Improvement of Water Removal Efficiency in Papermachine Wet Press

초지기 압착부에서의 탈수 효율 개선

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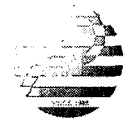

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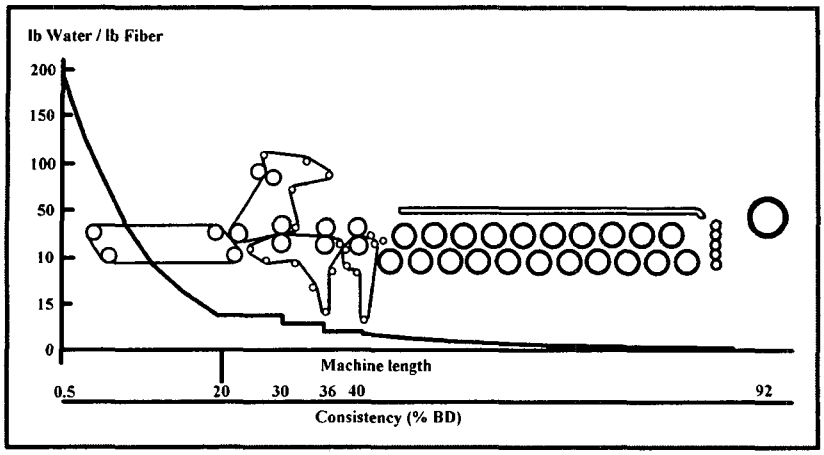
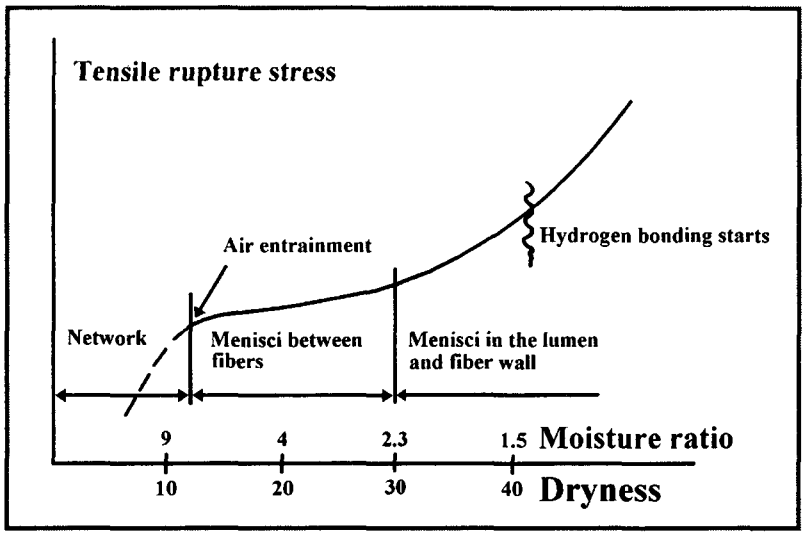
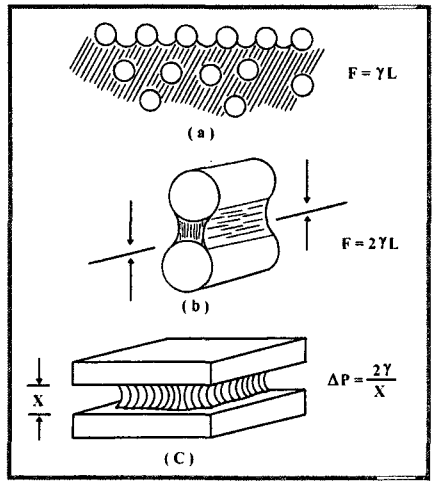
ROLES OF WATER IN PAPERMAKING PROCESS

- Dispersion and mixing of paper stock
- Carrying the paper stock
- Sheet formation
- Hydrogen bonding of fiber

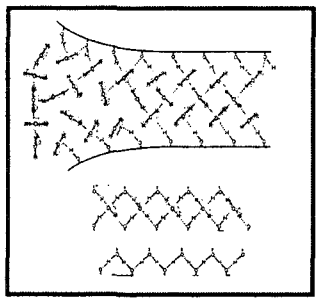

lb Water / lb Fiber
200
150
100
50
10
15
0
Machine length
0.5
20
30
36 40
92
Consistency (% BD)

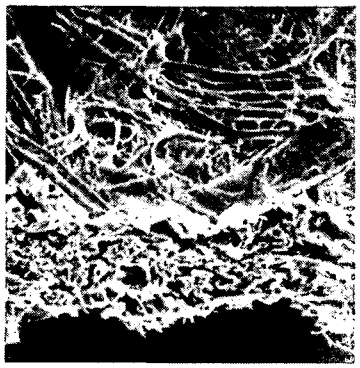

Tensile rupture stress
Air entrainment
Hydrogen bonding starts
Network
Menisci between fibers
Menisci in the lumen and fiber wall
9
4
2.3
1.5
Moisture ratio
10
20
30
40
Dryness

