Pulping Fundamentals

Lecture 2

Category of Pulping Process

- Chemical Pulping
  - Sulphate (Kraft) process
  - Sulphite process
  - Neutal
- Semi-chemical
- Chemi-mechanical
- Mechanical pulping

Table 3-1. Summary of pulping processes.[1]

Process	Chemicals	Species	Pulp Properties	Uses	Yield, %
Mechanical pulping	none; grindstones for logs; disk refiners for chips	Hardwoods like poplar or light-colored softwoods like spruce, balsam fir, hemlock, true firs	High opacity, softness, bulk. Low strength and brightness.	Newsprint, books, magazines.	92-96%
Chemi-mechanical pulping	CTMP; mild action; NaOH or $NaHSO_3$		Moderate strength		88-95%
Kraft process, pH 13-14	NaOH + Na_2S (15-25% on wood); unlined digester, high recovery of pulping chemicals, sulfur odor	All woods	High strength, brown pulps unless bleached	Bag, wrapping, linerboard, bleached pulps for white papers	65-70% for brown papers, 47-50% for bleachable pulp; 43-45% after bleaching

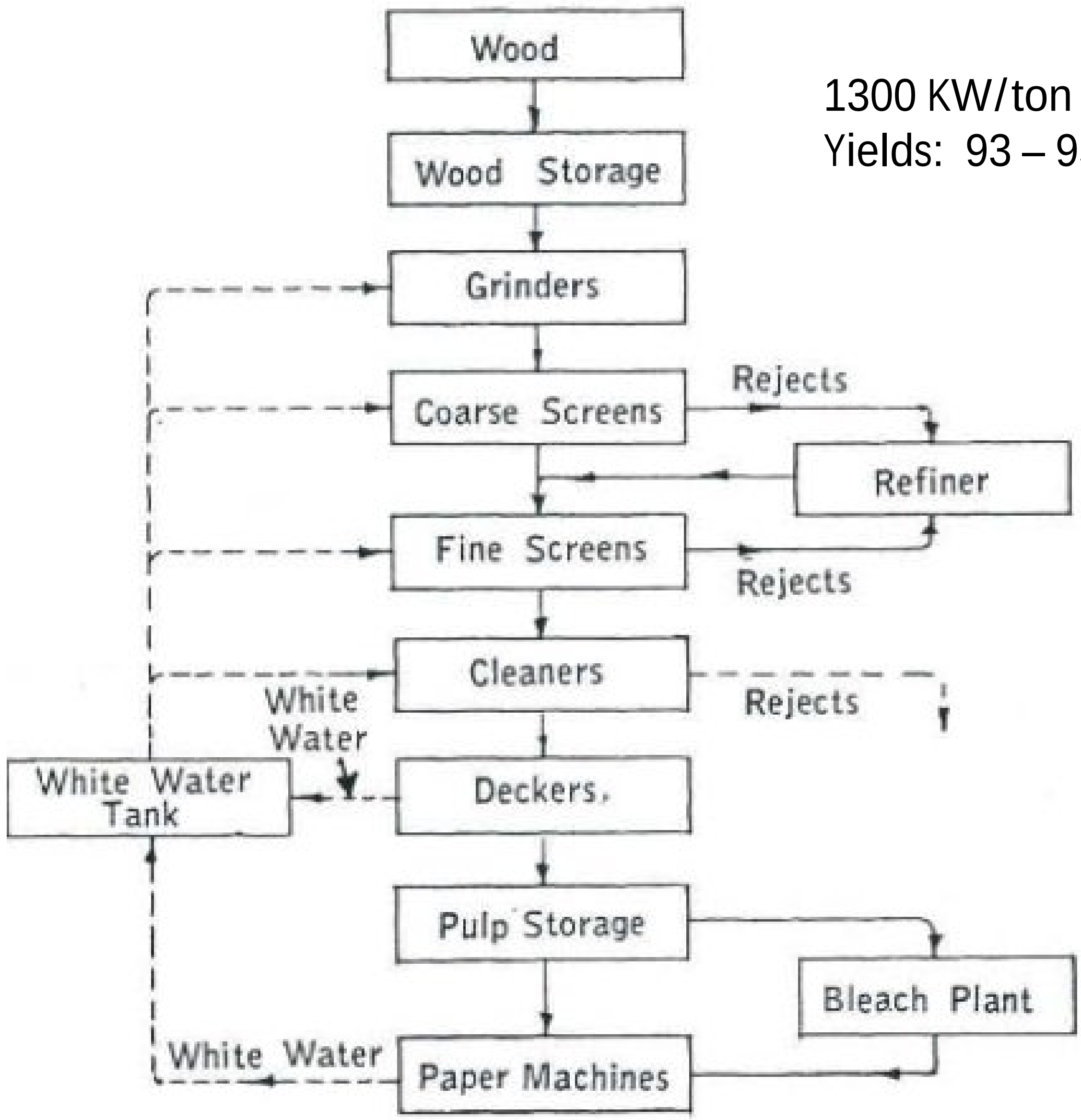
Process	Chemicals	Species	Pulp Properties	Uses	Yield, %
Sulfite, acid or bisulfite pH 1.5-5	$H_2SO_3 + HSO_3^-$ with Ca^{2+}, Mg^{2+}, Na^+, or NH_4^+ base; Ca^{2+} is traditional but outdated since no recovery process; lined digesters	hardwoods-poplar and birch and non-resinous softwoods; Douglas-fir is unsuitable	light brown pulp if unbleached, easily bleached to high brightness, weaker than kraft pulp, but higher yield	Fine paper, tissue, glassine, strength reinforcement in newsprint	48-51% for bleachable pulp; 46-48% after bleaching
	Mg^{2+} base	almost all species-spruce and true firs preferred	Same as above but lighter color and slightly stronger	Newsprint, fine papers, etc.	50-51% for bleachable pulp 48-50% after bleaching
Neutral sulfite semi-chemical (NSSC) pH 7-10	Na_2SO_3 + Na_2CO_3 about 50% of the chemical recovered as Na_2SO_4	Hardwoods (preferred) aspen, oak, alder elm, birch; softwoods Douglas-fir sawdust and chips	Good stiffness and moldability	Corrugating medium	70-80%

Mechanical Pulping

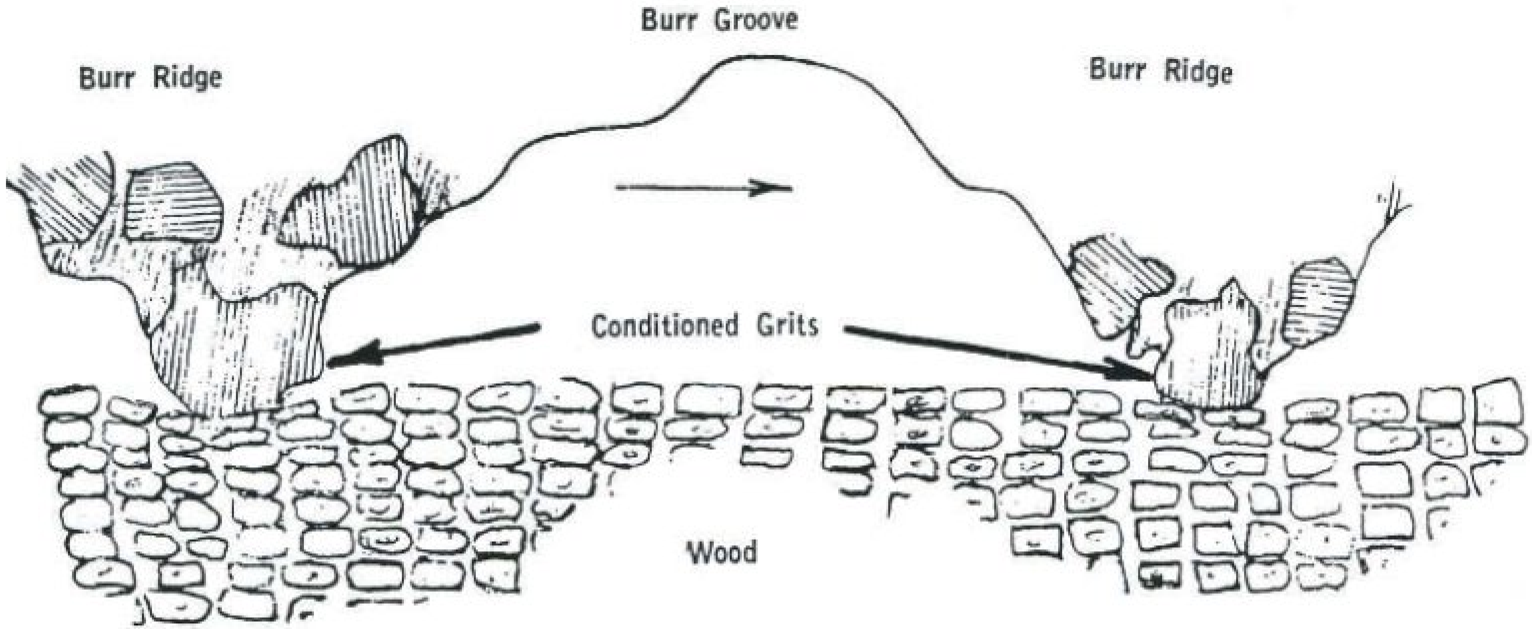
- Stone Groundwood (SGW) – wood logs
- Thermo-mechanical pulp (TMP)
- Chemi-thermo-mechanical pulp (CTMP)
- Bleached CTMP (BCTMP)
- Pressure Groundwood (PGW)

