Paper Grades

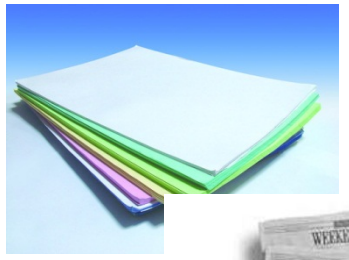
What is paper (and board)?

Paper is a random web of wood fibers that are bonded mainly with hydrogen bonding.

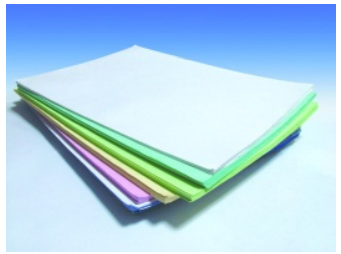
Hydrogen bonds are reversible, they are weakened when paper is put into water.

When wetted and mechanically agitated, paper falls apart into individual fibers.

This is the basis of paper recycling.



How is paper made?



Chemical (kraft) treatment

Unbleached kraft pulp (corrugated boxes)

Bleaching

Bleached Pulp (printing grades)

Grinding with metal disks

Mechanical Pulp (yellows with age) (newsprint, magazines)

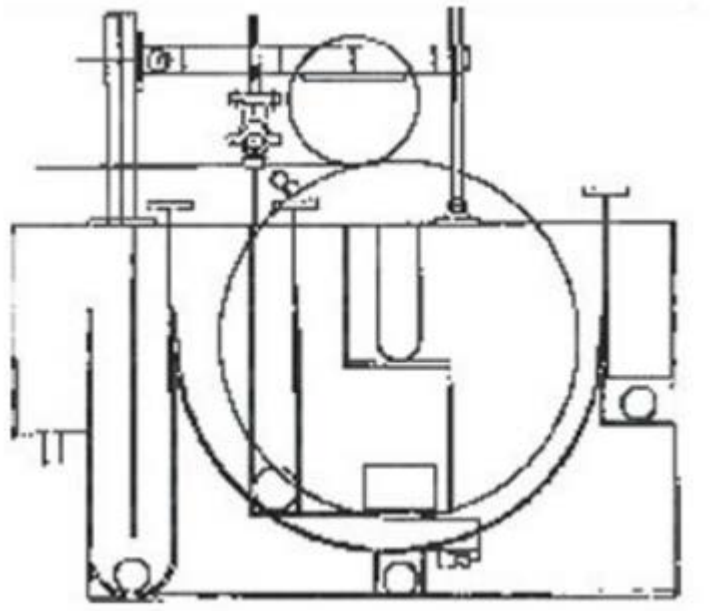
Wood contains papermaking fibers.

But lignin, a natural adhesive in wood, makes the fibers hard.

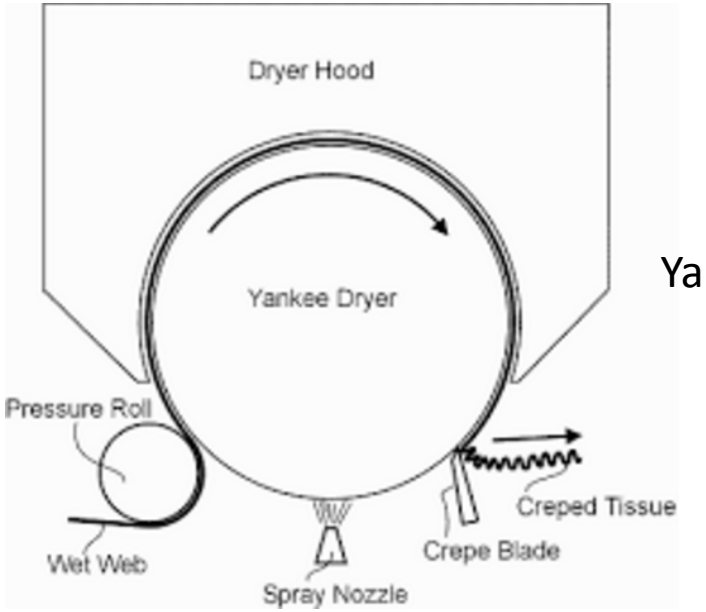
The fibers must be liberated from the wood by either chemical or mechanical actions.

How is paper made?

Fourdrinier Paper Machine



Cylinder Former (One of many vats)



Yankee Dryer: Creped Tissue

General Grades of Paper and Board

- Paper
  - Newsprint
  - Printing and Writing
  - Bags
  - Tissue
  - Towels
  - Napkins
- Board
  - Linerboard
  - Corrugating Medium
  - Tubes
  - Drums
  - Milk Cartons
  - Recycled Board (Called Chip Board: Shoebox, Cereal Box)
  - Roofing Felts
  - Fiberboard

Grammage

- Paper, board, and tissue are categorized by the weight per unit area
- Grammage: grams per square meter

- Tissue: typically 15-60 g/m2
- Paper: can range from 30-170 g/m2
- Paperboard: typically greater than 134 g/m2

- Common office copy paper is 75 g/m2.