FUNCTIONS OF WET PRESSING

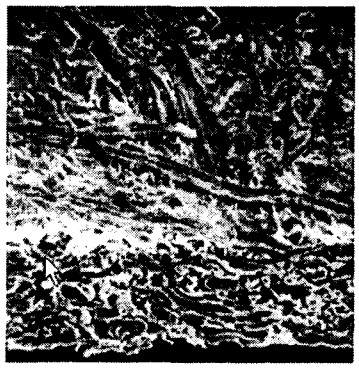


- Water removal
- Consolidation of web
- Paper properties

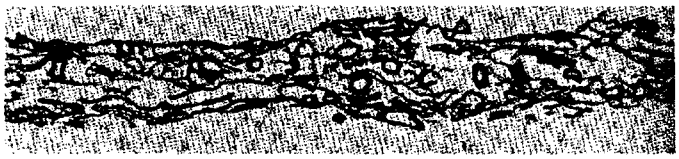




The Sheet
Before Pressing



The Sheet
After Pressing



After 2nd press

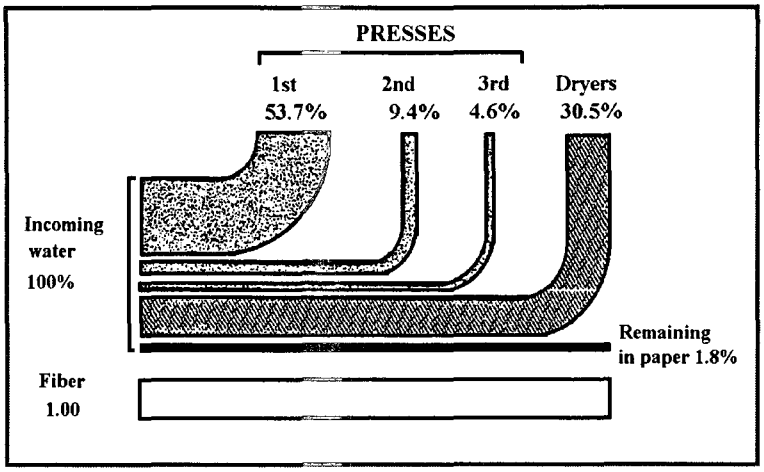
After 3rd press

After calendering

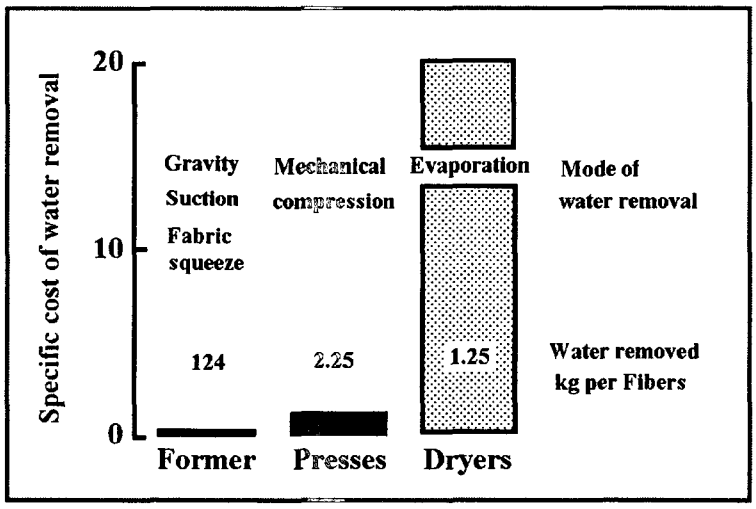
Consolidation of newsprint

WATER REMOVAL IN PAPERMAKING PROCESS

- The solid content of web is increased,
  - More difficult in water removal
  - More time and cost
  - Higher capital and operation cost

