TIP 0502-17

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Papermaker's formulas

Scope

This is a set of equations that can be used by paper mill superintendents and engineers during their day-to-day operation of the paper machine. Also included are general guidelines for the acceptable ranges of some of the variables being calculated. This is expected to be a dynamic list and the Papermakers Committee would welcome any additions or corrections that will make the list more useful.

Safety precautions

Anyone working around paper machines needs to be well trained in the hazard associated with operating machinery. The use of these equations will not cause hazard conditions but collection of data to make some of these calculations will present situations where expertise in the safety requirements of operating paper machines is absolutely necessary.

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Formulas

1. ***Tank sizing and capacity***

English Units	SI Units
$\text{Tons} = \dfrac{\dfrac{\text{lb}}{\text{ft}^3} \times \text{Volume}}{2000\ \text{lb/ton}}$ $= \dfrac{\%\text{B.D.} \times \text{Volume}}{1.6 \times 2000}$ Volume = 3200 × tons / %B.D. US Gallons = Volume / 7.4805	t = Volume × %B.D. / 100 Volume = t × 100 / %B.D.
where: lb/ft^3 = Weight of dry stock per volume of slurry Volume = volume of tank (ft^3) %B.D. = percent consistency of stock 1 US gallon = 231 in^3	where: t = metric tons Volume = volume of tank (m^3) %B.D. = percent consistency of stock

2. *Hydraulic pump power*

English Units	SI Units
$\text{Hydraulic Pump Power} = H \times Q/1714$	$\text{Hydraulic Pump Power} = H \times Q/60000$
Power (hp) H = Differential pressure from pump (psi) Q = flow (gal/min)	Power (kW) H = Differential pressure from pump (kPa) Q = flow (l/min)

In centrifugal pumps or blowers -

A. Capacity varies directly with speed
B. Head varies as the square of speed
C. Power varies as the cube of speed

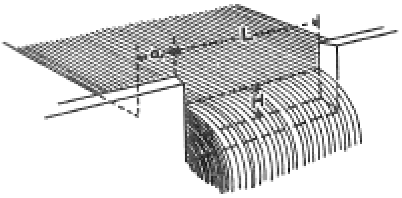
3. *Pipeline and channel velocity*

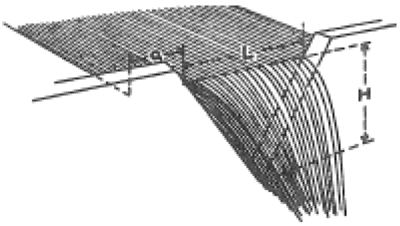
$V = Q \times k_1 / r^2$
$V = Q \times k_2 / A$

English Units	SI Units
Where, V = velocity (ft/s) Q = flow (gal/min) $k_1 = 0.0007092$ $k_2 = 0.321$ r = pipe inside radius (ft) A = pipe or channel cross sectional area (in.^{2})	Where, V = velocity (m/s) Q = flow (L/s) $k_1 = 3142$ $k_2 = 0.001$ r = pipe inside radius (m) A = pipe or channel cross sectional area (m^2)
Screen to headbox acceptable range is 7 to 14 ft/s.	Screen to headbox acceptable range is 2.1 to 4.3 m/s.

Note: These formulas are for savealls and general pipe flow, since there is no orifice coefficient included.

4. *Weir water flows*





Rectangular weir with end contractions

English Units	SI Units
$Q = C_d \times \frac{2}{3} \times \sqrt{2g} \times L \times H^{3/2}$ Where $C_d = 0.622 \times \left(1 - 0.2 \times \frac{H}{L}\right)$	
$Q = 3.33 \times (L - 0.2 \times H) \times H^{1.5}$	$Q = 1.837 \times (L - 0.2 \times H) \times H^{1.5}$
Q = Flow (ft^3/s) L = length of weir opening (ft) (should be 4-8 times H) H = head on weir (ft) (~6 ft back of weir opening) a = at least 3H (side of chamber to edge of weir opening)	Q = Flow (m^3/s) L = length of weir opening (m) (should be 4-8 times H) H = head on weir (m) (~2 m back of weir opening) a = at least 3H (side of chamber to edge of weir opening)

