LOGGING AND LUMBERING
or
FOREST UTILIZATION

A TEXTBOOK FOR FOREST SCHOOLS
BY
C. A. SCHENCK
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TO

GEORGE MERCK

A TOKEN

OF THE BILTMORE FOREST SCHOOL'S

DEEP GRATITUDE

PREFACE.

Nowhere on earth more than in the United States is the forest utilized by ingenious devices and by intelligent men.

In America, the knowledge of forest utilization has grown, within the last forty years, on a scale as wonderful as have the sums of money annually spent on forest utilization.

The amount of money thus spent, between tree and manufacturing consumer, is likely to exceed the billion dollar mark.

The manufacturing consumer of the United States is apt to put another five hundred million dollars into the value of the raw product refined by him.

Confronted by these figures, the layman is apt to ask:—"Are our forests utilized by haphazard methods or are they utilized in a scientific way?" And further:—"Why is it that the knowledge spent on forest utilization—on that grand American industry—does not rank amongst the so-called applied sciences of the country?"

The answer to these queries lies in two points. On the one hand, forest utilization has grown, in actual practice, so phenomenally fast that no scientific lumberman in this country could dare to keep up with the progress. On the other hand, the many facts concerning forest utilization which are known to the American lumberman have never been presented in a systematic form. A systematized knowledge of lumbering would at once entitle it to the rank of a science.

In the following pages, our present knowledge of forest utilization is presented, for the first time, in a systematic form.

C. A. SCHENCK.

ACKNOWLEDGMENT.

LOGGING AND LUMBERING

(FOREST UTILIZATION).

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(A) SYNOPSIS OF PARTS AND CHAPTERS.

(B) SYNOPSIS OF PARAGRAPHS.

(C) ALPHABETIC INDEX OF CONTENTS

PARAGRAPH I.

DEFINITION AND LITERATURE.

The term "forest utilization" comprises all acts by which forests – the immobile produce of nature – are converted into movable goods or commodities. Whether it be considered as a science or as an art, "forest utilization" constitutes the major part of that forestry which is actually practiced in the American woodlands. Logging and lumbering are the main components of forest utilization, so much so, that the term "logging and lumbering" is almost synonymous with the term "forest utilization."

As a scientific theme, forest utilization may be divided into two main parts, headed: – "Logging operations," and "Manufacturing operations," to be arranged in five chapters: –

Chapter   I.   Labor employed in the forest.
Chapter II.   Cutting operations.
Chapter III.   Transportation.
Chapter IV.   Foundations of manufacture.
Chapter V.   Manufacturing industries.

Among the foreign literature on forest utilization, publications of the following authors are particularly worthy of note: –

Carl Gayer, Richard Hess, William Schlich, Hermann Stœtzer, Carl Grebe, Wilhelm Franz Exner, Carl Schuberg, Heinrich Semler, H. von Nœrdlinger, Carl Dotzel, E. E. Fernandez, L. Boppe, M. Powis Bale.

PART I. LOGGING OPERATIONS.

CHAPTER I. LABOR EMPLOYED IN THE FOREST.

PARAGRAPH II.

MANUAL LABOR.

Forest labor requires physical strength, power of endurance, and skill obtained by experience.

In America the gregarious tendencies of man are such as to cause a concentration of all labor towards the centers of manufacture, leaving the forests and farms devoid of help. Thus it is that the labor problem in the American forests becomes more and more difficult of solution; and that immigrants furnished by Scandinavia, Poland, Italy, the Balkan States, Mexico, and Quebec are used largely in American logging operations. The American workman, on the strength of his greater intellect and alertness, occupies the position of foreman, and the foreigner supplies the demand for the common hand.

Exceptions to this rule are frequently met, notably in the Southern States, where the American negro is *the* workman of the forest.

The forest workman lives, usually, in "logging camps."

(A) LOGGING CAMPS. Two kinds of logging camps may be distinguished: — "Men's camps" and "family camps."

I. Men's camps consist of bunk houses, kitchen houses, storage houses, and dining houses. They are found particularly in the Northern States and in the West. They are run either by the owner (Lake States), or by jobbers (Adirondacks), or by the employes themselves (Southern Appalachians).

The advantages of camps where men only are fed and kept at the expense of the owner consist of:

A colored crew on the holdings of the John L. Roper Lumber Co., in the pineries of North Carolina.

(a) Possibility of military discipline;
(b) Men are supplied with wholesome food, productive of human energy;
(c) Entire time and entire thought of the employe belongs to the employer;
(d) Good sanitation;
(e) Camp can be shifted easily from place to place (camp houses consisting of detachable sections usually 10 feet long);
(f) The camp force can be increased or reduced more easily, according to requirement.

II. Family camps. In family camps, the entire families of the employes are housed in the midst of the woods and in close proximity to the logging operations. Family camps are found particularly in the South and there usually in connection with logging railroads, so that the workmen can be taken every morning from the camp village to their work.

Each workman is supplied with a separate and independent cabin to suit the size of his family.

The advantages of family camps are: —

(a) Increased comfort and reduced restlessness of the employe;
(b) Large receipts at camp commissaries;
(c) Chance for the employe to work at home on inclement days;
(d) Attachment of the workman and his family to the cause of the employer, and possibility of having generations of workmen from the same family.

Proper sanitation of the camps is of the utmost importance. So called "incinerators" are used to dispose of the human excreta. The live steam of the engines is used periodically to clean the bunk houses from vermin. In the bunk houses iron beds are preferable to wooden beds. Utmost

Men's camp on the holdings of the Champion Lumber Co., in the spruce woods of North Carolina.

cleanliness is of the utmost importance as a bar to disease, which, spreading in a lumber camp, will cause large losses to the owner.

The Whitney Company and the Chapman Timber Co., of Portland, Oregon, have established complete camp outfits on wheels, consisting of bunk cars, dining cars, kitchen cars, utility car, headquarters car with commissary, and so on. A 10-car outfit is said to cost $6,500. In the case of the Whitney Company it includes heating arrangements, shower bath, electric light, &c. Compare the "Timberman," Pacific Logging Congress. July 1910, page 31.

(B) DURATION OF EMPLOYMENT.

I. Determining factors are:—

(a) Climatic conditions;

(b) Economic conditions;

(c) Local custom.

In the South, work lasts all the year round.

In the Lake States and in New England, late fall, winter and early spring (from 4 to 8 months) comprise the usual period of activity.

Logging by rail requires continuity of employment. Logging by rail also facilitates such continuity for the reason that it does not depend on climate and weather.

II. Advisability of continuous employment, especially in the case of foremen and sub-foremen, leads to the adoption of means tending to attach the laborer to his job and to his employer.

Such means are:—

(a) Scale of wages rising with the length of service;

(b) Employes' cooperative insurance against the results of accident or sickness, and financial aid in such cases;

(c) Logging camps supplied with best food, clean sleeping and dining quarters, and, in the case of family camps, with good schools, churches, medical aid and the like;

(d) Advances and loans in case of need;

(e) Wholesale purchase of commodities so as to give the workmen the benefit of a reduced price;

(f) Firewood, forest pasture, and forest litter free of charge;

(g) Permission of agricultural use, for a number of years, of clear cut areas;

(h) Rent of cabins and farms at reduced rates;

(i) Employment during the season when cutting is stopped, in road building, fire patrol, planting, weeding, nursery work, &c.;

(j) Possibility for hands to rise to a foreman's position;

(k) Encouragement of home industries so as to keep the workmen busy on rainy or cold days, i. e., basket weaving, shingle making, wood carving, sieve making.

(C) REMUNERATION.

I. Means of remuneration.

(a) Money. Wages in the South are from $1·00 to $1·75 a day. On the Pacific Coast, $2 to $3 per day. In the Lake States, $24 to $32 per month, plus board; dry days only includedt.

(b) Commissary bills. This method of payment is used in the South only, in connection with colored labor.

(c) Privileges (house, farm, pasture).

(d) Board. Expense in the South, per capita 25 to 30 cents; on the Pacific Coast, 60 cents; in the Lake States, 40 to 50 cents per day; wages of camp cooks in Lake States $60 and over per month; in the South, $30 to $45 per month.

II. Scale of remuneration. Wages depend on the effect of labor or on the values created by labor.

Cutting of cordwood and of logs, building of railroad grades, and moving dirt are no more expensive in the United States than they are in Europe.

Influencing factors are:—

(a) Density of population;

(b) Human strength and technical skill required;

(c) Silvicultural understanding required;

(d) Hardships endured and risks taken;

(e) Prices of the necessary victuals;

(f) Length of day during cutting season.

Where contract work prevails, the following additional factors come into play:—

(g) Tools supplied by employer or employee;

(h) Softwoods or hardwoods;

(i) Amount to be cut per acre;

(j) Configuration of ground and remoteness from roads;

(k) Distance from home village;

(l) Possibility of continuing work during rain.

Experiments have shown that workmen paid under contract per one thousand feet b. m. earn more money in big timber than in small timber, and that a system of payment according to the diameter of the log is far more just.

In the pineries, the cutting crew is frequently paid either per log or per sawcut.

(D) METHOD OF EMPLOYMENT. In France the woodmen are employed by the purchaser of the stumpage; in Germany, by the owner of the forest. In America both systems are found. Whether the German or the French system is preferable, remains an open question.

I. Hands are often recruited from farm laborers; hence advisability of locally combining agriculture and forestry. In addition, the employes of the building trades, unoccupied during winter, supply help for the lumber camp.

II. Day work is advisable in preference to contract work (jobbers):—

(a) Where quality (effect) of labor cannot be controlled;

(b) Where the wages of experienced hands differ from those of inexperienced hands;

(c) Where contracts are unreliable or unsafe, owing to lien laws, to exemption clauses, &c.

III. Contract work is generally preferable to day work because its financial effect is more easily anticipated. Contract work is doubly advisable where the employer's liability laws work against the employer. Contracts should always be in writing. The specification sheet should be kept apart from the paragraphs of agreement, so as not to encumber the contract.

The main clauses of a contract cover:—

(a) Time allowed to complete work;

(b) Installments and payments;

(c) Building of snaking roads, sleigh roads, and skidways;

(d) Scaling of defective logs and of sound logs (logrule);

(e) Employer's liability;

(f) Fines for fire, stock at large, misconduct, and drunkenness; and demand for discharge of culprits;

(g) Shanties and camps and commissary bills;

(h) Supply of tools; deduction for loss and spoliation of tools;

(i) Fines for cutting trees not marked;

(j) Fines for leaving marked trees uncut;

(k) Fines for poor work and unnecessary damage;

(l) Possibility of speedy termination of contract in emergency cases;

(m) Nomination of umpire to avoid suits in case of discrepancies.

The specifications cover the following points: —

Height of stumps; peeling of bark; separating product according to quality; length, diameter, weight of product; nosing logs; cutting defects out (unsound knots, &c.); placing the product on sticks (so as to allow it to dry) or on skidways; method of carrying or moving products; swamping (removal of branches); use of road poles (breast works); skidways; road building.

(E) SUBDIVISION OF LABOR. The leading principle is that one division gang must push the other.

I. Logging.

(a) Cutting or felling crews, consisting usually of two hands; sometimes a third man to drive wedges and to make the axe cut;

(b) Swamping crew, to clear trees of branches and to open suspicious knots;

(c) Bucking crew, dissecting the bole into logs. Here, the foreman should be an ex-sawyer or an ex-lumber inspector;

(d) Snaking or skidding crew. In rough jobs, five hands for a three-yoke ox-team; three men to get the logs ready and to remove brush (debris) and two men to accompany the load. In smooth jobs, one man to a single horse. Many variations between these extremes.

(e) Skidway crew — two hands rolling logs onto skidways.

(f) Steam skidding crew, consisting of engineer, fireman, signal man, hook tender, rigging men, sniper, and whip tenders;

(g) Loading crew, with peavies or cant hooks, loading logs from the skidways, rolling them onto railroad cars or sleds, or else attending the steam log loader;

(h) Road crew, for railroad extension (engineer, fireman, foreman, fourteen hands), for ice roads (sprinklers and sanders), &c.

II. Cutting cordwood (for pulp, acid, cooperage, &c.)

The following additional hands may be required: —

(a) Carriers or carrying crew — often with hand sleighs or rollers or grapple hooks;

(b) Splitters — with heavy axes having broader, thicker cheeks than cutting axes;

(c) Piling crew — careful, honest men are required for piling the wood, where work is paid by the cord.

PARAGRAPH III.

ANIMAL LABOR.

(A) COUNTRIES. In Burmah, elephants perform the animal labor in the teak woods; in the Philippines, the native water buffalo (carabao) is used; in Germany, horses are used for skidding, sledding, and waggoning.

In the United States, the horse rules supreme in the North and in the entire West. In the Southern mountains, oxen alone, and in the Southern pineries, oxen and mules are employed.

(B) HORSES. Price $600·00 per team.

I. The numerical ratio between hands and horses in Northern camps varies from 2:1 to 6:1. Horse-power tends to be replaced by steam power.

The standard amount of work for one horse is: —

(a) A haul of 1,600 lbs., inclusive of waggon, on a level road over 23 miles per day;

    (b) An output of 10,560,000 footpounds per day of 8 hours.

II. Horses are employed for:—

    (a) Skidding or snaking;

    (b) Rolling logs on skidways;

    (c) Sledding, bobbing, trucking (two wheels), and waggoning (four wheels);

    (d) Loading on railroad cars;

    (e) Excavation in railroad cuts.

III. Food for horses.

    (a) Interdependence between food and effect in footpounds, per 1000 lbs. horse flesh, during a day's work is:—

Logging teams and teamsters on a Sunday morning in Michigan.

Daily food				
	Straw	2 lbs.	2 lbs.	2 lbs.
	Hay	19 lbs.	15 lbs.	11 lbs.
	Oats	2 lbs.	6 lbs.	10 lbs.
	Effect	3,000,000	9,000,000	15,000,000 footpounds;

    (b) Food required:—

After Thær, per 1,000 lbs. of horse flesh, 25 lbs. of good hay and oats per day;

In Northern camps, 50 lbs. of oats and 40 lbs. of hay per team per day.

A bushel of oats weighs 30 to 33 lbs.; its price varies in the general market, according to grade (≠2 white clipped oats, ≠2 white oats, ≠2 mixed oats) between 35 and 40 cents.

A bushel of corn weighs 56 lbs.; its price varies in the general market, according to grade (2 white corn, ≠2 yellow corn, ≠2 mixed corn) between 52 and 60 cents.

Timothy is the best hay ($26·50 per ton); mixed hay ($22·50) and ≠1 clover hay ($18·00) are inferior more in food value than in price.

Yellow corn has more food value than white corn.

Old horses require ground feed.

(C) MULES. Price $300 per team.

I. Mules are employed for:—

    (a) Skidding light logs, notably for long distances;

    (b) Waggoning logs, lumber, and provisions;

    (c) Hauling on rail tracks (wooden and iron rails);

    (d) Hoisting logs on inclines;

    (e) Plowing and scraping, in road and railroad building.

II. Food. A medium team of mules requires, per day, 30 lbs. of oats and corn, and 36 lbs. of good hay.

Mules require less care than horses, taking care of themselves and resisting over-

Mules at work on the holdings of John L. Roper Lumber Co., in the pineries of North Carolina.

work. They are frequently not fed at noon. In the pineries, rough tents serve as stables during the entire year.

(D) OXEN. Price per yoke is from ۶80 to ۶120, weight from 2,000 to 2,500 lbs.

I. Harness. Ox yokes form the rule, although efficiency of oxen in harness is superior. Shoeing for each claw separately — difficult and risky, but necessary on hard ground.

Special training takes place from second year on. Fitness for hard work begins in the fifth year, when ossification of bones is completed.

II. Employment. In the South for snaking heavy logs — or log trains in Oregon; for hauling logs suspended underneath high two-wheel trucks or on logwaggons in the pineries; rarely for loading cars or waggons.

Logging by cattle in the mountains of North Carolina.

III. Standard work. An ox walks 14 miles per day with load. An ox yields, during eight hours of work, 270 foot pounds per second; thus he produces only four fifths of the effect of a horse.

After Thær, an ox produces only one half as much power as a horse of the same weight.

IV. Feed.

(a) It is much cheaper to feed oxen than to feed horses of same weight. Ruminants have more digestive power than horses.

No feed is given in the middle of the day, and little expense is incurred during idle periods, where pasture is available.

(b) Careful treatment and good stables required. Oxen must not be hurried. Soft yokes, proper salting and regular watering. Continuous attention to hoofs.

(c) In the South, at the present time, cottonseed meal and hulls form the cheapest food. Food requirements per yoke per day are 20 lbs. of meal and 30 lbs. of hulls. Price of meal approximates ۶25 per ton; of hulls, ۶9 per ton.

(E) COST OF FEED PER 1,000 FEET b. m. of logs: —

The cost of animal feed, per 1,000 feet b. m. of logs removed, according to the statements made in an assemblage of Southern logging superintendents, amounts to the following number of cents: —

Arkansas ... from 16 to 22 cents;
Texas ... ... from 12·6 to 37·4 cents;
Louisiana ... from 12 to 36 cents;
Mississippi . from 14 to 18 cents.

Logging by cattle in the Southern pineries. (Cut supplied by Clyde Iron Works.)

CHAPTER II.　CUTTING OPERATIONS.

PARAGRAPH IV.
WOODMAN'S TOOLS AND IMPLEMENTS.

(A) AXE.　It consists of a handle, 32 inches to 42 inches long, made of hickory, ash, locust or mulberry, either straight or "S" curved, and of a blade or head forming a steel wedge of particular temper. The cheeks of the wedge are slightly curved in the midst, falling down gradually towards the upper and lower line.　The weight lies either close to the bit or close to the handle, according to local predilection.

The best make is the Kelly axe.　The woodman of Northern Maine prefers a homemade axe forged by the village smith.

Double bit axes, requiring straight handles, are largely used in the Lake States and on the Coast. Special splitting axes, of greater weight and broader cheeks, are rarely used (for sugar barrel bolts and retort wood).

For hardwood, a thin and light axe (a cutting axe) is preferred, while for softwood a broad and heavy axe (a tearing axe) is used.

A box of axes contains an assortment of various weights.　In Europe the bit is relaid with steel, after wearing off.

The axe is used : –

　　1. For cutting trees entirely or partly ;
　　2. For swamping (axe to be $\frac{1}{2}$ lb. heavier);
　　3. For splitting ;
　　4. For nosing logs ;
　　5. For driving wedges.

Price of axes from ℰ6 to ℰ8 a dozen.　Handles are ℰ1 a dozen.

(B) ADZ AND BROADAXE.　The adz and broadaxe are used for trimming and barking export – logs, squares, ties, and construction timber. The blade of the adz has such curvature as corresponds to the curve of the sweep through the air.　The cutting edge is ground concave on the inner side.

The broadaxe is either right or left sided, the plane oft he blade forming an angle of 5° to 10° with the plane of the handle.　The handle is usually short, the blade very heavy and wide.

(C) PEAVIES.　The peavy is a typical American tool, unknown in the Old World.　The best make is Morley Bros.' line of "blue tools."

The hooks are distinguished as round bill, duck bill, and chisel bill hooks, made of hammered steel.　The socket is either solid or it consists of rings.　The square-butted pick (point) is driven cold into the round bored point of the handle.　The handle (airdried; not kilndried) is 4 to 6 ft. long, straight, $2\frac{1}{2}$ inches to 3 inches through and is made of hickory, ash, or usually hard maple.　Price per dozen is ℰ10 to ℰ22.

A peavy must answer the following requirements : –

　　1. Hook adapted to any size log ;
　　2. Bill to be so constructed as to catch securely through any layer of bark ;
　　3. Proper length, greatest strength, and low weight.
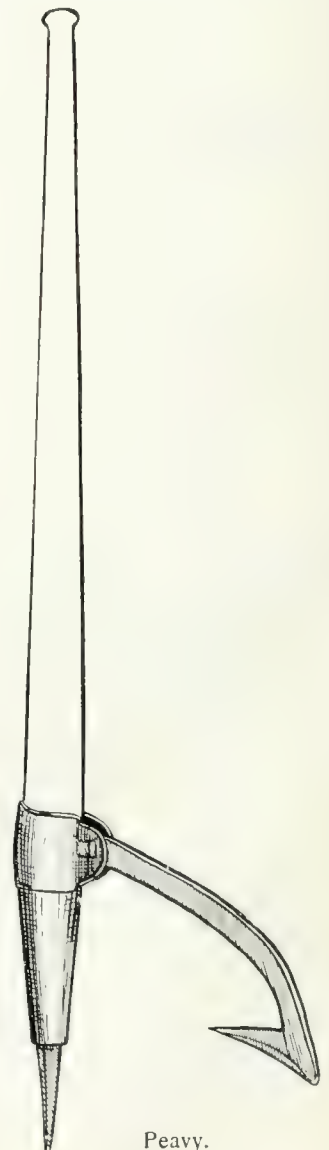
Peavy.

(D) CANT HOOKS. The cant hook is a peavy, lacking the pick (point).

The socket consists of two rings only joined by a narrow bar.

Cant hooks are used more in the mill and yard, peavies more in the woods.

(E) CROSS-CUT SAWS.

I. Radius experiments show a radius of 5 feet 2 inches to be best. The straight drag saws require excessive strength and are deficient in dust chambers.

II. Width of blade. It is at the widest point about $8\frac{1}{2}$ inches. The hollow back saws, a recent innovation, have about 4 inches width all along the blade.

III. Thickness of blade. The back of the saw is always somewhat thinner than the gauge of the teeth. Henry Disston gives the saw backs 4 or 5 gauges less thickness than the saw teeth. Atkins gives the teeth "14 gauge," the back at the handles "16 gauge," and at the center of the back "19 gauge."

IV. Uniformity of temper and proper temper are obtained by special processes. No hammering of blades. Cheeks are perfectly smooth.

V. Construction of teeth is very variable. Dust room between the teeth should be twice as large as the teeth.

For hardwoods more teeth are necessary than for softwoods.

There are two kinds of teeth, namely:—

(a) The cutter teeth, a couple or trio of which might be arranged on a common stock, to form "Tuttle or Wolf Teeth." Only the points of the cutters actually cut into the fibre.

(b) The raker or cleaner teeth, meant to plane-off the fibre when it has been severed by the cutters, and to shift the sawdust out of the kerf. European experiments claim to demonstrate the uselessness of cleaners. They occupy valuable dust room. The points of the rakers should lack 1/32 of an inch from being even with the line of the cutting points.

VI. Length of saw is from 4 feet to 10 feet.

Local crews use the "diamond cross-cut," price $2·25 for $6\frac{1}{2}'$ length, the "champion tooth," and the "hollow back" saw, price $1·30 for 6' length.

VII. Saw handles should be easily detachable. The material of the handle is maple, birch, and hickory. Handles are fixed (usually) vertically to back of saw. Sometimes, however, they are in the direction of the radius of the saw.

Large "bow" saws allow of a very thin blade and have a bow instead of handles. They are not used in America.

VIII. The effect of a saw is equal to the number of square inches cut by one man per minute. The effect is small in polewoods; it is said to be best with logs of about two feet diameter, being decidedly smaller for smaller logs, and noticably smaller for larger logs.

In cutting longleaf pine or redfir, the saw is continuously sprinkled with turpentine or kerosine.

The effect of curved saws is from 40 % to 50 % higher than the effect of straight saws.

The saw overcomes:—

(a) The resistance of the fibre by the sharp points acting as knives and planes;

(b) The friction at both cheeks of the blade by smooth cheeks and by a gauge narrowing toward the back;

(c) The friction of sawdust by deep teeth, curved line of teeth, perforation, large dust chambers, and possibly, by "cleaner teeth."

Cant hook.

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IX. Dressing of cross-cut saws.

(a) "JOINTING" means filing all cutting teeth down to exactly the same circumference.

The tool used is called a jointer. A file is placed in the joints and by a screw pressed into the proper curvature.

(b) "FIXING THE RAKERS" means filing them down with the help of a raker gauge. The rakers act as brakes if they project into the cutting line. Outside and forks of rakers are slightly filed to remove case hardening, and the point is sharpened to a planer edge.

A raker swage is being introduced to spread the points of the rakers and to give them a hook-like point, which is said to tear out long slivers instead of tearing out dust.

(c) "SETTING THE CUTTER TEETH" is done under the control of a "set gauge" with the help of a "set block and hammer," giving 3 to 4 taps (the best method when done by experienced men) or with the help of a "saw set." "Saw sets" are constructed either wrench-like or after the hammer and block principle.

Rules of setting are : —

1. Setting should never go lower than half the length of the tooth;
2. It should never exceed twice the gauge of the teeth;
3. More set is required for long saws and for soft woods than for short saws and hard woods;
4. When hammering, strike tooth fully $1/4$ inch from point of tooth;
5. If teeth are badly set, take, to begin with, all set out of the teeth;
6. Apply side file inside file holder, to take away slight irregularities of set (after filing the teeth).

(d) "FILING." Filing usually follows setting (except in the case of saws spanned in a vise, when the set is afterward given by holding the set block on one side of the spanned saw and hammering from the other).

Rules of filing are : —

1. File inside of tooth only;
2. File to a bevel or fleam of $45°$;
3. Push the file away and do not draw it toward you;
4. Do not file point to a feather edge;
5. Do not sharpen tooth below the cutting point.

(e) "GUMMING." Gumming deepens the dust chambers, so as to preserve their original size and form. Gumming is usually done with the file; the lever (punch) gummer may be used for the purpose, however.

REMARKS. A good, well-tempered saw holds sharpening and filing for three work days. Good sawyers working in hardwoods sharpen and file daily.

In the Pacific West "one-man cross-cut saws," up to six feet long are used for dissecting (bucking) the bole into logs.

A cross-cut saw file shows, on the cross section, a narrow triangle with curved back.

"Inserted-tooth" cross-cut saws are seen in the pineries.

The "spread set" of the cutting teeth has been tried and was found impracticable.

(F) WEDGES. Wedges are used : —

I. To split wood. The "axe wedge" is usually made of iron and should have straight (not convex) cheeks.

Wedges are sold by the pound.

Iron wedges are prevented from jumping by being heated; by dirt placed in the cleft; or by a rag (wet) being put over the wedge.

Wooden wedges are made of the butts of locust, hard maple, hornbeam, black gum, dogwood, and beech.

Iron wedges with wooden backs are frequently used abroad.

II. To prevent saw from getting pinched in the kerf; and to direct the fall of tree. Special saw wedges of oil-tempered steel are made by Morley Bros. Weight $1\frac{1}{2}$ to 3 lbs.

Frequently, saw wedges and axe wedges are used alike.

Wooden wedges must be driven with the axe or hammer.

Iron and steel wedges must be driven with a wooden maul.

(G) MAULS. Mauls are made of the butts of dogwood, beech, hornbeam, hard maple, gum, and locust, and are held together by two iron hoops made of $\frac{1}{2}$-inch by $\frac{3}{4}$-inch flat iron.

(H) PICKAXE AND MATTOCK. They are used where the stumps are utilized together with the bole (e. g. in cutting walnut) and in the preparation of forest roads. The points of both are relaid with steel after wearing out.

(I) BRUSH HOOKS. They are used in swamping and in making fagots or fascines; in clearing snaking roads; in dense underbrush.

(J) KREMPE. The krempe is used abroad and in India and resembles the picaroon or hookaroon used in America for handling ties, telegraph poles, and pulp wood. It is used in rolling and moving logs down hill, the pick acting as a lever, the fulcrum of which lies at the heel.

(K) PIKE POLES. Pike Poles are used with pike and hook or with pike only; are 12 ft. to 20 ft. long, made of selected white ash or spruce the points consisting of cast steel. The points are either screwed into the wood or driven without heating. Pike poles cost $10 to $25 a dozen. They are indispensable in driving and rafting operations and at mill ponds. Weight 7 to 12 lbs.

Three varieties of points for pikepoles.

(L) SCREWS FOR BLASTING. Such screws are used abroad, not to shoot stumps out of the ground but solely to split stumps where prices of firewood are high. The hollow screw loaded with blasting powder is inserted into an auger-made hole. In America, such screws can be used to good advantage in splitting unwieldy, huge logs into halves.
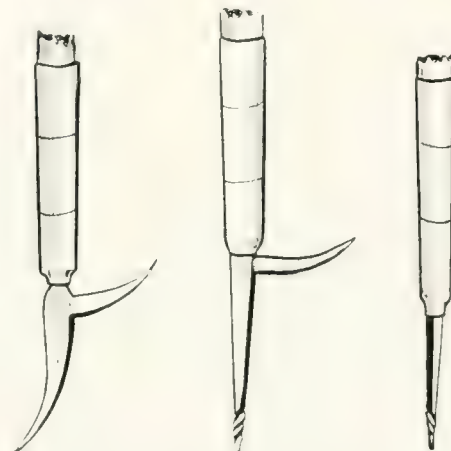
(M) GRINDSTONES. Grindstones should not be exposed to the sun, should be kept equally round and even and should always be kept wet while in use. A water trough underneath the stone should be rejected, as the submerged side softens unduly and unevenly. Stones are sold by the pound. A 70-lb. grindstone costs about $4. The extra fixtures, consisting of hubs, shafts with nuts, crank, &c. cost about a dollar.

(N) MACHINE SAWS. For felling, machine saws have proven a failure. The expense of carrying a machine from tree to tree is greater than the expense of cutting by hand.

The possibility of using a machine for bucking seems, however, more promising of success.

The cut is obtained:—

1. Either by wires heated to white heat by the electric current;
2. Or by a band scrollsaw, electrically driven, the cutting blade of which is turned by 90°, by means of sawguides;
3. Or by a fine steel chain, also electrically driven, the links of which are toothed.

(O) TREE-FELLING MACHINES. They are largely used abroad to obtain the stump of a tree together with the bole.

I. The "Nassau machine" consists of a 4-inch plank 10 inches wide into which regular steps are hewn, and of a pole about 25 feet long, with a curved pike at the small end, and squarely bound in iron at the big end. Half a foot above the big end the pole is perforated so as to receive a $1\frac{1}{2}$-inch round steel pin. The square base of the pole is placed on a step of the plank which is put flat on the ground, some 12 feet from the tree. The pole is inclined at an angle of about 50 degrees against the plank. The pike is securely placed in the bole of the tree. By means of two crowbars, the base of the pole is moved, step by step, toward the tree.

The "Buettner machine" adopts the principle of the Nassau machine. It consists of a large jack driven by two powerful hand cranks; it pushes, inclined at an angle of 45 degrees, a strong pole, some 20 feet long, against the tree. This machine is now largely used in European countries, in lieu of the Nassau machine. It is impracticable with trees having over two feet diameter.

II. The "wood devil" has been used for centuries in Switzerland. A rope or cable is fixed in the top of the tree to be felled, and a chain is fastened around a stump in the direction towards which it is to be felled. To this chain is attached a long lever, bearing a chain and hooks on either side of its fulcrum. The lower end of the rope is secured to another chain, the links of which are meant to receive the hooks. Moving the lever, to and fro, the hooks are inserted alternatingly in the chain-end of the rope, advancing two or three links at a time.

The instrument is cheap, simple, and powerful; at an angle of 45° the rope has the maximum of power.

PARAGRAPH V.
FELLING THE TREES.

Under "A" and "B" are described the chief "methods" of felling.

(A) OBTAINING BOLE WITHOUT STUMP AND ROOTS:—

I. By exclusive use of the axe, handled from one side only in cutting small trees, in thinnings and in coppice woods.

II. By exclusive use of the axe, cutting two kerfs on opposite sides. The first notch, on side toward which tree is intended to fall, made from 4 inches to 6 inches lower, must penetrate the center of the tree. Avoid felling toward the direction in which the tree leans.

Advantages of this method are the facts that one tool and one man only are required; that the bole is easily directed; that the logs obtain proper noses; that trees like hickory and redoak, notably in cold weather, are less liable to break and burst in falling, leaving long splinters on the stump.

Disadvantages are loss of bole, amounting to from 4% to 8% and loss of time and labor in large timber. This method of felling is still used in Maine, Quebec, Ontario.

III. By hewing "out of the pan," a method used for valuable heavy boles. Uncertainty of fall is counterbalanced by a gain in the length of the bole. The bole thus obtained is said to show less heart shakes.

IV. By using the two-handed cross-cut saw alone, without the help of the axe, a method not advisable for the reason that the fall of the bole cannot be directed.

V. By joint use of cross-cut saw and axe. The axe (in redfir, axe and saw combined) cuts a kerf on the falling side, the depth of which is $\frac{1}{4}$ to $\frac{1}{5}$ of the diameter, and the innermost point of which lies on a level with the saw kerf (in redfir, four inches below the level of the falling-side saw kerf). When the saw begins to pinch, drive wedges behind the back of the saw. Withdraw the saw when the tree begins to shake heavily and force it to fall by wedging. Be sure to fully sever the "corners" of the kerf, so that the falling tree turns on a streight hinge. Tough-barked trees are girdled before the saw is applied.

Ready to fell the Douglas fir, holdings of C. A. Smith Timber Co., on Coos Bay, Oregon.
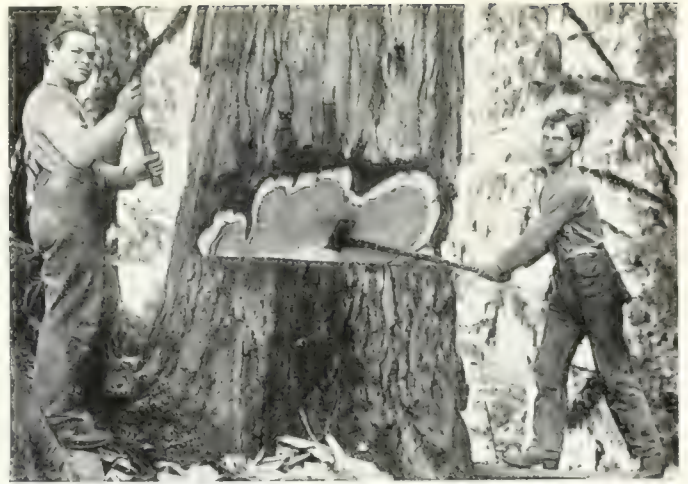
Making the under-cut in a Douglas fir, holdings of C. A. Smith Timber Co., on Coos Bay, Oregon.

Advantages of this method are:— The trees are easily directed; the loss of timber is small.

Disadvantages are:— Several tools and several men are required. In very thick woods and on very rocky, steep slopes, the use of the saw is not advisable or possible. Careless wedging may cause the bole to split at the butt. The saw and the wedge are said to be responsible for many heart shakes.

(B) OBTAINING BOLE WITH STUMP AND ROOTS:—

It is essential to thoroughly sever the main roots with axe, mattock, and pick. The tree is then forced over by a tree-felling machine, or with a rope fastened to a high limb.

Advantages are:— Longer bole; gain of lumber 8% to 10%. Possibility of obtaining knees for ship building (tamarack, redfir, cedar, and white oak). The tree falls gently, its fall being checked by the roots, so that the bole shows less splits, cracks, and wind shakes. The bole is less apt to break and can be allowed to dry out gradually. Further, root-breeding insects do not find any incubators, and agricultural use is facilitated.

Disadvantages are:— Greater expense; more tools; axes ruined in cutting roots; extra saw cut required to sever the butt log from the roots; above all, delay in finishing the logging job.

(C) CRITERIA OF A GOOD METHOD:

1. Safety for the workmen;
2. Certainty of felling in a desired direction;
3. Difference between log value obtained and expense spent in obtaining it;
4. Avoidance of injury to trees not to be removed.

(D) POLLARDING BEFORE FELLING:

Branches or tree tops are frequently lopped off before felling, for the following reasons:—

1. The younger generation of trees surrounding the tree to be cut receives less injury;

Felling an oak with roots and stump by the Buettner felling machine.

2. Lopped trees touch the ground all along the bole at one and the same time. Thus the danger for the boles to break or split is reduced. In addition, a light crown causes the tree to fall with decreased force.

(E) USUAL FELLING RULES:—

1. The trees must be thrown in such a way as to do least damage to themselves, to surrounding trees and to undergrowth;
2. The felled tree should lie in a position allowing of easy dissection of bole and of easy removal of logs;
3. Operations must be stopped during severe winds;
4. Trees over 6 inches in diameter should be sawn down, coppice woods excepted, when the axe is used;
5. No more trees should be felled than can be worked up within a reasonable time after felling. (Exception:—redwoods);
6. The stumps should not be higher than the tree's diameter;
7. All trees marked for cutting, and none else, must be cut;
8. The tops should be swamped so that they may come in contact with the ground.

The Southern logging superintendents, at a recent meeting, gave the following as the figures, in cents per 1,000 feet b. m., for expenses incurred by their concerns when cutting logs:—

Arkansas   ...   from 33·6 to 37 cents;
Texas ...   ...   from 23 to 45 cents;
Louisiana   ...   from 14 to 59 cents;
Mississippi ...   from 28 to 35 cents.

In the Pacific States, felling costs $20^1{}_2$ cents, and bucking another $20^1{}_2$ cents per 1,000 feet b. m.

PARAGRAPH VI.

DISSECTING (BUCKING) THE BOLES OF THE TREES.

(A) PURPOSE OF DISSECTION:—

1. Reduction of freightage;
2. Adaptation to different methods of transportation required for different assortments;
3. Accomodation of buyers requiring different assortments;
4. Obtaining manageable size of logs and wood;
5. Removal of defects.

As much net value should be obtained from the bole as is possible.

In no forest on earth is all the woody substance produced marketable. The amount of offal (waste, debris) depends merely on the expense of transportation to markets within reach. It is better to waste wood than to waste money. The modern lumberman gathering logs of 4 inches diameter and the modern forester objecting to any waste frequently neglect this truism.

(B) FACTORS INFLUENCING THE DISSECTION:—

1. Requirements of the market governed by custom, specifications, and inspection rules of lumber;
2. Distance from market:—the longer the distance, the better must be the quality of the product;
3. Locality (e. g. steepness of slope; swampiness);
4. Local laws (e. g. in North Carolina relative to 8-foot firewood);
5. Available means of transportation and their construction;
6. Freight rates varying with the degree of conversion;
7. Size of cars and waggons;
8. Length of mill carriage and of feedworks; size of drykiln.

(C) THE MAIN DIVISIONS OF WOODY PRODUCE obtained from dissected boles are:—

1. Piece stuff, e. g. logs, blocks, construction timber, sold by the foot, the standard, the pound;

2. Numbered stuff, e. g. poles, posts, mine props, ties, scaffolding poles, shingles, boards, staves, sold by the dozen, by the hundred, by the thousand, &c.;

3. Stacked stuff, e. g. industrial cordwood (for insulator pins, bobbins, pulp, tannin, &c.), tanbark and fuel, sold by the cord. In the case of tan bark, 2,240 lbs. are usually considered the equivalent of one cord.

Bucking at Coos Bay, Oregon, on the holdings of the C. A. Smith Timber Co.

(D) THE SPECIFICATIONS GOVERNING THE DISSECTION DESCRIBE:—

1. The dimensions, e. g. the range of length and diameter desired for each section obtainable;

2. The quality of each section and the defects allowed and prohibited therein.

(a) Saw logs for lumber:—

1. The dimensions. Spruce in New England is often cut 13 feet 4 inches long with a diameter of 5 inches and up.

For yellow pine logs, any length and any diameter over 8 inches are permissible.

Hardwood logs for lumber have a length ranging from 6 feet 4 inches to 18 feet 4 inches, arranged in intervals of 2 feet.

Hardwood logs for staves are cut, in Maine, to the following lengths:—10′, 8″, 13′, 4″, 16′.

Redwood logs are cut 16′, 18′, 20′, 24′, 32′, 40′ long, one year after the trees are felled.

In Douglas fir, the standard lengths of logs are from 24 feet to 40 feet.

Export logs of yellow poplar are 8 feet and 16 feet long.

Jack pine logs for cheap box lumber are often cut 6 feet 6 inches long, the diameters ranging from 4 inches upward.

2. Treatment. Saw cuts at either end of log should be perpendicular. Branches should be swamped off, knots cut level and laid open. In the case of conifers, the bark is frequently peeled off. Bark rings are sometimes left at the ends. Defects of bole must be concentrated in one log, or must be sawn out. Nosing is required for loose driving and for snaking.

Painting of end faces with red lead is prescribed for export logs. Very heavy logs are sometimes split in two. Putting logs on sticks to prevent spoliation of sap and to reduce specific gravity is often advised.

(b) Blocks for woodenware.

Poplar, for large bowls, must be entirely free from defects. White pine blocks are often cut between the whirls of branches.

(c) Hub blocks must be butt logs, the length allowing to cut either two or four out of the block;

(d) Construction timber is hewn according to local requirements. Minimum diameter at small end most important. Construction timber abroad is sometimes whip sawn;

(e) Poplar and walnut squares run from $4'' \times 4''$ to $10'' \times 10''$. They are whip sawn in the backwoods of Western North Carolina;

(f) Telegraph poles. The smallest diameter, the diameter at or close to the big end, the length, crooks and treatment of bark must be considered. Pointing of the small end is specified sometimes;

(g) Fence posts. Species, length, smallest diameter, straightness, method of manufacture, &c. must be considered. Usual length is $6\frac{1}{2}$ feet;

(h) Railroad ties. Specifications are very variable. Face is usually from $6'' \times 6''$ to $8'' \times 9''$. Sawed railroad ties are used, especially, in the yellow pine section. Great waste in hewing ties from trees just too small to yield two ties. Specifications cover allowance of sap, wind shakes, wany edge, dote, number of rings per one inch (in pine);

(i) Shingle bolts. Lengths are multiples of $16''$ and $18''$, usually;

(j) Mine props. Middle diameter from $3''$ to $8''$;

(k) Stave and heading bolts. Basswood heading bolts used in Michigan. Length $18''$ or $37''$ and diameter not less than $8''$. If from $12''$ to $18''$, split into halves. If over $18''$, split into quarters. White oak bolts measure $36''$ for stave bolts and $24''$ for heading bolts; core and sap must be hewn out; minimum face at inner edge $4''$.

Heading bolts for sugar barrels in the Adirondacks consist of spruce cut in lengths forming multiples of $22''$ with a diameter minimum of $6''$.

Stave bolts for sugar barrels consist of birch, beech, and maple, the lengths forming multiples of $32''$, with a diameter minimum of $8''$.

(l) Blocks for carriage spokes. Material is black or shellbark hickory, white oak, white ash, and post oak strictly free from imperfections. Minimum diameter $12''$; length $6\frac{1}{2}$ feet, $7\frac{1}{2}$ feet, $8\frac{1}{2}$ feet and so on;

(m) Paper pulp. Logs scale $4''$ and upwards; no dead timber. In the State of Maine pulp logs are peeled in the woods;

(n) Veneering blocks. Hardwoods preferred, of the biggest possible diameter, but certainly over $18''$ diameter. Blocks from 2 to 8 feet long;

(o) Tannin extract wood (chestnut). Length of wood 5 feet, split from logs 10 inches and over in diameter. Wormholes allowed. Fibre must be sound. A cord consists of 160 cubic feet. Higher price for peeled wood. Butt logs preferred. Cutting of saw logs out of same tree forbidden;

(p) Fuel cordwood. Advisability for piles to contain one cord. Weight of pieces should be such that one man can lift them easily. Splitting facilitates the process of drying; in sappy wood, it also prevents rotting.

CHAPTER III. TRANSPORTATION.

PARAGRAPH VII.
LAND TRANSPORTATION WITHOUT VEHICLES.

The following "methods" of transportation on land and without the use of vehicles, are en vogue: —

(A) CARRYING STOVE WOOD, pulp wood, extract wood, &c. on men's shoulders, a method of transportation largely used abroad and in India. Carrying distances range up to one eighth of a mile. In India, railroad ties are carried by the Hindoos over much longer distances.

"Stretchers" are sometimes used where slope is not steep, or "timber carriers." Morley Bros. lughooks are used in America.

At Biltmore firewood is carried to the roads over an average distance of 150 feet on men's shoulders. Tanbark is similarly carried to the sledding roads by the armful.
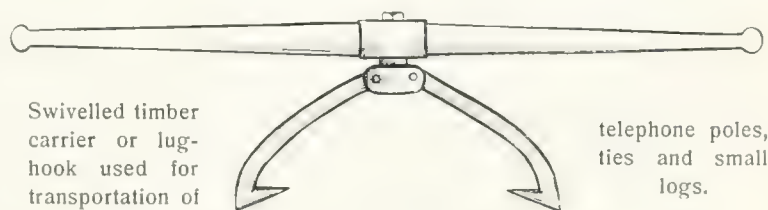
Swivelled timber carrier or lughook used for transportation of

telephone poles, ties and small logs.

(B) DRAGGING LOGS BY HUMAN FORCE where vehicles or water is near and where produce does not weigh over a ton. The front end of a log is placed on a tray (lizard) to prevent it from boring into the ground.

Barked or peeled and well trimmed logs are easily dragged.

(C) ROLLING LOGS and round blocks by human labor is necessary almost everywhere. Peavy, cant hook and "krempe" are used for the purpose.

On a slope of about 25 %, after removing obstacles, logs will roll easily.

Rolling by hand is a common method in the Southern Appalachians. On the steeper slopes the logs run away frequently, leaping and jumping with the result that they arrive at the bottom in a badly shattered condition.

Naturally, log rolling is also objectionable from the standpoint of silviculture.

A dell sloping at a grade of about 30 per cent is sometimes filled with (peeled) logs; then the top logs are rolled or shot down the dell over the other logs below.

(D) SHOOTING LOGS OVER "CHUTES." Chutes are slides, more or less roughly constructed in a mountainous country. Logs, bolts, or cordwood are placed in these chutes, and are conveyed downward by force of gravity.

Three kinds of chutes proper may be distinguished: —

> Pole chutes;
> Board chutes;
> Earth chutes.

I. **Pole chutes**, costing, according to quality of chute and to availability of suitable material, between ⨉ 300 (Appalachians) and ⨉ 3,000 (Pacific Coast) per mile, have been largely used in the mountains. They are said to last from seven to ten years and should have the following minimum grades: —

	For long logs	For short logs	For railroad ties
Dry chute	15—20 % ...	25—35 % ...	26 %
Iced chute	4— 8 % ...	8—12 % ...	6 %
Watered chute ...	3— 6 % ...	5— 8 % ...	5—8 %

Heavy curves must be avoided and the outside of light curves must be fixed with a number of "saddle logs."

A pole chute consists of a trough made of three to six poles. It is about three feet wide and requires cribs or yokes for a foundation where it is not laid into the ground.

Water, ice, oil, and soap are used for lubrication. Chutes made of hardwoods are said to run smoother than those made of conifers, owing to the greater elasticity of conifers. Where the grade is light, poles should be peeled and hewn on the inside. The grade of inlet must be steep; the shallow outlet should open into a pond. Frequently, when the job of chuting is finished, the poles or logs composing the chute are shot down themselves, thus dissolving the chute.

Steel pins placed in auger-made holes bored into the bottom logs, and projecting slightly above the holes may be used as brakes on steep grades.

The main disadvantages of pole chutes are:—

(a) Loss of logs by abrasion, by breaking after jumping, and by splintering;

(b) Impossibility of having a grade equally good for small as well as big logs, straight as well as crooked pieces, dry as well as wet weather. A grade particularly good for the running of the logs is not sufficiently steep for starting the logs to run;

(c) Waste of stumpage in the construction of wooden chutes;

(d) Impossibility of moving a chute from one site to the next;

(e) Requirement of continuous repairs.

Irregular grades, irregular frictional resistance, irregular size of logs counteract the advisability of the use of log chutes.

II. Board chutes, which are frequently movable, consist of 1-inch or 2-inch boards. They are used in delivering firewood, tanbark, and other short stuff over slopes of $25\,^{0}/_{0}$ to $35\,^{0}/_{0}$. The rougher the produce, the steeper must be the grade and the wider and smoother must be the trough. Sprinkling is required during dry weather, sanding during wet spells.

III. Earth chutes. These resemble snaking roads of a steep, steady grade. The grade must be:—

(a) Where snow or ice crust is available, 8 to $10\,^{0}/_{0}$;

(b) Where split cross ties are used, laid about 5 feet apart (for logs 16 feet long or longer), from $10^{1}/_{2}$ to $18\,^{0}/_{0}$;

(c) Where dry earth is used, $35\,^{0}/_{0}$ and over.

Road poles must be used on the valley side, especially so in curves, and bridges must cross all the gullies.

(E) "ROPING" is a method employed for moving long and heavy logs in the "Black Forest." A rope is fastened at the small end of the log to a ring dog and swung once or twice around the stump of a tree nearby. The log is started by the "krempe," and its speed is controlled by loosening or tightening the loop around the tree. When the rope is run out, the log is stopped by tightening the rope as it spins round the stump. That done, the rope is collected into a wreath, and the end fastened anew around a stump close to the log. A slope of 35 degrees is best adapted to "roping."

(F) SNAKING LOGS OR SKIDDING LOGS.

I. By oxen. Attachment by chains 12 to 16 feet long (per yoke) and $1/_{3}$ inch to $1/_{2}$ inch thick ending in "dogs." When a chain link breaks, a "cold shut" is put in its place (cost $3 per 100 for $1/_{2}$-inch chain). Ox harness is rarely used. In the South three yokes form a "team," usually, the chains running from yoke to yoke. The "leaders" require special training. The middle yoke is called "swing yoke," and the strong rear yoke is called "snub yoke." The driver manages the yoke of oxen by shouting, applying the whip as little as possible.

Timber chute for transportation of logs in Oregon.
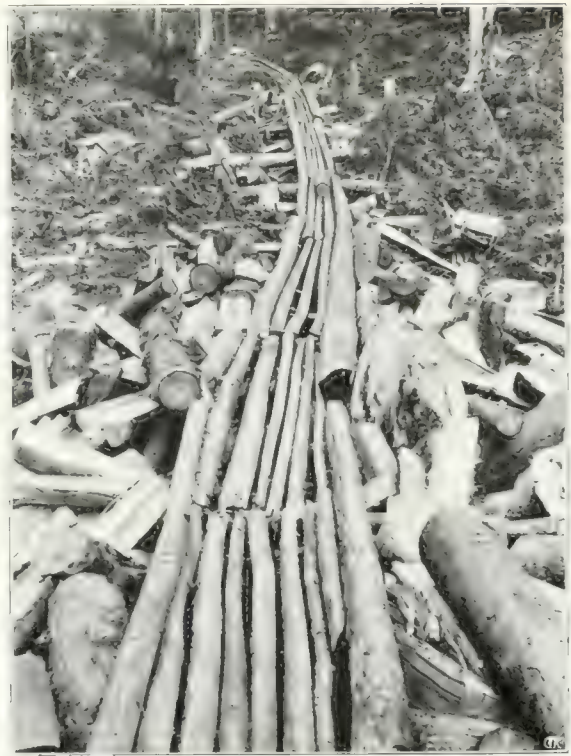
Pole chute for transportation of pulpwood in Western
North Carolina.

Junction of two pole chutes, holdings of Champion
Lumber Co., North Carolina.

Pole chutes in the Karpathians: to the right a pole
chute in use, to the left a pole chute dissolved, with
the supports still standing.

Carting grabs.

Logging by cattle in Western North Carolina.

Crotch grabs.

II. **By horses.** For smaller logs skidding tongs are used in place of dogs, attached to main chain by three rings, swivel and hook, and costing, per dozen, about $50.

Stretchers prevent the traces from hurting the legs of the horses.

On muddy soil, the nose of the log is frequently placed on a tray, or a lizard, or a triangle.

"Trailing logs" are frequently attached to the front logs by so-called "forepaws."

On steep routes, the traces are let out as long as possible, and the dogs or tongs are placed high on the log.

For uphill, the point of attachement is low, and the traces or chains are shortened.

On very steep snaking roads, drivers should let the horses run, with reins loose, provided that the horses are attached to logs by "jaycrabs" which unhook automatically, when the horses take refuge in a "jayhole," or escape, dug sideways from the logging road.
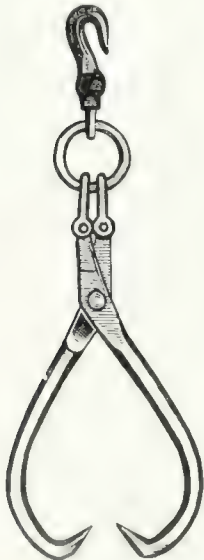
Skidding tongs

Trailing a train of logs in a jungle of rhododendrons, Biltmore Estate, North Carolina.
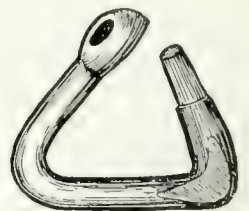
Cold shut.

III. **Roads for skidding or snaking.**

(a) Uphill grades must be avoided; even level stretches are disastrous. The grade depends on the season of usage. Where ice and snow are available 1% or 2% are ample. On dry rocky ground 50% is the maximum. On an average, 20% seems best.

(b) Curves must be strictly avoided, especially "inside curves" skirting a gully. Herein lies the greatest difficulty encountered in the construction of snaking roads in sections where the mountain slopes are deeply gullied.

(c) In the Appalachians the surface of the road is $2^1/_2$ to $3^1/_2$ feet wide, and "road poles" laid on the valley side or crossties laid diagonally across the road prevent the logs from leaving the road.

Swampy and moist places are corduroyed lengthwise with the road. Creeks must be bridged. It must be kept in mind that one bad spot in a snaking road requires the use of additional teams frequently over the entire length of road.

Out West, cross ties are placed on the road 7 feet apart. Long log trains are formed. In such trains, the pull or strain on the animals is evened or equalized, some logs sliding down hill while other logs of the same train overcome impediments.

Logging by cattle in Oregon.

(d) Means of lubrication are: — Sprinkling with water; laying cross ties or length ties; peeling of logs; greasing the ties.

Means of braking the logs are: — Sprinkling earth, sand, hay and branches on the road; throwing chains on the road, or tying chains around the logs.

(e) Snaking distance. Snaking distances range up to one mile (usually), averaging about one third of a mile. Where many logs, say 100,000 board feet of logs or more, must be transported on the same road over an average distance greater than one third of a mile, means of transportation other than snaking are usually preferred.

In the Appalachian hardwoods, the expense for 1,000 board feet snaked over $^1/_2$-mile amounts to about $4. In the Adirondacks skidding costs 40c to 50c per 1,000 board feet, the distances being short, since the logs are merely skidded to the skidways arranged alongside the sleigh roads.

(G) LOG SLIDES. Slides are troughs consisting of two strings of logs (maple, beech, birch 10 inches and more in diameter) resting on heavy, round ties. They are used on grades ranging between 5 and 25 per cent, down hill. Crooked trough logs are made straight, and straight ones are forced into curvature by saw incisions made in the bends.

The logs are placed in line, pinned to the supporting ties at the outside by pins driven into ax notches. The inside is hewn to a plane. The inclination of the plane against the horizon depends on the curvature. The hewer uses a broad ax and is guided by a chalk line. The width of the slide at the top, between the logs composing it, is 24 inches approximately. Small poles are sometimes fixed in the base of the trough. Oil is used as a lubricant where grade is insufficient. The danger of the slide being burned is much increased by the use of oil.

The trough is parallelled by a 6-foot road for a team of horses to walk on. The team pulls from 5,000 to 10,000 feet at a time, being attached to the last log of a "train" by a long chain. Before the log train is started the logs are spread apart.

Oiling a log slide.

Here and there auger holes are bored into the hewn faces of the logs or else into the top of the ties supporting the logs. Into these holes steel pins are inserted for the purpose of:—

Preventing the running away of logs where the grade is steep.

Collecting a log train.

Safeguarding the horse teams from stray logs getting away behind.

The slides end in dumps, the logs dropping down automatically, one after the other, through a gap in the trough.

The expense for a first-class slide varies between $2·50 and $5 per rod.

(H) DRUMS, WINCHES, GYPSIES, CAPSTANS, POWER DONKEYS. These machines consist of drums on which a rope or cable is wound by hand power, horse power, or steam.

Horses pulling a string of logs over a timber slide on the holdings of the Little River Lumber Co., Tennessee.
(Photograph kindly supplied by H. H. Gibson.)

I. **Hand drums** or winches are used for yarding logs and especially for hoisting logs uphill on steep inclines, the distances not exceeding 300 feet. A one-man "drumgrab," weighing 275 lbs. and exerting a power of two tons, costs $30. A log attached to the rope's end is hoisted up when the drum revolves.

II. **Drums with mules** as motive power are used in Eastern Tennessee for hoisting logs up to the rim of the sandstone plateaus. An "upright" is secured in swivels above and below. A mule is attached to a 10-foot pole forming a radius to the upright; the mule walking round the upright and thus revolving it, causes a rope to be wound up close to the top of the upright.

III. **Steam power** is now universally used out West in connection with hoisting drums known as "bull donkey," "donkey," "road engines," "yard engines," "gypsies," &c. The cylinders are from $9'' \times 10\frac{1}{4}''$ up to $13'' \times 14''$.

Attempts to run these engines by electricity or by compressed air with the help of electricity have been futile so far, owing to the extraordinary demands made on the electric motor under the conditions of Western logging.

The motor, to answer logging purposes, should be of unusually rugged design, capable of withstanding large overloads (peaks) for short periods. The three-phase current seems to have given the best results so far. Circuit breakers and protective devices should use special devices permitting the motor to hold on to a heavy overload — up to one hundred per cent — for a few seconds. A large amount of surplus power must be available at the central station supplying the current.

The use of fuel oil in steam donkeys has not met with success on the Pacific Coast.

Log slide in West Virginia.

Westinghouse-Willamette electric skidder on trial at the C. A. Smith Mill, Marshfield, Oregon.

Heavy road engine at work on holdings of
C. A. Smith Timber Co., Marshfield, Oregon.

Steam donkey engines must possess: —

> Plenty of power (large boiler capacity, so as to maintain pressure in spite of poor fuel).
> Unbreakable construction.
> Fast working speed.
> Spark arrestors and water pumps, to prevent fires.

With the yard engines, skidding roads are usually dispensed with.

With the road engines, excellent "roads" are used, covered closely with wide and strong ties, costing in the redwood belt as much as ⨯5,000 per mile; or else log-troughs (pole roads) forming an immense gutter through which the logs are pulled.

The machines consist of upright boilers (100 to 200 pounds pressure) on sled runners, one or two quick-acting steam engines, and two, three, or four drums.

"What a steam donkey may pull." Washington Iron Works, Seattle, Wash.

Well known manufacturers are: —

Lidgerwood Mfg. Co., 96, Liberty Street, New York City; Lambert Hoisting Engine Co., Newark, N. J.; Washington Iron Works, Seattle, Wash.; Willamette Iron and Steel Works, Portland, Oreg.

The drums are used: —

To wind up the haul-in cables, (over "fairleaders"), thus pulling logs or log trains toward the machine;

To play out the haul-in cable, with the help of a tripline (pull-back cable) running over a series of sheaves or tackle-blocks, having from 9 to 18 inches diameter.

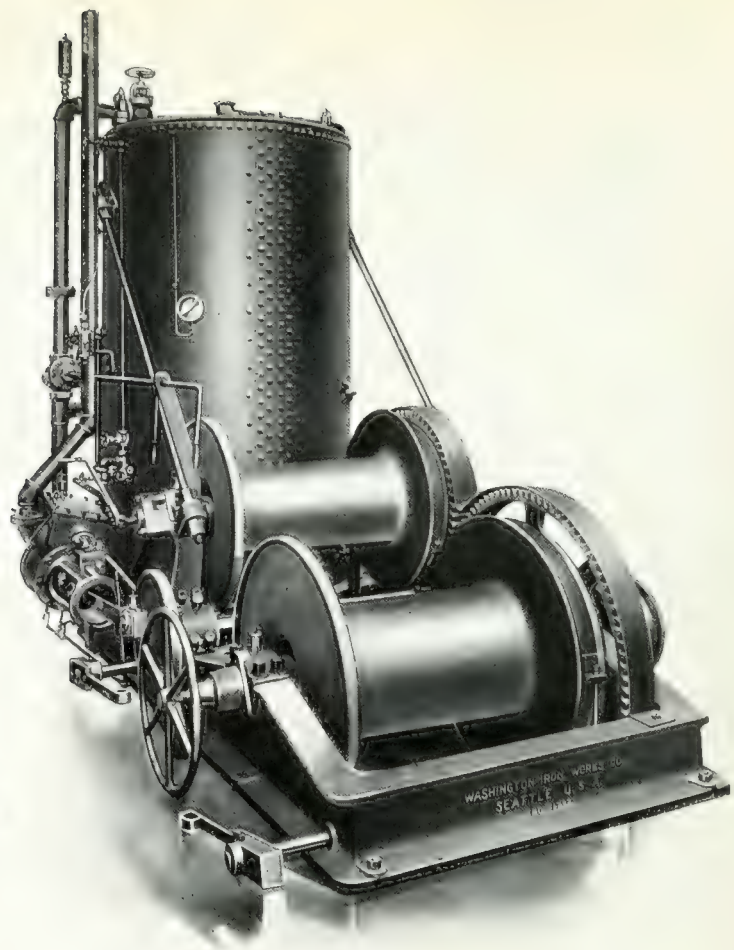The skidding (yarding) distance should not exceed 1,200 feet.