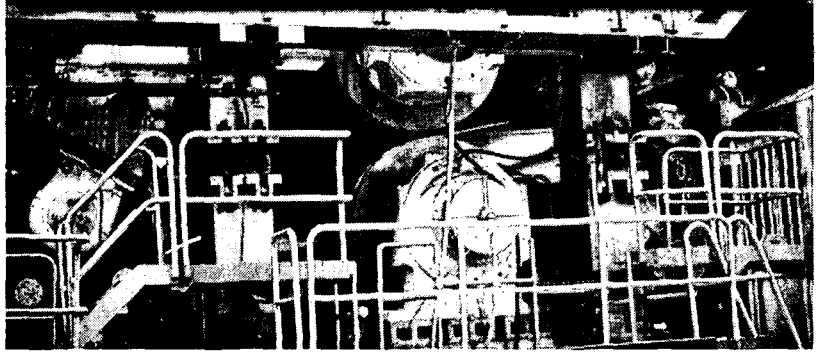


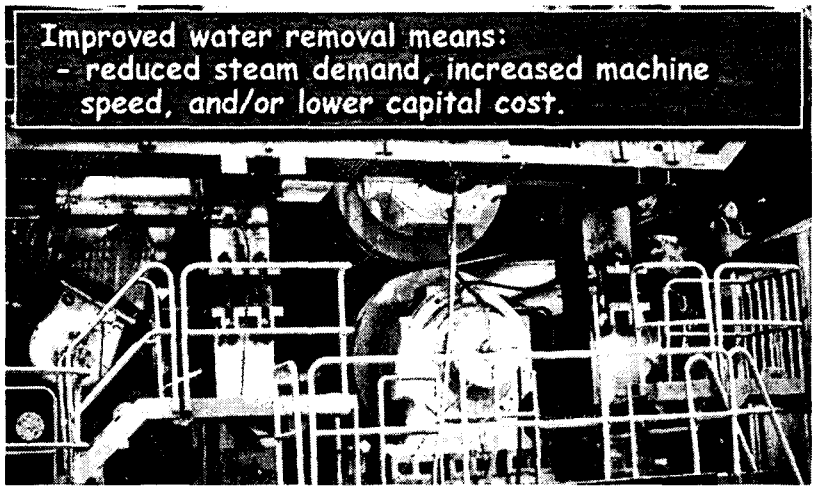
Relative water removal in wet press and dryer section



$4.00 to remove 1000 gallons of water in the presses, but $80.00 to remove the same amount of water in the dryers.

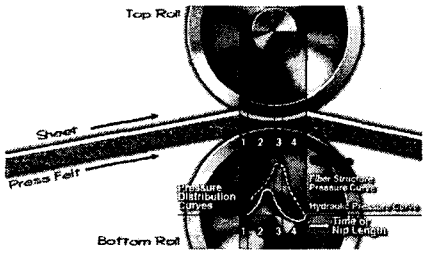
Every 1% improvement in sheet solids after the press section results in a .4 to 5% reduction in drying load.

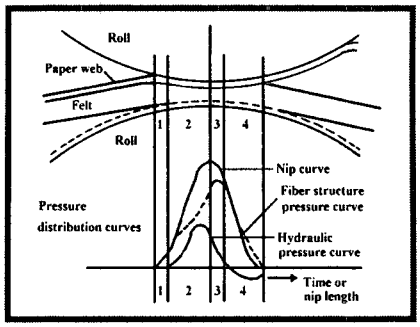




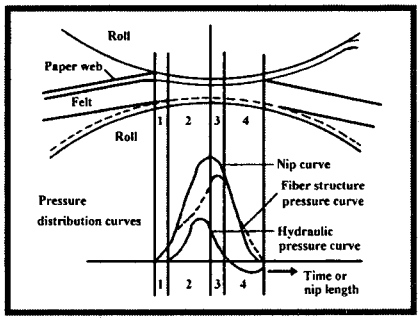
DEWATERING MECHANISM IN WET PRESS

- The wet web is compressed between two press roll, of which one or both are felted.
- Water removed from the web in the press nip escape either into the felt or through the felt into the cavities provided in the press roll.





- **Phase 1**
  - Air flows out of both sheet and felt until the web is saturated and no air remains.
  - No hydraulic pressure is built up in the web.
- **Phase 2**
  - The sheet is saturated and the buildup of hydraulic pressure in the sheet causes movement of water from the paper into the felt.
  - When the felt reaches saturation, water moves out of the felt.
  - Total pressure reaches the maximum.



- **Phase 3**
  - The nip expands until the fluid pressure in the web is zero.
  - This correspond to the point of maximum dryness in the nip.
- **Phase 4**
  - The web and felt expand.
  - The rewetting can be occurred by one or a combination of mechanisms (capillary competition, **vacuum in the sheet** or separation rewetting).

Amount of Water Removed at Press Nip

$$Q = \frac{KLPN}{\mu T}$$

Q : Water removed
K : Permeability coefficient of web
L : Nip length
N : Nip width or Nip residence time
μ : Viscosity of water
T : Web thickness

FACTORS AFFECTING PRESS PERFORMANCE

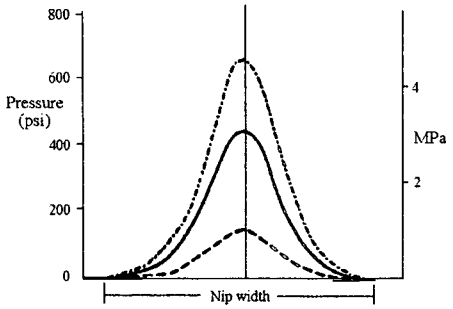
- The amount of water removed is a complex function of a large number of factors.

Primary	Secondary
Post-nip rewet	Initial felt flow resistance
Ingoing web dryness	Ingoing felt dryness
Grammage	Rewet in the nip at speed
Furnish properties	Shape of pressure profile
Double felting	Roll cover
Sheet temperature	Felt design
Impulse (Pressure x time)	Roll venting
Felt pressure uniformity	

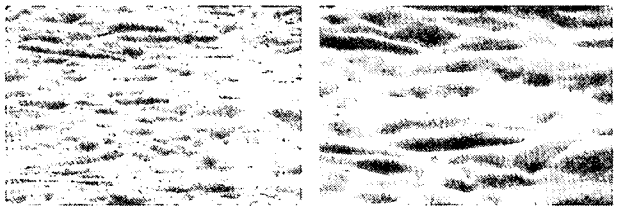
Primary Variables

- **Press loading**
  - Nip load : kN/m or pli
  - Press action is a function of nip loading per unit area.
  - Moisture removal is directly related to nip pressure.
  - The pressure varies continuously in the machine direction within the nip.
  - Average nip pressure
    - ANP(kPa) = Nip load(kN/m) / Nip width(m)
    - ANP(psi) = Nip load(pli) / Nip width(in)

