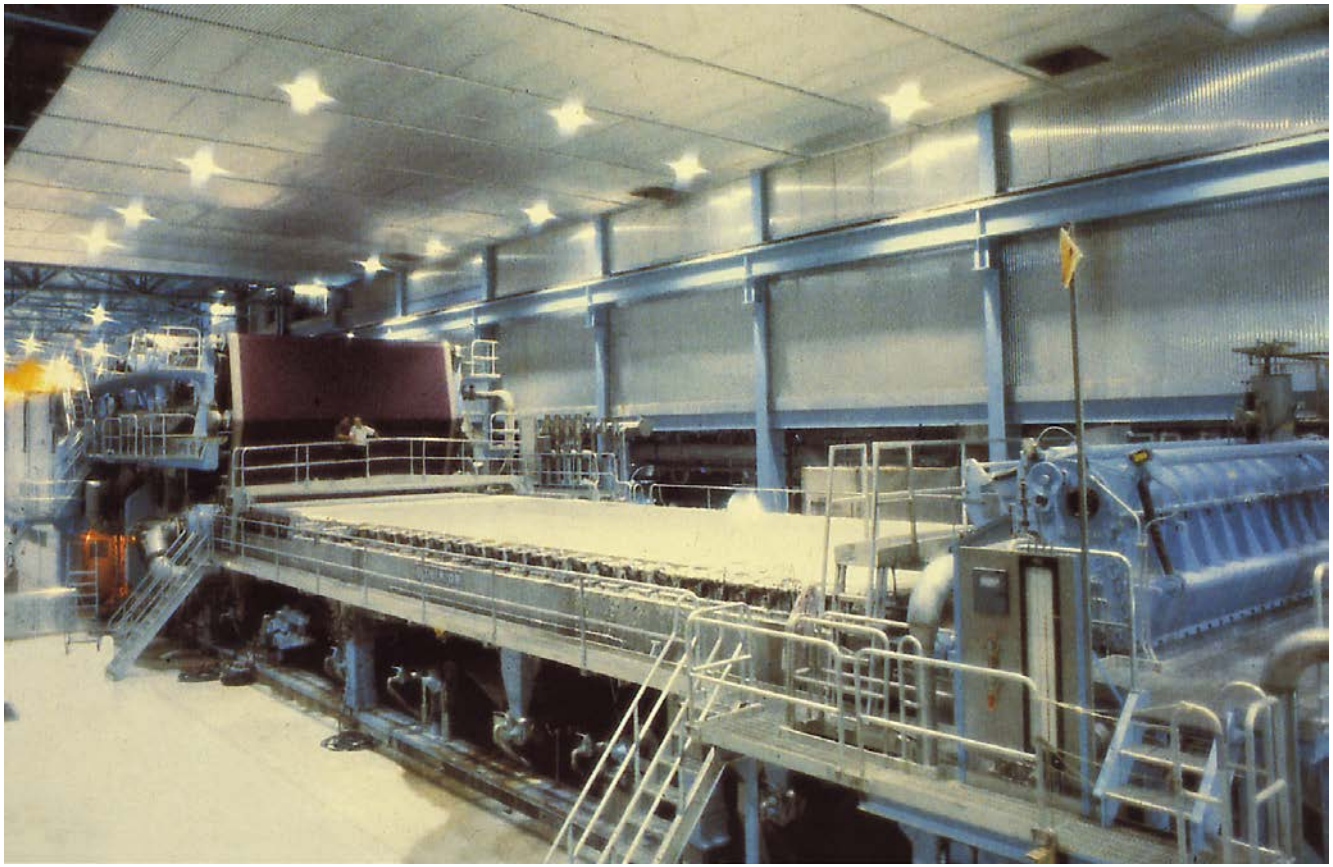


# Slice Lip

- Local basis weight can be controlled by deflecting the ‘slice lip’.
- Individual screws adjust deflect jet
- Sensor/scanner detect local basis wt.
- Basis weights:
  - Printing and writing 60-90 g/m^2
  - Newsprint: 45-50 g/m^2
  - Boxboard: 150-450 g/m^2
  - Coated papers: 30-250 g/m^2