The cable used is the best make of plough steel wire rope cable (J. A. Rœbling Works, Trenton, N. J., or Broderick & Bascom, 809, Main Street, St. Louis, Mo.).
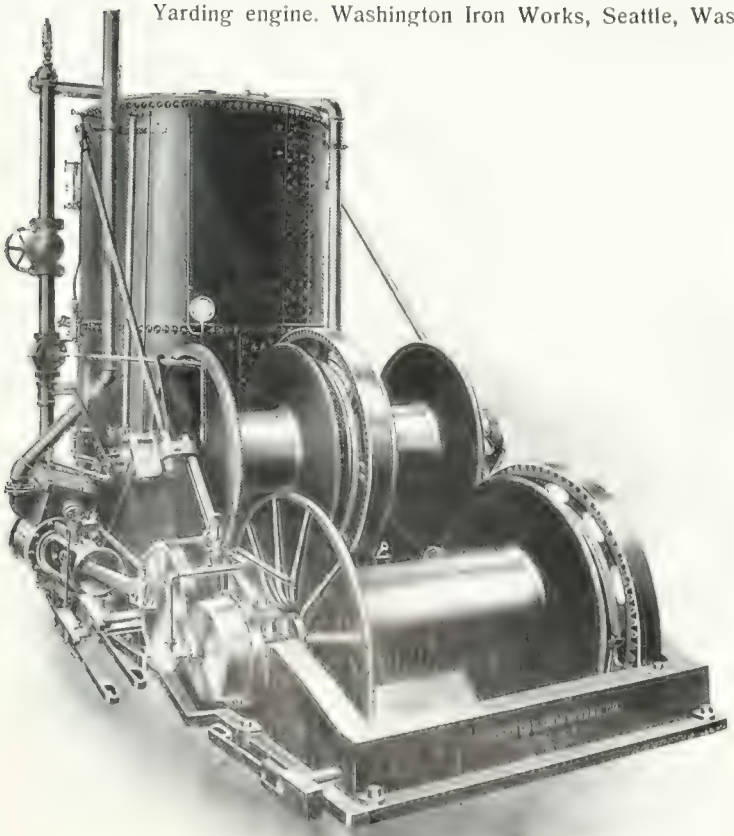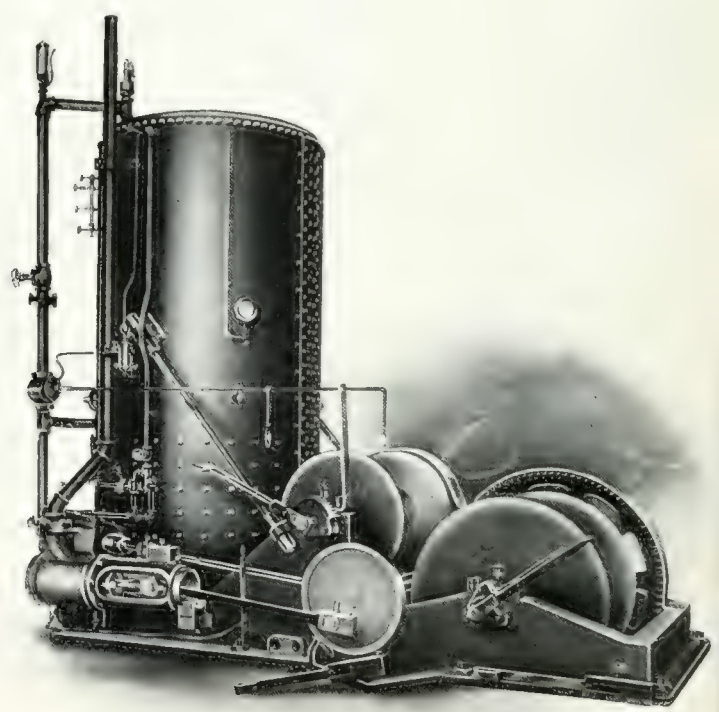
Yarding engine. Washington Iron Works, Seattle, Wash.

Road engine. Washington Iron Works, Seattle, Wash.

Three-spool road engine. Washington Iron Works, Seattle, Wash.

Small donkey engine. Washington Iron Works, Seattle, Wash.

The size and length of cables customary in Western skidding is:—

Hauling line   ...   1¼″   5,000′ on road engine; 1,500′ on yard engine;
Pull-back line ...   ¾″   15,000′ on road engine; 3,000′ on yard engine;

The wire cable is usually made of 6 strands, each containing 19 wires, wound around a hemp center. Running cables should never be galvanized. The proper load of a cable is only one fifth of the breaking strain in tons. Steel ropes (cables) have twice the strength of charcoal iron ropes. Zig-zags can be made by using tackle blocks ("butt chain blocks," made of manganese steel) on the hauling line. One engineer and one fireman are all the crew required in addition to one hook tender, two rigging men, and one whistle boy. Frequently the engine loads the yarded logs on railroad cars by means of a third drum. Engines are moved from place to place by their own power. Skidding expense per 1,000 feet about 50 cents, on an average. Price of donkey engines ⋆2,000 to ⋆5,000.

Self-propelling donkey engines on wheels (gypsy locomotives) are used on the Pacific Coast for:—

Log skidding;   ...   Pile driving;   ...   Switching cars;
Log loading;   ...   Stump pulling;   ...   Wrecking.

These gypsy locomotives have two drums, or gypsies, in front of the horizontal boiler, each drum carrying 600 feet of ¾-inch cable. The wheel base is 11 feet.

IV. Clyde and Lidgerwood systems. In the North, South, and East, in connection with railroads, the steam skidding (ground skidding) systems of the Clyde Iron Works, Duluth, Minn., and of the Lidgerwood Mfg. Co., 96, Liberty Street, New York, are being used extensively.

Excellent as these systems are, they have proven unfit:—

For Western logging (logs too heavy);
For skidding distances exceeding 900 feet;
For rough mountain countries;
For stumpage averaging under 5,000 feet per acre.

The machines may be described as donkey engines placed on flat cars. The cables are run over the tips of huge, convergent beams extending from the end of the flat car into the air to an elevation of 35 feet above the rails. The two-line independent skidders, with outhaul lines, but without cable, cost from ⋆7,000·00 to ⋆8,000·00, depending on the size of engines and boiler, and the style of truck. The four-line independent skidders range from ⋆7,500·00 to ⋆12,500·00, without cable.

The crew required for a modern steam skidder, skidding from two sides simultaneously, consists of 2 engineers, 1 fireman, 2 signal men, 4 hook tenders, and 4 whip tenders. The ground covered at one setting is a square at each side of the railroad having sides 900 feet long.

The machines are self-propelling. Their capacity will actually average, in the pineries of the South, for two-side skidders, 60,000 feet per day.
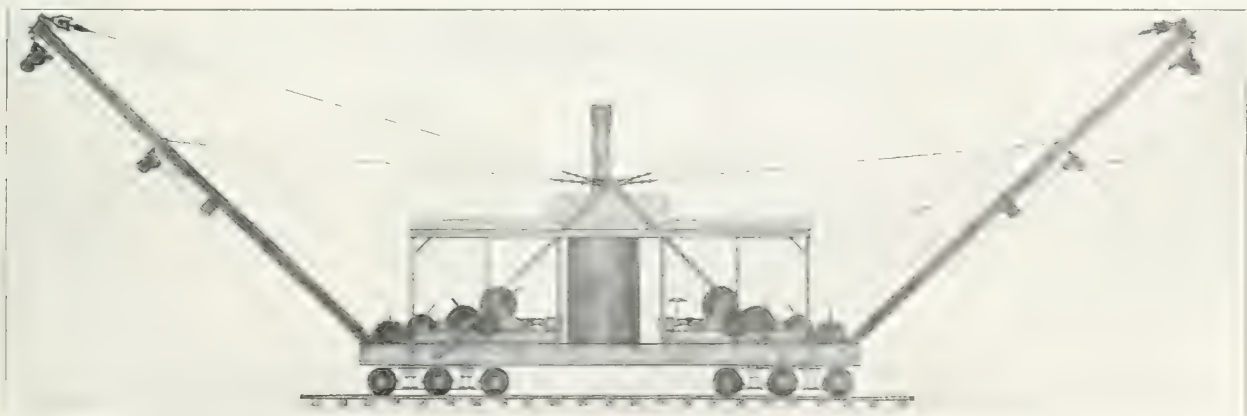
Double-end self-propelling ground skidder, without loader. Lidgerwood Mfg. Co., Liberty St., New York.

Four-line skidder in operation. Clyde Iron Works, Duluth, Minn.

There are two engines, to the right and to the left of an upright boiler. Between the engines are two stretcher drums, containing 3,000 feet of ¹₄-inch stretcher cable, which is merely used to stretch out the

rehaul at the time of setting up. The stretcher cables are pulled out by hand over three or four sheaves, placed on the corners of the squares to be logged.

In front of the stretcher drums are the left hand and the right hand "skidder drums" each carrying 1,000 feet of ⅝- inch steel wire cable. These cables are run over sheaves (blocks) at the tip of the beam.

At the front end of the platform there are found the right hand and the left hand "rehaul drum." These drums carry each 3,000 feet of ½-inch rehaul cables. The end of the rehaul cable is attached to the end of the skidder cable, making a solid circuit over the sheaves. The rehaul is meant to carry the skidder cable back to the hook tenders.

Clyde skidder en route to a new location on J. L. Roper Lumber Co.'s holdings, N. Carolina.

There may be found, also, an additional set of drums, the "log deckers," with a short ⅝- inch cable. The purpose of the decker is the adjustment of skid- ded logs on proper skidways along the railroad track, so as to facilitate loading.

Finally, a series of "guy ropes" are strung out from stumps near by, over spring- supported blocks at the tip of the beam towards drums to the right and the left of the plat- form. By this means the tip of the beam can be fastened and held through steam pressure, with the result that the shocks to the beam are well absorbed.

The skidders require a heavy rail — forty pounds or more — and strong ties.

So-called combined skid- ders and loaders are worked to advantage in small jobs.

Obviously, the skidding capacity of an engine is not proportioned exactly to its loading capacity. The amount of logs skidded per day varies according to the density of stumpage and to the obstacles met.

The price of a combination skidder and loader is $2,000 for a 7 × 10 engine and $2,500 for a 8½ × 12 engine. The price of self-propelling machines is over twice these figures.
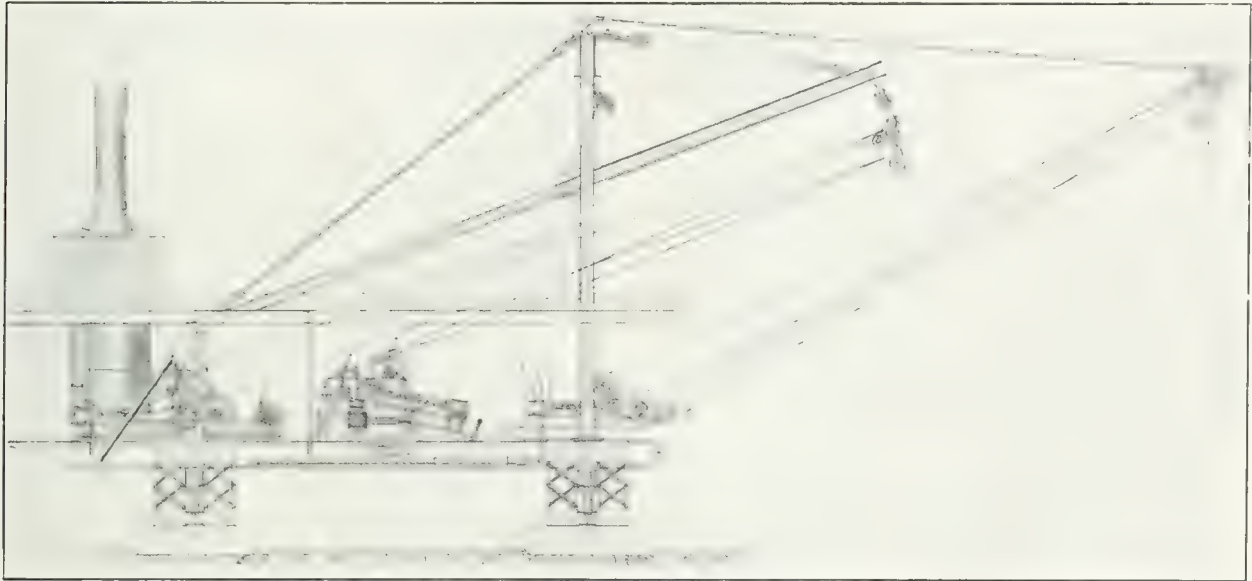
Self-propelling combined ground-skidder and loader. Lidgerwood Mfg. Co., Liberty St., New York.

The regularity of the mill run and the regularity of the movement of the trains are best subserved by independent skidders and loaders.

In the pineries of the South it is stated that the entire expense of cutting, skidding, and railroading does not exceed an average of $2 per 1,000 feet b. m. Skidding by horses, with 2-wheel trucks, is said to be about $1, and skidding by 4-mule waggons is said to be about $2 more expensive than steam skidding, under otherwise equal conditions.

It is obvious that steam skidding is compatible only with a system of clear cutting. It does not answer the purpose of selective cutting, for silvicultural reasons as well as for economic reasons.

PARAGRAPH VIII.

WATER TRANSPORTATION.

Logs or lumber are driven loosely, floated in rafts, or flumed.

(A) LOOSE DRIVING is a method used in Eastern America for short logs, pulp wood, and firewood.

Specific gravity of material driven must be reduced below 1·00. Heavy species might be deadened some months before driving, like teak in India or cypress in the South, to attain this end, provided that attacks from fungi or insects, on the deadened trees, can be avoided.

Under favorable conditions, where the creeks are narrow and well watered, no special arrangements for driving are required.

I. Splash dams. The proper site for a splash dam is the rocky narrows of a water course below a broad bottom of little fall, or else at the outlet of a natural lake.

Large splash dams must be placed on rock foundations. The expense of building increases at a cubic ratio with the height of the dam.

Small splash dam, seen from below, at the summer
camp of the Biltmore Forest School.


Splash dam with the gate swung open

Splash dams built in tributaries are preferable to dams in the main creek, provided that they can be filled quickly enough.

A system of dams of first, second, and third importance is frequently formed.

The distance of effectiveness of a dam depends on the size of the water reservoir, the width of the water course below the dam, and the rapidity of its fall.

Splash dams meant to be permanent must be built of stone and are exceedingly expensive. The Yellow Poplar Lumber Co., of Coal Grove, Ohio, have built a concrete splash dam in West Virginia at an expense, it is said, of $200,000.

The usual splash dam consists of timber cribs filled with rock and joined by logs laid crosswise. The front of the dam must be slanting and
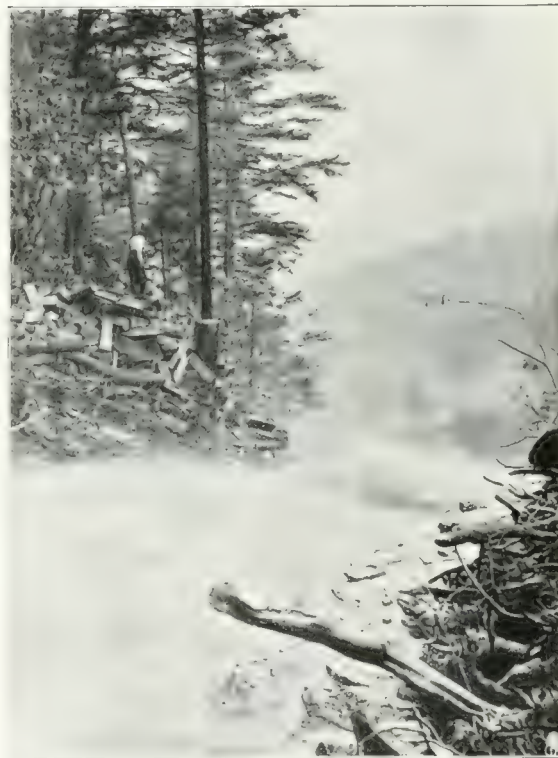
In the midst of the splash.

is covered with a double layer of boards. The gateway of the dam must allow of rapid drawing (or opening) of the basin. The gates are either constructed barn door fashion, held in place by a strong key and lever, or consist of piling, the individual piles to be lifted by a crowbar or drum. Half-moon-shaped gates are used in the Lake States and in the Adirondacks.

The smaller the water supply and the greater the pressure, the tighter must be the gate.

Frequently additional small gates are made to give a "fore-water," meant to loosen the logs in the creek below the dam. The actual

Large splash dam in the Karpathian mountains. The small
ladder protruding from the top of the dam opens a small
gate by which the fore-water may be given.

Fixtures along the banks of a stream used for splashing
and driving.

A small splash dam used for splashing of pulp-wood, Western
North Carolina.

Russian river drivers at work after a splash: Notice the
destruction of the river bank.

splash presses the logs down the creek, instead of floating the logs. The expense of a splash dam of
the first order is from $1,000 to $3,000. A timber splash dam lasts from six to ten years.

II. Dams in the creek bed itself are sometimes required to raise the water in a shallow section.

III. Before driving begins, the creek bed must be cleaned out, by removing old log jams, leaning trees
and huge boulders. Sharp bents of the creek must be cut through, so as to straighten the creek bed.

IV. Fixtures along the bank of the creek are required to prevent logs from getting smashed when
striking a bluff; from being thrown on the bank in a curve of the creek; from destroying the banks, and
further to prevent the spread of water and loss of force, where a splash is expected to overrun adjoining flats.

Such bank fixtures consist of: —

Pole cribs filled with rock, the poles lying solid, pole to pole, or of inclines of poles laid horizontally, supported by strong uprights from behind, or of alternating layers of fascines and stone, joined together by strong piling driven into the ground; or, finally, of brush laid on the sloping bank and irregularly covered with rock.

V. **The bottom of the creek** is sometimes paved with stone or poles laid lengthwise, where the bottom consists of muddy clay. This is especially necessary in artificial channels or canals dug through sharp curves of the creek, or dug close to the connecting booms.

VI. **Driving on a large scale**, in rivers swollen by melting snow.

(a) Crew: — 50 men, including cook;

(b) Outfit: — 4 work boats, 1 wangan boat, 2 waggons, 4 tents, including cook tent, 3 horse teams;

(c) Boats: — Boats are manned by 4 oarsmen, 1 bowman, and 1 steerman using paddle and pikepoles. An extra hand sits between stroke oar and steerman. Two boats crews on each side of river. The preceding crew rolls the stranded logs back into the water. The succeeding crew pushes the logs into the current. Usually, the majority of the crew walks along the bank of the stream;

(d) Jams are distinguished as "dry wings" (on one shore), "dry centers" (on an island), "eddies" (in a bay at the foot of rapids). Small "dry wings" are loosened by the steerman sticking his pike into the "key" log, the man sitting next to him helping. A small bunch of logs is loosened at a time (not single logs), the crew rowing the boat back into the current. "Eddies" are "swept" by a "sweep boom" stretched round the eddy, thus: — Logs are rolled into water; longer logs are boomed in the rear by chains; shore end of boom is tied to a tree; river end is pulled by all four boats rowed together; boom logs are unfastened and set loose.

In a large drive, the expense per 1,000 feet b. m., taken over 100 miles, approximates $ 1·50.

VII. **Booms.**

(a) THE CORDWOOD BOOM is a rake boom, the teeth of the rake formed by strong palings.

The tops of the teeth are connected by strong timber bars, which are held in place by stone cribs.

The boom is stretched diagonally across the river. The wood is merely diverted by the boom and forced into an artificial side canal ending in a reservoir near the mill or depot; it is not caught or kept in the boom.

Rake-boom in Galicia, seen from above.

Rake-boom in Galicia, seen from below.

A gridiron or sieve, filtering the river at a waterfall and retaining the wood on the gridiron, has been used in the Tyrol by the Bavarian Government for many decades.

(b) THE LOG BOOM consists of two sections, an upper shear boom extending diagonally across the stream and a lower storage boom stretching for miles along the river bank, where the water is quiet and the current slow. Both booms are floating booms consisting of one or two strings of prime logs, the logs joined by anchor chain. The booms are kept in place either by wire cables $3/4$ inch to 1 inch thick, by piles driven into the river bottom, or by stone filled cribs. It is advisable to have the storage boom consist of independent sections so that a break of the boom empties one section only.

Log boom and piers in the St. John's River, Maine.

Frequently several mill concerns form "boom companies."

The logs are lifted out of the booms by "jack works" or "log hoists."

VIII. Driving and splashing must be considered a backwoods method, applicable to cheap stumpage. It is rarely practiced on the Pacific Coast, owing to the size of the logs and to poor water facilities. Where there are plenty of natural lakes, in the coniferous forests of the Adirondacks, Maine, Quebec, and Minnesota, the method continues to be practiced.

Splashing is the more advisable: —

(a) The smaller the specific gravity of timber;

(b) The shorter the logs;

(c) The lower the stumpage price;

(d) The more reliable the rainy season and the gauge of the river;

(e) The better the natural conditions are at the dam sites, in the creek bed and at the boom site;

(f) The poorer the natural conditions are for railroad building and waggon road building;

(g) The less land owned by other parties is traversed by splashed logs;

(h) The more the saw timber improves while being bathed in running water;

(i) The longer the distance;

(j) The more inclined the log owner is toward taking risks and the less affected he is by reduced fertility along the river bank.

REMARKS: — In the pine woods of the South in olden times ditches were dug about three feet wide, connecting stumpage with swamps and rivers.

The outlay per 1,000 board feet in splashing and driving is, at Biltmore, from 50c to $1 (for manual labor only).

Log boom and log hoist in the St. John's River, Maine.

River driving of cord wood at Biltmore from the upper end of the Biltmore Estate to Asheville, inclusive of yarding at the boom, costs 50c per cord.

(B) RAFTING.   Loose logs are tied into rafts at a place where the flow of the creeks and rivers begins to be more gentle.

Only rarely are rafts used in connection with splash dams on very rapid streams (Black Forest).

According to the size and species of logs, rafts are formed either with the logs lying with the stream (longleaf pine rafts, &c.), or with the logs lying square to the stream. in this latter case the length of the logs should not exceed eighteen feet.   Square rafts consist usually of hardwood logs.

I. Logs with the stream.

(a) The logs are joined into raft sections, each section one log long; the narrow end of the log points down stream; joining usually by rope, cable or chain; ring dogs or eye dogs are used, or wooden pins in connection with auger holes;

(b) At the tail section the rear ends of the logs are allowed to spread fan shaped;

(c) The raft is directed by long rudders (sweeps), by brakes (poles which are pressed against the bottom of the river) and pike poles, also by tugboats, or by ropes attached to the shore where the raft passes by whirlpools;

(d) The width of the raft and the tightness of binding depend on rapidity of stream, span of bridges to be passed, sharpness of bents of river and width of river bed.

REMARKS:—Ring dogs for rafting weigh about $1\frac{1}{2}$ pounds, are four inches long and have a $2\frac{1}{2}$-inch ring, through which rope is run. Price 10c apiece.

Eye dogs are made of $\frac{1}{2}$-inch round iron, are six inches long and cost 6c per pound.
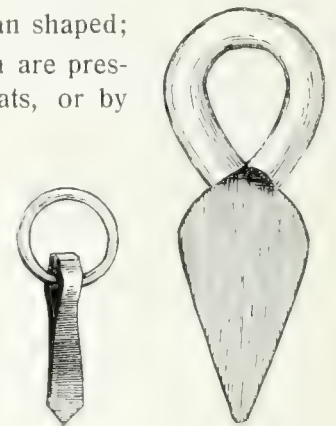
Ring dog for rafting.   Eye dog for rafting.

II. Logs square to the stream.

(a) The ends are joined by cross poles, sometimes imbedded in the logs and held in place by pins driven into auger holes, or by chain rafting dogs, consisting of two small wedges joined by two rings and five links of chain.   Weight $2\frac{1}{2}$ pounds.   Price 12c.

(b) The logs must have about equal length. Species not floatable otherwise are tied up with floaters of pine, yellow poplar, cottonwood and linden.
In the Mississippi two oak logs are floated by three cottonwood logs.

(c) Such rafts are naturally stiff and cannot be used on rapid streams. The small ends of the logs should alternate with the big ends so as to keep the sections straight.
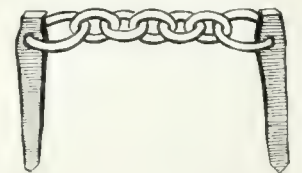
Chain rafting dog.

(C) FLUMES.

Flumes resemble mill races made of boards. They must be water tight. They are largely used in the Southern Appalachians, in the Sierras and in the Cascades.

I. A V-shaped cross section has proven best. Side boards are equally long (about 16 feet). Angle of the V = 110 degrees.   Top width is 3 to 4 feet.

The square box flume requires more water than the V-flume; and it fails to have the strongest current in the center.   On the other hand, the bottom of the square box may consist of short slats placed square; and the expense for lumber and for construction is reduced.

II. An even constant grade of from 1 to 5 degrees is necessary, also slight curves and large water supply, the latter often obtained from artificial reservoirs. High trestle bridges are sometimes required.

III. The main flume has a number of tributaries. A crew is stationed along the flume; special attention is given to the inlets of tributaries. Patrol trails along the flume.

Lumber flume at Waynesville, North Carolina.

Box flume in Swaine county, North Carolina.

IV. Heavy dimension stuff, to be resawn at the outlet of the flume, is sent down from the Sierras. Here the lumber placed in the flume forms one continuous chain, so that it is prevented from sticking and catching at the side walls of the flume.

Famous flumes are those at Chico, Sierra Nevada Range (40 miles of flume), the flume of the Bridal Veil Lumber Company, and the Great Madeira flume, in California. The latter is 54 miles long, and has a daily carrying capacity of 400,000 feet of lumber. It costs $5,000 per mile.

The scarcity of water in California is the greatest obstacle to the continuous use of flumes.

High trestle bridge carrying a timber flume in the Sierra.

Hexagon lumber flume, near Biltmore, North Carolina.

Log-dump of the Chapman Timber Co., in the Willamette   On the bridge of the log - dump, Chapman Timber Co.,
Slough near Portland, Oregon.   Portland, Oregon.

V. In North Carolina, flumes are used for the conveyance of pulpwood, tannic acid wood, and hard-wood lumber. Many of the flumes, cheaply constructed, have failed to fulfil the expectations of their owners. Irregular grades, sharp curves, weak supports, jams caused by frost or by light lumber overreaching the slow-floating oak, have led to endless expense and to disappointment. The usual flume charges are $1 per 1,000 feet of lumber. Cost of construction is $700 to $3,000 per mile.

VI. At Hood River, Oregon, log flumes of a peculiar type are used in canyons unfit for railroading. The flume is a box measuring $6' \times 4'$ across, constructed of $\frac{3}{4}$ plank. Its fall is 1 inch in 100 feet. The flume sections are terraced, one below the other, and the logs are dumped from one section into the other, with the smallest possible loss of water. The logs are towed by hand (one man to 50 logs) from the upper end of a section to the lower end. Such a log flume, constructed at an expense of $3,000 per mile, has a daily capacity of 250,000 feet. Ten men only are required to tow the logs and to handle the "gates" at the dumping points.

(D) WATER TRANSPORTATION OVER SLOUGHS, LAKES, AND SEA is effected in the following ways:

I. In the "fiords" of the Pacific Coast, logs standing upright are chained together so as to form a stockade in which train loads of logs are placed, like so many bunches of cigars, filling it tightly. Such stockades hold about half a million board feet of logs at a time and form a seaproof raft, pulled to the mill by tugboats.

II. In the estuaries of the rivers joining the Atlantic along the Southern Coast, two cars of pine logs are chained together into a log bundle. A number of such bundles are towed by small tugboats over distances averaging thirty miles to the mills situated close to the navigable water of the ocean.

III. Spindle shaped rafts are taken, during the summer months, from the Oregon and Washington Coast to San Francisco, being launched like steamboats and towed by tugboats. The steamship companies consider spindle - shaped rafts a great danger to navigation.

IV. In carrying logs over the sloughs of the Pacific Coast, or across the lakes in the Adirondacks and in

Tugboat pulling "raft" or "bagboom" of red fir logs on Coos
Bay, Oregon, for Smith-Powers Timber Co.

the Lake States, light ring booms are used ("bagbooms" on Pamlico Sound; "rafts" on Coos Bay).

The logs are placed into such booms at "the landing," and are rafted (driven) to the outlet of the lake viz. to the loghoist either by wind, current, or tugboat.

PARAGRAPH IX.

TRANSPORTATION ON LAND BY VEHICLES:—THE ROADS.

(A) USE, NOMENCLATURE, AND FACTORS influencing the construction of forest roads.

I. "**Forest roads**" are routes of travel for locomotives, cars, sleds, waggons, &c., engaged in the transportation of woodgoods. It might be said that forest roads are the only all-comprising means of transportation, and for that reason superior to any other.

Forest roads are more independent of weather conditions than any other means of transportation; forest roads are therefore the most reliable means of transportation.

Roads are used for:—

(a) Transportation of forest products from the forest;

(b) Transportation of camp supplies and logging supplies into the forest;

(c) Protection against fires, storms, insects, and trespass, the road acting as a fire lane, as a severance cutting, and as a means to keep possession;

(d) Yarding places for forest products; means to increase the farm value of the country contiguous to the road; lines of compartments or blocks.

II. According to the amount of traffic for which a road is used, there may be distinguished:—

(a) "Main roads" devoted to continuous, general use, including haulage of supplies;

(b) "Spur lines," forming feeders of main roads and built at a smaller expense; used temporarily, not continually, for transportation of forest produce, and left unattended after being used.

III. According to the character of the road surface, there may be distinguished:—

(a) Earth surfaced roads;

(b) Ice and snow surfaced roads;

(c) Stone surfaced roads (Macadam, Telford, gravel, shell, and Koltz roads); stone pavement; asphalt and bitulithic pavement);

(d) Wood surfaced roads (brush, fagots, corduroy, pole roads; wooden rail railroads; sawdust roads; wood pavement);

(e) Steel surfaced roads (railroads; steel troughs).

The surfacing of a road might extend over the entire face of a road or merely over the routes used by the wheels (e. g., railroads, Koltz roads).

Steel rails are the only kind of surfacing which allows of transfer from one road line to another.

IV. The investment in roads is governed by the following factors:—

(a) Topography;

(b) Situation of market or of point of delivery;

(c) Volume of forest produce to be conveyed;

(d) Wages of manual and team labor;

(e) Price of raw material required for road building.

It is evident that the amount of money to be invested on roads is controlled by forest-financial considerations:— That sum of money must be spent for road building which will bring the investments made (soil, timber, farms, mines, orchards) to the highest state of relative productiveness, with the result that the highest and safest annual surplus dividend is secured from the aggregate investment.

A road system must be so planned and built that it increases the value of the forest estate by more than the actual cost of the road. A road system is often meant to last for a number of years. For that reason it is necessary to anticipate, when building it, the requirements of the future. A road system should be planned invariably with the help of a topographic map.

The unwillingness of the average forest owner to sink additional capital into permanent betterments is one of the main hindrances to the development of conservative forestry in America.

V. Road system:— A road system in a mountainous section may contain "Crest Roads," "Slope Roads," "Valley Roads," and connections between them.

The Valley Roads should be close to the creek or river (if its fall does not exceed the permissible grade), so as to make both slopes readily accessible; and so as to give the road builder the choice between the slopes, bridges connecting the slopes from time to time, without extraordinary expense. Naturally, however, the road must be a few feet above the high water mark of the water course or depression followed by it.

The plan of the road system should be embodied in a topographical map and should form an integral part of a "working plan."

The direct line joining two points is found either with the help of a map by reading the direction of the line on a protractor, or by trying,— the usual method.

Surveying means trying. The best route can be selected only when a number of routes have been tried.

Stakes for narrow roads had better be placed at the upper side of the proposed bed. Stakes for wide roads built on solid foundation may be placed at the lower side. Usually, stakes are placed in the middle.

When the road is staked out, the right of way should be cleared from trees and bushes so as to allow of the discovery of obvious mistakes. The building of a rough trail along the staked line facilitates the movement of the crews, the control of the expense and the control of the grade.

VI. The roll of roads in conservative forestry. Conservative forestry requires, among other permanent investments, means of transportation built in a permanent way, so that the outlay incurred for new arteries of transportation need not be reimbursed from the annual gross revenue. The upkeep account alone should form a charge on the annual budget.

It can be shown easily that the development of conservative forestry abroad has gone hand in hand with that of public and private roads. Abroad as well as here, in the absence of permanent roads ready for use, destructive forestry is found to be en vogue. Where a road system is established, it is both possible and remunerative to cut a "wood" or a part of a "wood" at the time when it reaches financial maturity. Selective cutting is possible only, practically speaking, where permanent roads are at hand.

The period of waiting between successive cuts is decreased by the presence of permanent roads.

Permanent forestry will and can come only with the advent of permanent roads. The advent of permanent roads entails increased stumpage values and increased prospective values for seedlings, saplings, and small poles.

The importance of permanent roads as fire lanes is obvious, as is their value to the sportsman, to the health seeker, and to the pleasure seeker. As a health resort, the woods will be available only when they are made accessible by permanent roads. Then, too, the appreciation of the woods by the public will increase.

In the primeval woods of America, permanent investments in roads are prevented by the uncertainty of the future, notably as to taxes, tariffs, forest fires, and wood substitutes, and also with reference to future means of transportation better than and different from those now en vogue. The means of transportation applied to a first growth must be different from those applied to a second growth.

(B) SURVEYING INSTRUMENTS. Instruments are required to ascertain or to survey the grade and the curvature of the roads, and the volume of dirt to be moved in grading.

Road instruments should have the following qualities:—

(a) Portability (light weight and ease in setting up);
(b) Strength;
(c) Open sights instead of telescopic sights;
(d) Possibility of use without tables.

I. Instruments for measuring vertical angles. Instruments reading per cent are preferable to those reading degrees.   The horizon is established by a plumb bob or by a spirit level.

(a) PLUMB BOB INSTRUMENTS.

1. *The "Bose."* The instrument itself is a plumb bob. It consists of a metal frame hanging from a horizontal pin on a Jessup staff 5 feet high.   The target or flag has the same height.   The base of the metal frame is weighted down with lead.   The vernier with ocular hole slides up and down on one side of the metal frame, which is subdivided into percentages of grade.   The objective thread is stationary in the midst of the other side of the metal frame. The distance between the ocular hole and the objective thread is 100 units when the vernier is placed at zero.   The Bose, costing 𝔰20, in the hands of a forester understanding the instrument, works with an accuracy of decimals of per cents.   Mistakes are readily discovered and readily repaired in the woods. Mistakes are possible if: —

   Either target or staff is held obliquely;

   The staff is not inserted into the same hole and to the same depth into the hole which was used by the target;

   The target is not exactly as high as the objective of the instrument;

   The plumb bob fails to place the zero-line of the instrument horizontally.

   The correctness of the instrument can be controlled readily when target and instrument are made to change positions.
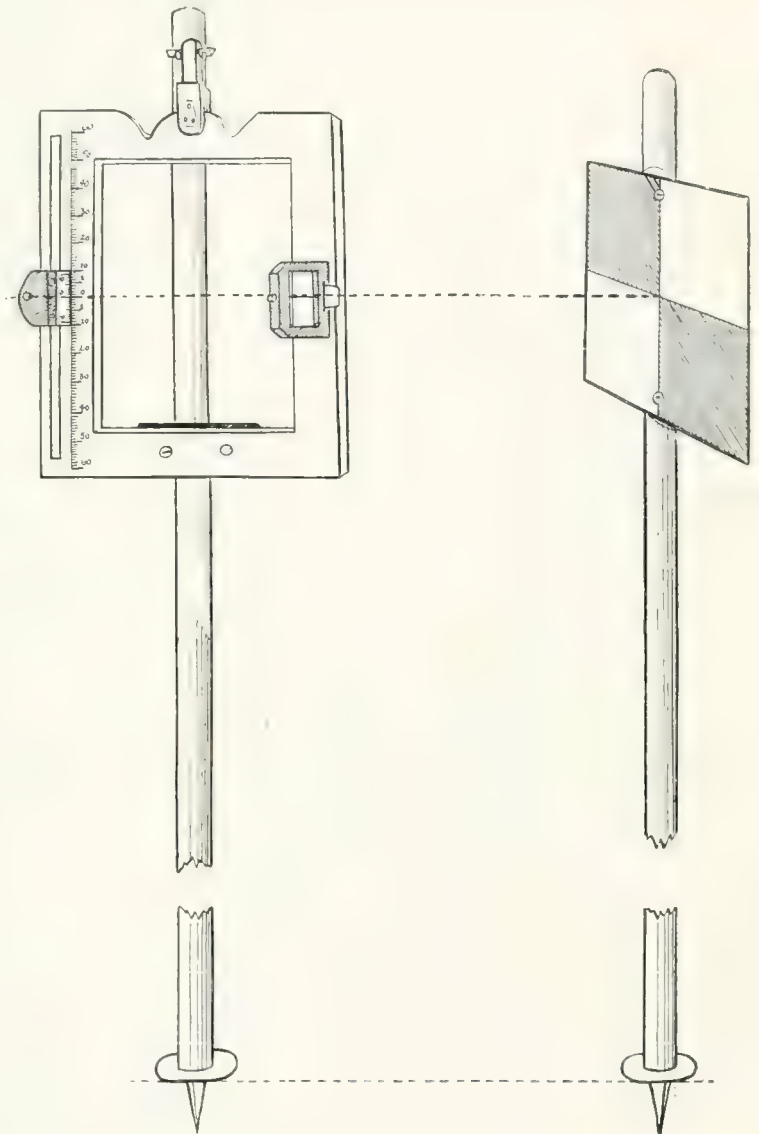
Bose road level and target thereto.

2. *The "Brandis clinometer"* consists of a small metal case in which is suspended, on a delicate axle, a small wheel, with the circumference graded in degrees.   An open telescope, without lenses, is attached to the wheel case.   The wheel is held in perpendicular position by a lead weight at its base.   Sighting through the telescope, the gradation on the circumference of the wheel is read simultaneously.

3. *A number of forest instruments* usually used to measure the height of trees ("hypsometers") can also be used to determine the grade of roads.   The Weise, the Klausner, the Kœnig, the Faustmann, and the Pressler can be thus used to good advantage.   When the distance scale of these instruments is placed at 100, the grade of the roads is read directly in per cent.

(b) SPIRIT LEVEL INSTRUMENTS.

Spirit level instruments seem to be more exact but are no more exact than plumb bob instruments. Any spirit level used by the mason, the carpenter, or the plumber can be used in connection with a target graded in inches and feet, to ascertain or to lay out the grade of a road.

1. *The small pocket instruments,* seemingly handy, are apt to be very inexact, particularly so when they have a vernier outfit. The so-called "altimeters" consist of a short telescope and of a dial topped by a spirit level. With the help of a mirror placed inside of the telescope, and through a hole above it, the eye controls the bubble in the spirit level while sighting simultaneously through the telescope. The readings are taken from the dial of an arc graded in degrees.

2. *The Staudinger* has a long open sight line, is securely fastened to a tripod, and works with the exactness of a highgrade transit. The horizon is established by a large spirit level, and the objective slides over units of gradation forming the 100th part of the distance between ocular and objective.

II. Instruments for measuring horizontal angles. A common compass, set on a Jessup staff, is the best and handiest instrument for forest use. A small plane table can be used to excellent advantage, also, in the construction of roads, road curves, and so on.

For description of these instruments compare Cary's "Handbook for Northern Woodsmen," Harvard, 1909, page 91 and 95.

III. Instruments for measuring both vertical and horizontal angles. An ordinary surveyor's transit is best adapted to this purpose. All transits have, unfortunately, telescopic sights and all of them require a substantial tripod. All of them, in the hands of a man who does not handle a transit continuously, are apt to result in misuse and mistakes. Compare Cary, Handbook, page 69.

Barometrical measurements are valuable in preliminary surveys.

(C) FRICTIONAL RESISTANCE ON ROADS. Friction is the force of resistance to the passage of one substance over another.

Sliding friction is much greater than rolling friction.

Friction is due partly to adhesion, and partly to the roughness of the surfaces in contact. The amount of friction is proportioned to the pressure exerted perpendicularly on the lower surface. Similar substances excite a greater degree of friction than dissimilar substances.

Velocity augments friction slightly.

The amount of friction is independent of the extent of the surfaces in contact. Thus the friction of a body sliding upon another will be the same whether the body moves upon face or upon edge.

Waggon wheels and sled runners 4 inches wide create no more friction than those 2 inches wide.

The "angle of repose" is defined as the greatest angle of obliquity between two planes consistent with stability.

Frictional resistance is that portion of the pressure of a moving body which must be exerted by a counter force to overcome the resistance to moving.

Under "coefficient of friction," f, is understood the ratio existing between frictional resistance, R, and pressure, P, or, which is the same, the frictional resistance per one lb. of pressing weight.

$$f = \frac{R}{P}$$

(f = coefficient of friction; R = frictional resistance; P = pressure of body on incline.)

"Coefficient of friction" is that factor by which pressure must be multiplied in order to obtain a counter force just sufficient to overcome the inclination of a body to slide on the "angle of repose."

The tangent of the angle of repose equals the coefficient of friction.

$$tg = \frac{R}{P} = f$$

The coefficient of friction on roads is generally given (in per cent of the pressure of the load moved) for

Loose sand	25 %	approximately; or	500 lbs. per ton
Fresh earth	12·5 %	approximately; or	250 lbs. per ton
Common dirt	10 %	approximately; or	200 lbs. per ton
Gravel	5 %	approximately; or	100 lbs. per ton
Macadam	3·3 %	approximately; or	66 lbs. per ton
Pavement	1·4 %	approximately; or	28 lbs. per ton
Iron shod sleds on hard snow	3·3 %	approximately; or	66 lbs. per ton
Railroad	0·3 %	approximately; or	6 lbs. per ton

The coefficient of friction within the hub is inversely proportioned to the square root of the diameter of the wheel. Within reasonable limits, the size of the wheel may be disregarded.

In railroads, there must be considered the combined friction of the journals and of the wheel flanges against the rails, which depends, aside from curvatures, on quality of the track and of rolling stock. It is at least 5 pounds per ton; it amounts to $6^1{}_2$ pounds for first class equipment; to $20-40$ pounds for bad equipment; and in extreme cases it rises to 100 pounds per ton.

In addition, the frictional resistance depends on the speed, to a certain extent. This additional resistance equals, in pounds per ton, approximately $\left(3 + \dfrac{S}{6}\right)$, wherein S represents the speed. At a speed of 36 miles, for example, the frictional resistance is increased by 9 pounds per ton. The geared locomotive, being slow of speed, encounters little speed resistance.

(D) GRAVITY RESISTANCE ON ROADS.

I. The interdependence between degrees, sin and tg of grade is the following:—

grade	sin	tg		grade	sin	tg
$\frac{1}{2}$	0·87	0·87	...	5	8·72	8·75
1	1·75	1·75	...	6	10·45	10·51
$1\frac{1}{2}$	2·62	2·62	...	7	12·19	12·28
2	3·49	3·49	...	8	13·92	14·05
$2\frac{1}{2}$	4·36	4·37	...	9	15·64	15·84
3	5·23	5·24	...	10	17·36	17·63
$3\frac{1}{2}$	6·11	6·12	...	15	25·88	26·80
4	6·98	6·99	...	20	34·20	36·40
$4\frac{1}{2}$	7·85	7·87	...			

Within reasonable limits (up to $8°$) sin and tg are almost equal.

Grade is expressed either in degrees or in per cent. The percentage is equal to the tangent of the angle forming the grade. The ratio between percentage P and angle A is, for grades not exceeding 15 degrees, surprisingly constant, amounting to 0,0175.

$$\frac{P}{100} = A \times 0·0175$$

II. The mileage of the shortest route joining two points of different elevation is inversely proportioned to the percentage of the grade. If distance and difference in elevation are approximately known from a map, then the average percentage on an airline road amounts to 100 times the difference in elevation divided by distance.

$$p = 100 \frac{\text{difference in elevation}}{\text{distance}}$$

If the percentage thus obtained is too heavy for the purpose, counter curves (zigzags, switchbacks) are required, with a view to increasing the distance.

Steep roads are always rough roads, since they are more severely injured by erosion and traffic. The lowest gaps of a mountain system are the "strategic points" of a road system.

III. The tractive force of a team or of a locomotive lifts a certain load or weight G, to which the weight (g) of the animals or of the locomotive must be added, by D · sin A feet, where D represents the length of an incline and A the angle of the grade.

The work accomplished by the horses or by the locomotive for every foot of distance traveled amounts, in foot pounds, to

$$(G + g) \sin A$$

Theoretically, the horse-power required to haul a certain load up to a certain point is independent of the grade. If the horses, e. g., are allowed the same total time for haulage at a proportionally decreased average speed on a steep grade, their task of lifting is no more severe, either in toto or per minute, than it would be on a reduced grade. On steep roads, however, horses and machines are apt to be overworked.

Gravity resistance increases in exact proportion to steepness of grade expressed in per cent. Thus it is always 20 pounds per ton of load for each per cent.

Work of lifting equals weight lifted times height of lifting. Height of lifting equals velocity of lifting (number of feet per second) times number of seconds required for lifting.

A heavy horse puts up per second a force of 154 lbs. at a speed of 4 ft. (over 1 horse-power) during eight hours of working time. An average horse yields only $\frac{2}{3}$ horse-power. If the work time is decreased, the tractive force can be proportionally increased when speed remains the same.

After Mascheck, the ratio between standard force, speed, and time (F, S, T) and actual force, speed, and time (f, s, t) is shown by the following approximation:—

$$\frac{F}{f} = (3 - \frac{S}{s} - \frac{T}{t})$$

Steep grades reduce the cost of road building but increase the cost of maintenance of traffic.

IV. The motive power P hauling a load up hill must overcome:—

(a) The frictional resistance R, which is equal to the coefficient of friction f multiplied by the pressure of the weight G on the road

$$R = fg \cos A;$$

(b) The gravity of the object to be moved (weight of load G and weight of tractive force [locomotives, horses] g) amounting to $(G + g) \sin A$;

(c) Hence $P = (G + g) \sin A + fg \cos A$;
and, since cos A approximates 1,

$$\sin A = \frac{P - fg}{G + g}$$

(E) CURVES. Curves in roads take the place of angles. Curves inside the angle decrease the length and increase the grade. Curves outside the angle increase the length and decrease the grade.

I. The minimum radius permissible on road curves depends on the flexibility of the vehicles using it.

(a) FOUR WHEEL WAGGONS. This flexibility is governed by the distance (e) between the axles (equal to the length of the reach or coupling pole) and the maximum of the angle (A), which the tongue and the prolonged coupling pole may form. According to the construction of the waggon, this angle varies from 30 to 45 degrees unless the front wheels are made to cut under the bed (as in high bolstered log waggons). The radius of the curve measured from the middle of the front axle is $\frac{e}{\sin A}$ or measured from the middle of the rear axle $\frac{e}{tg\ A}$

Obviously, the shorter the distance between the axles, the smaller is the permissible radius.

As tg A differs slightly from sin A for angles of 30 to 45 degrees, the hind wheels cannot follow in the same rut behind the front wheels, and the width of the road in a curve must be correspondingly increased by the difference of the radii running to the front and the hind wheels.

"Return" curves built on a slope are very expensive, since it becomes necessary to dig into the slope to the depth of the diameter of the curve; and at this depth rock is almost invariably encountered. The proper place for return curves are flats or terraces, shoulders, "epaulettes," spurs, coves, &c.

(b) LOCOMOTIVES AND CARS. Minimum curvature for a railroad depends on:—

1. Length of wheelbase of trucks, or rather of locomotive, the base of which is apt to be longer than that of the trucks;

2. Height of wheels—high wheels being more apt to climb the rail;

3. Gauge of road—the outer wheel describing, partly sliding, a wider circle than the inner wheel (unless wheels run round the axle, not with the axle). "Conical" tires may make up for this, in part;

4. Possibility of widening track in curves, depending on width of tire of wheel;

5. Strength of flange of wheel;

6. Ratio between tractive force and load.

In practice, the following maxima of curvature hold good:—

Standard public carriers ... ... 10^{0}
Standard logging roads ... ... 23^{0}
Narrow-gauge logging roads ... 35^{0}.

The railroad engineer expresses curvature in degrees of the centerangle (A) spanning a subtended chord 100 feet long.

$$\text{Radius} = \frac{50}{\sin A/2} \text{ or approximately Radius} = \frac{100}{\sin A}$$

II. Curve-resistance. In the case of railroads, curve-resistance is to be reckoned with. It is much greater per ton per degree for light curves than for heavy curves. The resistance of a 1-degree curve in a standard-gauge road is, for example, $1\cdot6$ pounds per ton; that of a 20-degree curve approximately 10 pounds per ton. As a general rule—since the sharpest curve determines the hauling capacity of an engine—the engineer reckons with a resistance of $\frac{1}{2}$ pound per ton (equal to $0\cdot025$ per cent) per degree of curvature.

The curve-resistance in a narrow-gauge road is directly proportioned to that of a standard-gauge road at the ratio of the gauges. The frictional-resistance, for instance, on a standard-gauge road in a 28-degree curve is about 14 pounds per ton; on a 36-inch gauge road it is about

$$14 \times \frac{36}{56} = 9 \text{ pounds per ton}$$

III. Curve-equations.

(a) The inside curve replacing the angle B found between two lines, starting from one line at (a) and ending at the other line at (c), with (a) and (c) equidistant from the apex of angle B, has for its radius:—

$$\text{Radius} = \frac{ac}{2\cos B/2}$$

(b) The center angle A formed between two radii, and subtended over a chord 100 feet long is found from the equation:—

$$\sin \frac{A}{2} = \frac{100}{2 R}$$

IV. Construction of curves.

(a) CURVES ARE CONSTRUCTED either inside or outside the angles which they replace. A special case of an outside curve is the "loop."

(b) METHODS FOR CONSTRUCTION of curves inside the angle are:—

1. *The radius method;* staking out radii from center of curvature;

2. *The quartering method;* join the 2 points at which the curve is to begin and to end by a line (a); draw a perpendicular (b) at middle and on (a) making (b) equal to (or smaller than) (a) divided by 2. Join the free end of (b) with both ends of (a) by lines (d) and (d). Erect in the midst

6

of (d) perpendiculars (e) the length of which is equal to $\frac{b}{4}$. Join the end of (e) with the ends of (d). Erect in the middle of each line of junction a perpendicular, the length of which is $\frac{b}{16}$. The ends of the perpendiculars and of the lines of junction are points of the curve.

3. *The chord method:*— Divide each side of the angle into an equal number of sections. Join the section points 1, 2, 3, 4, n of one side with the section points N-IV, III, II, I, of the opposite side. The intersections of corresponding lines are the curve points.

4. *The plane-table method:*— Survey and sketch the tangents to be joined by a curve and the distance between them; draw into the sketch thus obtained, with the help of dividers, the curve in such manner as suits the topography and of such radius as is indicated. Stake out with the help of the plane table as many of the curve points thus obtained as may be necessary. In the absence of a plane table, a camera tripod or even a soap box can be used to good advantage.

PROBLEM :— Connect A D and B D by a curve, using the plane table, starting at A, and ending at any point on line B D.

1. Set up the plane table at A, and enter direction A D and A B. (B assumed point.)
2. Measure and enter distance A B.
3. Move table from A to B; adjust it by backsighting to A; get and enter direction B D.
4. Cut off and enter A D on B D, reaching E.
5. Draw perpendiculars in A and E, finding the center of the curve in the point of intersection.
6. Draw the curve, on the paper, with the help of a string, or of dividers. Sketch a series of chords, of convenient length, (e. g. 1 chain long), from A on round the curve to E.
7. Set-up the table at A, transfer the chords, one after the other, from the table to the field, marking the end-points consecutively by stakes.
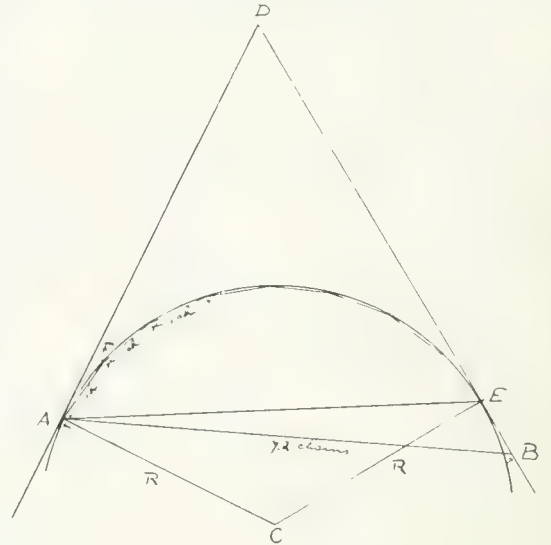
5. *The method of equal offsets* in equal chords (hammering method). The usual offset or "hammer" is (tg $\alpha \times$ P) feet, the chord subtended over angle α being P feet long. For small angles, tg α can be substituted for sin α. The way of proceeding is as follows:—Prolong the straight line (tangent) over the beginning point (E) of the curve by P feet. Erect a perpendicular offset, the length of which is $P \times tg \frac{\alpha}{2}$, at the end of the P feet which brings you to B. Join B to beginning point E; prolong this line by P feet and erect at the end A of the prolongation a perpendicular offset, the length of which is $P \times tg \alpha$, ending in C. Then join C to B, and prolong the line of junction by P feet, erecting a perpendicular $P \times tg \alpha$ at the end of the prolongation, &c., &c.

The ratio between α, P, and the radius of the curve R is:—

$$\sin \alpha = \frac{P}{2R}$$

PROBLEM :— Connect E E₁ and F F₁, two parallel lines, by the best possible curve with the help of the hammering method. The length of the tape (or of a pole cut in the woods) is P.

1. Measure E F (vertical distance of the parallels) using it for diameter of the curve to be designed. If the diameter equals 160 feet, the radius R equals 80 feet.
2. Obtain by calculation the length of the hammer h, in triangle ABC.

$$\sin \alpha^0 = \frac{h}{P}$$

$$\sin \frac{\alpha^0}{2} = \frac{B C}{2 \times 80}$$

2 sin $\frac{\alpha}{2}$ approximates sin α.
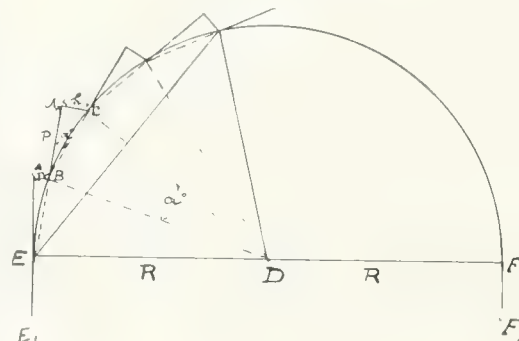
A B is almost equal to B C, provided that α is a small angle.

$$\frac{B C}{80} = \frac{A B}{80} = \frac{P}{80} = \frac{h}{P}$$

If P equals 25 feet, the hammer h is

$$\frac{25^2}{80} = \frac{625}{80} = 7 \cdot 8 \text{ feet.}$$

3. Construct curve, starting at E as follows:—

Prolong E E, over E by length of the pole P. At the end of the pole, make a perpendicular offset equalling half the length of the hammer, or 3·9 feet, the end-point of which is at B. Mark B by a stake; join E with B, and prolong E B over B by P; at the end of P, make another perpendicular offset, this time the full length of h, ending at C. Join B to C and prolong B C over C by P; make perpendicular offset at end of prolongation, and so on, and so on, till F F, is reached.
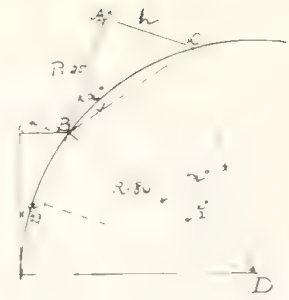
In the logger's practice, the curves of a road can be constructed readily with the help of an ordinary tapeline 21′ 8½″ long. Here, for P equal to 21′ 8½″, a "hammer" or offset of 1 foot (12 inches) corresponds with a road curve of 12 degrees, a hammer of 2 feet (24 inches) with a road curve of 24 degrees, &c. In other words:—every inch of "hammer" is the equivalent (approximately) of one degree of curvature.

To be exact,

the first prolongation should be   .. $(P \text{ feet} \times \cos\frac{\alpha}{2})$

and the subsequent prolongations   ... $(P \text{ feet} \times \cos \alpha)$

the first perpendicular should be   ... $(P \text{ feet} \times \sin\frac{\alpha}{2})$

and the subsequent perpendiculars   ... $(P \text{ feet} \times \sin \alpha)$

6. *The engineer working with transit* or compass obtains a given curvature of A⁰ by a deflection of $\frac{A^0}{2}$ from the line of the tangent toward the desired side for a distance of 100 feet, and thereafter by a similar deflection of A⁰ for every 100 feet. Intermediate points are established by halving or by quartering the angles and the distances. More properly, the lengths of shorter intermediate chords should be prorated to the length of a 100-foot chord at the ratio of the sines of the angles formed respectively between the tangent and the chords.

$$\sin B : \sin A = \text{short chord} : 100$$
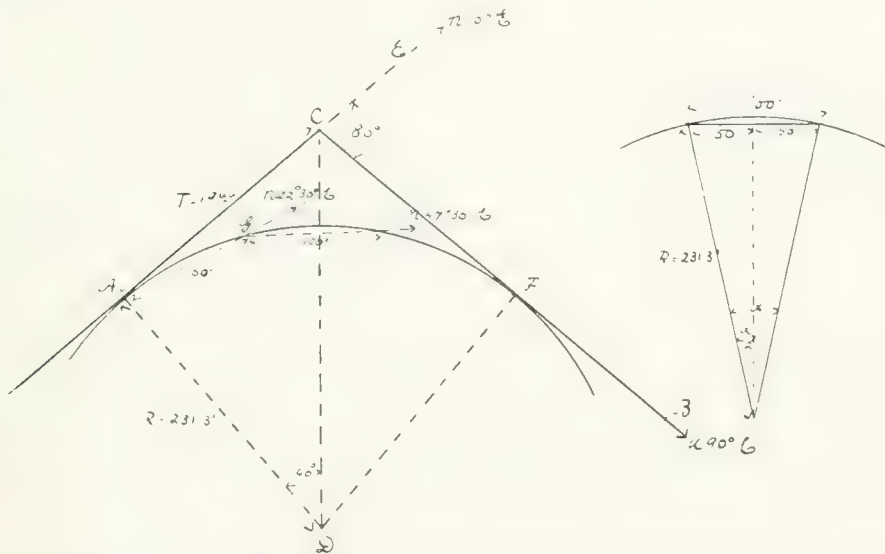
PROBLEM:—Connect, using compass and chain, course A C and course C B by a curve starting at A.
Given are:—

Bearing A C is N 10° E, and C B is N 90° E
Distance A C is 194·4 feet = T.

1. Find the radius R of the curve.

$$B C E = \quad A D F = 80^{0}$$
$$A D C = {}^{1}/_{2} A D F = 40^{0}$$
$$\cot 40^{0} = \frac{R}{T} = \frac{R}{194 \cdot 4}$$
$$R = 231 \cdot 3$$

2. Find the angle of the curve.

$$\sin \frac{x}{2} = \frac{50}{R} = \frac{50}{231 \cdot 3}$$
$$\sin \frac{x}{2} = \cdot 216$$
$$\frac{x}{2} = 12^{0} 30$$
$$x = 25^{0}$$

3. Design the curve of 25°.

Start from A, deflect from A C by 12° 30′ and run a chord of 100 feet, reaching G; then move the compass from A to G, deflect from A G by 25°, run a chord of 100 feet, &c.

REMARKS:— In developing a road system showing a great many curves, it is wisest to make a plane table map of all of them to begin with, and to stake the curves out from the map, with the help of the map. In S-curves on a railroad, a tangent 100 feet long should form the stem of the S.

(F) WIDTH OF ROADS:— The cross section of a road shows a "lower side slope," an "actual travelling bed" (the crown) and an "upper side slope," frequently with a side ditch.