- **Press load uniformity**
  - The largest factor in nip pressure uniformity is the felt.
  - There are significant variations in peak pressures at constant press load.
    - 100 psi ~ 500 psi
    - 226 psi ~ 2677 psi
  - The felt fibers are very coarser than the web structure
  - The water removal is affected by the felt nonuniformity or nonuniform pressure application.
  - The fineness of felt surface can control sheet dryness.
    - Nonuniform contact → nonuniform mechanical pressure → localized high hydraulic pressure → lateral transfer of water → nonuniform solid

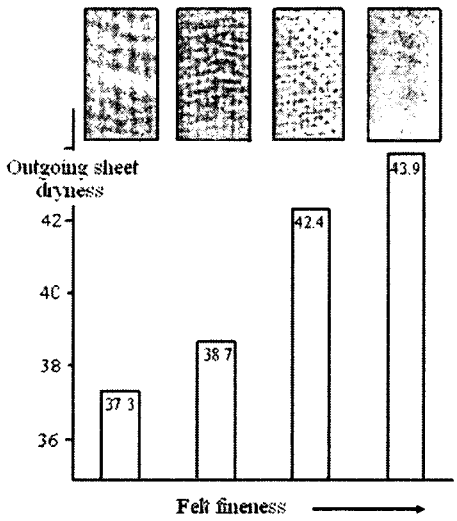


Peak pressure variations



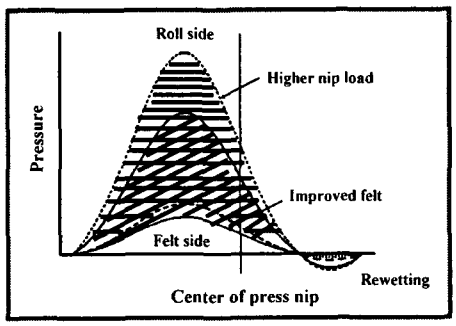
X48 **X90**

Foil impressions of felt under loading



Felt fineness and dryness

- **Machine speed**
  - As speed is increased, water removal from the web will decrease with other conditions held constant.
  - The more fundamental variable is nip residence time(NRT).
    - NRT(sec) = {Nip width(in) x 5} / Machine speed(fpm)
- **Press impulse(Nip impulse)**
  - Press impulse = Average nip pressure x nip residence time
  - Press impulse = Nip load / Machine speed
  - Two way of increasing water removal
    - Application of a greater nip load increases the hydraulic pressure and the nip impulse.
    - Installation of a more permeable felt or a more open press roll increases the water removal by reducing the hydraulic pressure on the bottom side of the web.