Stone Groundwood (SGW)

1300 KW/ton
Yields: 93 – 95%



Stone Groundwood Process—Flow Diagram



Fiberizing by Compression of the Wood by Conditioned Grits

Sharpening must done after 50 – 150 hr

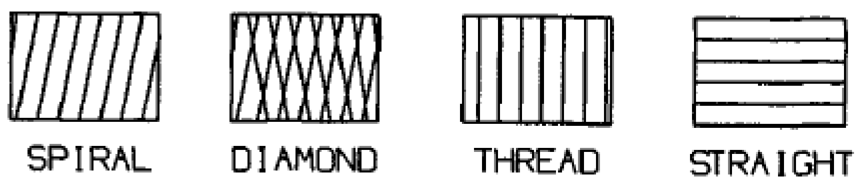
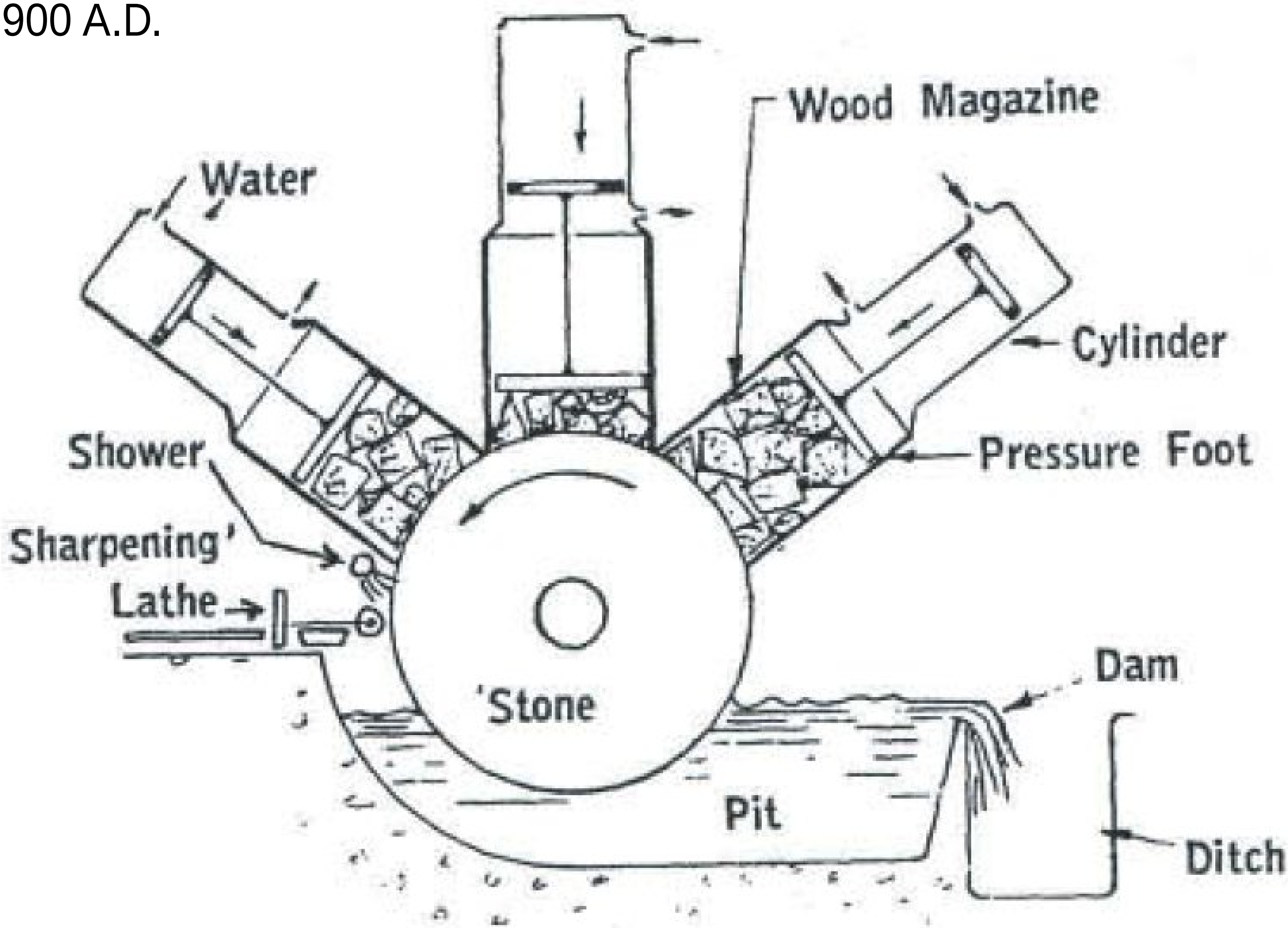


Fig. 3-4. Burr patterns used for sharpening pulp stones for stone groundwood production.

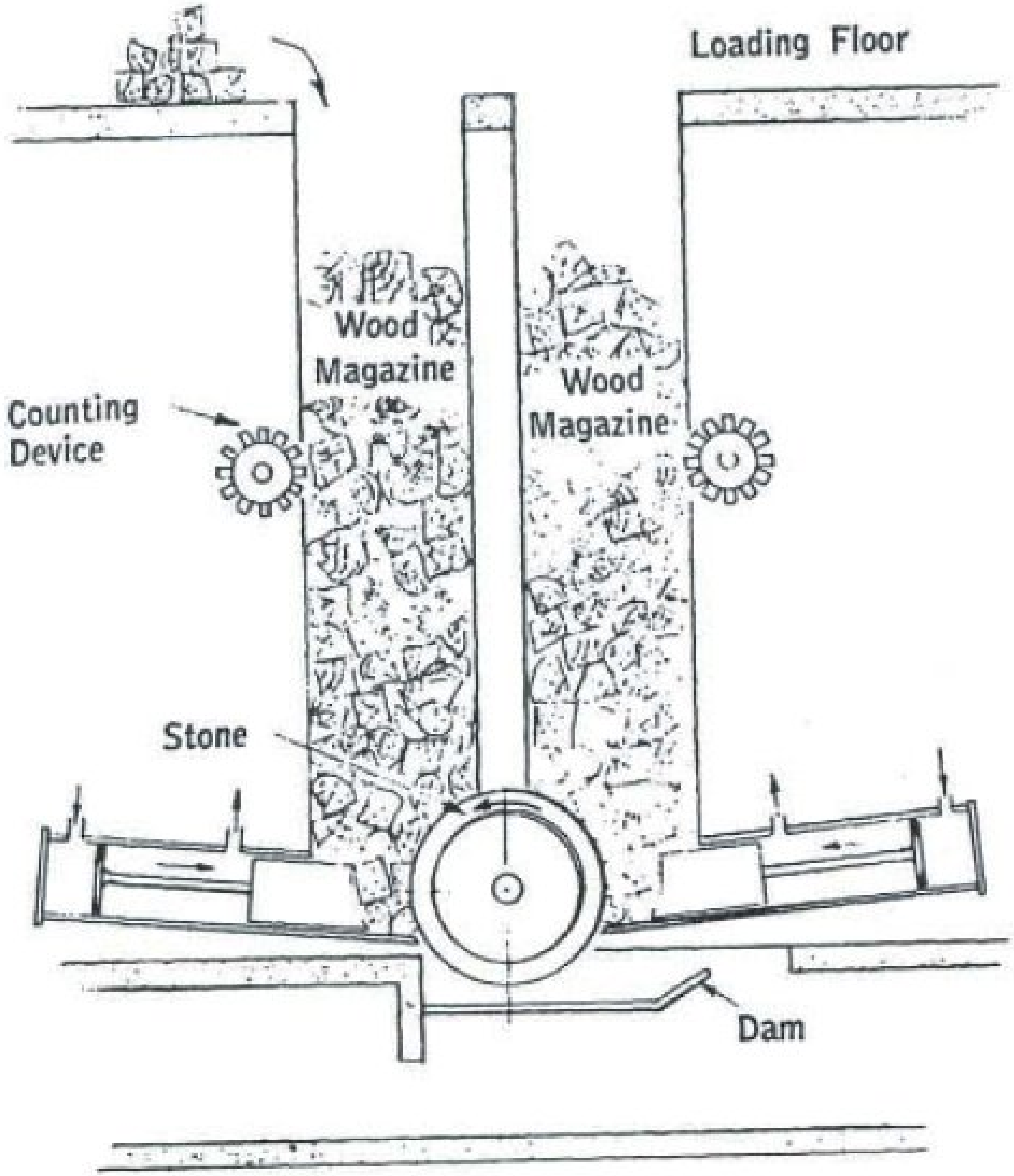
The important grinding variables are:

- Wood species and other wood variables.
- Type of pulpstone.
- The use (or not) of a water-filled grinding pit.
- Type of burr pattern on the stone.
- Stone surface speed.
- Hours on the stone since last burring.
- Pressure of wood against the stone.
- Temperature of grinding surface, 130-180°C
- Amount of water used (and, therefore, the final pulp consistency).

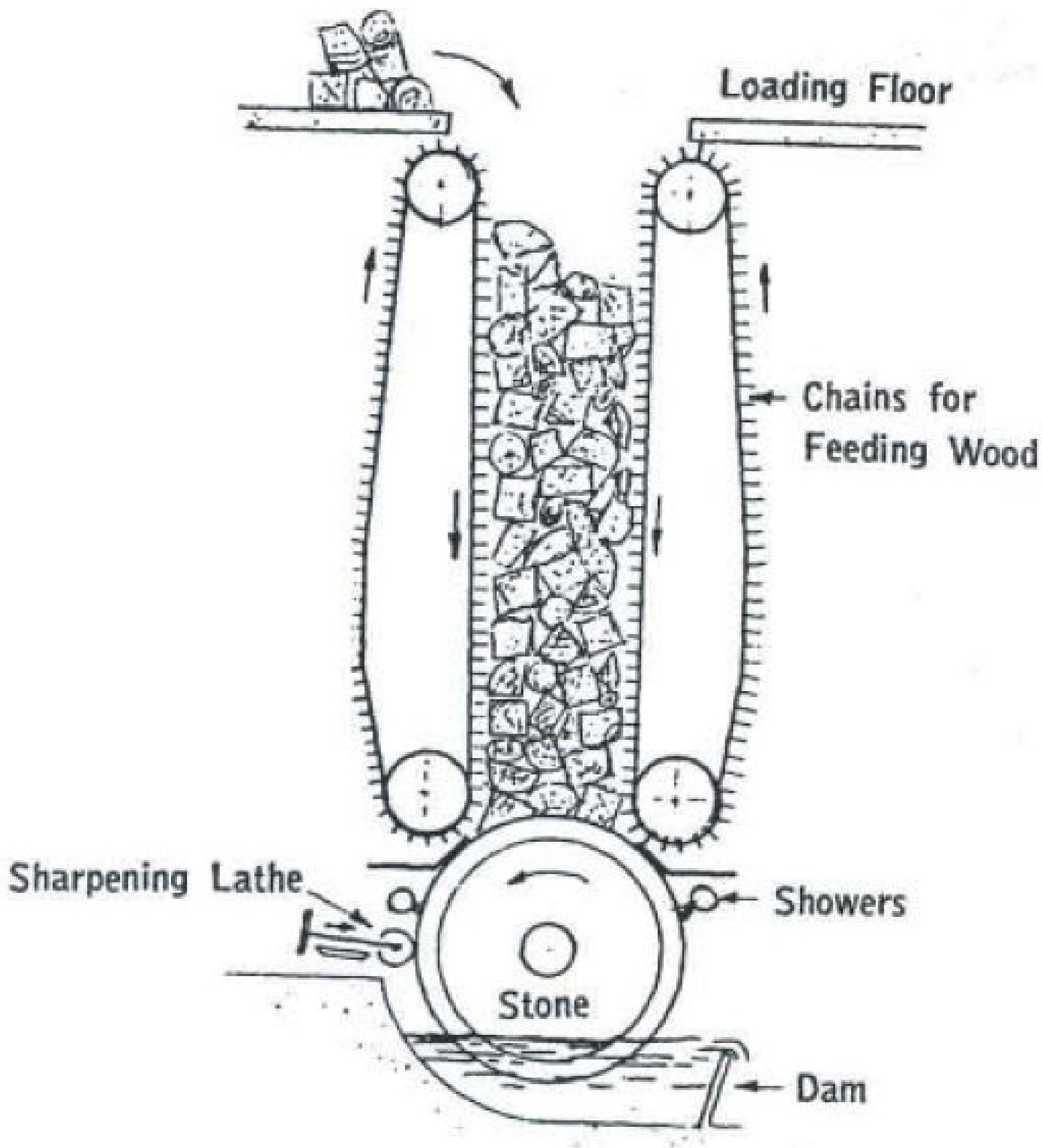
1900 A.D.



