MECH 450 – Pulping and Papermaking Calendering

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Purpose of Calendering

- Provide a smooth surface for printing
- Improve CD thickness profile
  - Reel building
- Reduce thickness (newsprint)
- Side effects
  - Decreased stiffness/caliper

On machine vs off machine

- Most calenders now on-machine
  - More efficient and economical
  - Improved reel building
  - Soft nip calenders replacing

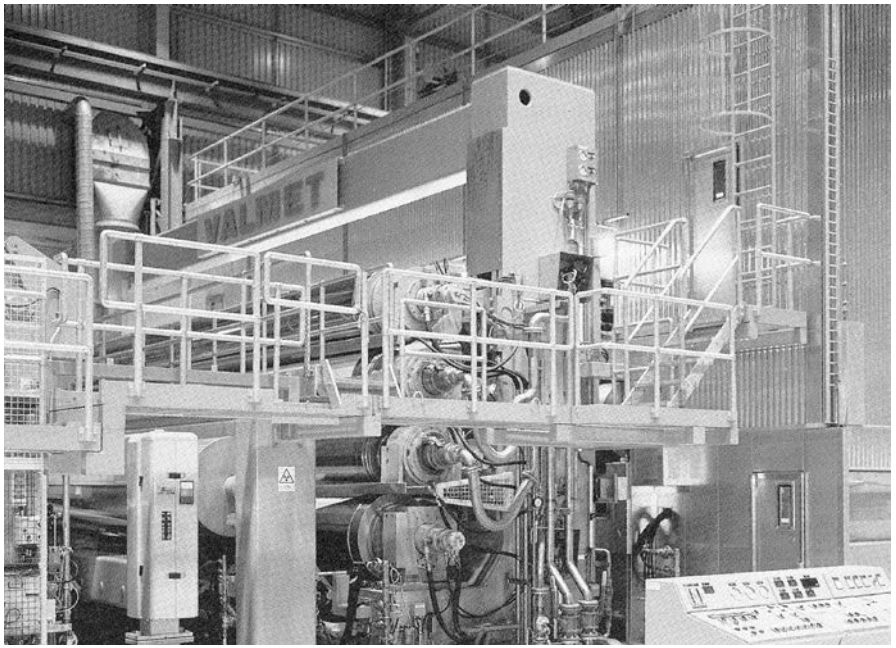
    off-machine supercalenders in the less critical grades

Types

- Hard-nip
- Soft-nip
- Multi-nip
- Specialty
  - Long-nip

Hard Nip

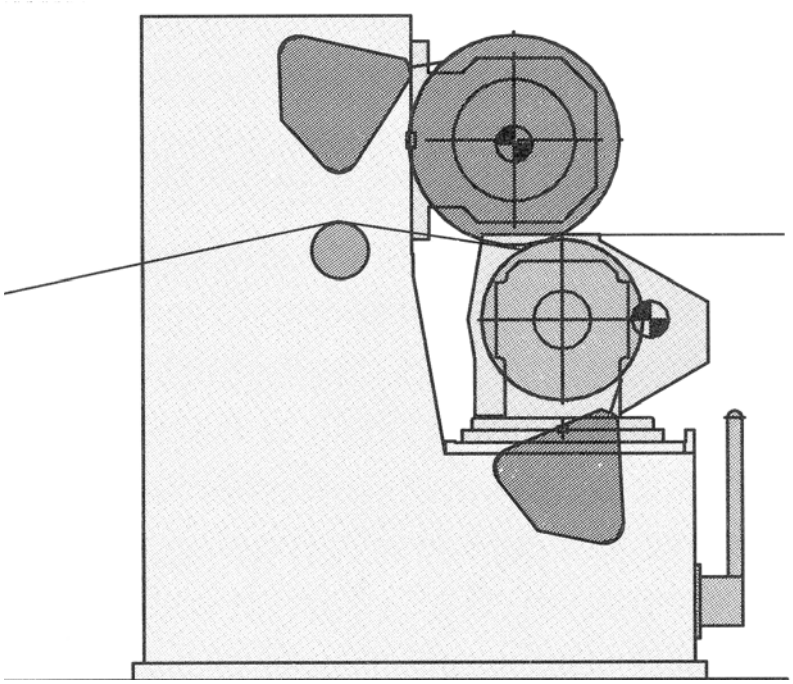
- Web pressed between two or more hard rolls
- Two-roll
  - Pre-calendering before coating
  - Finishing uncoated wood free paper
- Multi-roll
  - Newsprint
  - Smooth woodfree papers
  - Specialty papers



Principles of hard nip

- Densify sheet with pressure
- Copy the surface of the rolls to the web
- Nip is small
  - Small diameter hard rolls
  - High pressure
  - Compression of fibre flocs
    - Mottling, blackening
  - Fibre crushing, breaking of interfibre bonds