$$Nip\ impulse = \int_{Tb}^{Te} (P_1 - P_2)dt$$

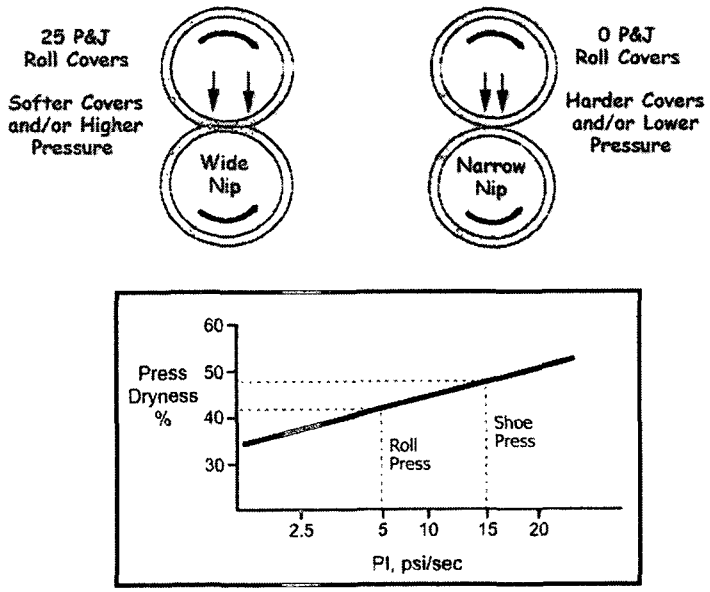
T_b : time, pulse beginning

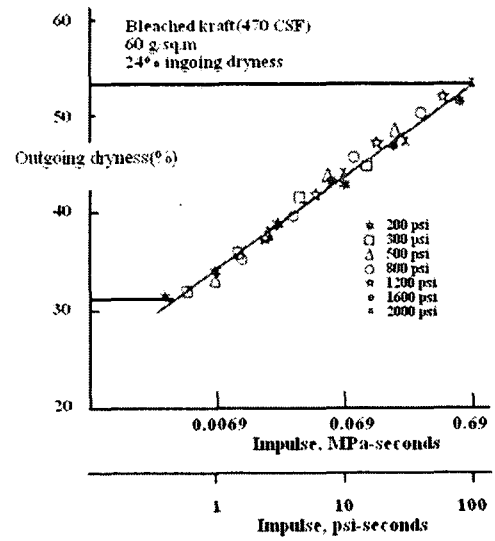
T_e : time, pulse end

P_1, P_2 : pressure on the two sides

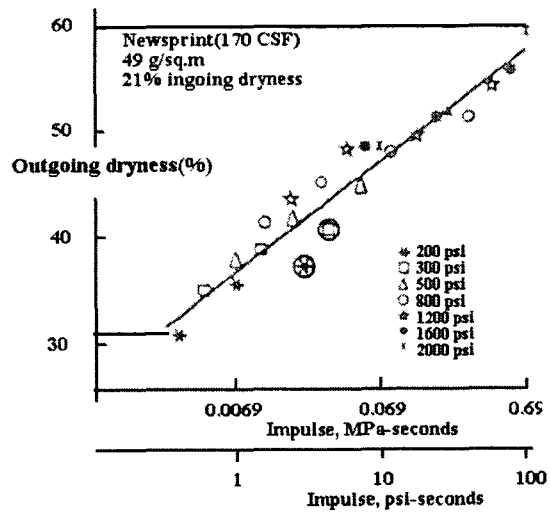
- In a single felted press,
  - The felt offers relatively low resistance to a vertical water flow.
  - The hydraulic pressure is greater on the roll side than on the felt side.
- The hydraulic pressure differential between the two sides of the web is the **driving force for water removal.**
- The amount of water removed is proportional to the **hydraulic pressure differential** or **nip impulse.**

- Average nip pressure(psi) = nip pressure(pli)/nip width(in.)
  - ANP = 500(pli)/0.25(in.) = 2,000
  - ANP = 500(pli)/1.0(in.) = 500
- Nip residence time(sec) = {(nip width, pli) x 5}/speed(fpm)
  - NRT(sec) = {0.25(in) x 5}/2,000(fpm) = 0.000625
  - NRT(sec) = {1.0(in) x 5}/2,000(fpm) = 0.0025
  - The nip residence time can be extended by the application of
    - Softer roll covers
    - More compressible felts
    - Larger diameter press rolls
    - Shoe press

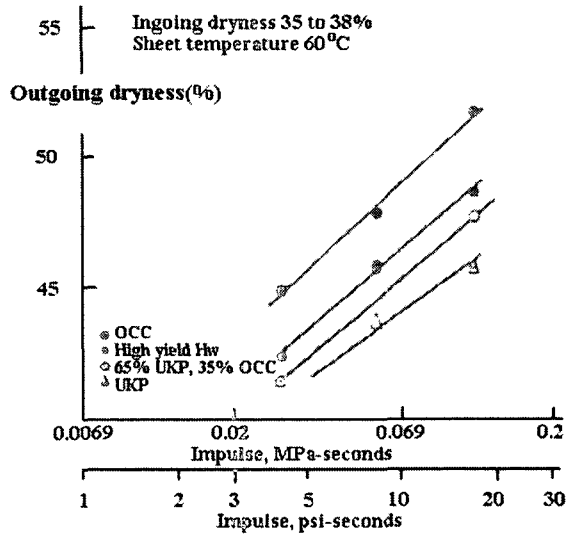




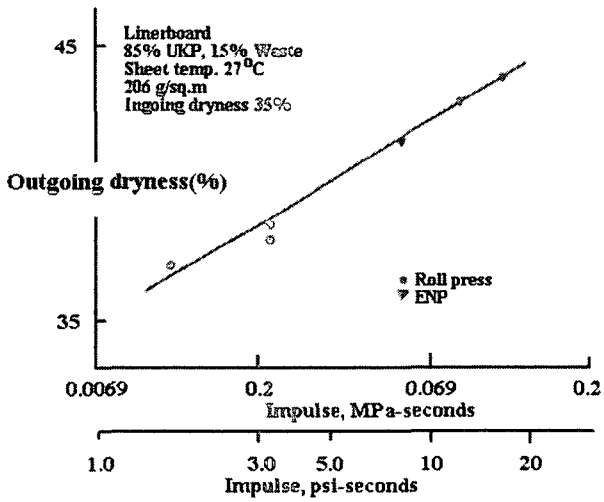
Pressure impulse and dryness (BKP)



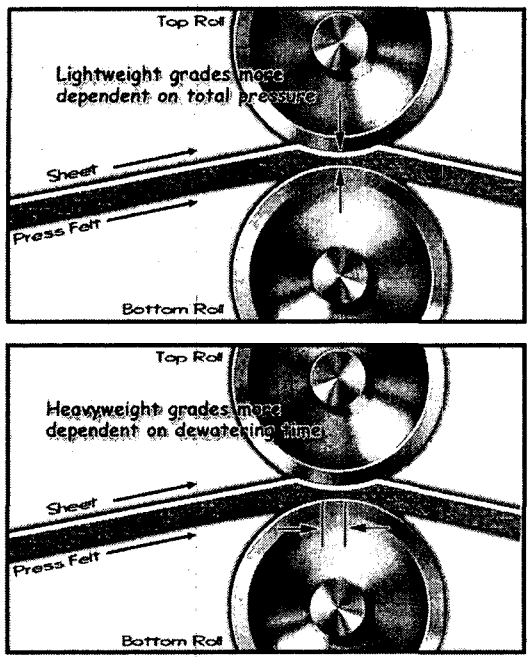
Pressure impulse and dryness (Newsprint)