The width of a road depends on:—

(a) track of vehicle (locomotive, car, waggon, sled) used;

(b) width of bolsters;

(c) meanderings of road and radius of curves;

(d) configuration and composition of the ground;

(e) length of pieces loaded.

The wheels of the vehicle or the edges of the ties should not come within a distance closer than one foot of the edges of the road. The minimum width of the road must, therefore, equal track (ties) plus two feet.

In order to avoid ruts in waggon roads, add $^{1}/_{2}$ of track width, so as to allow the teams to change the ruts. Where loaded waggons meet one another, the width of the road should be doubled.

Theoretically, a steep slope of a mountain side requires, for various reasons, a wide road. Practically, however, the road is narrowed under such circumstances.

Wide roads are maintained at a smaller expense than narrow roads.

The expense of road building E bears the following proportion to the width of the road w and to the grade of the slope A, f being a factor depending on toughness of soil to work, on price of labor, &c.

$$E = f \times \frac{w^{2}}{2} tg A$$

Per foot of road measured lengthwise, every additional foot added to the width of the road requires the removal of (tg A) cubic feet more dirt than were required in the case of the preceding foot. The expense of dirt moving incurred for the 1st, 2nd, 3rd, 4th, &c. foot forms an arithmetical progression in which the constant factor equals tg A × expense per cubic foot of dirt.

Building a road on "half solid base" (one half of the road on solid ground, the other half on filled ground), the expense of dirt work is reduced by 75 per cent. In this case, the cost of breastworks (if any) must be added.

Every additional foot of width of road costs more than the last preceding foot, however, not merely because it requires the moving of more dirt, but also because it necessitates the moving of material harder than that which was encountered with the preceding foot.

That part of the road, however, which lies more than 4 feet below the original surface of the slope is apt to be free from roots, and particularly from heavy stumps, the removal of which is more costly, usually, than that of rock of equal volume.

For a 16 foot road built on solid basis (the dirt removed being wasted), the grade of the mountain slope traversed influences the expense of building as follows, if dirt is removed at 15 cents per cubic yard:—

Grade of slope		Dirt moved per mile		Cost per mile
20 %	...	5,280 yards	..	$\$$ 792
40 %	...	10,560 yards	...	1,584
60 %	...	15,840 yards	...	2,376
80 %	..	26,120 yards	...	3,160.

(G) GRADING:—

I. **According to the disposition made of the dirt** in a road line, the following systems may be distinguished:—

   (a) Shifting dirt "sideways."

      1. Building on solid foundation and wasting all dirt by throwing it overboard.

      2. Building road on partly solid foundation, with, without, or with partial breastworks to retain the filled part of the roadbed.

   (b) Shifting dirt "lengthways"—system of equal cuts and fills—usually adopted in railroading, and in road building in the Old Country;

   (c) A combination of the systems given under a and b.

II. **Where dirt is shifted sideways**, the following points must be considered:—

   (a) Steepness of slope;

   (b) Width of road;

   (c) Composition of the soil;

   (d) Availability of suitable timber or stone for breastworks.

While the expense of excavating in case of roads built on half solid foundation approximates one quarter only of the expense incurred for roads built on solid foundation, a scarcity of stone or timber suitable for breastworks may lead to the adoption of the latter method.

Where dirt is moved sideways, the road follows the natural contours of the topography.

III. **Where dirt is shifted lengthways** there must be considered:—

(a) THE LENGTH PROFILE. From the grade found between consecutive points of the road and from the length of the sections between them, the relative and the absolute elevations of all section points are ascertained.

The elevations as well as the section-lengths are plotted on profile paper, the former usually on a larger scale than the latter.

The lines of junction presented on the paper require raising in one and sinking in another place, so as to improve the grade of the road. The dirt volume of the "cuts" should be equal to the dirt volume of the "fills." To that end, a preliminary line (or a silk thread) is drawn on the paper in such a way that the areas of the length profiles of cuts and fills, found above or below the preliminary line, are fairly equalized. Care should be taken to provide that all dirt is moved down hill. "Borrow pits" should be avoided. A good road engineer gets along with the dirt found on the line of the road; and he does not "waste" any dirt obtained from cuts.

(b) THE CROSS PROFILES. "Cross profiles" taken at the various section points further facilitate the equalization of cuts and fills. Any road instrument may be used for the field survey of cross profiles. A straight board, e. g., the length of which equals the width of the road and which has a plumbob attachment to secure its horizontal position, is used for the taking of cross profiles on dirt roads. The

cross profile of each point is sketched on cross section paper. In this case, different scales, for the heights and for the widths entered on the paper, are not permissible.
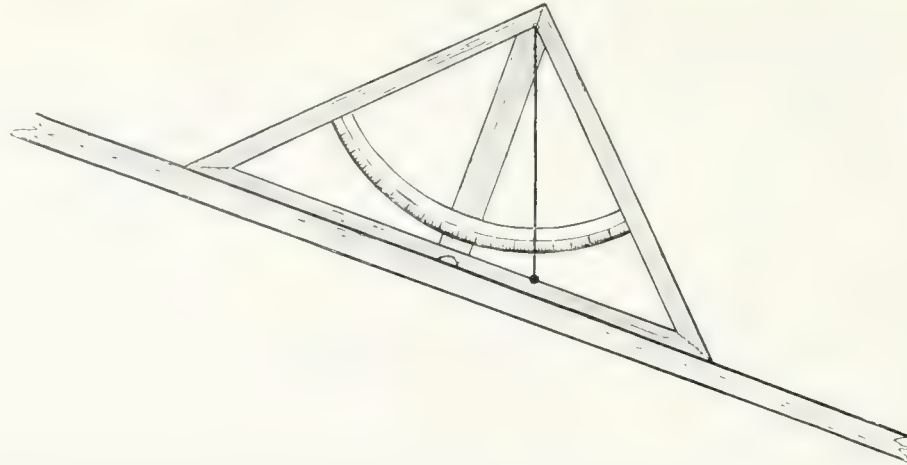
Then, into the actual cross profile, is entered the "normal cross profile" of the road, exhibiting its upper and lower slope, the ditch, and the crown of the road.

For each section point, from this sketch, is ascertained the sectional area of dirt to be filled in or to be cut out. The sectional areas are ascertained:—

1. By dividing them into triangles and trapezes; or
2. By counting the number of squares on the paper, or with the help of a glass plate on which the units of measurement are engraved; or
3. With the help of a planimeter; or
4. With the help of the trigonometric functions of the actual natural slope and of the artificial side slope of the road.

Auxiliary tables are constructed which show, for given slopes, given widths of road and given depths, directly the sectional areas of the profiles in cuts and fills.

SECTIONAL AREAS OF CROSS PROFILES OF CUTS AND FILLS

calculated in square yards for an artificial slope
(on fill or in cut) of 60 degrees, and for a road surface 12 feet wide.

Natural Slope		Height in feet									
		5′	10′	15′	20′	25′	30′	35′	40′	45′	50′
%	∢	Sectional area in square yards									
5	2° 50′	8	20	35	53	74	98	126	157	191	228
10	5° 40′	8	20	35	53	74	98	126	157	191	229
25	14° —	9	20	35	54	75	99	128	160	195	233
40	21° 50′	9	21	37	56	80	104	133	166	202	241
55	28° 50′	10	23	39	59	83	110	141	175	213	254
70	35° —	11	25	43	64	90	119	152	189	230	273
85	40° 20′	13	28	48	71	99	132	168	209	254	303
100	45° —	16	34	56	83	114	151	193	240	291	348
115	49° —	20	41	68	100	138	182	232	287	348	416
130	52° 30′	29	56	90	132	182	239	305	376	456	543
145	55° 30′	45	87	134	195	267	350	443	549	665	792

The first column gives the percentage and the second the grade in degrees of the natural slope. The subsequent ten columns give the cross sections in square yards for cuts or fills from five feet to fifty feet deep, the depth being measured at the center of the road.

(c) THE VOLUMES OF CUTS AND FILLS. The actual amount of dirt to be moved between two stations is ascertained as distance between stations times arithmetical mean of sectional areas of stations.

If it is found that the total volume of fills exceeds the total volume of cuts, two remedies are possible:—

1. Lowering the road line parallel to itself;
2. Shifting the road line into the slope of the hill.

If one of two consecutive road points is to be cut while the other requires filling, then an auxiliary point (grade point) must be established and its distance from the end points of the section ascertained with the help of the mapped length profile. The dirt volumes to be moved have a wedge shape and their volume equals sectional area by $1/2$ of length of subsection.

Stœtzer recommends to allow for the "spreading" of the dirt, in equalizing the volumes of cut and fill. Sand volumes increase by 3%, loam by 6%, clay by 15%, rock by 20%.

On the Pacific Coast, with wet soil, shifting sand, and difficult grading, some firms prefer to build the entire railroad on piles. It is claimed that the only disadvantage of this method is the increased danger from fire. Six men construct 100 feet of pile road per day, including clearing of right of way. (See Timberman, Logging Congress 1910, page 18.)

At Coos Bay, Oregon, the piledriver crew constructs, under normal conditions, 10 complete "bents" per day. The cost per mile (not counting the value of 300,000 feet of stumpage used) is given as $5,500.

Piledriver of Smith-Powers Logging Co. at work on Coos Bay, Oregon.

IV. Instruments and implements for grading.

(a) INSTRUMENTS.

Shovels:—Short handled, round pointed billies at $10 per dozen are preferred;
Mattocks, $6 per dozen;
Picks, $4·50 per dozen;
Crowbars, 5 feet long, 12 to 20 pounds in weight, price 40 to 60 cents each;
Drilling or striking sledges, 6 to 10 pounds in weight, price 32 to 53 cents each.

A portable blacksmithing outfit is required to relay with steel all mattocks, picks, and driving steel when worn.

(b) IMPLEMENTS.

1. *Black blasting powder* comes in kegs of $6^1/_4$, $12^1/_2$, and 25 pounds each; it costs 20 to 25 cents per pound. It is used notably in soft rock. It is composed of 75 per cent saltpetre, 12 per cent sulphur, and 13 per cent carbon. Per cubic yard of rock to be removed, between $1/_4$ and $1/_2$ pound of powder is required. One quart of powder forms when exploding 880 quarts of gas. The charge of powder for a given blast should be $\frac{L^3}{V}$ pounds, wherein L represents, in feet, the line of least resistance, and wherein V varies, according to hardness of rock, between 25 and 32. The line of least resistance should not exceed one half of the depth of the hole.

In the usual practice a hole is charged to one third of its depth. A series of holes should be blasted at one and the same time, so as to increase the effect. Powder cans should not be opened with a pick or a chisel. Deep and large holes allow the charge to be placed low, and by this means the effect of the charge is increased.

A hole 1 inch in diameter and 2 feet deep requires about $\frac{1}{5}$ of a pound of powder. A hole $1\frac{1}{2}$ inches in diameter and $3\frac{1}{2}$ feet deep requires about 3 pounds of powder.

2. *Dynamite.* Dynamite contains, usually, 75 per cent of nitro-glycerine and 25 per cent of silicic acid. It comes in sticks measuring $1\frac{1}{4}$ by 8 inches, and in boxes containing 25 or 50 pounds.

35 per cent dynamite, at $12\frac{1}{2}$ cents per pound, is used for blasting stumps, ice, or lighter rock; 45 to 50 per cent dynamite, at 14 cents per pound, is used in hard rock; 60 to 75 per cent dynamite, at 18 cents per pound, is used for extremely hard rock and for submarine purposes.

Dynamite freezes at 46 degrees Fahrenheit. It is not easily exploded, like powder, in the course of transportation, and can be used under water.

Whilst tamping is not required, tamping with moist clay results in economy.

Dynamite is dangerous particularly when it is partly frozen or during the act of thawing out. It should not be placed in warm water for thawing; it should be placed in a can, and the can should be kept in luke-warm water. Dynamite should not be exposed to the sun, to the camp fire, or to the heat of a stove. Old dynamite, owing to partial decomposition, looses its strength. Oily wrappers prove that some nitro-glycerine has leaked out. Green spots on the wrappers indicate extreme danger in handling.

3. *Caps, fuse, detonators.* Caps come in boxes of 100, costing 80 cents. They are attached to the fuse with the help of fuse cutters and cap crimpers.

The common cotton fuse costs $3·35 per thousand feet; single-tape fuse for damp soil and double-tape fuse for wet soil and triple-tape fuse for use under water costs between $4 and $5·60 per thousand feet. The cap should be placed in the top of the charge and not in its midst.

Electric detonators are more efficient than caps, for the reason that they cause a simultaneous discharge of a number of holes.

If a shot fails the crew should wait 30 minutes before touching it. The charge should never be picked out; it should be left alone and a new hole should be drilled at a distance not less than 2 feet from that which has failed to be discharged.

It is unwise to use two kinds of explosives in one and the same hole.

(c) WORK. The drilling of the rock is obtained either by sledges, steel, and hand labor, or else with the help of air drills.

In road building, the removal by blasts of small quantities of rock (for ditches, culverts, or cross runs) should be avoided.

The success of the blast depends on the stratification of the rock, and, above all, on the skill of the workmen.

In gneiss rock, 3 men will drill by hand 18 feet of 1-inch holes or 10 feet of 2-inch holes in the course of a day.

V. **Transportation of dirt.** Dirt is transported with the shovel, with wheel barrows (capacity 2 cubic feet, price $1·50 for wooden and $12 for steel barrows), by scrapers, with and without wheels (capacity 5 cubic feet, price $6 to $10, weight 100 pounds), by 2-wheel horse trucks, by temporary railroads with dump cars or flat cars, and by cable transmission. A team load ordinarily consists of 1·3 cubic yards of dirt.

A ton of earth is composed of 21 cubic feet of sand,
25 cubic feet of coarse gravel,
28 cubic feet of marl or clay.

Transportation of dirt by contract is preferable to transportation by day labor.

Aside from the influence of dirt quantities, the local ratio prevailing between the cost of manual labor and the cost of team labor must decide whether wheelbarrows, carts, or teams are to be used for the

transportation of dirt. For short distances, hand labor; for longer distances, animal labor; for long distances and large quantities, steam labor is to be advised.

Stœtzer gives the following table:—

Distance in feet	Hours required to move 1 cubic yard of dirt	
	By hand labor	By animal labor
70	0·8	—
160	1·1	0·23
330	1·6	0·30
650	3·0	0·39
1000	3·9	0·46
1330	5·0	0·55
1650	6·2	0·65

Perishable material must be excluded from filled ground. Stones should be put on the "valley side" of the fill. No heavy stone and no stumps should be suffered within at least 6 inches of the road surface.

Where steam railroads are available and where the quantities to be moved are large, steam shovels and dump cars come into play. Fills are made with the help of temporary trestle bridges to be buried in the dirt dropped on them.

VI. Expense of dirtwork. The estimate of the amount of work to be performed and of the expense connected with it is made with a view to:—

Condition and volume of soil to be moved.

Length of transportation and means available therefor.

Amount of surfacing required on the road.

The mere work of digging amounts, per 1 cubic yard, to the following number of work hours, where hand labor is used exclusively.

(a) For loose soil:—

1. Without stones, roots, or stumps, 1·6 hours.
2. With stones, but without roots or stumps, 1·7 hours.
3. Without stones, but with roots and stumps, 1·9 hours.
4. With stones, roots, and stumps, 2·3 hours.

(b) Rock in layers, somewhat decomposed (gneiss, sandstone, and limestone) to be picked with the pickax, 4·7 hours;

(c) Solid rock, to be blasted, 8·2 hours.

The surfacing of the road requires, per square yard of surface, from 0·1 hour to 1·5 hours.

The removal of the top soil with matted roots requires 0·1 hour to 1·7 hours per square yard.

VII. Fortification of roads above and below roadbed.

To strengthen the slope of a fill, there may be used:—

(a) Wicker work;

(b) Sods of grass;

(c) Plantations (willow, locust);

(d) Timber breastworks, spiked, or cribbed;

(e) Dry stone walls, allowing the water to trickle through, with base imbedded in solid ground to a depth of 1½ feet or more.

In cases (d) and (e), the batter of the wall should be at least 1 in 4. Frequently a partial wall or a partial breastwork is sufficient, even preferable, with a view to side drainage from surface of road.

7

REMARK:— The Southern logging superintendents, at a recent meeting, gave the following as the figures, in cents per 1,000 feet b. m. of logs handled over the railroad, for expenses incurred by their concerns when cutting right of way, breaking ground, grading, and building bridges:—

Arkansas ...	from 14·6	to	16 cents
Texas	from 30	to	47 cents
Louisiana ...	from 27	to	59 cents
Mississippi...	from 32	to	75 cents

(H) DRAINAGE OF FOREST ROADS.

I. **Water is the chief enemy of roads.** The following means of defense may be adopted:—

1. Curvature of the crown.
2. Sloping the road bed toward the valley side.
3. Shelving or terracing the slope above the road.
4. Side ditches in connection with cross runs or culverts.
5. Covering the slope with stones, brush work, or sods of grass.
6. Ditches of about 10 per cent grade some 35 feet above the road emptying just above culvert.
7. Removal of shading trees, especially on South slopes, and fostering dense and low underbrush above roads.

The number of protective measures and their construction depends on grade, ground, local precipitation, &c.

II. **Side ditches secure drainage** in the most efficient manner provided that they have sufficient depth, width, and pitch. They intercept the waters streaming, superficially or subterraneously, down the hillside above the road; they convey these waters rapidly to outlets; they draw the ground water out of the roadbed itself. A road without a ditch on the hillside "soon becomes a ditch itself." Ditch-cutting along the road, however, in a mountainous section, is extremely expensive.

Theoretically speaking, a ditch should gradually increase in cross section toward the lower culvert, through which it empties.

The cross section of a ditch depends on:—

1. Maximum cross section of water apt to pass through it after a cloud burst.
2. The grade of the road.
3. Distance between culverts or outlets. If this distance is halved the cross section of ditch might be reduced to one fourth.

The standard ditch measures 3 feet at the top, 1 foot at the bottom, 1 foot in depth; its sides are inclined at an angle of 45 degrees.

In clay soil, ditches of steeper sides are permissible.

The common ditch found along the railroads is 2 feet wide.

III. **Cross runs.** By "cross runs" are understood drainage arrangements built across the road, their purpose being either to carry water from the side ditch across the road, or to intercept the water found in the roadbed itself. The capacity of a cross run, like that of a ditch, should be sufficient to meet a cloud burst.

Main rule for all cross runs:— Pitch secures drainage better than size.

Cross runs are either "open" or "covered."

(a) OPEN CROSS RUNS. Water running down the ruts of a waggon road will never get out of the rut unless there are maintained either shallow side ditches leading to right and left from rut; or paved cross runs (saucer shaped) falling at least one foot across the road; or cross poles (thank-you-ma'ms) of the same fall, placed above the roadbed; or culverts, the tops of which are raised about 6 inches above the surface of the road. An impediment to the run of water in ruts must necessarily be an impediment to traffic. On dirt roads it is wise to secure drainage rather by the inclination of the open cross runs than by the depth of open cross runs.

Open pole cross runs consist of 1, 2, or 3 poles, framing an open ditch running either diagonally or square across the road. Open cross runs constructed of boards are rarely found. Open cross runs paved with stones put on edge and having a pitch across the road of 5 to 10 per cent are very effective. They are the most reliable means of open cross drainage. They are, however, bad impediments to traffic, unless they are run diagonally with the stones thoroughly driven into the ground.

Cross runs consisting of cross ditches filled with stones placed loosely on a solid basis, or filled with poles or faggots are permissible only where the soil is fairly permeable and where the grade of the road is not too steep.

(b) COVERED CROSS RUNS. Covered cross runs are either culverts, usually consisting of drain pipes imbedded in the soil, or causeways constructed in dry masonry, or small bridges.

The simplest culvert is a wooden box made of four pieces of $2'' \times 10''$ plank. This box, however, is apt to get stopped up; it rots quickly in the ground unless it be made of chestnut, white oak, cypress, &c.

Stone causeways are advisable where the underlying rock is stratified (sandstone, schist, slate) so that large flat stones can be cheaply obtained for covering purposes. The span should not be over 3 feet.

Causeways constructed as bridges consist of 2 or 4 mud sills placed with the big end towards the valley, three stringers 6 to 12 feet long and a covering of boards or half-splits.

In certain sections of Pennsylvania, corrugated iron culvert pipes (18 cents a foot for 8-inch pipe) have been found a splendid substitute for open thank-you-m'ams. The pipe is laid into the cross run, loose rock is packed tightly against it so as to form a protective wall, and the whole is covered with a surface dressing of small gravelly material.

The cheapest drain pipe is the cement drain pipe constructed at the place of using with the help of a turned wooden cylinder and a wooden box.

At the outlet of cross runs, the slope of the road might be protected from washing by stone walls or pole chutes.

Causeways and culverts do not intercept the ruts. It is necessary to force the water to the right and left from the road bed either by side runs or by ties (as in railroads), or by occasional pieces of heavily crowned pavement. On slate rock it is often possible to give the entire roadbed a pitch of not to exceed 10 per cent across the road.

The expenses of culverts consist of the following:—

1. Digging or blasting of ground and rock.
2. Hauling of timber, stones, and pipes.
3. Construction of walls, pavement, covering.

One workman lays in one day 1·3 cubic yards of dry stone walls, for which are required 1·7 stacked cubic yards of rock, there being some loss.

A good workman puts up in one day from 24 to 36 square (not cubic) yards of rough rock pavement.

The following "rule" relative to distance between and to number of cross runs might be kept in mind:—The average distance between successive cross runs should be $\frac{200}{p}$ paces, when p is the percentage of grade of road. The number of cross runs per mile should be 10 p.

(I) SUPERSTRUCTURES STRENGTHENING THE TRAVELLED SURFACE OF A ROAD. Water and traffic destroy the road. A strong road surface is required to prevent or to check destruction. This surface may consist of:—

A dirt cover (dirt road, sand-clay-roads).
A wooden cover (corduroy, plank roads, &c.).
A steel cover (railroads).
A stone cover (Macadam roads, &c.).

I. Dirt cover. Dry dirt roads are as good as stone roads. Wet weather, however, causes the "melting" of clay and lime. Quartz sand is, indeed, invaluable, and its "affinity" to water is small. Sand, however,

is so loose that it cannot withstand the pressure of a wheel. Two things can be done to strengthen a dirt road:—

(a) The top surface can be formed by that mixture of clay and sand which combines the good qualities of the two materials most efficiently ("sand-clay-roads");

(b) The top surface can be so crowned or so tilted toward the valley that the water falling on it is forced sideways, the surface acting as a roof.

In spite of all, nevertheless, a dirt road is never fit for heavy traffic in wet weather.

II. Ice cover.

(a) NORTH OF MASON AND DIXON'S LINE the winter months offer, for a certainty, frozen ground frequently covered for a number of weeks by a layer of snow.

By this means is made possible the use of sleds in logging. The frictional resistance which sleds meet on "iced roads" is small, amounting to 3 per cent of the load approximately.

This means to say that sleds on a 3 per cent downhill grade do not require any tractive force, the frictional resistance being overcome by the gravity pull.

In the South, snow and ice are, owing to the irregularity of their ocurrence, an impediment to the transportation of logs in the woods. In the North, the logging operations are frequently concentrated on the winter months. Then it is that the soil is in an excellent condition of firmness.

(b) ICE ROADS. The ice roads are laid out in the summer and fall preceding the winter's campaign. The roads should follow the depressions, so that the skidding to the roads can be effected from two sides. The swamps of the valleys, or glacial lakes left in the North woods, offer excellent routing for the roads.

Uphill grades should be avoided. Downhill grades exceeding 15 per cent endanger the horses. On steep grades it is necessary to increase the frictional resistance and to sprinkle the ice with sand, hay, small twigs, and the like.

Heavy frictional resistance, however, causes the sled runners to wear rapidly. It is also responsible for the stalling of teams, with the result that all the teams in the rear of the team stalled are badly delayed.

According to the chances which the operator takes with reference to the layer of snow, the stumps on the route are removed entirely or are left at a height of $1\frac{1}{2}$ feet.

The result of a winter's logging on the ice of an Adirondack lake.

(c) OPERATION. To begin with, the snow is plowed away by a snow plow where it has accumulated unduly. The plow is followed by a "tracking sled" lightly loaded and meant to impress on the snow the ruts of the sled runners. The tracking sled in turn is followed by the "sprinkling sled," usually run at night, which sprinkles water in the ruts, so as to cause the formation in them of a strong ice crust.

III. Woodcover.

(a) WOOD COVERED ROADS are found in the form of sawdust roads (Southern States) and of plank roads (swamps). The planks are placed directly on the ground, square across the road bed. Sometimes, on the Gulf Coast, plank roads consist of long and low trestle bridges.

(b) CORDUROY ROADS are especially met where there is swampy or moist soil, or deep humus on the ground floor. Corduroying costs, at Biltmore, according to width of road and distance of transportation of split chestnut wood, from $4 to $10 per hundred feet of length. In the balsam swamps of the Adirondacks,

corduroy consisting of balsam poles is met frequently. Discarded railroad ties form an excellent raw material for corduroying.

(c) FASCINE ROADS, frequently constructed on wet clay or in swamps, corduroy fashion, consist of alternating layers of sand and brush bundles, fastened together by stakes driven vertically.

(d) IN HUNGARY, WOODEN TRACKS are formed of poles 8 inches thick, placed parallel and lengthwise with the road in two rows. The distance of the pole rows, from center to center, exceeds the waggon gauge, measured from the outsides of the tires, by 1 inch. The inner and upper quarter of the poles is hacked out, with ax and adz. The waggon wheels run in the grove thus obtained.

(e) AFTER THIS PATTERN, PLANK RUNS are constructed at Biltmore. Two lines of 10-inch plank are placed lengthwise on the road surface. Each line carries a rail of $2'' \times 4''$ scantling fastened in such a manner that the outer edges of the scantlings are 4 feet 8 inches apart. The gauge of the waggon between the tires being 4 feet 9 inches, the wheels running on the planks have a play of 1 inch. Plank runs must be straight. In curves, the entire surface must be planked up.

(f) POLE ROADS. A statistic of 1886 finds in the United States over 2,000 miles of pole roads, using over 400 locomotives and over 5,000 cars. The rails are made of straight, preferably coniferous poles, sufficiently trimmed to fit the double flange of the car wheels. No ties are required, the rail being gradually pressed into the ground.

The wheels of the cars should not turn with the axle. An oval concave rim is said to be inferior to a flat rim with heavy flanges. Each wheel has about 2 inches room for side play. The reach should turn like a swivel in hind and front set, allowing all wheels to stay on the track.

All lumbermen agree nowadays that pole roads are impracticable for locomotives.

(g) WOODEN RAILROADS use, in lieu of the steel rail, a sawn wooden rail. The rail consists of 2 layers, each measuring 2 by 4 inches in the cross section. The lower layer should consist of a species lasting long in contact with the soil; the upper layer should consist of a kind resisting abrasion best. Hickory, birch, maple, beech, and also white oak, are commonly used. In curves, abrasion is prevented by nailing a strip of iron, ¾ inch in width and ½ inch in thickness, on the edge of the rail subjected to abrasion.

Wooden railroads are frequently seen in the Southern Appalachians. The wheels of the logging cars, light and low, turn round the axle, like waggon wheels, instead of turning with the axle, like those of railroad cars proper. The tire of the wheel is 4 inches or more, and the flange 3 inches or more. The motive power is supplied, usually, for the loaded cars by gravity. The empty cars are pulled up the hill by mules or oxen.

The wooden rails are fastened to rough ties by 10-penny nails. During wet weather the ties are slippery, and the cars are apt to run away on grades exceeding 10 per cent, in spite of sanding. Grades exceeding 15 per cent are impracticable, for the reason that the animals find it difficult to haul the empties up the hills.

Obviously, wooden rails are not compatible with the use of locomotives exceeding a weight of 15 tons. On the other hand, during dry weather, a locomotive will slip less on a wooden rail than on a steel rail.

(h) WOOD PAVEMENT. Wood pavement is noiseless, dustless, and soft. It is used particularly on such streets as are in the heart of the business sections of large cities The leading raw materials used abroad are teak (in London) and creosoted beech (in Berlin, Paris, Frankfort).

In the United States, wood pavement has not been very successful, for the reason, that round blocks of white cedar and of pine were used, rudely placed on a surface insufficiently prepared. Where impregnated Douglas fir was used, the heat of a hot summer has caused the creosote to ooze out, much to the annoyance of the public. The fault does not lie, however, with the wood pavement as such:—It lies in the misapplication of wood pavement. Wood pavement, to be serviceable, must be sawed into small blocks of regular size, shaped in such manner as to conform to the curvature of the surface of the road. For impregnation, no more creosote must be used than the wood will hold at the temperatures prevailing in the hot season (Rueping process). On steep roads, wood pavement becomes slippery and therefore dangerous during wet weather.

A good wood pavement is laid on asphalt, with tar acting as a cement to join the blocks.

In the East, Beech, in the West, Douglas fir form the best raw material. The logs are sawn into pieces some 6 inches thick and some 4 inches wide, of 4 to 6 feet length. These pieces are run by chains through an edger, of particularly strong construction, so as to be dissected into blocks of a face measuring 1 to 6 inches and of a depth measuring 6 inches. The blocks are charged automatically into steel baskets, fixed on wheels, to be run into the impregnating cylinders. The American Creosoting Co. of Creosote, Washington, specialises in this line.

IV. Stone cover.

(a) STONE COVERED ROADS are constructed either as pavements or after the Telford, Macadam, and Koltz systems.

The Macadam system is advisable where trap, syenite, basalt, and other hard volcanic rock is available.

The Telford or the Koltz system is indicated on granite, gneiss, sandstone, limestone, and slate formations.

(b) TELFORD SYSTEM. Curbstones are placed on both sides of the roadbed. The bed is well rounded, the subgrade having a stronger curvature than that intended for the stone surface. On the bed are placed, with the tips up, roughly broken stones, 8 to 14 inches long, in such a manner that the stones fit one into the other. The tips are knocked off with a sledge hammer, so that the surface looks evenly curved. On top is given a dressing consisting of small stones that would pass through a $1\frac{1}{2}$-inch ring. Rolling is not required, although it is advisable. A workman puts up 27 square yards of pavement in a day, and cuts in a day from 1 to 2 cubic yards of small stones for top dressing.

The work and the expense required per 100 running feet of road 10 feet wide, situated within 1,500 feet from a quarry, consist of the following:—

1. The formation of the subgrade requires 6 days' work.
2. The transportation of the stone requires 1·8 team days.
3. The placing of curbstones requires 0·6 days' work.
4. The breaking of the stone to size in the quarry requires 9 days' work.
5. Placing the pavement and decapitating the pavement stones so as to obtain even tops requires 3·6 days' work.
6. Top dressing with small stones, to a depth of 3 inches and crushing such stone by hand, 4·8 days' work.

A Telford road, as described, costs about $15 per 100 running feet. A Telford road drains itself well, through the interstices left between the stones standing on edge.

(c) MACADAM SYSTEM. The road is constructed with a heavy crown. It consists of a series of separate, distinct layers of small stone, each layer pressed and rolled separately under sprinkling. The pressure must be so applied as to reduce the original thickness of each layer by 20 per cent. The stones for the bottom layer should pass through a $2\frac{1}{2}$-inch ring. The stones for the upper layers are smaller, the top layer consisting of ground stone or coarse sand. The minimum thickness of the stone bed should be 8 inches. Where trap rock is easily available, the Macadam system is superior to the Telford system.

Hand crushed stone is preferable to machine crushed stone.

(d) KOLTZ SYSTEM. This system is also known as Luxembourg system. Two parallel ditches are cut, $1\frac{1}{2}$ feet deep, 1 foot wide, 5 feet (waggon gauge) apart.

These ditches form "artificial ruts;" they are filled with stone placed Telford-fashion. Side ditches connect the stone filled ruts with the gutter and the valley side of the road. The Koltz system offers the advantage of a thorough drainage of the road itself, and economizes in the use of stone where stone is expensive. The disadvantages of the Koltz system lie in the following:— The ditches must be widened in all curves; in the course of heavy hauling the stone ruts cannot be discerned by teams and teamsters; one team meeting another may force a loaded waggon to leave the ruts, never to return. The expense approximates $4·50 per 100 running feet.

V. Steel cover. The routes actually used by the wheels are "covered" with steel.

The steel road consists either of two steel troughs, in which the waggon wheels are running, or of two steel rails supporting grooved or flanged wheels.

Within the last 20 years, the use of steel railroads has increased enormously in the forests of the United States.

Lumbering in heavy stumpage on a large scale is considered impossible, practically speaking, without railroads.

Railroading requires, on the other hand, a large and heavy traffic of loads. It results, as a consequence, in large, coherent clearings.

Locomotive sparks are often responsible for the fires destructive of a second growth.

(a) PORTABLE TRACK. In American lumbering "portable railroads" are little used. The sections of which portable railroads consist are necessarily light and, consequently, unfit for the heavy, huge primeval logs. They have a place, however, where the forests are second growth, or else in the lumber yard and the wood yard. The sections are usually $6\frac{1}{2}$ feet long, have $2\frac{1}{2}$ feet gauge and weigh 80 pounds. Steel ties are preferred at the ends, so that the joints are supported by ties. The sections are joined by a hook arrangement without being bolted together.

Biltmore Forest students inspecting a portable forest railroad; notice the minute trucks, and the small six horse-power gasoline motor. Darmstadt, Germany.

Usually the sections are merely laid on the dirt. Motive power is supplied by gravity, men, or horses. Wheel flanges are, frequently, on both sides of the rail. Rail sections of trapeze form are sometimes used in building curves. Bridge switches are preferable to split switches.

In the wood yard at Biltmore sections of wooden rails were used, the ties being replaced by iron rods. The top of the rail was shod with a strip of $\frac{1}{4}$-inch iron, the ends joined by hook and pin, and by hole and pin. Steel sectional tracks are manufactured, amongst others, by the C. W. Hunt Co., New York. The trucks used have the wheel flange outside. Curves and switches are ready made. Straight sections are 6 feet to 20 feet long.

(b) REGULAR, FIXED TRACK.

    1. *Rail.* The form is usually the T rail. Grooved rails, flat rails, rails inclined toward center of track, &c. are freaks merely. In logging railroads the rails are often fastened lengthwise on sawn or hewn stringers, which arrangement allows of light rail. The gauge is measured inside the tops of the rails if the flange is inside, and outside the rails if the flange is outside. If the wheel has a double flange, measure from center to center of rails.

In lumbering operations, the standard gauge (56½ inches) is generally preferred, since heavier loads can be taken and since the rolling stock can be disposed of more readily at the end of operations. Of the narrow gauges, 36 inches is best, since the odd gauges prevent ready exchange, increase and sale of rolling material.

In mountainous sections, narrow gauge is preferred. Here the expense of wide gauge track is too high, since it requires flatter curves. Otherwise, there is no saving in 36-inch gauge track.

The weight of the rail does not depend on the gauge of the track. It depends on the weight

At the upper terminus of a cable car slide in Western North Carolina.

of the loads (notably locomotives, steam loaders, and steam skidders, load per wheel), and also on the number and quality of the ties.

The modern lumberman uses one and the same type and weight of rail on all lines, thus obtaining interchangeable tracks.

In standard lumbering operations a heavy rail (60 lbs. and up) is now preferred, the upkeep of the track being cheaper, the bed for the track being less expensive and fewer ties being required for the heavy rail. Light rails are so twisted, after short use, that they can not be sold at second hand. For 36-inch gauge a rail weighing 30 to 40 pounds is common.

Rule for number of tons of rail required per mile:—

(a) Tons of 2,000 pounds:—

Multiply the weight of the rail by $^7/_4$ and you obtain the number of tons required per mile. For example, 20-pound rail $\times ^7/_4 = 35$ tons.

(b) Tons of 2,240 pounds (after which rail is usually sold):—

Multiply weight of rail by $^{11}/_7$ instead of by $^7/_4$.

The price per ton of rail (steel) varies from $25 to $35

Under normal conditions, the rail stands, for every pound of its weight per yard, a pressure of 225 pounds of weight on the drivers in the case of light rail, and of 300 pounds in the case of heavy rail.

The interdependence between a locomotive's weight and the minimum weight of the rail permissible is given by the following equation:

$$\frac{w}{n} \times 8 = r$$

wherein w stands for weight of locomotive on the drivers in tons; n for number of drivers; r for minimum weight of rail in pounds.

In an offhanded way, n is usually considered equal to 8.

2. *Ties.* Sixteen ties are commonly used per rail. On spurs, the rail is fastened by spikes only to every second tie. Ties on spurs measure $4'' \times 5'' \times 7'$, or consist of light poles, of dead tops, and other inferior material. On the main line, regulation ties are used, measuring up to $8'' \times 8'' \times 9'$. Impregnated ties might be cheapest in the end, even in the forest.

3. *Laying track.* The crew consists of 1 foreman, 12 hands, 1 locomotive engineer, and 1 fireman. The ties are collected (from the old spur) on top of a "road car," and the rail are placed on

both sides of the car, where they rest on the bolsters next to rollers. The splice joints left on the rail are showing to one side. The crew removes usually, at a time, 20 rails from each side of track, together with the ties belonging thereto. The removal and the laying of 400 yards of track constitutes a day's work.

The right of way is cleared to a width of eighteen feet. Dead trees and overhanging trees are also removed from near by. Rough cribs are built of dead trees over depressions and swampy places, where longitudinal stringers carry the rail.

The consensus of opinion, amongst Southern logging superintendents, places the cost, incurred per 1,000 feet b. m. of logs, for taking up steel, laying steel and repairs to track at the following figures:—

Arkansas ... from 51 to 55 cents
Texas ... ... from 28·2 to 30 cents
Louisiana ... from 21 to 38 cents
Mississippi ... from 21 to 25 cents

Per mile of track, consisting of 30-foot rail, 352 pairs of fish plates and 1,408 bolts are required. The cost of each joint (2 fish plates and 4 bolts) approximates in cents the weight of the rail in pounds. The bolts come in kegs of 200 pounds. A keg contains from 210 bolts $3/_4" \times 3^1/_2"$ up to 600 bolts $1/_2" \times 3"$.

Per mile of track, containing 2,640 cross ties, there are required 9,560 railroad spikes. Spikes sell at 2 cents per pound, approximately; they come in 200-pound kegs, a keg containing from 375 spikes $9/_{16}" \times 5^1/_2"$ up to 1,342 spikes $3/_8" \times 2^1/_2"$. Multiplying the weight of the rail by 120, the approximate weight in pounds of adequate spikes required per mile of road is obtained. Twenty pound rail requires 3-inch spikes, thirty pound rail 4-inch spikes; heavier rail requires 5-inch spikes.

If the rail weighs n pounds and costs $30 per ton, the cost of iron and steel per mile of new road is in dollars:—

Rail:— $n \times \dfrac{11}{7} \times 30$

Joints:— $\dfrac{n}{100} \times 352$

Spikes:— $n \times 120 \times \dfrac{2}{100}$

Total:— $n \left[\dfrac{330}{7} + 3·52 + 2·40 \right] = 53·06\, n$

Rail-laying car and engine at work on John L. Roper Lumber Company's holdings, Eastern North Carolina.

"Where it is easy to lay the rail," Eastern North Carolina.

Logging by narrow gauge railroads in the Austrian State forests, Galicia.

The Crosset Lumber Company, Arkansas, on their standard gauge spurlines, lay and remove the track in sections with ties attached of one rail length, using the steam log loader for that purpose.

4. *Grade.* A proper survey is very essential. Grades of 11 per cent are feasible on straight track for locomotives having eight drivers. As a rule, however, grades exceeding 5 per cent require the use of geared locomotives. Grades exceeding 8 per cent should be avoided even in that case. A high percentage for a very short distance is, however, permissible.

Some logging roads in the South have grades running up to 15 per cent for uphill traffic, obtaining the necessary impact by a corresponding downhill grade. The expense of maintenance and of train service added to the frequency of accidents render steep grades highly expensive. The standard railroads do not have any grades exceeding 4 per cent.

5. *Curves.* The minimum radius of curves depends on gauge of track; longest wheelbase; length of timber to be carried, and grade in the curve. Standard railroads do not allow of an angle exceeding 10 degrees.

In curves, to relieve the increased friction, and, further, to prevent the wheels from jumping the track, owing to centrifugal force, three remedies are required:—

(aa) Lessened speed and reduced grade. In practice for standard gauge of $56\frac{1}{2}$ inches, for each degree of curvature the grade is released by 0·03 per cent; for narrow gauge by 0·02 per cent;

(bb) The outer rail is elevated for standard track by $\frac{1}{2}$ inch for every degree of curvature; for 36-inch gauge (usual narrow gauge) by $\frac{1}{3}$ inch for every degree of curvature;

(cc) The track is widened in curves by $\frac{1}{16}$ inch for every $2\frac{1}{2}$ degrees of curvature.

(J) BRIDGES. Bridges on forest roads are wooden bridges.

There may be distinguished:—

(a) According to the purpose subserved by the bridge, between "dry spans" (taking the place of a dirt fill) and "water spans" (built across a running water course subject to freshets);

(b) According to the traffic over the bridge, between railroad bridges and waggon road bridges.

Forest bridges are built of round logs, hewn timber or sawn timber, or of a combination of them.

Forest bridges are supported by cribs, bents, piers, abutments; by braces underneath or by a hanging system overhead.

I. Crib bridges. The crib logs should consist of white oak, chestnut, heartpine, &c.; should be saddled one into the other, solidly pinned with dry (locust) pins ($1\frac{1}{2}$ inches) so that the entire crib forms one exceedingly strong basket. The crib should be placed on a solid foundation by removing loose stones, and should, in case of wet spans, foot on a heavy layer of branches, forming a fringe around the base of the crib where running water is apt to undermine it. The crib is filled with stone. Some foresters deem it advisable to floor the crib with heavy half splits so as to prevent the rock from dropping out if the crib is underwashed. On the upper side, the crib exposed to torrential floods is fortified by a nose or keel (frow). This arrangement forces the water and the flood debris through the bridge spans and prevents the underwashing of the cribs. The nose after

A bridge spanning 85 feet across Davidsons's River, Biltmore Estate. The two white oak cills supporting the bridge contain each 1,500 feet b. m.

being filled with rock is framed sideways with splits or boards. Its foundation is formed by layers of branches.

Abutments built crib-fashion should have a heavy filling of rock, and should be built as full cribs, in case of "wet spans." In case of wet spans, also, the breadth and height of the cribs, and the distance between them must be such as to offer plenty of room for the water to pass during freshets.

The height (thickness) of the stringers is of more importance than their width; stringers placed on corbels are more strongly supported than stringers without corbels. By a number of corbels, the upper ones gradually increasing in length, a very strong support can be obtained for long stringers.

For waggon bridges, at Biltmore, three stringers (white oak) are used, up to 40 feet long without

Bridge across stream used for log drives. Notice the clever combination in the bridge of bracing and suspending members.

supports. In railroad bridges, stringers are 28 feet long, covering 2 spans of 14 feet each. Red oak and yellow poplar are not better, but are more easily found than white oak and chestnut of good lengths.

The covering of the bridges for waggon and sled roads consists either of poles or half splits (punching), or of 2-inch plank. In-ferior lumber can be used by doubling the layer.— The expense of bridge building depends largely on the distance overwhich the bridge timbers must be hauled, and on the pre-sence or absence of a sawmill.
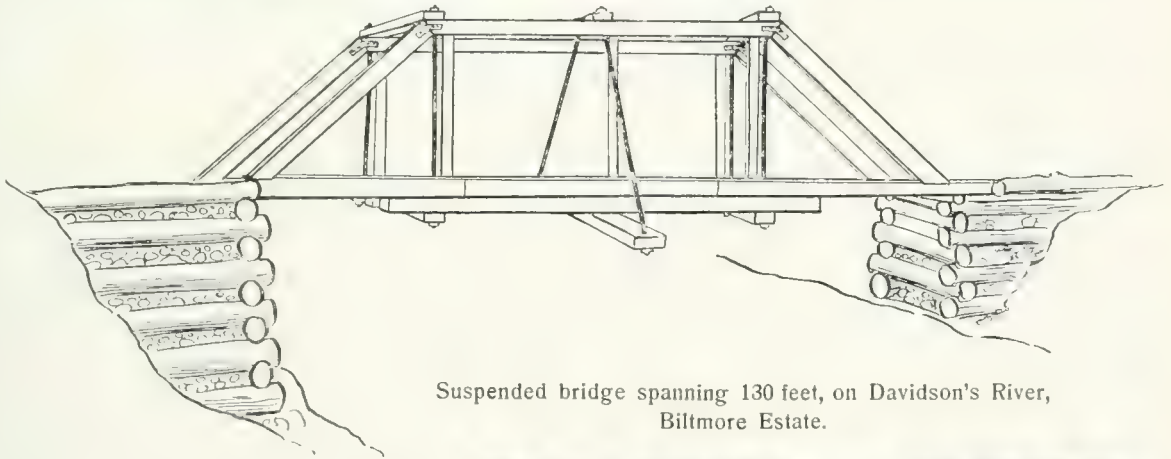
Suspended bridge spanning 130 feet, on Davidson's River, Biltmore Estate.

The expense in the Appalachian forests for dry spans covered with punching is $1 per running foot; for wet spans with cribs $1.80 per running foot; for a suspension bridge 100 feet long $350; for a bra-ced bridge 100 feet long $250.

II. Suspension bridges are those the span of which is supported overhead. The oblique members of the bridge yield the maximum of effect if inclined at a grade of 45 degrees. The caps are held to the oblique mem-bers by perpendicular "Kingrods" and "Queenrods," the former attached to the ends and the latter attached to the middle of the oblique members. The rods, made of $1\frac{1}{2}$ or 2-inch iron and threaded at both ends, may be replaced by "Kingposts" and "Queenposts."

III. Braced bridges are frequently found as "dry spans" over deep gullies. Here, the oblique members

Braced bridge across Looking-glass Creek, Biltmore Estate.

Climax engine in operation on a trestle, over wooden rail. Climax Mfg. Co , Corry, Pa.

are found below the stringers. They are mortised at one end into the abutments or bulkheads, at the other end into the corbels supporting the caps and stringers.

IV. Bent (trestle) bridges (notably for railroads). Bents are either "pile trestle bents" or "frame trestle bents."

Piles are timbers (oak, longleaf pine, Douglas fir) driven into the ground by pile drivers. Pile trestles are trestles wherein the vertical members or supports consist of piles. By "bent" is understood a group of bridge members forming a single vertical support. They are designated as "pile bent" when the principal members are piles, and as "frame bent" when the principal members are framed timbers.

The timbers are best joined by mortises 5 inches deep and $3'' \times 8''$ wide. The posts, sway-braces and caps of wet spans should be boxed up so as to prevent the twisting influence of mud and debris lodged in the meshes of the bents.

The foundation for frame trestles may consist of piles, wooden subsills, or masonry.

By "sill" is understood the lower horizontal member of a frame bent.

By "subsills" are understood timbers bedded in the ground and meant to support frame bents.

Sills for frame trestles should scale $12'' \times 12''$, and should be securely drift-bolted or anchor-bolted to the foundation.

The vertical members of the bent of a frame trestle are the "posts." Posts should scale $12'' \times 12''$, and should be secured with drift bolts or dowels. The outside posts should have a batter of 1 in 4.

By "caps" are understood the horizontal connecting members upon the tops of piles or posts. Caps should scale $12'' \times 14''$, should be 14 feet long, and should be drift-bolted to posts or piles with $3/_4$-inch drift bolts.

The spans between the bents are usually 14 feet between centers. Stringers, the longitudinal members extending from bent to bent, should be laid with broken joints, and should be bolted together with $3/_4$-inch bolts and cast-iron back spools. The stringers are secured to the caps with 2 drift bolts for each cap. The cross section of the stringers is best at 8 by 16 inches.

Cross braces are members extending diagonally from bent to bent in vertical planes.

High trestle bridge and sharp curve negotiated by a log train pulled by a Heisler locomotive.
Heisler Locomotive Works, Erie, Pa.

Sway braces are members bolted or spiked to the bent and extending diagonally across its face. They are secured with $^3/_4$-inch bolts. The cross section of the brace is $3'' \times 10''$.

A "bulkhead" consists of timbers placed on edge against the side of an end bent for the purpose of retaining the embankment.

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PARAGRAPH X.

TRANSPORTATION ON LAND BY VEHICLES:—THE VEHICLES.

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(A) SLEIGHS AND SLEDS.

I. Hand sleighs, home made, very light, are frequently used abroad at grades of 10 per cent and more. The steerer sits in front of load and directs with legs and side brake. On steep slopes such sleighs are used in summer as well. Fifty cubic feet is an average load for one man. The workman carries his empty sleigh uphill on his shoulders for the next load.

Sleighing roads for summer sleighing are frequently supplied with cross ties placed at short intervals and greased at slight grades.

II. The Appalachian tanbark sled, a home made affair, consists of runners 12 feet long made of sourwood, with a natural crook in front. The upright side stakes (hickory), 6 to each side, are mortised into the runners, and are joined by longitudinal and by transverse stays. The load rests on 6 light white oak bolsters, bored at both ends to receive the stays. The gauge is 4 to 5 feet. The animals (oxen) pull either from a chain or from a pole fixed to the front bar. The chain, shifted on the front bar to the right or to the left, allows the sled to turn on sharp angles. The pole, directly coupled to the yokes, makes it possible for the steers to hold the sled back on steep grades. The capacity of a sled is from $^3/_4$ cord to $1^1/_4$ cords of bark.

A chain swung round the runners is used for a brake on steep grades.

The sledding road, roughly cleared of bushes, runs straight down the hill.

III. The winter sled for logs has little in common with the summer sled. A strong team of horses is always used for motive power. For sled-trains, in the last few years, the use of sled traction engines has gained much favor.

(a) THE SLEIGH, OR SLED, consists of two sets:— The front set has a tongue of rock elm or oak and a "front roller," in which the tongue is set. Runners are 7 to 9 feet long, 3 inches to 4 inches wide, shod with ¹⁄₂-inch steel shoes or cast-iron shoes either below only or both above and below; bottoms are either slightly convex or flat. The front of the runner should be of a natural curve or croock, not hewn. Material is white oak. The cross beams, either ironed or plain, rest in saddles or nose plates with knees.

Logging sleds made by Eau Claire Mill Supply Co., Eau Claire, Wis.

The "back roll" of the hind set is coupled to the front set by chains attached crosswise to the front cross beam. There is usually no tongue to the hind set.

Snow plows are required to move and to settle the deep snow. Tank sleds carry the water used at night for icing the ruts made by the runners.

The sleds are loaded from the skidways either by chains and cables slung round the logs and pulled by horses or else by means of a "jammer" (tripod, tackleblock, rope, chain, loading hooks).

Log binders take about half a foot of slack out of the loading chain. The same end may be secured by poles and the twisting of the binding chain. A sled costs about ҂35. The usual capacity of a sled is five tons, while that of a waggon is only two tons. The actual load depends on distance, grade, and condition of road. In the Adirondacks, about 2,000 board feet form a load; in Ontario, 1,500 board feet of white pine or spruce.

Sledding roads are constructed in the Adirondacks at an expense of ҂25 to ҂150 a mile. The sledding distance when horses are used should not exceed three miles, usually. The expense of sledding 1,000 board feet per mile should not exceed 35 cents. In Maine, the regular contract price for cutting, skidding, and sledding is ҂2·50 per cord of spruce wood.

The relative distance of snaking and sledding depends on configuration and density of stand. Sledding roads are preferably built on swampy soil. Heavy grades downhill require a heavy outlay for sanding; insufficient grades a heavy outlay for icing. Carelessness allowed in surveying the sleigh roads is extremely expensive in short, mild, snowless winters. The modern lumberman surveys his roads with instrument in hand, completing them before snowfall.

To begin with, an empty or lightly loaded sleigh is run over the road to mark and set the track.

(b) SLED TRACTION ENGINES are manufactured, amongst others, by the Phœnix Manufacturing Co., of Eau Claire, Wis. Horse teams are used, in connection with the engines, to assemble the loaded sleds into log trains.

1. *The traction engine consists of:—*

A 100 horse-power engine.

15′ ✕ 3′ horizontal boiler, with 1³⁄₄-inch flues, 200 lbs. pressure.

Four cylinders, 6¹⁄₄″ ✕ 8″, two on each side of the engine.

Four heavy steel sprocket wheels, two on each side, over which the friction chains are running on the snow.

A front steering sled, on which the steerer sits.

Sled traction engine, made by Phœnix Manufacturing Co., pulling 16 double sleds loaded with 66,825 feet b. m. of logs.

Sled traction engine pulling cord wood.

2. *The traction engine requires:*—

Well prepared, level, and well iced roads.

Extra number of wide and strong sleds, with short stub tongues.

$1\frac{1}{2}$ tons coal per day.

Water every five miles, or a tank sled (same as used for sprinkling).

Crew of three men (engineer, fireman, steerer).

3. *Capacity:*—The engine, travelling at night preferably, covers 35 to 50 miles per day. It pulls a train consisting of 10 to 15 heavily loaded sleds at a time. Uphill grades of 10 per cent are said to be feasible for the engine. The engine is not recommended for hauls under three miles long.

(B) TWO-WHEELERS. The Southern logging superintendents, at a recent meeting, gave the following as the figures, per 1,000 feet b. m., for labor expenses incurred by their concerns when hauling or skidding to tracks by two-wheel trucks:—

Arkansas ...	from 35·3 to 63 cents	Louisiana ...	from 49 cents to $2·09
Texas	from 45 cents to $1·61	Mississippi ...	from $1·60 to $1·80

I. **High wheelers**, with wheels 7 to 10 feet high, are used in the pineries of the South, in California, and in the Lake States for hauling logs or bunches of logs, regardless of log length and of log diameter. The

Slip-tongue arrangement of high wheeler, seen from behind.

Logging by slip-tongue carts, side view, holdings of John L. Roper Lumber Co.

Ready to unload a bunch of hardwood logs, Cadillac, Mich.

High wheeler about to dump a bunch of logs at the loading station of the narrow gauge railroad, Cummer-Diggins Co., Cadillac, Mich.

High wheelers and steam log loaders at work near Cadillac, Mich.

logs are made fast underneath the axle, either by using the tongue as a lever or with the help of a winch handled by crowbars, or by the "slip-tongue," found notably in the pineries. Here, a square tongue (which carries the doubletree) some 22 feet long, "slips" between the hounds when the mules begin to pull. In doing so, the tongue turns a winch by means of a lever and of a chain

Large type two-wheeler used in Michigan.
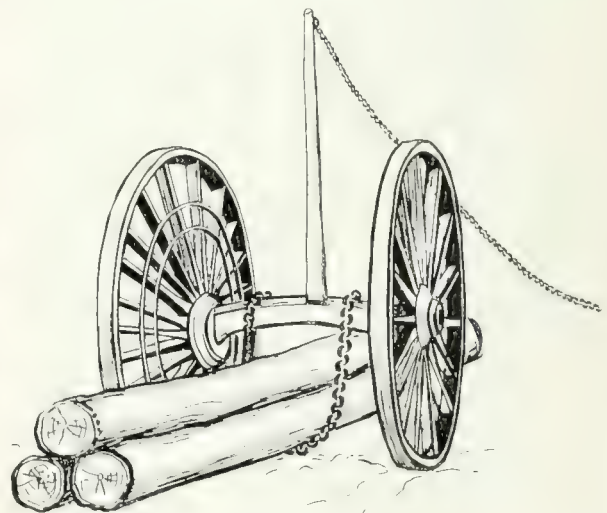
Overpack wheels dumping load.

the ends of which are attached to the tongue. The turn of the winch lifts the logs by logging chains, which are made fast to the winch. The logs (1, 2, or 3) are held by means of grapple hooks. As soon as the team stops pulling, the tongue slips back and the logs drop to the ground.

In the South, 3 yokes of steers or 2 teams of mules are attached to each truck.

In the North, where 10-foot wheels are the standard, one strong horse team will do.

The logs are usually ground skidded to form bunches of 3 to 6 logs (400 to 800 feet b. m. lying parallel on the ground between the high truck wheels) and to be raised from the ground by this or that device. The front end of the logs is sometimes fastened to the tongue.

In the South, the trucking distance does not exceed half a mile, usually averaging one quarter of a mile.

The best makes are those of:—

Bodley Wagon Co., Staunton, Va.; Snyder Wagon Co., Shreveport, La.; S. C. Overpack, Manistee, Mich. Price from $100 to $150 per truck.

II. Low wheelers, usually called "bummers," the wheels consisting of solid tree sections of $1\frac{1}{2}$ feet diameter held by iron rims, are used particularly in the Gulf States and in Arkansas. They are met also in Idaho. The top of the axle-bolster is even with the top of the wheels. The tongue is only 6 feet long, and is used as a lever in loading. The bummer is pulled by a chain attached to the point of the tongue, and is loaded by placing the axle parallel to the log and close to the middle of the log, with the tongue standing perpendicular. The log is fastened to the axle by short chains and dogs. When the team begins to pull, the perpendicular tongue is forced down. The log swings automatically into position, its nose rolling over one of the wheels, and the team starts on its trip without a moment's delay.

High and low wheelers are used on undulating ground for downhill pull on soil free from rock, ice, swampy places, debris, and brush.
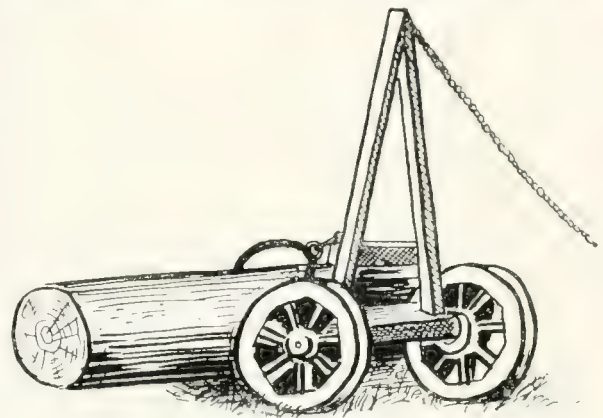
Log bummer, ready for the load.

(C) LOG WAGGONS. Log waggons are used largely in the Old Country, where the forests are traversed by a network of well graded stone roads. In carrying long boles, the front and hind trucks are separated, the bole taking the place of the reach. Steep curves can be made if the rear ends of the logs are fastened underneath the axle of the hind truck. The tip of the reach is forced towards the outside of the curve either by hand or by a jackscrew.

I. The American log waggon has a gauge, measured from center to center of tire, of 4 feet 6 inches or of 5 feet.

Wheels are usually made entirely of white oak. The wood is air-seasoned. The tire is 3 inches, 5 inches, and over. Front and hind wheels are usually equally high (2 feet to $3\frac{1}{2}$ feet). Eight-wheelers are now widely advertised.

Skeins are preferably made of welded steel instead of cast, 3 inches to 5 inches in diameter.

Steel axles have not proven a success, owing to difficulty of repairs in the backwoods. Bolsters should reach to or over the top of the wheels.

The reach should allow of a changing distance between front and rear set; its tip should be swivel-jointed to the front truck.

Main requirements in a log waggon are:—

Strength.   Ease in loading.
Possibility of repairs in the woods.   Ease in turning.
Low center of gravity.   Light weight of waggon itself.

The prices of log waggons range from $80 to $200 according to carrying capacity; the weights from 800 to 1,800 pounds; the carrying capacity from $1\frac{1}{2}$ to 5 tons.
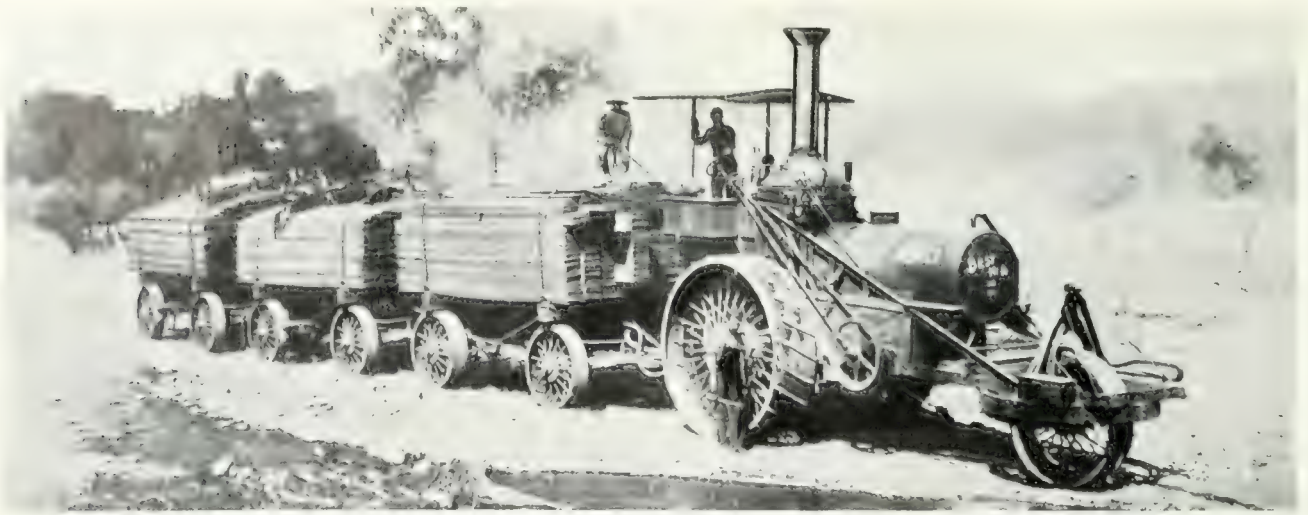
California traction engine at work. Best Mfg. Co., San Leandro, Cal.