Triangular Notch Weir with End Contractions

English Units	SI Units
$Q = C \times (4/15) \times L \times H \times \sqrt{2 \times g \times H}$	
Q = Flow (ft^3/s) L = width of notch at H distance above apex (ft) H = head of water above apex of notch (ft) C = 0.57 a = should be not less than ¾L (side of chamber to edge of weir opening) g = 32.174 ft/s^2	Q = Flow (m^3/s) L = width of notch at H distance above apex (m) H = head of water above apex of notch (m) C = 0.57 a = should be not less than ¾L (side of chamber to edge of weir opening) g = 9.81 m/s^2
For 90° notch, the formula becomes:	
$Q = 2.4381 \times H^{5/2}$	$Q = 1.3466 \times H^{5/2}$
For 60° notch, the formula becomes:	
$Q = 1.4076 \times H^{5/2}$	$Q = 0.7776 \times H^{5/2}$

5. ***Theoretical head (approximate headbox pressure required to achieve target jet speed)***

English Units	SI Units
$\text{Theoretical Head} = (V/100)^2/K$	$\text{Theoretical Head} = (V)^2/70610$
V = spouting velocity (ft/min) K = constant (see table)	Head (m of H_2O) V = spouting velocity (m/min)

Units for Head	K
in. of H_2O	1.9304
ft. of H_2O	23.165
in. of Hg	26.196
PSIG	53.336

6. ***Approximate spouting velocity***

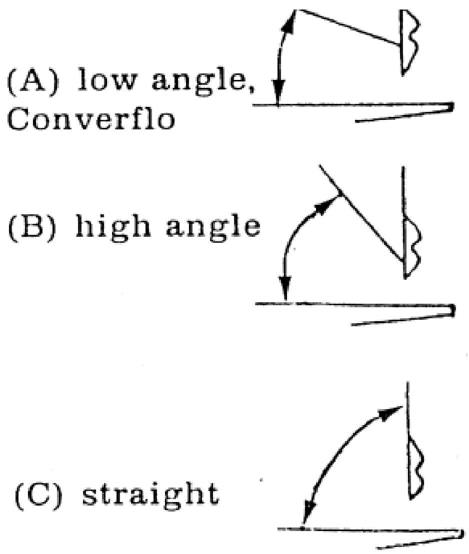
English Units	SI Units
$V = K\sqrt{h}$	$V = 265.7\sqrt{h}$
V = spouting velocity (ft/min) h = head (units consistent with table for K) K = constant (see table below)	V = spouting velocity (m/min) h = head (m H_2O)

Head	in. of H_2O	ft. of H_2O	in. of Hg	PSIG
K	139.2	481.5	513.3	732.3

7. ***Headbox flow rate per unit width (slice method)***

English Units	SI Units
$\text{gal/min/in.} = \text{S.O.} \times \text{V} \times 0.052 \times \text{C}_c$	$\text{L/min/m} = \text{S.O.} \times \text{V} \times \text{C}_c$
V = spouting velocity (ft/min) S.O. = slice opening (in.) C_c = orifice (contraction) coefficient (See table for approximate values)	V = spouting velocity (m/min) S.O. = slice opening (mm) C_c = orifice (contraction) coefficient (See table for approximate values)