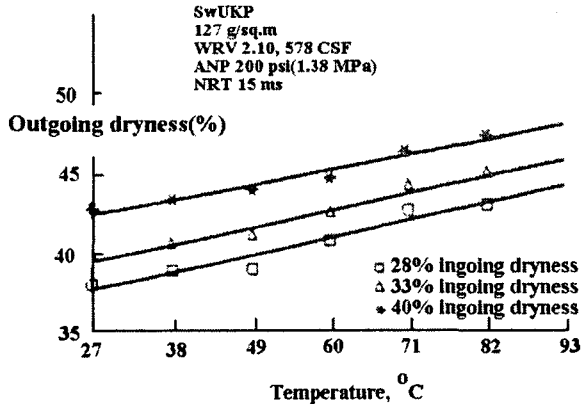
Pressure impulse and dryness (Linerboard)



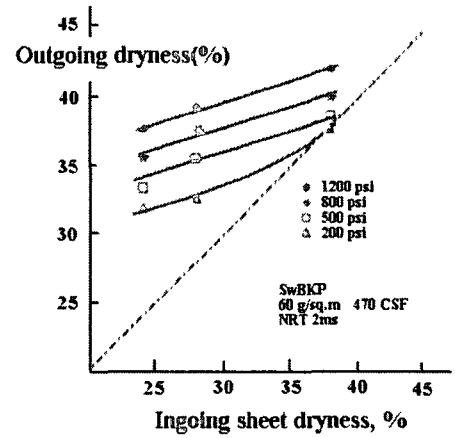
Pressure impulse and dryness (roll and extended nip press)



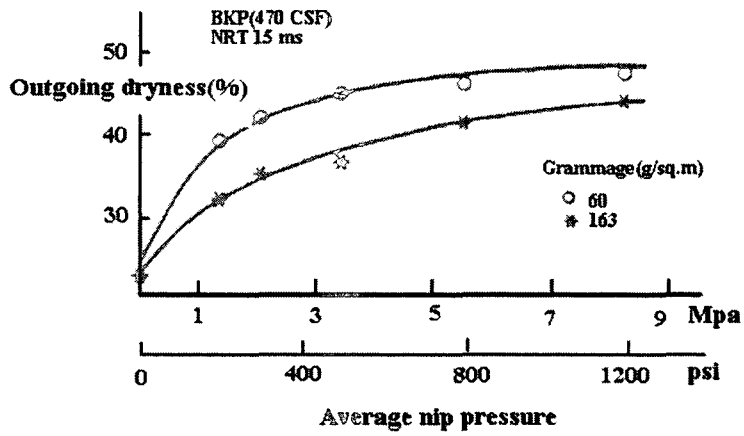
- **Web temperature**
  - As the web temperature is raised,
    - Both surface tension and viscosity of the water decrease
    - Lowers the resistance of water movement through the sheet into a felt at the press



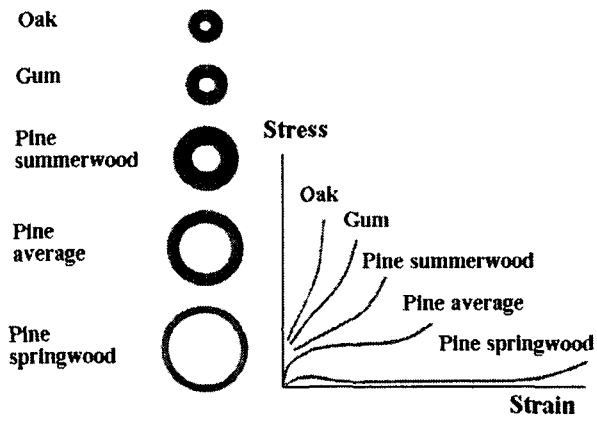
- **In-going web dryness**
  - In-going dryness is a major factor in determining out-going dryness.
  - It is more often viewed as one of the determinants of water load to the nip.
  - It is established by prior processing rather than being a controlled variable.