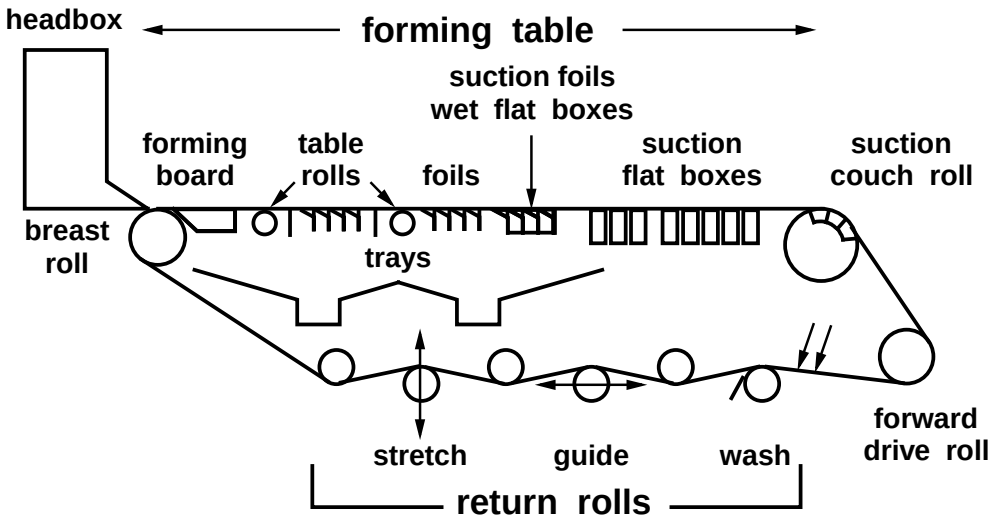


# Formers - Fourdrinier



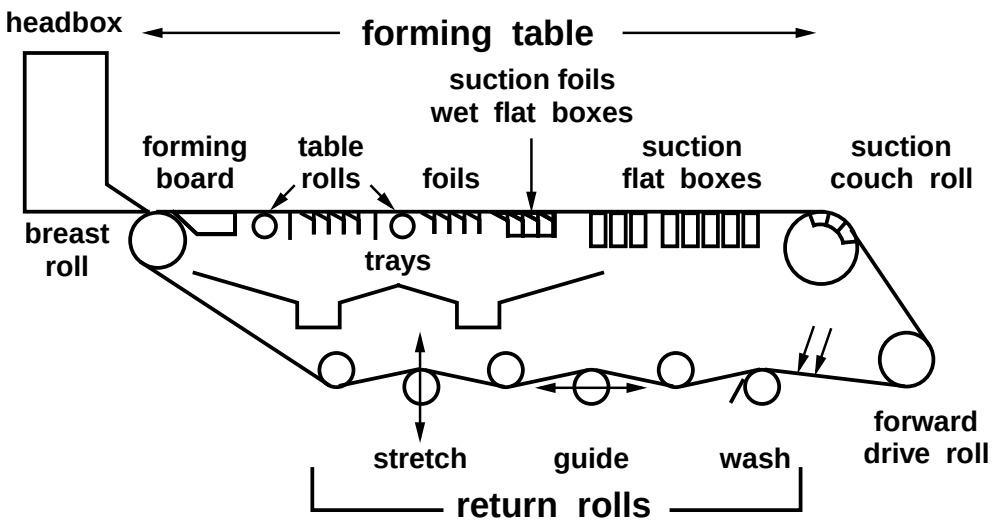
# Formers

- Fourdrinier former components
  - Headbox
  - Breast roll: rubber coated roll that takes up tension in wire
  - Forming board: supports wire