II. Traction engines for log waggons are used in the United States on a small scale, since stone roads seem to be prerequisites. Loose sand, deep mud, or swamp are impracticable for traction engines.

In Pennsylvania and in North Carolina, four-wheelers costing $1,500 for 16-horse-power compound engines, able to take 12 per cent grades and to turn 30-foot curves, have proven failures. The use of traction engines plows the roads during rain.

In the California mountains, where drought prevails during 6 months of the year, the three-wheelers (price $5,500) manufactured by the Best Co., of San Leandro, Cal., have been largely and successfully introduced. High wheels (diameter, 8 feet) and broad tread cause little injury to the route travelled.

Three-wheel traction engine. Best Mfg. Co., San Leandro, Cal.

The boiler is a combination of upright and horizontal, concentrating weight on the driving wheels and preventing water and fuel from dropping back from the flues on steep grades. The engines are said to be able to ascend 30 per cent grades and to climb over logs, brush, stone, &c. The front wheel is meant for steering only. A front drum can be used for skidding or loading by wire cable.

Special waggon trucks (at ≮900 each) of 16 tons capacity, are used in connection with this machine.

III. Logging motor trucks (power waggons). Motor vehicles fit for use on rough or temporary forest roads have still to come.

Heavy loads require heavy foundations for the vehicles to rest on.

For transportation in well-paved cities of firewood and lumber, the three-ton gasoline delivery trucks of the White Company, Cleveland, Ohio, have proven a success.

Self-propelling logging trucks will require stone roads or plank roads. The Koltz system of roads, or plank-covered runways might answer.

IV. Logging cars.

(a) LOGGING CARS ARE DISTINGUISHED:—

1. According to the flange and the tire of the wheels, as cars for pole roads, wooden railroads, and steel railroads. The wheels may turn freely and individually on and round the axle (like waggon wheels) or they may turn with the axle, the axle revolving in journals and bearings.
2. According to the arrangement of the trucks, as double-truck cars or single-truck cars.
3. According to the car surface, as skeleton cars and flat cars.
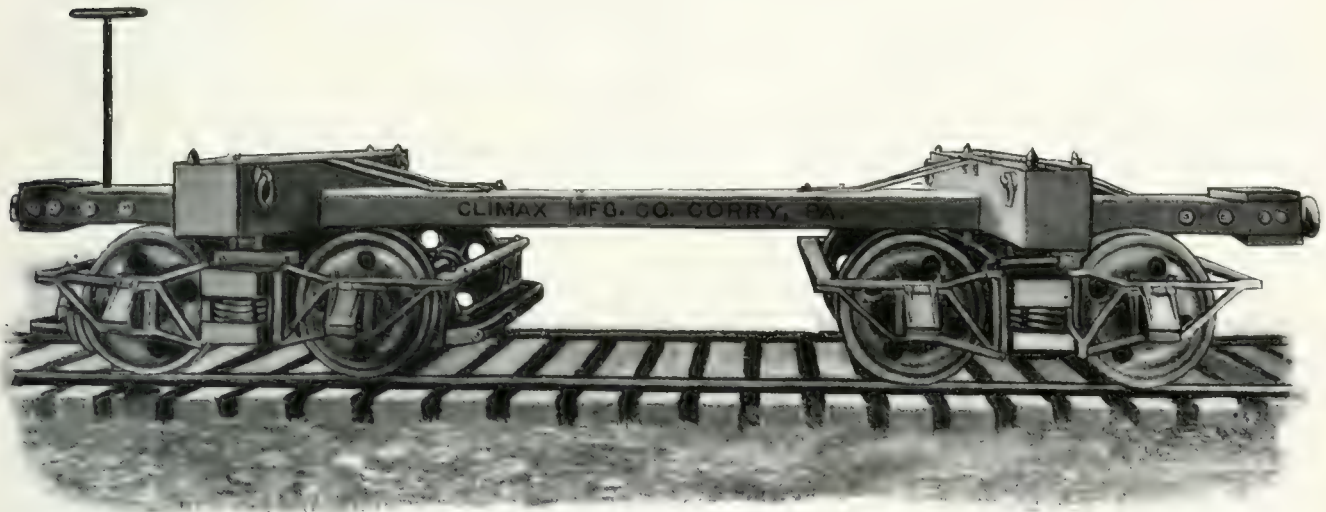
Logging car made by Climax Mfg. Co., Corry, Pa.

(b) REQUIREMENTS:—The logging cars are run, after being loaded, in the roughest possible manner, over the roughest railroads in the world. Extremely strong construction is, as a consequence, a necessity.

A car must:—

Be loaded and unloaded with ease and without breakage.
Stand derailment.
Protect the track.
Take a large, heavy load.
Have low center of gravity.
Be coupled and uncoupled easily.
Allow of repairs in the woods.
Be able to round sharp curves.
Have reliable brakes.

(c) WHEELS:—The diameters of the wheels range from 12 inches in case of pole road truck and wooden rail truck up to the standard diameter of 33 inches which the most modern loggers seem to prefer.

The usual wheel is a 22, 24, or 26-inch wheel made of chilled charcoal cast iron.

The face of the tread is from 3 to 6 inches wide (for wooden rails); it slants toward the outside so that the car may adapt itself to sharp curves, when the outer wheel must cover a larger distance than the inner.

The flange is 1 to 3 inches deep; in the case of pole roads even deeper than that.

The wheel base should be as short as possible. In standard equipment, it is about 3 feet 9 inches.

The weight of the wheels varies from 50 lbs. for a 12-inch wheel to 300 lbs. for a 24-inch wheel, and so on.

(d) THE TRUCK FRAME carries the boxes and the bearings outside the wheels (with light axles outside and inside). The top bar and the arch bar join the forward to the rearward journals. The arches carry the sandboard with the spring coils supporting the spring bolster. The log bolsters (8 by 10 inches) are heavily ironed; they are bolted and braced to the sills, in case of double truck cars. Steel bolsters and all steel trucks are slow in replacing the timber structures. The bolsters are up to 8 feet wide, with and without scabbards for carstakes at the ends.

Flat cars are by about 30 per cent heavier and by about 20 per cent more expensive than skeleton cars. Detached trucks take care of the longest logs.

(e) EQUIPMENT:—Brakes, if any, are usually hand brakes (with detachable brake staff).

Air brakes, which are unadapted to disconnected trucks, are being adopted in the West.

Link and pin coupling forms the rule.

Automatic couplers save much delay in making up the trains.

(f) PRICE:—A four-wheeled truck, complete, for narrow-gauge wooden rail, gravity road, costs from $50 to $80.

A standard modern two-truck Western skeleton car costs about $750.

The majority of the lumber companies are in the habit of buying wheels, axles, archbars, topbars, and all other iron parts ready to be attached to frames, sills, bolsters, and other wooden parts of home-made manufacture.

For shipping, the iron parts for four logging cars make up one standard car load.

(g) WEIGHT AND CAPACITY:—The weight of the standard skeleton car varies between 8,000 lbs. in the Southern pineries and 19,000 lbs. in the forests of the Pacific Coast.

The capacity of the cars runs up to 50 tons.

A good car carries 5 feet b. m. of logs for every 10 pounds of its own weight.

V. Locomotives:—Logging locomotives are manufactured, amongst others, by the Baldwin Locomotive Works, Philadelphia, Pa.; H. K. Porter, Pittsburg, Pa.; Climax Mfg. Co., Corry, Pa.; Davenport Locomotive Works, Davenport, Iowa; Lima Locomotive and Machine Co., Lima, Ohio (for Shays); Vulcan Iron Works, Wilkes-Barre, Pa.; Heisler Locomotive Works, Erie, Pa.

Locomotives are either "direct connected" or "geared." The best geared types are Shay, Heisler, and Climax.

The price is practically independent of the gauge, being influenced more by horse-power, weight, and construction.

Four driving wheels are usually sufficient. On steep grades six drivers, and, on very steep grades, eight drivers are used.

The number of drivers required depends also on the weight of the rail.

(a) DIRECT CONNECTED VERSUS GEARED LOCOMOTIVES. Geared locomotives are preferable for short hauls, steep grades (above 5 per cent), sharp curves, uneven track, light rails, and light trestles. The geared locomotive is more expensive, ton for ton of weight, than the direct connected locomotive. It is, however, more practicable on a cheaply built track; and the economy in track laying and in grading often outweighs

Logging with Climax locomotive. Climax Mfg. Co., Corry, Pa.

by far the extra cost of the geared machine. That the geared can run on a poor track more readily without accident than the direct connected locomotive is explained by three facts:—

1. The weight is distributed over a larger number of drivers.
2. The front and the rear truck supporting the machine are flexibly connected.
3. It runs necessarily on a very slow speed.

Heisler locomotive with a train of logs operated by Lamb-Fish Co. Heisler Locomotive Works, Erie, Pa.

A train or a horse moving a load at a fast speed, consumes more power than a train or a horse moving at a slow speed. The drivers of a direct connected locomotive make one revolution for every stroke of the pitman; whilst those of the geared locomotive require, at the will of the constructor, for every revolution, an indefinitely large number of strokes. As a consequence its speed is slow and its hauling capacity is large. Geared locomotives are too slow for long hauls. Their place is the spur line rather than the main line.

(b) LOCOMOTIVES SHOULD BE EQUIPPED WITH:—

Syphons, to inject water at any branch.   Water pumps.
Hydraulic jacks.   Lights fore and aft.
Up-to-date car replacers.   Sanders fore and aft.
Spark arresters.   Air and steam brakes.

(c) "TRACTIVE FORCE" is the weight in pounds which a locomotive, standing on level track, with speed disregarded, can lift, by tackle block and rope, out of a pit.

It is calculated in pounds as follows:—

$$\text{Tractive force equals} \left[\frac{d^2 \times 1 \times p}{D} \times 0.85 \right] \text{pounds}$$

wherein designates
$d = $ diameter of cylinder
$1 = $ length of stroke
$p = $ boiler pressure in pounds
$D = $ diameter of drivers
$0.85 = $ constant factor

The tractive force should be between $\frac{1}{4}$ and $\frac{1}{6}$ (average $\frac{1}{5}$) of the weight on the drivers, both expressed in pounds; lest the locomotive is "overcylindered," causing drivers to slip too easily, or "undercylindered," preventing drivers from slipping at all.

(d) HAULING CAPACITY:—Hauling capacity is the weight of the heaviest train (locomotive, cars, and their load) which the locomotive can start on a straight track.

Ordinarily, the hauling capacity of a direct connected engine is:—Tractive force multiplied by 2,000 divided by the sum of the frictional and gravity resistance, both expressed in pounds per ton, diminished by the weight of the locomotive.

Example:—Weight of locomotive, 25 tons.
Frictional resistance, 8 lbs. per ton.
Gravity resistance, 30 lbs. per ton.

$$\text{Hauling capacity} = \frac{25 \times 2,000}{5 \times 38} - 25$$

The weight actually hauled should never exceed $\frac{1}{5}$ of the actual hauling capacity.

(e) MAKES AND THEIR CHARACTERISTICS:—

1. *Shay locomotive:*— The boiler, placed towards the left-hand side of the framework, exceeds that of the standard locomotive by exceptionally large firebox, heating surface, and steam space. On the right-hand side of the boiler, three steam cylinders are bolted to a bracket. All the eight wheels
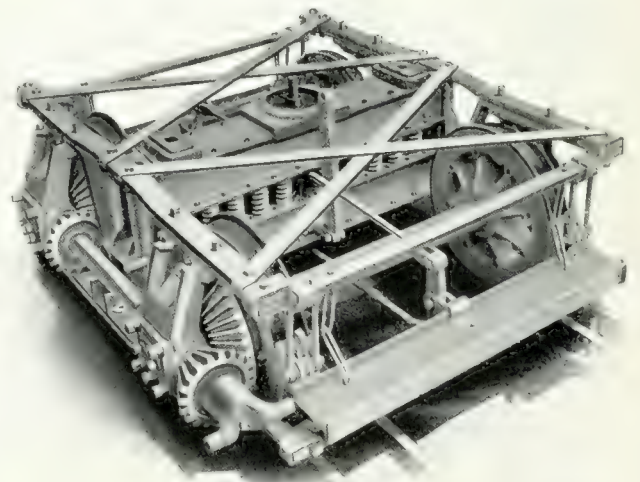
Front truck of Shay locomotive. Lima Locomotive Works, Lima, Ohio.
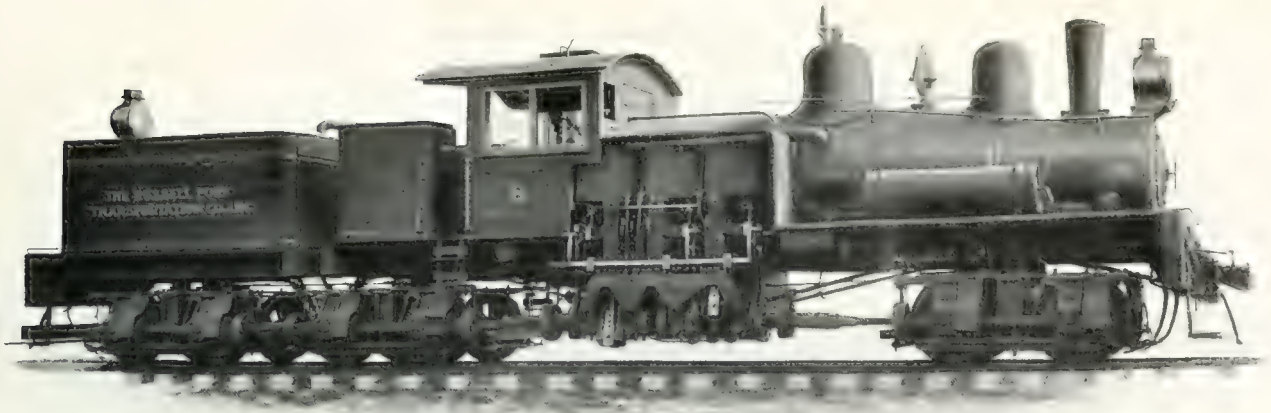
Class A Shay locomotive. Lima Locomotive Works, Lima, Ohio.

of the two trucks are gearwheels and all are drivers. The only connection of the trucks with the main frame is through the center plates, so that the trucks can adjust themselves to rough and curved tracks. The crank is either double-throw or three-throw. Twelve to eighteen impulses are required per revolution of the drivers. The crankshaft turns the driveshaft extending outside the wheels from the foremost to the rearmost of the right-hand drivers. All friction parts are readily accessible. The driveshaft may be extended so as to turn also the eight wheels of the tender. The flexibility of the driveshaft is secured by a series of scabbards which, joining the sections of the driveshaft, allow them a large amount of play. Thus, when a left-hand curve is made, the driveshaft is lengthened, and when a right-hand curve is made, the driveshaft is shortened. The boiler pressure runs from 150 lbs. in the small to 200 lbs. in the largest Shays. A 20-ton Shay can make curves of 50 feet, and a 50-ton Shay can make curves of 100 feet radius. Oil is practicable, and after Pacific experiences with a daily outlay of $8·60 for a 45-ton oil-fed Shay even cheaper than wood.
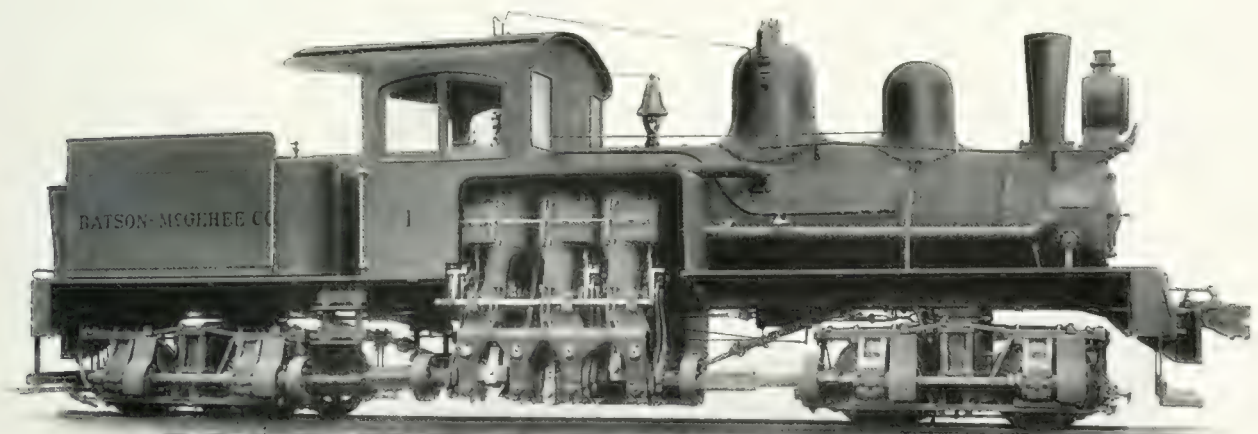
Class C Shay locomotive. Lima Locomotive Works, Lima, Ohio.

Heisler locomotive:—The two cylinders are right and left handed; they stand in a plane vertical to the track, and are inclined against the horizon by 45 degrees. The pitmans work on the crank of a central, longitudinal driving shaft, which extends from the fore-axle of the four-wheel front truck to the rear-axle of the four-wheel rear truck causing these axles to revolve by oil-submerged gears and pinions. The four drivers of each truck are connected by side rods outside. The journals are inside the wheels. The trucks are swiveled in the main frame so as to be able to pass sharp curves on uneven track. Frame, boilers, and engines are of a particularly simple and strong design. All parts are readily accessible. Each truck can be removed easily and completely. The side rod comes in good stead when the locomotive is jacked up after being derailed. The price of the Heisler ranges from $150 to $200 per ton of weight.
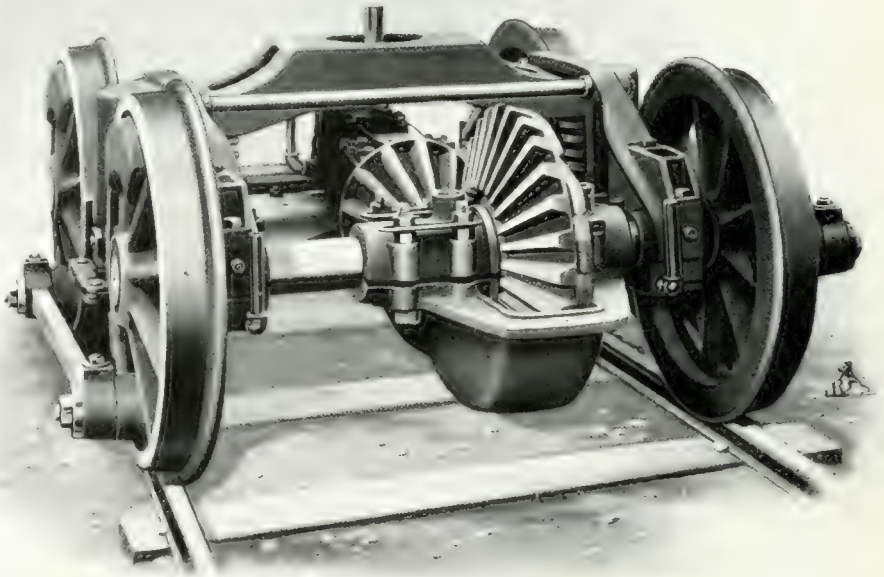
Gear arrangement of Heisler geared locomotive.
Heisler Locomotive Works, Erie, Pa.
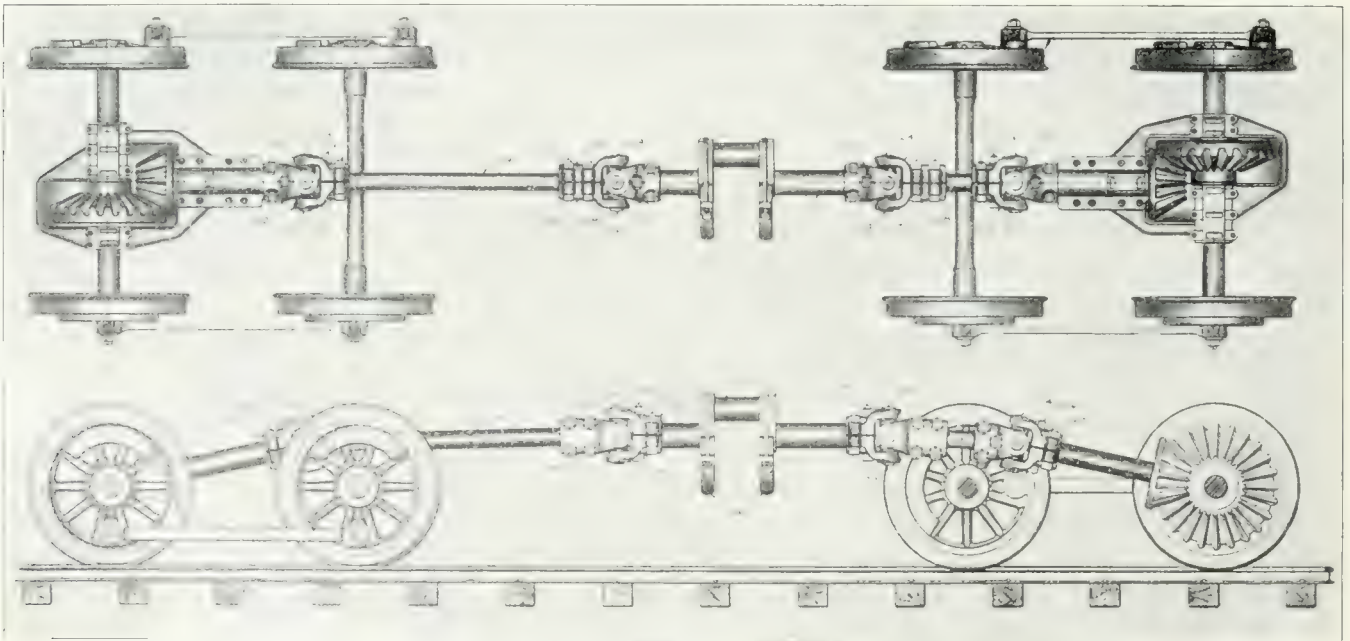
Drive shaft of Heisler geared locomotive seen from above, and seen from the side. Heisler Locomotive Works, Erie, Pa.

115 Crank shaft	118 Center shaft, front	121 Coupling, slip joint,	124 Coupling bushings
116 Crank counter balance	119 Center shaft, rear	female	125 Coupling bolts, short
117 Crank counter-balance	120 Coupling, slip joint,	122 Coupling, clamp joint	126 Coupling bolts, long
straps	male	123 Coupling cross	127 Coupling bolts, slip-joint

Side view of new type Heisler geared locomotive. Heisler Locomotive Works, Erie, Pa.

3. *The Climax* (price from $2,500 to $12,000), made at Corry, Pa., has its two engines, one on each side, working in a plane parallel to the track and inclined against the

horizon by about 30 degrees. The engines turn a crankshaft secured to the main frame square across the frame, which in revolving turns the longitudinal main driving shaft, centrally located beneath the frame, by means of skew gears. All the four axles (two in front truck and two in rear truck) are driven from the main driving shaft by rack and pinion gears. The journals are on the outside of the wheels, as in the Shay. In the light Climax (20-ton), the engines
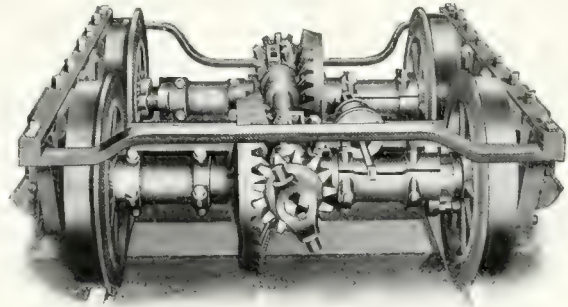
End view of Climax trucks. Climax Mfg. Co., Corry, Pa.
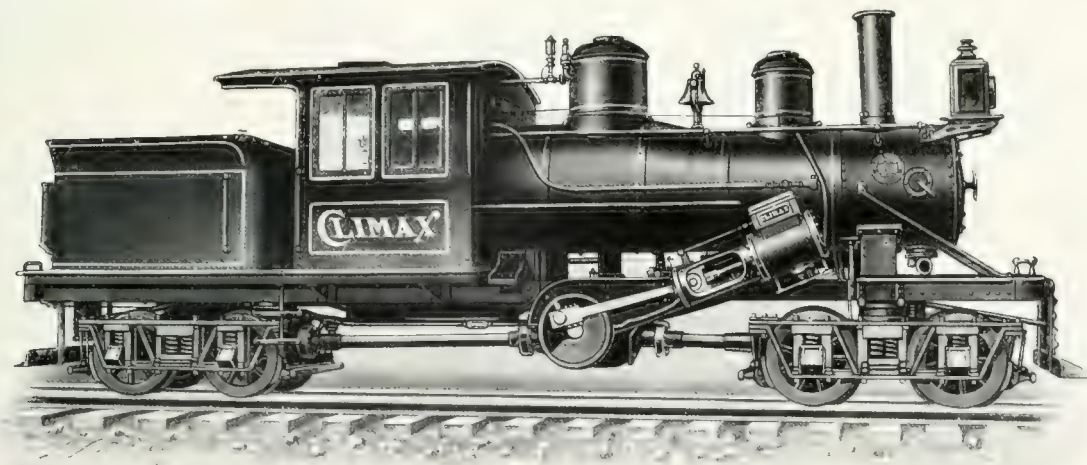
Climax class B logging locomotive. Climax Mfg. Co., Corry, Pa.
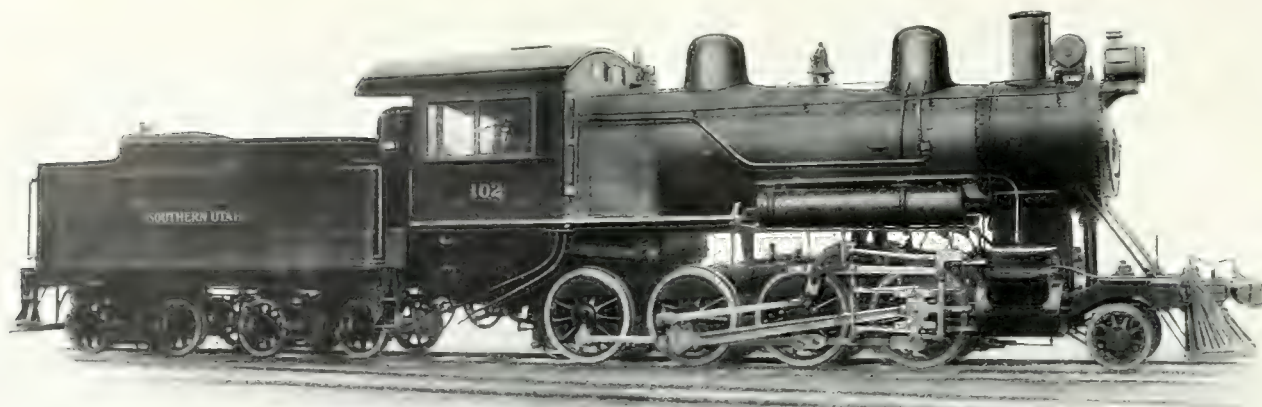
Consolidation type of logging locomotive. Lima Locomotive Works, Lima, Ohio.

are vertical and are centrally located between the rail. The boiler is a combination upright and horizontal.

4. *Direct connected, or rod locomotives.* With grades not exceeding 5 per cent for any considerable distance, the rod locomotive is invariably preferred on the main line. Types like the Mogul (2 leading truck wheels, 6 drivers, no trailing trucks), like the Consolidation (2 leading truck wheels, eight drivers, no trailing trucks) and like the Prairie (2 leading truck wheels, 6 drivers, 2 trailing truck wheels) are preferred. The tanks may be "saddle tanks," "side tanks" or "rear tanks." The drivers should be small, the boiler power ample, and the weight per driver about 19,000 lbs., with 60-lb. rail.

Discarded passenger engines are unfit for logging. The modern lumberman buys an entirely new outfit, all from one and the same responsible firm, all specially designed to meet his own particular task. The firm supplying the outfit should have a depository of repair parts at a distance not too far from the point of operations. The price of a logging rod engine ranges, according to size, approximately between $2,500 and $10,000. In the pineries, a 35-ton locomotive is customary.

5. *The Mallet.* The progressive West is introducing the articulated Mallet locomotive (Baldwin Locomotive Works), weighing over 100 tons and designed to operate on 35-lb. rails, 20 degree curves, and 8 per cent grades. The Mallet consists, practically speaking, of two complete
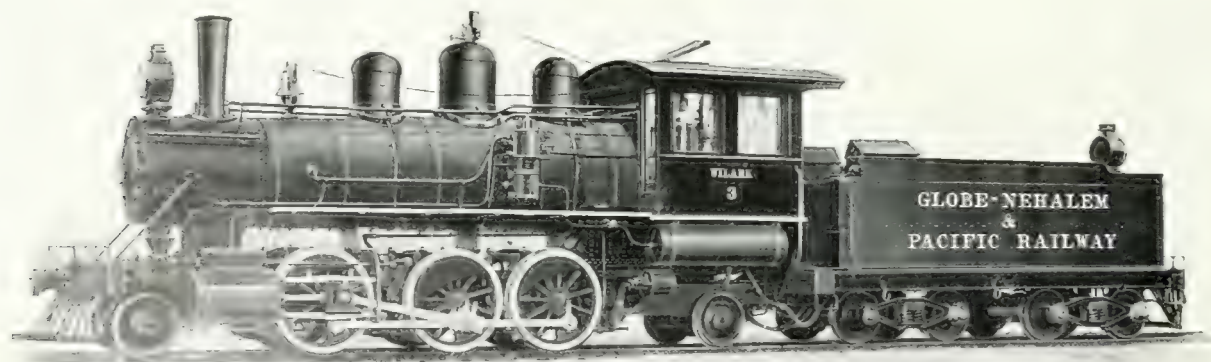
Prairie type of logging locomotive. Davenport Locomotive Works, Davenport, Iowa.

locomotives with one boiler. The rear engine is held rigidly to the boiler; the forward engine accommodates itself to the curves by a lateral motion. The leading and the trailing truck, controlled by a radius bar, are free to swivel and swing into the curves. The exhaust from the small cylinders of the rear engine acts as the live steam for the larger cylinders of the forward engine. The Mallet locomotive, when starting a train, is practically non-slipping. The weight is distributed over 12 to 16 drivers.

(f) COST OF HAULING BY LOGGING LOCOMOTIVES:—The cost of hauling logs on a standard railroad, per carload of 40,000 pounds, amounts to $5 for distances of 1 mile to 50 miles, and to $6 for distances of 50 to 100 miles. In small jobs, the cost of hauling can be given as ranging from 30 cents to 60 cents per 1,000 feet b. m., for a hauling distance of from 5 to 10 miles. The logger in the Redwood belt counts on a hauling expense (for payroll, for wear and tear) of 5 cents per mile and per 1,000 feet b. m.

VI. Mono rail traffic. The mono rail portable railway is a French invention (Gaillet) and has been tried to a limited extent in India. It consists of one rail only, resting on steel sole plates at intervals of a few feet, and is laid down direct on the surface of the ground. Rails are joined together by scabbard fish plates. The trucks have two low wheels, grooved at the rim, the carriage hanging between the wheels a few inches above the rail. Cars are bal-anced by a telescopic rod and are kept in balance, like a bicycle, by the motive power itself, which consists of an animal hitched in a frame alongside the carriage.

The mono rail system might be appli-cable to the transportation of bark, cord-wood, and minerals.

Experiments are being made to secure locomotion by steam power and balance by the gyroscope.

PARAGRAPH XI.

ARRANGEMENTS FOR LOADING LOGS ON WAGGONS, SLEDS, AND CARS.

Special loading arrangements are re-quired, wherever vehicles are used, except for bummers and high wheelers.

(A) LOADING ON WAGGONS AND SLEDS:—

I. Rolling logs from a higher bank onto vehicles. Only one layer can thus be loaded conveniently. (This method is also used to load redwood and redfir logs from a plat-form on cars.)

II. Rolling logs up an incline, either with peavies or rope, the top of the incline rest-ing on the tops of he wheels.

III. A (drum) winch in front of wag-gon, incline behind waggon, pulling logs up by rope.

Loading by horses. Photo by Clyde Iron Works, Duluth, Minn.

IV. **Tackle block attached to a tree,** the waggon stand-ing between the tree and the log; a rope attached to an outside wheel, passed beneath and returned over the log, then passed through the tackle block, and the free end pulled by animals.

V. **The skidway scheme.** Trained horses running on prepared track opposite the skidway. Two poles leading from skidway to waggon; rope running from outer wheel of waggon under and around the log and back over the waggon to the horses.

VI. **A jack, consisting of a crank,** a gear wheel, and a toothed iron bar.

VII. **The logjammer,** consisting of a mast supported by braces and guyropes, and of a swinging arm holding a tackle block over the vehicle, made fast to the mast top by a rope and to the mast body by a swivel and ring. A cable or rope is passed through the tackle block. One end of the rope grapples the log; the other end is pulled by a team.

(B) LOADING ON RAILROAD CARS. Additional methods:—

I. **A huge tripod** and a differential hoist.

II. **A drum and wire cable rig** (e. g., that of a donkey engine), the loading cable running over a tackle block sus-pended over the track.

III. **Portable cranes or derricks.**

IV. **Steam log loaders.** Where steam log loaders are used, proper skidways can be dispensed with. It is unwise, however, to leave the logs scattered along the railroad.
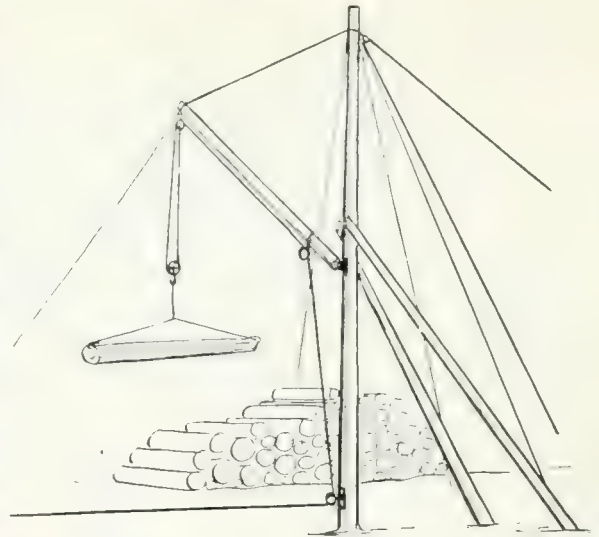
Jammer for loading or unloading logs by horses.

Team of horses loading cedar poles.
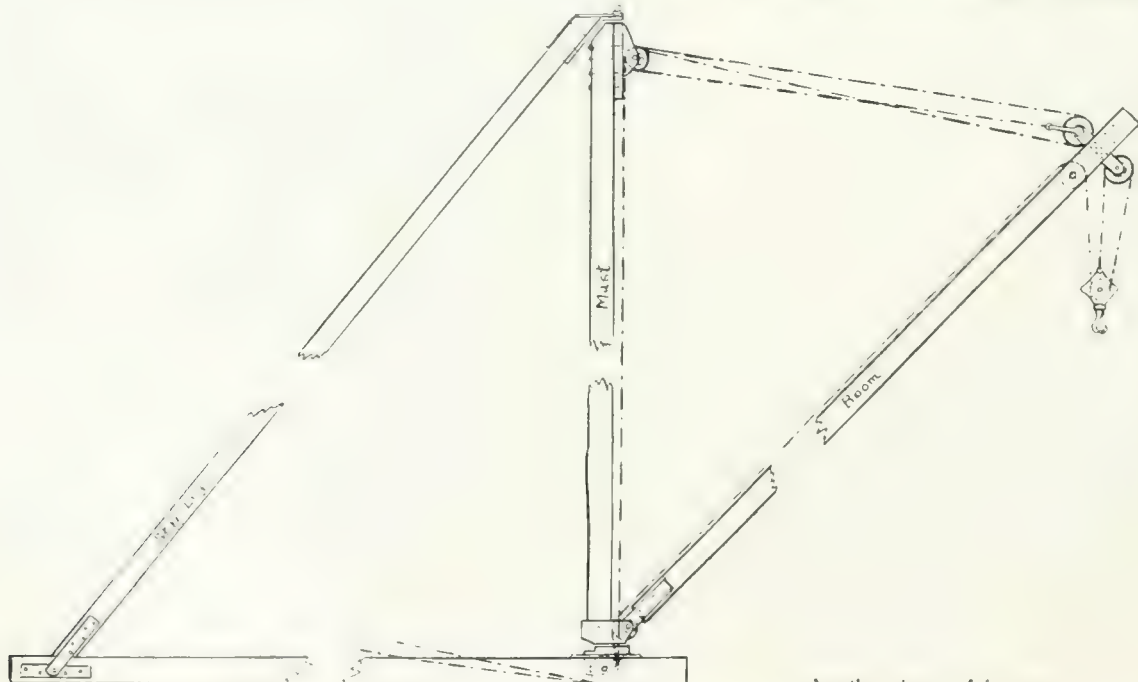
Another type of jammer.
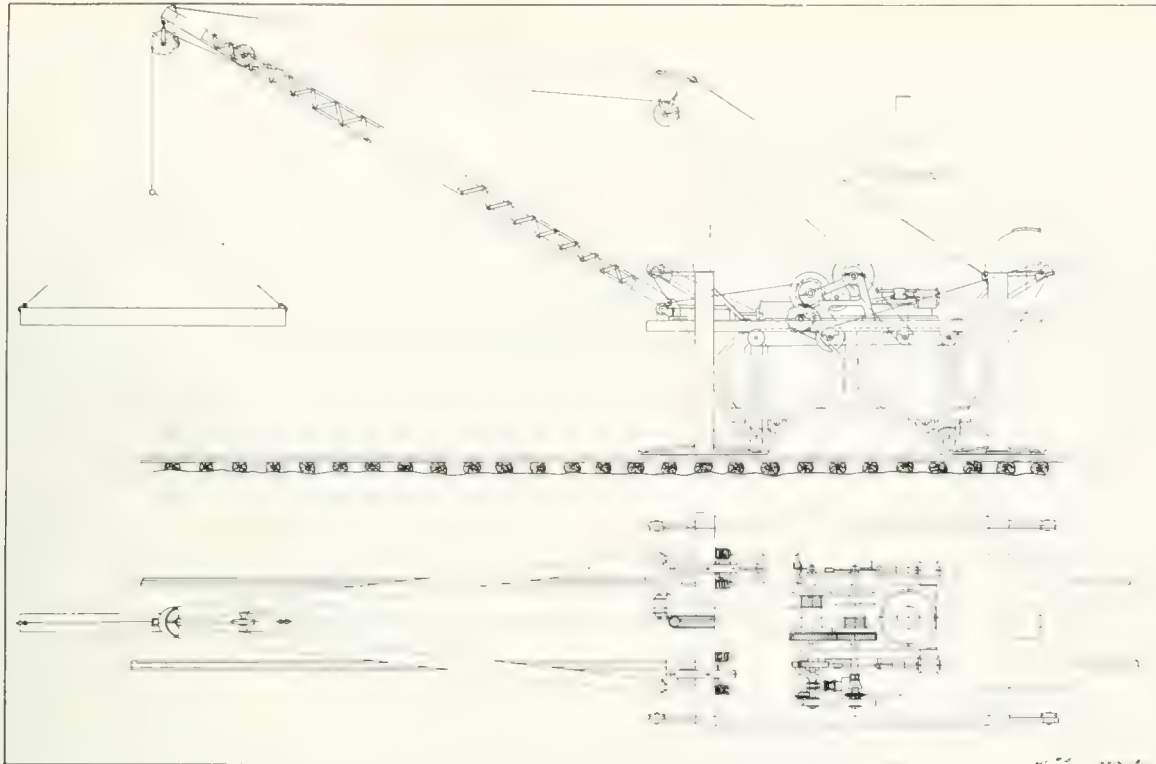
Ground plan and elevation of the McGiffert log loader.

Log loaders are of use also in driving piles, in handling trestle timber, in stump pulling, in grading, in ditching, and in wrecking.

The following classes of steam log loaders may be distinguished:—

(a) SELF-PROPELLING, CAR-SPOTTING LOG LOADERS WITH RIGID (OR SEMI-SWING) BOOM. Main types:— The Decker and the McGiffert log loaders, manufactured by the Clyde Iron Co., of Duluth, Minn. The most modern types have eight instead of four wheels, so as to be compatible with light rail.
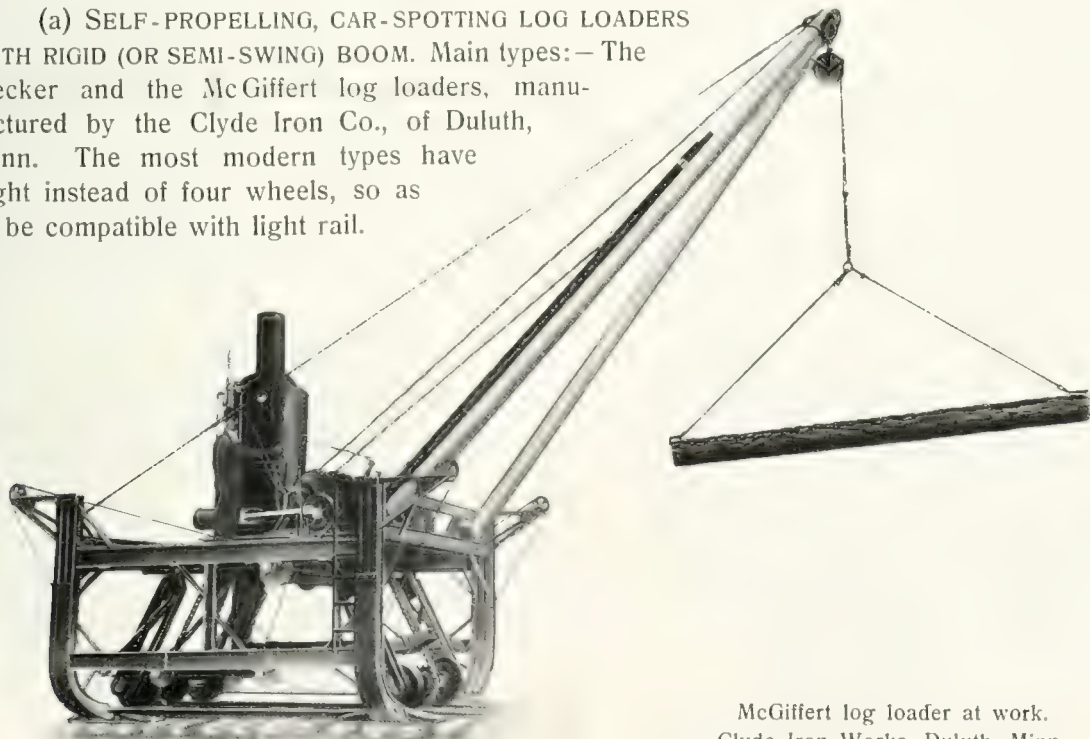
McGiffert log loader at work.
Clyde Iron Works, Duluth, Minn.

Empties passing through McGiffert log loader.
John L. Roper Lumber Company's holdings.

McGiffert log loader at work. Clyde Iron Works,
Duluth, Minn.

The machines are self-propelling donkey engines on wheels. The Decker (price $4,500 to $6,000) has a "sort of an open tunnel" above the axles and below the frame carrying the donkey, so wide and so high, that empty cars may run through the tunnel on steel rail, bridge-switched onto the rail of the main track at both sides of the tunnel.

The McGiffert (price $4,500 to $6,700) removes its own wheels by swinging them, pendulum fashion, against the top of the tunnel and by sinking, simultaneously. on steel footings resting on the ties outside of the steel rail, thus giving sufficient clearance to the passage of empties. The empties are pulled through the tunnel from behind to the front, ready to receive the load, by means of a cable.

For use on wooden rail, the machines have wheels of 6-inch tread and 2½-inch flange.
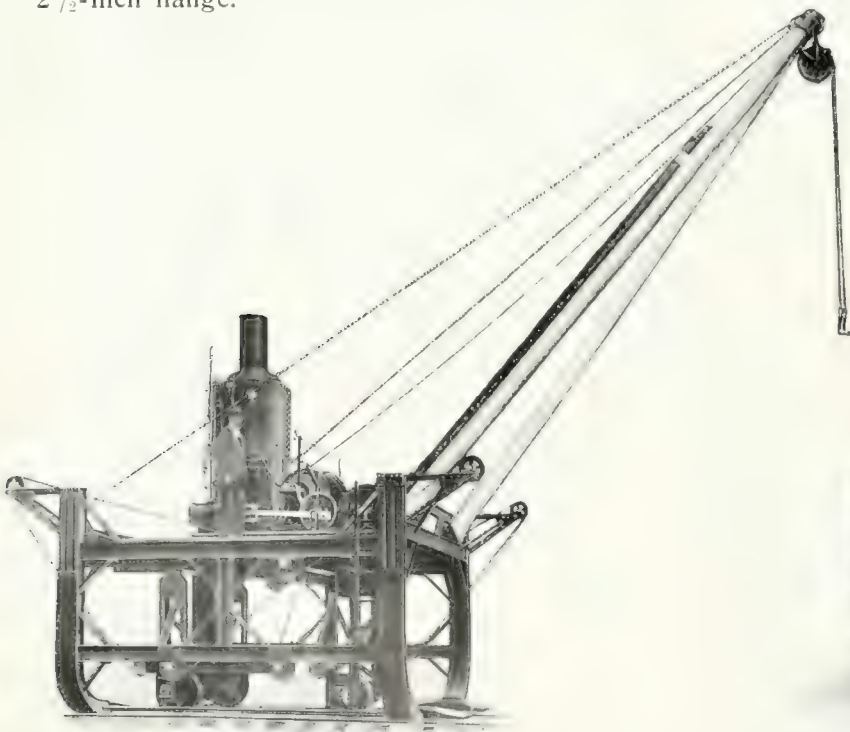
McGiffert log loader ready to move itself.
Clyde Iron Works, Duluth, Minn.
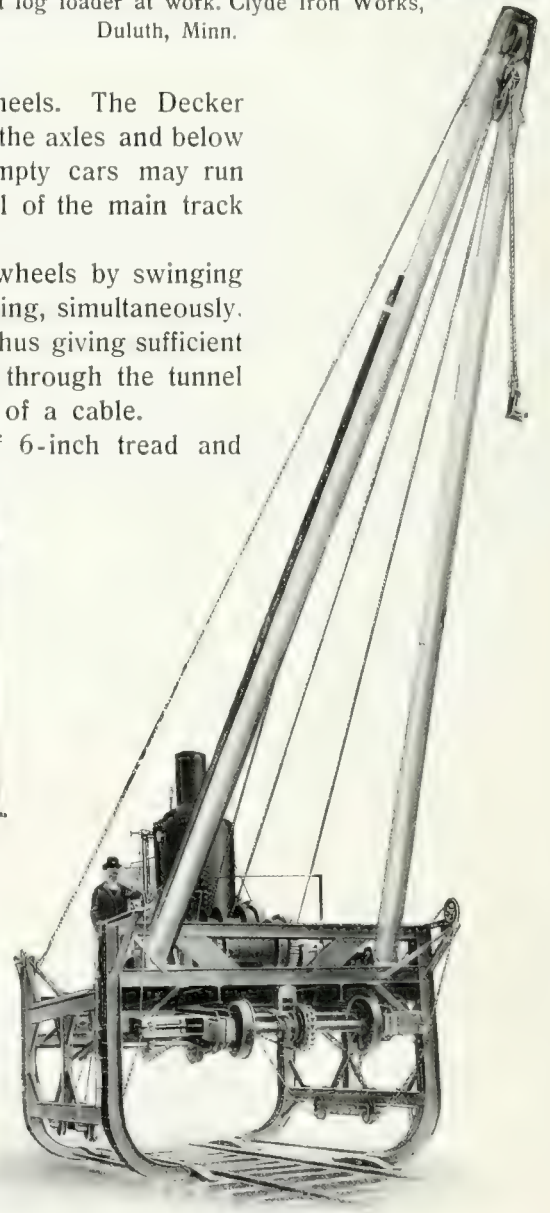
McGiffert log loader ready for passage of empties.
Clyde Iron Works, Duluth, Minn.
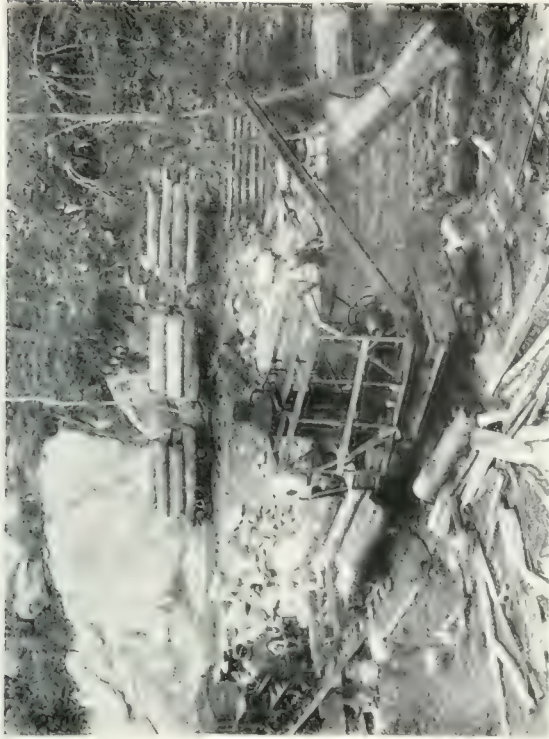
Log loader at work in Western North Carolina, assisted by a Shay engine for spotting the empties.
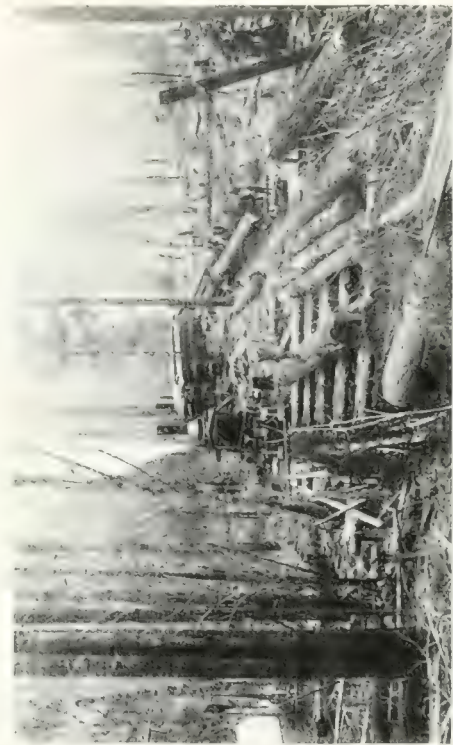
Three-spool Willamette engine skidding and loading logs simultaneously. Holdings of Chapman Timber Co., Portland, Oreg.
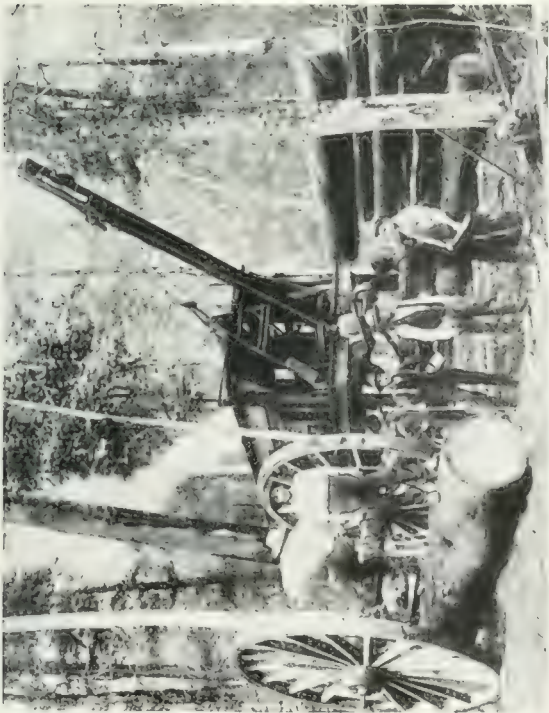
Unloading from high wheelers and loading by the McGiffert at Cadillac, Mich.

McGiffert log loader at work (also Biltmore students at play) in the pineries of Eastern North Carolina, owned by J. L. Roper Lumber Co.

The loading cable runs over a swivel loading block suspended from the tip of the boom so as to hang centrally over the empty to be loaded. The two hook tenders hold the "Martin" loading hooks to the faces of the logs. The pull of the cable inserts the hooks securely, and the machine either throws the log, by impact and timely dropping, directly into position, or else lays it to rest quietly, as if it were a baby, into a secure place on the car. A top loader handling a light cant-hook helps in adjusting the load. When a change of loading site is desired, powerful, ratchet-driven chains, at the will of the engineer, are set in motion by a clutch lever, revolving the axles of the wheels as the chains pass over them. In the pineries, one engineer and three colored helpers load, with a McGiffert, 100,000 feet b. m. of logs per day.

(b) SELF-PROPELLING, CAR-SPOTTING LOG LOADERS, WITH SWINGING BOOM. The American log loader (manufactured by the American Hoist & Derrick Co., St. Paul, Minn.), Models "D" and "E," is a self-propelling locomotive crane, with swinging boom, strong enough
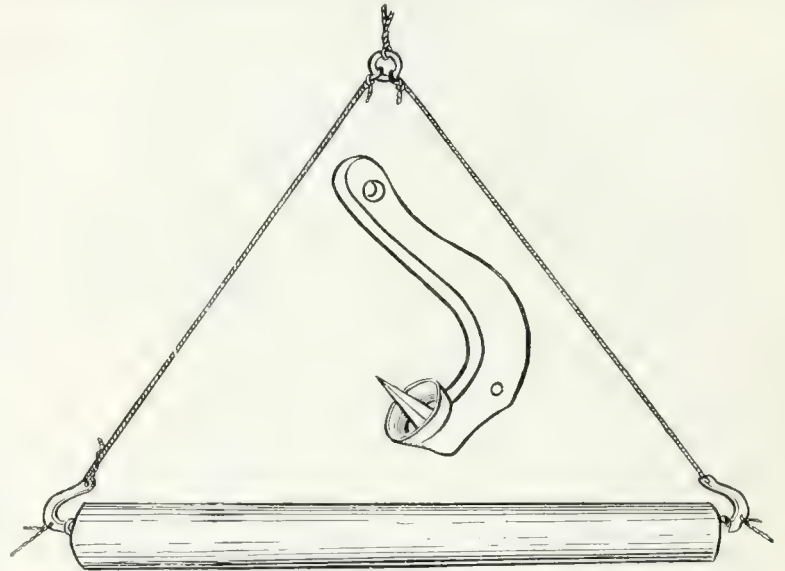
The "Martin" grip hook, adapted to light as well as to heavy logs.

to push or pull a few loaded cars. It spots its empties by swinging them, by a turn of 180 degrees of the crane, bodily from behind to the front. The machine is useful also in moving and in laying track.

(c) NON-SELF-PROPELLING, NON-CAR-SPOTTING LOG LOADERS WITH SWINGING BOOM. The American log loader, models "C" and "G," (manufactured by the American Hoist & Derrick Co., St. Paul, Minn.),

American log loader, self-propelling type, spotting its own empties by swinging them from the rear to the front.

and the Barnhart log loader (made by the Goodyear Lumber Co., Buffalo, N. Y.) belong to this class. The wheels of the American travel, under its own steam, over a steel rail track laid by the machine in sections directly on the bolsters of the cars to be loaded. The Barnhart requires rails permanently fastened to the bolsters. The boom is a swinging boom, capable of swinging in a circle (American) or in a semi-circle (Barnhart), thus picking up logs from the right or from the left rapidly by means of a cable running from the Martin hooks at the log ends, over a sheave in the boom tip and then over the drums of the engine. The machine leaves the empty, on which it stood when loading, after finishing the

American log loader laying its own rail sections, in midst of act. American Hoist & Derrick Co., St. Paul, Minn.

American log loader putting its own rail sections from one empty in front to another empty in the rear.
American Hoist & Derrick Co., St. Paul, Minn.

—

load; recedes to the next empty in the rear, over the rails thereon, by means of a cable; and removes, that done, the rail on which it stood a moment ago to the car next following in the rear (in the case of the American).

The American loads a car in 15 minutes with 4,500 feet b. m., attended by one engineer, four hook tenders, and one top loader. It recedes in 1^1_4 minutes to the next car, ready to load (data by W. B. Mershon, Jr., collected at Bellemont, Arizona).

(d) OTHER MAKES OF LOG LOADERS are the Russel (Russel Wheel and Foundry Co., Detroit, Mich.), the Flory (S. Flory Mfg. Co., Bangor, Pa.), and the Brownhoist.

The price of an up-to-date log loader ranges between $3,000 and $6,000.

V. **The Southern logging superintendents**, at a recent meeting, gave the following as the figures, per 1,000 feet b. m., for expenses incurred by their concerns when loading logs on cars:—

Arkansas	from 21·9 to 22 cents	...	Louisiana ...	from 17 to 58 cents
Texas ...	from 17·6 to 50 cents	...	Mississippi ...	from 28 to 31 cents

PARAGRAPH XII.

AERIAL LOGGING.

The logs are suspended in mid-air from a block carriage travelling on a stationary cable. The carriage is propelled by gravity, by steam, or by electricity.

(A) GRAVITY SYSTEM ON STEEP SLOPES. On a grade of 35 to 50 per cent, the logs descend by gravity, suspended from a carriage formed by two trolley blocks held apart by a strong rod or pole about 15 feet long. At the upper end of the cable, curved iron rails lead, like bridge switches, onto the cable. The cable is kept tight by heavy drums, over which the ends of the cable are wound. The speed of the double block carriage is regulated by manila rope, wire, or light wire cable, and the empty block carriage is carried backward by the same rope without any motive power other than that of a loaded block carriage going down hill. Proper switches allow the empty block carriage to pass the loaded one at a halfway point.

1. In Switzerland, lines two miles long are found, without any supports. In the Hartz Mountains, supports are given every 700 feet and the expense is $800 per mile for entire equipment.

2. In West Virginia and Western North Carolina, short cable conduits of this character are in successful use, and in India (in the Himalayas), the most extensive plants of this character are said to exist.