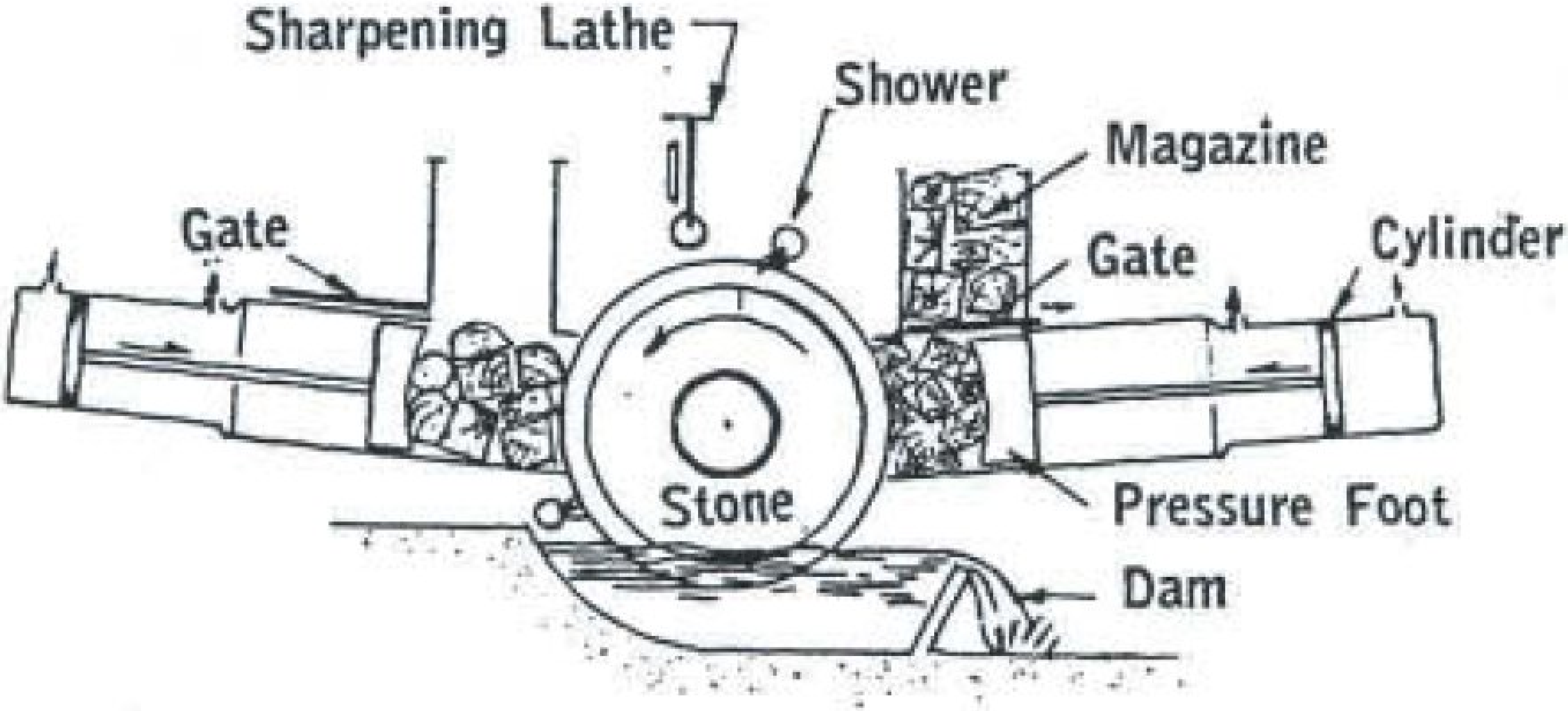
Three Pocket Hydraulic Grinder



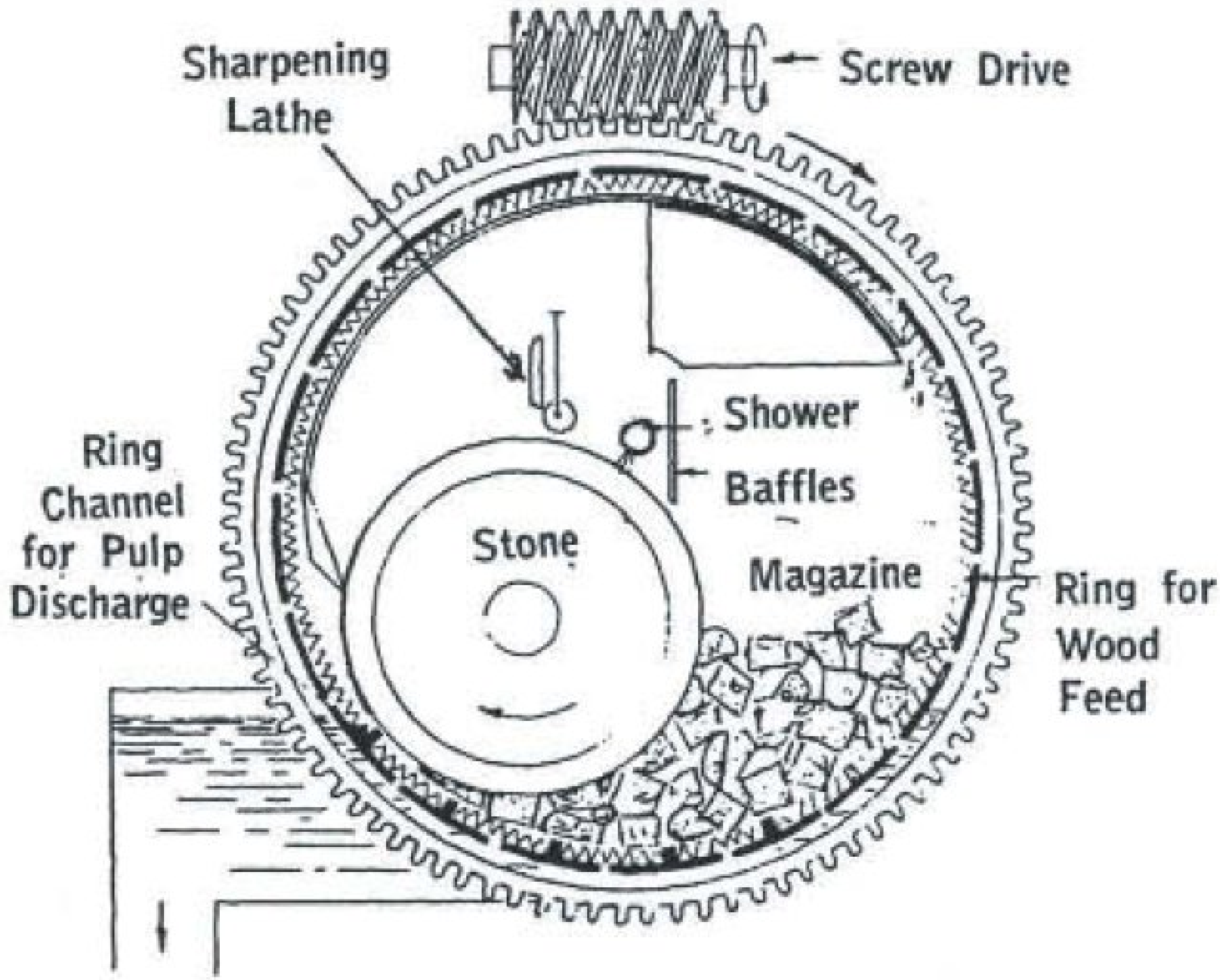
Hydraulic Magazine Grinder



Chain Grinder



Great Northern Grinder



Roberts Ring Grinder

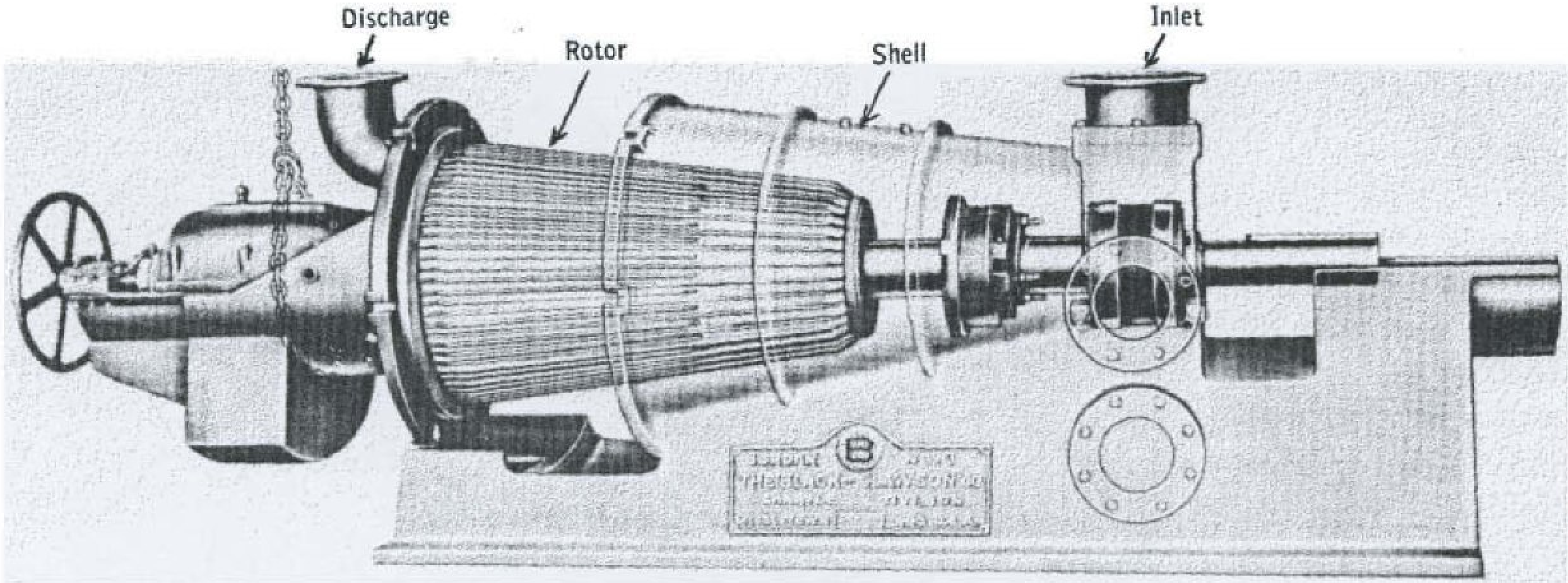
Pressure Grindwood (PGW)

Similar as SGW:

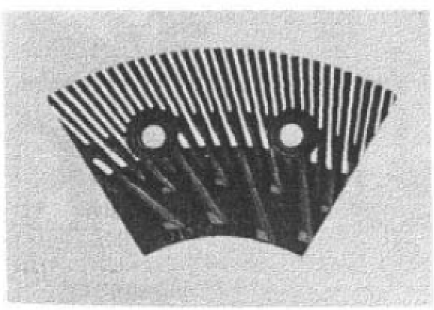
- By pressurizing the wood with steam at temperatures of 105-125°C , the wood is heated and softened prior to the grinding process.
- This gives better separation of fibers with less cutting action and lower fines generation.
- This process yields a pulp that has higher tear strength and freeness and is brighter than SGW.
- Lower power requirements.