Type	**C_c**
Nozzle	0.95
A	0.75
B	0.70
C	0.60



8. ***Approximate headbox slice flow rate per unit width (consistency method)***

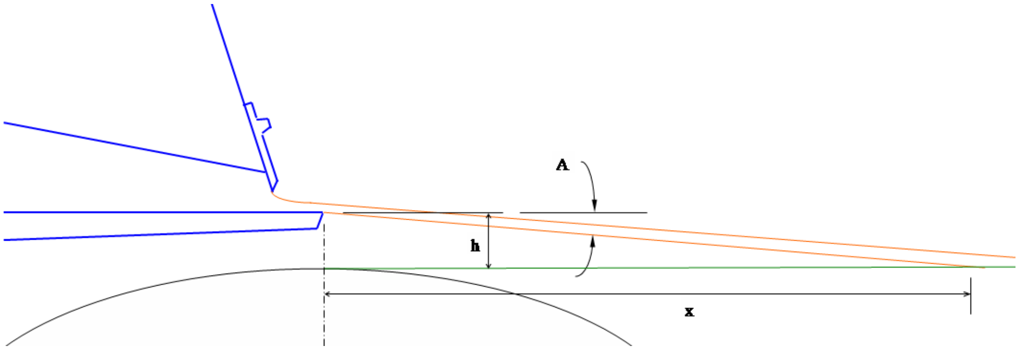
English Units	SI Units
$\text{gal/min/in.} = \dfrac{(\text{B.D.Ton/24 hr/in.})(16.76)(1.5 - \text{Tray Consistency})}{1.5 \times \text{Net Consistency}}$	$\text{L/min/m} = \dfrac{(\text{B.D.MT/d/m})(70)(1.5 - \text{Tray Consisitency})}{1.5 \times \text{Net Consistency}}$
Net Consistency = Headbox Consistency - Tray Consistency	

9. ***Tissue headbox flow rate per unit width***

English Units	SI Units
$\text{gal/min/in.} = \text{T.O.} \times \text{V}/19.25 = \text{T.O.} \times \text{V} \times 0.052$	$\text{L/min/m} = \text{T.O.} \times \text{V}$
T.O. = throat opening (in.) V = spouting velocity (ft/min)	T.O. = throat opening (mm) V = spouting velocity (m/min)

Note: assumes contraction (orifice) coefficient = 1.0

10. ***Headbox free jet length***



$$x = \frac{\upsilon \cos A}{g}\left(\sqrt{\upsilon^2 \sin^2 A + 2gh} - \upsilon \sin A\right)$$

Notes: a) Applies for case of level jet landing surface (fabric).
b) Use positive value for angle A with jet downward from horizontal.
c) See TIPs 0410-02, 0410-03, and 0410-04 for estimating jet angle, A.

English Units	SI Units
$x = \frac{\upsilon \cos A}{9652.5}\left(\sqrt{\upsilon^2 \sin^2 A + 19304h} - \upsilon \sin A\right)$	$x = \frac{\upsilon \cos A}{35305}\left(\sqrt{\upsilon^2 \sin^2 A + 70610h} - \upsilon \sin A\right)$
υ = initial jet velocity (ft/min) A = jet angle (degrees) g = 32.174 ft/s^2 h = height of apron tip to wire (in.) x = jet length, apron to landing (in.)	υ = initial jet velocity (m/min) A = jet angle (degrees) g = 9.807 m/s^2 h = height of apron tip to wire (m) x = jet length, apron to landing (m)

11. ***Flow/tons/consistency relationship***

English Units	SI Units
Ton/d = C × Q / K	t/d = C × Q × 4.1727/ K
Where, C = consistency (%) Q = flow (gal/min) K = a temperature related factor (see below)	Where, C = consistency (%) Q = flow (l/min) K = a temperature related factor (see below)

T (°F)	T (°C)	K
100	37.8	16.76
120	48.9	16.83
140	60	16.93

12. *Retention*

Retention (%) = (Net Consistency / Headbox Consistency) × 100

Retention (%) = [(Headbox Consistency – Tray Consistency) / Headbox Consistency] × 100

13. *Approximate stock thickness on forming fabric*

English Units	SI Units
$T = \dfrac{BW \times 0.1925}{C \times R \times \text{Ream} \times (J/W)}$	$T = \dfrac{BW/10000}{C \times R \times (J/W)}$
T = thickness of stock on table (in.) BW = basis weight (lb) Ream = ream size (ft^2) C = consistency (%/100) R = retention from that point down the rest of the machine (%/100) J/W = jet/wire ratio = 1.0 except at slice	T = thickness of stock on table (cm) BW = basis weight (g/m^2) C = consistency (%/100) R = retention from that point down the rest of the machine (%/100) J/W = jet/wire ratio = 1.0 except at slice

Note: Result T for headbox slice is after vena contracta.