3. A gravity cable way system, near Hood River, Oregon, is intended to deliver large quantities of logs from the brink of a plateau to a millpond in a steep abyss,
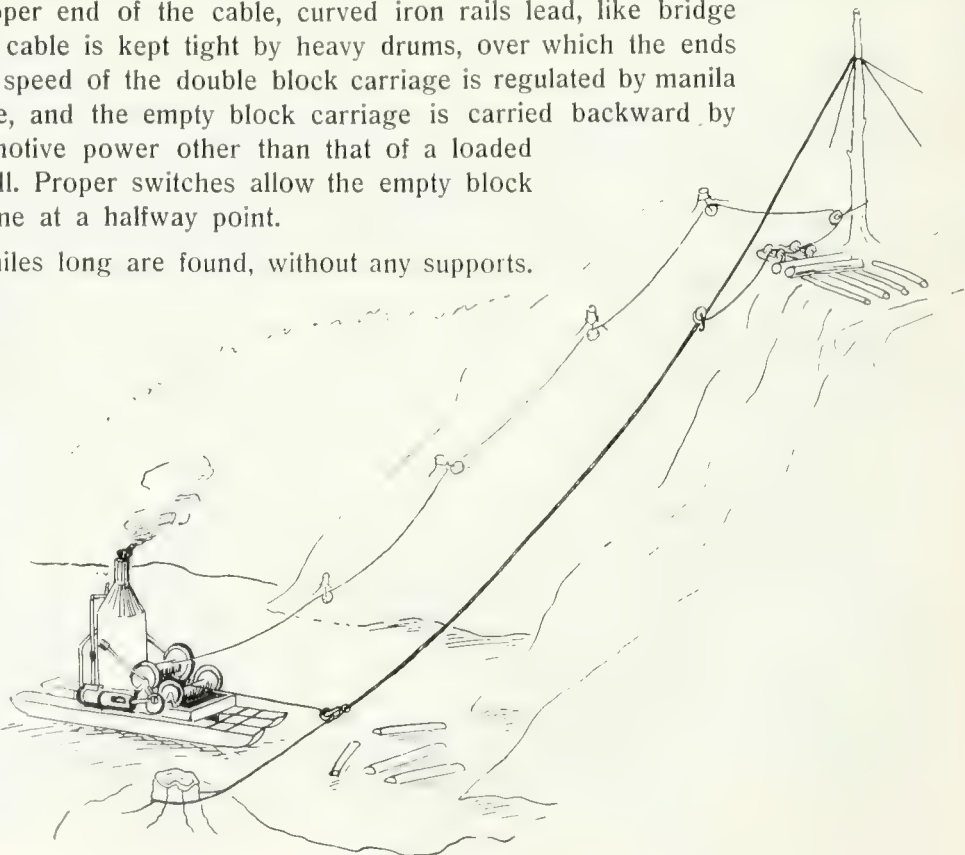
Aerial logging by gravity on Hood River, Oregon.

without breakage of logs.—1,500 feet of 1¼-inch cable are used in the "standing line;" the upper end of this line runs over a 16-inch sheave attached some 40 feet above ground to a tree standing at the brink of the plateau; it is made fast to a stump nearby. The slack is taken out by a purchase line, running from a stump at the millpond to a 9½-inch by 11-inch donkey engine over a 16-inch tackle block forming the lower end of the standing line. The trip line, 3,000 feet long, runs from the donkey engine over a series of sheaves, the last one attached to the tree at the brink some 8 feet above ground. The trip line ends in a "travelling block carriage," with swivel and hook and "buttchain" 7 feet long, to receive the load of logs with the help of a wire rope "choker."
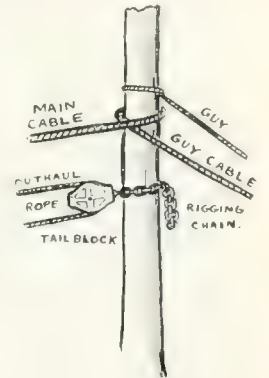
Raising load:—By taking up slack from standing line through purchase line.

Dropping load into pond:—By slackening the purchase line until the logs hit the water, when the hooks binding the choker open automatically.

(B) THE LIDGERWOOD SYSTEM:—On the Pacific Coast, in the Appalachians and on the Atlantic Coast, the Lidgerwood cable way aerial system is used, on a rapidly increasing scale, in connection with spur lines run at distances 1,800 feet apart. Where the ground is particularly rough or particularly swampy, the "flying machines" are at their best.

Head spar tree for aerial skidding.

Tail spar tree for aerial skidding.
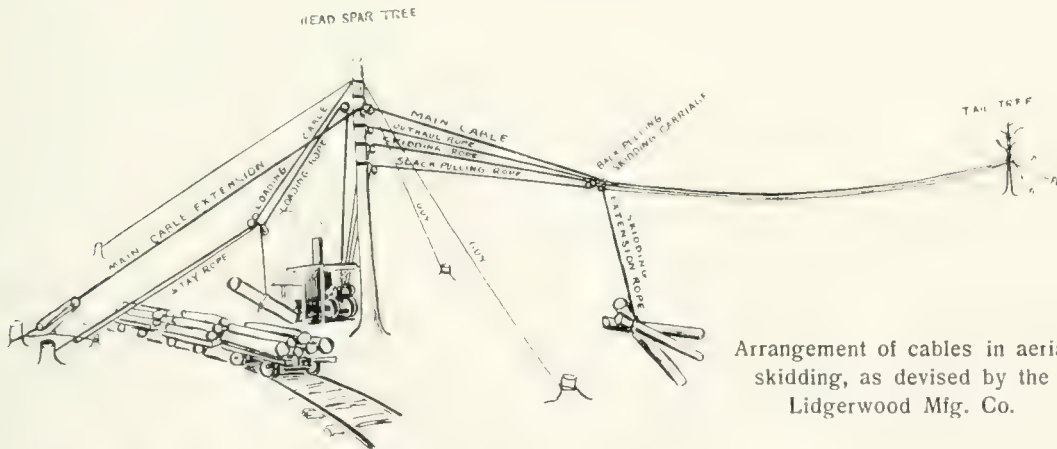
Arrangement of cables in aerial skidding, as devised by the Lidgerwood Mfg. Co.

Aerial skidding, with "flying machine" standing on the track.
Lidgerwood Mfg. Co., Liberty St., New York.

Aerial logging, with main spar at loading engine. Lidgerwood Mfg. Co., Liberty St., New York.

By the railroad track, a Lidgerwood engine is placed close to a "main spar tree," which must have a diameter of 24 inches at a height of 60 feet above ground. At a distance of 900 feet from the spar tree, at the circumference of the circular district to be logged at one "setting," there is selected a "tail tree."

The main standing cable, $1^1/_4$ inches in diameter, extends over the main spar tree to the tail tree. The ends of this cable are fastened tightly to stumps. The slack is taken out by a cable run over one of the spindles of the bulldonkey. The top of both the spar tree and the tail tree are secured by guys to stumps nearby.

On the main cable runs a carriage consisting of a double travelling block and supplied with loading lines, tongues or chokers.

The carriage is played rapidly to and fro, between tail tree and spar tree, by the "skidding rope," and the "outhaul rope." The "slack pulling rope" feeds the skidding rope out to the tong-hookers. The skidding rope is a $^3/_4$-inch cable, and the slack pulling rope is a $^3/_8$-inch cable.

The skidding line is said to last about a year, and the standing line may last as long as 18 months. The capacity of a rig averages 40,000 feet per day.

Two main standing cables are used; one is put up while the other is being used, so as to prevent delays. The tail trees are selected at distances of 150 feet one from the other.

A full crew for the rig consists of 15 men (skidder, loading leverman, fireman, woodcutter, 3 loaders, 2 tong hookers, 1 signal man, 1 tong shaker, 4 riggers).

The catalog of the Lidgerwood Manufacturing Co., 96, Liberty Street, New York, contains interesting information pertaining to aerial log transportation.

For logging uphill out of deep canyons, aerial transportation is the only system feasible. The system can be used with a portable steel main spar base, where there are no main spar trees conveniently located along the line of the railroad.

The cars are loaded with a swinging loading boom or with a guy loading arrangement, by one and the same engine.

Aerial logging in operation. Lidgerwood Mfg. Co., Liberty St., New York.

In the fir-woods of Washington, the expense of aerial logging is by $1/_3$ less than the expense of logging by donkeys, provided that the trees are plentiful and not too large, and further provided that pulls exceeding a distance of 900 feet can be avoided.

The Lidgerwood cleans up rapidly, at one setting, a circle having a radius of 900 feet equal to 60 acres approximately.

PARAGRAPH XIII.

CHOICE BETWEEN THE VARIOUS SYSTEMS OF TRANSPORTATION.

Conditions governing the selection of means of transportation are:—

(a) Topography. Steep grades make it advisable to send products down by their own weight, so that animals and vehicles need not reascend the grade;

(b) Periodicity of rain and snow fall (Examples:—West Virginia for spring rains, Lake States for snow fall, California for spring drouth) invite the use of means relying on water supply, on layers of snow, on dry soil;

(c) Rocky soil entails blasting expenses and thus increases the expense of railroading and road building. Wet or swampy soil requires an artificial surface on which means of transportation are placed;

(d) Existence of drivable creeks and rivers, their grade, rockiness, curves, steadiness of flow, the spans and number of bridges crossing them, the danger or help expected from freshets are factors bearing on the advisability of water courses used as means of transportation;

(e) Availability of building material in the forest, especially the price of rails and ties and the quality of stone, &c.;

(f) Total amount of stumpage, and stumpage per acre to be carried away from a given locality annually, periodically or once only;

(g) Maximum weight and size, also average, weight and size of pieces to be handled;

(h) Price and effect of day labor and prospects of changing prices under the influence of labor laws and socialistic legislation;

(i) Relative price of team labor and of manual labor;

(j) Condition of existing public means of transportation; roads, railroads, and navigable rivers;

(k) Laws relative to rights of way and relative to damage inflicted on outsiders in the course of transportation, e. g., by splashing logs or by raising water level of lakes and thus destroying trees, &c.;

Skidding by two-wheelers.   Photo by Clyde Iron Works, Duluth, Minn.

(l) Mileage of the various links forming the chain of transportation and speculation as to the building of additional public links of transportation;

(m) Silvicultural considerations, or choice between conservative and destructive lumbering. Steam skidding on the ground is the destroyer of a second growth intended to be left. High two-wheel logging carts can be used advantageously to save a young growth;

(n) Possibility and amount of damage to logs and loss of logs in course of transportation. Loss of bark. Loss of sapwood. Deterioration by fungi and insects. Theft. Loss of interest on value of logs;

(o) Regularity and reliability of means of transportation;

(p) Possibility of using the means of transportation for purposes other than carrying forest products (access to mines and farms; passenger traffic; supplies for lumber camps; use of snaking roads as fire lanes, patrol trails, sport trails);

(q) The general political and economic condition of the country (settled or unsettled); the possibility of financial surprises.

Students and river drivers on a stream in Germany used for driving since centuries.

A donkey pulling a string of logs over a slide across a deep ravine in Western North Carolina; in the rear the dumping place of a log slide and a steam log loader.

Curve in a timber slide, Western North Carolina.

Logging with slip-tongue carts in the pineries of Eastern North Carolina.
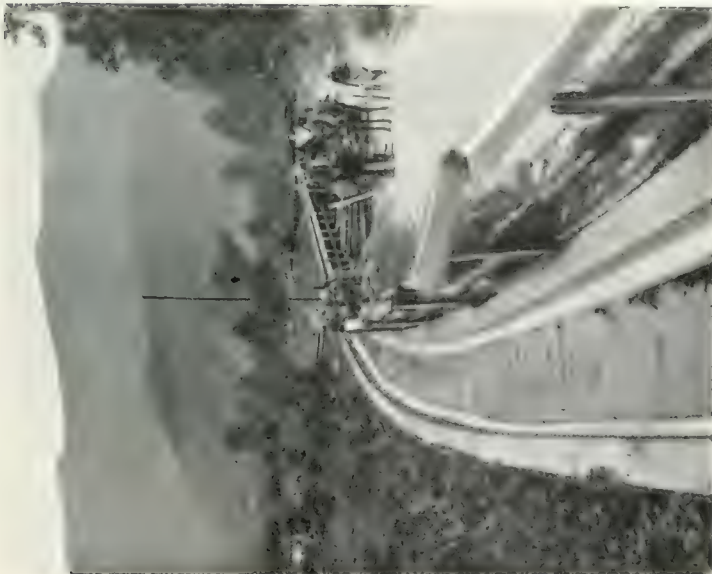
Flume paralleling waggon road in the mountains of North Carolina.
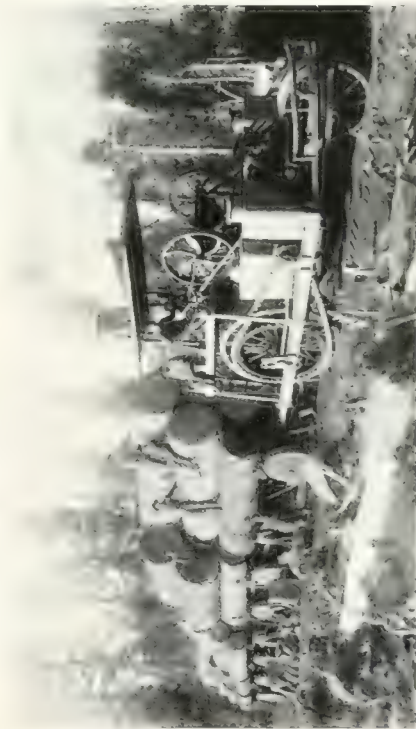
Traction engine at work in the Siskiyou mountains.

ADDENDA to pages 12 and 13.

TREE-FELLING MACHINES.

A hydraulic tree-felling machine has been invented by Forester Stendal, and is being placed on the market by Albert Dœring Manufacturing Company, Sinn, Hessen-Nassau, Germany. The Biltmore Forest School had a chance to see the machine in operation at a time at which this book was in the press. The appliance, illustrated by the cut here shown, seems important enough to justify its consideration.
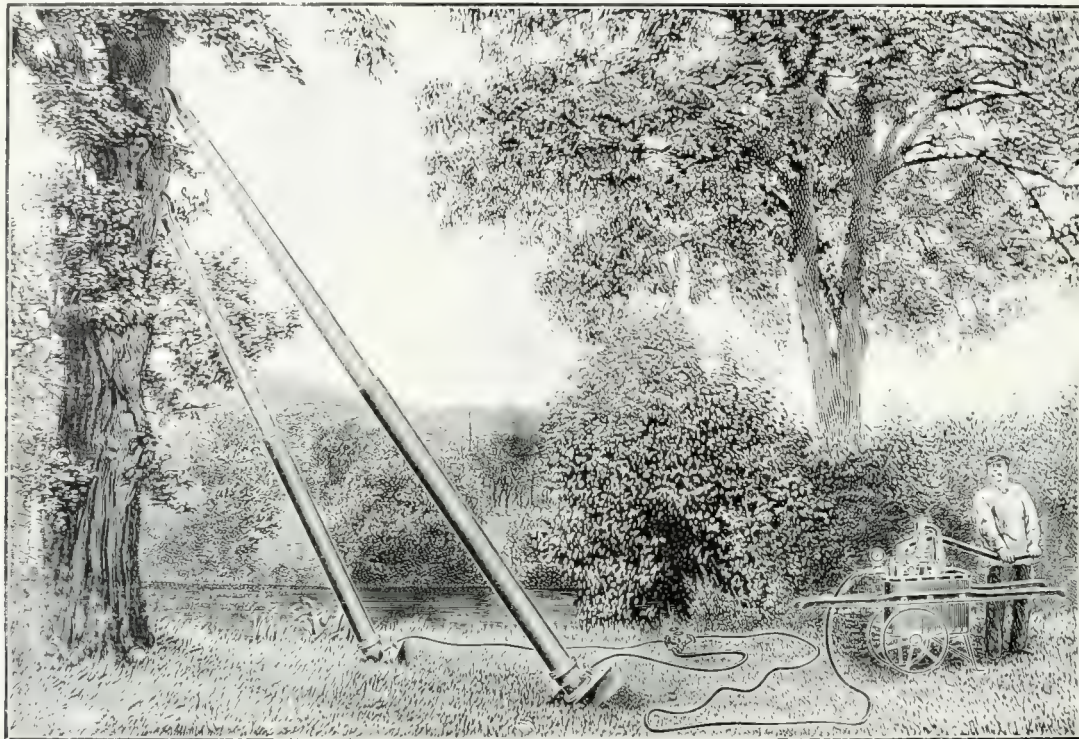
Hydraulic tree felling machine in operation.   Dœring Mfg. Co., Sinn, Germany.

The machine consists of: —

    1. A Mannesmann steel tube, containing a leather piston and a wooden forcing beam, ending in a pair of claws, to be placed against the tree.

    2. A hydraulic hand-pump, on wheels, connected with the tube by an aluminum-wired rubber hose.

In felling heavy trees, several tubes may be applied simultaneously to good advantage. In lieu of a hand-pump, a small gasoline engine can be used. The weight of the outfit, without the wooden beam, is 520 lbs.; the price is $125·00. This hydraulic tree feller is the only machine on the market capable of throwing large trees, without requiring the main roots to be severed on that side of the tree towards which it falls. Where it is intended to convert the forest into farms, the use of this machine is to be commended.

PART II. MANUFACTURE OF WOOD PRODUCTS.
CHAPTER IV. FOUNDATIONS OF MANUFACTURE.

PARAGRAPH XIV.
THE AMERICAN FORESTER AS A LUMBERMAN.

In the Old Country, a large portion of the products grown in the forest go to the holders of prescriptive rights (easements). The balance is sold either under private contract or at public auction or under sealed bids.

In France, standing stumpage is sold, while in Germany the trees are dissected, before the sales at the owner's expense, into the assortments required by the local manufacturing trades.

Usually, in the Old Country, the raw products of the forest are not refined by the forest owner. The forest industries are in the hands of parties who do not own or control an acre of woodland.

In Canada, timber leases or timber "limits" are sold at public auction by the various provincial and by the Dominion Government. The purchaser pays, aside from the auction price, an annual rental (so-called ground rent) and, further, for every 1,000 feet b. m. cut, a specified royalty. Neither ground rent nor royalty is object of the auction sale.

On the forest reserves of the United States auction sales are meant to form the main method of disposal of forest products, exceptions being made only in the interest of local residents.

The private owner of woodlands in the United States, and his forester, is and will be compelled to be a manufacturer for many a year to come.

The conditions necessitating this course are:—

(a) The forests yielding our lumber are situated so far from the market that the transformation of their bulky and cheap raw material – the logs – prior to shipment into a merchandise of condensed value and of light weight becomes unavoidable. Lumber weighs, per 1,000 feet b. m., approximately one third of the logs producing it;

(b) The stumpage market was, and still is to a certain extent, a buyer's market. In the United States, 3,000,000 (Forest Service Circular No. 171) owners of woodland (prospective sellers) are confronted by only 45,000 owners of sawmills (prospective buyers of stumpage).

Under these conditions, the owner of timberlands becomes a manufacturer even if manufacture – a mere means to convert stumpage into money – fails to yield a manufacturer's profit.

The lumberman need not be a forester; but the forester should be a full-fledged and experienced lumberman, superior in technical and scientific knowledge, and therefore in efficiency, to the lumberman of the past.

Woe to conservative forestry in the United States, if the forester, satisfied to give silvicultural advice, fails to devote to lumbering and manufacture the larger part of his energies!

PARAGRAPH XV.

MOTIVE POWER IN MANUFACTORIES.

Motive power is supplied by:—

(A) ACTUAL ANIMAL POWER said to be used in Texas for running portable sawmills.

(B) WIND, which furnishes an insufficient and unreliable power.

(C) WATER.

The horse-power of falling water is: $\dfrac{v \times h \times 62\cdot5}{33,000}$

wherein:—

    v stands for volume of discharge in cubic feet per minute;

    h stands for height of fall in feet;

    62·5 represents the weight of a cubic foot of water;

    33,000 equals one horse-power per minute.

The engineer measures the velocity of running water not at the surface, but at about 40 per cent of the depth of the water.

The discharge can be approximated:—

(a) BY COMPARING THE HEIGHT OF THE WATER, at a vertical stake inserted at a poind some five feet above a weir made of plank beveled at its rectangular spillway, by means of a spirit-level with the height of the tip of the rectangle over which the water falls.

(b) BY MEASURING THE HEIGHT OF THE WATER, over the apex of a right angle (placed vertically with the apex down), which acts as the spillway in a dam across the stream.

INTERDEPENDENCE
between the discharge in cubic feet per minute and the head of the water at the spillway.

A discharge per minute in cubic feet	Corresponds with a height of the water measured	
	at the stake by method (a) with a spillway 10″ wide	at the apex by method (b) with a triangular spillway
cubic feet	inches	inches
2	$5/_8$	$2\,1/_4$
4	$1\,1/_8$	$2\,3/_4$
6	$1\,3/_8$	$3\,1/_4$
8	$1\,5/_8$	$3\,3/_4$
10	$1\,7/_8$	4
15	$2\,3/_8$	$4\,3/_4$
20	$2\,7/_8$	$5\,1/_4$
25	$3\,3/_8$	$5\,3/_4$
30	$3\,7/_8$	$6\,1/_4$
40	$4\,5/_8$	7
50	$5\,3/_8$	$7\,3/_4$

Water wheels are either vertical, viz., overshot, breast and undershot wheels, or horizontal, viz., turbines.

I. Overshot wheel Effective power is 60 to 70 per cent of possible power. The proper velocity at the circumference of the wheel is 5 feet per second, and is at its best if it is equal to 0·55 of the velocity of the water.

In falls of 20 feet to 40 feet and over, overshot wheels are more effective than turbines.

The buckets, framed by the shrouding, should be curved or elbowed and not radial. They should have a capacity three times as large as the volume of water actually carried, a depth of 10 inches to 12 inches and a distance apart, from center to center, of 12 inches.

Ventilated buckets, having holes in the bottom and allowing air to escape, have an increased effect.

It is difficult to transform the slow speed of an overshot into the rapid speed required for a circular saw. Transformation is either by countershaft or by cog wheel.

II. The breast wheel has an effective power of from 45 to 65 per cent, is best applied to falls of from 5 feet to 15 feet and to a discharge of from 5 to 80 cubic feet per second. While in the overshot the water works by weight only, it works in the breast wheel largely by impact.

The velocity of wheel should be such as to fill the buckets to 0.5 or 0.6 of their volume. The buckets here are usually called blades and must be ventilated.

The wheel runs in a curb or mantle, formed by the inclined and incased end of the sluiceway.

The distance of the blades, from center to center, should equal the depth of the shrouding, both being from 10 inches to 15 inches. The clearance between the curb and the shrouding must be at least $\frac{1}{2}$ inch.

"High breast" wheels are semi-overshot and "low breast" wheels are semi-undershot wheels.

The "flutter" wheel is a low breast wheel of small diameter and high speed. It is largely used in the Appalachians for sawmill purposes where water is plentiful and fall about 20 feet.

III. Undershot or current wheels have an efficiency of from 27 to 45 per cent only and are usually kept anchored in rapid streams, so as to be independent of the water gauge. There are no buckets, but long blades instead.

The diameter of the wheel is from 13 feet to $16\frac{1}{2}$ feet; there are usually 12 blades, the depth of which is 3 feet to 4 feet. The blades should be completely submerged when passing underneath the axle.

IV. Turbines have an efficiency of 60 to 80 per cent. Usually the water does not work so much by weight, as by impact, pressure, reaction and suction.

The speed in turbines is much higher than in vertical wheels; it is well adapted for circular sawmills.

A turbine, however, is badly affected by variations of water supply and suffers from debris and sand and ice. The effect of the water is greatest when the turbine is entirely under water, the flow of water filling the curved channel completely.

Turbines are:—

    (a) Outward flow turbines, water fed from near the center;

    (b) Downward flow turbines, water fed and pressing from above;

    (c) Inward flow turbines, water fed from the perimeter;

    (d) Reaction turbines, working after the principle of a lawn sprinkler;

    (e) Impulse turbines, principle of flutter wheels.

Modern turbines are worked both by impact and reaction and, if possible, by suction.

The advantages of watermills are:—No fuel, no fireman, no engineer, no explosion, less insurance, possibility of using dust and slabs commercially, &c.

The disadvantages are:—Usually small power, small speed, and small capacity; power less controllable and less reliable than steam-power, and not portable.

The small capacity of a watermill does not justify a large outlay for good sawmill machinery.

(D) STEAM.

I. Boilers. Tubular boilers are universally used. Diameter of tubes is measured outside, including metal.

    (a) BOILERS IN COMMON USE ARE DESIGNATED AS:—

        1. *Internally fired boilers,* when firebox and waterbox are comprised by one and the same steel shell; so all portable boilers and all locomotive boilers. Common forms are the Cornish, the Lancashire, and the Galloway. In the locomotive boiler, the firebox is surrounded by a waterleg.

2. *Externally fired boilers,* when a masonry firebox is found underneath a boiler traversed by a large number of tubes. Gases pass first to combustion chamber at rear end and then through tubes back to front.

To this class belongs the water tube boiler, with inclined tubes, a horizontal top vessel and vertical tail tubes, creating a continuous circuit of water.

(b) POINTERS ABOUT BOILERS:—

1. Twelve square feet of heating surface of boiler furnish one horse-power.
2. Each horse-power requires one cubic foot or $7\frac{1}{2}$ gallons of water per hour. Nominally, the conversion of 34·5 lbs. (= 4·1 gallons) of water into steam at 212 degrees is the equivalent of one indicated horse-power.
3. Mud drum at base of boiler to receive impurities deposited by water. Where no mud drum exists, boiler should be blown off weekly through a bottom valve (mud cock).
4. Steam and water capacity must be sufficient to prevent any fluctuation in pressure or water level. If fire is fed from mill refuse, steady heat and steam can be retained only with boilers of large water capacity. The larger the boiler, the greater the fuel economy.
5. A large water surface (horizontal versus upright boilers) prevents steam from carrying along particles of water. Usefulness of dome is doubtful as a means to secure the return of watery particles to the boiler.
6. Water should occupy three quarters of boiler space.
7. Combustion chamber should allow of full combustion of fuel and gases.
8. Draft area should be one eighth of grate area. Heating surface should be as nearly as possible at right angles to the current of escaping gases.
9. Very best water gauges, safety valves, injectors and steam gauges are prerequisites. All boiler fixtures should be readily accessible.
10. Safety valves must be tried once daily. The water level should be controlled by gauge cocks, glass gauges alone being unreliable.
11. Cold water should not be fed directly into boiler and should never come in direct contact with the boiler metal. Steam injectors will not lift hot water so well as cold water.
12. Steam pressure gauge must stand at zero when pressure is off.
13. In case of low water and danger of explosion, cover fire with wet earth.

II. Engines:—

(a) ENGINES IN COMMON USE ARE DESIGNATED AS:—

1. Condensing (low pressure) or non-condensing (high pressure) engines.
2. Reciprocating (single or double acting) and rotatory engines.
3. Center crank or side crank engines; center crank engines are preferable for small portable sawmills, since they allow of exchange of flywheel and main driving pulley.
4. Single cylinder or double cylinder engines; double cylinders are more effective than single cylinders, especially if not hitched tandem fashion. This arrangement, however, allows of using one piston rod for the pair of cylinders.

(b) POINTERS ABOUT ENGINES:—

1. Horse-power of engines is:—
   Sectional area of piston in square inches times pressure times velocity in feet over 550. Deduct 10 to 20 per cent for friction.
2. Pressure on the piston is not much over one half of pressure in the boiler (60 per cent).
3. Interdependence between size of cylinder and horse-power actually developed is approximately:—

Diameter, inches	8	9	10	12	12	12	14	16
Length, inches	15	15	15	15	20	24	24	30
Horse-power	12	15	20	25	30	35	50	85

These figures hold good for single cylinder engines and are lower than the usal catalogue figures. A new engine develops more power than an old one.

4. The flywheel should weigh 600 pounds for every inch of cylinder diameter.
5. Engines cannot get along any better, without care, than horses. Repair and watch the smallest defects! Have the firmest possible foundations!
6. Sawmill engines are put to the severest possible tests owing to frequent and rapid change of strain.

(E) ELECTRICITY.

I. The electric drive in woodworking plants has come to the front rapidly in recent years, owing to the following advantages:—

(a) Most effective arrangement of machines. The motors can be placed vertically or horizontally, at any distance from the power source, and at any distance one from the other. Frequently, nevertheless, several like machines are driven in groups from one motor;
(b) Easy connection of driving power to load;
(c) Ease of extension of plant in any direction;
(d) Minimizing of losses in transmission. There are less belts and less shafts. The main shafts are idle during 35 to 90 per cent of their running time;
(e) Ease of determining power cost for each machine;
(f) Less congestion on floor of plant;
(g) Minimum fire risks and insurance charges;
(h) Reduced oil bills.

Load factor is the ratio of actual average load to total connected load. It varies in woodworking plants between 3 and 50 per cent.

II. The current supplied is either alternating (usually) or direct (e. g., in case of adjustable speed tools like wood lathes). If the distribution of heavy cur-
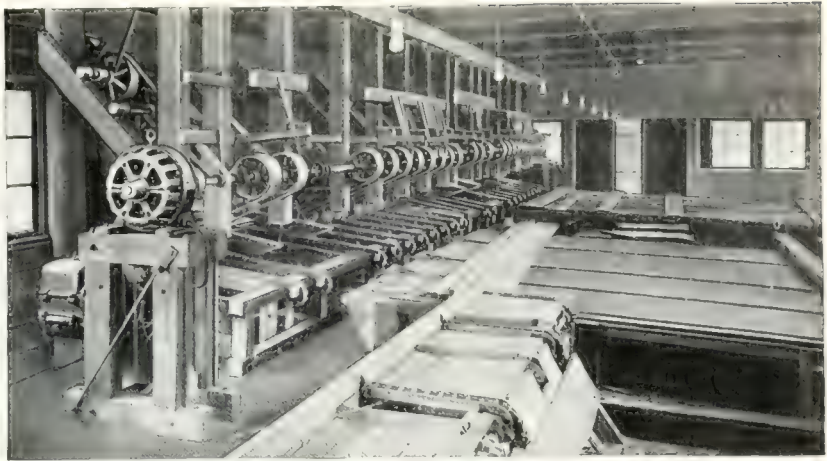
Trimmers, electrically driven. Westinghouse Electric Co., East Pittsburgh, Penns.
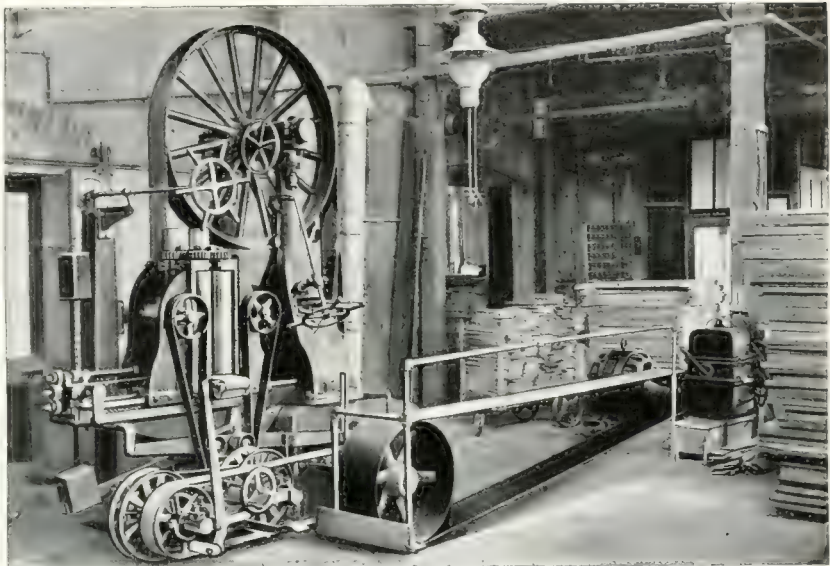
Band resaw, electrically driven. Westinghouse Electric Co., East Pittsburgh, Penns.
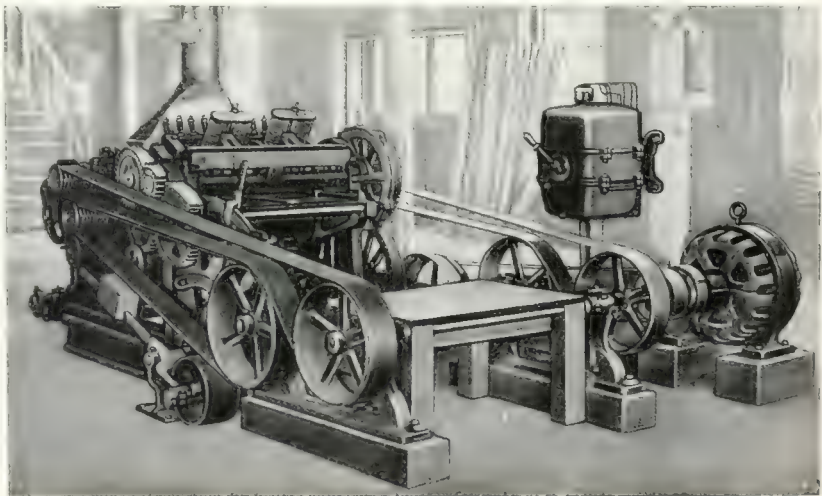
Thirty-inch double surfacer, electrically driven. Westinghouse Electric Co., East Pittsburgh, Penns.

rents over large areas is necessary, three-phase current (2,300 volt, 60-cycle transmission, transformers for supplying 220 or 440 volts) is advised.

It is much better, usually, to buy the current from a central power station than to produce it from mill refuse through the medium of steam.

III. In ascertaining the power required for a plant, there must be considered:—

(a) The continuously operated machines (notably the blowers; the "fanload" amounts to from 25 to 40 per cent of total power where a central blower system is used).

Three-roll sander, electrically driven. Westinghouse Electric Co., East Pittsburgh, Penns.

(b) The intermittently operated machines.

The electric current is inferior to steam power in one important point:—In the steam engine, the boiler acts as a storage of reserve power, so that for short periods of time a machine can be supplied with a power surplus. In other words, steam power is pliable; electric power (alternating) is stiff.

If the motor meets a resistance which it cannot overcome, something must break. Steam in such a case would act as a buffer.

In installing motors, be sure to instal motors of sufficient power surplus.

Power requirements are, approximately:—

42-inch band ripsaw ...	10 horse-power
30-inch planer	15 horse-power
24-inch planer	10 horse-power
60-inch veneer knife ...	3 horse-power
Double cut-off saw ...	5 horse-power

Pony surfacer, electrically driven. Westinghouse Electric Co., East Pittsburgh, Penns.

Seven-inch molder driven by Westinghouse motor. Westinghouse Electric Co., East Pittsburgh, Penns.

PARAGRAPH XVI.

TRANSMISSION OF POWER.

(A) BELTS. Belts in woodworking establishments are always dry and dusty and are kept at a high and often irregular rate of speed. Dust materially decreases the transmitting power of belts.

The heavier the belt, the more powerful is it; use light belt on small pulleys, however, for high speeds.

I. Pointers about belts: –

(a) Belt tighteners are required where a belt itself is not heavy and not long enough to cause a sufficient sag;

(b) The sag should always be on top and not on the bottom of the belt;

(c) The angle of belt against the horizon should not exceed 45 degrees, to prevent loss of power;

(d) Placing the driven pulley above the driving pulley requires a tight belt. Heating in the bearings and destruction to the belt are thus invited;

(e) Belts should run off a shaft in opposite directions to relieve one-sided friction of shaft in bearings;

(f) The pulley must be wider than the belt;

(g) The larger the pulley the greater the tractive power of the belt;

(h) Belts should not rub against any beam or other solid object;

(i) Long belts have greater adhesion than short belts, because they have more weight;

(j) Belt dressing, to prevent slipping-off of belt, is objectionable, because it gathers dust and dirt, except perhaps linseed oil used on rubber belts;

(k) Belts will slip if: –

1. The pulleys do not run in one and the same plane.
2. The shaftings are not parallel.
3. The pulley is not as wide as or wider than the belt.
4. The belt ends are improperly joined.
5. The speed is too high for the weight of the belt.

II. Kinds of belts: –

(a) LEATHER BELTS. Leather belts are either single or double. They come in rolls of from 200 feet to 300 feet, are run with the grain side in and are preferably joined with studs – not by leather laces requiring holes; belt cement is now largely used, laps being reduced to a fine edge.

Leather belts must be well protected from moisture, grease, lubricating oil, &c.

Transmitting power of a single belt is only 70 per cent of that of a double belt.

The price of a 7-inch single belt per running foot is $1; for double belt $2, approximately.

(b) RUBBER BELTS. Rubber belts withstand moisture better than leather belts. They are cut from $1/_8$ inch to $1/_4$ inch shorter per foot than the circuit on which they run and are run with seam side out.

They are sold as 2, 4, 6 or 8-ply rubber belt, the 4-ply being equivalent to single leather belting and the 6-ply to double leather belting.

The price of 4-ply 7-inch rubber belting is 70c per running foot; of 6-ply, $1, approximately.

The ends are joined either by belt cement or by lace leather. The laps are strengthened by a strip of leather on the outside.

Metal studs should never be used in rubber belts.

(B) PULLEYS. Pulleys are made either of iron or of wood; quite recently also of steel.

The adhesion of leather to wood is much greater than to iron; hence greater transmitting power of wooden pulleys.

Split wood pulleys are preferable in many cases, but shortlived. The best make is the Dodge split wood pulley, costing for 24-inch diameter and 10-inch face $11·20. Steel split pulleys are made by the American Pulley Co., Philadelphia, Pa.

So-called "clutch pulleys" consist of two wheels wedged one into the other, the inner one loose, the outer one fastened onto the shaft.

Iron pulleys must be absolutely symmetrical.

Pulleys for stationary belts are slightly crowning, while those for shifting belts are straight faced.

Pulleys for heavy work should be placed close to bearings of shaft. The main driving pulley must stand between bearings not over four or five feet apart.

The ratio between the speed of driving and driven pulley is inverse to the ratio of the diameters.

(C) SHAFTING. Cold rolled shafting is said to have a torsional strength 30 per cent greater than that of hot rolled shafting.

The usual diameters of shafting in sawmills are from $1\frac{1}{2}$ inches to $3\frac{1}{2}$ inches. The proper speed for shafting is 300 to 400 revolutions and its transmitting power is given as $\dfrac{D^3 \times R}{80}$ horse-power.

Herein stands:— D for diameter of shafting.

R for revolutions of shafting per minute.

80 for a constant factor.

Couplings by which the sections of shafting are joined should be close to a hanger or a support. They should be easily detachable without driving keys.

Shafting comes in sections usually 12, 14, 16, or 18 feet long.

The section closest to the main driven pulley is often stronger than the other sections.

The bearings should be long, say four times as long as the shafting is thick, and should have self-lubricating devices.

Hangers for 3-inch shafting and of 3-foot drop cost about $20 each.

Bearing-boxes are lined with an anti-friction alloy melting easily and offering little friction even under severe pressure. A space of $\frac{1}{8}$ inch to $\frac{1}{2}$ inch is left between the cast-iron box and the shafting (journal) to be supported. The box is held in a "babbitting jig" while the melted alloy is poured from a ladle. Babbitt metal (invented by Isaac Babbitt) consists of about 96 parts tin, 4 parts copper and 8 parts antimony.

Rules for shafting are:—

1. Be sure that line of shafting is parallel to axis of driver.

2. Place all heavy work on the main shaft and close to the main driver.

3. Oil freely and watch bearings constantly. Oil after stopping work, while bearings are still warm.

4. Drive only minor machinery from gear wheels.

Price of shafting is about 5c or 6c per lb.

REMARKS:—Machinery is started by belt tighteners, the belt running over flanged pulleys, by clutch pulley, by tight and loose pulley with shifting belt, by eccentric boxes, and by friction pulleys.

A rotation is reversed by crossed belts (belt turning 180 degrees), or by paper friction pulleys, or by forcing the belt against a driven pulley remaining outside the belt circuit (e. g., in double band mills).

A rotation is turned at right angles by giving the belt a quarter-twist (90 degrees), or by gear and pinion, or by beveled friction or by running the belt over an intermediate pulley, placed between driver and driven at an angle of 45 degrees against each of them.

Before building or before remodelling a mill, be sure to consult the insurance companies, submitting mill plans.

The insurance rates depend on the distance between the yard, boiler house, engine house, mill and dry kiln; on building and roofing material; height of buildings, smoke-stacks, parapets; system of dry kilns, blowers, shaving vaults, &c.

PARAGRAPH XVII.

TECHNICAL USE MADE OF THE TREES, BY SPECIES.

(A) HARDWOODS. Cucumber tree:—Ox yokes; pump logs; water troughs; cabinet making; ceiling; flooring; invariably mixed with and substituted for yellow poplar.

Tulip tree or yellow poplar:—Panels; flooring; molding; clapboarding; sheathing; shingles; siding on railroad cars; interior finish of Pullman cars; coffins; bodies of automobiles, carriages and sleighs; sides of farm waggon beds; woodenware; bungs; slack barrels and tobacco hogsheads (staves and heading); backing, tops and sides for pianos; veneers; boxes, especially biscuit boxes and cigar boxes; scroll saw work; wood carving; wood burning; matches; excelsior; paper pulp; porch columns; hat forms; cores of composite furniture and of interior finish.

Linden or basswood:—Mirror and picture backs; drawers and backs of furniture; molding; woodenware; panels and bodies of carriages; ceiling; wooden shoes; inner soles of shoes; cooperage heading; slack barrel staves; butter churns; laths; boxes; grape baskets; excelsior; parts of pianos and organs (main frame); fine carving; papier-mâché; paper pulp. The flowers are used for tea; the inner bark of some species for coarse cordage and matting and glue brushes.

Holly or ilex:—Mallets; edging and engraving blocks; fine cabinet work; painting on wood; tool handles; mathematical instruments.

Buckeye:—Artificial limbs; woodenware; paper pulp; wooden hats; fine wood carving; pyrography.

Maple:—Furniture (curly and bird's-eye); flooring; sugar barrels; mantels; runners of sleighs; peavy handles; ox yokes; axe handles; sides, backs, and bridges of violins; bicycle rims; woodenware; wooden shovels; shoe pegs and lasts; gun stocks; saddle trees; teeth of wooden gear wheels; piano keys and hammers; wood split pulleys; framework of machinery; ship building; paddles; maple sugar; surveyor's implements; plane stocks; wooden types; faucets; clothespins; charcoal; acetate of lime; wood alcohol.

Sumach:—Tanning; dyeing and dressing skins; Japanese lacquer work.

Black locust:—Police clubs; fence posts; insulator pins; construction work (bridges); turnery; wheelwright work; tree nails (pins); ship building (ribs); hubs of wheels (automobiles); house foundation.

Mesquit:—Fence posts and rails; used extensively for fuel (destructive to boilers).

Black cherry:—Fine furniture; cabinet work; interior finish; tool handles; surveyor's implements.

Crabapple:—Pipes, mallets; wooden measure rules; tool handles.

Witch hazel:—Extract.

Dogwood:—Tool handles; spools; bobbins; shuttles; mauls; wheel hubs; machinery bearings; engraving blocks.

Black gum:—Heavy (waggon) hubs; rollers in glass factories; mangles; ox yokes; stock of sledge hammers in steam forges; veneers for berry baskets and butter dishes; slack barrels; in cheap furniture for backing and drawers; barn flooring; excelsior.

Tupelo gum:—Chemical paper fibre; barrel staves (rotary veneer cut); wooden shoes and woodenware; the corky root is used under the name of corkwood for bicycle handles and floaters of fishing nets.

Sweet gum:—Known in Europe as satin walnut and used for fine furniture (lining) and cabinet work, in America for cheap furniture; building lumber; flooring; plug tobacco and cigar boxes; waggon beds; slack barrels; strawberry boxes; crates; truck barrels; veneer cut dishes; coiled hoops; street paving.

Sourwood:—Tool handles; machinery bearings; sled runners.

Rhododendron:—Bruyere pipes; tool handles; turnery; toys; rustic furniture.

Persimmon:—Bobbins; spools; shuttles; tools; golf club heads; plane stocks; shoe lasts; wood engraving. The black heart is cut into veneers and used for ebony.

White ash:—Waggons and carriages (poles, shafts, frames); interior woodwork; inner parts of furniture; mantelpieces; sporting goods (bats, &c.), oars and gymnastic bars; lances; agricultural implements; tennis

_quets; snowshoes; skis; wooden pulleys; barrel hoops; pork barrel staves; baskets; dairy packings (firkins, tubs, &c.); tool handles.

Catalpa:—Fence posts; railroad ties; telegraph poles.

Sassafras:—Light skiffs; fence posts; rails; cooperage; insect-proof boxes; ox yokes. Roots used to make sarsaparilla.

California laurel:—Ship building; cabinet work and interior finish.

Elms:—Wheel stock, especially hubs; buckboard beds; neck yokes; swingle trees; fence posts; ribs of small boats; top spans in covered railroad cars; railroad ties; tongues for sleighs and sleigh runners; saddle trees; flooring; exported for inner lining of boats; butcher blocks and churns (butter); cheese boxes; furniture; sugar and flour barrel staves; patent coiled hoops for slack cooperage; agricultural implements; bicycle rims; basket making; gun stocks; frame timber of piano cases; wheelbarrows; hockey sticks; construction of battle ships.

Hackberry:—Fencing; occasionally for cheap furniture; hames.

Mulberry:—Fencing; cooperage; in the South for boat building; axe handles.

Osage orange:—Fencing; paving blocks; railroad ties; wheel stock; toothpicks; fine mallets; substitute for fustic wood.

Sycamore:—Furniture (lining of drawers); plug tobacco boxes; butchers' blocks; interior finish; beehives (hollow log sections); butter and lard trays; wooden bowls.

Walnuts:—Interior finish; furniture; gun stocks; tool handles; cabinet work; boat building.

Hickories:—Axe handles; waggon stock (especially whiffletrees; neck yokes, spokes, tongues, felloes, axles); buckboards; rustic furniture; barrel hoops; screws; mallets; parts of textile machinery; farm implements; wooden rails (top); baskets; bows of ox yokes; boat building; hickory bark for flavoring sugar (to imitate maple syrup).

Oaks (white and burr):—Furniture; waggon and carriage stock, especially spokes, felloes, hubs, tongues, hounds, bolsters, sandboards, reaches, brake bars, axletrees, whiffletrees; railroad ties; freight cars (framework); ship building; house building and interior finish; shingles; agricultural implements; bridge building; mining timber; wine, beer, and whisky barrels; parquet flooring; staircases; split wood baskets; hogshead and barrel hoops; bark used for dyeing.

Post oak:—Fencing; railroad ties; construction; staves; carriage and waggon work; farm implements.

Basket oak:—Baskets; cooperage; wheel stock; fencing; agricultural implements; construction.

Chestnut oak:—Bark used for tanning; fencing; bridges; railroad ties; substitute for white oak, but objectionable in tight cooperage.

Live oak:—Ship building; furniture.

Red oak:—Shingles; furniture; interior finish; tight and slack cooperage; railroad ties.

Texas oak:—Same as red oak.

Black oak:—Plow beams; furniture; lumber; bark for tanning and quercitrin.

Tanbark oak:—In California bark used for tanning.

Chestnut:—Tanning extract; soda fibre; coffins; furniture (cores of composite furniture); interior finish; shingles; fencing; railroad ties; sheathing; jacob staff for compasses; bridge building (trestles); telephone poles; backing of piano veneers; slack barrel hoops; staves (brandy, kirsch, &c.).

Beech:—Wood alcohol; wood ashes; charcoal; shoe lasts; plane stocks; clothespins; handles; wooden bowls; horse collars (hames); parquet strips; flooring; street paving; railroad ties; sugar barrels; furniture made from veneers, or bent after steaming; chairs.

Hop hornbeam:—Posts; levers; tool handles; waggon brakes; shoes; wedges.

Hornbeam:—Used for same purposes as above, and teeth of gear wheels.

White birch:—Toothpicks; shoe pegs and lasts; wood pulp; spools; clothes-pins; screws; flooring; veneers; furniture; bobbins and spindles; wooden skewers; hand-made barrel hoops.

Gray birch (yellow):—Furniture (usually mahogany finish); match boxes; wheel hubs; tool handles; buttons; brush backs; shoe pegs; clothes-pins; sugar barrels; dry distillation for wood vinegar, wood alcohol, charcoal, &c.

River birch:—Furniture; woodenware; wooden shoes; ox yokes.

Red birch (sweet birch):—Imitation cherry furniture; ship building; bark distilled for oil of wintergreen.

Oregon alder:—Furniture; cigar boxes; mining props and water conduits; charcoal in gunpowder.

Black willows:—Osier culture (imported species); baskets; baby-carriages; carriage bodies; pollarded for fascines; the Missouri species for fence posts after thorough seasoning; bats for baseball; a drug, salicylic acid, made from the bark; charcoal for smokeless powder.

Cottonwoods:—Boxes; wood pulp and fibre; slack barrels; woodenware; flooring; excelsior; cores for veneers in organs and pianos; matches; building lumber; furniture; waggon beds; turnery; woodenware; fence boards.

(B) CONIFERS. Incense cedar:—Water flumes; fencing; furniture; interior finish; laths and shingles.

White cedar (Northern):—Posts; fencing; telegraph poles; railroad ties; tanks and buckets; shingles; street paving; boats.

White cedar (Southern):—Woodenware; tanks; buckets; barrels; telegraph poles and fence posts; shingles; railroad ties; boats; lampblack.

Red cedar (Pacific):—Canoes; interior finish; fencing; shingles; cooperage; tanks; buckets.

Port Orford cedar (Lawson's cypress):—Lumber; piling; telephone posts; wharf planking, sash, doors, and blinds; inside finish; flooring; railroad ties; fence posts; matches; ship building. The rosin is a powerful insecticide.

Western juniper:—Fences.

Red cedar (of the East):—Tanks, posts, buckets; telephone poles; chests; pencils; interior finish.

Bald cypress:—Tanks; shingles; doors; house building; interior finish; sash; blinds; molasses barrels; railroad ties; posts; coffins; car siding; flooring; wharf piles.

Big tree:—Lumber; fencing; shingles; construction; water conduits.

Redwood:—House building and finishing; shingles; fencing; telegraph poles; vineyard stakes; railroad ties; car lining; tanks; coffins.

Yew:—In Oregon for bows and fishing rods.

White pine:—House building and finishing; boxes and crates; sash, doors, and blinds; shingles; backing of fine veneers; excelsior; matches; laths; woodenware; slack barrels; framing of machinery; furniture; patterns for casting metals; ship masts; baled shavings for filtering gas, bedding for horses, packing for crockery.

Sugar pine:—Same uses as white pine; cooperage; shakes (large board shingles).

Lodge-pole pine:—Cheap lumber; mining timbers; railroad ties; used where other timber is not available.

North Carolina or Shortleaf pines (taeda and echinata):—Common lumber; cheap veneers; shingles; house building purposes altogether; mining timber; boxes; rice and potato barrels; laths; naval stores; soda fibre.

Table mountain pine:—Charcoal.

Longleaf and Cuban pine:—House building; dimension stuff; shingles; tanks; flooring; interior finish; railroad ties; railroad bridges; car sills and framework of cars; furniture; sash, doors and blinds; framework of machinery; mining timber; ship building; masts; waggon tongues and beds; naval stores.

Scrub pine (Virginiana):—Lumber; boxes; soda fibre.

Jeffrey's pine:—Coarse lumber; mining timber.

Bull pine: (ponderosa):—Lumber; railroad ties; mine props; shingles; boxes; slack barrels.

Jack pine (divaricata):—Ties and piling; cheap lumber; boxes; laths; soda fibre.

Norway pine:—Lumber generally; ship building; construction; flooring; masts; piles of wharves; covering, lining, siding, flooring, and sills of railroad cars; railroad ties.

Eastern spruce:—Chemical fibre and paper pulp (down to 5 inch. diameter); matches; excelsior; construction; posts; railroad ties; fresh-water ship building; clapboards; flooring; ceiling; step-ladders; sounding boards (from butt logs); oars; paddles; spars; wharf piles; telegraph poles; toys; wood type; butter buckets; slack cooperage; wooden thread (for mattings); chewing gum; vanillin. In Europe, spruce bark is used for tanning.

Engelmann's spruce:—Common lumber.

Tideland spruce:—Lumber; construction; outer finish; woodenware; paper pulp.

Hemlock:—Lumber; dimension stuff; construction timbers; shingles; railroad ties; fencing; paper pulp and fibre; bark for tanning.

Douglas fir:—All building lumber; furniture; lath; construction timbers; railroad ties; trestle bridges; piles; car material, notably sills; ship building; masts; flagpoles; mining timber; bark sometimes used for tanning.

Firs:—Paper pulp and fibre; corduroying; local lumber; packing cases; cooperage; interior finish; mine props.

Tamarack (Eastern):—Fence posts; telegraph poles; soda fibre; ship's knees; railroad ties.

Tamarack (Western):—Posts; railroad ties; car construction; dimension stuff; building lumber.

(C) TROPICAL AND SUBTROPICAL TIMBER.

Yucca:—Paper pulp and fibre for ropes; pin cushions.

Eucalyptus:—Street paving; railroad ties; mine props; piles; ship building; waggon making; orchard paling.

Mangrove:—Bark very rich in tannin.

Palmetto:—Wharf piles; pin cushions; brushes.

Lignum vitae:—Bowling balls; blocks for pulleys; fine interior finish and furniture; railroad ties in Panama.

Teak:—Ship building and flooring; railroad cars; street paving.

West India cedar:—Racing boats; cigar boxes.

Olivewood:—Turnery; inlaying; furniture; backs of hair brushes; wood carving. The fruit yields the best oil for table use.

Quebracho:—Tanning; paving; railroad ties.

Lancewood:—Fishing rods.

Mahogany:—Furniture; ship building; pianos; interior finish.

Fustic wood:—Dyeing.

PARAGRAPH XVIII.

TECHNICAL QUALITIES OF THE TREES.

(A) BOTANICAL STRUCTURE OF THE TREES.

I. Botanical structure of hardwoods.   The cells forming the woody tissue are:—

(a) Ducts (pores, vessels) formed by the resorption of the partition walls in a vertically running string of cells.   Such ducts are characteristic of hardwoods;

(b) Sclerenchyma, cells of heavy walls and small lumina, usually forming long fibres;

(c) Parenchyma, cells of thin walls and large lumina, frequently containing grains of starch.

Medulla or pith is found in the central column, in the primary, secondary, tertiary rays and (rarely) in medullary spots (birch). The central pith is:—

> Heavy in ash, maple, elder, catalpa.
> Triangular in birch, alder.
> Quinquangular in hornbeam.

Broad leaved species are called "ring porous," if the spring wood of the annual ring contains strikingly large pores, or else "diffuse porous," if the ducts, are more evenly distributed over the entire ring. Sapwood and heartwood are merely distinguished by a difference of color, caused by incrustations of pigments,

lignin, tannin, &c., in the walls of cells formed a number of years before. The number of years elapsing before incrustation takes place is small in catalpa, chestnut, locust; and larger in yellow poplar, white oak, walnut where it comprises about thirty or forty rings. Beech, maple, basswood, &c. do not form any heartwood proper. A darker coloring of the inner layers indicates, in the cases of these species, the beginning of a decomposition rather than an incrustation.

HARDWOODS.

RING POROUS (always with heartwood)		DIFFUSE POROUS	
Medullary rays on cross section	Pores of spring wood large and conspicuous; those of summer wood indistinct or invisible to the naked eye	Pores of spring wood only slightly larger and more numerous than those of the summer wood	With heartwood	Without distinct heartwood
Scarcely visible	Hicoria ([1]) Fraxinus Castanea Toxylon Diospyros Cotinus	Juglans Rhamnus Rhus Xanthoxylum Syringa Santalum Sambucus	Pyrus malus Sorbus Salix Nyssa ([2]) Amelanchier ([3]) Betula lenta ([4]) Mahogany	Alnus Pyrus communis Crataegus Betula lutea ([4]) and papyrifera Aesculus Populus Magnolia Fraseri Rhododendron Kalmia Ostrya Oxydendron Hamamelis Halesia (Mohrodendron)
Distinct but not broad	Sassafras Catalpa Gymnocladus Gleditsia Ailanthus Tectonia Cedrela Celtis Morus Ulmus ([5]) Robinia ([5])	Prunus	Liriodendron Magnolia acuminata Liquidambar Cornus ([6])	Acer Tilia ([6]) Corylus Ilex
Broad and distinct	Quercus Vitis Aristolochia			Platanus Fagus Carpinus

([1]) Sapwood frequently very thick.
([2]) Heartwood indistinct and not recognized as such by lumbermen.
([3]) Heartwood not distinct.
([4]) Rays more distinct than other members of this group.
([5]) Rays less distinct than other members of this group.
([6]) Rays very conspicuous on radial section. Cornus florida sometimes has heartwood.

II. Botanical structure of softwoods:—

(a) The tissue of softwoods is more homogeneous than that of hardwoods. It is mainly formed by tracheae. The cell walls formed in early spring are thinner and the lumina formed in early spring are larger than those formed in summer.

(b) Parenchyma is found in the medullary rays and around the rosin ducts.

(c) Ducts of the form found in hardwoods exist only close to the central pith column.

(d) The medullary rays are very fine (microscopic), usually only one cell wide and about a dozen cells high. The lowest string of cells in the ray is usually formed by tracheae (exception — red cedar).

(e) Rosin ducts are not cells merely, but, unlike the ducts of hardwoods, hollow tubes, the walls of which are formed by parenchymatic cells. These ducts are running horizontally as well as vertically in picea, pinus, larix, pseudotsuga. The tissue of the genera abies, taxus, juniperus, thuja, tsuga, libocedrus, cupressus, taxodium, sequoia, chamaecyparis, &c. lacks the ducts.

(f) Heartwood and sapwood of conifers are distinguished merely by a difference in color, due to incrustations of rosin in the inner (heartwood) rings. Spruces, firs and hemlocks have no heartwood. Heartwood is conspicuous in the pines, red and white cedars, Lawsons cypress, yew, larch, Douglas fir, &c.

SOFTWOODS.

	With resin ducts		Without resin ducts	
	numerous and distinct	unevenly distributed and not numerous		
Without heartwood	Picea		Abies, Tsuga	
			Heartwood of distinct color	Heartwood differing only in shade from sapwood
With distinct heartwood	Pinus Picea sitchensis	Pseudotsuga Larix	Sequoia Juniperus Taxus Taxodium Cupressus Tumion Cryptomeria Cephalotaxus Thuyopsis Biota Wellingtonia Cedrus	Libocedrus Chamaecyparis Thuya

(B) CHEMICAL QUALITIES OF WOOD.

I. The walls of the tissue are formed by cellulose and by incrustating substances (lignine).

Cellulose is $C_{72} H_{120} O_{60}$, or 12 $(C_6 H_{10} O_5)$.

Oxy-cellulose is formed by oxidation, accompanied by the destruction of the organic substance.

Hydral cellulose is $C_{36} H_{62} O_{32}$.

Cellulose treated with nitric acid forms nitro-cellulose.

(a) SO-CALLED "SOLVENTS" OF CELLULOSE ARE:—

    1. Solution of chloride of zinc.

    2. Copper hydroxide dissolved in ammonia.

These solvents, however, do not dissolve cellulose as such; they alter and transform it incidentally.

(b) THE PERCENTAGE OF CELLULOSE CONTAINED IN WOOD dried at 110 degrees centigrade is approximately 45 per cent.

For example (after Dr. Councler, Z. f. F. & J. W., 1907, page 428):—

    1. Oak wood contains:—

Cellulose	45·56 %
Incrustating substances ...	36·99 %

        Substances that can be withdrawn:—

By alcohol-benzol	8·85 %
By water	8·60 %
	100·00 %

    2. Pine wood contains:—

Cellulose	45·19 %
Incrustating substances ...	33·92 %

        Substances that can be withdrawn:—

By alcohol-benzol	15·60 %
By water	5·29 %
	100·00 %

II. Wood and bark contain on an average 45 per cent (weight) of water. Conifers contain less water broad-leafed species. The percentage varies irregularly with the seasons and with the precipitations.

Substances found in the woody tissue are:—

    (a) In the sap and medulla:— Albumen, starch, sugar, oils;

    (b) In the cells and cell walls:— Tannin, rosin, and pigments.

The specific gravity of pure wood fibre is 1·56.

(C) OUTER QUALITIES, or qualities discernible by eye, touch or scent.

I. Texture. The texture is fine or rough according to the ease with which the parts composing the tissue can be distinguished.

The texture is:—

    (a) Very fine in yew, box, holly, persimmon;

    (b) Fine in pear tree, hornbeam, black gum;

    (c) Pretty rough in spruce, fir, magnolia, cottonwoods;

    (d) Rough in cherry, sycamore, maple;

    (e) Very rough in oak, elm, locust, beech.

II. Color. Color is an advantage in the furniture trade and a disadvantage in the manufacture of paper. The heart of seasoned wood is always darker than the sapwood.

Tropical species are particularly rich in color.

Wood exposed to air changes its color more or less distinctly, in the course of weeks or years. The heart of yellow poplar changes to a dark brown. Alder changes from white to red. Ash from white to light violet. Mahogany from brown to black.

III. Gloss. Gloss is due to evenness, number and size of medullary rays.

Shining species are maple, ash, elm, beech.

Medium shining are oak, alder, hornbeam.

Dull are peach, pear, conifers.

Quarter sawing and planing increases the gloss.

IV. **Odor.** Odor is important for the use of wood in the package industry. The strong odor of fresh wood is usually lost in the course of seasoning. The following species retain, however, a characteristic odor:—Sweet birch, sassafras, red cedar, white cedar.

(D) INNER QUALITIES, or qualities discernible by mechanical tests.