Refiner Mechanical Pulp (RMP)

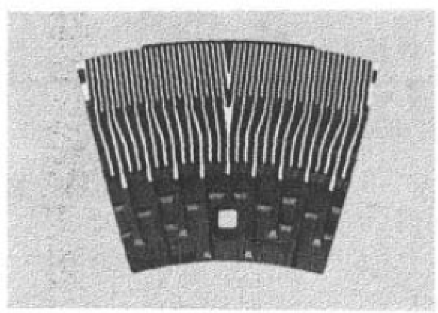
- Chips are used.
- Power requirements are 1600-1800 kWh/ton.
- Disk refiners are up to 1.5 m in diameter and rotate at 1800 rpm with 60 Hz power; this gives a velocity at the periphery of up to 140 m/s.
- The plates containing the metal bars must be replaced every 300-700 hours or low quality pulp is produced and energy use increases.
- Refining is usually carried out in two stages. The first is at 20-30% consistency to separate the fibers, while the second is at 10-20% consistency to alter the surface of the fibers for improved fiber bonding in the final paper.



Jordan



Fiber Development — Medium Bar



Double-Disc Refiner

Fiberboard

RMP

Thermo-Mechanical Pulp (TMP)

- Most important mechanical pulping method.
- The TMP process is very similar to the RMP process except that pulp is made in special refiners that are pressurized with steam in the first stage of refining. First stage: Elevated T (110-130°C, just below the glass transition temperature of lignin 140°C, enhance fibrillation) & P. second stage: Ambient T, P
- Higher pulp strength. Energy req. 1900-2900 kWh/ton
- An even consistency of 20-30% is ideal
- The pulp yield is 91-95%

Chemi-Mechanical Pulping (CMP)

- C before SGW, PGW, RMP or TMP.
- The grinding requirements were about half that required without pretreatment and the CSF was 300-350 ml.
- 2 stage: Chemical Pretreatment + Mechanical pulping
- Chemical Pretreatments:
  - Hot sulfite: brighter, low strength
  - Cold soda: drains faster, coarse fiber,

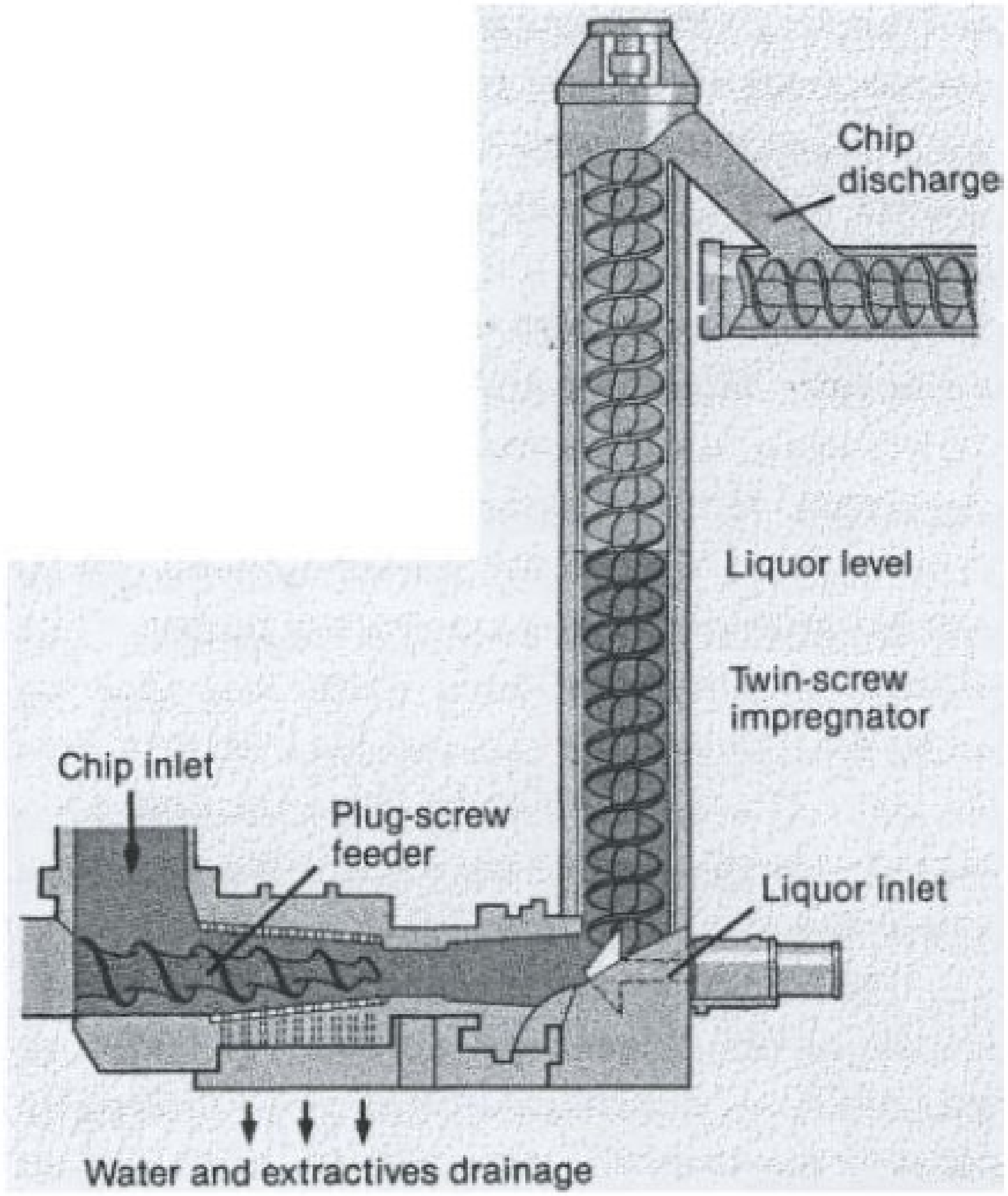


Fig. 3-9. Liquor impregnation using the pressure-expansion technique. Courtesy of Sunds Defibrator.

Alkaline Peroxide Mechanical Pulping (APMP)

- APMP is alternative Bleaching CMP process which requires 30-40% less energy than with sulfite pretreatment for BCTMP pulp.
- Chemical impregnation is used prior to RMP.

Semi – Chemical Pulping

Vapor phase pulping:

- After impregnation by chemicals, chips are further cooked in steam atmosphere.

Semi-chemical pulping:

- High yield chemical pulping (60-80%)
- Similar to any of the commercial chemical pulping methods (to be described), except that the temperature, cooking time, or chemical charge is reduced. NSSC and Kraft semi-chemical methods

Neutral Sulfite Semi-Chemical (NSSC)

- High pulp yields are obtained (75-85%).
- Cooking liquors contain Na_2S0_3 plus Na_2C0_3 (10-15% , act as a buffer); the liquor pH is 7-10.
- Cooking time is 0.5-2 h at 160-185°C.
- The residual lignin (15-20%) makes paper from this pulp very stiff.
- Subsequent refining energy of the pulp is 200-400 kWh/ton

Kraft green liquor semi-chemical process

General Chemical Pulping

- *Delignification*
- *Kappa number or Permanganate (K) number*
- *Pulp viscosity:* degree of polymerization(DP)
- *Fiber liberation point*
- *Full chemical pulps, unbleached, bleached*
- *Dissolving pulp*
- *Digester:* Batch, continuous

Batch digester

- 70-350 m^3, 6-8 digester in a plant.
- Direct or indirect heating
- Time to, at temperature