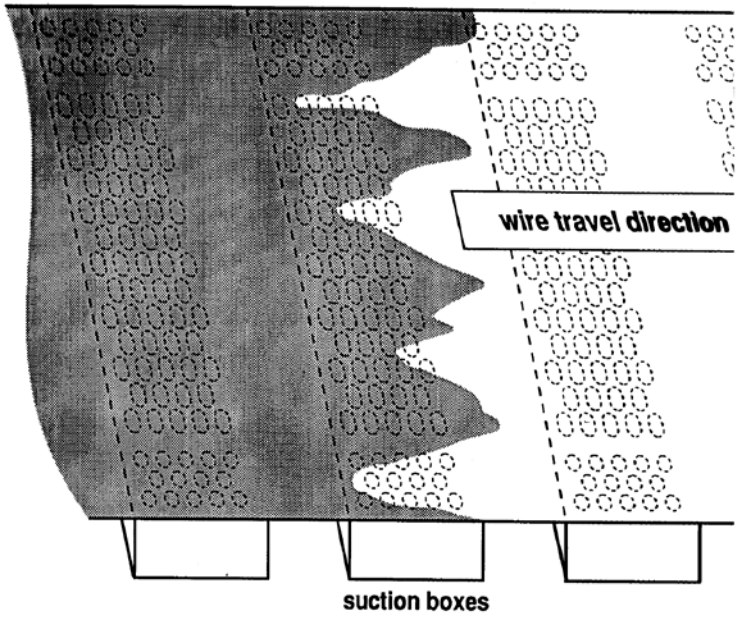
# Formers

- Fourdrinier dewatering components
  - Table rolls:
    - create turbulence and downstream suction pulse
  - Foils:
    - gentle turbulence
    - Better dewatering
  - Suction foils
  - Suction flat boxes
  - Couch roll



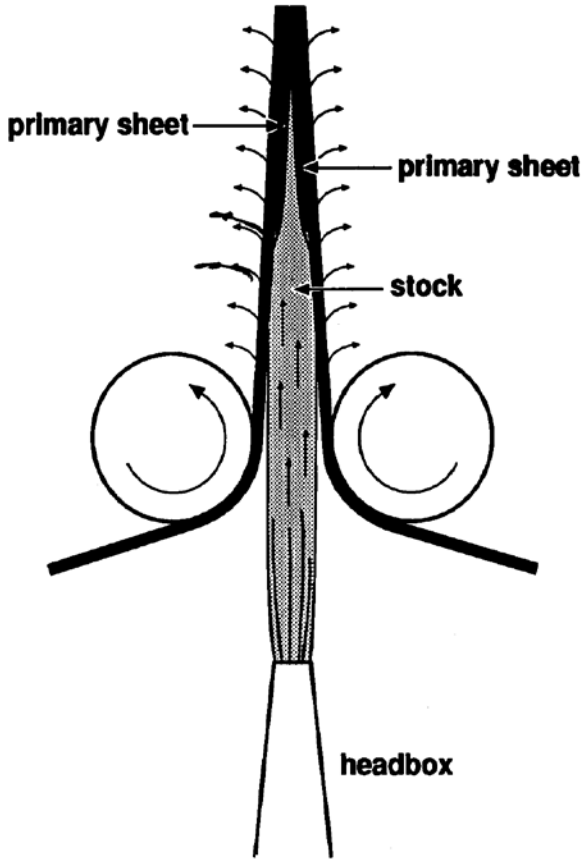
# Suction boxes and Dandy roll

- Suction boxes
  - 15-40 kPa
  - Remove more water than foils alone
- Dandy roll
  - Wire covered roll to even out top surface
- Couch Roll
  - Use suction … last stage of dewatering
- Leaves at 18-20% consistency