Example: Determine the overall retention of a machine with slice opening of 0.5 in. (1.27 cm) making 50 g/m^2 at 0.6% slurry and jet/wire ratio of 0.95. Assume the headbox jet contraction coefficient is 0.75 yielding final jet thickness after vena contracta of 0.375 in. (0.952 cm).

$$R = \frac{50/10000}{0.0060 \times 0.952 \times 0.95} = 0.921\text{, or } 92.1\%$$

14. *Fourdrinier forming length guidelines*

Wire Speed or Grade	Dwell Time (sec) (headbox slice to first flatbox or dandy roll)	Machine Speed that can be Supported
<1200 ft/min (<366 m/min)	1.5	Forming Length × 40
	2.0	Forming Length × 30
> 1200 ft/min (<366 m/min)	1.0	Forming Length × 60
42lb/1000ft^2 Liner (205 g/m^2)	1.25	Forming Length × 48
Foodboard	2.0	Forming Length × 30

Resulting machine speed is in ft/min with forming length in feet or in m/min with forming length in meters.

15. ***Formation - blade pulse frequency***

$$f = \frac{V}{k \times \lambda}$$

English Units	SI Units
V = wire speed (ft/min) λ = blade spacing, tip to tip (inches) k = 5	V = wire speed (m/min) λ = blade spacing, tip to tip (m) k = 60

Optimum frequency for formation improvement varies by grade: typically, f > 60 cycles/sec and can be as high as 150 cycles/sec.

16. ***Fourdrinier shake number***

$$\text{Shake Number} = \frac{\text{Amplitude} \times (\text{Frequency})^2}{\text{Wire Speed}}$$

English Units	SI Units
With, Amplitude (stroke length) (in.) Frequency (strokes per min) Wire Speed (ft/min)	With, Amplitude (stroke length) (mm) Frequency (strokes per min) Wire Speed (m/min)
Formation benefit normally seen at shake number over 30. Suggested target is 50-60. Shake numbers greater than 60 may be beneficial but equipment limitations often prevent reaching higher values.	Formation benefit normally seen at shake number over 2500. Suggested target is 4200-5000. Shake numbers greater than 5000 may be beneficial but equipment limitations often prevent reaching higher values.

17. ***Dandy roll rotational speed***

$$\text{RPM} \cong \frac{\text{Wire Speed}}{3.142 \times \text{Dandy Roll Diameter}}$$

English Units	SI Units
With , RPM = rotational speed (rev/min) Wire Speed (ft/min) Diameter (ft)	With , RPM = rotational speed (rev/min) Wire Speed (m/min) Diameter (m)

Target = 125 - 150 rev/min
Equation is shown as approximate due to potential for slippage between dandy and wire.

18. ***Gas laws (commonly used in vacuum system applications)***

$P \times V = \eta \times R \times T$ (Ideal Gas Law)

$P_1 \times V_1 = P_2 \times V_2$ (Boyle's Law)

English Units	SI Units
$V_2 = \frac{29.92 - P_1(\text{in. Hg})}{29.92 - P_2(\text{in. Hg})} \times V_1(\text{cfm})$	$V_2 = \frac{1.0132 - P_1(\text{bar})}{1.0132 - P_2(\text{bar})} \times V_1(\text{m}^3/\text{h})$
or for temperature cooling effects, the combined gas law: $\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$	
P = absolute pressure, lb/ft^2 = (psi gauge + 14.7) × 144 V = total gas volume (ft^3) η = weight of gas (lbf) T = absolute temperature (°R = °F + 460) R = gas constant [ft•lbf / (lb•mol × °R)] R_a (air) = 53.3 R_w (water vapor) = 85.8	P = absolute pressure, bar = (bar gauge + 1.0132) V = total gas volume (m^3) η = weight of gas (kg) T = absolute temperature (°K = °C + 273.15) R = gas constant [bar• m^3 / (kg•mol × °K)] R_a (air) = 0.00287 R_w (water vapor) = 0.004614

19. ***Tension power***

English Units	SI Units
$\text{Tension HP} = \frac{N \times F \times w}{33000}$	$\text{Tension P} = \frac{N \times F \times w}{60}$
HP = Horsepower N = Speed (ft/min) F = Tension (lbf /in.) w = width (in.)	P = Power (kW) N = Speed (m/min) F = Tension (kN/m) w = width (m)