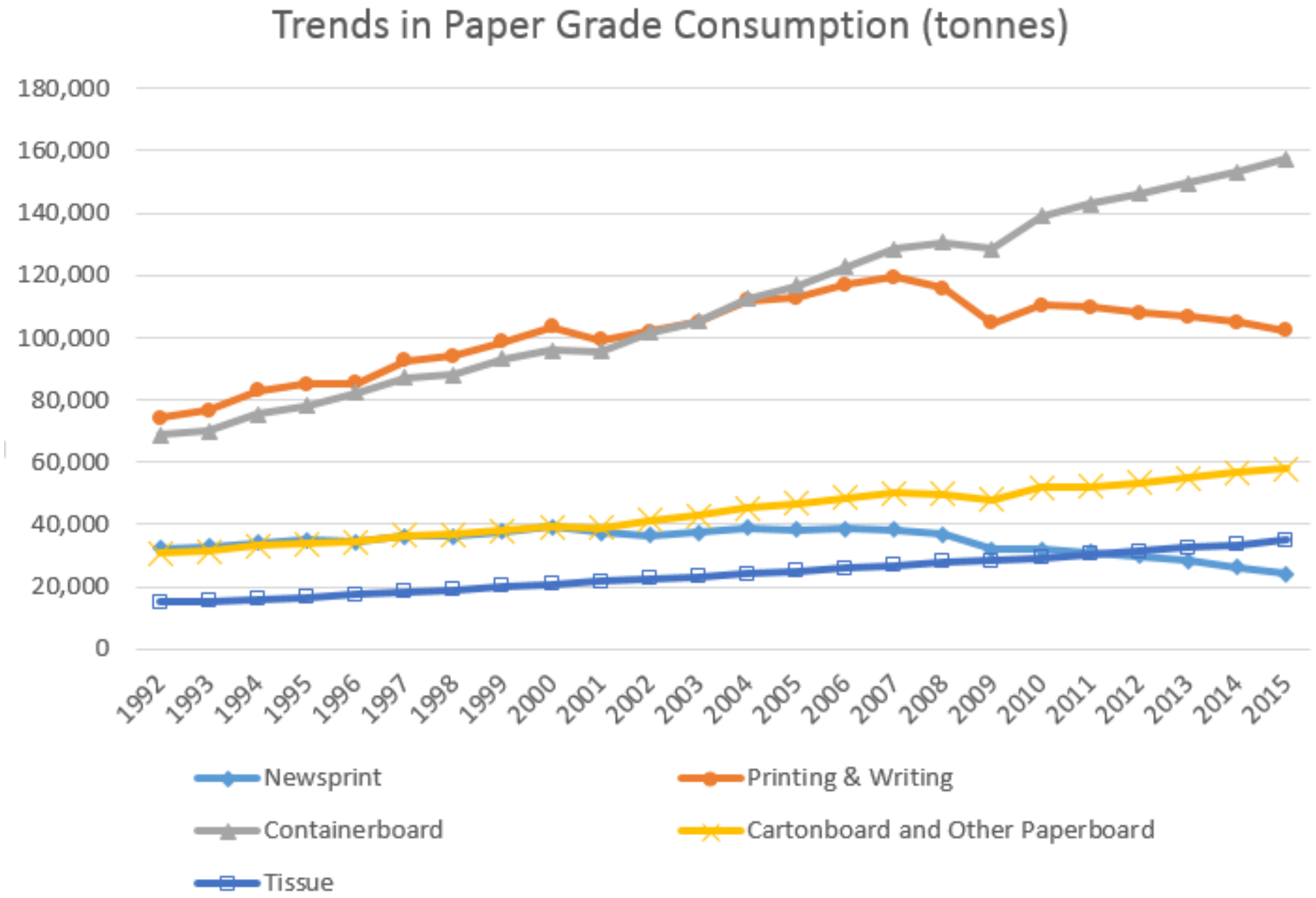
Paper Grade	Basis Weight (g/m2)
Tea bag tissue	18
Oil filter	139
Toilet Tissue	17
Vacuum dust bag	42
Blotting paper	130
Cigarette tissue	25
Bond paper	76
Newsprint	53
Copy paper	80
Writing paper	88
Wrapping tissue	12
Cardboard	247
Glassine	36
Paper Physics Niskanen	

TAPPI: TIP 0404-36 Paper Grade Classifications

- A particular grade of paper is typically identified in one or more of the following three ways:
  - Final use of the paper
  - Furnish used in making the paper
  - Type of machinery which was used.
- Example: “off-machine coated groundwood publication paper”
- 100’s of specific paper grades
- 12 major grades are in common usage and represent over 95% of all paper tonnage produced

Global Paper and Board Consumption, 2015

Grade Consumption 2015	Thousand Tonne	%
Paper and Board	410,794	100
Newsprint	24,104	6
Printing & Writing	102,188	25
Uncoated Woodfree	52,841	13
Coated Woodfree	25,063	6
Uncoated Mechanical	11,758	3
Coated Mechanical	12,526	3
Packaging Paper and Board	231,569	56
Containerboard	157,417	38
Cartonboard and Other Paperboard	57,932	14
Wrapping Paper	16,220	4
Tissue	34,947	9
Other Paper and Board	17,985	4