I. **Specific gravity:**—

(a) Pure wood fibre forms in fresh wood, with broad leafed species of temperate climates, about 35 per cent of the entire weight, while conifers show an average of about 25 per cent;

(b) Air-dried wood still retains from 10 per cent to 15 per cent of water. If the dry kiln reduces the percentage of water below that figure, the hygroscopicity of the wood will speedily cause it to return; if it is much reduced, wood looses or changes its fitness for technical use;

(c) Factors influencing specific gravity of air-dried wood within the same species are:—

1. The width of the rings, in ring-porous hardwoods and in conifers forming heartwood.
2. The incrustation of rosin, tannin, and pigments in the heart.
3. The age of the tree.
4. The decay of the fibre.
5. The section of the tree, since roots are very light, butt logs heavy, bole fairly light, and branches fairly heavy.

   In the case of the diffuse-porous hardwoods and of conifers without heart, no rule can be given relative to specific gravity of inner and outer layers, of wide and narrow rings.

(d) Air-dried lumber has, on an average, the following weights:—

Species	Specific gravity	Weight of 1,000 feet b. m.
Turkey oak, hickory, service-bush	over 0·75	over 4,000 lbs.
Ash, white and red oak, locust, beech, hornbeam, hard maple, pear tree	0·70—0·75 ...	about 3,750 lbs.
Elm, soft maple, apple tree, sycamore, birch	0·60—0·70 ...	about 3,400 lbs.
Horse chestnut, chestnut, yellow poplar, larch, longleaf pine	0.55—0·60 ...	about 3,000 lbs.
Yellow pine, Douglas fir, spruce, fir, willow, cottonwood	0·45—0·55 ...	about 2,600 lbs.
White and sugar pine	under 0·45 ...	about 2,200 lbs.

(e) Rules.

1. Specific gravity times 5,200 equals the weight of 1,000 feet b. m. of sawn lumber, since 1,000 superficial feet of water 1 inch deep weigh 5,200 lbs.
2. Specific gravity times 8,000 times "cordwood reducing factor" equals the weight of a cord of wood, since 128 cubic feet of water weigh 8,000 lbs.

(f) Heavy planks do not dry so thoroughly as thin boards. $\frac{1}{4}$ oak requires four months, and $\frac{1}{4}$ oplar requires three months to become "shipping dry;"

(g) Weight determines freight and custom charges; also adaptability to packages, floatability in flumes and rafts, and possibility of loose driving.

For rates of freight, compare Schenck's Forest Policy, pages 31 to 33.

Transcontinental freight rates on lumber are (Eastbound) close to 50 cents per 100 lbs.

Transatlantic freight rates are close to 16 cents per 100 lbs.

Freight rates from Asheville, N. C., are:—

To New York, lighterage free ..	26$\frac{1}{2}$	cents
To Philadelphia	22$\frac{1}{2}$	cents
To Baltimore	21$\frac{1}{2}$	cents
To Chicago	26	cents
To Cincinnati	16	cents

The freight rate on logs for 50 miles is at least $5 per car load; for 100 miles at least $6.

II. Hardness. By hardness is understood the resistance of the fibre to axe and saw worked vertically to the fibre.

Factors of hardness are:—

(a) Density; wide rings in oak and narrow rings in pine increase the hardness;

(b) Incrustation; heartwood is harder than sapwood;

(c) Moisture contents; dry wood is, on the whole, harder than green wood. With some broad-leafed species of loose tissue (willows and cottonwoods), however, moist wood is tougher and therefore harder as well;

(d) Frost, which increases hardness.

SCHEDULE OF HARDNESS

Hard	Medium	Soft	Very soft
Hickory	Ash	Chestnut	White pine
Dogwood	Oak	Tulip tree	Sugar pine
Sugar maple	Elm	Sweet gum	Sequoia
Sycamore	Beech	Douglas fir	Paulownia
Locust	Cherry	Fir, Hemlock	Willow
Hornbeam	Mulberry	Yellow pine	Red cedar
Persimmon	Birch	Larch, Linden	(Juniperus)
	Sour gum	Horse chestnut	
	Longleaf pine	Cottonwoods	
		Spruce	

III. Cleavability or fissibility. Cleavability is the resistance of fibre to axe, saw and wedge, worked lengthwise in the direction of the fibre. Radial cleavage is usually by 50 to 100 per cent easier than tangential cleavage (except in black gum, dogwood, and bald cypress).

Factors of cleavability are:—

(a) A straight, long, elastic fibre;

(b) Heavy and high medullary rays;

(c) Straightness of growth;

(d) Branchiness;

(e) Moisture (very green and very dry wood splits best);

(f) Frost (reduces the cleavability);

(g) Hardness and softness (extremely hard and extremely soft wood splits badly; this rule holds good only in hardwoods).

SCHEDULE OF CLEAVABILITY

Hard to split		Easy to split	Medium to split	
Black gum	Beech	Chestnut	Oak, Ash	Birch
Elm	Holly	Pines	Larch	Cottonwood
Sycamore	Sourwood	Fir	Hickory	Linden
Dogwood	Hornbeam	Cedar	Maple	Yellow poplar

IV. Pliability. Under pliability is combined "flexibility" and "elasticity."

(a) FLEXIBILITY:—Wood which is easily bent without breaking is flexile (flexible). Softwoods are naturally less flexile than hardwoods.

Flexibility depends on:—

1. Toughness and cohesive force of fibre.
2. Moisture, which increases it very much.
3. Heat, which increases it.

4. Age of tree, inasmuch as young shoots are tougher than old wood.
5. Impregnation, natural as well as artificial, checks flexibility. Heartwood is less flexible than sapwood.
6. Root wood is more flexible than stem wood.

REMARK:—Heat and moisture as a means to increase flexibility are applied in the following industries:—Cooperage, for bending staves and hoop poles; carriage works, for bending poles, shafts, felloes, top frames, seats, &c.; furniture works, for bent wood furniture; ship building; veneer peeling; basket work; manufacture of musical instruments.

(b) ELASTICITY is the force with which an object resumes its old shape when released after being pressed out of shape. Qualities which increase flexibility frequently reduce elasticity, and vice-versa.

The factors of elasticity are:—

1. Length and straightness of fibre.
2. Width of rings in conifers.
3. Moisture (which reduces elasticity).
4. Frost (which destroys elasticity).
5. Excessive contents of rosin (which increase elasticity).

SCHEDULE OF ELASTICITY

Very elastic are		Less elastic are	
Yew, Larch	Red cedar	Cottonwood	Walnut
Fir, Locust	Lancewood	Birch	Yellow pine
Chestnut	Spruce	Maple	Yellow poplar
Hickory	White pine	Elm	Beech
Osage orange	Ash, Oak	Alder	

V. Strength.

(a) STRENGTH IS RESISTANCE TO:—Tension, to which timber is usually not exposed; compression (arches, pillars, scantling); torsion (shafts, screws, axles); shearing (railroad ties); transverse straining (beams, girders, joists).

(b) FACTORS OF STRENGTH ARE:—

1. Specific gravity.
2. Soundness of tissue.
3. Freedom from branches.
4. The locality where the timber was grown.
5. The quality of the soil producing it: whether good, bad, or indifferent.
6. The sylvicultural form under which the timber was produced.
7. The rate of growth.
8. The age of the tree.
9. The season of the year at which the tree was cut.
10. The method of storing and of drying the timber since it was cut.
11. The position of the test piece within the log producing it.

Timber, like any other material, should never be loaded to over one fourth of its indicated strength.

Transverse strength is always proportioned to length of girder; to width of girder; and to the square of the depth of girder. It is *the* quality of timber which is most valuable in material used for building and construction.

The "International Association for Testing Raw Materials" has passed a resolution, at a meeting in Copenhagen in 1896, with reference to the unification of the methods and sizes used in timber tests. The resolution in question covers the following points notably:—

1. The strength of the timber shall be tried by pressing, by bending, by shearing, by tearing, and by cleavage.
2. The size of the test pieces and their position in the log from which they are obtained is stipulated for each test series.
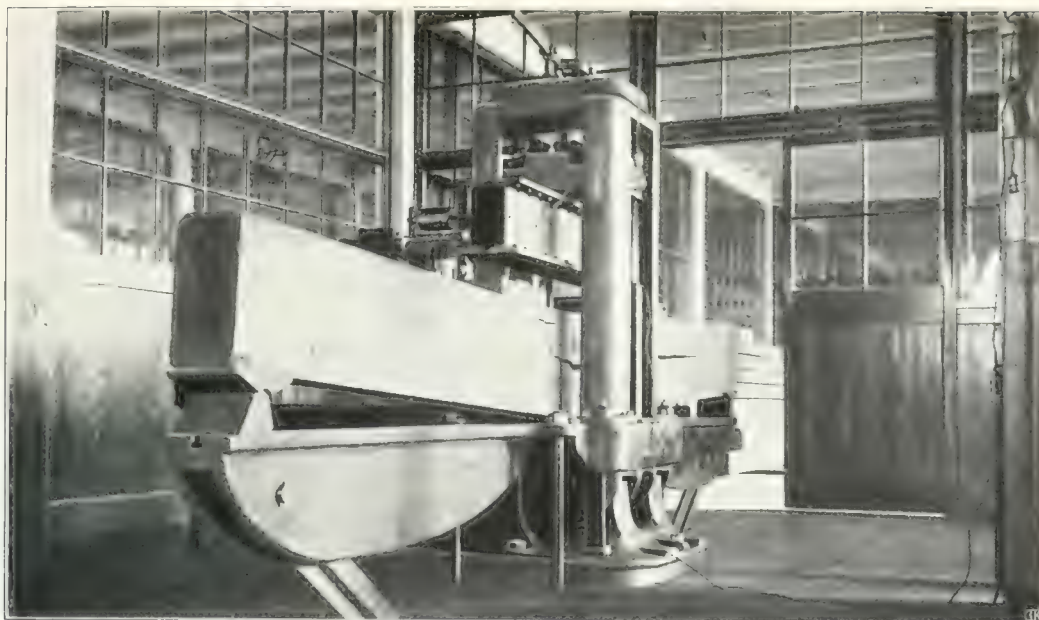
Testing the strength of Douglas fir at the U. S. Forest Experiment Station, Seattle, Wash.

3. The test pieces shall be dried in the air so as to contain 15 per cent of moisture.

4. The test load shall be increased gradually at the rate of 20 kilograms per square centimeter per minute.

5. The observations shall be recorded after the lapse of one minute succeeding the appearance of a change of form.

VI. Hygroscopicity.

(a) TIMBER CHANGES FORM, COHERENCE, AND VOLUME with greater or lesser ease under the influence of moisture, applied in gaseous or liquid form. Hence shrinking, swelling, warping, checking, cracking, casehardening, and working.

(b) IN FRESH WOOD, WATER INVARIABLY SATURATES the cell walls; in addition, it may or may only partially fill the lumina.

(c) SAPWOOD INVARIABLY CONTAINS more water than heartwood.

(d) SPEED OF DRYING depends on the species, looseness of tissue, dimensions of object to be dried, presence or absence of bark-cover in logs, preceding treatment by floating, deadening, steaming, prevalence of sapwood or heartwood, season of year, exposure to wind, climate, &c.

(e) BOILING AND STEAMING reduce hygroscopicity and produce, consequently, a more even shrinkage.

(f) THE EVAPORATION from the cross section bears to that of the tangential and to that of the radial section the ratio of 8 to 1 to 2.

(g) IN THE DRY KILN, temperatures of 160 to 180 degrees Fahrenheit are gradually produced. Drying is accomplished by hot air, steam and moving air.

Conifers stand the dry kiln process much better than hardwoods. The better qualities of hardwoods undergo air-drying before being kiln dried, especially so in waggon, furniture, and barrel works.

The dry kiln saves piling charges, insurance and interest on large stocks of lumber, and it allows the lumberman to rapidly fill pressing orders for lumber. It prevents the staining of sapwood in summer. It causes, on the other hand, existing defects to open up and knots to drop out of the boards.

(h) WOOD IS LEAST PERMEABLE FOR WATER IN THE DIRECTION of the tangent or vertically to the medullary rays, a fact important for tight cooperage.

(i) SHRINKAGE.

    1. *It is least along the fibre;* it is up to 5 p. c. along the radius and is up to 10 p. c. along the tangent.
Shrinkage of over 5 p. c. of green volume occurs in walnut, linden, beech, elm, chestnut, birch.
Shrinkage of 3 to 5 per cent occurs in oak, maple, sycamore, ash, cottonwood, yellow pine
Shrinkage of 2 to 3 per cent occurs in spruce, larch, fir, and white pine.

        A large percentage of rosin, narrow annual rings and light specific gravity reduce shrinkage
within the same species.

    2. *Tests at Biltmore as to the effect of shrinkage* in volume and in grade on $^4/_4$ red oak lumber
have shown, in the course of four months, that:—

        (aa) 10,000 feet of green firsts and seconds shrink down to 8,514 feet of dry firsts and seconds,
plus 1,096 feet of dry common #1;

        (bb) 10,000 feet of green common #1 shrink down to 7,499 feet of dry common #1, plus
2,090 feet of dry common #2;

        (cc) 10,000 feet of green common #2 shrink down to 9,043 feet of dry common #2, plus
547 feet of dry common #3.

  (j) CHECKING. It depends on the rapidity of the drying process; on size of piles and of piling sticks;
on size and dimension of object; on presence or absence of bark from logs; on homogeneity of tissue.

    Checks (so-called season checks) are often of a temporary nature, disappearing when the inner layers
are as dry as the outer layers.

    Hardwoods check much worse than softwoods; rift sawed or quarter sawed lumber checks less than
bastard sawed lumber.

    1. *Remedies against checking of logs are:*—Winter cutting; strips of bark left near the end of
peeled logs; felling with the roots and leaving the crown on the undissected bole; deadening;
"S" shaped iron clamps driven into logs; boards nailed onto the ends of the logs; earth cover
at the end of the logs; end painting of logs.

    2. *Remedies against checking of lumber are:*— Quarter sawing; slow air drying under sheds; veneer
sawing; steaming or boiling; many and thin sticks placed close to the ends (or else far from the
ends) of tiers in lumber piles; shading or end painting the piles on the side exposed to sun and wind.

    3. *Checks are radial* since the tangential shrinkage is greatest. The so-called wind (or ring) shakes
are not caused by the hygroscopicity of the timber; they are merely a form of disease of timber
due to frost, heat, fire, or insect plagues interfering with the radial cohesion of adjoining rings
in wind-exposed localities.

  (k) SWELLING, WARPING, AND WORKING. These phenomena are due to re-absorption of water after
drying. The swelling is greatest tangentially. Heartwood warps less than sapwood, and conifers warp
less than hardwoods. Boards obtained from close to the slab warp worst of all.

    Remedies against working are steaming; varnishing; forming composite boards by gluing (crossbanding)
fine veneers squarely one upon another; allowing framework of doors to be sufficiently grooved for
receiving the panels; placing dimension stuff on edge to dry in the piles; quartersawing; impregnation
with oils or with colophony (e. g., beech flooring).

VII. Duration of wood.

  (a) DURATION OF WOOD DEPENDS ON:—

    1. *The surrounding conditions* (e. g., tropics or arid deserts); presence of insects and fungi; contact
with clay, limestone or sand soil; immersion in sweet or in salt water (teredo); exposure to
atmosphere; moisture and heat conditions; presence of preserving matter (salt water, humic
acid, copper mine water).

    2. *The natural qualities of wood,* especially the presence or absence of rosin, tannin, and other
preservatives; the specific gravity; the percentage of sapwood; the susceptibility to fungus and
insect diseases. Locust, Eastern red cedar, sequoia and bald cypress are less subject to fungus
diseases when dead than when alive.

(b) Remedies against destruction are:–Impregnation; painting; charring the part imbedded in the soil; winter cutting; change of species when replacing ties; kiln drying, steaming and smoking; raising buildings high above ground.

(c) Schedule of duration:–

Very durable	Durable	Short lived
Locust, Sequoia	Yellow poplar	Beech
Red cedar	Larch	Sycamore
Walnut	Yellow pine	Birch
White oak	Spruce	Linden
Catalpa	Hemlock	Cottonwood
Sassafras	Fir	Black gum
Chestnut	Douglas fir	Hickory
Longleaf pine	Ash	Buckeye
White pine	Maple	

VIII. Heating power. Heating power or fuel value bears a direct ratio to specific gravity air-dry. All wood fibre having the specific gravity 1·56, equal weights air-dry of our common species furnish equal heat. On the other hand, light weight means greater inflammability and a quicker heat, which naturally lasts for a short time only. The heating power of hard coal is to that of lignite and to that of wood as 5·2 : 4·3 : 1. In other words:–1 pound of hard coal yields as much heat as do 1·21 pounds of lignite or 5·2 pounds of wood.

(a) Influencing factors are found in the following conditions:–

1. *Presence of rosin increases* the heating power by about 12 per cent.

2. *A cord of wood containing 45 per cent moisture* has, after German experiments, the heating power of half a cord of air dried wood. After Sargent, the discrepancy is not so great. One cord of green wood contains 250 gallons of water, and the calories of heat required to convert this large amount of water into steam are lost to heating purposes.

3. *Unsound wood has a reduced heating power,* the cell walls being decayed.

4. *Chestnut, and to a certain extent larch and spruce,* are despised in open fires owing to crackling and emission of sparks. Black gum is despised because it is difficult to split and therefore difficult to season. Hornbeam, birch, and alder are said to furnish a particularly quiet flame.

(b) Schedule of the heating power of wood:–

Best	Good	Moderate	Bad
Hickory	Oak	Spruce	White pine
Locust	Ash	Fir	Alder
Beech	Birch	Chestnut	Linden
Hornbeam	Maple	Hemlock	Cottonwood
Heart pine		Sap pine	

(c) Conversion of fuel wood, to serve in the production of energy, into " Wood Producer Gas," is being recommended. A gas engine generator is the means to the end. One cord of pine or Douglas fir wood is said to yield 150,000 cubic feet of wood gas, equal to 1·155 kw. hours.

The cost of a "Wood Producer" gas plant is given as $130 per kw. The heat liberated in cooling the gas from 1·200 down to 70 degrees is said to be sufficient, in addition, to drive the pumps and other equipment connected with the plant.

IX. Miscellaneous technical qualities of wood.

(a) Adaptability to planing, molding, and lock cornering; varnishing and polishing; painting and gluing; mortising (bad in rock birch used for hubs, good in oak or beech).

(b) NAIL HOLDING POWER, which is said to be excellent in hemlock.

Experiments described in *Engineering News,* January 10, 1894, claim the following ratio of tenacity of 6d nails.

Kind	Plain	Barbed	Blued	Average
White pine ...	106 ...	94 ...	135 ...	111
Yellow pine ...	190 ...	130 ...	270 ...	196
Basswood ...	78 ...	132 ...	219 ...	143
White oak ...	226 ...	300 ...	555 ...	360
Hemlock ...	141 ...	201 ...	319 ...	220

The figures represent resistance to pulling in lbs. offered per square inch of nail surface.

(c) TWISTED GROWTH, which is frequent in chestnut, chestnut oak, Lombardy poplar, and horse chestnut. Certain twists are due to a hypertrophical growth of the tissue and are highly prized by the trade under the names of birdseye maple, curly poplar, curly walnut, curly cherry, curly ash, &c. It is often impossible to say whether a standing tree is "curly" or not. Sap-sucking woodpeckers may start the "freak."

(d) KNOTS CHECK the value of lumber. A standard knot is a knot, the diameter of which varies according to inspection from $1\frac{1}{4}$ inches (hardwoods) to $1\frac{1}{2}$ inches (shortleaf pine). Usually the knotty part of a log is sawn into dimension stuff (boxed heart). The core of a log, necessarily, shows knots, since there is no height growth without simultaneous formation of side branches.

(e) THE DISCOLORATION of the inner layers of certain species (beech, maple) which resembles heart-wood is a disease often found in old trees and causes rejection for certain applications in the trades (impregnation).

Logging scene in the mountains of Saxony, a country
where conservative forestry pays its way.

CHAPTER V. MANUFACTURING INDUSTRIES.

PARAGRAPH XIX.
THE SAWMILL.

(A) THE SAW. Three kinds of log saws are used:—

    1. Straight saws, viz.:—Vertical straight saw; gang saw; horizontal frame saw.

    2. Circular saws, viz.:—Solid tooth single saw; solid tooth double saw; inserted tooth saw.

    3. Band saws, viz.:—Single cutting band saw; double cutting band saw; horizontal band saw.

I. Straight saws.

(a) SINGLE VERTICAL STRAIGHT SAW. At the toothed edge this saw has a thickness of from 5 to 10 gauge. Its blade is 8 inches wide and at least twice as long as the log diameter.

A short blade yields the finest work, since it can be spanned more tightly.

The gauge along the back should be finer than the gauge along the cutting line.

The saw is able to cut, usually, logs having up to four feet diameter.

The saw cuts by the down stroke while the log is moved against the saw during the up stroke.

The saw is spanned in a guide frame and is given as many inches inclination toward the log as the feed of the carriage per stroke amounts to. If the saw were not inclined, all the work would be done by the lowest teeth.

The usual set is still the spring set and not the swage set, although the latter is sure to be superior in efficiency.

Usually the ends of the boards are not sawn through but are held together by the "comb," which is finally split with the axe.

In filing mill saws, obtain sufficient pitch of teeth to prevent saw from kicking out of the cut. Too much pitch, however, causes chattering.

Gullets must be kept carefully rounded.

(b) GANG SAWS. They are used in large mills for inferior and small logs.

The best make is Wickes Bros'., Saginaw, Michigan, and Wilkin Challoner Co., Oshkosh, Wisconsin. Particularly strong foundations are required.
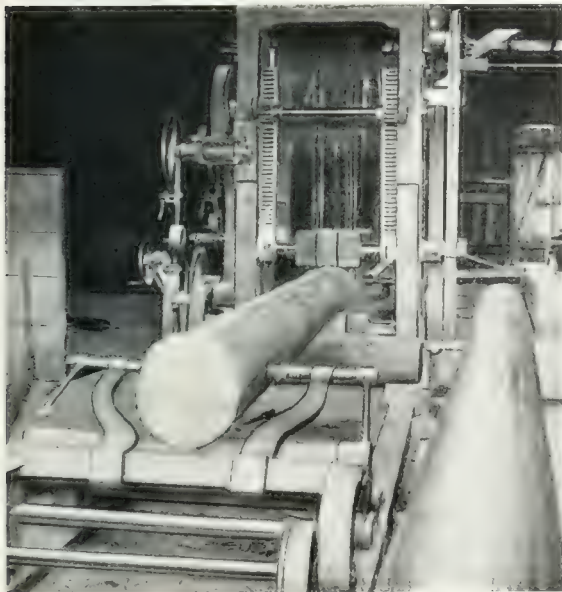
The usual type of sawmill found in Germany (Mahr, Darmstadt, Germany).
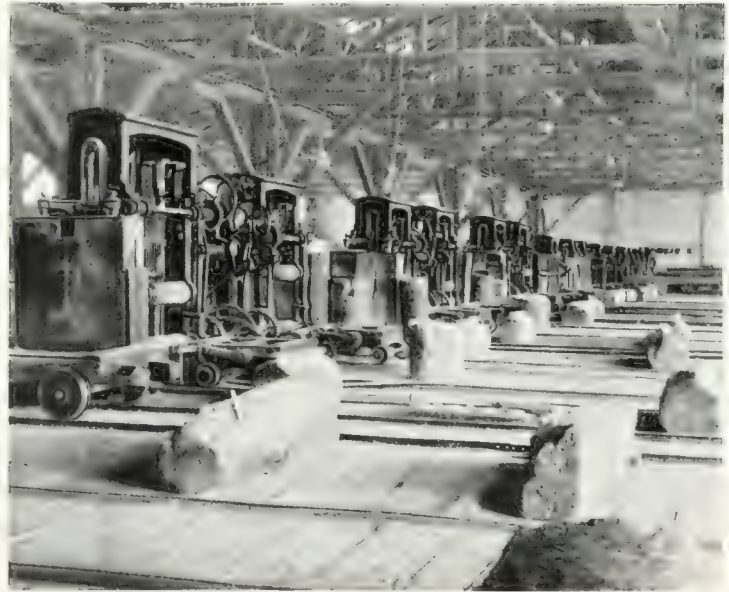
The largest sawmill in Europe, employing 20 single-log gang-saws, all belt-driven from one shaft.

The saw frame has an oscillating motion which presents the saw to the cut in an easy raking sweep, forcing each tooth to do its full share of the work.

Gang saws are either fed from a carriage (Germany) or the logs are run through feed rolls, feeding the logs into the saws.

Blades are 6 to 10 inches wide, and of 8 to 16 gauge.

Horse-power required is, for friction 3 horse-power; for first blade 4 horse-power, and for every additional blade $\frac{1}{2}$ horse-power more.

Where log heaps (up to 12 logs) are run through the gang saw, the logs are slabbed by a "rosser" or "log siding machine," so that the logs can be placed one upon another.

The logs are not turned, and all boards obtained lie parallel in the log.
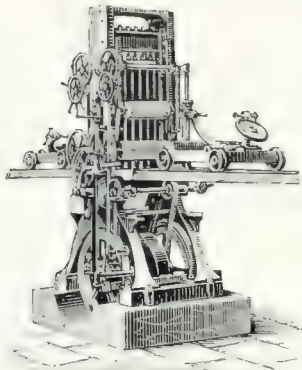
Miniature of a heavy gang-saw, with trucks, made by Schmaltz, Offenbach, Germ.
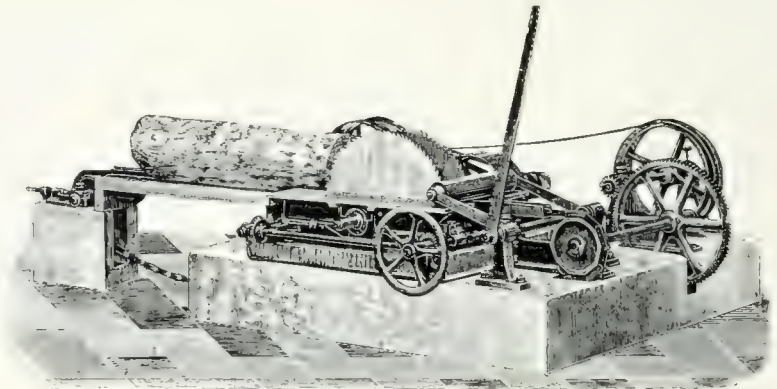
Double circular saw removing two slabs simultaneously, made by Schmaltz, Offenbach, Germ.

(c) HORIZONTAL FRAME SAW. It is used to cut fine veneers and valuable timber. Its advantage lies in the fact that very little weight rests on the saw, that the saw may cut on both trips (to and fro), that high speed may be applied and that a thin gauge can be used.

The best makes are Kirschner's, Leipzig, Germany, and Schmaltz', Offenbach, Germany.

Horizontal straight saw at work, mill of W. Mahr, Darmstadt, Germ.
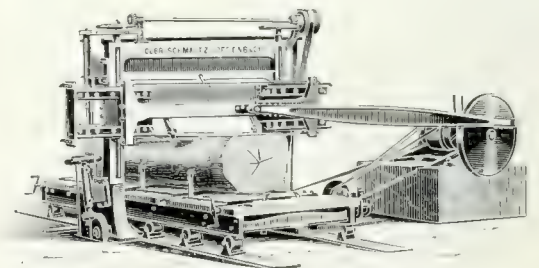
Horizontal straight log saw, made by Schmaltz, Offenbach, Germ.

II. Circular saws.

(a) POWER. Generally speaking, the horse-power required equals $\frac{1}{3}$ of the diameter of the saw:—

10 horse-power should manufacture 5,000 board feet per day
20 horse-power should manufacture 10,000 board feet per day
30 horse-power should manufacture 30,000 board feet per day

Interior of a portable circular mill on the Biltmore Estate.
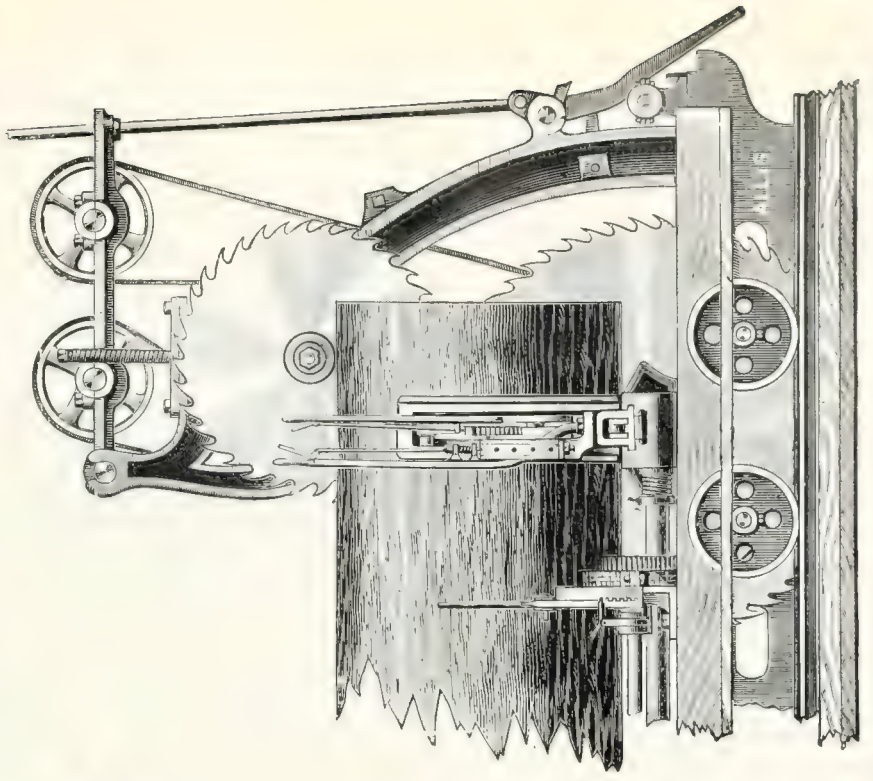
Right-hand double circular saw. Allis-Chalmers Co., Milwaukee, Wis.
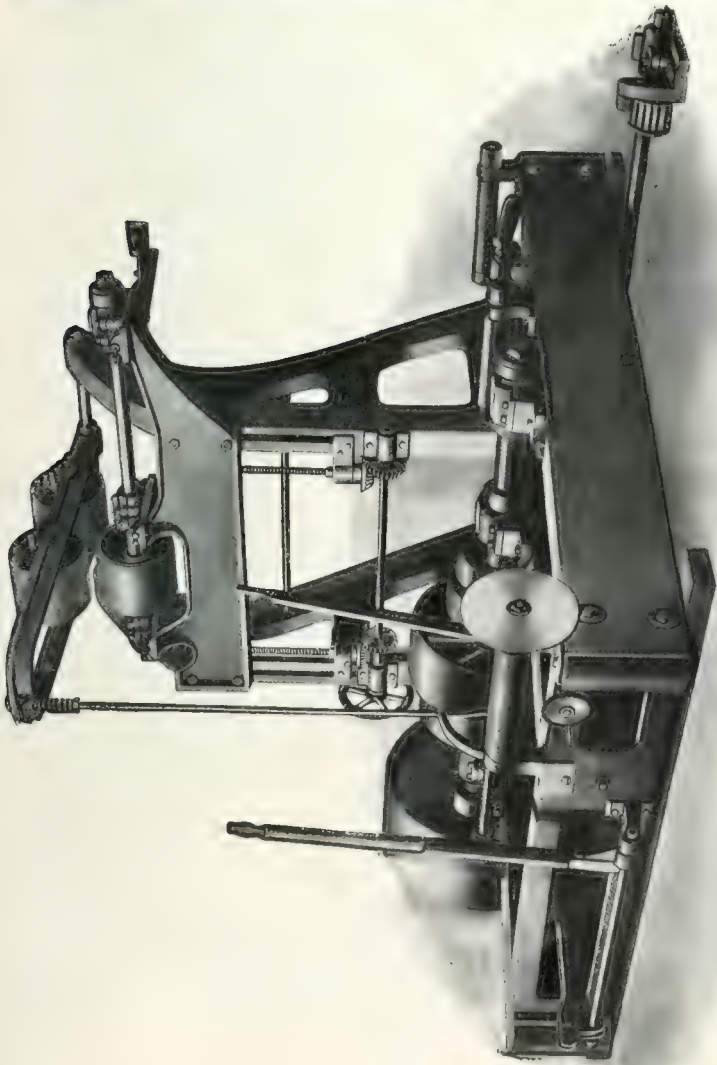
Double circular sawmill. Wheland Machine Works, Chattanooga, Tenn.

Small portable circular mill on the Biltmore Estate.

15

Each additional horse-power should add 1,000 board feet to amount cut.

The amount depends, naturally, on size of logs and on hardness of fiber. To give an approximation, there is required:—

8 horse-power for a 20-inch to 30-inch saw
12 horse-power for a 30-inch to 40-inch saw
15 horse-power for a 48-inch to 50-inch saw
25 horse-power for a 50-inch to 62-inch saw

Softwoods require less power than hardwoods; thin gauges less than heavy gauges.

(b) RIGHT-HAND AND LEFT-HAND MILLS. If the carriage is to the left of the observer while the saw runs toward him, the mill is a left-hand mill, and vice-versa. A right-hand saw is screwed to the arbor by a left-hand nut, and is usually driven by a left-hand steam engine.

Center crank engines can be used for either right or left hand mills.

(c) SPEED. Disregarding the power available, the proper speed at the rim of a circular saw is 9,000 feet per minute. Reducing the number of teeth, the speed must be reduced also, and the power can be reduced proportionately.

There should be a speed indicator to control the saw's speed. It costs 75 cents.

If the power is too light to run the mill at standard speed, the sawyers in portable mills usually increase the speed of the engine, and put a larger receiving pulley on the saw mandrel.

Mills running with small horse-power, should run the rim of the saw at a speed not exceeding 360 feet per minute to each horse-power, and the teeth should be 5 or 6 inches apart. Obviously, speed requires power; and many small mills consume all the power at hand to produce speed, having none left for the saw to cut.

More speed is required for sawing hardwoods than for sawing softwoods.

(d) PROPER QUALITIES OF A SAW.

1. *The usual thickness* is 7, 8, or 9 gauge. Finer gauges (10 or 11) are compatible with first-class equipment. Frequently the center is heavier than the rim.

2. *There should be a sufficient number of teeth* for the amount of feed.
   Each tooth must cut as much as is offered to it at a revolution.
   To cut a gash of one inch into the log, one may use, for example, either:—

   8 teeth, cutting $1/8$ inch each, or
   16 teeth, cutting $1/16$ inch each, or
   32 teeth, cutting $1/32$ inch each

   The number of teeth for one inch of feed should be, in hard timber, 12 teeth, and in soft timber, 8 teeth.
   The distance between the points of consecutive teeth varies between 7 inches (maximum) and 3 inches (minimum possible).
   The usual feed is from 1 inch to 6 inches per revolution. The quicker the feed, the more teeth and the more power is required to do the work.

3. *The saw must be hung perpendicularly,* and must slip easily on the mandrel against the fast collar, so as not to twist out of true when the loose collar is tightened up, thus causing it to buckle.
   The loose collar is hollow at the center (small saws excepted) and has about 6 inches diameter and $3/4$ inch rim.
   By pressing a layer of writing paper between the collar and the saw, the latter may be slightly bent toward or away from the carriage.

4. *The saw must be evenly set* (either spring or swage set). The teeth, filed square (not to a point but to a cutting edge), must form an exact circle and must retain that form in the course of operation.

5. *The teeth must have the proper pitch.* A shallow tooth cuts the smoothest lumber, but forbids of rapid feeding.

The modern shape of teeth is such as will facilitate filing and as will preserve the original pitch.

A tooth gets dull over as much of an inch as it cuts.

The gullet of the tooth must be larger for softwood than for hardwood. Large gullets weaken the saw, small ones increase the friction very badly.

A tooth should be filed two to four times a day. The backs of the teeth must never protrude beyond the point.

Gullets must be kept circular carefully. Any sharp edge in a gullet is sure to cause a crack.

6. *The mandrel must not heat* in the journals. The boxes require frequent rebabbitting. The stem of the mandrel must be exactly level and perfectly straight.

Mandrels run hot owing to excessive friction in bearings, to excessive tightness of belts, to insufficient lubrication or to heating of the saw in the center.

A hot mandrel expands the saw in the center, causing crooked sawing.

(e) LINING OF THE SAW with the carriage into the log. The saw must "lead into the cut" just sufficiently to keep the saw in the cut. The proper lead is $1/8$ inch in 20 feet. Too much lead into the cut causes the saw to heat at the rim. A lead out of the cut causes the saw to heat at the center.

The $1/8$-inch lead in 20 feet is obtained by sighting over the saw and fixing the saw plane for a radius of 10 feet. This may be done by putting two staffs vertically into the ground 10 feet from the saw center behind and in front of the saw within the plane of the saw; that done, a horizontal stick is fastened to a head block so as to just touch the forward staff. Then the carriage is gigged backward to the other vertical staff where the horizontal stick must lack exactly $1/8$ inch from touching.

(f) FILING ROOM. Automatic sharpeners and gummers are required for mills having over 15,000 feet daily capacity.

Setting instruments for spring set are similar to those used with cross cut saws, constructed either after the wrench principle or after the block and hammer principle.

The spring set is gradually discarded for the swage set.

In swaging use oil on the point of the tooth, after filing to a sharp point. Swaging should draw the tooth out and should not shove it back.

The set or swage of teeth should increase the gauge at the rim by at least $3/32$ of an inch.

The pitch of the tooth might be controlled by a so-called trammel.

Gumming is required to preserve the original hook or rake of the tooth as well as the original roundness of the gullet.

Gumming as well as sharpening are usually done with emery wheels.

Emery wheel rules are as follows:—

1. *Do not put too much pressure* on emery wheel so as not to change the temper of the tooth (bluing and casehardening and consequently crumbling of the tooth).

2. *Do not try to fix a tooth fully* at one time. Treat it gradually at five or six revolutions of the saw.

3. *Proper speed for emery wheels* at the rim is 4,500 feet per minute.

4. *After gumming remove the irregularities* at the edges with a side file, since cracks in saw are apt to start from them.

5. *Hammering becomes necessary* when the use of emery wheels has caused the saw to expand ("let down") at the rim.

For small mills gumming with a file or a butt gummer is preferable to the use of emery wheel.

Softwoods require more set or spread and less pitch than hardwoods.

Swaging is also called upsetting or spread setting.

(g) Inserted tooth circular saws.

1. *The insertion into each socket* of the rim consists of a holder and of a chisel point. These points are extremely hard; still they can be filed and swaged with the help of specially-constructed files. It does not pay, however, to spend much time in filing since new points are cheap, and since they are readily inserted with the help of a special wrench.

   Points are oiled before being inserted.

   When renewing one individual point be sure to have it dressed down to correspond to the line of old points.

   If the saw guide is not properly adjusted, it may touch the holder and smash the saw.
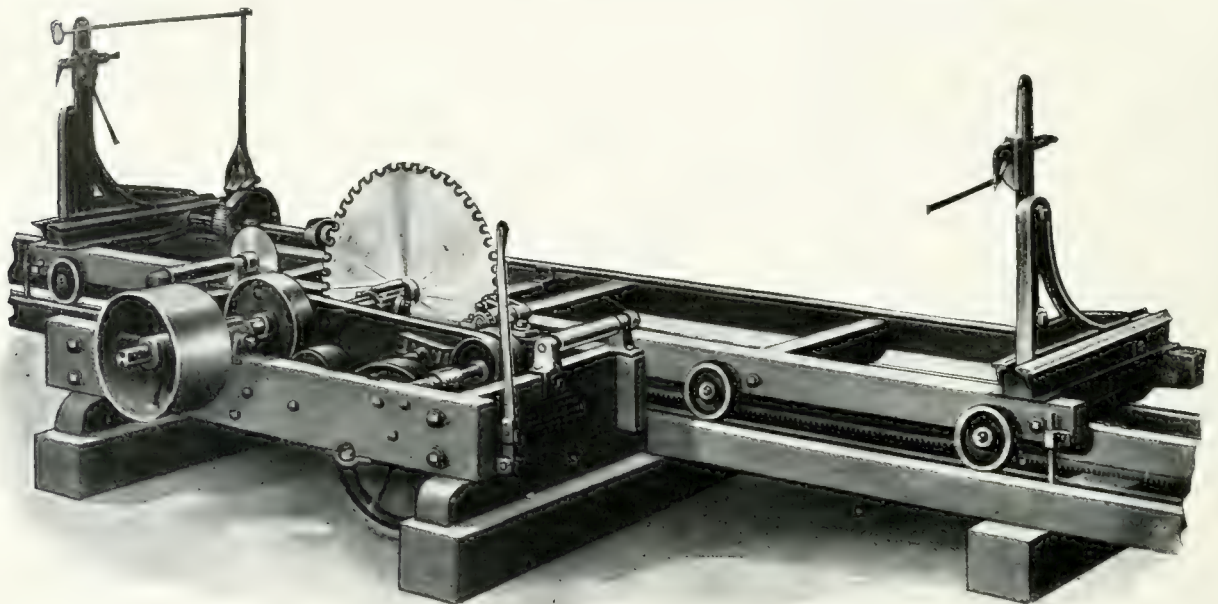
Small inserted tooth circular sawmill with carriage. Wheland Machine Works, Chattanooga, Tenn.

2. *Advantages of inserted tooth saw* are:—

   Temper of the teeth can be harder than that of the saw itself.

   Less experience is required for dressing a saw.

   Less filing and gumming.

   Less saw repairs in backwoods.

   Diameter of saw remains unchanged during its use.

3. *Disadvantages of inserted tooth saw* are:—

   The saw kerf is very heavy.

   The teeth are large and hence few, so that feed must be comparatively slow.

   The price of the inserted tooth saw is higher than that of the solid tooth saw.

   The best makes are the Atkins, Simonds, and Disston saws.

(h) The double circular saw. For big logs and high speed a double circular saw must be used. The width of the widest board which a single circular saw may cut equals radius minus three inches. Hence much valuable material is wasted in the common circular sawmill when heavy logs are sawed.

The double circular saw usually shows an under or lower saw of 56 inches or 60 inches and an upper saw of 30 inches or 36 inches diameter.

A hanger top saw can be added readily to any single saw. Both saws should have the same speed at rim. The rotation of the top saw should be the reverse of that of the main saw, so as to prevent the saws from throwing sawdust one in the other's kerf.

The advantages of the double sawmill are:—

1. Less chattering and truer cut than would be possible for one big saw.
2. Thinner kerf.
3. Faster feed.
4. Less expense for saws.
5. Less repairs.

In the Pacific forests, triple circular saws are said to be used. Here, a fourth horizontal saw is used to split the board on a line with the mandrel of the middle saw.

REMARKS RELATIVE TO "PUTTING UP" portable circular sawmills of 20 to 30 horse-power:—

The minimum yard required for a "setting" is 50,000 board feet.

The expense of tearing down and putting up is about $50.

Thirty horse-power portable circular mill on Biltmore Estate, North Carolina.

For foundation timbers, place two pieces 8″ × 10″ × 11′ long on either side of the saw pit (3 feet deep) and underneath the "husk." One piece 4″ × 6″ × 7½′ long is saddled into the two big pieces, spanning the saw pit underneath the far rail of the track.

Construct the carriage track absolutely straight and level on the track ties (16 to 25 in number) and over the saw pit.

Place carriage with rack shaft, feed and gig works in place and fasten the track by cleats and nails solidly to the foundation timbers. Then place the husk on them at a distance of about 6 inches from the track, putting wedge blocks between the husk and track. Then spike the husk to its foundation — to begin with in two places only, viz. at the sawyer's corner and at the middle of the opposite side, so as to enable the sawyer to change the lead by wedging the blocks. Then fix or hang the saw and set the saw guide.

III. Band saws.

(a) THE BLADE. The blade material is steel. The width of the blade for log band saws is from 10 inches to 16 inches; 14 inches being usual. Gauge of blade is from 19 gauge to 13 gauge.

Under "tension" of blade is understood the curvature across the width, which is increased or decreased by hammering at center or at edge. The tension gauge with curved edge guides the filer.

(b) THE TOOTH. Its width is from 1¼ inches to 3 inches.

The hook or pitch is from 40 to 65 degrees.

The depth should be as shallow as possible, with gullets kept round, since cracks usually start from a corner in the gullet.

For sharpening the tooth, a medium soft emery wheel should be used and should not be crowded too hard against the saw, so as to prevent casehardening.

The teeth are swage set, and are never spring set. The full amount of set should not exceed 9 gauge in a 14 gauge saw.
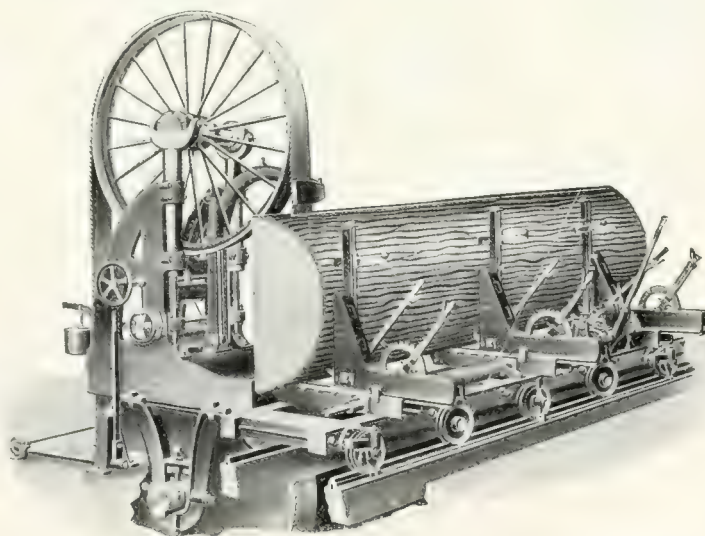
Band sawmill, with carriage. Fay & Egan, Cincinnati, Ohio.

Side filing or side dressing, after swaging, is usually practiced, although objected to by the saw makers. For gumming, either a gumming press or the emery wheel is used.

(c) THE FILING ROOM. Every band sawmill has a separate filing room preferably above the mill-floor, equipped with automatic dressing machines, viz., automatic sharpener, automatic swage, automatic swage shaper, saw stretcher, &c.

In the band sawmill, the filer is considered more important for the success of the mill than the sawyer.
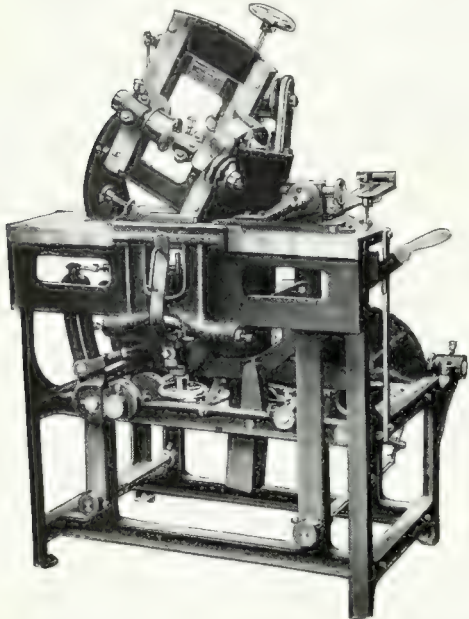
Band saw sharpener. Hanchett Swage Works, Big Rapids, Mich.
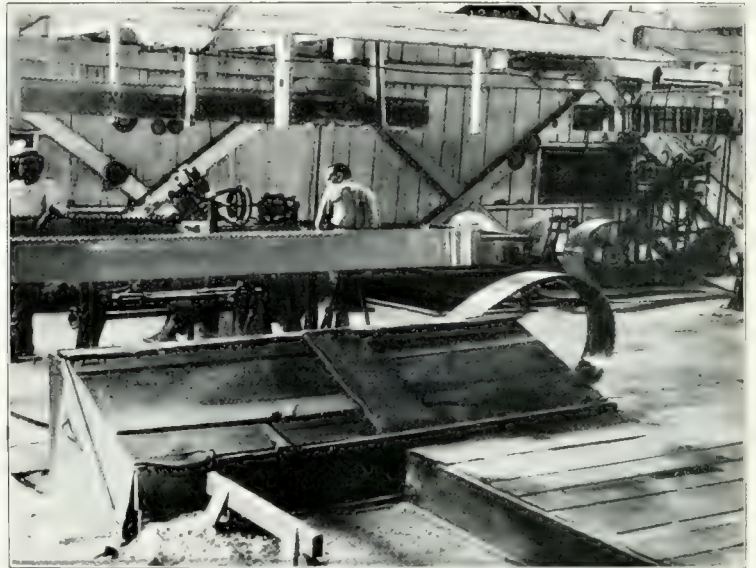
In the filing room of a band sawmill.

Saws are changed three or four times a day.

"Brazing" of a band saw means joining the loose ends, uniformly beveled or ground to a feather edge $3/4$ inch long. A strip of silver solder is placed between the cleaned laps, which are then taken between the cheeks of the brazing clamps heated to a bright red heat. After pressing the clamps together for several minutes and allowing them to cool, the braze is dressed down with a file to the proper thickness.

The filer arrests cracks by punching a small pin hole or dot at extremity of crack.

(d) THE WHEELS. The band saw runs, belt like, over two wheels weighing from 1,500 to 3,000 pounds (the lower heavier than the upper); the lower wheel driving the upper by the band saw acting as a belt.

The diameters of the wheels are 5 to 11 feet; the face being more narrow than the sawblade, the teeth overlap the wheel.

The crown of the tire is up to $1/64$ inch.

The entire length of the log band saw varies from 30 feet to 70 feet.

The saw guides, lined with wood or babbit metal, prevent the cutting part of the blade from bending toward the
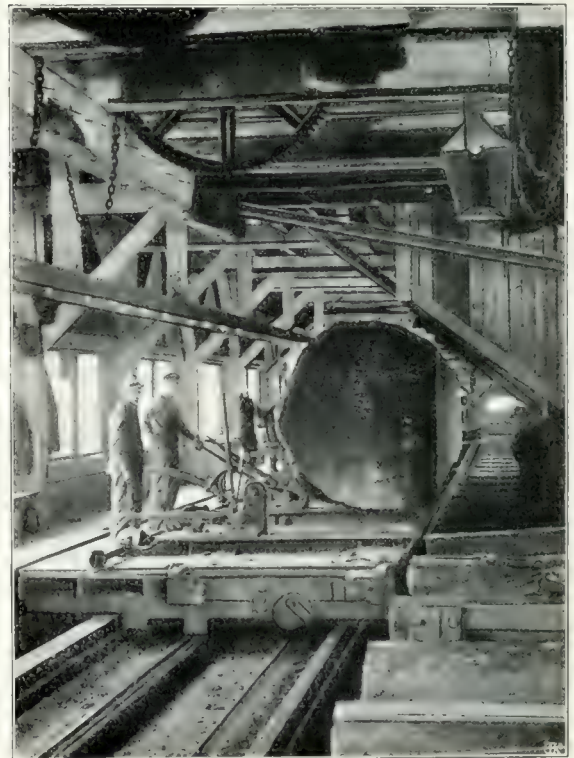
Interior of an Oregon band sawmill.

carriage or toward the wheels, while the guard rolls, standing about 2 inches back of the saw, prevent it from slipping backward at the approach of the log.

The strain on the saw, by which slipping-off is prevented, is obtained by raising the upper wheel through worms or gears.

The strain should be, approximately:—

For 8-inch blade, 14 gauge, 7,000 lbs.
For 15-inch blade, 14 gauge, 12,500 lbs., &c.

The giant band saws at the C. A. Smith mill, Marshfield, Oregon, are worked with a tension of 22,000 lbs.

The maximum diameter of logs that can be handled by band saws is about 90 inches.

The weight of a band sawmill complete is 20,000 to 40,000 pounds.

(e) THE DOUBLE CUTTING BAND SAW. The saw blade has teeth on both edges, so that a board is obtained at each trip of the carriage.

In the "telescopic" double band mill, the entire machinery is raised or lowered by hydraulic pressure with a view to bringing the top of the logs immediately underneath the upper wheel.

IV. Conclusions.

(a) THE SUPERIORITY OF THE BAND OVER THE CIRCULAR SAW lies in a saving of approximately 1,000 board feet in every 16,000 feet of $^4/_4$-inch boards obtained. In heavier planks the saving is less, in lighter boards more. The boards obtained have a better width. Logs over four feet thick cannot be handled to advantage by circular saws. Further, the band saw allows of a more rapid feed. Hence it is used preëminently for valuable logs, for big logs, and for large output.

The band saw yields, on the other hand, a larger percentage of mis-sawn boards than the circular saw, under otherwise equal conditions. Circular sawn lumber runs more smoothly through the planers than does band sawn lumber.

Frequently mills of large output employ simultaneously band, circular, and gang saws,

Double cutting telescopic band mill. Allis-Chalmers Co., Milwaukee, Wis.

allotting the logs according to their quality, the best to the band saw and the poorest to the gang saw.

Two edgers and one trimmer can take care of such a combined output.

(b) MAMMOTH MILLS are now considered uneconomical, since it is difficult to take care of the output of boards at the outlet from the mill floor.

The output per mill hand in big concerns is up to 7,500 board feet daily.

Four acres of mill pond hold up to 1,000,000 board feet of logs.

(B) THE CARRIAGE.

I. The composing parts are: — The truck with head blocks, knees, dogs, setworks, and the driving machinery.

The carriage is subject to the roughest treatment. Still, its proper alignment is as essential as that of the saw:—
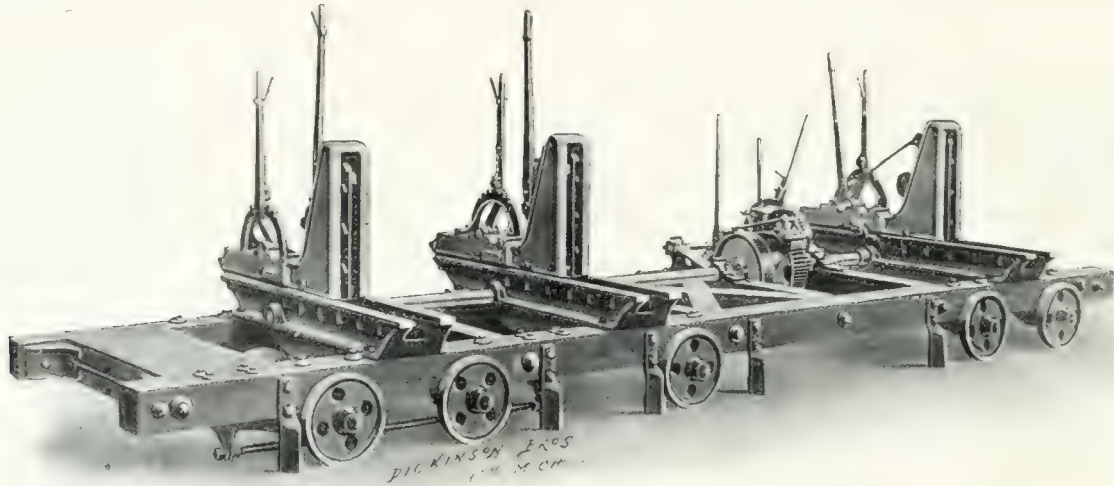
Carriage for sawmill. M. Garland Co., Bay City, Mich.

(a) THE TRUCK in small mills is made of timber at least 6 inches square, thoroughly seasoned and strongly braced and bolted.

Construction material is:—

Up North — Norway pine, birch, and maple.

Down South — yellow pine and white oak.

The length of the carriage should correspond with the maximum length of the logs.

So-called screw block trailers may be added, increasing the length (in longleaf pine mills) up to 72 feet.

(b) THE HEAD BLOCKS, iron with steel face, are let into the timbers of the truck and form a groove for the tongue of the knee, which slides on the head blocks, being moved forward and backward by the set works.

The head block and knee form a right angle into which the log is firmly pressed.

(c) THE KNEE is either solid or hollow and carries the dogs.

Head block, with knet and sed works. Wheland Machine Works, Chattanooga, Tenn.

The dogs are hooks or clamps or teeth, meant to grasp the log. They are fastened either inside or outside of the knee.

Two tooth bars, playing inside a hollow knee and pressed by a powerful lever, replace the original dogs in modern mills.

"Underdogs" are used in quarter sawing.

The number of head blocks, knees, and dogs is variable. The minimum is two of each.

(d) THE SET WORKS CONSIST OF:—

    1. The set beam, a shaft running underneath the carriage from head block to head block, with a pinion at each head block. This pinion corresponds with a rack forming the tongue or basis of each knee.

    2. The index disc and ratchet.

    3. The set lever, handled either by the sawyer, in small sawmills, or by the

Opening of knee on carriage.
Allis-Chalmers Co.,
Milwaukee, Wis.

...lled taper movement.

...vice or, on the gig motion

... the car.

... floor. The near wheels

... tire.

...the face of the log from

...feeding and gigging trips.

ERRATA:

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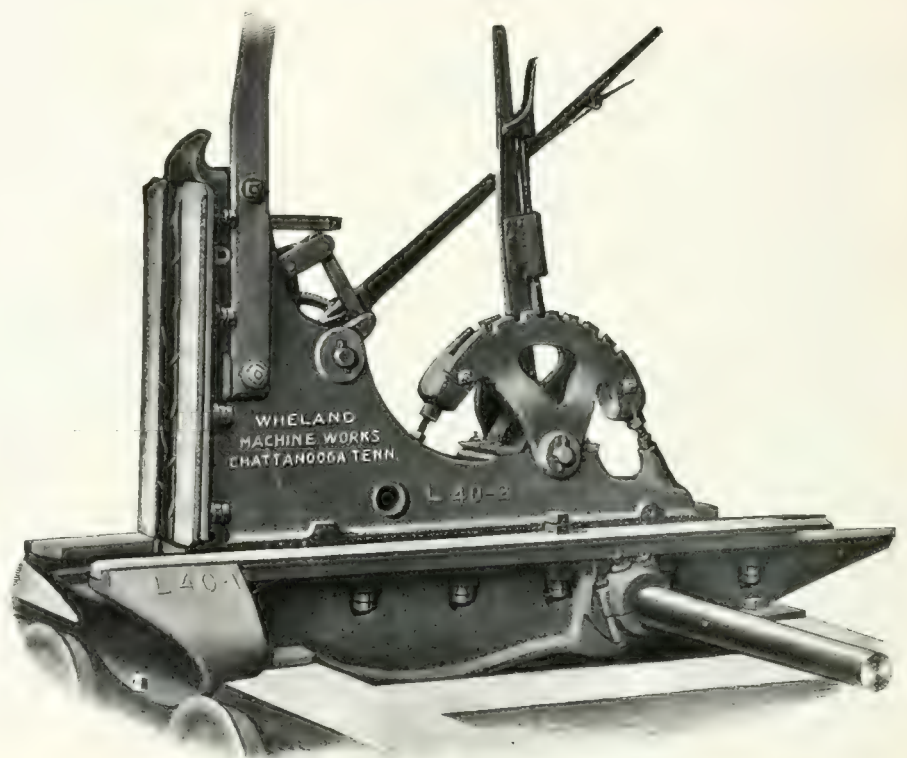
"Head block with knee and set works"
instead of
"Head block with knet and sed works".

    1. *Rack and pinion device.*

    2. *Chain, rope, or cable* running over one or several sheave drums.

The speed is regulated either by so-called cone pulleys (two, three, or four on the same shaft) or by a paper friction device.

The so-called Reamy Disc Friction allows of a variable speed.

The usal feed, with the cone pulley, is from $^3/_4$ inch to 3 inches per revolution of saw.

(b) IN LARGE MILLS (unless the logs are long) the piston of a steam cylinder pushes the carriage to and fro (so-called shotgun feed). In that case the carriage usually runs on three rails (center guide rail).

(C) ADDITIONAL PARTS OF HIGH GRADE SAWMILLS:—

I. "**The log haul-up**" (elevator) consists of a flanged foot wheel and an inclined trough, on the bottom of which runs a strong endless chain driven by sprocket wheels. The chain has steps (called welds) at intervals of about 6 feet.

The haul up is driven by a separate engine or from the main shaft by double gear wheels. It consumes a great deal of power.