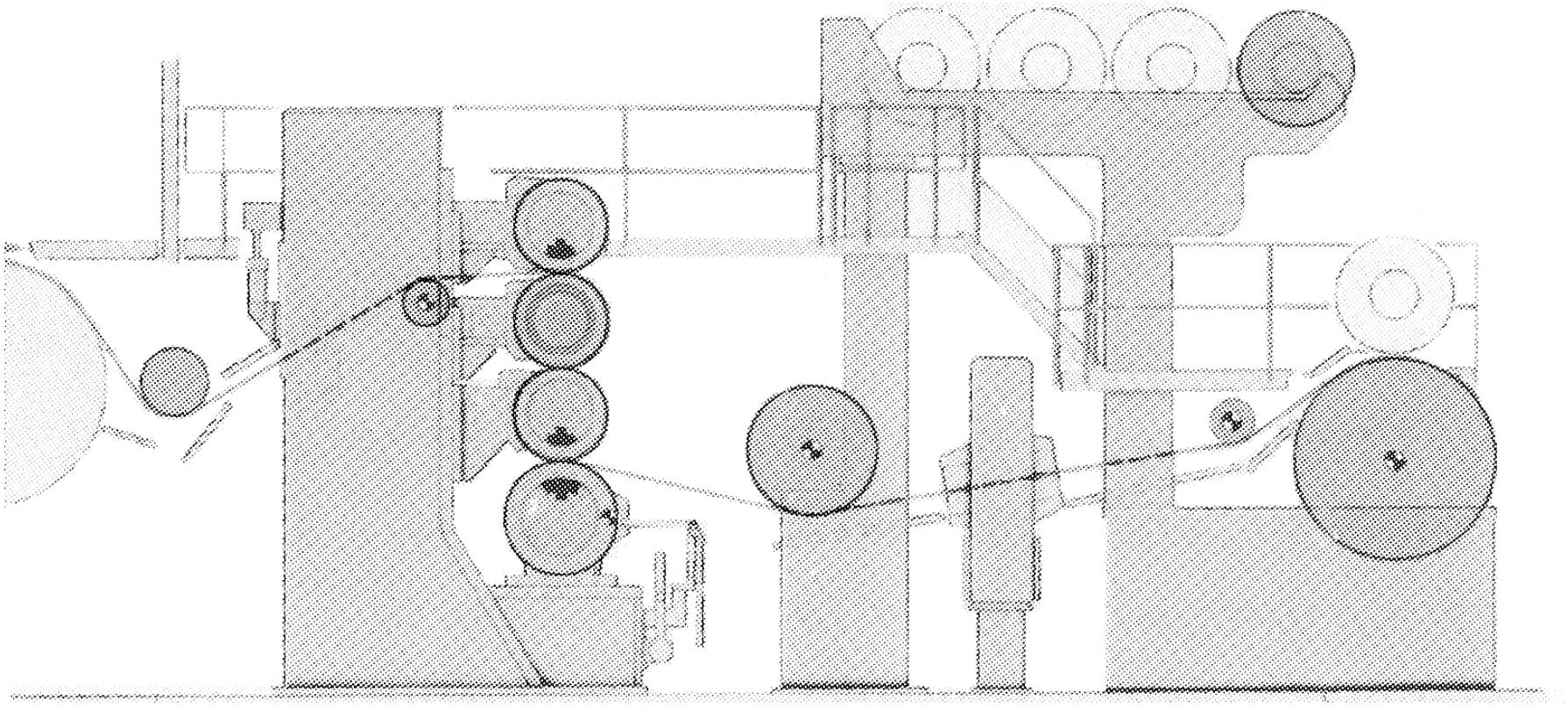
Two roll hard nip



Problems with one nip

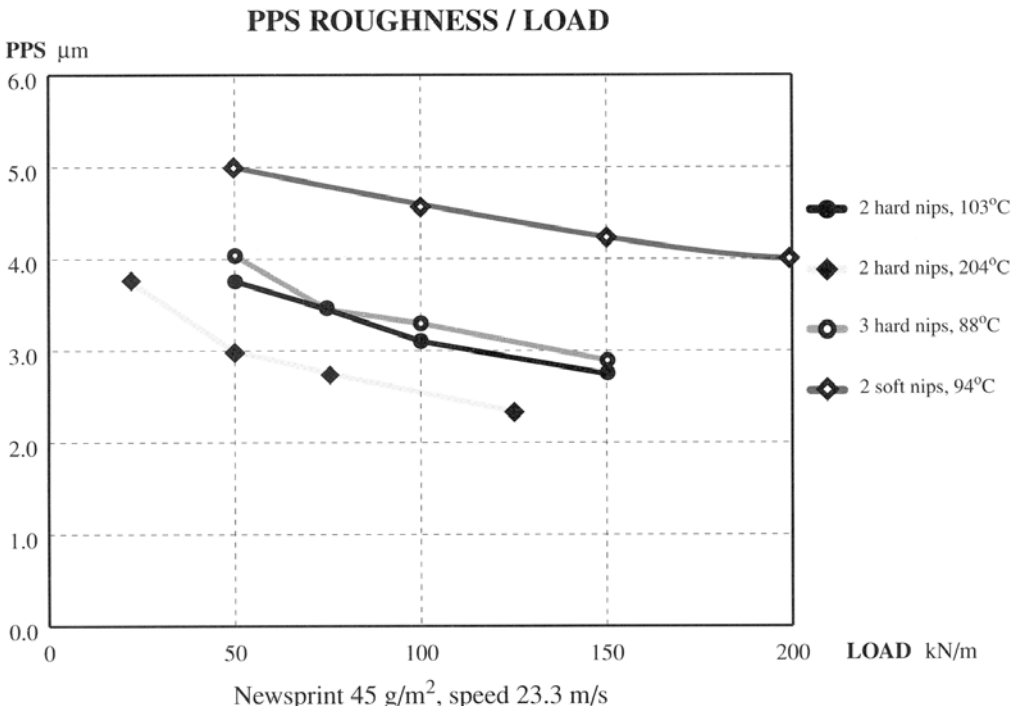
- Surface quality function of total applied pressure
- If use one nip:
  - Calender must be precise and rolls perfect
  - Need large heavy rolls to withstand the pressure

Multi roll, hard nip

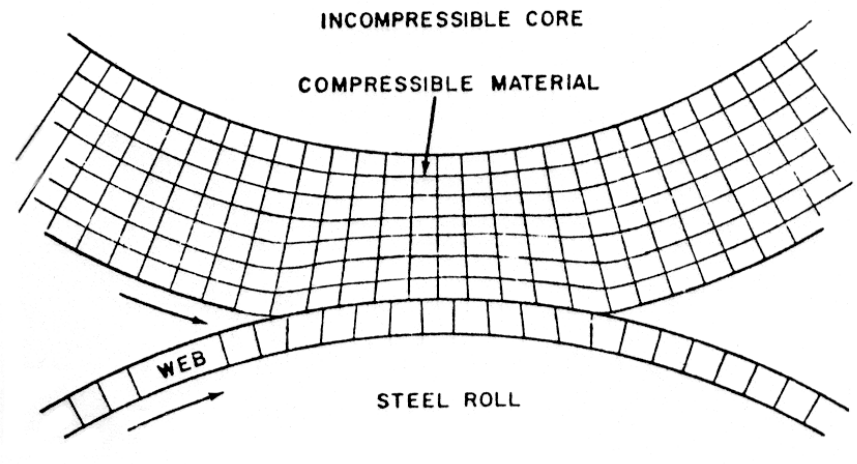


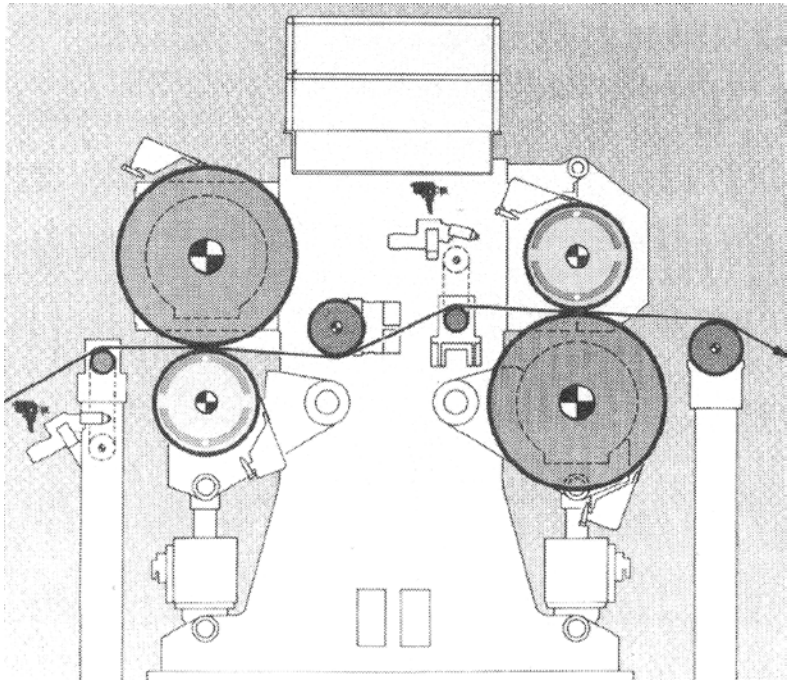
Effect of temperature and load

- Increased load improves smoothness
- Increased Temperature improves smoothness



Action of soft nip calendering

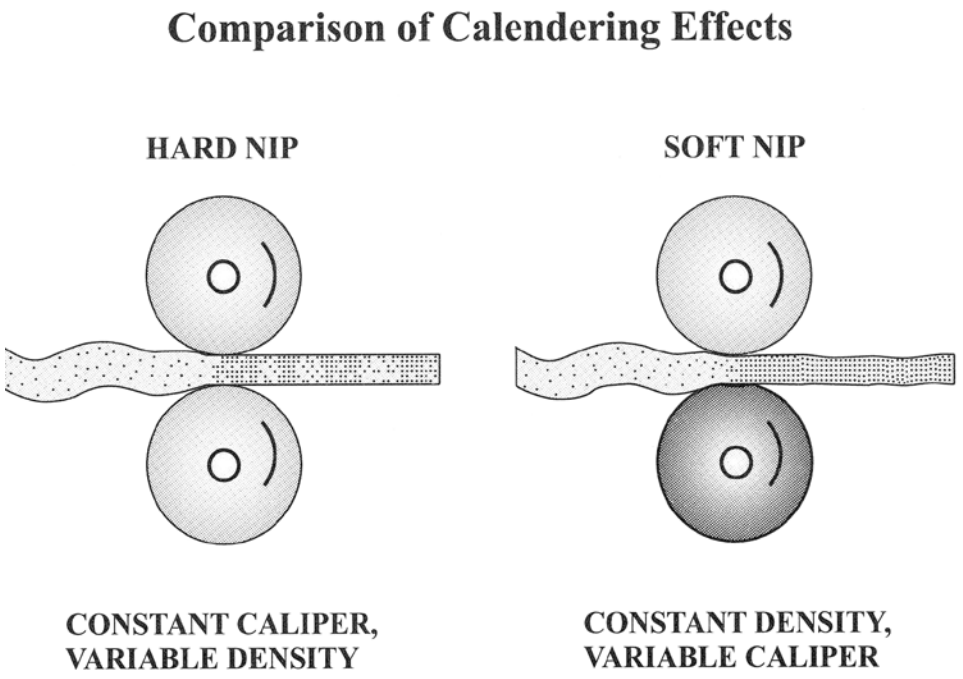




On-line soft calender

Comparison of Hard vs. Soft

- Soft roll cover on one of the two rolls
  - Usually hard roll is heated
  - Matt grade both rolls are soft
  - Process variables
    - Linear pressure, running speed, roll surface temperature, cover material, steaming