Trends in Paper Grade Consumption (tonnes)
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Newsprint
Printing & Writing
Containerboard
Cartonboard and Other Paperboard
Tissue

Uncoated groundwood:

- Uncoated mechanical pulps, could be TMP or other… not necessarily groundwood
- 80% is newsprint
- 24-75 g/m2 with newsprint 40-50 g/m2
- Directory, computer paper, catalog, advertising supplements
- Needs to be cheap, strength, brightness, bulk, ink receptivity

Coated groundwood:

- At least 10% mechanical pulps, typically 50-55%, balance chemical pulp
- Finished sheet grammage of 45-130 g/m2
- Letterpress, offset, light weight coated (LWC), and magazine.
- 70% of magazines are this grade
- Needs to be cheap, strength, brightness, bulk, ink receptivity

Coated Publication Grades

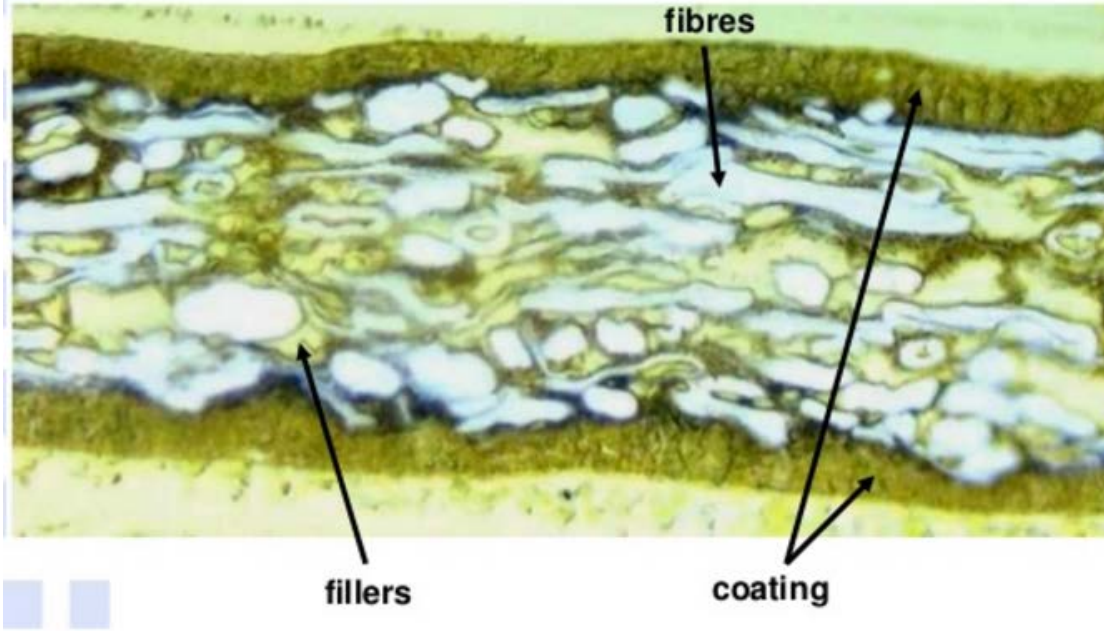
TABLE 20-5. Characteristics of coated publication grades.

General characteristics	*Typical use*	*Base stock*	*Coating*	*Brightness*
No. 1. Enameled, double-coated, hand-sorted, expensive base and coating; high gloss; basis weight above 70 lb	Annual reports	High-brightness chemical pulp Heavily filled	High in TiO_2 High gloss Enameled Synthetics	82-88
No. 2. Double-coated, expensive base and coating	Expensive advertising	High-brightness chemical pulp Filled (clay)	High in TiO_2 Some clay Synthetics	78-82
No. 3. Single- or double-coated lower quality basesheet	Advertising	Chemical pulp Minor amounts of groundwood	Mostly clay, some TiO_2 Less expensive	76-82
No. 4. Lower cost, lower brightness	Magazine	Groundwood and chemical pulp, some clay filler	Less expensive Coating — clay and TiO_2	72-78
No. 5. Lower basis weight, high groundwood content	Directories, catalogs, magazines	Mostly groundwood or TMP, chemical pulp for runnability	Variable, some contain synthetics	68-72

Paper Coatings

- Coating color – the term used for the coating when in the slurried state before application to the paper, even if white.