20. ***Drag load- conventional***

English Units	SI Units
$DL = \frac{\Sigma(V \times A)}{0.226 \times v \times S} \times 0.8$	$DL = \frac{\Sigma(V \times A) \times 0.06}{v \times S} \times 0.8$
DL = drag load (lbf/in.) V = Drive Volts (V) A = drive amps (AMPS) v = nominal fabric speed (ft/min) S = nominal fabric width (in.)	DL = drag load (kN/m) V = Drive Volts (V) A = drive amps (AMPS) v = nominal fabric speed (m/min) S = nominal fabric width (m)

21. *Component drag load (wet end)*

English Units	SI Units
$DL = (V_n/V_s - 1)(EM - T_s)$	$DL = (V_n/V_s - 1)(EM - T_s)$
DL = dragload (lbf/in.) V_n = fabric speed at point n in fabric run (ft/min) V_s = fabric speed on slack side of fabric run (ft/min) EM = fabric elastic modulus (Young) at temperature T (lbf/in.) $\approx EM_r - KT$ EM_r = elastic modulus at reference temperature r (lbf/in.) K = Modulus/temperature constant (lbf/in./°F) T_s = slack side tension (lbf/in.)	DL = dragload (kN/m) V_n = fabric speed at point n in fabric run (m/min) V_s = fabric speed on slack side of fabric run (m/min) EM = fabric elastic modulus (Young) at temperature T (kN/m) $\approx EM_r - KT$ EM_r = elastic modulus at reference temperature r (kN/m) K = Modulus/temperature constant (kN/m/°C) T_s = slack side tension (kN/m)

22. *Approximation for vacuum component line load when taking nip impressions*

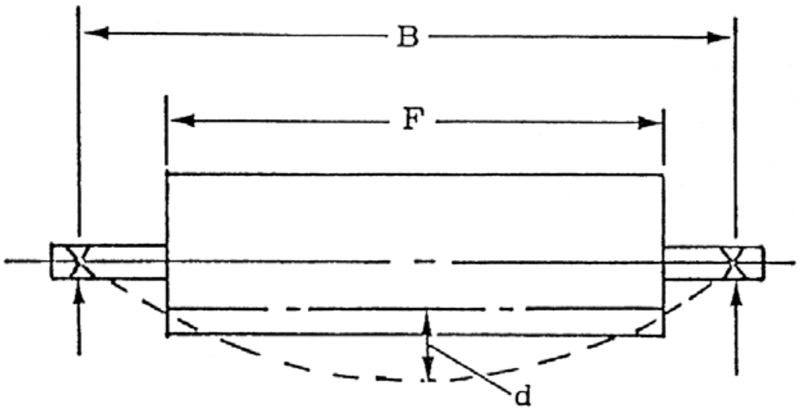
English Units	SI Units
$\text{Line Load} = \dfrac{\text{Vacuum Box Width} \times \text{Vacuum}}{3}$	$\text{Line Load} = \dfrac{\text{Vacuum Box Width} \times \text{Vacuum}}{1.5}$
Line Load (lbf/in.) Vacuum Box Width (in.) Vacuum (in. Hg)	Line Load (kN/m) Vacuum Box Width (m) Vacuum (kPa)

23. *Approximate method for determining proper change in total crown of two rolls from nip impression width*

$$C = \frac{(N_e^2 - N_c^2)(D_1 + D_2)}{2D_1D_2}$$

C = change in total crown of two rolls
N_e = Nip width at ends
N_c = Nip width at center
D_1 = Top roll diameter
D_2 = Bottom roll diameter
Units: can be either SI or English but must be consistent.

24. ***Deflection of a roll over face (normally used for crown calculations)***



$$d = \frac{wF^3(12B - 7F)}{384EI}$$

English Units	SI Units
d = deflection (in.) over face w = resultant unit load on shell (lbf/in.) F = shell face (in.) B = centerline to centerline bearings (in.) E = modulus of elasticity (lbf/in^2) I = moment of inertia (in^4) = 0.0491 (D_O^4 - D_I^4) D_O = outside diameter (in.) D_I = inside diameter (in.)	d = deflection (m) over face w = resultant unit load on shell (kN/m) F = shell face (m) B = centerline to centerline bearings (m) E = modulus of elasticity (kN/m^2) I = moment of inertia (m^4) = 0.0491 (D_O^4 - D_I^4) D_O = outside diameter (m) D_I = inside diameter (m)