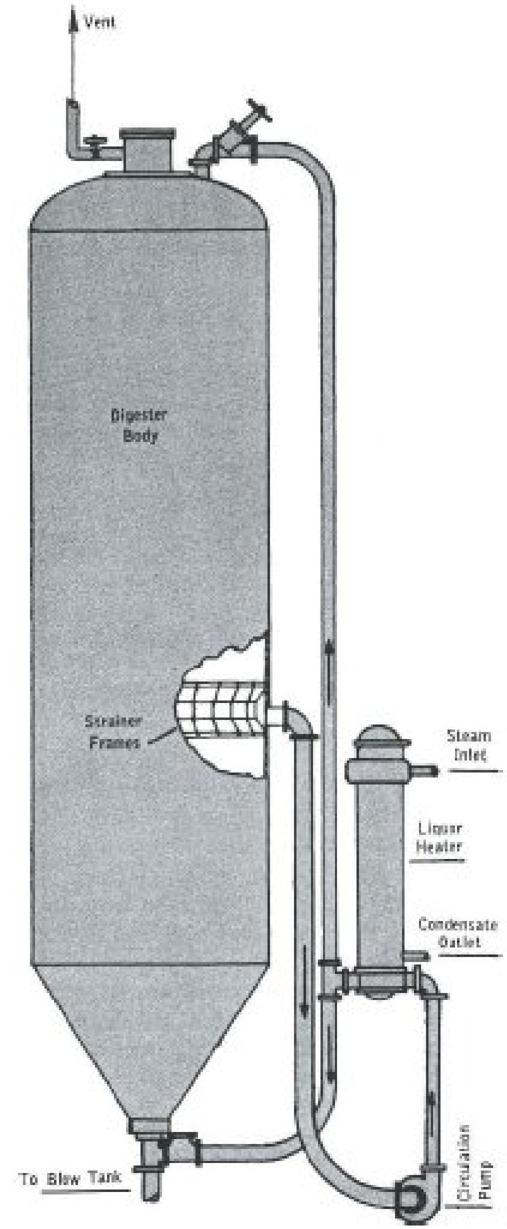


Fig. 3-11. A stationary batch digester with indirect heating of the liquor. Reprinted from *Making Pulp and Paper*, ©1967 Crown Zellerbach Corp., with permission.

Sequence of events in batch digester

1. The digester is first opened and filled with chips, white liquor, and black liquor.
2. After initial circulation of the liquor additional chips are added as the contents settle.
3. The digester is then sealed and heating with steam begins. The temperature rises for about 90 minutes until the cooking temperature is achieved.
4. The cooking temperature is maintained for about 20-45 minutes for the kraft process. During the heating time, air and other noncondensable gases from the digester are vented.
5. When the cook is completed, as determined by the kappa of pulp from the digester, the contents of the digester are discharged to the blow tank.
6. The digester is opened and the sequence is repeated.

Continuous Digester

- A continuous digester is a tube-shaped digester where chips are moved through a course that may contain elements of presteaming, liquor impregnation, heating, cooking, and washing.
- Continuous digesters tend to be more space efficient, easier to control giving increased yields and reduced chemical demand, labor-saving, and more energy efficient than batch digesters.
- Special feeders is needed e.g., Screw feeder, Rotary valve

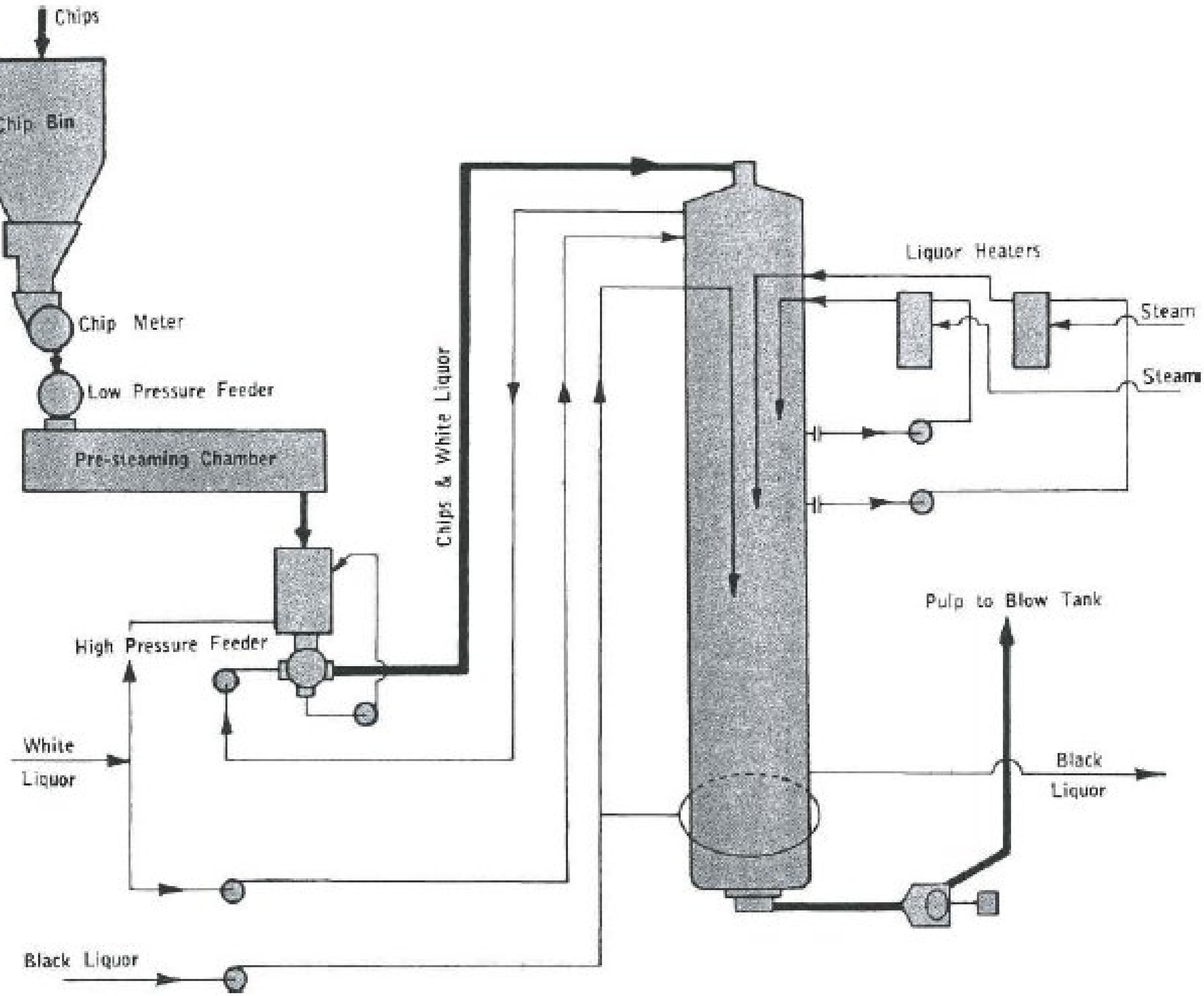


Fig. 3-13. The Kamyr continuous digester. Reprinted from *Making Pulp and Paper*, ©1967 Crown Zellerbach Corp., with permission.