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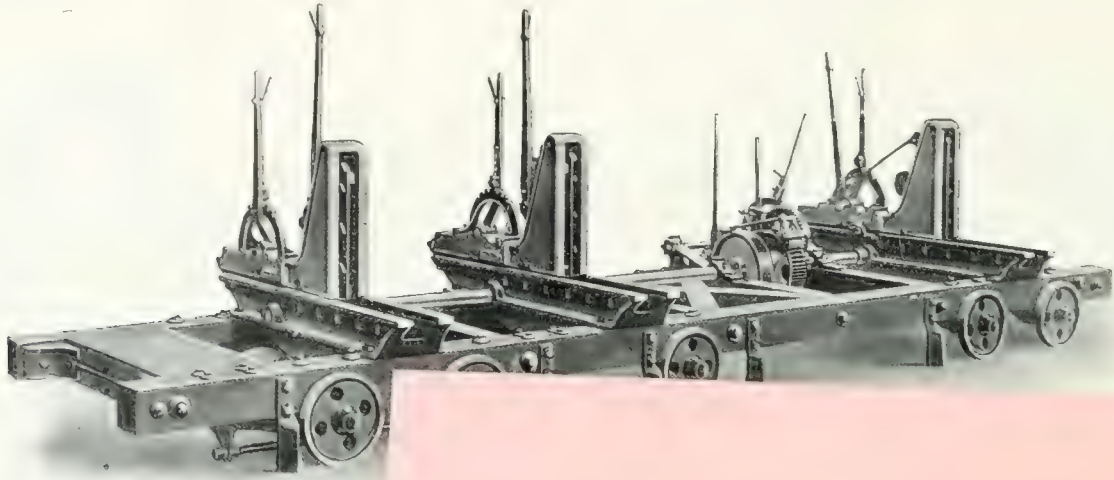
Carriage i

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Head block, with knet and sed works. Wheland Machine Works, Chattanooga, Tenn.

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    2. The index disc and ratchet.

    3. The set lever, handled either by the sawyer, in small sawmills, or by the setter, in larger mills.

Opening of knee on carriage.
Allis-Chalmers Co.,
Milwaukee, Wis.
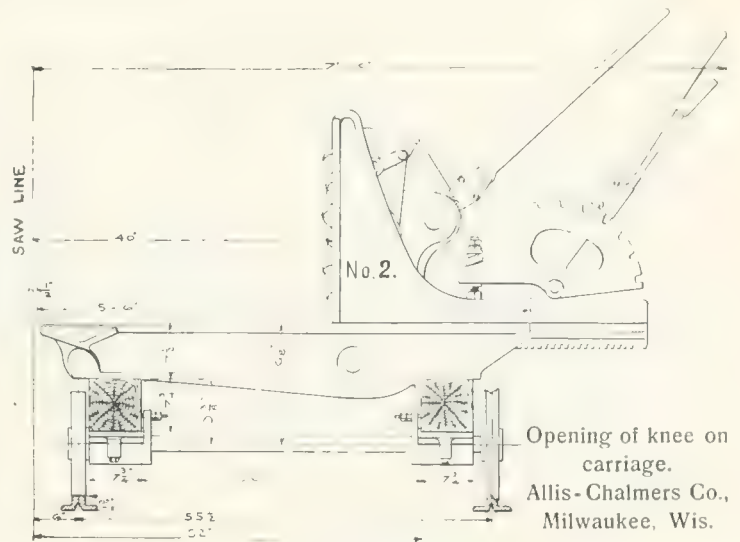
The set works are usually double acting, so that the knees advance with the to and fro motion of the set lever.

In addition, each knee can be moved individually on its rack by the so-called taper movement.

Rope driven and steam driven setworks are largely used in modern mills.

The knees, before a new log is loaded, are receded either by a spring device or, on the gig motion of the carriage, by a friction device.

The brake wheel on the setshaft acts as a buffer when logs are loaded on the car.

(e) THE WHEELS. The wheels are attached either to the carriage or to the floor. The near wheels are flat on the tire and the far wheels, called guide wheels, are grooved on the tire.

In single cutting band mills an automatic off-set is required to prevent the face of the log from striking the saw on the gig motion.

The steel rails are invariably placed on stringers.

II. Driving machinery. The to and fro trips of the carriage are known as feeding and gigging trips.

(a) IN SMALL MILLS the motive power is derived from the saw arbor by:–

    1. *Rack and pinion device.*

    2. *Chain, rope, or cable* running over one or several sheave drums.

The speed is regulated either by so-called cone pulleys (two, three, or four on the same shaft) or by a paper friction device.

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The usal feed, with the cone pulley, is from $3/4$ inch to 3 inches per revolution of saw.

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I. "The log haul-up" (elevator) consists of a flanged foot wheel and an inclined trough, on the bottom of which runs a strong endless chain driven by sprocket wheels. The chain has steps (called welds) at intervals of about 6 feet.

The haul up is driven by a separate engine or from the main shaft by double gear wheels. It consumes a great deal of power.

At the upper end of the haul up, a log flipper "boxes" the logs out of the trough onto the log deck, which is usually inclined toward the carriage.

On the log deck, the logs are freed from dirt and bark by hand.

II. "**The nigger,**" handled by the sawyer, throws the logs on the carriage and turns them by a boxing movement.

III. "**The hog**" is a steel box within which the edgings and trimmings are cut into small slices by very strong knives rapidly rotating.

IV. "**Dust conveyors**" convey the output of the hog and the sawdust automatically to the boilers or to the burner.

(D) THE EDGER. The boards, falling from the log, are conveyed automatically or by hand to the edger.

I. **Parts of the edger are:—**

(a) One or several circular saws of 12 inches to 28 inches diameter;

(b) Feed works, either power or hand driven, consisting either of a carriage or of feed rolls or of barbed chains by which the boards are fed into the saws;

(c) Edger table.

II. **Task of the edger is:—**

(a) Removal of defects, knots, wany edge, &c., at the side of a board;
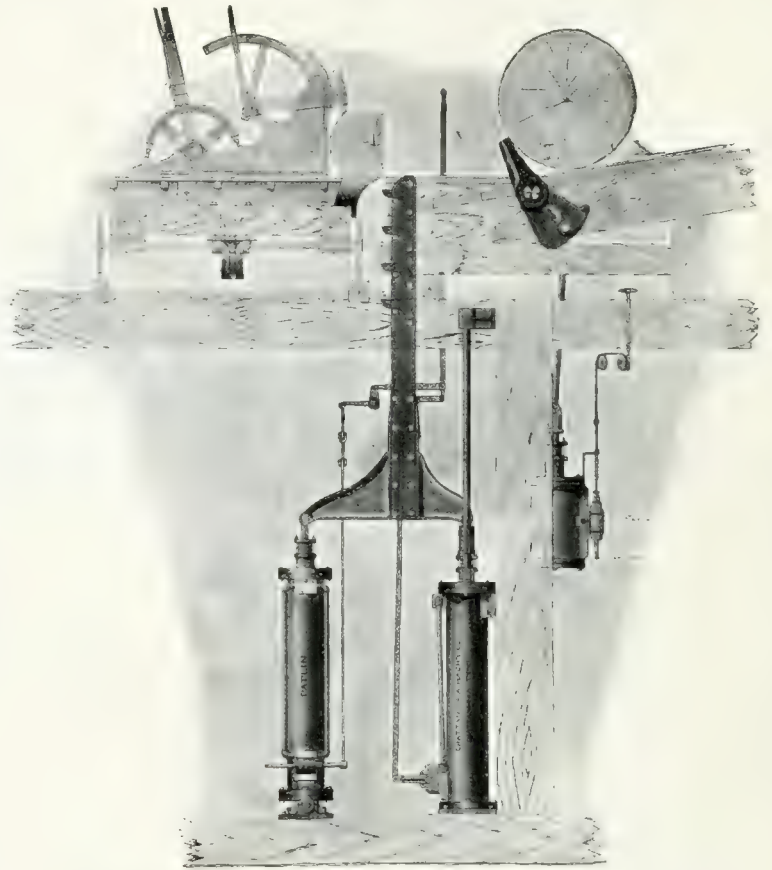
Steam nigger. Wheland Machine Works, Chattanooga, Tenn.

Mill pond and log haul-up of Champion Lumber Co., Crestmont, North Carolina.

Waste conveyor and open burner at a Maine sawmill.
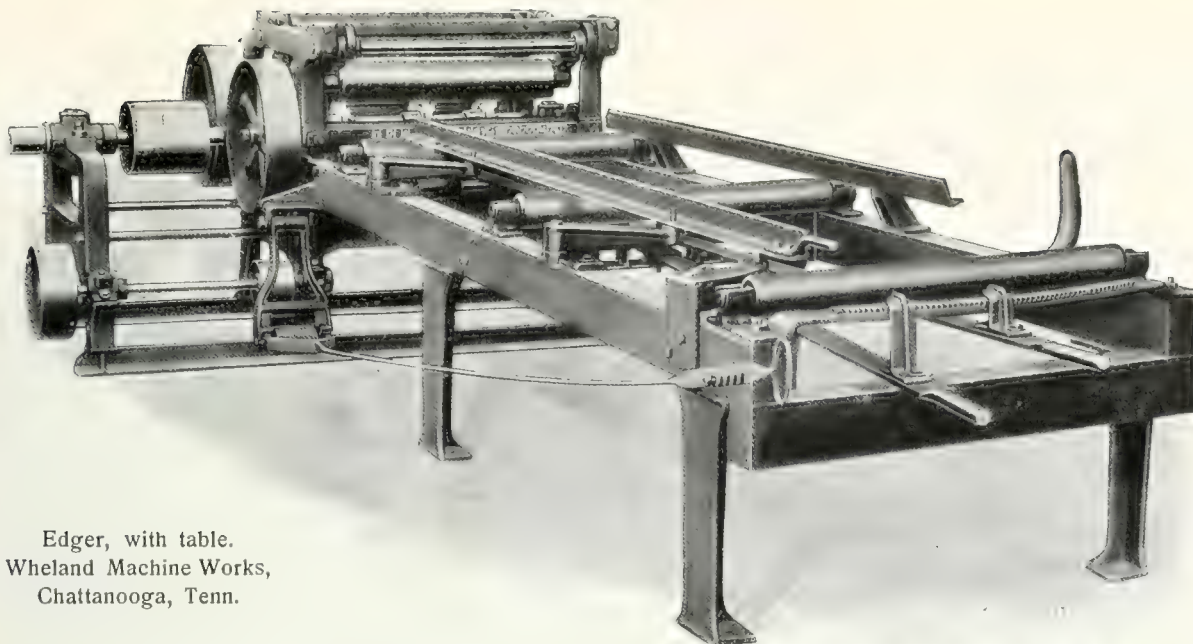
Edger, with table.
Wheland Machine Works,
Chattanooga, Tenn.

(b) Splitting boards into pieces of different quality;

(c) Rapid sawing of lumber to proper width required for special purposes.

III. Kinds of edgers:—

(a) Hand feed edger, with one or two saws;

(b) Power feed edger, usually with a single saw;

(c) Gang edger.

IV. Pointers:—

(a) The distance between the various saws in gang edgers is regulated by overhead levers or by hand wheels;

(b) Several boards can be fed at one time;

(c) The attendant of the edger must be aware of the intricacies of lumber inspection, so as to turn out the maximum value of edged product;

(d) The boards are conveyed by hand from the edger to the trimmer.
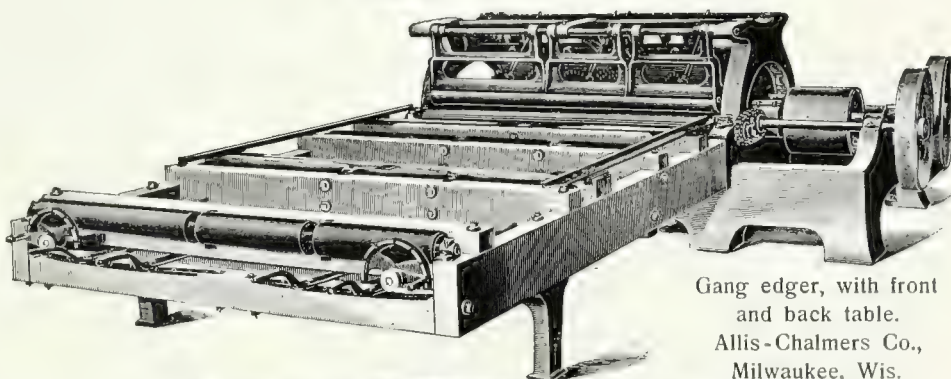
Gang edger, with front and back table.
Allis-Chalmers Co.,
Milwaukee, Wis.
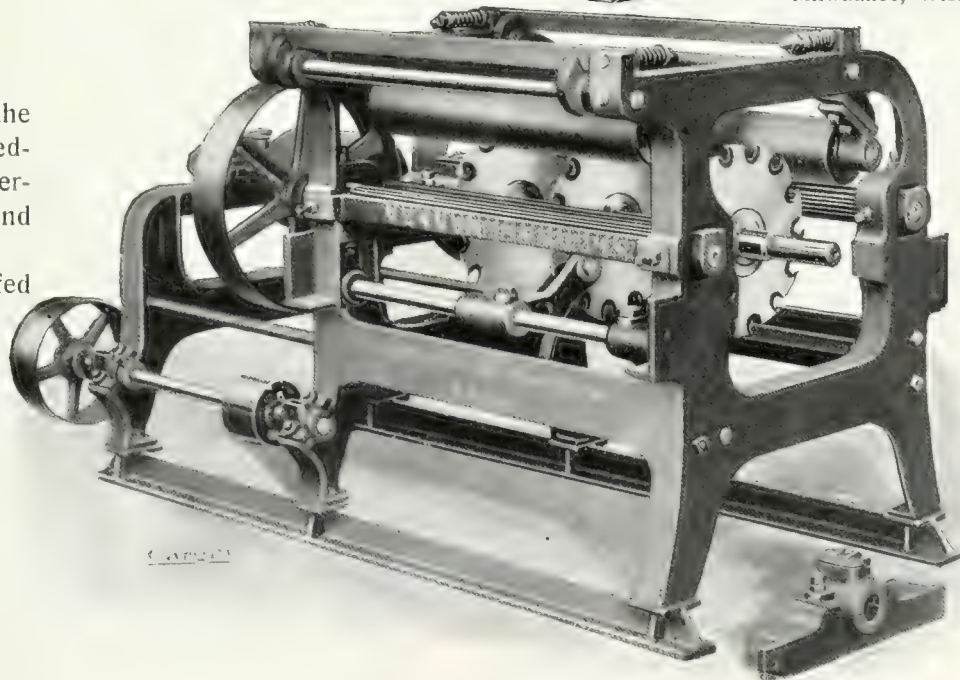
Edger, without table, the saws with inserted teeth. Wheland Machine Works, Chattanooga, Tenn.

(E) THE TRIMMER. In large mills, trimming follows edging. In small mills, edging follows trimming.

I. Parts of the trimmer are: —

    (a) One or several circular saws about 18 inches in diameter. A one-saw trimmer is called a "cutoff;"

    (b) Feed works, viz. live rolls or carriage or barbed chains running over sprocket wheels;

    (c) Table.
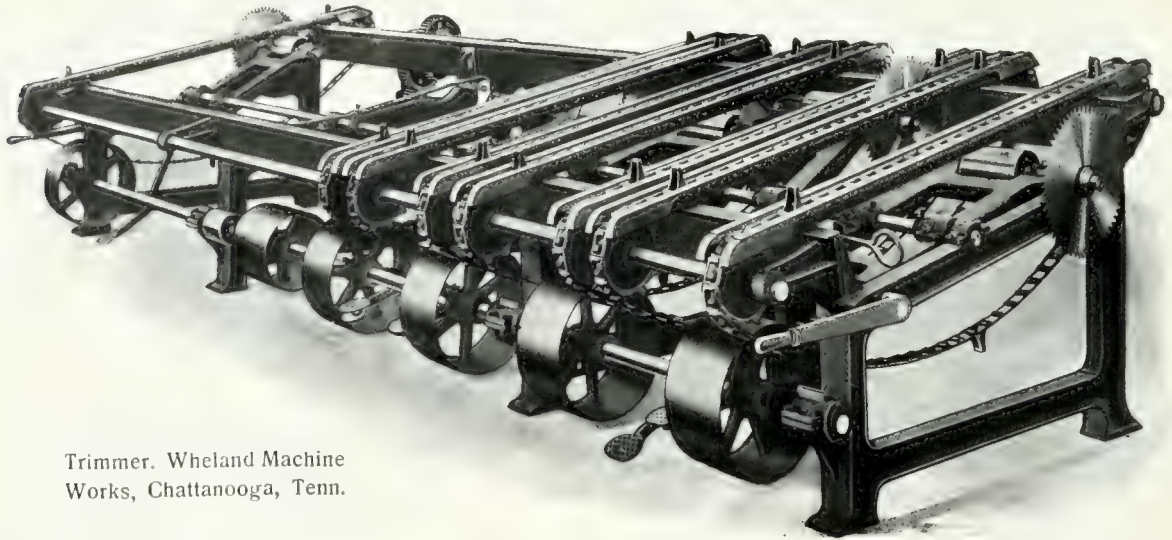
Trimmer. Wheland Machine
Works, Chattanooga, Tenn.

II. Task of the trimmer is: —

    (a) The shortening of boards to standard lengths allowing 2 inches extra for shrinkage;

    (b) The removal of defects at either end, so as to raise a board into a higher grade;

    (c) The cutting of straight ends.

III. Pointers.

    (a) Where two saws are used, the distance between them is changed by a lever or by a screw wheel, shifting one of the saws, while it is in motion, along the shaft;

    (b) Chain power fed trimmers are used in all large mills. The saws are either jump saws, easily pushed from below the table, or swing saws, hanging above the table and, similarly, pressed down by the attendant by a touch on hand or foot levers.

(F) YARD WORK (SORTING AND PILING).

I. Sorting. The board after leaving the trimmer is taken up by a chain or cable conveyor and passes by the lumber inspector, who pencil-marks its quality.

The various qualities are either at once thrown into parallel gutter conveyors, leading to separate chutes, below which a waggon or truck is in waiting, or are transferred to the piles by endless chain conveyors, by hand

Yellow poplar lumber yard of the Biltmore Estate.

trucks and waggons. Frequently elevated roads traverse the yard on which and below which such conveyance takes place.

II. Piling. The foundation blocks should be large and should not be subject to rot. Concrete blocks costing 10 cents each are used in the most modern yards.

Strong, high, horizontal ground sills are of the utmost importance. The front sill should be higher than the middle and back sills, except in shed drying.

In some yards the front of the piles is given an overhanging "batter," to protect it from rain, an arrangement feasible only in low piles. The usual pitch of the pile is 1 foot in 10 feet.

The tiers of boards are kept apart by three or four well seasoned cross pieces called "stickers," sawn 1 inch thick, usually.

White maple, basswood, and buckeye are particularly subject to "stickrot."

The usual width of the piles is from 6 to 10 feet.

The distance between the piles is at least 1 foot and should be 3 feet.

In order to prevent end cracks, the sticking should be placed exactly at the ends or slightly projecting over the ends.

If the boards are not sawn to exact length, it is wise to have the "overlaps" long. Overlaps of 3 to 6 inches are almost sure to split. Long overlaps are less subject to splitting.

Each pile must contain equal lengths. Boards of odd lengths (e. g., 11 feet long) are placed in the pile containing the next longer even length of board (e. g., 12 feet long).

Valuable wide boards and heavy planks are often painted at the ends, or "end-cleated."

Panels of yellow poplar and the best grade of white maple are shed-dried, the boards being placed exactly vertical, without stickers between the tiers. By these means, any pressure of one board against another is prevented.

Oak, ash, hickory, and elm require at least four months for air drying; lynn, poplar, and pine about two and a half months.

Slow drying involves danger from sap stain, loss of interest, large yard room, large insurance, and slow filling of orders. Still, in the case of high-grade heavy hardwoods, the immediate and unrestricted use of the dry-kiln is disastrous to green lumber.

The largest lumber shed on the Atlantic Coast at the John L. Roper Mill, New Berne, North Carolina.

In summer, sappy hardwoods might be put to the dry kiln for a few hours at a low temperature, before being yarded; or they are dipped into or sprinkled with a 5 per cent to 10 per cent solution of (lukewarm) sodium bicarbonate when they come from the saw.

Thin lumber does not check as badly as thick lumber. Squares check worst of all.

A fermentation and incidentally a discoloration takes place where two fresh sawn surfaces touch one another.

Each pile should have a roof 12 inches high in front and 6 inches high in back, projecting in all four directions over the pile.

Proper curing of lumber is as important as is proper sawing of lumber.

III. Dry kiln. A dry kiln consists of:—
    Shed with gates or curtains closing tightly.
    Lumber conduit.
    Heating apparatus.

The heat is supplied either:—
    By a hot-air fan.
    Or by a system of steam pipes.
    Or by steam admitted into drying room.

The air in the dry kiln must be kept in constant motion, so as to prevent the lumber in the piles from drying unequally.

Lumber can be more evenly dried by steam than by hot air.

Sap water converted into steam expands 1,670 times. Consequently, wood kept at 212 degrees would retain only a small portion of the water originally contained in it. In the dry kiln, the temperature is raised slowly to 160 degrees. It should never be allowed to reach steam heat.

No two dry kilns are absolutely alike in the proper method of handling, in the manner in which the temperature should be guided, and in their efficiency under seemingly identical conditions. The effect of a dry kiln depends on its geographic location, and also on the weather of the four seasons of the year. Each kind and each thickness of lumber requires a special study. The moisture of the lumber itself, as it goes to the kiln, must be carefully considered. The foreman in charge of a new kiln must become acquainted with it, by watching it carefully and conscientiously, before the best results can be obtained. Nothing must be left to haphazard.

Leading manufacturers of dry kilns are the Standard Dry Kiln Co., Indianapolis, Ind.; the Grand Rapids Veneer Co., Grand Rapids, Mich.; the National Dry Kiln Co., Indianapolis, Ind.; and B. F. Sturtevant & Co., Hyde Park, Mass.
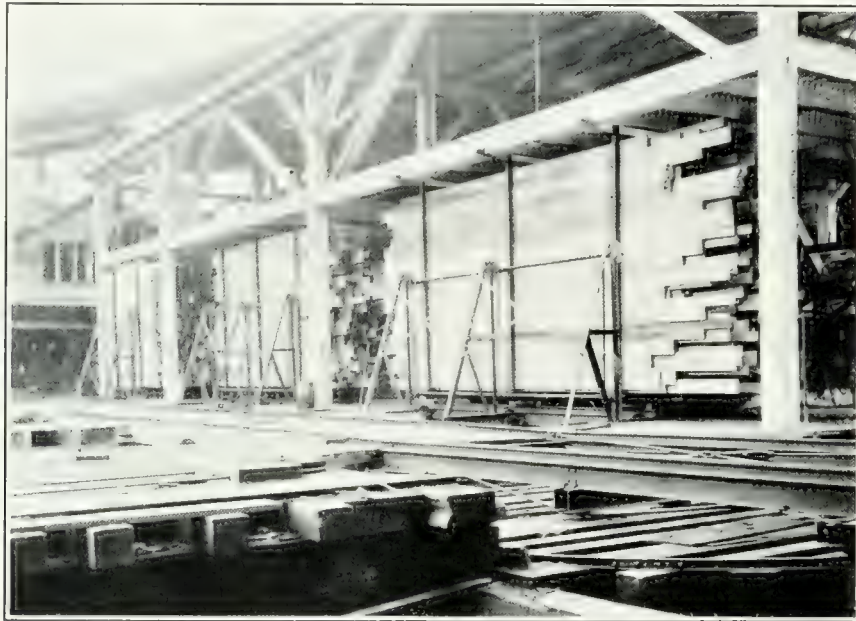
Dry kiln cars automatically stacked by stacker of North Coast Dry Kiln Company, Seattle, Wash.

Quite recently, successful experiments have been made with the "preparation" of lumber prior to kiln drying.

The Krætzer steam cylinder preparator, manufactured by the Krætzer Company, 537, South Dearborn St., Chicago, Ill, consists of a horizontal steel cylinder that can be sealed hermetically with great ease and into which the lumber, loaded on small cars, is placed. In lieu of stickers, wire screen is used.

The lumber is placed into this steam cylinder green from the mill.

Live steam is admitted, under pressure, for a number of minutes. The Krætzer preparator is not a dry kiln. It shortens, however, the dry kiln process. It prevents staining, checking, and end-splitting; it secures, after kiln drying, a reduced weight in the lumber.

An automatic stacker for lumber going into the dry kiln is used largely in the South and also in the West. The lumber is delivered to the stacker on endless rolls and is placed, not horizontally but vertically onto the dry kiln cars. Similarly, an automatic unloader for dry kiln cars is being used, the lumber being taken up by the welds of endless chains, automatically, tier after tier.

PARAGRAPH XX.

THE WOOD WORKING PLANT.

(A) PLANING (surfacing, dressing, or sizing). The planer consists of cylindrical cutter heads carrying from two to six knives and making 3,000 to 5,000 revolutions per minute. It is belted preferably at both sides.

The smaller the diameter of the cylinder with its knives, the smoother is the planing.

The feeding is done either by two to four feed rolls (above) and friction rolls (below), or by a travelling bed. The entire cutting length of the knives should be uniformly used. The top cutter should do the heavier work in double surfacers.

The "wedge platen" device patented by the S. A. Woods Machine Company, Boston, Massachussetts, allows of relieving or of increasing instantaneously either the upper or else the lower cut of a double surfacer, without altering the final thickness of the finished product.

The knives are usually sharpened automatically.

The lumber is fed into the machine, with the grain, at the rate of 20 feet to 150 feet per minute. Hardwoods are fed more slowly than softwoods

The chip breaker is a front pressure bar preventing long splinters from being torn off.

Price of single planers is $100 to $400; of double planers $400 to $800.
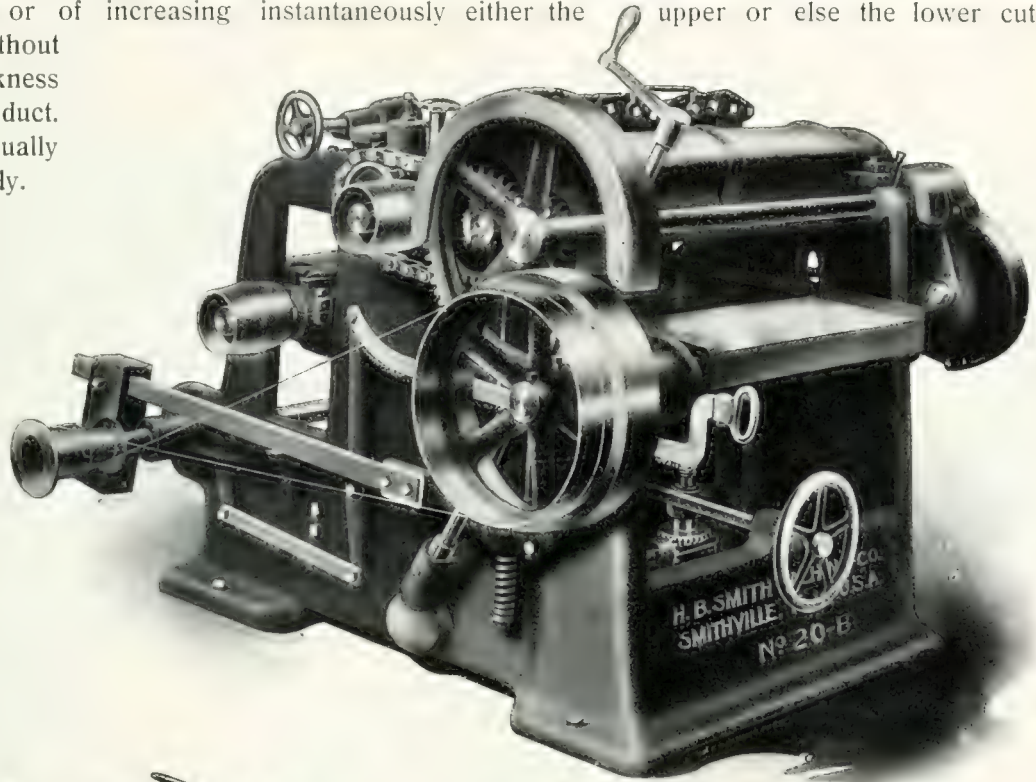
Twenty-four-inch by eight-inch surface planer, with divided feed rolls and divided chip breaker. H. B. Smith Machine Co., Smithville, N. J.
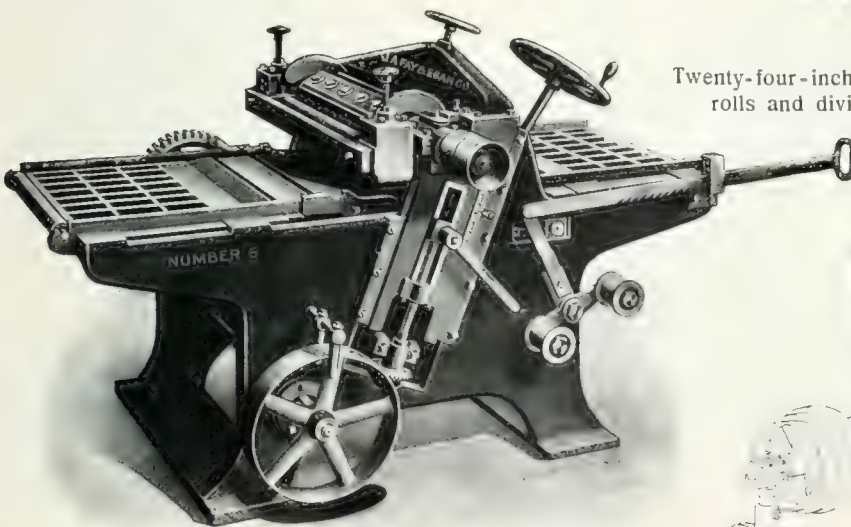
Endless bed surfacer. Fay & Egan, Cincinnati, Ohio.   Surfacer No. 206. Fay & Egan, Cincinnati, Ohio.
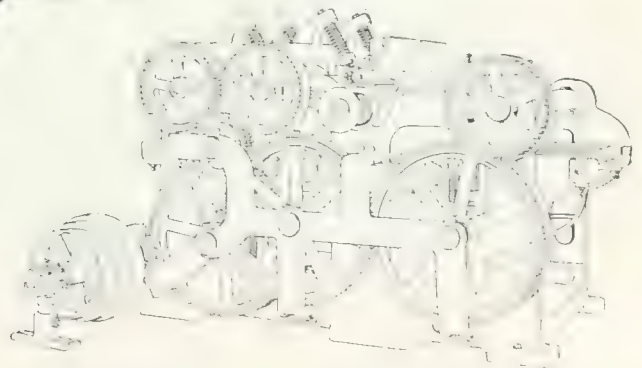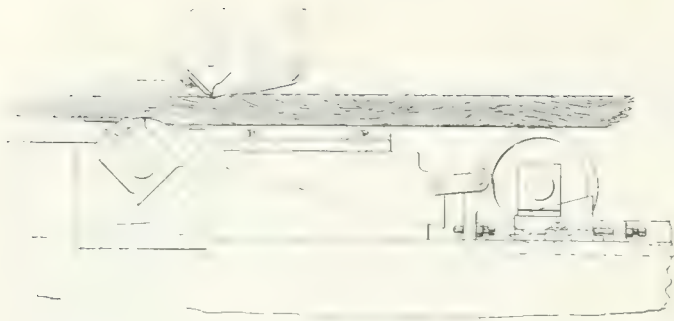
Wedge platen, length profile. The upper cut is heavier than the lower cut. S. A. Woods Machine Co., Boston, Mass.
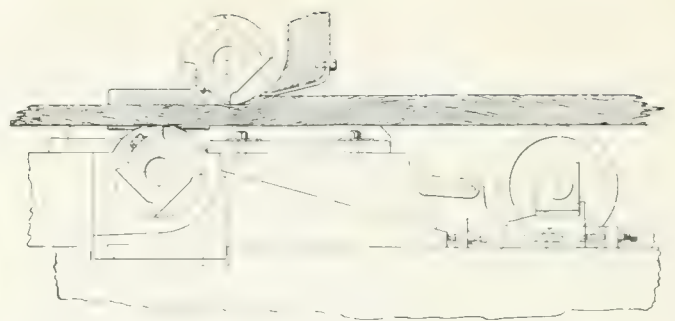
Wedge platen, length profile. The lower cut is heavier than the upper cut. S. A. Woods Machine Co., Boston, Mass.
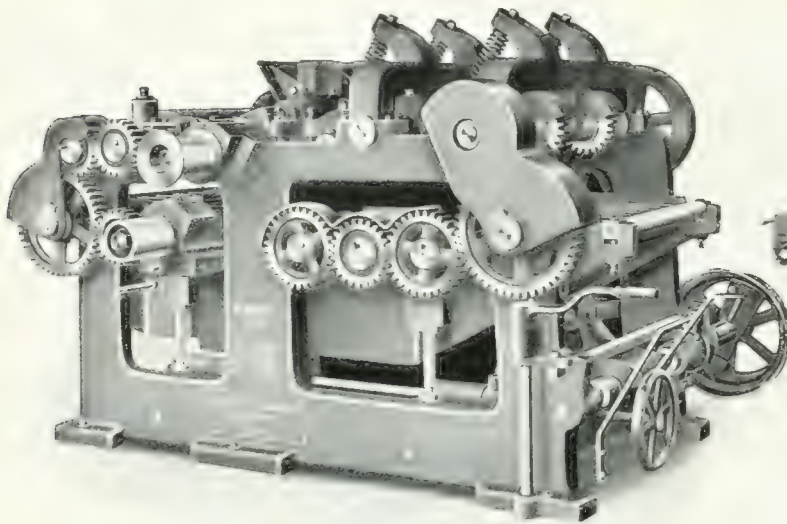
Surfacer No. 206.   Fay & Egan, Cincinnati, Ohio.
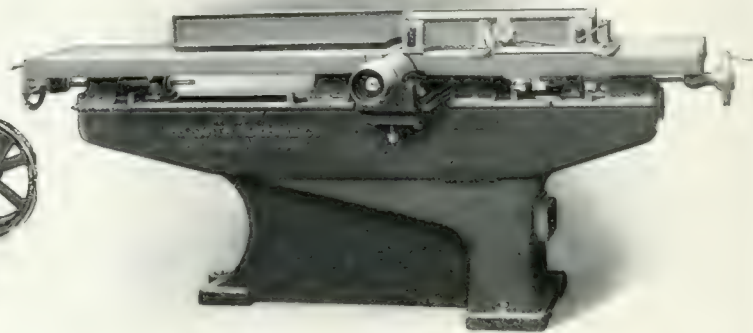
Hand planer and jointer, rear side view. H. B. Smith Machine Co., Smithville, N. J.
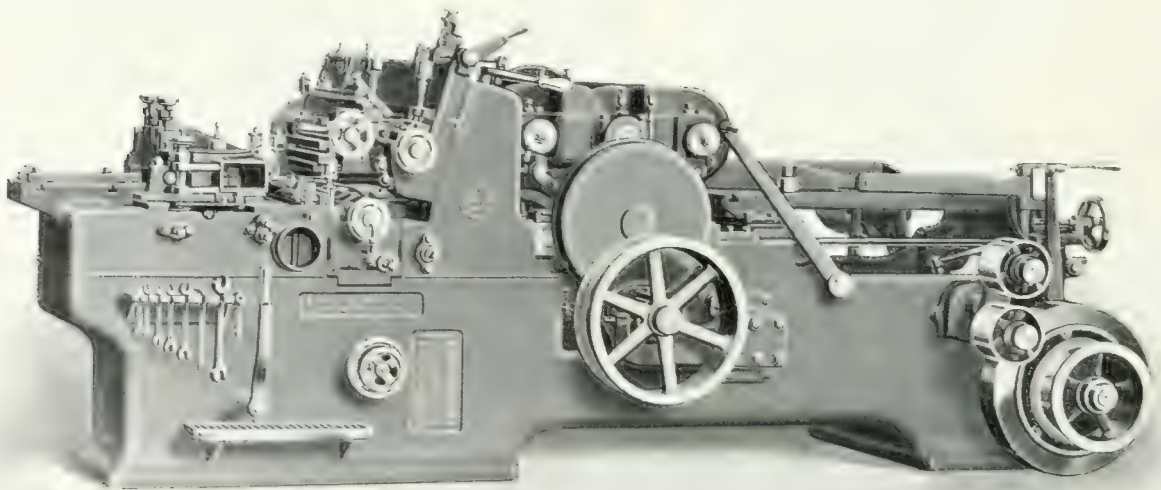
Four-roll high speed planer No. 403. S. A. Woods Machine Co., Boston, Mass.
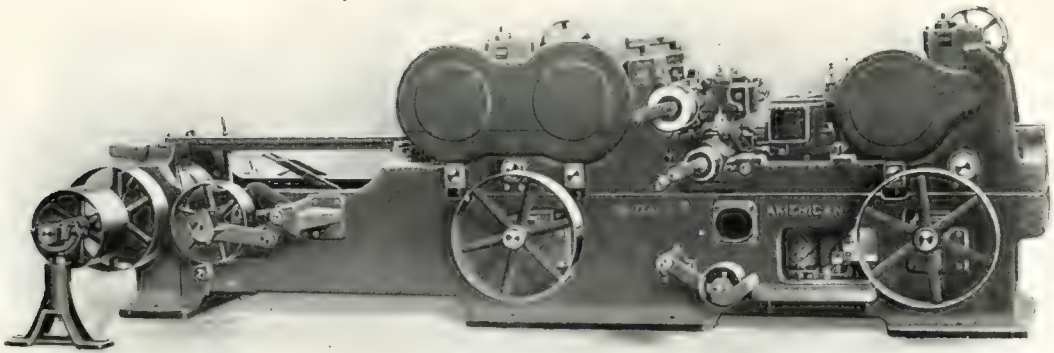
Planer and matcher (floorer). American Woodworking Machine Co., Rochester, N. Y.
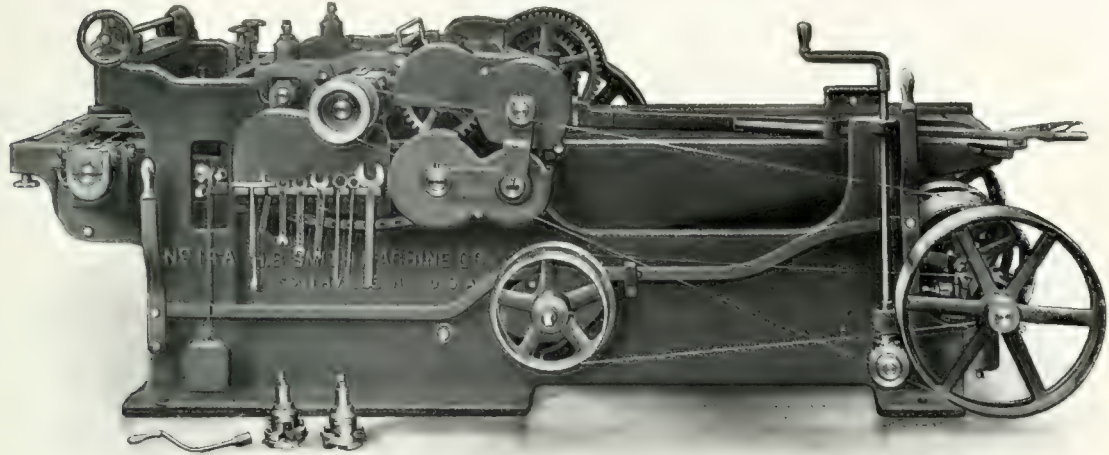
Planer and matcher (floorer). H. B. Smith Machine Co., Smithville, N. J.
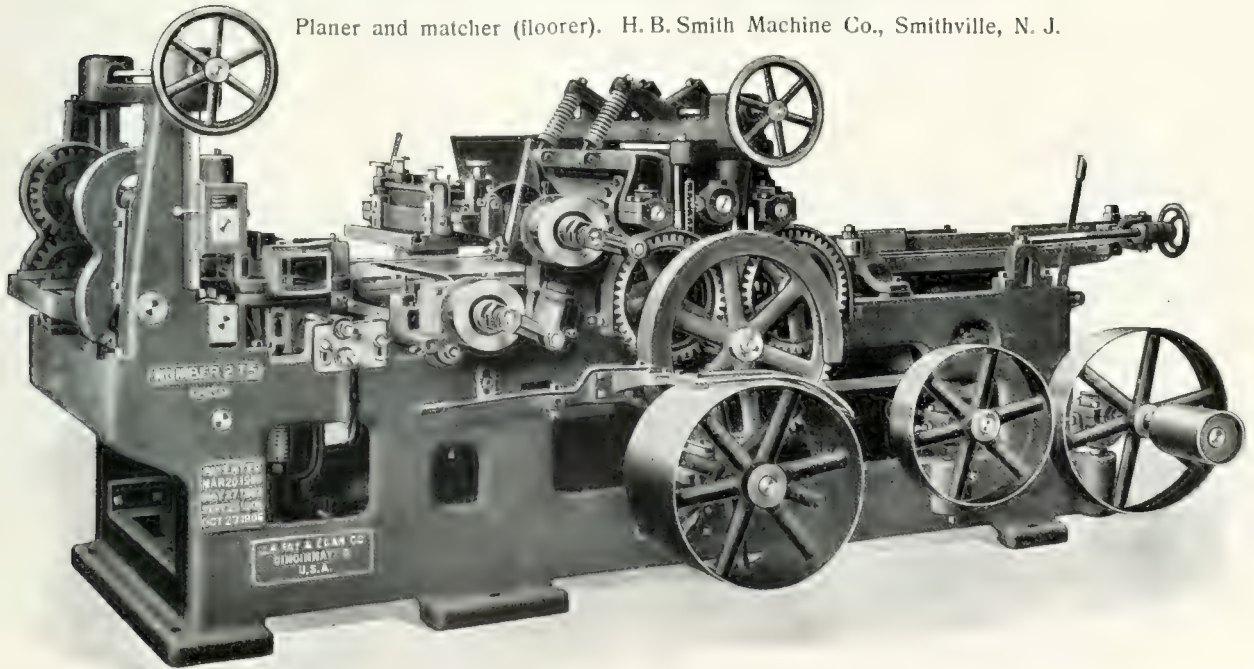
Planer and matcher (floorer) No. 275. Fay & Egan, Cincinnati, Ohio.

(B) FLOORING. The flooring machine is a double surfacer having an additional outfit of two side cutters revolving on ratchet spindles and cutting tongues and grooves.

The machine weighs 5 tons and more.

The usual flooring made is oak, pine, maple, beech, birch, and red fir flooring.

Planers and flooring machines must be provided with folding hoods connected with blowers or exhaust fans, so as to prevent the shavings from clogging up the machinery or from pressing themselves into the planed surfaces.
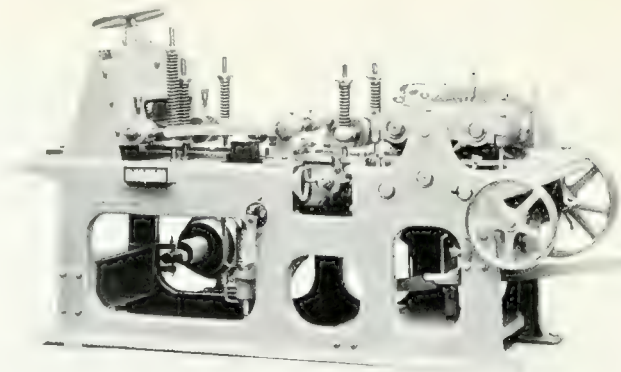
Planer and matcher, made by Schmaltz, Offenbach, Germany.
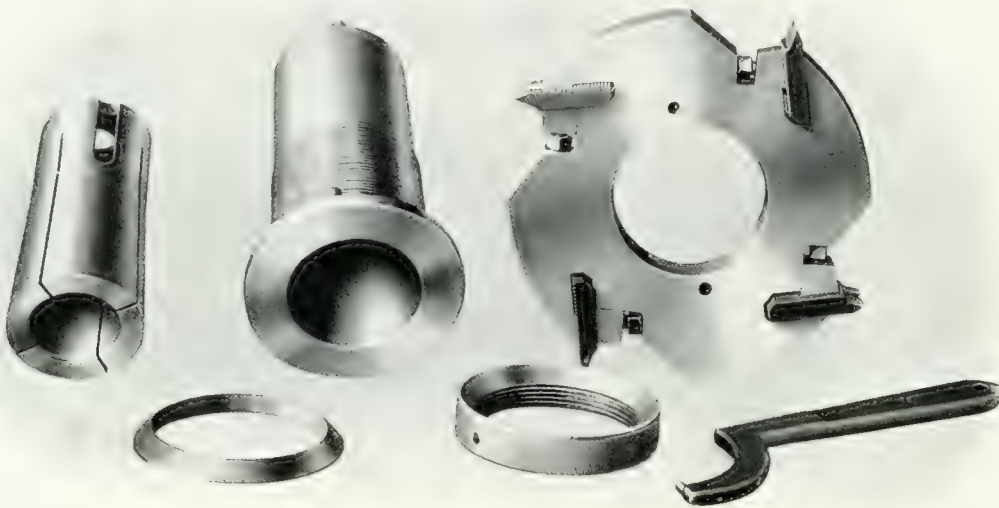
Parts of tongue flooring head taken apart.
S. A. Woods Machine Co., Boston, Mass.

Flooring head (side head). S. A. Woods Machine Co., Boston, Mass.
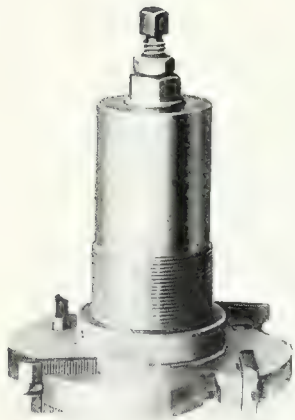
Flooring head (side head). S. A. Woods Machine Co., Boston, Mass.

The proper alignment of the various bits or knives in a given cutter-head presents a problem of extreme difficulty. To begin with, the operator may succeed in adjusting the cutting edges so as to make them partake in one and the same mathematical circuit: — Still, a difference in the temper of the steel of the cutters, however slight, will allow one edge to become dull quicker than the other; or centrifugal force will throw the heavier and the lighter of two cutters out of the original alignment. This danger is great particularly with speeds exceeding 4,000 revolutions per minute. When the bits are getting dull, after two hours of work in hard wood, the tongues made at the beginning of the period will fail to catch the grooves made at its end.

Automatic truing devices may be used, whilst the machine is in operation, to secure a high degree of uniformity in the work performed.
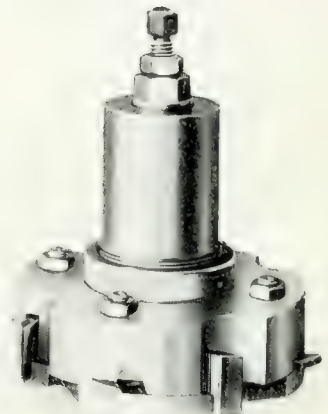
(C) RESAWING. Resaws are either circular or band resaws.

The use of a resaw involves a great saving, since it takes a fine kerf and at the same time relieves the work of the main saw.

A resaw working tandem with the main logsaw is capable of increasing the output of the mill greatly. The C. A. Smith mill at Marshfield, Oregon uses a quintuple system of five large band resaws in connection with two main saws.

The feed is automatic and consists, usually, of four rolls.

Circular resaws have as low as nineteen gauge at the rim and are frequently built as segment saws.

Band resaws are either vertical or horizontal. The horizontal resaw offers the following advantages:—

1. It can be used for the simultaneous passage of several planks.
2. Pieces of different thickness, and notably slabs, can be fed without change of the rolls.

The feed in horizontal resaws is by travelling bed or by endless chains. The boards or slabs are held down by pressure rolls overhead.
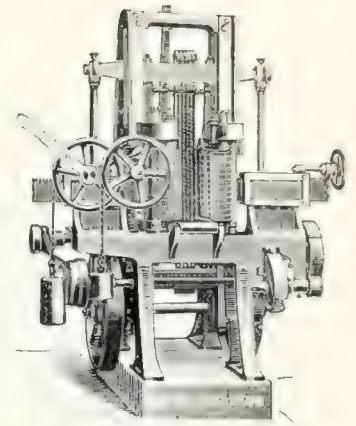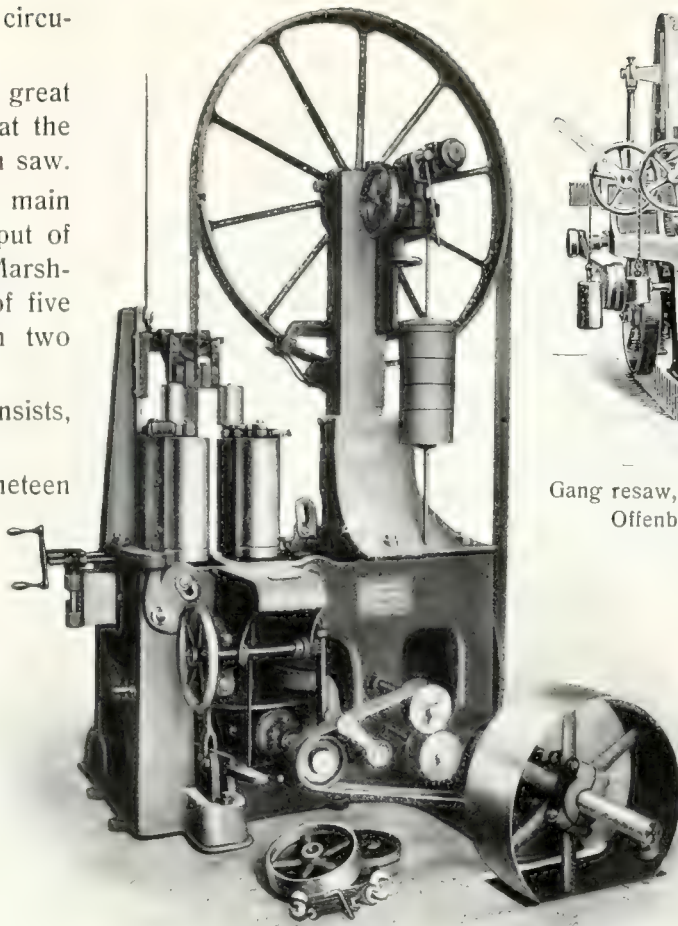
Gang resaw, made by Schmaltz, Offenbach, Germany.

Mershon band resaw.
W. B. Mershon Co., Saginaw, Michigan.
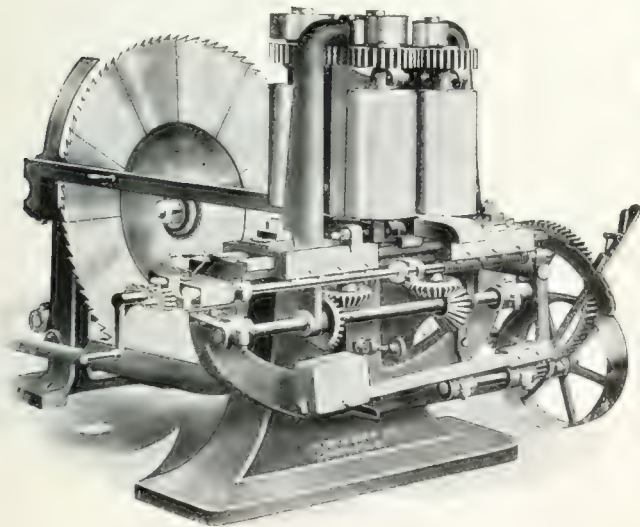
Circular resaw, front view. Fay & Egan, Cincinnati, Ohio.
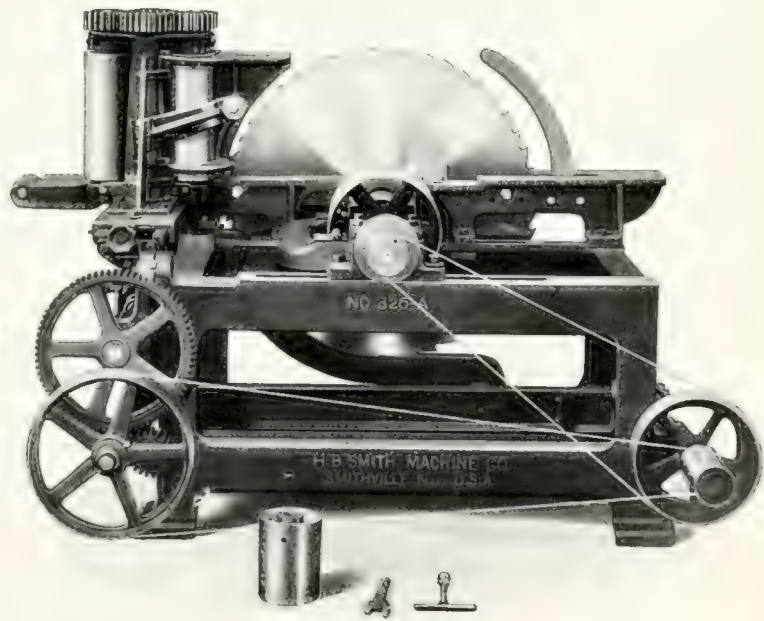
Circular resaw, side view. H. B. Smith Machine Co., Smithville, N. J.

(D) RIPPING. The ripsaw is a circular saw or a bandsaw (Fay & Egan) running on a bench and allowing, by a gauge arrangement, to cut any desired width of board or strips. It is either hand fed or power fed.

A power fed gang ripsaw is an edger.
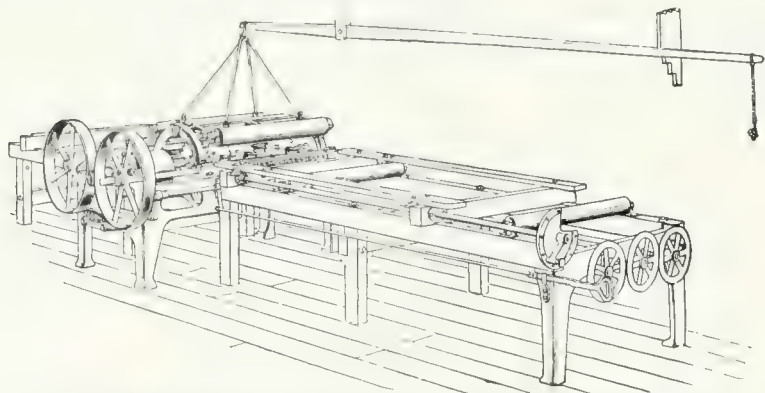
Self feed gang ripsaw and edger. Fay & Egan, Cincinnati, Ohio.
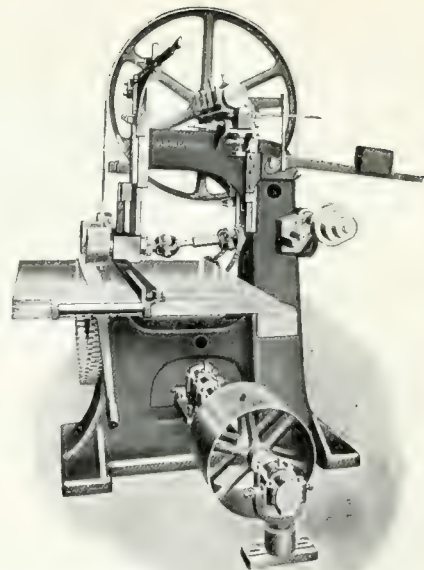
Band ripsaw No. 202. Fay & Egan, Cincinnati, Ohio.
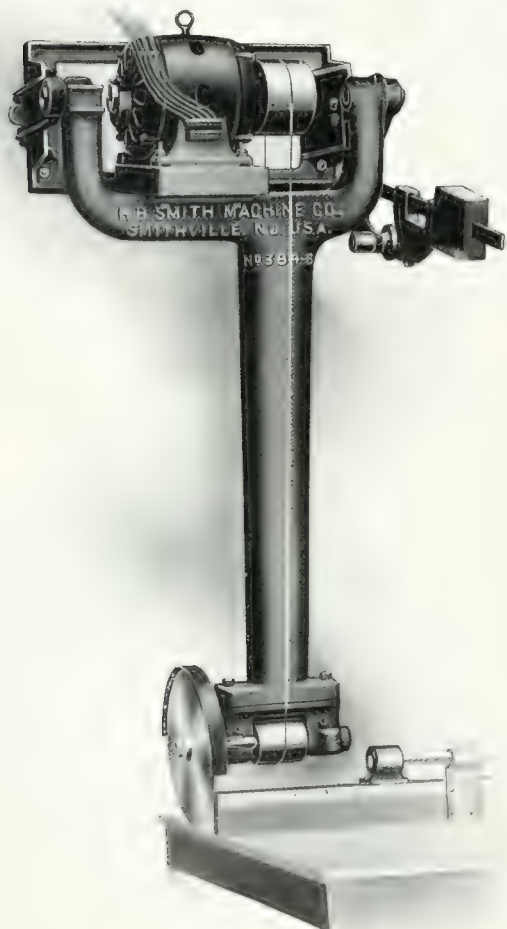
Swing cut-off saw, driven by electric motor.
H. B. Smith Machine Co., Smithville, N. J.
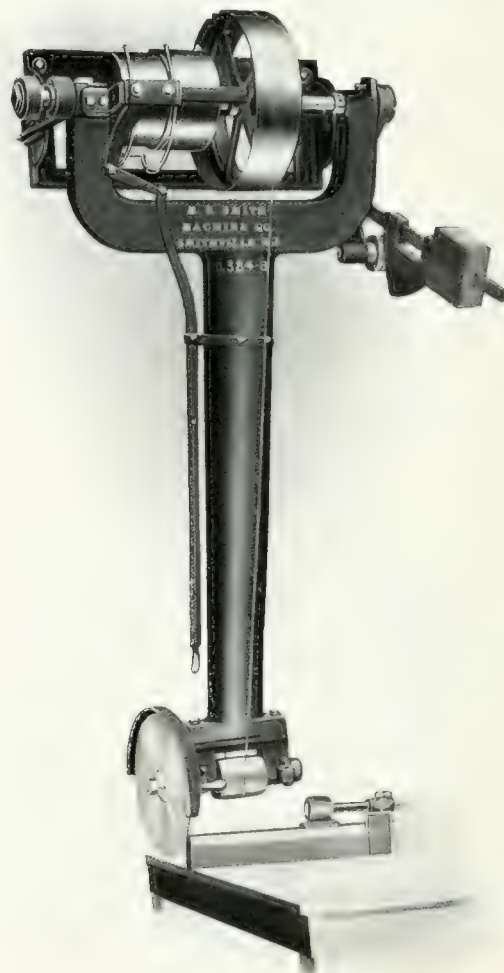
Swing cut-off saw, belt driven.
H. B. Smith Machine Co., Smithville, N. J.

(E) CUT-OFF SAWS. Cut-off saws are either swing saws, jump saws, or stationary saws with carriage moved by hand or automatically, or travelling railway cut-off saws when the saw is moved horizontally against the timber.

(F) SANDPAPERING.

1. Belt sandpapering, for carriage spokes, axe handles, table legs, buggy poles, &c.
2. Disc sandpapering, notably for boxes.
3. Spindle sandpapering, for small toll handles.
4. Swinging post sandpapering.
5. Cylinder drum sandpapering, with two, three, or four "rolls."

The object to be sandpapered is fed onto the machine by hand, excepting case 5.
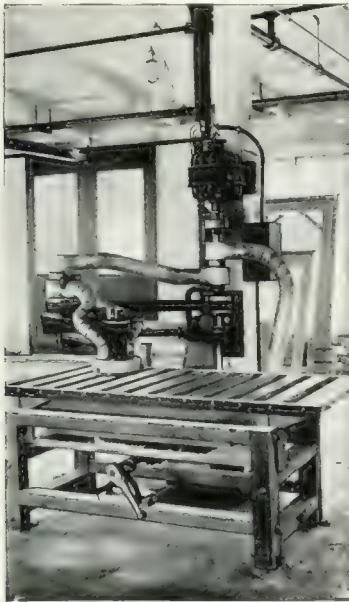
Triple drum sander, left-hand side view. H. B. Smith Machine Co., Smithville, N. J.

Post sander, electrically driven. Westinghouse Electric Co., East Pittsburgh, Penns.
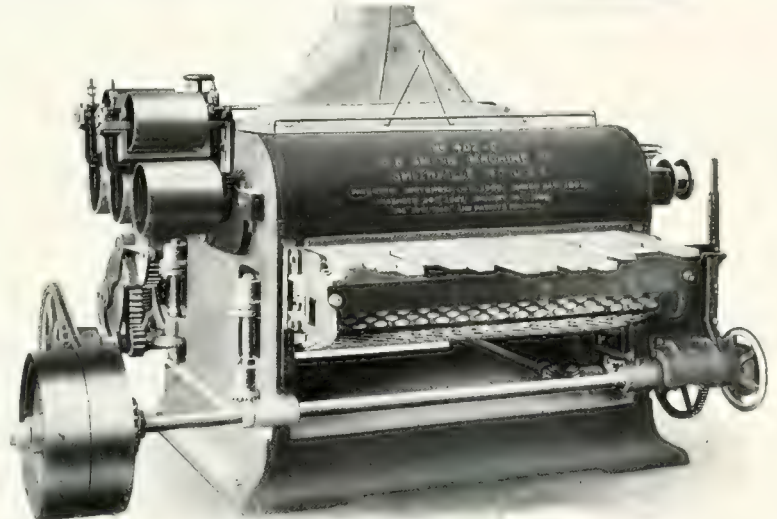
Triple drum sander, endless bed feed, front view. H. B. Smith Machine Co., Smithville, N. J.