25. ***Press impulse***

English Units	SI Units
PI = 5 × PLL / Speed	PI = 0.060 × PLL / Speed
PI = Press Impulse (PSI•s) PLL = press line load (lbf/in.) Speed = nip speed (ft/min)	PI = Press Impulse (MPa•s) PLL = press line load (kN/m) Speed = nip speed (m/min)

26. ***Paper web draw***

$$\text{Draw, \%} = \left(\frac{S_F - S_I}{S_I}\right) \times 100$$

S_F = final speed
S_I = initial speed

27. ***Drying rate for uncoated paper***

$$M = \frac{L}{E} - 1 \qquad R_W = 60\frac{SBM}{NA\pi D}$$

where
R_W = drying rate, amount of water evaporated
S = machine speed
B = basis weight of the sheet as it leaves the dryer section as dried (wet basis)
M = weight of water evaporated per unit weight of paper as dried (wet basis)
N = number of steam-heated dryers which contact the sheet
A = area of standard ream
D = diameter of dryer cylinders
L = percent dryness (wet basis) of sheet leaving the last cylinder (the larger number)
E = percent dryness (wet basis) of sheet entering on the first cylinder (the smaller number)

English Units	SI Units
R_W (lb/h•ft^2) S (ft/min) B (lb/ream) A (ft^2) D (ft)	R_W (kg/h•m^2) S (m/min) B (kg/ m^2) A (1.0 m^2) D (m)

28. ***Drying Rate for coated paper***

Use formula #27 except that values for basis weight and entering dryness are determined using the following formulas.

$$B = \frac{B_c(P/100) + W}{(L/100)} \qquad E = 100 - 100\left[\frac{B_c(1 - \frac{P}{100}) + W(\frac{100}{C} - 1)}{B_c + \frac{(100W)}{C}}\right]$$

Where,
B_c = basis weight of the sheet entering the coater (wet basis)
W = dry coating weight applied
P = basis percent dryness of sheet entering coater
C = percent coating solids in coating solution as applied to the sheet (wet basis)

English Units	SI Units
B_c (lb/ream) W (lb/ream)	B_c (kg/ m^2) W (kg/ m^2)

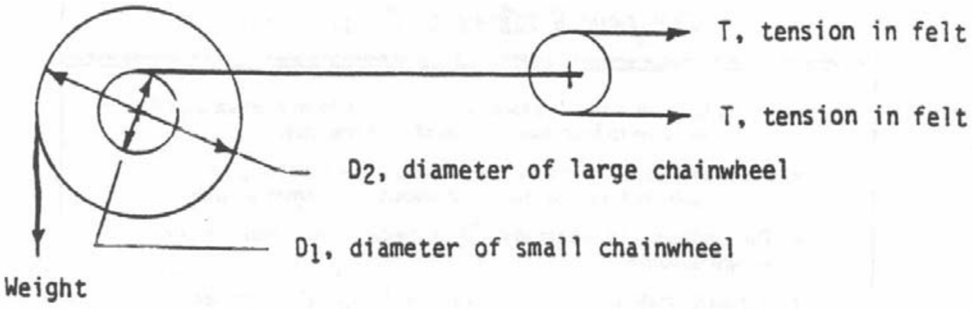
29. ***Rimming speed (5-ft and 6-ft dryers)***

$$\text{Rimming speed (ft/min)} = [5720 - (2160/D)]\ L^{1/3}$$

where
D = inside diameter of roll (ft)
L = condensate film thickness (ft)

Note: This is an empirical equation. Use English units and convert result to SI (multiply result by 0.3048 to obtain m/min)

30. ***Dryer felt tension (hanging weight tensioner)***



Note: Sometimes chainwheel teeth can be counted easier than determining chainwheel diameter. If this is the case, N_1 and N_2, the number of small and large chainwheel teeth, can be used in place of D_1 and D_2 in the equation below.