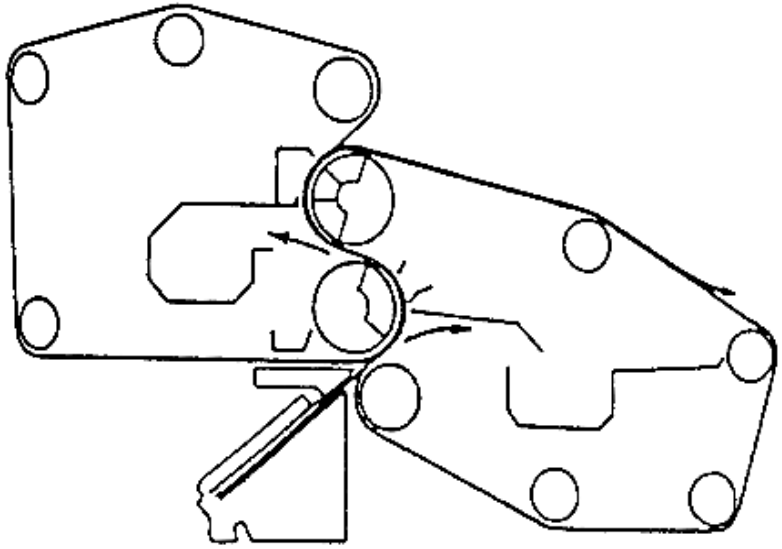
# Twin Wire Formers

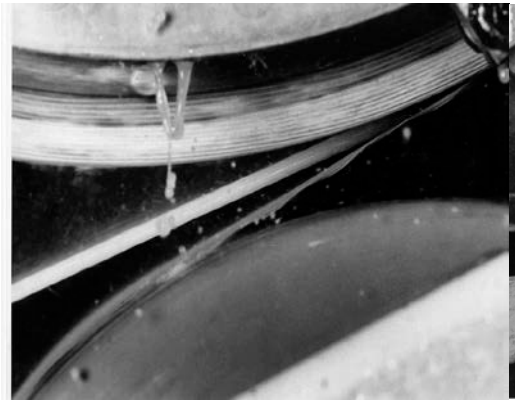
- Stock captured between two moving wires
- Advantages
  - Higher dewatering: two-dewatering surface
  - Less 2-sidedness
  - No Free surface instabilities
  - Improved formation

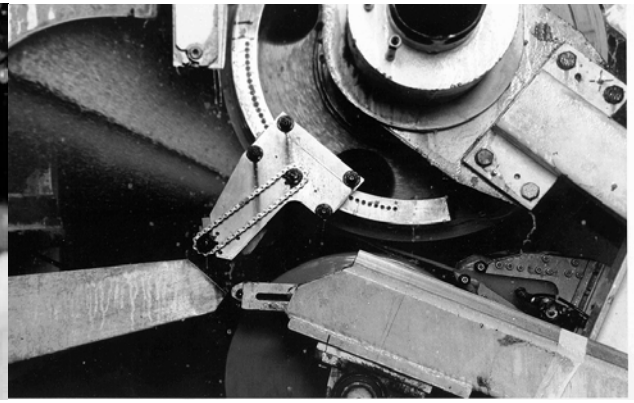


# Twin Wire – Roll Formers

- Jet impinges on roll
- Initial pressure due to inertia
- Can be analyzed using Bernoulli Equation