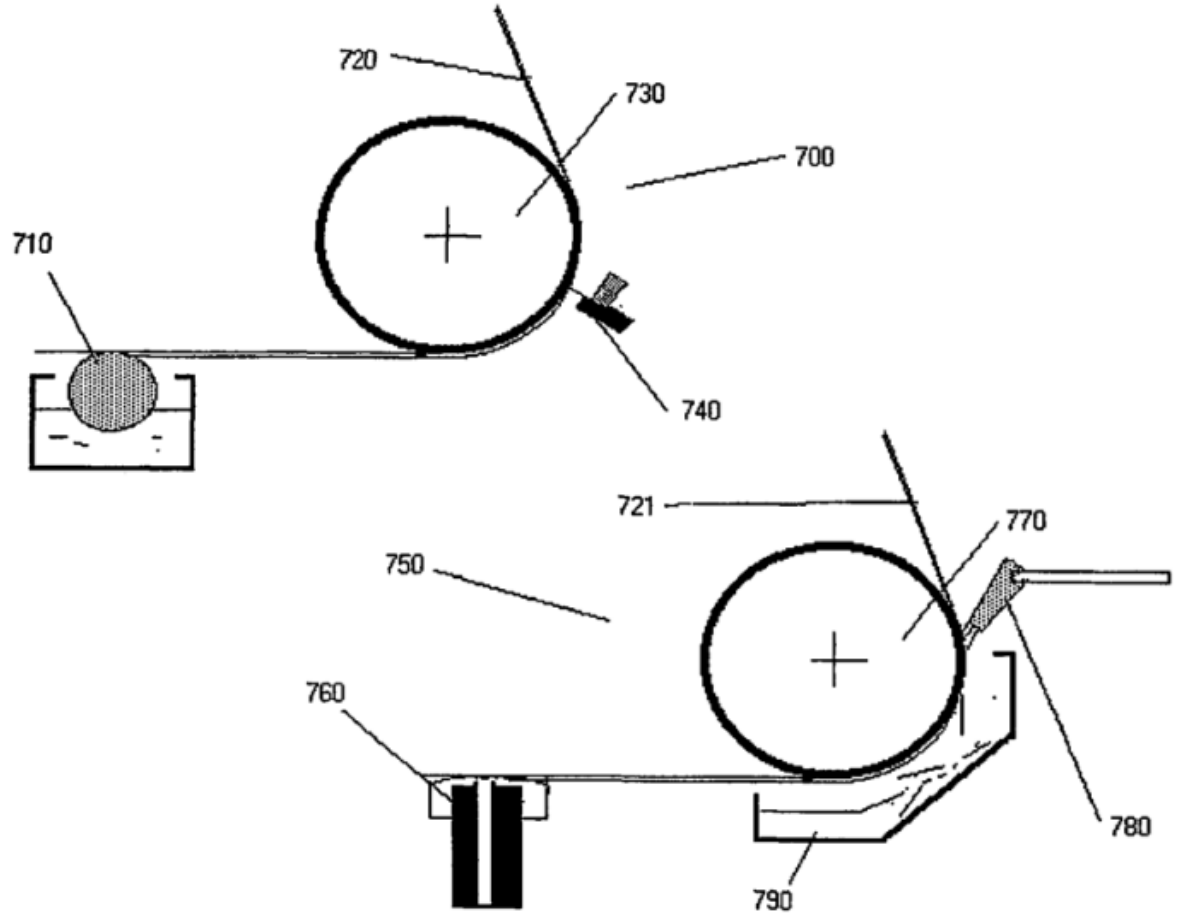
- A coating color is typically about 50-70% solids.
- The coating color is applied so that the coating forms a 4 to 8 lbs./3000 ft^2 (6.5 – 13 g/m^2) per side on the sheet.
- The dried coating may form up to 30% of the total weight of paper.
- Coatings improve smoothness, gloss, opacity and printability



Coating Formulation

- Three main components to a coating color:
  - Water
    - Function is to serve as a vehicle for the coating components
  - Pigment (typically clay or calcium carbonate)
    - Function is to provide color, opacity, and smoothness to the surface
  - Binder (typically latexes or starch)
    - Function is to make the coating layer strong

Schematic illustrating Blade and Air Knife Coaters



Coating Formulation

- All but the simplest formulas will have additional components known as *additives* such as:
  - Flow modifiers
  - Colorants
  - Optical Brighteners
  - Defoamers
  - Dispersants
  - Preservatives
  - Etc.
- It is not uncommon for coating formulations to have 10-15 components.

Uncoated wood-free:

- Less than 10% mechanical pulp, normally 0%
- Not coated
- Office papers (forms, copy, bond, tablet, and envelope), carbonless, and printing papers (offset, cover, text).
- Other names: printing, writing, and book papers.
- Needs exact color/whiteness/brightness, smoothness, ink receptivity, surface strength, stiffness

Grammage g/m2	Basis weight by lb/17x22 in by 500 sheets
48	13
60	16
75	20
90	24

Coated wood-free:

- Less than 10% mechanical pulp, normally 0%
- Magazines, books, and commercial printing.
- 70 g/m2 to 170 g/m2 for the finished sheet.