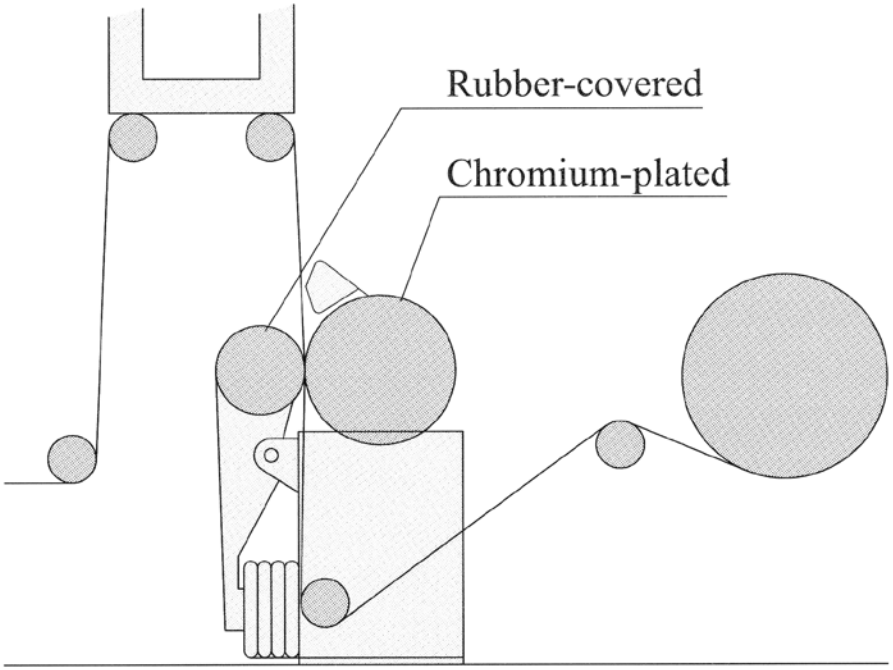


Benefits of hard vs. soft

- More uniform sheet density
  - More uniform absorption properties
  - More uniform printing
- High spots not as compressed
  - Less gloss mottle
  - Smoother surface without blackening
  - Better strength

Gloss Calender

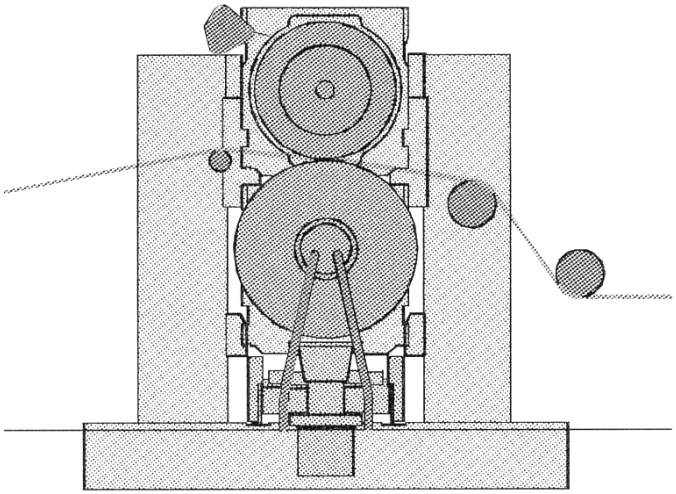
- Used for board
- Uses high temperature and low pressure
- Produces good gloss/smoothness without compressing board



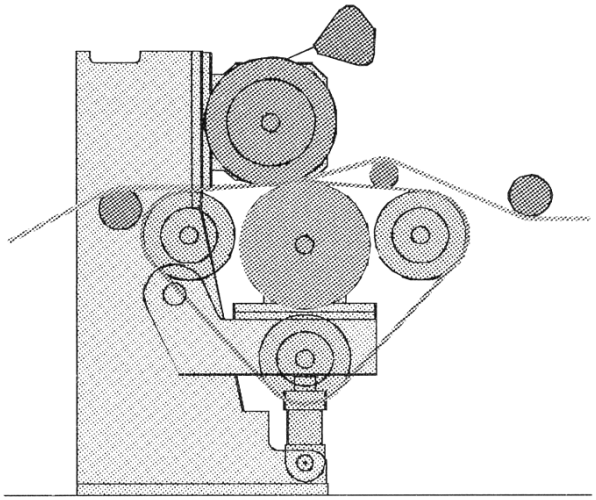
Long nip calenders

- Extend time in nip
- Extending the nip improves surface at a given bulk
- Used for board grades

Shoe type calender

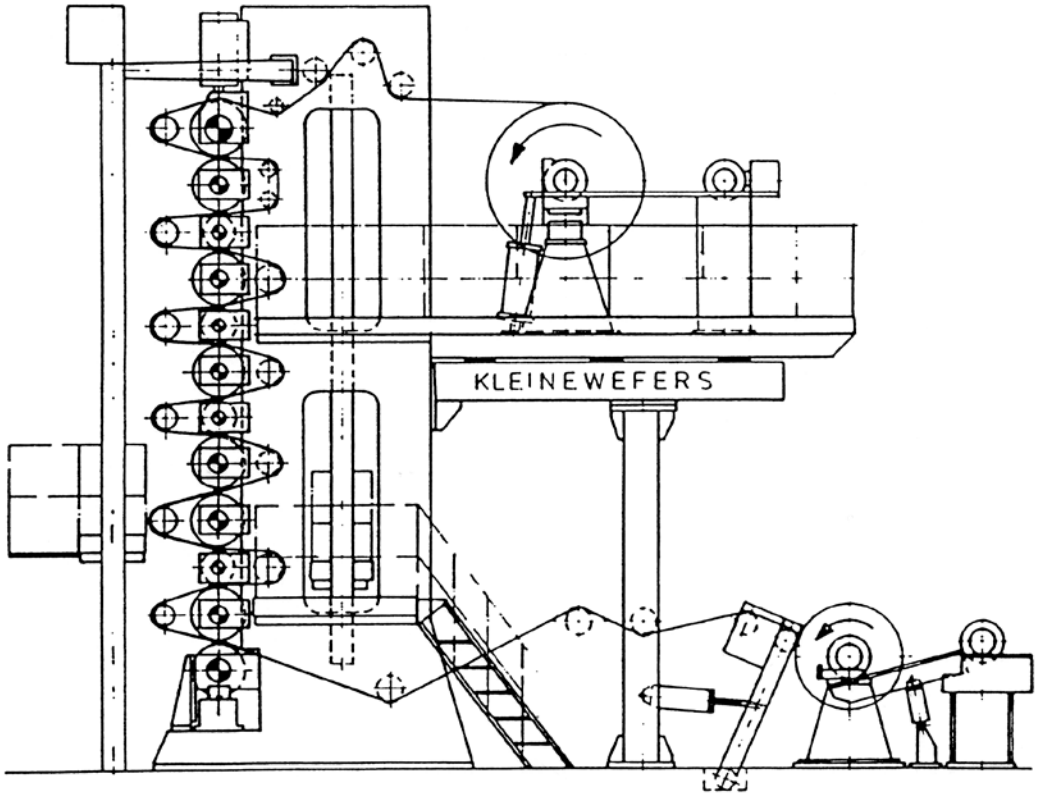


Belt type calender



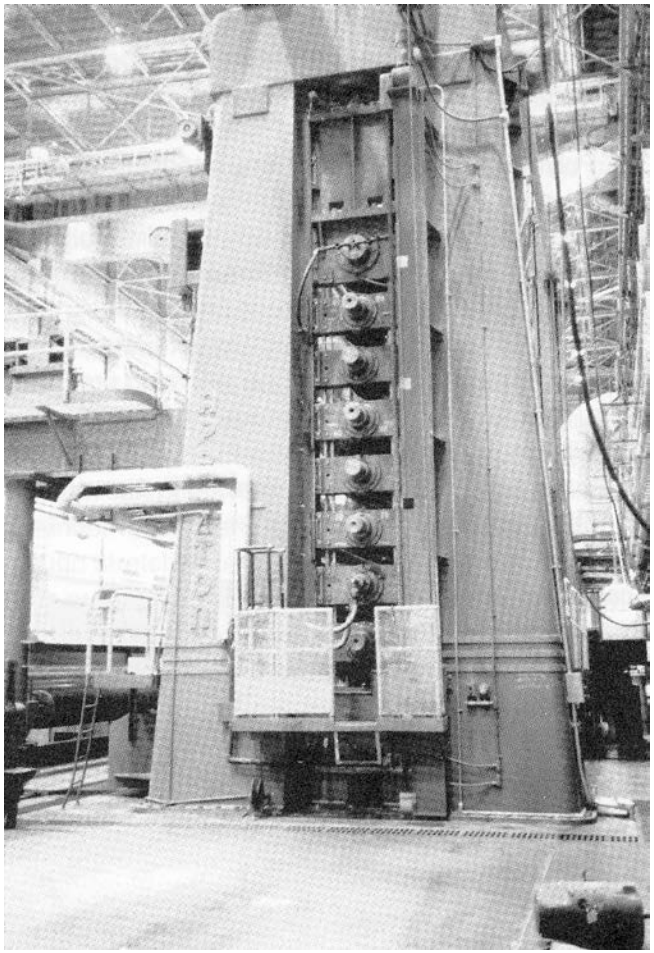
Supercalenders

- Calender of steel and polymer rolls
- Imparts gloss to coated and highly-filled papers