English Units	SI Units
$T = \dfrac{W \times D_2}{2 \times FW \times D_1}$	$T = \dfrac{0.00981 \times W \times D_2}{2 \times FW \times D_1}$
T = Felt Tension (lbf/in.) W = Weight (lbf) D_1 & D_2 (in.) FW = Felt Width (in.)	T = Felt Tension (kN/m) W = Mass (kg) D_1 & D_2 (m) FW = Felt Width (m)
Common material densities: Carbon Steel: 0.284 lbf/in^3 Wrought Iron: 0.278 lbf/in^3 Stainless Steel: 0.290 lbf/in^3 Gray Cast Iron: 0.260 lbf/in^3	Common material densities: Carbon Steel: 7861.1 kg/m^3 Wrought Iron: 7695.0 kg/m^3 Stainless Steel: 8027.2 kg/m^3 Gray Cast Iron: 7196.8 kg/m^3

31. *Tissue crepe*

There are two commonly used methods to describe crepe (note that results are different and not directly comparable):

Method 1: %Crepe = ((Yankee Speed – Reel Speed)/Reel Speed)*100

Method 2: %Crepe = ((Yankee Speed – Reel Speed)/Yankee Speed)*100

Units can be either English or SI but must be used consistently.

32. *Instantaneous production rate (off reel)*

English Units	SI Units
$P = S \times BW \times T \times 5 / R$	$P = S \times BW \times T \times 0.06$
P = production (lb/h) S = speed (ft/min) BW = basis weight (lb/ream) T = reel trim (in.) R = ream size (ft^2) Multiply result by 0.012 to convert result to ton/d	P = production (kg/h) S = speed (m/min) BW = basis weight (g/m^2) T = reel trim (m) Multiply result by 0.024 to convert result to t/d

33. *Lineal paper on roll*

English Units	SI Units
$L = \pi \times (OD^2 - ID^2) / (48 \times \text{caliper})$	$L = \pi \times (OD^2 - ID^2) / (4 \times \text{caliper})$
L = lineal paper on roll (ft.) OD = outer diameter (in.) ID = inner diameter (in.) caliper (in.)	L = lineal paper on roll (m) OD = outer diameter (m) ID = inner diameter (m) caliper (m)

34. *Paper caliper*

English Units	SI Units
$\text{Paper Caliper} = \text{BW}/(\text{Ream} \times 144 \times \text{Density})$	$\text{Paper Caliper} = \text{BW}/(\text{Density})$
Caliper (in.) BW = basis weight (lbs./area) Example: for 30 lb/3000 ft^2, use 30. Ream (ft^2) (use 3000 for the example above) Density (lb/in^3), see table below	Caliper (mm) BW = basis weight (g/m^2) Example: for 60 g/m^2 use 60. Density (kg/m^3), see table below

Average Paper Density		
Grade	Density lb/in^3	Density kg/m^3
Coated & Supercalendered	0.042	1162.56
Coated Only	0.038	1051.84
Newsprint	0.023	636.64
Fine Paper	0.029	802.72
Linerboard	0.024	664.32
Board (Coated)	0.028	775.04

35. *Basis weight conversions*

Offset (lb/3300 ft^2) × 1.48 = g/m^2
Bond (lb/1300 ft^2) × 3.76 = g/m^2
Liner (lb/1000 ft^2) × 4.89 = g/m^2
News and Tissue (lb/3000 ft^2) × 1.63 = g/m^2
Market Pulp (lb/2880 ft^2) × 1.70 = g/m^2

36. *Roll rotational speed*

English Units	SI Units
$RPM = 3.82 \times V / D_o$	$RPM = 0.3183 \times V / D_o$
RPM = revolutions per min V = speed (ft/min) D_o = roll outside diameter (in.)	RPM = revolutions per min V = speed (m/min) D_o = roll outside diameter (m)

Maximum 250 rev/min for size press rolls.