- Needs exact color/whiteness, smoothness, ink receptivity, surface strength, stiffness

Kraft Paper

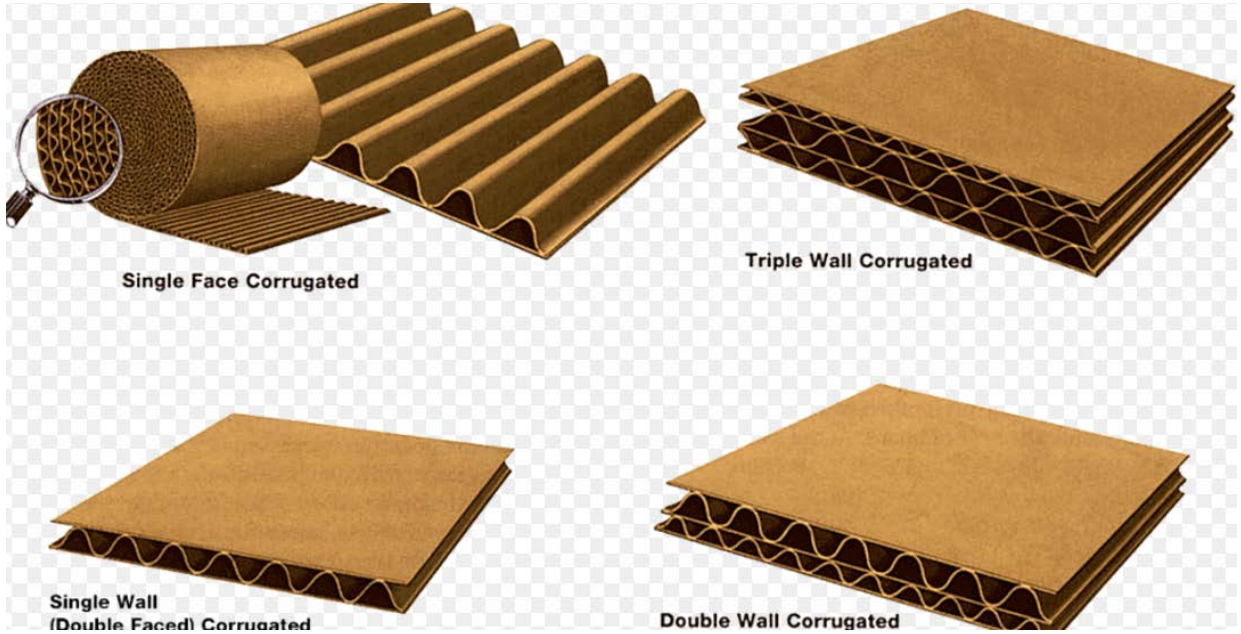
- Unbleached or bleached kraft pulp
- 50 g/m2 to 134 g/m2.
- Wrapping, bag/sack, shipping sack, and other converting (such as saturating and cable)
- High tensile and tear strength

Bleached paperboard

- Bleached kraft pulps primarily
- About half is coated
- Generally above 134 g/m2, typically from 200 g/m2 to 500 g/m2.
- Primarily folding carton and milk carton.
- Also included: cups, plates, printing boards, tag stock, computer cards, file folders, and index cards.
- Needs stiffness, strength, barrier properties

Unbleached paperboard

- Unbleached and made from virgin kraft or neutral sulfite semichemical pulp
- Also may have recovered paper as a feedstock
- 130 g/m2 to 450 g/m2
- Primarily linerboard for corrugated containers. Typically: 205 g/m2 or 42 lb/1000 ft2
- Also included in this is corrugated medium, made with semi-chemical and often some amount of recycled. Typically 9 point medium, 125 g/m2 or 26 lb/1000 ft2
- Needs strength, burst, stiffness, tensile, water resistance



Recycled paperboard

- Sometimes called chipboard.
- Made entirely of recovered paper, often newspapers and low valued recovered papers
- Often made on a multi-cylinder machine
- Have greyish color since not deinked
- Used often to make solid fiber boxes that require low strength --- make up with thickness
- Grades include corrugating medium, folding boxboard (clay coated), setup boxboard (uncoated), and paperboard.
- Also included are gypsum liner, core tube stock, and roofing felt.
- Needs to be cheap, substitute thickness for fiber strength properties

MG kraft specialties:

- Machine glazed finish, high gloss
- Made by allowing the coating to dry on a large, chrome plated dryer with polished surface
- Grades include wax base, wrapping, carbonizing, and kraft specialties.