10 cylinder calender stack

Supercalenders



Variables

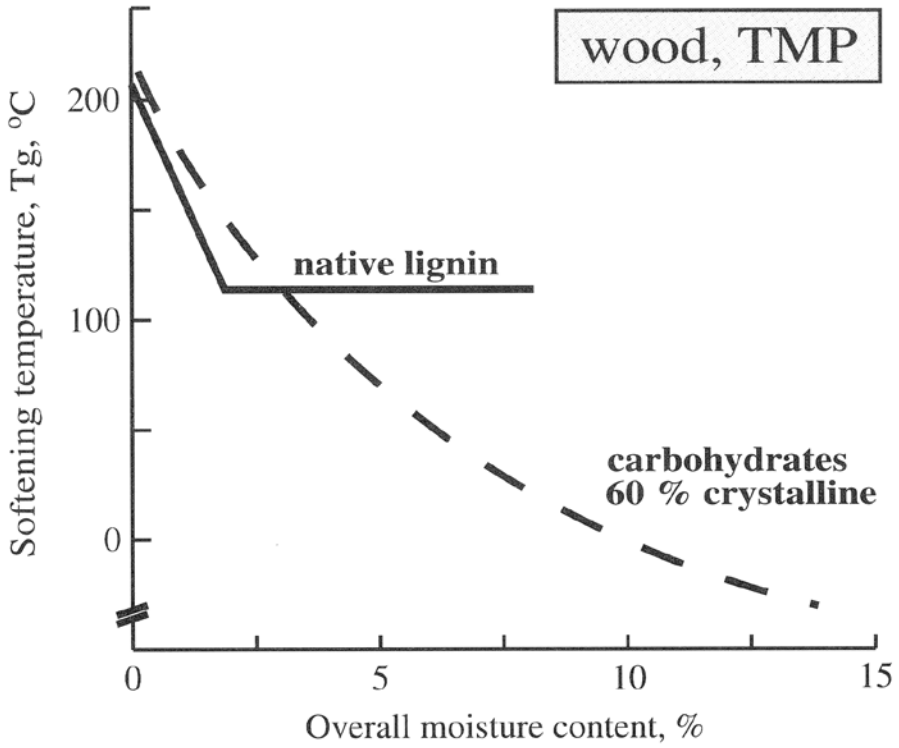
Paper variables

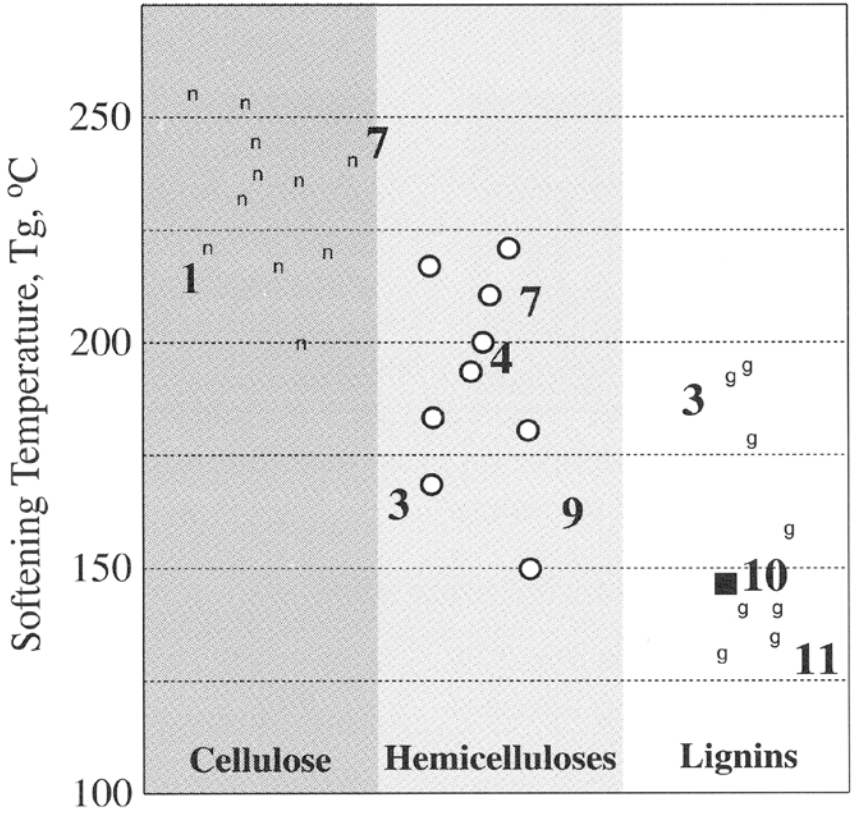
- Affecting sheet plasticity
  - Moisture
  - Temperature
  - Furnish coating formulation
- Other paper variable
  - Formation

Roll variables

- Affecting plasticity
  - Roll temperature
  - Steaming
- Affecting mechanical work
  - Linear load
  - Number of nips
  - Speed
  - Soft roll material
  - Other (roll diameters, roll smoothness)
  - Nip pressure
  - Nip dwell time