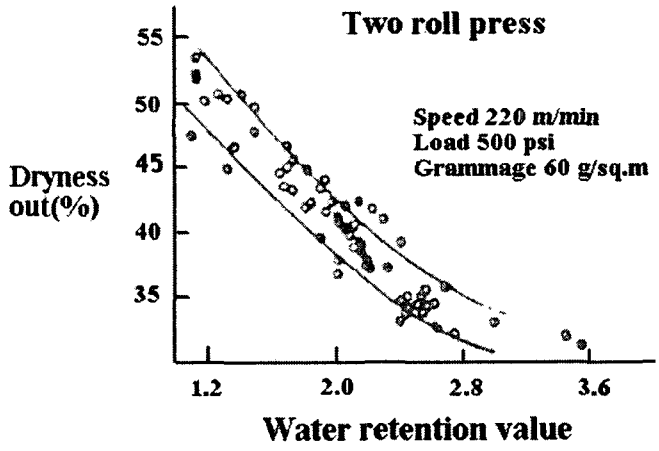
- **Basis weight (Grammage)**



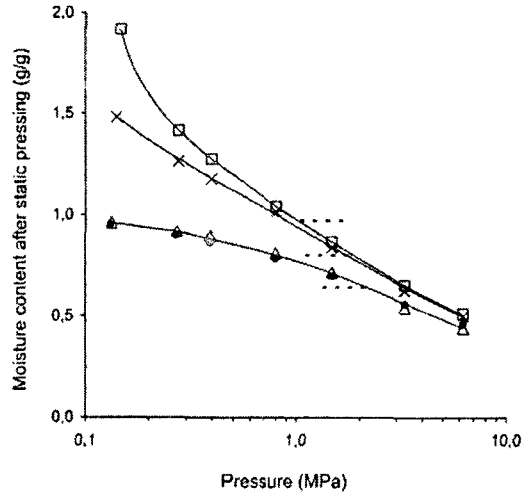
- **Furnish properties**



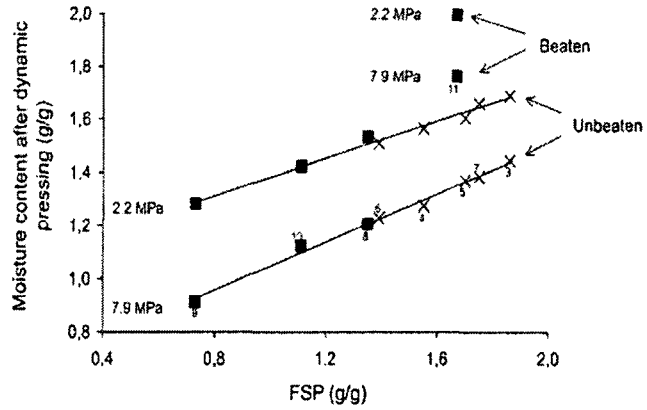
Cross-sections and stress-strain behavior of different fibers



Water retention value and dryness



Static pressing response of never dried, unbeaten USW(X) ; never dried, beaten USW(□) ; hornified, unbeaten USW(●) ; TMP(Δ).



Moisture content after dynamic pressing(16-17 ms pulse)

■ : USW, X : UHW

- **Felting**
  - The wet felt is the receptor that acts as an absorptive interface between the press and the web.
  - Felt surface uniformity can have a dramatic effect on water removal.
  - The difference in void volume between the compressed and relaxed conditions is a approximation of the absorptive capacity.
  - More important thing is the felt's void volume at the most compressed state.
  - Double felting has been an effective method of increasing water removal in press.
- **Rewet**

STRATEGIES FOR MAXIMIZING WATER REMOVAL

- Increase nip width (nip residence time)
- Minimize the maximum horizontal travel distance of water
- Selection of the optimum felt for stock/press characteristics
- Increase nip impulse (pressure impulse)
- Minimize the rewetting of web and felt
- Strict maintenance of felt
  - Maintain cleanness
  - Maximize the porosity and permeability

OPTIMIZATION OF WET PRESS SECTION

- **Document current performance**
  - Review current press design specifications and drawings
  - Note any press section operation problems
  - Determine the web solid after forming section and after press nip where samples can be obtained
  - Available press section operating parameters
  - Note information on press rolls
  - Note information on press fabric
  - Review CD profiles of fabric MC, caliper and permeability
  - Check vacuum sources
  - Note suction box cover type and open area
  - Note fabric cleaning system and chemicals
  - Review papermachine operation records for a period of at least 6 months
  - Review paper quality parameters
  - Check fabrics

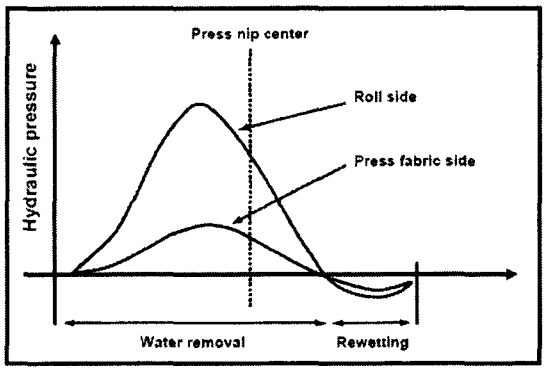
- **Implement use of detailed log book**
  - Routine use of a log book should be implemented to document all changes that could have an effect on press section performance
  - Detailed records are necessary to confirm the effectiveness of any change

- **Press section operation review**
  - If web solid entering the press section is low ?
  - Are the indicated press loads being applied to the web ?
  - Are press nips uniform across the machine and rolls properly aligned ?
  - How would changing the relative press loads between presses after final sheet dryness or sheet properties ?
  - Are the best fabric designs being used for the operating parameters ?
  - Is fabric conditioning a problem ?
  - Is vacuum application to suction press rolls and suction boxes adequate ?

- Are press rolls left in the machine too long ?
- Are press fabrics left on the machine too long ?
- Are there opportunities to increase temperature of the web ahead of the last press nip ?
- Is press section doctor application satisfactory ?
- Is sheet threading through the press section a problem ?
- Is press section vibration a problem ?
- What are individual and total draws in the press section ?
- Is rewet occurring after press nip ?
- Are fabrics being damaged by paper wads ?
- What is the state-of-the-art press design for the grade being produced ?