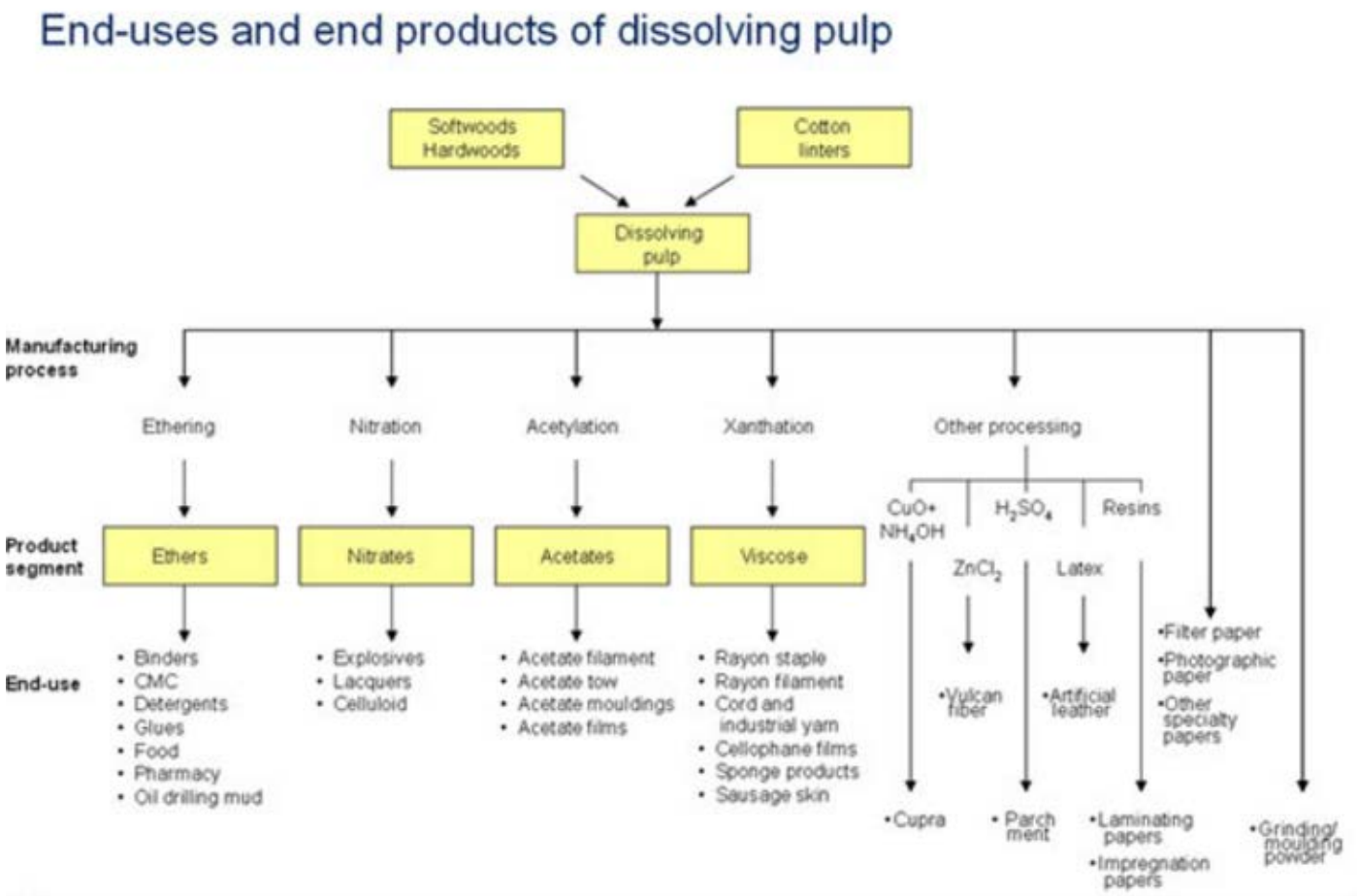
30gsm machine glazed tissue paper for wrapping articles

Tissue

- At home: bleached chemical pulps
- Away from home: recovered paper
- Manufactured on Yankee machines with either a wet or dry crepe operation
- 20 g/m2 to 75 g/m2
- Primarily tissue, towel, bathroom, napkins, etc.
- Also: wrapping tissue, tracing tissue,
- Soft, bulky, absorbent, moderate strength

Market Pulp

- Pulp is typically bleached hardwood or softwood kraft pulp
- Deinked market pulp also exists
- Wet lap (50% solids) or dry lap (80-85% solids)
- Unbleached or mechanical pulp grades are not common
- Sold in sheets, bales or rolls
- Needs to have HW or SW, cleanliness
- Fluff pulp is a special type of market pulp, typically bleached kraft pulp that is made to be processed in a hammer mill to produce fluff suitable for diaper or other personal care products
- Dissolving pulp is a special type of pulp, high purity, very high cellulose content used to make cellulose derivatives, eg, cellulose acetate



Other

- Grades that do not fit conveniently in other categories
- Less than 5% of all paper or board
- Examples are hardboard, asbestos board, thin papers (cigarette tissue, condenser, bible), and dense papers (glassine, grease proof, release, and vegetable parchment).

Basis Weight – Units – lbs.

- mass or weight of paper per unit area.