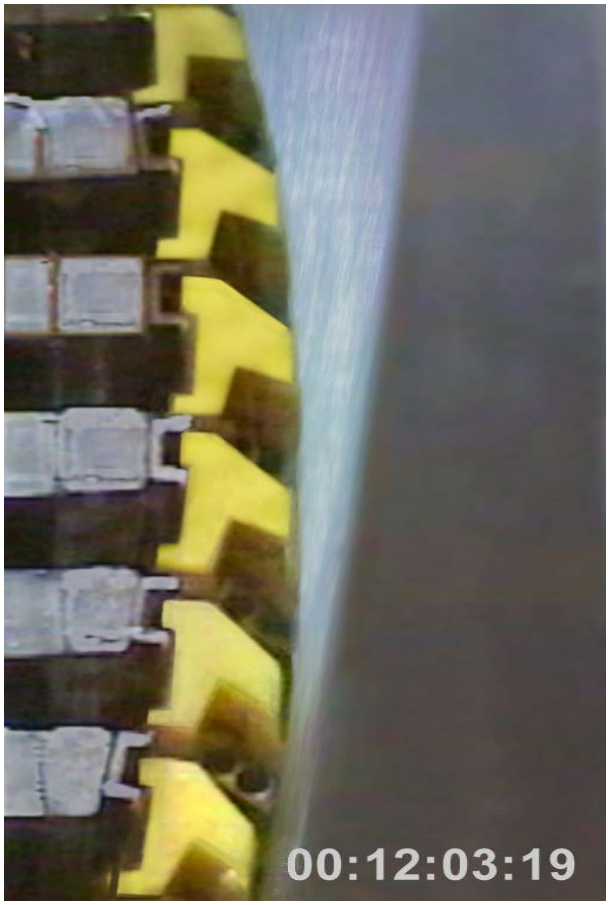






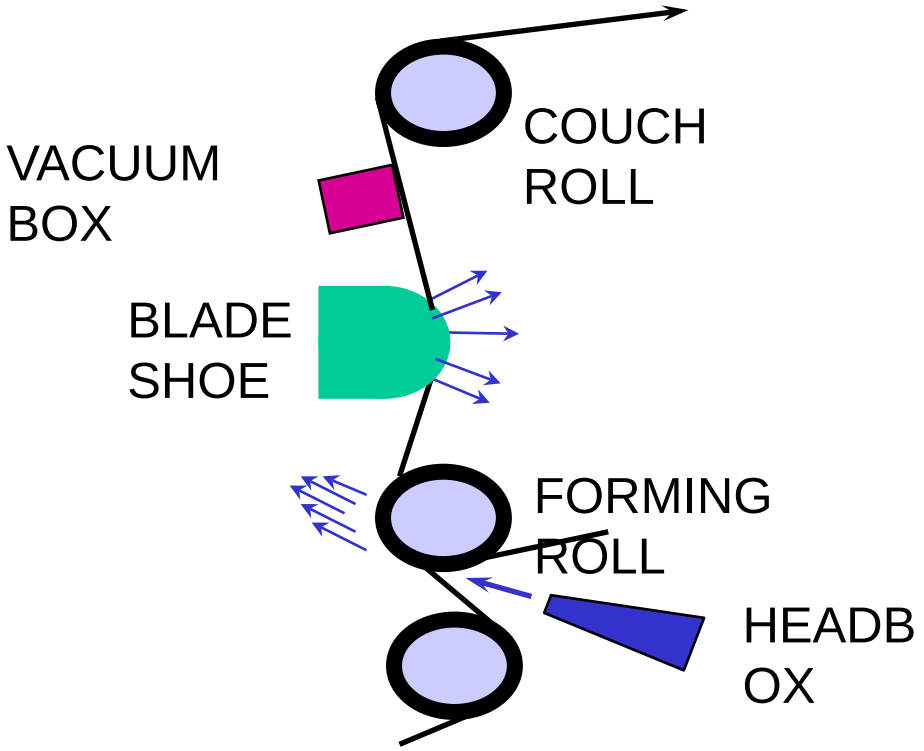
# Blade formers

- Dewatering due to blades (foils)
- Arranged in a large radius curve
  - Less dewatering pressure
  - Better formation
- Staggered sets of blades



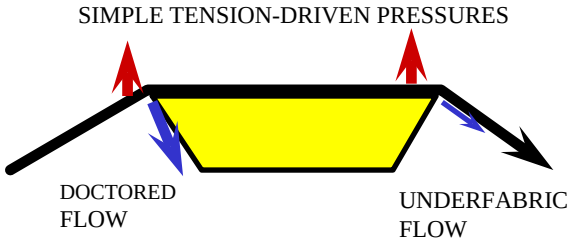
# Roll-Blade Formers

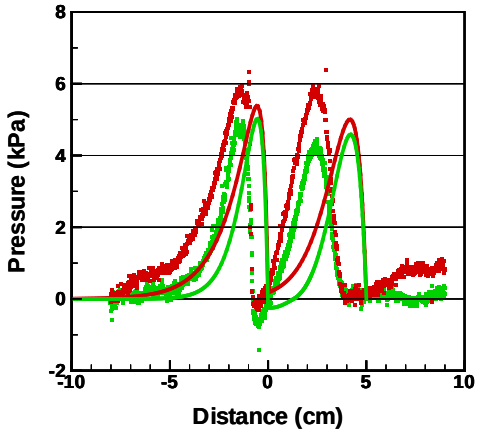
- Combination of rolls and blades



# Pressure on foils

- Produce positive pressure ‘pulse’
- Re-arrange fibres to give better formation
- Also dewater pulp
- Bottom side doctors water away