- **Press section monitoring**
  - TIP 0404-19

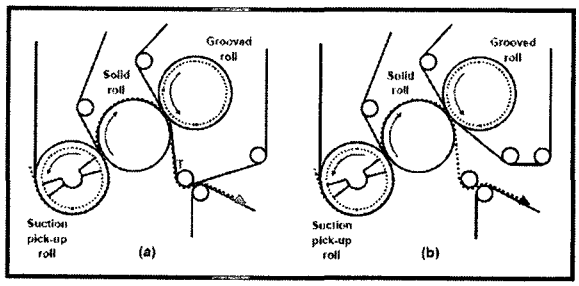
MINIMIZATION OF SHEET REWET



- Intra-nip rewet
- Post-nip rewet

- **Intra-nip rewet**
  - Re-absorption of moisture by the web prior to web exit from the nip
  - On the incoming nip side, all the air and a portion of water contained in the web and in the press fabric are squeezed out
  - In the middle of the nip, all voids in the sheet/fabric sandwich are filled by water
  - New voids are created and filled with air as the web and fabric expand on the outgoing side of the nip
  - Rewetting start as the pressure is reduced in the nip between mid-nip and the point of web/fabric separation
  - Rewetting in this area depends on the rate of expansion of the web and fabric and on fabric moisture content
  - The film of water between the sheet and press fabric is interrupted at the point where the web separates from the fabric
  - A large portion of this interfacial water film remains with the web since it has smaller capillaries and thus generates greater capillary forces

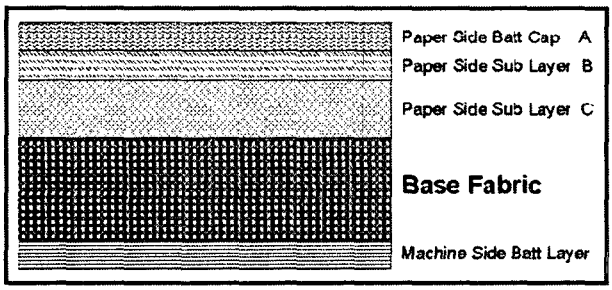
- **Post-nip rewetting**
  - Moisture gain by the web following the press nip due to contact with the press fabric
  - It increases with time, MC, and rougher fabric surfaces, and can depend on the surface and compression characteristics of the web
    - A contact length of 1 m after the nip could lower the web solids
      - 5% for 49 g/m^2 newsprint(900 m/min)
      - 6% for 200 g/m^2 linerboard



FACTORS AFFECTING REWET

- **Web run effects**
  - Minimizing sheet-to-fabric contact outside the nip is the most practical approach to reducing post-nip rewet
  - Speed has an effect on the amount of rewet
    - The amount of post-nip rewet increases with increasing web-fabric contact time for speeds up to 1000 m/min (newsprint)
    - The post-nip rewet is negligible at speeds greater than 1200 m/min
  - Transfer belts receive no water and hence do not contribute to rewet

- **Fabric effects**
  - When the web expands while still within the nip during initial pressure release, it will take up more water from the fabric when surface is uneven.
  - On light grades, one tries to minimize intra-nip rewet and maximize pressure uniformity by using as fine a batt fiber as possible without increasing wear, fill-up, compaction and excessive felt-hair loss
  - It is important that the water removed from the web flow away from the web as quickly as possible so the fabric is as dry as possible



- **Surface layer**
  - ✓ **Fine surface**
  - ✓**Hydrophobic**
  - ✓**Minimize water accumulation**
- **Lower/Main structure**
  - ✓**Highly permeable**
  - ✓**Trap water**
  - ✓**Prevent water back**

- **Effects of temperature**
  - Use of steam boxes
    - Increase web temperature
    - Result in lower water viscosity
    - Increase water removal
    - Lower surface tension
    - Decrease rewetting
  - Higher web temperature decreases the web spring back, decreasing rewetting tendency.
- **Effect of web**
  - The effect of rewet for heavyweight grades is much less significant than for lightweight grades
  - For a given grades, the amount of rewetting is somewhat greater for less consolidated web leaving the nip with lower exiting solids
  - More resilient web (mechanical grades) rewet more than less resilient web (wood-free grades), especially at high dryness levels

RELATED REFERENCES

- The Paper Machine Wet Press Manual, 3rd Edition, TAPPI Press
- Determination of water removal by wet pressing : TAPPI TIS 0404-01
- Press section economic evaluation : TAPPI TIS 0404-22
- Press section monitoring : TAPPI TIS 0404-19
- Press section optimization : TAPPI TIS 0404-52
- Press section water balance using potable sensors : TAPPI TIS 0502-18
- Water permeability of press fabrics : TAPPI TIS 0404-43
- Press roll cover application guidelines : TAPPI TIS 0404-37
- Papermachine shower recommendation : TAPPI TIS 0404-61
- Physical characterization of press fabrics : TAPPI TIS 0404-20
- Technique for nip impressions : TAPPI TIS 0404-46
- Porosity measurement of press felts : TAPPI TIS 0404-29