Grade of Paper	Sheet Dim. (in.)	No. of Sheets in Ream	Square Feet Per Ream
Writing and Printing	17 x 22	500	1298.6
Paperboard			1000
Wrapping	24 x 36	480	2880
Book	25 x 38	500	3298.6
News/Tissue	24 x 36	500	3000
Bag			3000

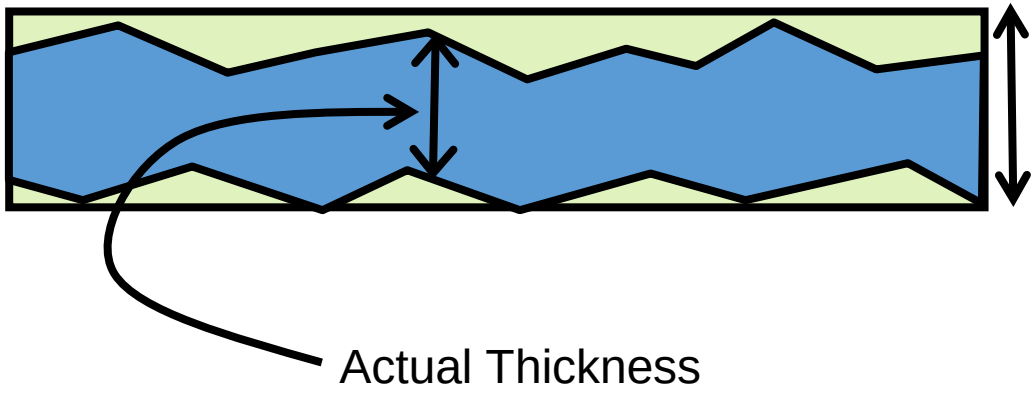
SI or International Units are grammage (grams/meter^2).

20 lb copy paper = 75 g/m2

Thickness or Caliper

- The dimension of the paper in the Z-Direction (out of plane).
- Units are:
  - mils = points (pts) = 1/1000 inch
  - millimeters = 1000 micrometers (μm)
  - To convert from mil to micrometer, multiply by 25.4

	Thickness (microns)
Towel Tissue	200
Copy Paper	100
Newsprint	70
Board for dry wall	350



Apparent density: the mass divided by the volume

Apparent Bulk: the volume divided by the mass

	Density	Bulk
	kg/m^3	m^3/mt
Tissue	**281**	**3.56**
Napkin	**355**	**2.82**
Liner Board	**698**	**1.43**
Newsprint	**704**	**1.42**
Copy Paper	**778**	**1.29**

Moisture Content The mass of water divided by the total mass of the initial sample (i.e. the wet mass) times 100 %.

		Towel Tissue	Copy Paper	News print	Board for Gypsum
Total Air dry mass, g	A	0.39	.78	1.82	1.93
Oven dry mass, g	O	0.36	.73	1.67	1.75
Moisture Content, %	**MC**	**7.7**	**6.4**	**8.2**	**9.3**

MC=100%*(A-O)/A

Moisture Content

- Hysteresis, the MC depends on the direction.
- All mechanical properties depend on moisture content.

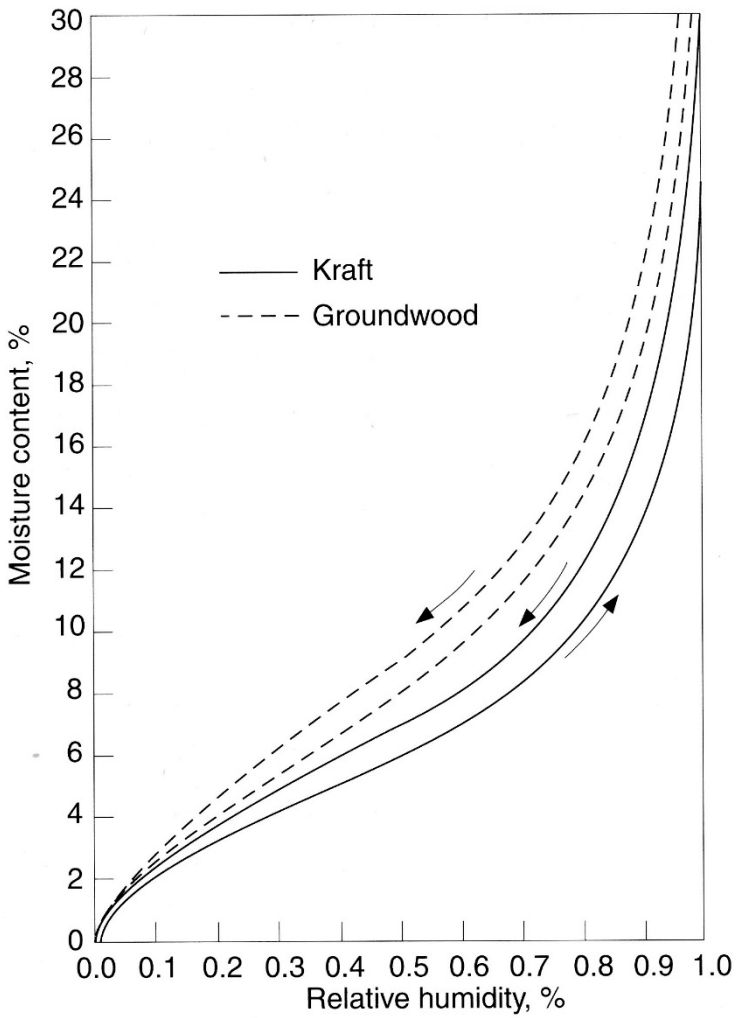
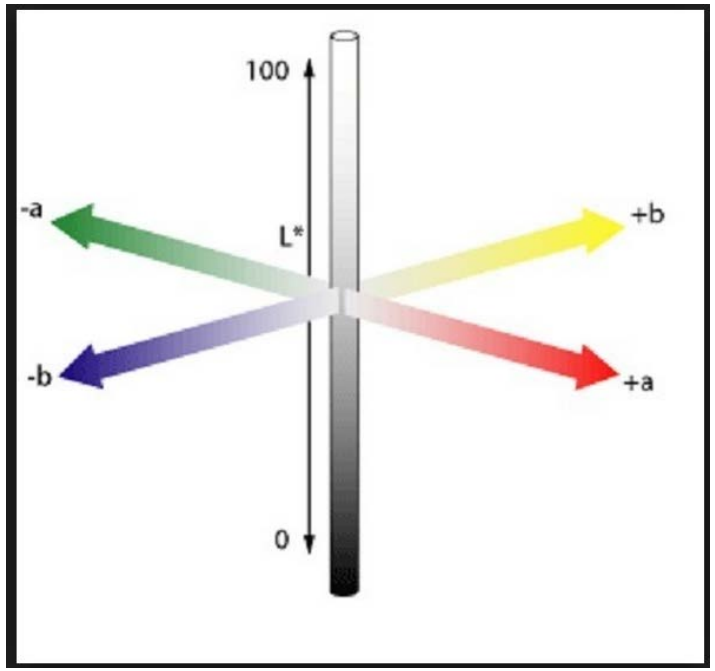