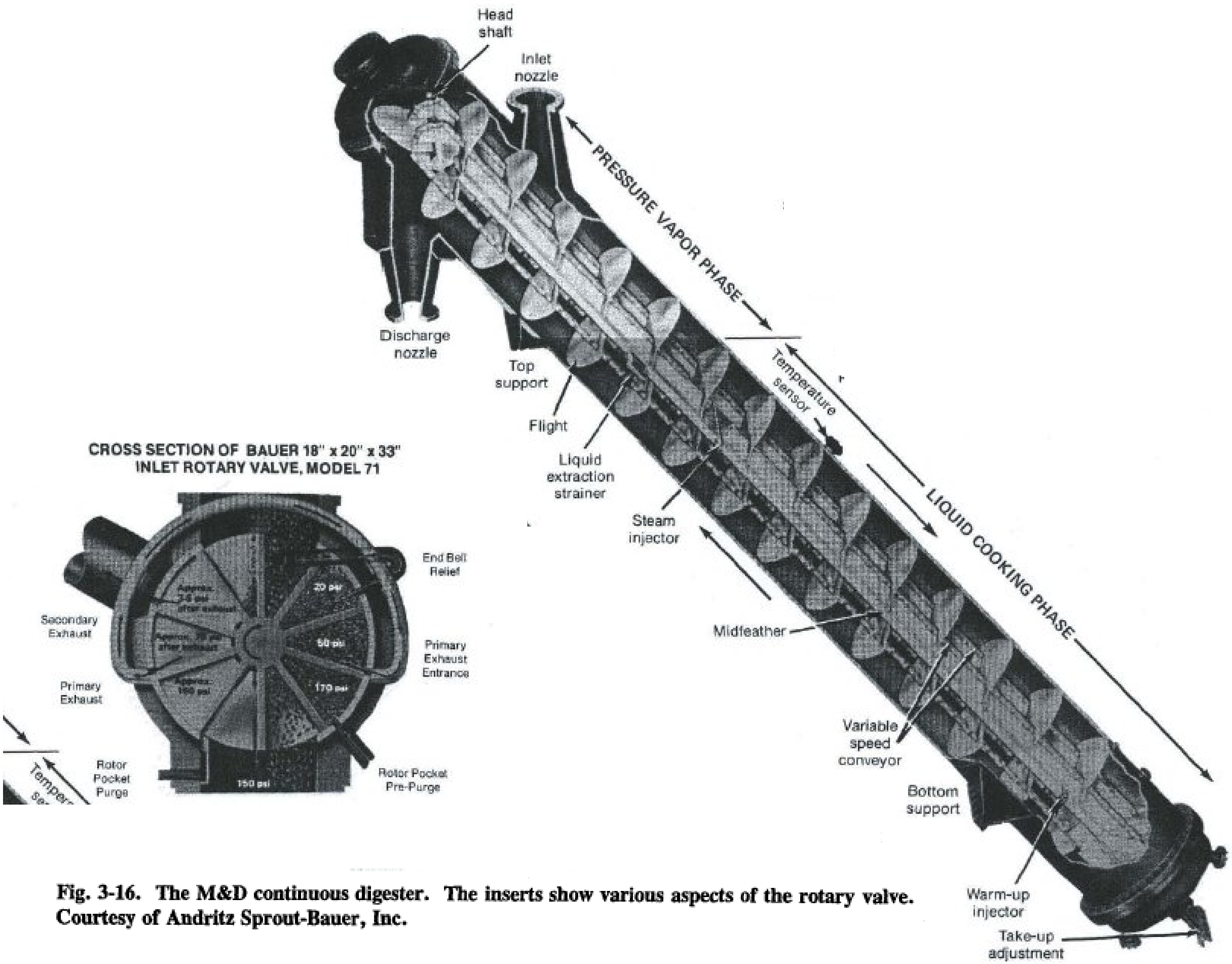


Fig. 3-16. The M&D continuous digester. The inserts show various aspects of the rotary valve. Courtesy of Andritz Sprout-Bauer, Inc.

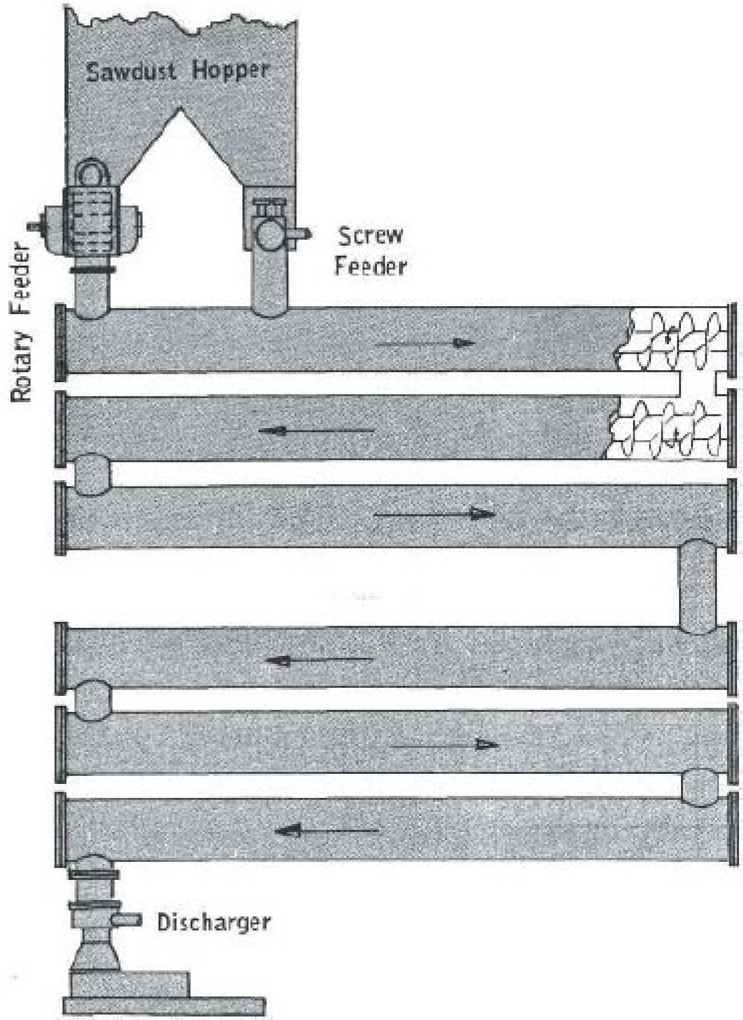


Fig. 3-19. Pandia digester. Reprinted from *Making Pulp and Paper*, ©1967 Crown Zellerbach Corp., with permission.

Blow tank

- Up to 1000 kg of steam per ton of pulp is generated by batch digesters and some continuous digesters and must be condensed.
- Condensation of the blow gases also decreases pollution by recovering most of the volatile reduced sulfur compounds, organic compounds such as methanol, and related materials known together as foul condensate.

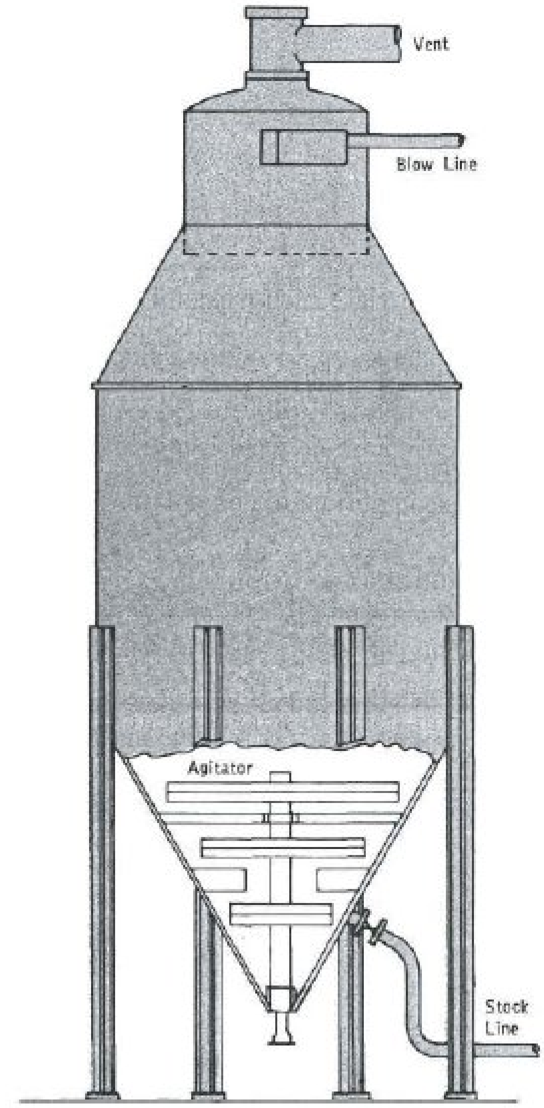


Fig. 3-20. Blow tank. Reprinted from *Making Pulp and Paper*, ©1967 Crown Zellerbach Corp., with permission.

Delignification selectivity

- Delignification selectivity is the ratio of lignin removal to carbohydrate removal during the delignification process.

Rejects, knotter or screener and pulp screener

Brown stock washers

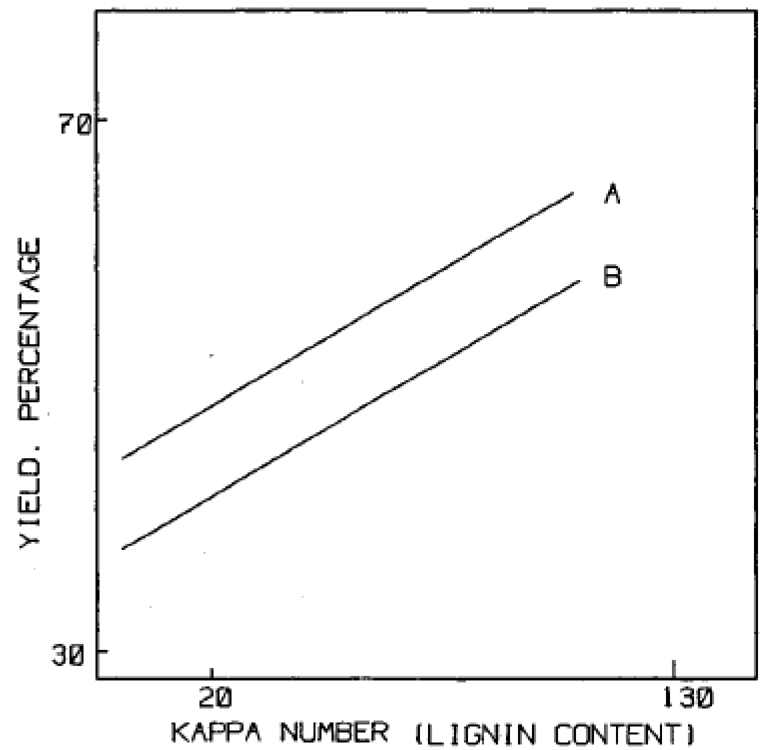


Fig. 3-21. Pulping selectivity curve.