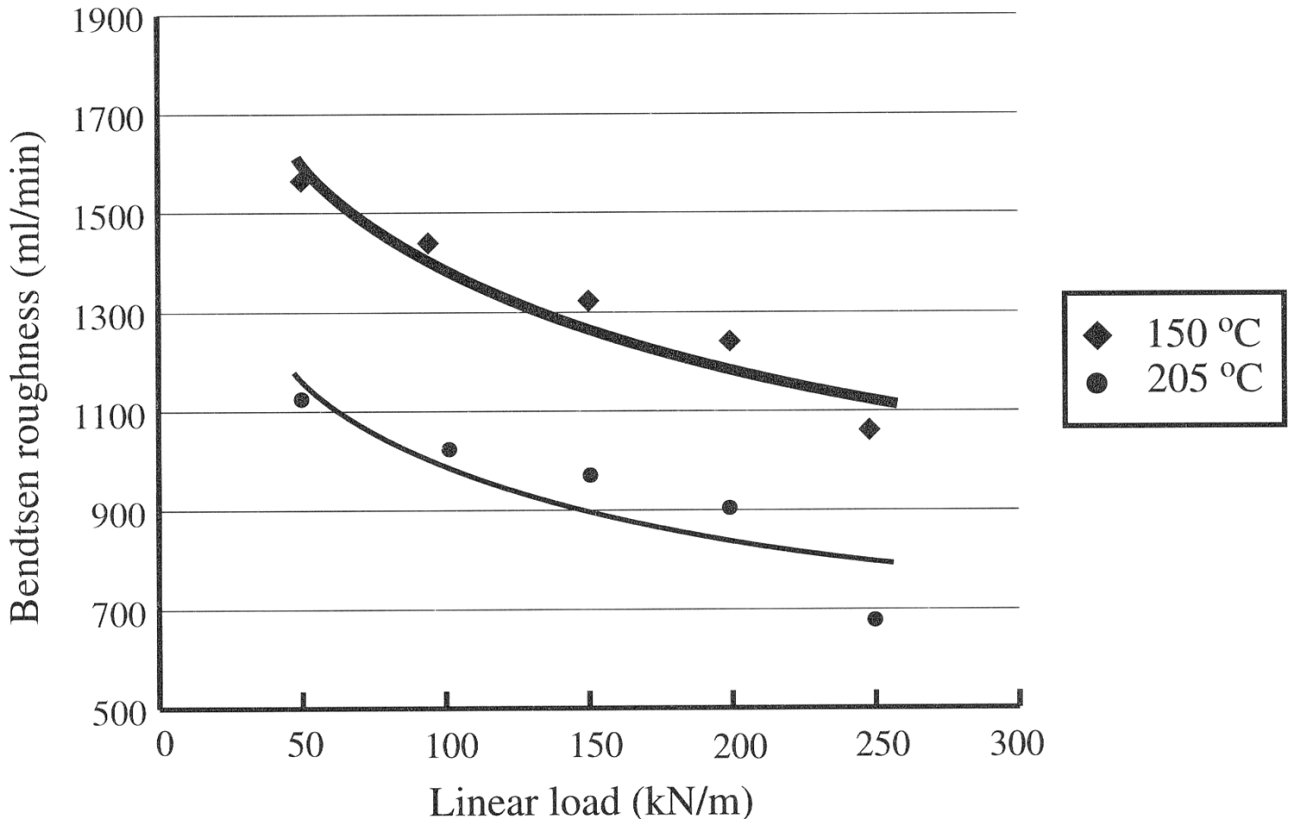
Softening temperature





Effect of water on softening

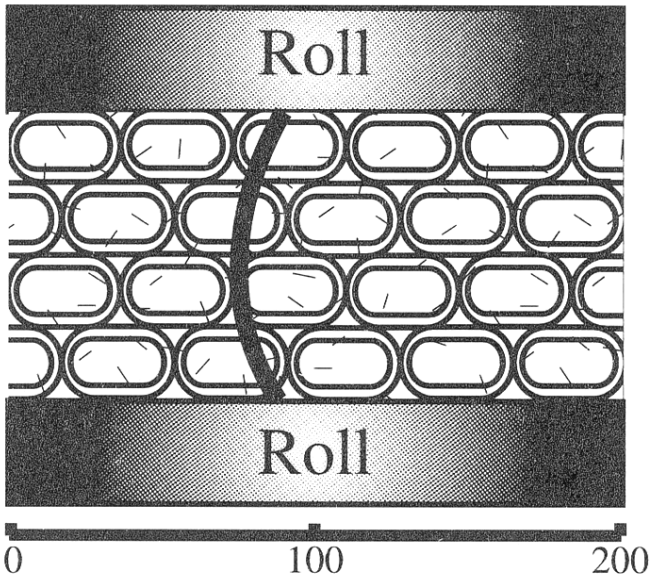
Effect of roll temperature



Liner board one-nip soft calender

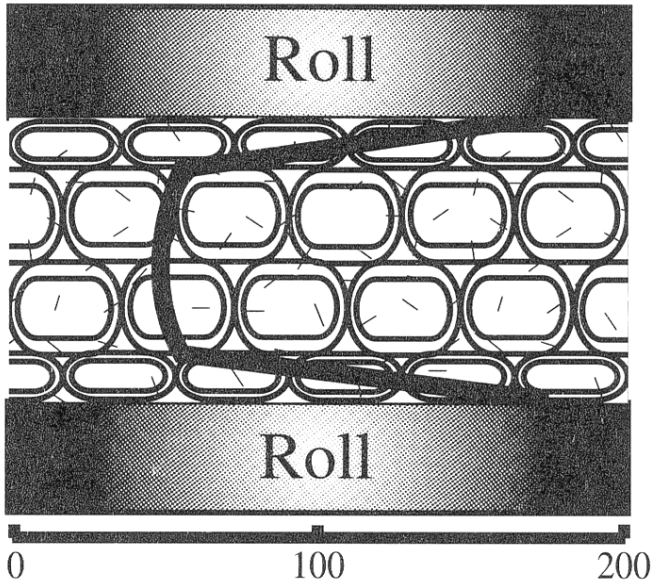
Temperature gradient calendering

$T_{paper} >> T_{roll}$



A

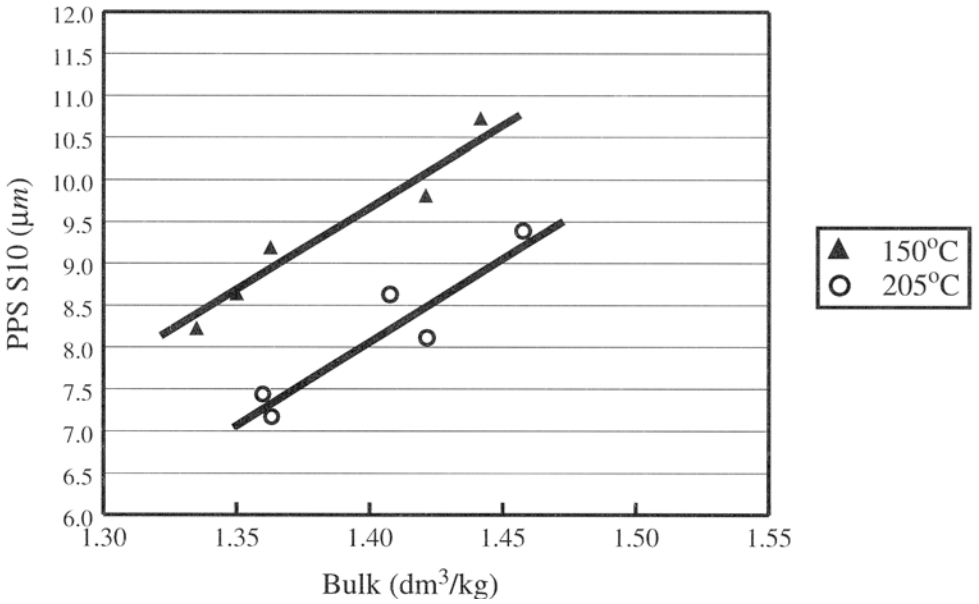
$T_{paper} << T_{roll}$



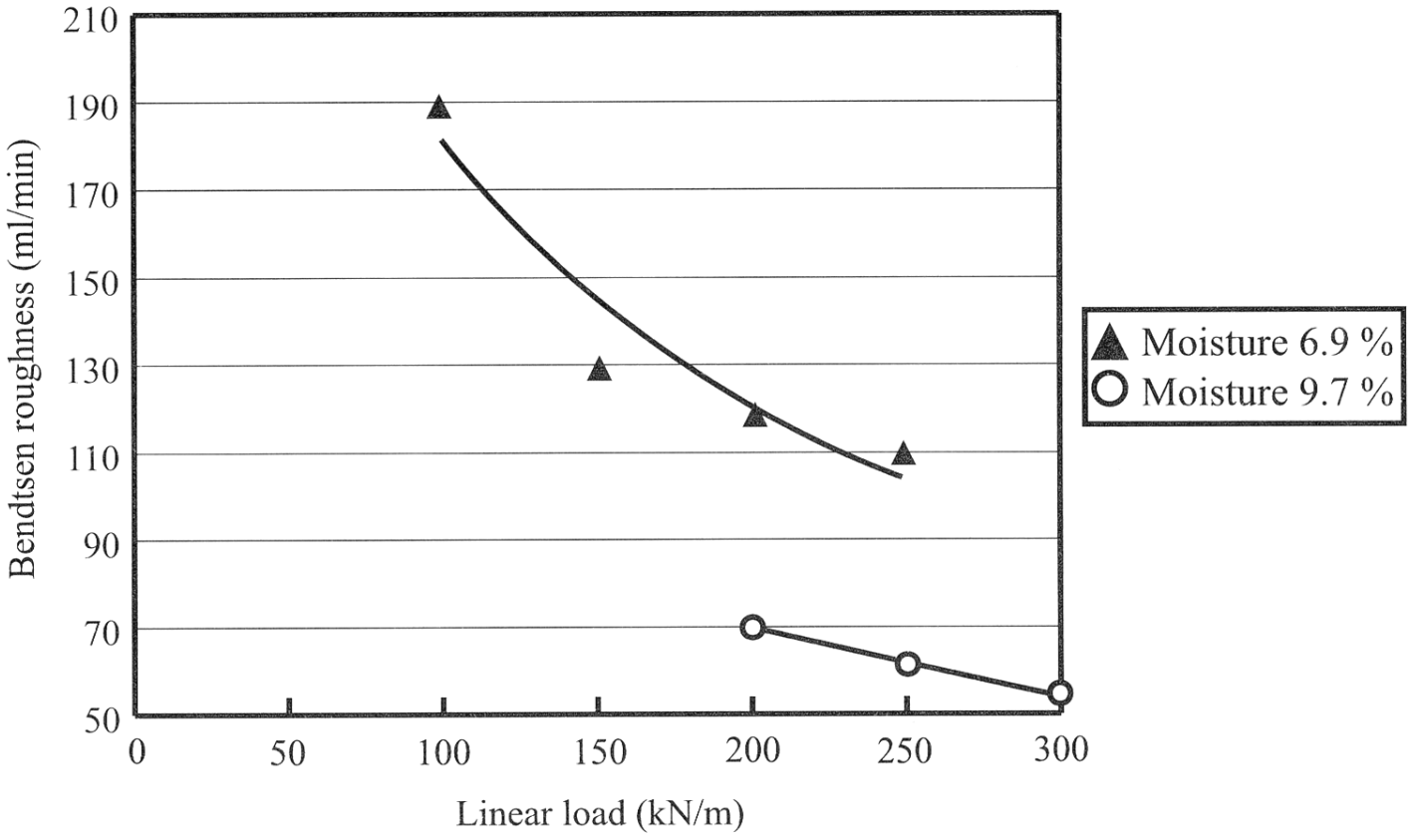
B

Roughness vs. bulk