Figure 3. Moisture content vs. relative humidity in a chemical pulp and a groundwood at[2] $T = 50°C$.

Selected Optical Properties

- Brightness is a measurement of the reflectivity of a material at a wavelength of 457 nm (the blue region) or R ∞ at 457 nm.
- Opacity determines the ability of a material to prevent light from transmitting through it.
  - Printing opacity is Ro/R ∞
- Gloss determines the amount of specularly reflected light coming from the surface.
- Color: the quality of an with respect to light reflected by the object, usually determined visually by measurement of hue, saturation, and brightness of the reflected light



- Ro is the light reflectance of a single sheet of paper with black backing
- R ∞ is the light reflectance of an infinite stack of paper

Selected Strength Properties

- Tensile strength: ultimate force to break paper in tensile
  - Breaking length: length of paper that can have its weight supported
  - 8-10 km for bleached softwood
  - 20 km for pine
  - 4.5 km for steel

- Tear strength: energy required to propagate a tar through paper for a fixed distance

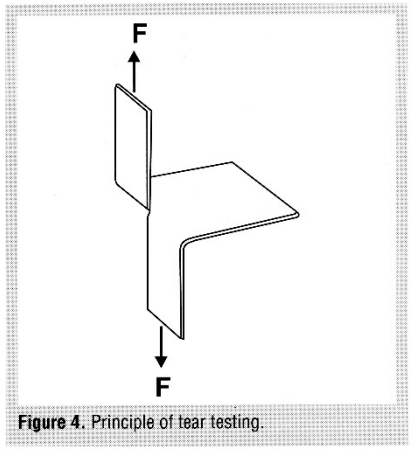
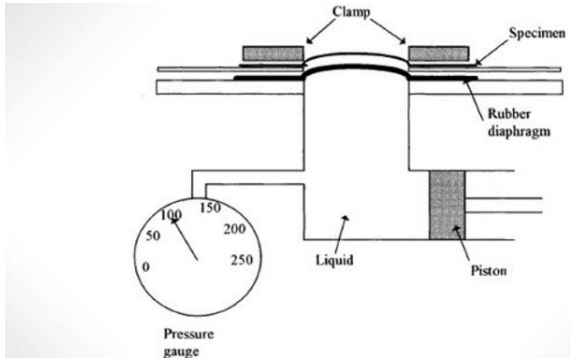


Figure 4. Principle of tear testing.

- Burst Strength: amount of hydrostatic pressure to rupture a surface of paper
  - Uses a rubber bladder to puncture paper



Selected Strength Properties

- Folding Endurance: number of double folds a 15 mm wide paper can endure before failing in tensile under a 1 kg load
- Stiffness (STFI) edgewise compression strength test.
- Stiffness (Taber): bending moment of a 1.5 in wide paper at 15 degrees from center

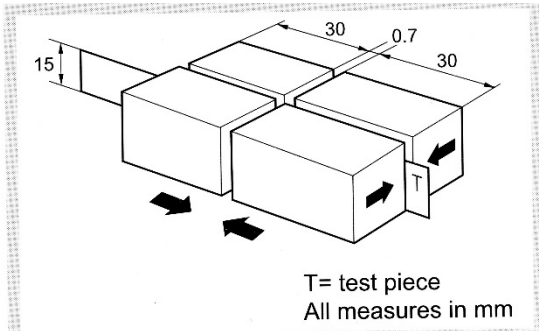


Figure 5. When the clamps move toward each other, the length decreases and the stress in the test piece increases until rupture occurs.