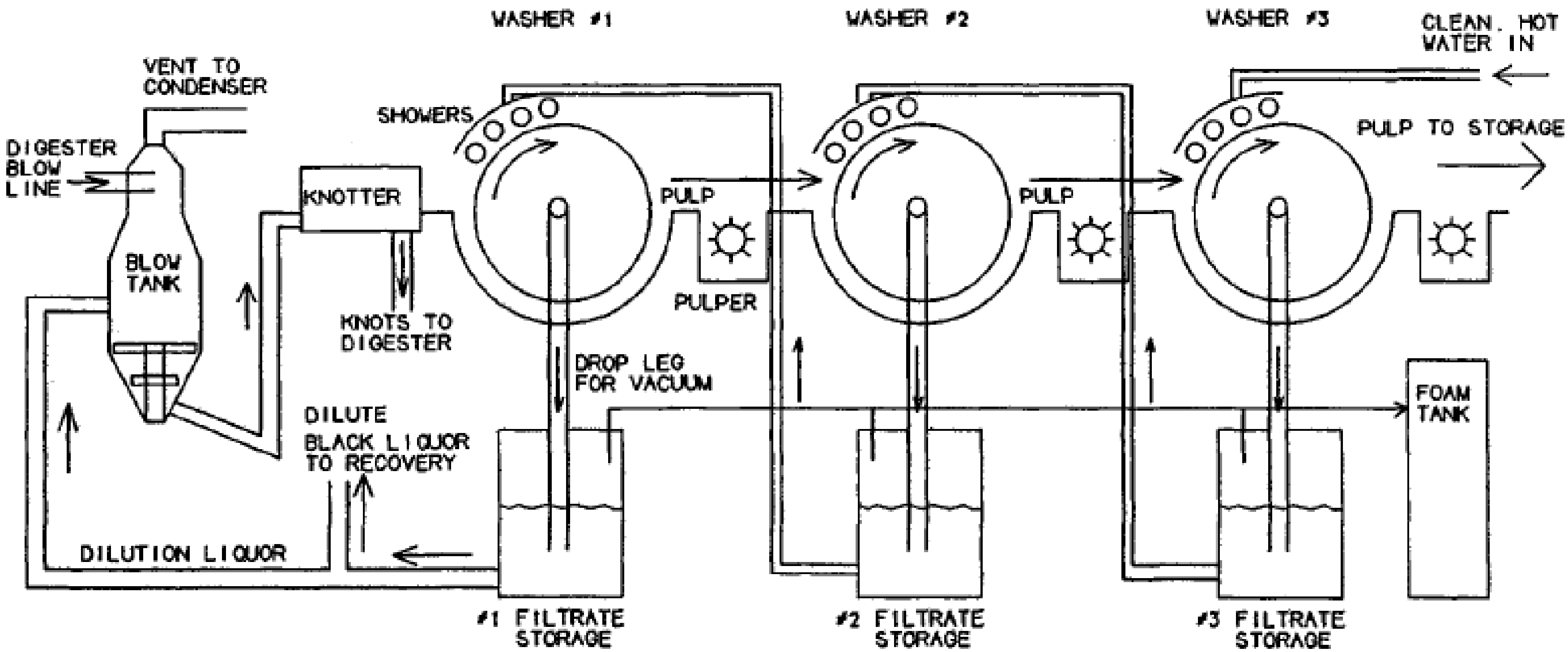


Fig. 3-24. Brown stock washers showing countercurrent flow.

Soda Pulping

- Invented in England by Burgess and Watts in 1851, but was not popular.
- The soda process still has limited use for easily pulped materials like straws and some hardwoods, but is not a major process.
- Anthraquinone may be used as a pulping additive to decrease carbohydrate degradation.

Kraft pulping (Sulfate)

- In 1879, Dahl, a German chemist
- Much faster delignification and stronger pulps, since shorter cooking times are used resulting in less carbohydrate degradation.
- Kraft pulping is a full chemical pulping method using sodium hydroxide and sodium sulfide at pH above 12, at 160-180°C , corresponding to about 800 kPa (120 psi) steam pressure, for 0.5-3 hours to dissolve much of the lignin of wood fibers.

- *H-factor:* combines cooking temperature and time into a single variable that indicates the extent of reaction(Kraft process only). The rate of delignification approximately doubles for an increase in reaction temperature of 8°C.
- *White liquor:* NaOH + Na_2S + low Na_2CO_3
- *Black liquor:* Waste liquor from cooking. About 7 tons of black liquor at 15% solids are produced per ton of pulp. This liquid is burnt at 65-70% solid content .

- *Green liquor, chemical recovery:* Green liquor is produced by dissolving the smelt from the recovery boiler (Na_2S, Na_2CO_3, and any impurities) in water. Further processing of the green liquor converts to white liquor.
- *Total chemical or total alkali (TA)*

$$TA = NaOH + Na_2S + Na_2CO_3 + Na_2S_xO_y$$

- *Total titratable alkali (TTA)*

$$TTA = NaOH + Na_2S + Na_2CO_3 \quad (\text{as } Na_2O)$$

- *Active Alkali (AA)*

$$AA = NaOH + Na_2S \quad (\text{as } Na_2O)$$

- *Effective alkali (EA)*

$$EA = NaOH + \tfrac{1}{2} Na_2S \quad (\text{as } Na_2O).$$

- *Sulfidity*

$$\text{sulfidity} = \frac{Na_2S}{NaOH + Na_2S} \times 100\,\%$$

- *Causticity*

$$\text{causticity} = \frac{NaOH}{NaOH + Na_2S} \times 100\,\%$$

- *Causticizing efficiency*

$$\text{causticizing eff.} = \frac{NaOH}{NaOH + Na_2CO_3} \times 100\,\%$$

- *Reduction efficiency*

$$\text{reduction eff.} = \frac{Na_2S}{Na_2S + Na_2SO_4} \times 100\,\%$$

- *Dead load:* NaCl
- *Residual Alkali:* NaOH present after cooking

Sulfite Pulping

- Using mixtures of sulfurous acid and/or its alkali salts (Na^{+2}, NH_3^{+}, Mg^{+2}, K^{+} or Ca^{+2}) to solubilize lignin through the formation of sulfonate functionalities and cleavage of lignin bonds.
- Advantages: Bright, easily bleached pulps, relatively easily refined pulps, pulp that forms a less porous sheet that holds more water than kraft pulps (for use in grease-resistant papers), and pulps with higher yield than kraft.
- Disadvantages: Weaker than kraft, not all species of wood can be pulped easily, cooking cycles are long, and chemical recovery is complicated.
- Treats the wood chips with cooking liquor at 120-150°C from 500-700 kPa .

- *Sulfite Liquor preparation*
- *Brown (or red) liquor*
- *Sulfite pulping base metals*

  - Calcium, Magnesium, Sodium, Ammonia
- *Chemical recovery:*

$$S + O_2 \rightarrow SO_2$$

$$SO_2 + H_2O \rightleftarrows H_2SO_3$$

$$H_2SO_3 + MOH \rightleftarrows MHSO_3 + H_2O$$

$$MHSO_3 + MOH \rightleftarrows M_2SO_3 + H_2O$$

1. Washing of the spent sulfite liquor from the pulp.
2. Concentration of the spent sulfite liquor.
3. Burning of the concentrated liquor.
4. Heat recovery during liquor combustion.
5. Pulping chemical regeneration.
6. By-product recovery (mostly in Ca^{+2} based system).

Class test 3

Date & Time:

18 September, Saturday @ 11:AM

Syllabus:

Pulp and paper covered till now