37. ***Natural frequency of single degree of freedom system***

English Units	SI Units
$F = 3.127/\sqrt{d}$	$F = 0.4986/\sqrt{d}$
F = natural frequency (cycles/s) d = static deflection due only to weight of body (no externally applied forces) (in.)	F = natural frequency (cycles/s) d = static deflection due only to weight of body (no externally applied forces) (m)

38. ***Critical speed of calender roll***

English Units	SI Units
$\text{C.S.} = 4.12\times10^6 \times \frac{R_O}{L^2}\sqrt{R_O^2 + R_i^2}$	$\text{C.S.} = 1.26\times10^6 \times \frac{R_O}{L^2}\sqrt{R_O^2 + R_i^2}$
C.S. = critical speed (ft/min) R_O = outside radius (in.) R_i = inside radius (in.) L = centerline to centerline bearing (in.) (assumes L = face + 40 in.)	C.S. = critical speed (m/min) R_O = outside radius (m) R_i = inside radius (m) L = centerline to centerline bearing (m) (assumes L = face + 1 m)

39. ***Approximate critical speed of a roll***

English Units	SI Units
$\text{C.S.} = \frac{49.12 D_O}{\sqrt{d_9}}$	$\text{C.S.} = \frac{93.96 D_O}{\sqrt{d_9}}$
C.S. = critical speed (ft/min) D_O = outside diameter of roll (in.) d_9 = roll deflection (in.) over face, due to roll weight only (not to include externally applied forces). See formula 24.	C.S. = critical speed (m/min) D_O = outside diameter of roll (m) d_9 = roll deflection (m) over face, due to roll weight only (not to include externally applied forces). See formula 24.

40. ***Inertia (WR^2) of a roll***

English Units	SI Units
$WR^2 = (0.000682)(w)(L)(D_o^4 - D_i^4)$	$WR^2 = (0.09817)(w)(L)(D_o^4 - D_i^4)$
WR^2 = Inertia (lbf • ft^2) w = density (lb/$in.^3$) L = length (in.) D_o = outside diameter (in.) D_i = inside diameter (in.)	WR^2 = Inertia (kg • m^2) w = density (kg/m^3) L = length (m) D_O = outside diameter (m) D_i = inside diameter (m)

41. ***Torque***

$$T_q = \text{Force} \times \text{Radius}$$

English Units	SI Units
T_q = Torque (lbf • in.) Force (lbf) Radius (in.)	T_q = Torque (N • m) Force (N) Radius (m)

42. ***Power***

$$\text{Power} = T \times N$$

English Units	SI Units
$HP = \frac{T \times N}{63025}$	$P = 0.1047 \times T \times N$
HP = Horsepower T = Torque (lbf • in.) N = Speed (rpm)	P = Power (W) T = Torque (N • m) N = Speed (rpm)

43. ***Common conversion factors***

1 HP = 33,000 ft•lbf/min = 550 ft•lbf/sec
1 HP = 746 W
1 HP = 42.4 BTU/min

$$\text{Electric HP} = \text{Amps} \Big/ \left(\frac{746}{\text{Volts} \times \text{decimal efiiciency}} \right)$$

$$= \frac{\text{Amps}}{7.2}, \text{with } 120\text{V} \ @ 86\% \text{ efficiency}$$

$$= \frac{\text{Amps}}{3.6}, \text{with } 240\text{V} \ @ 86\% \text{ efficiency}$$

$$= \frac{\text{Amps}}{1.8}, \text{with } 550\text{V} \ @ 75\% \text{ efficiency}$$

For H_2O, density = 62.4 lb/ft^3 = 8.34 lb/gal
1 Imp. gal = 4.546 liters

$$\frac{1\,\text{lb}}{3000\,\text{ft}^2} = \frac{1.6275\,\text{g}}{\text{m}^2}$$

$$°F = \frac{9}{5} \times °C + 32$$

$$°C = (°F - 32) \times 5/9$$

$$\text{lbf/in.} = (\text{kN/m}) \times 5.7$$

$$\text{lbf/in.} = (\text{kg/cm}) \times 5.6$$

$$\text{ton} = \text{t} \times 1.1023 \text{ (ton = short ton; t = metric ton)}$$

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Additional Information

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Working Group:
Scott Pantaleo, Chairman, Weyerhaeuser Company
Jeff Reese, International Paper
Philip Wells, Wells Enterprises Inc.
Richard Reese, Dick Reese and Associates, Inc.
Bob Kinstry, Jacobs Engineering Group, Inc.
Ben Thorp, Retired
Brian Worcester, Toscotec North America
Jay Nelson, Gardner Denver Nash
Peter Jasak, Potlatch Corporation

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