- Higher temperature leads to smoother paper at a given bulk



Effect of moisture content

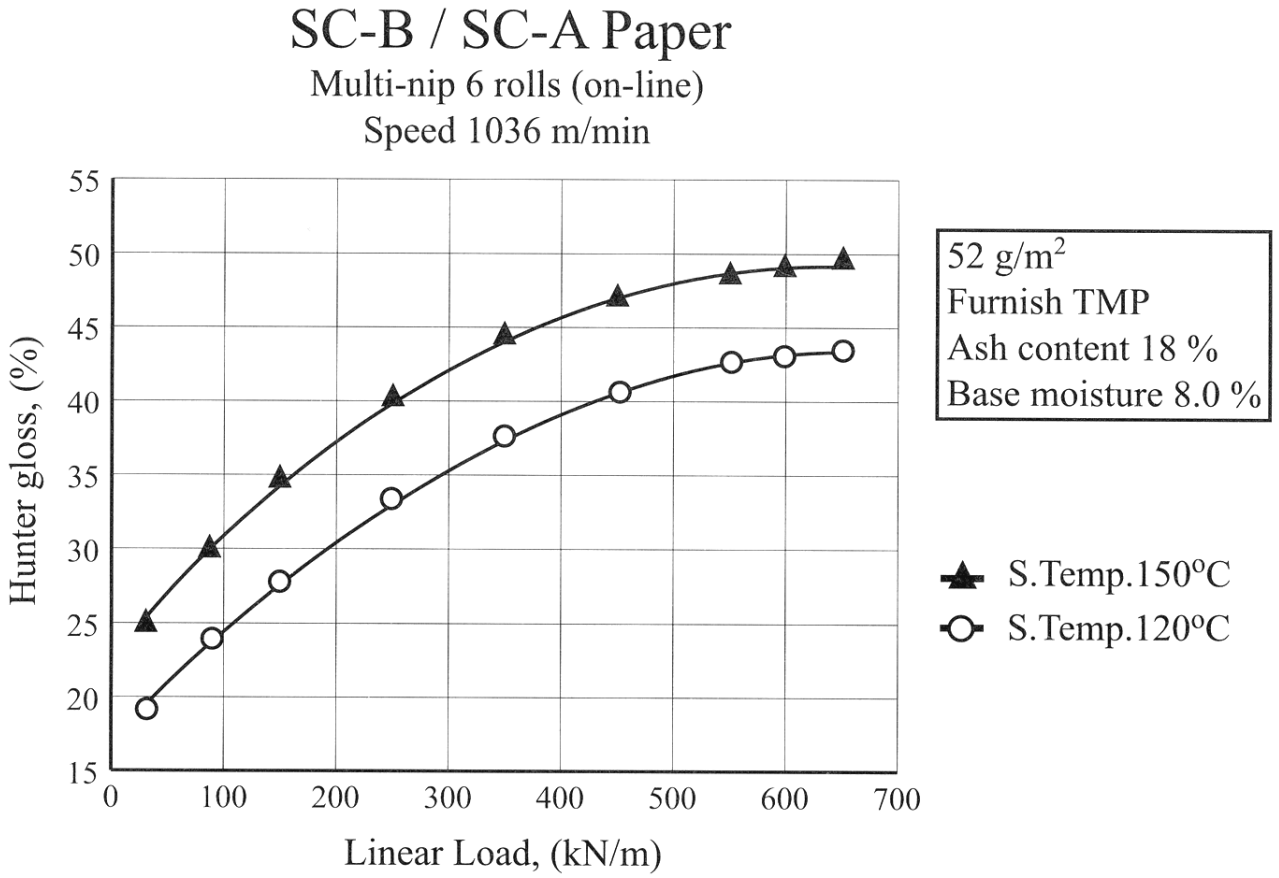


Newsprint 2 nip soft calender : roll temp 140C, 1050 m/min

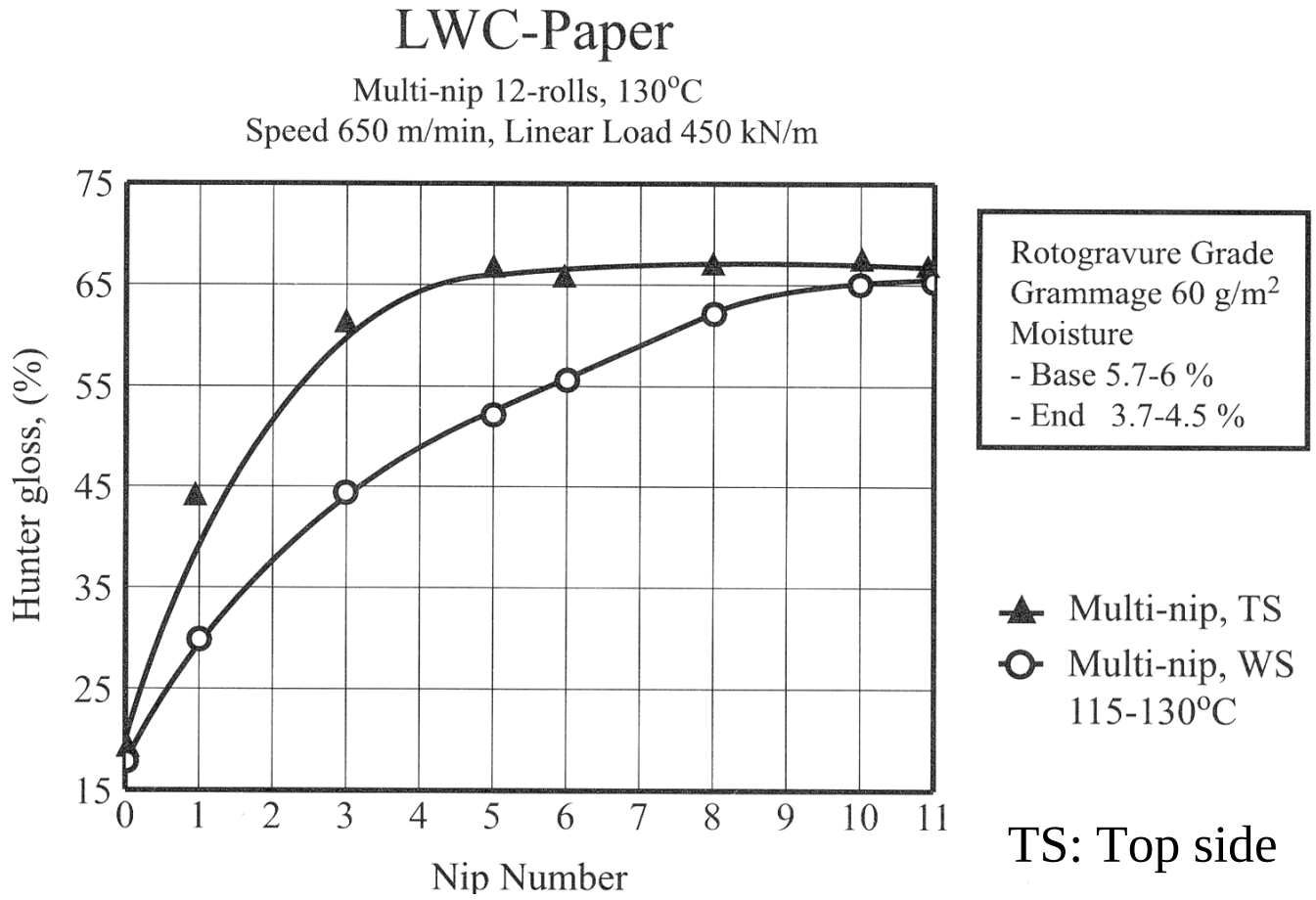
Linear load

- Force applied divided by the calendering width: Units kN/m
- Nip pressure
  - Linear load/nip length
    - Soft Calenders - 5 to 80 MPa
    - Nip lengths 5 mm to 15 mm
  - Nip lengths longer for soft calenders