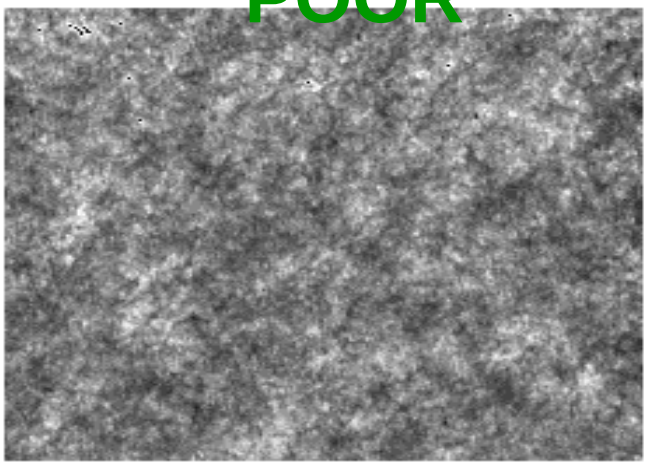


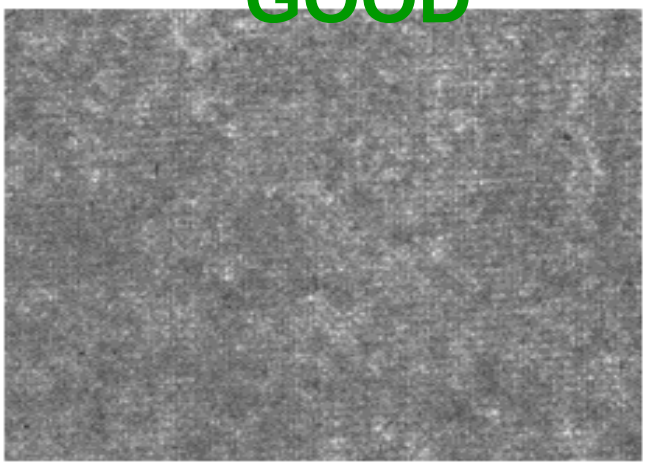
# Formation

- In addition to fibers, paper consists of fiber fragments, mineral fillers and chemical additives.
- In the web formation process, they all settle stochastically onto the wire.
- Paper formation is the resulting nonuniform distribution of particles.
- More precisely, formation is the variability of the basis weight of paper.
- Such variation can be easily seen with the naked eye, for some sheets.

POOR



GOOD



- The basis weight variation depends on:

1. The randomness of single fiber distribution.
2. Fiber interactions.
3. Flocculation - increases the variability of basis weight.
4. And hydrodynamic forces in the web forming process.
   - Turbulence can decrease basis weight by breaking flocs.
   - “Hydrodynamic smoothing” improves sheet uniformity.

- The nonuniform basis weight distribution affects many properties of paper.
- Formation effects:
  1. Print unevenness - resulting from local porosity.
  2. Tensile strength.
  3. Cockling
- In the case of strength and cockling, local basis weight variations are not separate from the effects of local fiber orientation and dried-in strains.

# Characterization

- A useful definition of formation is the small scale basis weight variation in the plane of the paper sheet.
- This provides for simple measurement and unambiguous connection to paper structure.
- Other terms used include mass formation, mass distribution or the distribution of mass density.

# Measurements

- Measurement of formation is almost always indirect.
- The measured values must be calibrated to basis weight.
- A good method is to use $\beta$-radiation for which the transmitted intensity decays exponentially with basis weight and the absorption coefficient is independent of furnish, for $\beta$-sources that emit no $\gamma$-rays.
- $C^{14}$, $Pr^{147}$ or $Kr^{85}$ are pure $\beta$-sources.
- X-rays can be used, but attenuation is greater for fillers than fibers.

# Quantification

- It makes sense to describe the formation of paper in terms of the standard deviation of basis weight, $\sigma_b$.
- The specific formation $f_N$ is defined by

$$f_N=\sigma_b/\sqrt{b}$$

where b is the average basis weight.

- Note the dimensions of $f_N$ are square root of basis weight.
- The coefficient of variation

$$COV(b)=\sigma_b/b$$

is dimensionless.