Gloss increases with load



Number of nips



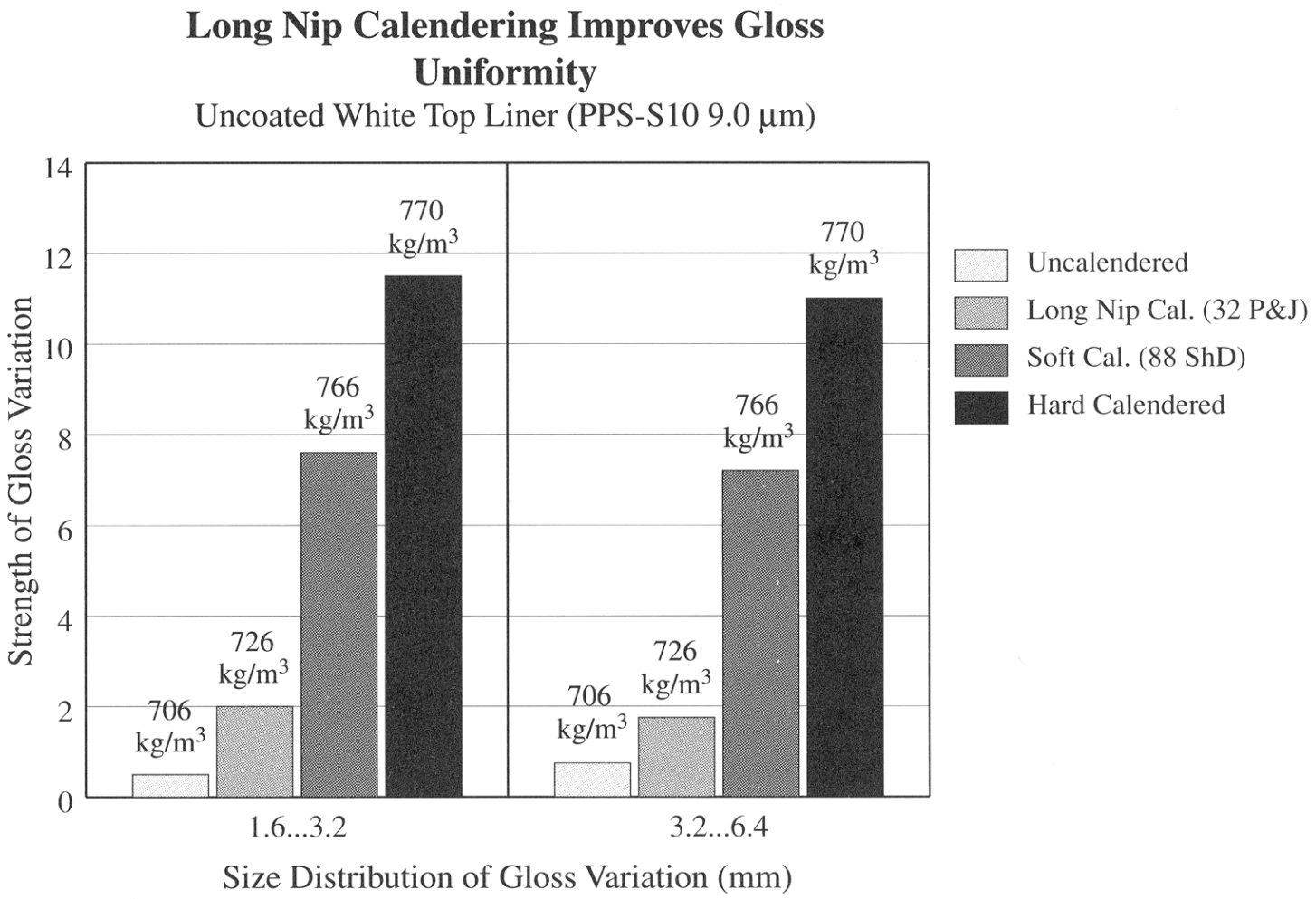
TS: Top side

WS: Wire side

Calender speed

- Off-machine calenders
  - Lower speed
    - Higher nip dwell time
    - Better surface properties

Calendering top liner



Coated boards

- Pre-calendering prior to coating
  - Multi- roll hard nip calenders
    - 4 – 11 rolls
  - Trend toward hot hard or soft calendering (up to 200^{o}C)
  - Calendering effect boosted by steam showers
- Conditions depend upon furnish and desired smoothness

Final calendering

- Soft calenders
  - Higher bulk at given gloss
  - Roll temperature – up to 200^{o}C for glossy grades; lower for matte grades
  - Linear loads 20-150 kN/m,

Uncoated board

- Calendering not required for rough test liner grades or medium
- Calendering used when containers used to promote
  - White top liners – soft calendered
- Trend to long nip calendering to preserve bulk

Calendering Equation

$$\in = \left(B_i - B_f \right) / B_i$$

$$\in = A + \mu B_i$$

Parameters		Coefficients
B_i	Initial bulk (cm^3/g)	
B_f	Final bulk (cm^3/g)	
L	Nip load (kN/m)	a_L
S	Machine speed (m/min)	a_S
R	Equivalent roll radius (m)	a_R
θ	Average mid-nip web temperature (°C)	a_θ
M	Web moisture (%)	a_M
	Intercepts	A, a_o

$$\mu = a_o + a_L \log L + a_s \log S + a_R \log R + a_\theta \theta + a_M M$$

Works for: $-A/\mu \le B_i \le (1-A)/2\mu$

Outside that:

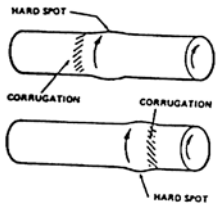
$B_f = B_i$ for $B_i < -A/\mu$

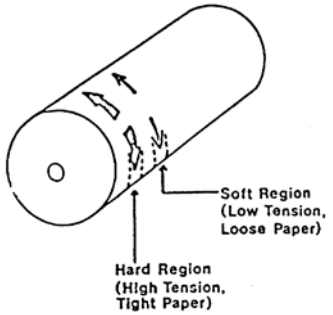
$B_f = (1-A)^2 / 4\mu$ for $B_i > (1-A)/2\mu$

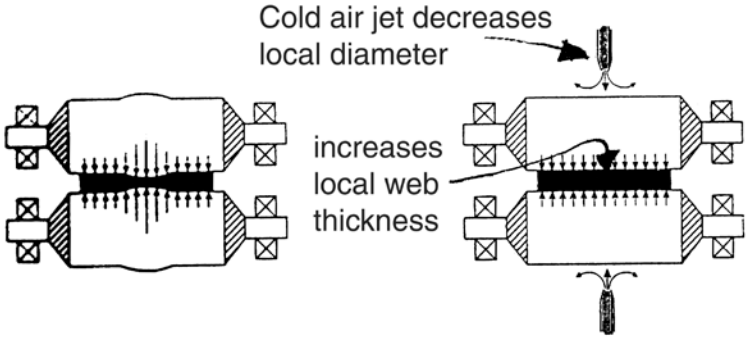
Note: $a_R \approx -\left(a_L + a_S \right)/2$

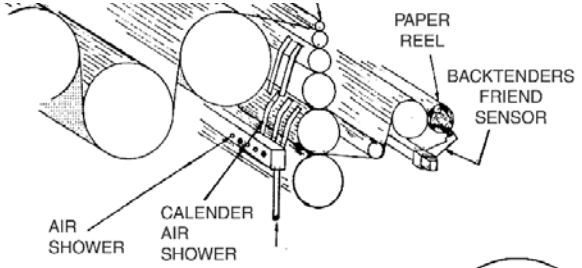
Reeling - CD thickness control

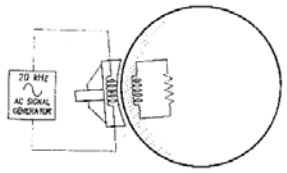
- Hard spot in roll if paper is locally thicker.
  - Paper is stretched in this spot (stretched / baggy through press)
  - Increase average paper tension, leads to press breaks
- Corrected using calendering
  - Cool cylinder locally to increase diameter
  - Narrows gap and decreases paper bulk





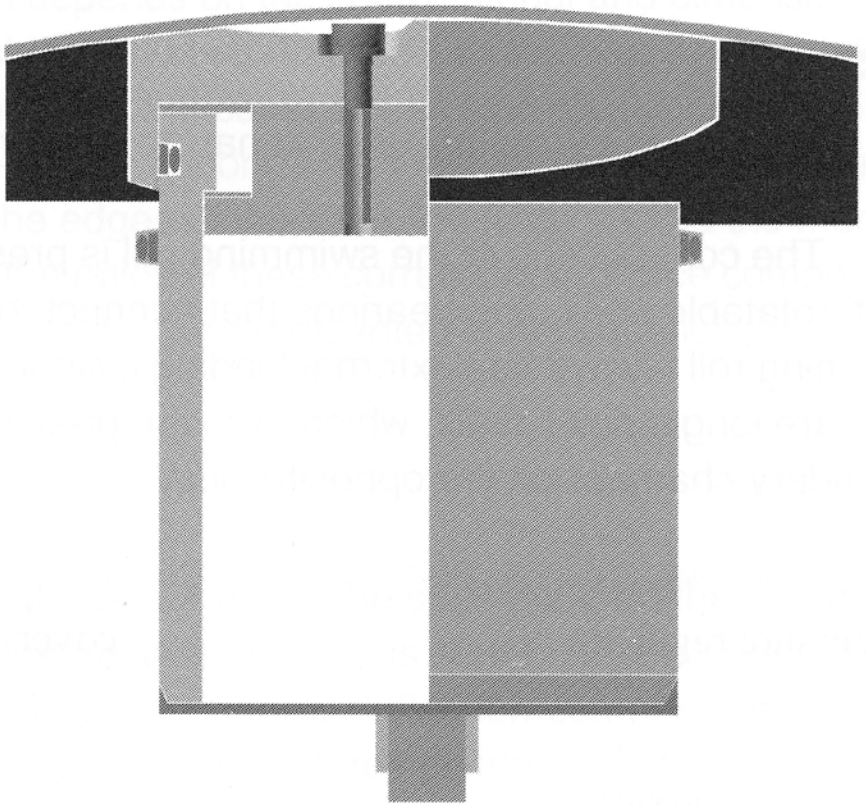






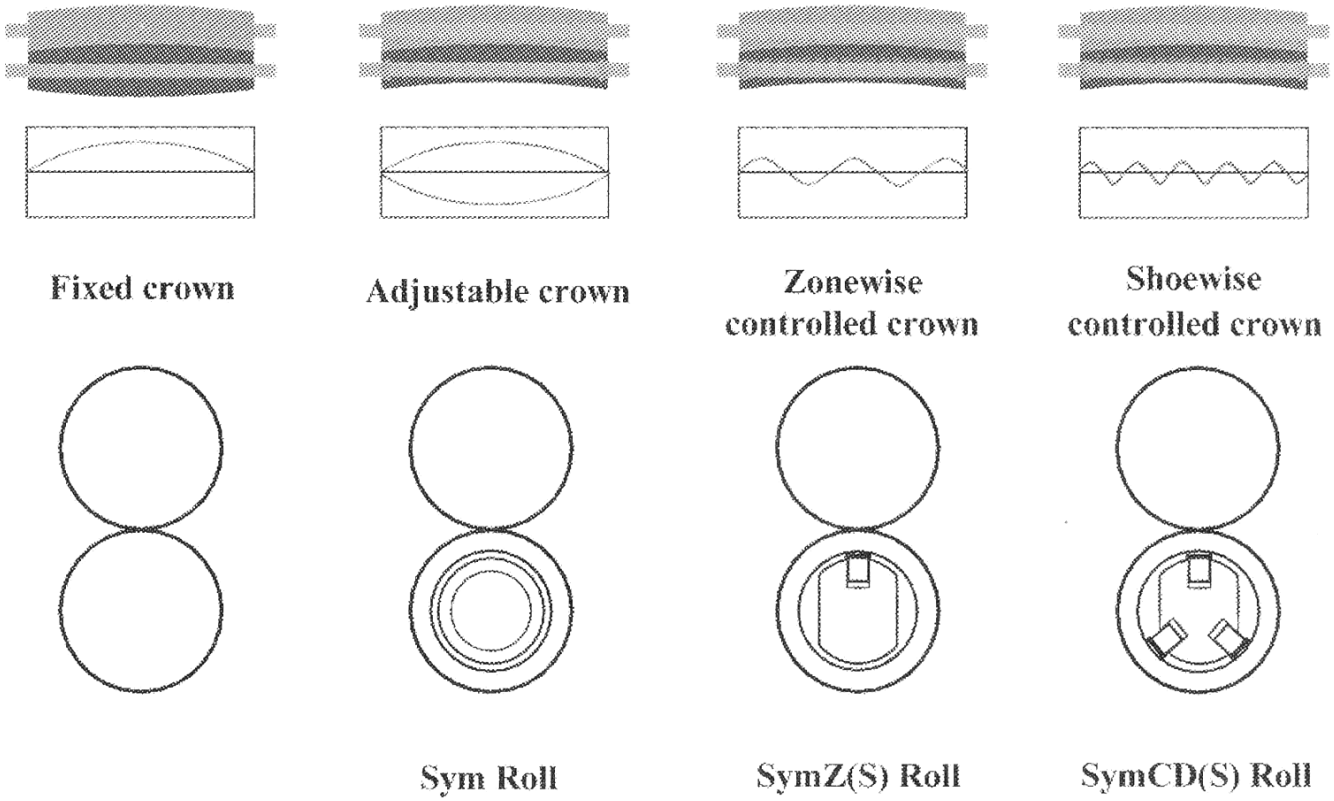
Zone controlled rolls

- Stationary centre shaf and rotating cylinder
- Supported by hydrauli elements



Load deflection

Evolution of Deflection Compensated Rolls



A close up look at paper
Supercalendered magazine

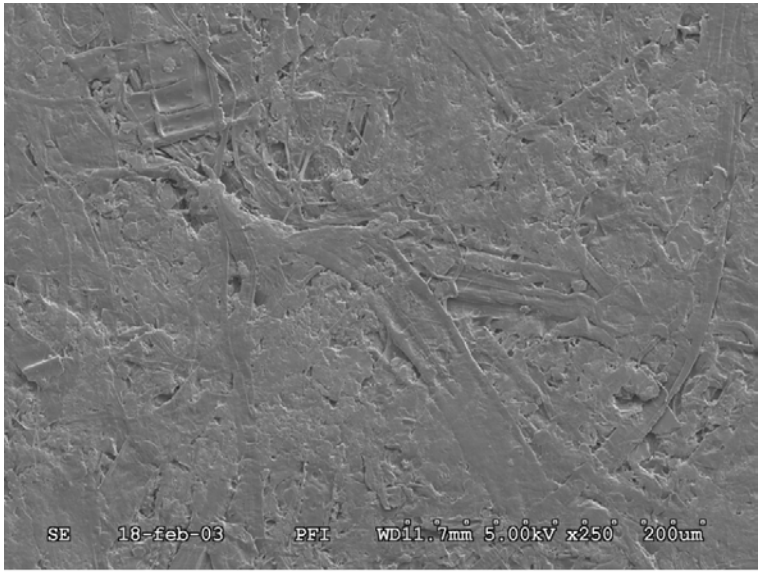


Figure 5: Surface of supercalendered (SC) magazine paper.