(G) SCRAPING. By "scraping" is understood the removal of an extremely thin (not over $\frac{1}{64}$ inch) layer of tissue from a planed surface. It is meant to replace and to cheapen the process of sandpapering, and is not intended to reduce the thickness. The scraper consists of power driven, smooth feed rolls and of one or two stationary knives, over which the boards are passed. Corky or stringy lumber cannot be scraped.

(H) MITERING. In mitering the stock is run along the so-called "fence" against a circular saw, the plane of which forms a variable angle with the plane of the saw table.

Outside molder No. 209. Fay & Egan, Cincinnati, Ohio.
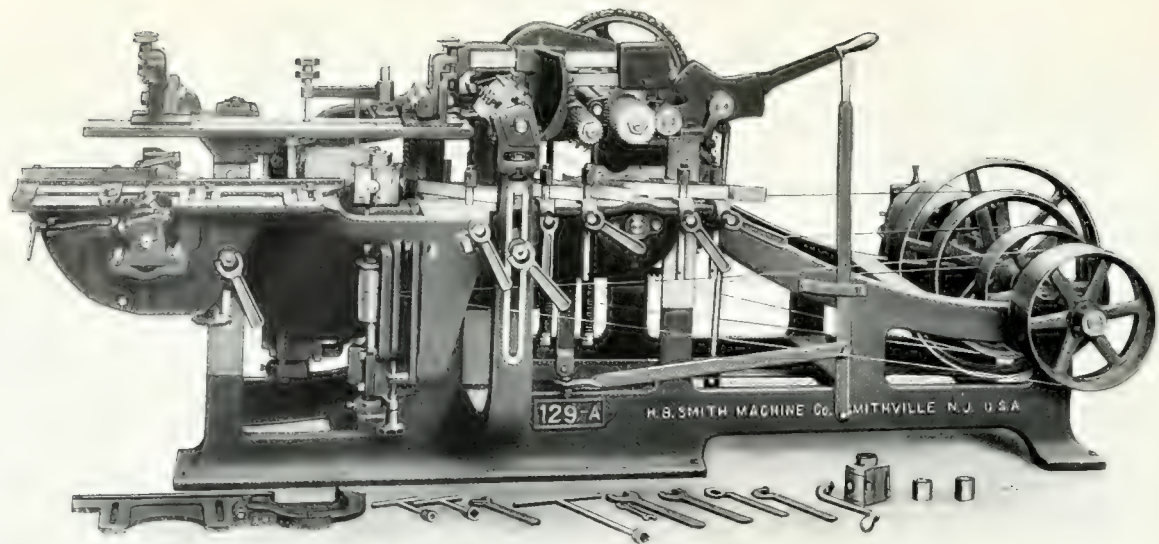
Six-inch heavy outside molder. H. B. Smith Machine Co., Smithville, N. J.
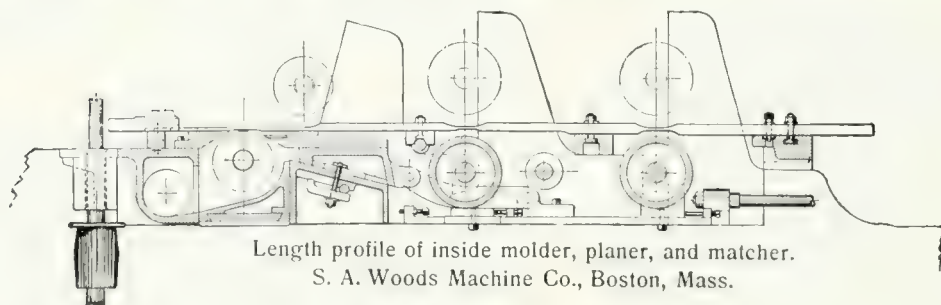
Length profile of inside molder, planer, and matcher.
S. A. Woods Machine Co., Boston, Mass.
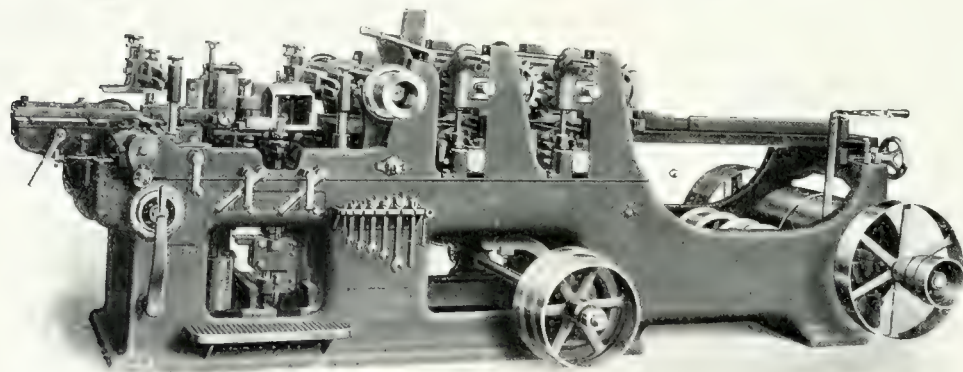
Inside molder, planer, and matcher, or floorer No. 107. S. A. Woods Machine Co., Boston, Mass.

(I) MOLDING. Molders are either "inside molders" or "outside molders." They carry (like floorers) two horizontal and two vertical cutter heads. "Bits" of many sizes and forms inserted into the cutterheads secure an endless variety of moldings.

The "sash sticker" is a molder making the small frame-sticks used in window sash.
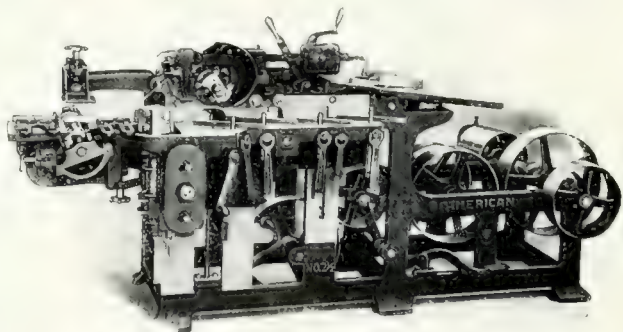
Sash sticker. American Woodworking Machine Co.,
Rochester, N. Y.

(J) MISCELLANEOUS. By "matching" is understood the cutting of a tongue and a groove into the edges of box boards, heading boards, &c. The work is done by bits and cutter heads.

The "Linderman" automatic dovetail glue jointer, manufactured by the Linderman Machine Co., of Muskegon, Mich., is a wonderful machine securing a perfect glue-joint, by a dovetail groove and tongue (tapering lengthwise) between two boards—regardless of their width—by one single operation.

By "gaining" is understood the ditching across a piece.
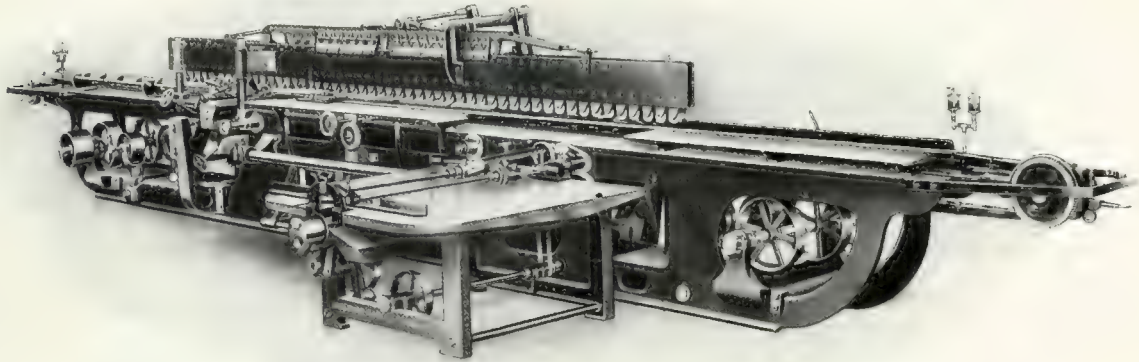
Linderman glue jointer and matcher. Linderman Machine Co., Muskegon, Mich.

By "plowing" (rabbetting) is understood the ditching along a piece.

"Tenoning" is especially required for doors and blind slats; single and double tenons being distinguished.

Door panels go through a "panel raising" machine.

Sash and door "relishing" means the biting or sawing of large teeth into the tenon.
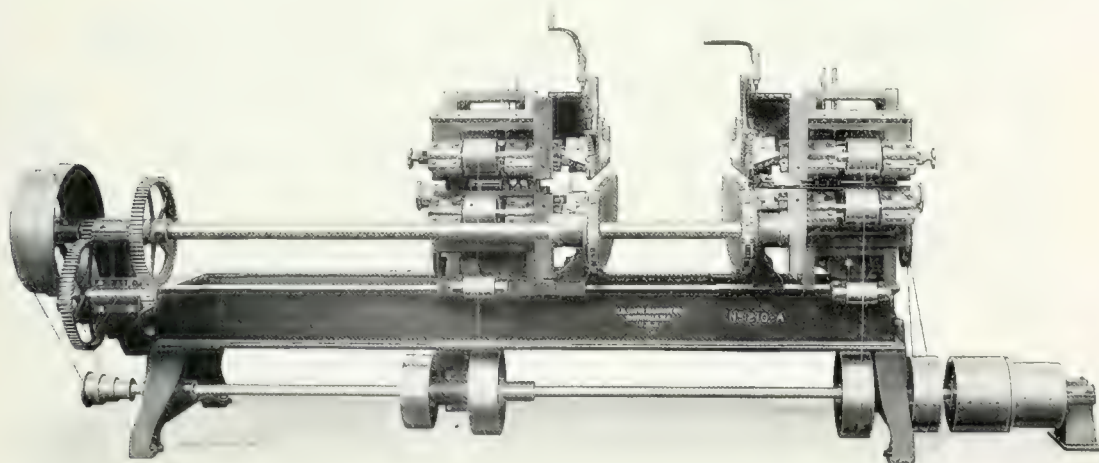
Double end tenoner. H. B. Smith Machine Co., Smithville, N. J.

The "mortiser" removes, whilst it produces a clean-cut mortise, the dust and shavings automatically. It consists either of a square, hollow chisel containing a spiral spindle which ends in a bit; or else of a fine endless chain, cutting the mortise by its sharp welds. In either case a "plunger" drops, at the pressure of a foot-lever, the mortiser into the cavity to be made.

PARAGRAPH XXI.

VENEERING PLANT.

Veneers are either sawn or peeled (sliced). The furniture factory and the package trade use veneers, with entirely different ends in view, on a daily increasing scale.

The thickness of sliced veneers ranges down to $1/120$ inch; veneers less than $1/40$ inch thick, however, are rarely used.

Sawn veneers are $1/20$ inch thick or thicker.

Very thin veneers are uneconomical because they require a high-grade core.

Sliced veneers allow the glue to show at the outside more easily than sawn veneers; their upper and lower surfaces fail to be equally smooth.

Composite doors and composite furniture, consisting of a number of veneers laid and cross-laid onto an inner core (yellow poplar, basswood, cottonwood, chestnut, &c.,) are apt to be stronger and sure to be less influenced by weather conditions than are solid makes.

The veneer machines of the Coe Manufacturing Co., Painesville, Ohio, are considered standard in the United States.
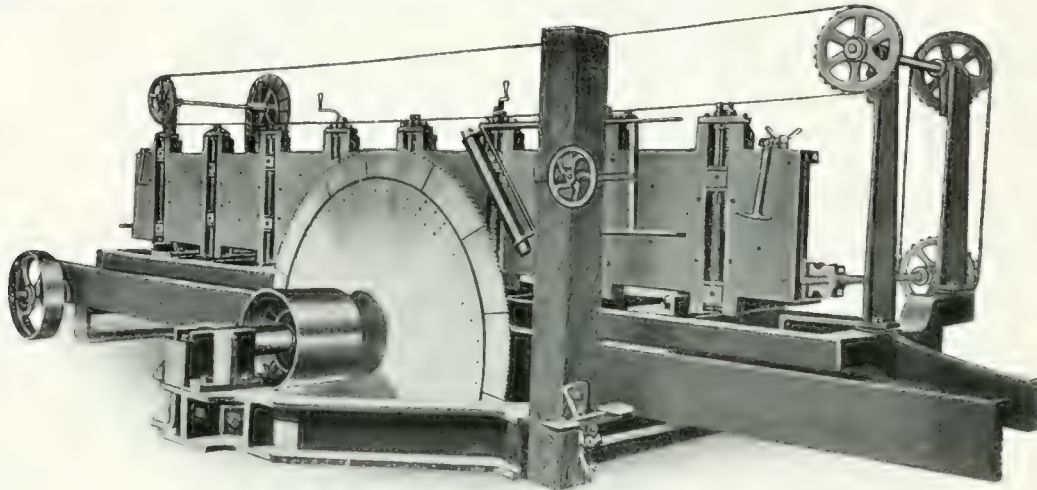
Circular veneer saw.   Coe Mfg. Co., Painesville, Ohio.

(A) VENEER SAWS.   Any saw of a fine gauge is a veneering saw.   Largely used are the:—

1. Horizontal mill saw.
2. Fine band saw.
3. Circular saw ground to a fine gauge (19 gauge) at rim, strong (5 to 10 gauge) at center; there is only one collar, to which saw is screwed. Circular veneer saws consisting of sections screwed to a centerpiece are common.

(B) VENEER CUTTING MACHINES.   Usually, the logs are boiled or steamed (in exhaust) for several hours beforehand. Logs 3 to 12 feet long are used, the length of the log almost equaling the length of the knife.

I. The rotary veneer machine peels any log of, say, over 18 inches diameter, notably poplar, lynn, gum, and cottonwood, into thin layers by revolving the log slowly against a stationary knife. A "clipper" cuts the roll into pieces of proper size for boxes, staves, potato barrels, box boards, furniture backing, veneer cores, &c.   The core of the log, some 6 inches in diameter, does not allow of peeling.
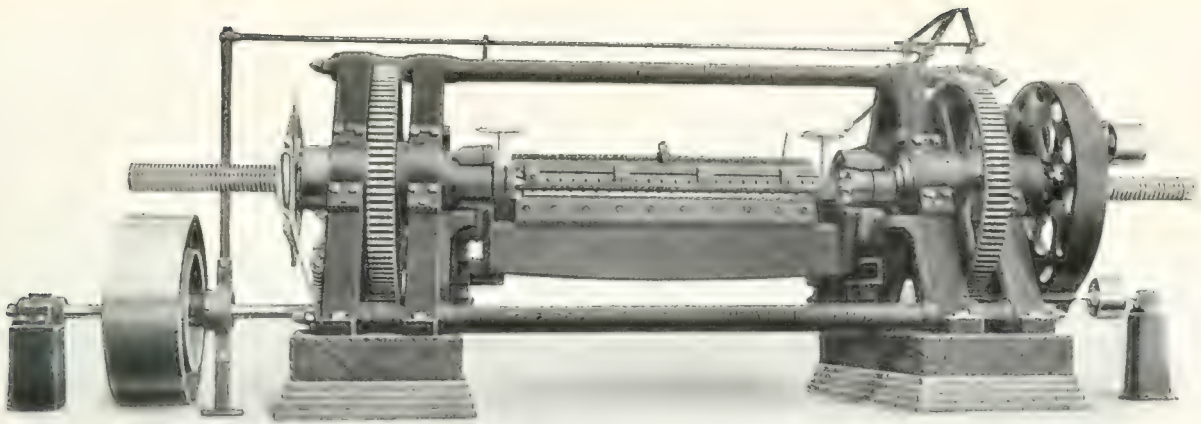
Rotary veneer cutting machine, front view.   Coe Mfg. Co., Painesville, Ohio.
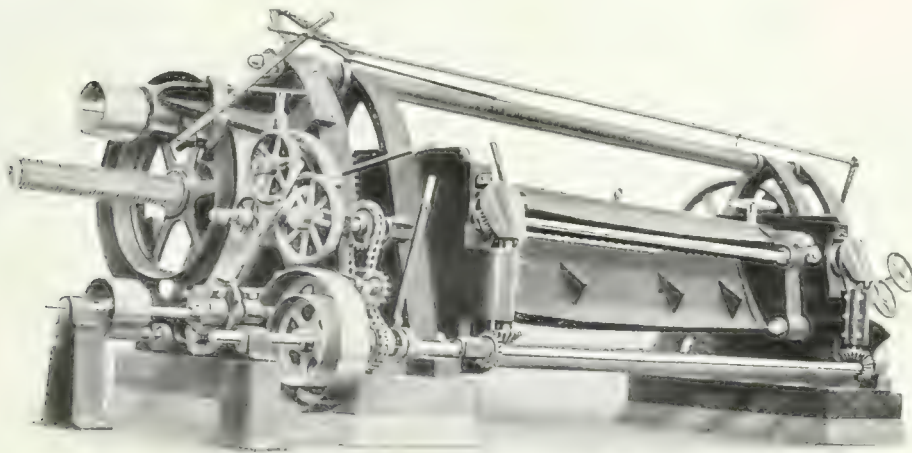
Rotary veneer cutting machine, rear view.   Coe Mfg. Co., Painesville, Ohio.
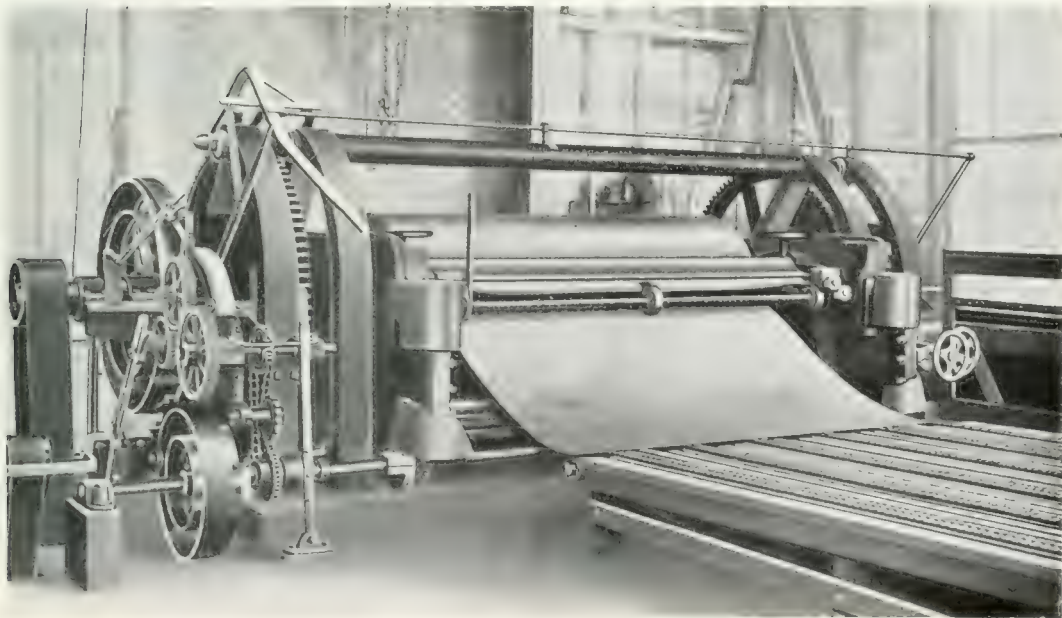
Rotary veneer cutting machine in operation.   Coe Mfg. Co., Painesville, Ohio.

II. **The stationary veneer slicer** consists of a stationary knife up to 12 feet long and of a sliding sash-frame holding the log or flitch, removing at each shearing stroke a thin slice or veneer.

In German veneer slicers, the flitch of the timber is stationary and the knife spanned in an exceptionally heavy frame passes, guided by steel guides, over the flitch.
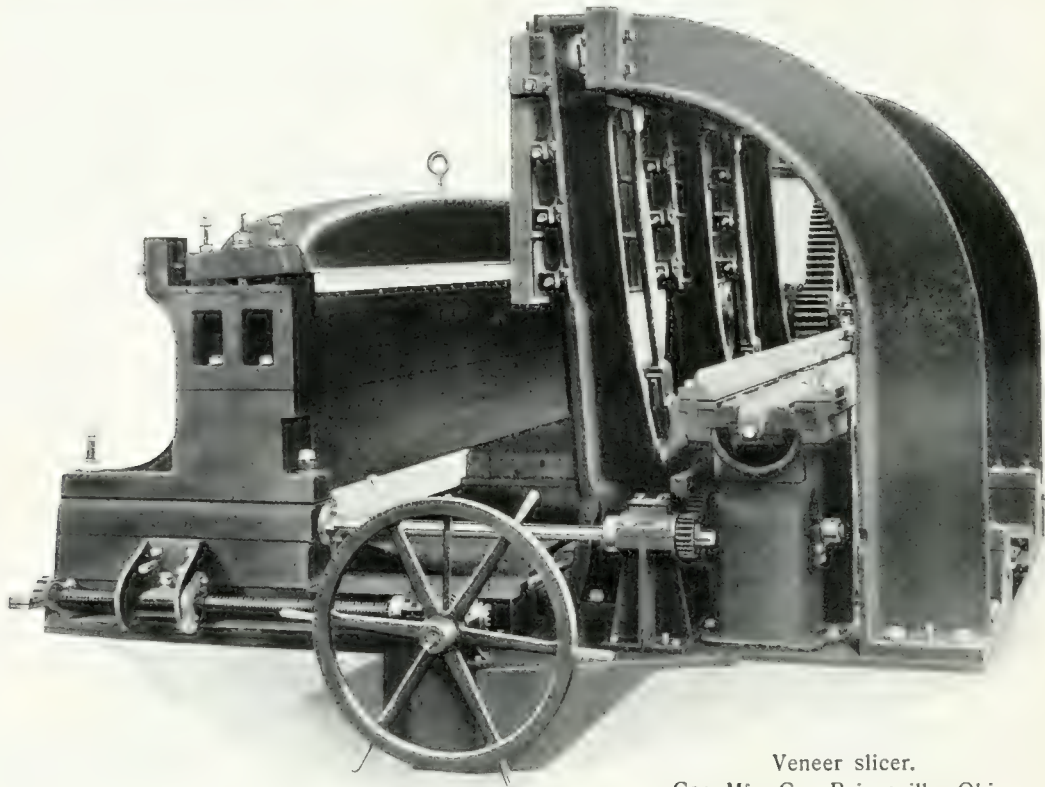
Veneer slicer.
Coe Mfg. Co., Painesville, Ohio.

(C) ADVANTAGES OF VENEERING:—

1. There is little or no loss of timber for kerf and sawdust. Logs too short for lumber are fit for veneering.
2. Veneers show little damage by warping and little checking. Hence they allow of rapid seasoning. For that purpose, the veneers are frequently passed between heated rollers.
3. The rotary machine yields large sheets often entirely free from knots which are merely contained in the core left unpeeled.
4. Composite furniture, also composite doors, wainscoating, &c., are less subject to "working" than is solid furniture.

PARAGRAPH XXII.

BOX FACTORY.

(A) KINDS OF BOXES:—The trade distinguishes between the following box patterns:—

Planed or unplaned.
Knocked down, shooks, or set up.
Nailed, lock-cornered, or dovetailed.

(B) MATERIAL. Wood as light as possible, readily planed, nailed, glued, or treated. The best is white pine; next are spruce, basswood, poplar and, more recently, yellow pine, hemlock, gum, cottonwood. Elm, ash, and sycamore are used for special purposes.

(C) MACHINERY. A well equipped plant contains planers, resaws, rip saws, cut-off saws, box board matchers (which tongue and groove composite sides), Linderman's (automatic dovetail glue jointers), lock corner machines (or nailing machines or dovetailing machines), sand paper machines and printing machines (drum pattern).
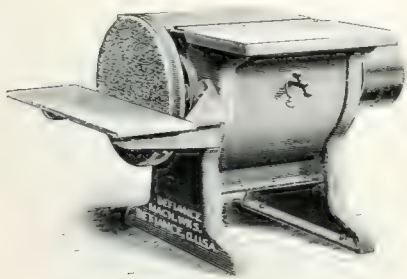
Drum and disc sander. Defiance
Machine Works, Defiance, Ohio.
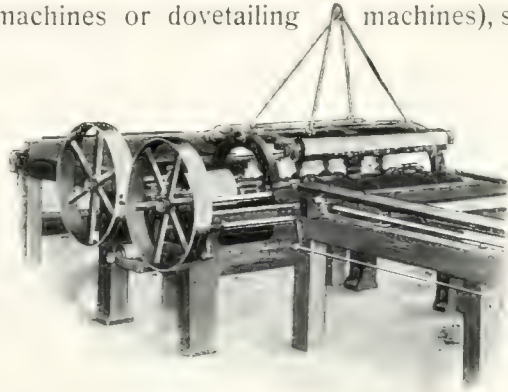
Self feed rip saw and edger. Fay & Egan, Cincinnati, Ohio.
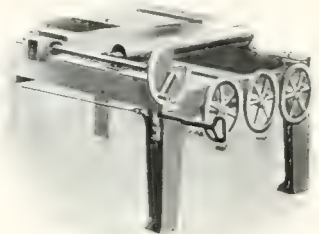
(D) BUSINESS SIDE. The skill of the box maker is shown by working up, without waste, the proper proportions of widths and thicknesses. Careful piling of lumber in the yard, separating according to width and thickness, is very essential.

The interdependence between crop prospects and box prices is easily felt by the box makers.

For large boxes the nailed pattern is preferred, being the strongest. Box shook fasteners and box strapping increase the strength of the box.

Lock cornering machine. Morgan
Machine Co., Rochester, N. Y.
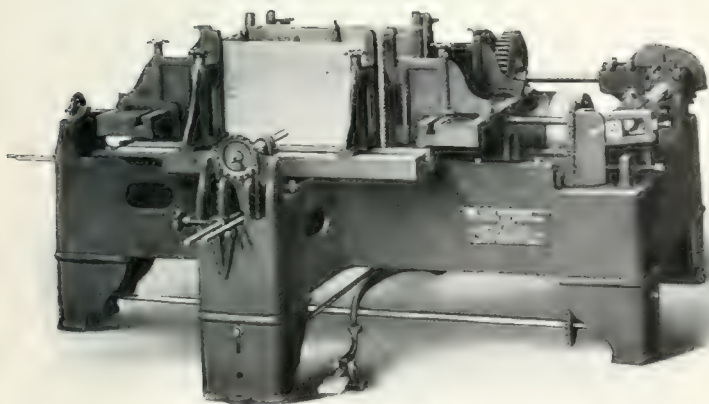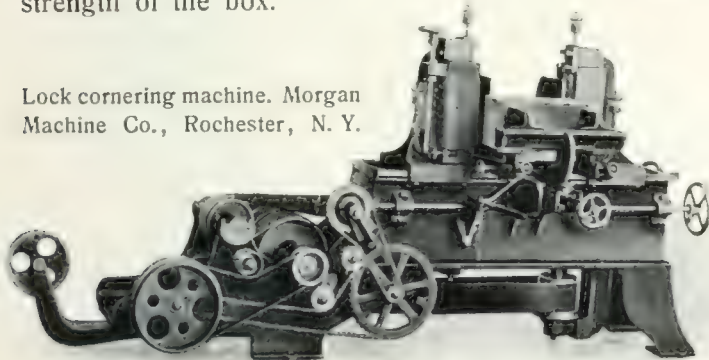
Machine for setting up the lock cornered box. Morgan Machine Co.,
Rochester, N. Y.
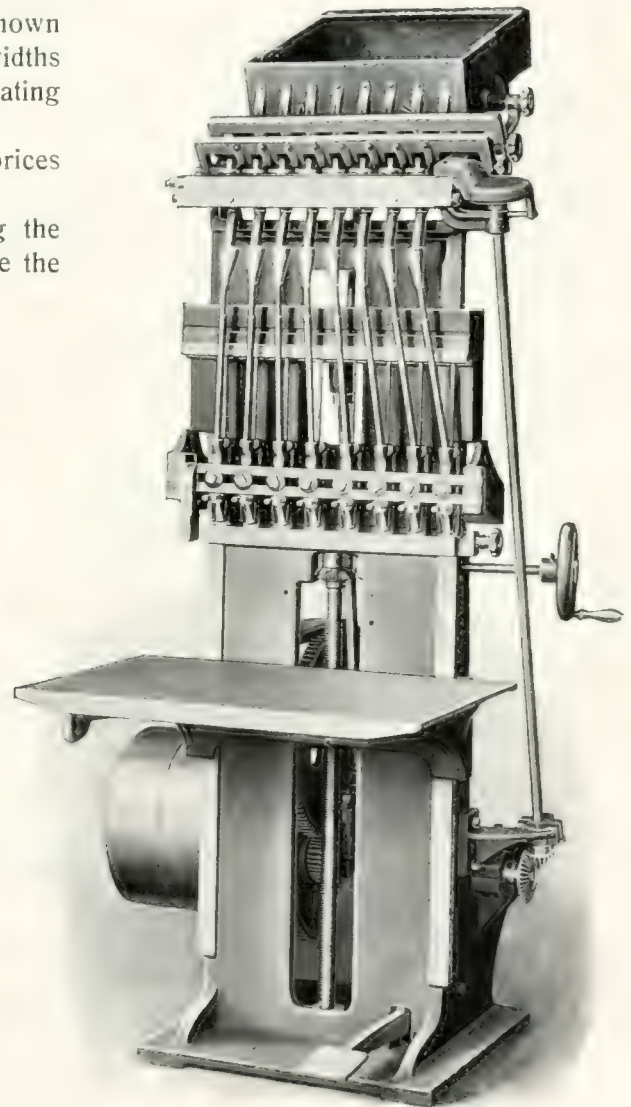
Box nailing machine. Morgan Machine C...
Rochester, N. Y.

The lock cornered box is preferred for starch, plug tobacco and small boxes. Lock cornered boxes are required either by the bad qualities of the lumber or by the quality of the stuff packed. Locked corners demand gluing. "Bevel locked" corners and "inclined locked" corners are scarcely used. The dovetailed box does not require gluing. The mechanical process for stamp locked corners (dovetails stamped into thin boards) is not yet perfected.

(E) EXPENSE OF MANUFACTURE:—

1. The manufacture of 1,000 feet of lumber into shooks involves an outlay of about $4 for labor and $1 for wear and tear.
2. One thousand small lock cornered boxes, $9'' \times 6'' \times 3''$, $1/4$ inch thick for frame and $3/16$ inch for top and bottom, require 700 board feet of lumber worth $8.50; $5.10 for labor; $2.72 for glue, wear and tear; $2.50 for ten packing crates.

PARAGRAH XXIII.

BASKET WORKS.

(A) WILLOW BASKETS. They are hand or machine made, mostly from cultivated shoots of Salix rubra, viminalis, amygdalina and caspica. Shoots one to two years old are used, being cut either in fall or in spring. In the first case, the bundles of shoots are kept in water over winter. The shoots are peeled after the rising of the sap by being passed through an iron or wooden fork; then rapidly dried to retain the white color. In this condition the material may be stored away for years. The shoots are bathed in water before weaving to restore flexibility and toughness. The bottom of the basket is made first, and then, frequently with the help of a model, the standards or uprights of the wall are fixed.

(B) WOODEN BASKETS. They are used for picking and transportation of bulky farm produce. Sizes $1/2$ bushel to 2 bushels.

I. **The hand made basket** consists of thin strips split and shaved from basket oak and white oak (sapwood); also from spruce.

II. **The Briggs stave basket** consists of radial ribs cut from $2^3/4$-inch oak planks; cross cut into lengths varying from $12^5/8$ inches for $1/2$ bushel to 18 inches for 2 bushel baskets. The ribs are jointed and pointed to an exact fit for a round center plate and then bent over a model form having grooves indicating the proper position for each rib and for the strong elm hoop clasped around the rim.

III. **The common wood basket** is made of straight long ribs up to $1/4$ inch thick, cut on a rotary veneer machine. No center piece, no pointing and no jointing are required. The ribs are bent over a model form. A workman is said to make about 300 baskets in a day.

PARAGRAPH XXIV.

COOPERAGE WORKS.

(A) TERMINOLOGY:—

1. "Slack" cooperage deals with barrels for lime, vegetables, cement, salt, nails, crockery, sugar, flour, &c.
2. "Tight" cooperage deals with barrels for liquids and for meat (pork).

(B) MATERIAL USED. Any species may be used for slack cooperage. Alcoholic liquors must be cased in white oak (Quercus alba, michauxii, prinus, macrocarpa, minor &c.). Red oak will not hold whisky, but is used for oil staves, flour barrel heading, sawn and coiled hoops.

White ash is used for pork staves and butter tubs.

Elm yields the best coiled hoops and the best slack staves.

Cottonwood and gum are cut for slack staves on a large scale.

Chestnut is used for cheap slack barrel hoops and for brandy staves; yellow poplar for staves of tobacco hogsheads; basswood for flour barrel headings; gum, birch, elm, beech, and maple for sugar barrels; pine for rice and crockery barrels; second growth of hickory, birch, and ash for hoops.

For buckets, red and white cedar are preferred; for tanks, cypress and redwood.

(C) SPECIFICATIONS:—

I. **Flour barrels** contain 196 pounds, or 3·57 bushels, or 32 gallons of flour. The diameter of the head is 17 inches; the length of the staves 28 inches.

The forms preferred in slack cooperage, either locally of for given goods, vary to such a degree that figures descriptive of the forms cannot be recorded.

II. **The "Tight Coopers' Union"** specifies:—

(a) Whisky barrel staves—length 34 inches to 35 inches, thickness $7/8$ inch, width $4\frac{1}{4}$ inches after jointing, measured across bilge on the outside;

(b) Wine barrel staves—length 34 inches, thickness $^{11}/_{16}$ inch after drying and planing, width $4\frac{1}{2}$ inches;

(c) Oil, tierce and pork staves have similar dimensions, allowing, however, of sap, of one or two sound worm holes and of knots showing on one side only.

Variations of $1/8$ inch in length and $1/16$ inch in thickness are permitted in all staves (so-called equalized staves).

Pipes, butts and puncheons contain over 100 gallons and are used for port, rum, &c.

A hogshead of claret is 46 gallons.

(D) STATISTICAL NOTES:—

1. One thousand feet board measure in logs—Doyle's rule—yield 2,500 sawed flour staves, 3,200 veneered staves, 4,000 cut hoops or 3,000 sawn hoops.

2. One cord of bolts, with the bark, will make 1,000, or, without bark, 1,200 slack staves.

3. In Tennessee, eight white oaks (of over 18 inches diameter) are said to average 1,000 half barrel beer staves.

The price of white oak material has risen rapidly and must continue to rise indefinitely, full substitutes for white oak being impossible.

In slack cooperage, on the other hand, raw material continues to be plentiful, and new, cheaper forms of packages enter into daily competition with the barrel.

(E) ILLUSTRATION FOR PRICES and their tendency:—

Kinds	April, 1901	February, 1904	June, 1911
Staves:—			
No. 1 elm flour, per 1,000	$9·00	$11·00	$9·50
No. 1 gum, per 1,000 ...	—	$10·00	$8·75
Heading, flour, per set	$5\frac{1}{2}$ c	$8\frac{1}{2}$ c	$7\frac{1}{4}$ c
Hoops, coiled elm, per 1,000	$7·00	$9·50	$10·75
Flour barrels, each	39 c	45 c	42 c
Pork tierces, each	$1·00	—	$1·45

(F) MANUFACTURE of heading, staves, hoops, and barrels.

I. **Heading.**

(a) HEADING FOR TIGHT COOPERAGE is sawn from split bolts. These bolts are obtained in the woods by halving, quartering, and splitting (by hand and always with the grain) round blocks which slightly exceed in length the diameter of the heading. The heart of the bolt is not removed. The bolts are waggoned or sledded to the heading plant, where they are inspected, sorted, piled, and air-dried. A long number of months are required to prepare, by exposure to the athmosphere, the raw material desired by the cooper.

Twenty-five horse-power are said to be required at a heading plant. The output at a "setting" of the plant averages 200,000 sets of heading.

The tight heading plant usually contains a sawing machine, an equalizer, and a jointer:—

1. *The heading sawing machine* consists of a vertical circular saw (44 inches diameter) screwed to the arbor without a loose collar; a pendulum swing with "grate" and "dogs" to receive the bolt; a slide guiding the swing; a gauge, adjusted by screws; a separator throwing the sawed slats to the side. Price ℳ 300.

2. *The equalizer* contains a tilting table or a carriage, which is forced against a pair of circular saws.

    In German makes, a pair of wheels feeds the slats automatically into the saws. The equalizer cuts the heading slats to uniform length. Price ℳ 50.

3. *The jointer* edges the slats. It consists of a strong wheel, or better of two wheels, carrying on its side 4 to 6 straight knives. The wheel is covered by a hood. Price ℳ 140.

    For tight cooperage the joints are made secure by blind nails and by coopers' flag (Typha latifolia) placed into the joints; more rarely by tongues and grooves.

    Two more machines are required to finish the heading prepared by the apparatus mentioned under 1, 2, and 3, viz.:—

4. *The heading planer* which carries knives 16 inches to 24 inches long and has a capacity of 8,500 headings a day.

Heading sawing machine. Trevor Mfg. Co., Lockport, N. Y.
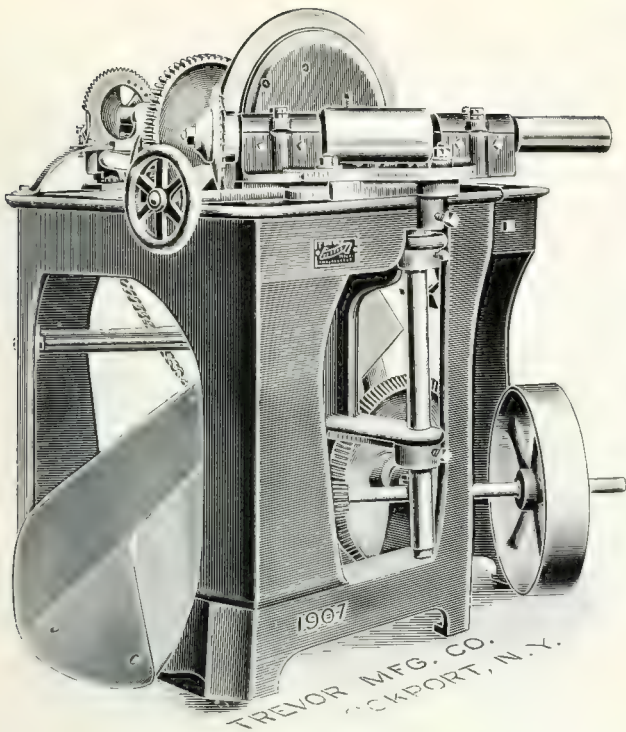
Heading turner. Trevor Mfg. Co., Lockport, N. Y.
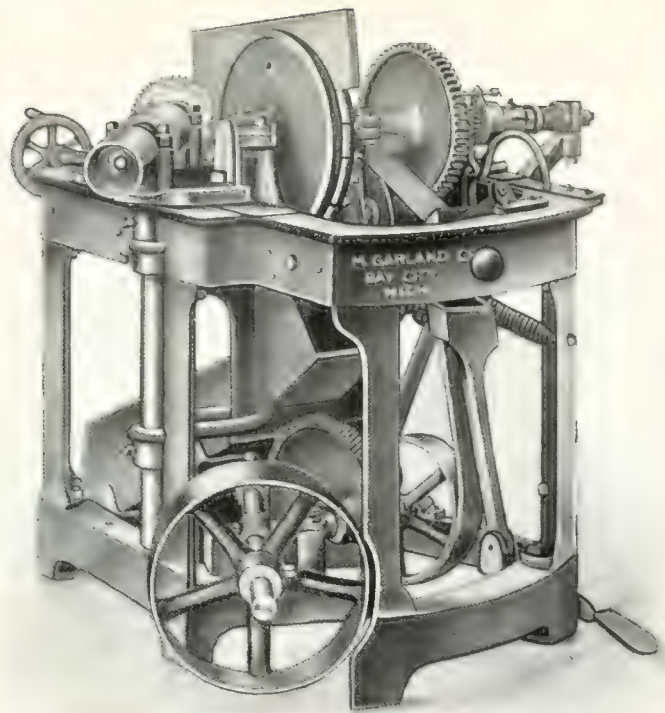
Heading turner. M. Garland Co., Bay City, Mich.

5. *The heading turner* which cuts the heading circularly and carves the required bevel edge. It usually carries a concave saw, to cut through the boards, and on the same mandrel a small, thick circular saw which gives the bevel.

The heading, held in clamps, rotates obliquely against these saws. Price $235. Capacity 5,000 a day. Heading is usually kiln dried.

(b) FOR SLACK HEADING, QUARTER SAWING IS NOT REQUIRED. Ordinary lumber can be used. The slack heading plant may or may not contain all of the machines enumerated under a, b, c, d, and e.

The machines d and e are usually combined with the cooper works.

Slack heading of small diameter may be sawn directly by a cylinder saw from a board having a width exceeding such diameter.

II. Staves.

(a) STAVES FOR BARRELS CONTAINING THE MOST VALUABLE BEVERAGES are hand made (rived staves). The riving of staves wastes timber. Proper bilge and curvature are obtained either by hewing (Germany) or in the finishing plant (America).

The white oak timber used must come from straight-grained trees of over 18 inches diameter. Such trees are found in clumps only. Hence the necessity of a portable finishing plant, using from 15 to 35 horse-power. At each set or site—now usually 15 miles from the railroad—at least 100,000 staves are manufactured. Six hundred rough staves have the weight of one thousand finished staves. Hence it is wise to bring the plant close to the timber.

The felled tree is sawed (by hand) into blocks of two inches more than stave length. The blocks are placed on their larger ends. Then the sap line is demarcated with a pencil, and inside the sap line, with the help of a pattern showing the cross section of a stave, as many staves are pencil-marked as possible.

By axes, wedges, and wooden mauls the block is then halved and quartered (and rehalved and requartered in case of heavy blocks), the clefts following the pencil marks. The sectors are then split into rough staves, always following the pencil marks.

The core, of at least four inches diameter, containing the small limb-stubs is thrown away.

The rough staves are inspected and sorted and piled hogpen-fashion for air drying, either before or after sledding or waggoning to the finishing plant. It might be added here that this finishing plant is—contrary to expectation—never combined with a heading plant.

(b) THE "STAVE BUCKER," by which three fourths of all rived staves made in the United States are refined, dresses and planes both sides of the staves to proper curvature and bilge. A rack forces the rough staves through the narrow passage left between two knives (either straight knives, or curved to correspond with the periphery of the finished barrel) which are fastened in a rocking frame.

(c) THE "STAVE DRESSER" frequently takes the place of the bucker. It carries knives on two cutter-heads, dressing and forming the stave on both sides to proper thickness and leaving either an abrupt or a gradual shoulder.

(d) THE STAVE SAW YIELDS staves of equal form, but of greater permeability, more economically than the hand.

Stave bolts must have the following minimum dimensions:—Thickness with grain 5 inches; width close to heart 3 inches.

The bolts are barked and hearted in the woods, being split from logs having at least a diameter of 15 inches inside the bark.

The stave saw consists of:—

1. A hollow steel cylinder, having the diameter of the barrels to be made and carrying saw teeth at one end.
2. A carriage with clamps passing the saw cylinder.
3. A stave holder running into the cylinder and removing the sawed staves. Capacity 12,000 staves per day.

In 1909, ninety per cent of the tight staves produced in the United States were sawn staves.

(e) IN SLACK COOPERAGE, a stave cutter is often used, consisting of a knife 36 inches long, bent to a 20-inch circle, and of a tumbler-cradle to receive the bolts. The tumbler makes per minute 100 to 150 rocking strokes against the knife. The stave bolts are steamed beforehand. The knife separates, at each stroke of the tumbler, a stave from the bolt.

Capacity 140,000 per day. Price $ 130. Horse-power 4.
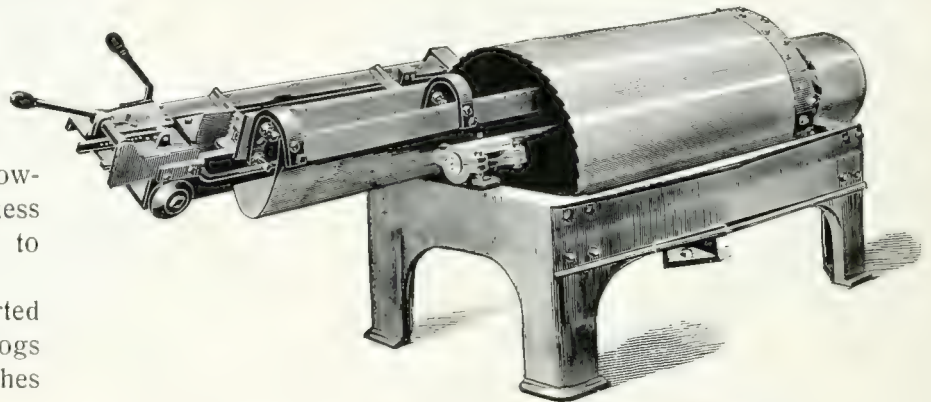
Stave cylinder saw. E. & B. Holmes Machinery Co., Buffalo, N. Y.
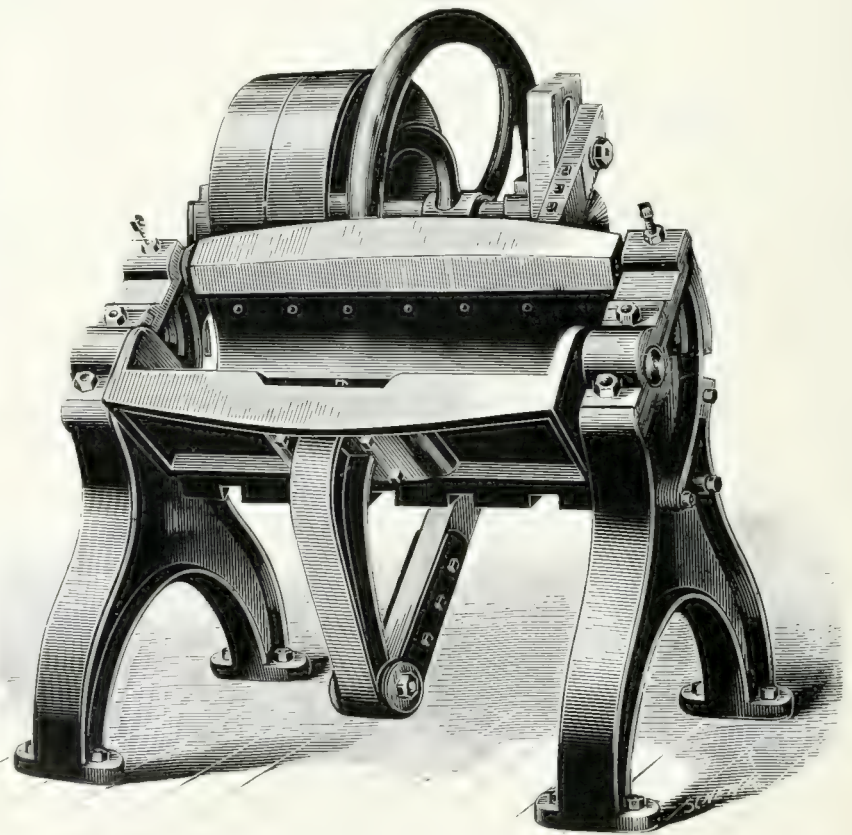
Stave cutter. E. & B. Holmes Machinery Co., Buffalo, N. Y.

(f) THE ROTARY VENEER MACHINE is now also used to cut 4-inch or $4\frac{1}{2}$-inch slack gum staves.

(g) THE STAVE EQUALIZER trims the ends and gives the staves the proper length. It consists of two circular saws and a tilting bed or a carriage.

(h) STAVE LISTERS OR JOINTERS edge the staves in such a way that the edges coincide with a plane through the axis of the barrel.

Staves for export are straight listed and without bilge.

The stave jointer is either a circular swing saw; or it consists of two circular saws; or of a number of inclined knives held by cutterheads; or of one knife running in a vertical sash frame; or it consists of two large, vertical, concave wheels in rapid rotation. Whether the one or the other wheel is to be used depends on the grain of the staves. Staves must be jointed with the grain. The wheels carry, close to their circumference, a number of knives. The stave is held by dogs in an inclined position, and is forced into the cavity of the wheel so as to form a secant by which the knives pass with a shearing stroke. The proper bilge and the proper joint are thus obtained simultaneously.

Stave jointer. E. & B. Holmes Machinery Co., Buffalo, N.Y.

(i) IN THE "STAVE PLANER," a steel pattern passing through the machine with the stave lifts the cutters in such a way as to allow the shoulders of the staves to retain a greater thickness than the middle of the staves.

Beer barrel staves require a heavier shoulder and a heavier thickness than wine barrel staves.

Gebrüder Schmaltz, Offenbach, Germany have placed on the market a machine planing the inside of the finished barrel, before it receives the heading.

Stave planer. Schmaltz, Offenbach, Germany.
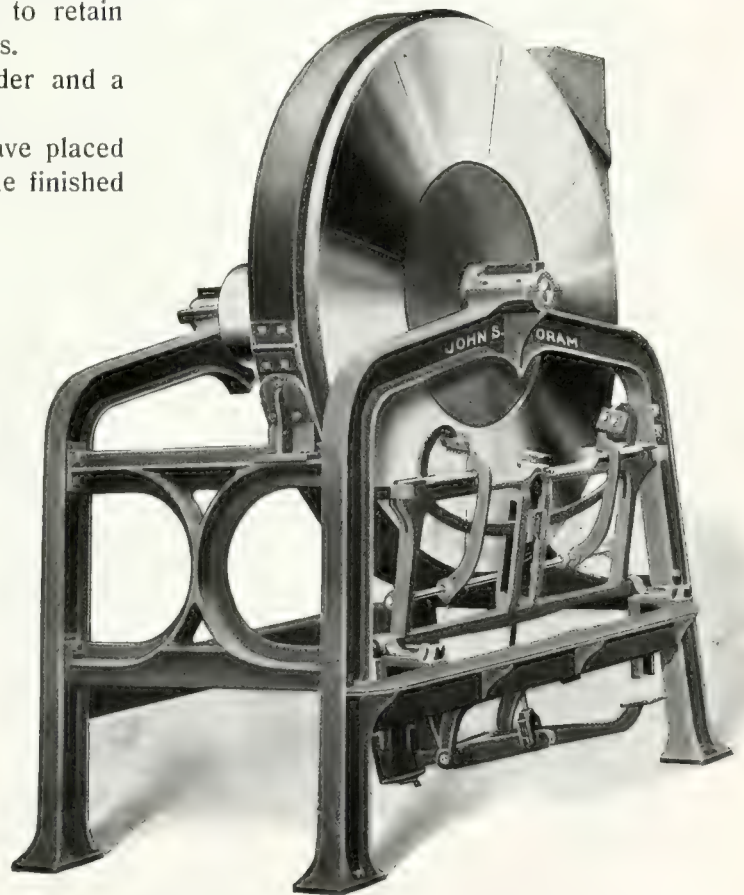
Stave jointer. John S. Oram, Cleveland, Ohio.

III. **Hoops.** In tight cooperage, steel or iron hoops are used, made in the cooperage shop by means of a press and a rivetter, driven over the barrel by hoop drivers or trussing machines and sometimes fastened by hoop fasteners.

Wooden hoops are more easily drawn to the barrel, and stick to it more readily when thus drawn, during changing weather, than do iron or steel hoops.

In slack cooperage, wooden hoops are still preferred and wire hoops are only occasionally used. Wooden hoops are either hand made, especially the long white oak hoops used on tobacco hogsheads, or sawed from plank by a hoop machine, or finally knife-cut on a rotary machine or a sash frame machine.

A machine by which sawed hoops are obtained directly from logs does not seem to be much used.

By special machinery hoops are planed, pointed, lapped, and punched.

A hoop coiler rolls the hoops into bundles. Usually the outfit of a "sawed hoop" plant consists of a saw bench, a saw machine, and a coiler.
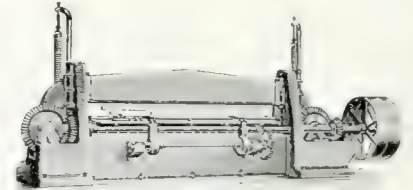
Hoop cutting machine. Defiance Machine Works, Defiance, Ohio.

IV. **Barrels.** Putting up a barrel requires:—

(a) HEATING, in order to increase the flexibility of the staves held together by an iron form and by one or two hoops.
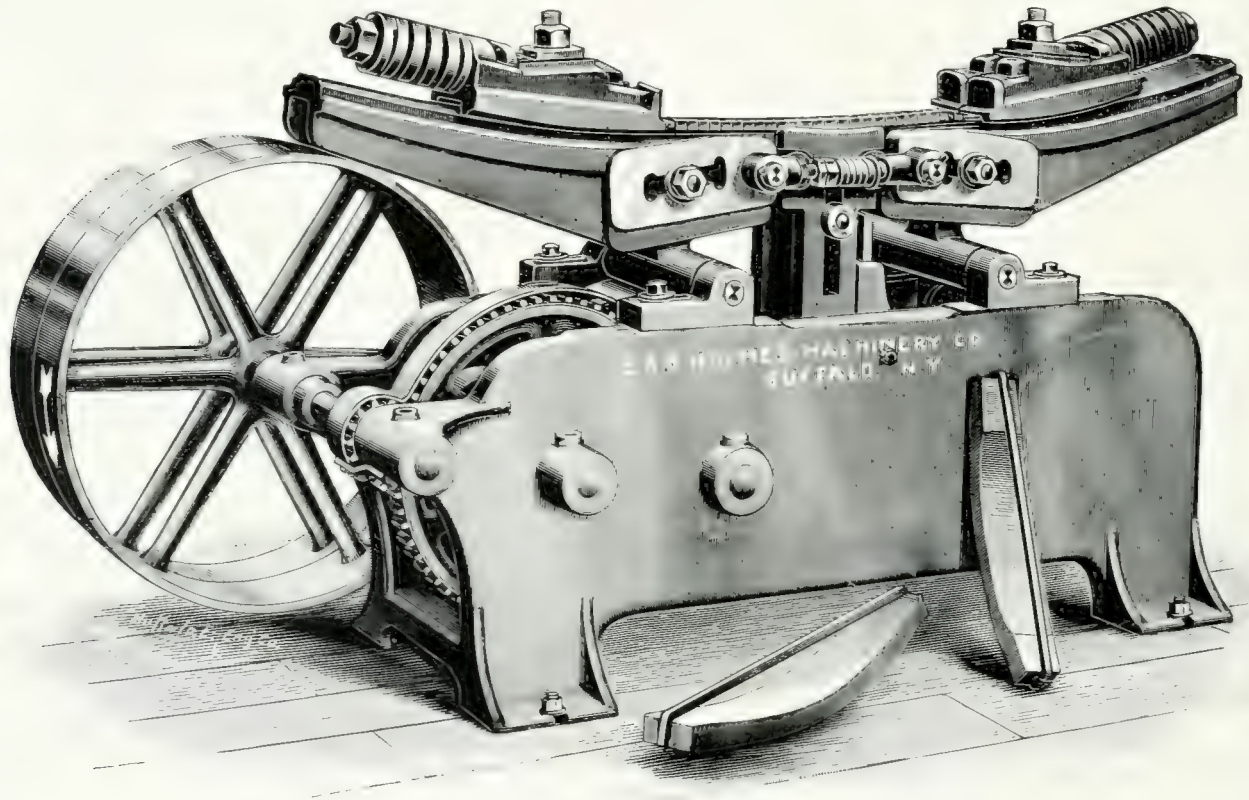
Stave bending machine. E. & B. Holmes Machinery Co., Buffalo, N. Y.

(b) BENDING in an apparatus consisting of screw and rope, windlass and rope, or of a bending press.

(c) CROZING, viz., making a groove for the insertion of the heading, either by a hand planer or by a power groover.

(d) HOOP DRIVING. The finished barrel is automatically planed on the outside; if it does not assume the exact form of a doubly truncated paraboloid, it is pressed into shape by a barrel leveler.

(G) WOODEN PIPES. Wooden pipes are either bored pipes used for the protection of electric cables; or wire woven, composite pipes, consisting of staves, and used for water conduits on a daily increasing scale.

I. The leading raw material for solid-bored pipes is Douglas fir, 4 inches by 4 inches thick. The pieces are bored, in two operations, first by a small and then by a large hollow bit. One end is rounded on a lathe, the other is crozed so as to tightly receive the round end. The pipes are next treated to impregnation by the creosote process.

II. The best raw material for wooden water conduits is also Douglas fir, the best quality of stock being used. Pipe lines of over 24 inches in diameter are constructed in the field, from staves held in place by steel hoops cinched until every individual stave is firmly clamped. There are no pipe joints.

III. The ordinary wire woven pipe has a diameter of 4 to 24 inches, comes in sections 12 to 16 feet long, and is made in the factory (e. g., Pacific Coast Pipe Co.) from well seasoned lumber 4 to 6 inches wide and 1 inch thick. The pieces are run through an inside molder, dressed convex above and concave below, jointed on both sides in keeping with the radius of the pipe to be constructed, and also tongued and grooved, to increase the tightness of the joint. The tongues and grooves are triangular. The staves are assembled, so as to form a cylinder, and are clamped temporarily, to be conveyed to the wiring lathe. The starting end of the wire is fastened by staples several inches back from the end of the cylinder, so as to allow of the use of couplings. The wire is wound spirally from one end of the cylinder to the other. The wire is payed out from the spool while the spool travels along the rotating cylinder. The distance of the wire spirals and the tension can be adjusted at will. Then the ends of the pipes are shaped to suit the couplings, by means of cutter heads and bits. The outer surface of the pipe is coated in tar and asphalt, and finally covered with sawdust to make a skin which is not easily abraded. The couplings are either inserted joints, one pipe end fitting directly into the other, or wood sleeves, made like the pipe itself but of greater diameter and with the wires set closely together. Wooden pipe is cheaper, more durable, less corroding, more portable than iron; it does not burst by frost, does not shrink with heat, and is easily tapped at any place.

PARAGRAPH XXV.
WAGGON WORKS.

(A) THE RAW MATERIAL for waggons must be tough and strong and, necessarily, air dry. The dry kiln often follows after two or three years of air drying.

Second growth of black or shell bark hickory, further ash, oak, and elm, is used for tongues, shafts, spokes, rims, axles, neck yokes, whiffletrees, and eveners.

White oak or burr oak is used for spokes, tongues, bolsters, hounds, reaches, and axles.

Black birch, rock elm, white oak, and locust are used for hubs.

Waggon beds are made of yellow poplar, pines, or cottonwoods, the composing boards being either ship lapped or tongued and grooved.

White ash, bending easiest and best of all woods, is used for rims, bent seats, bent bows, shafts, &c.
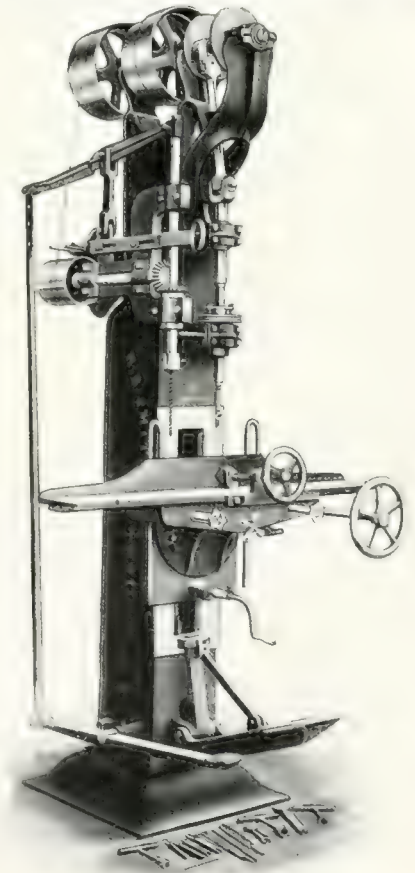
Reciprocating power mortiser. H. B. Smith Machine Co., Smithville, N. J.

(B) THE MANUFACTURING MACHINERY is usually supplied by the Defiance Machine Works Defiance. Ohio.

I. **Hubs** are cut direct from the log to proper length by double equalizing saws; turned on outside automatically on a lathe; bored for boxes (thimbles); chisel mortised for spokes; and set with two to four iron rings.

II. **Spokes** are obtained from bolts by rip sawing into squares which are turned on a lathe; tenoned at the big end; sandpapered and polished; driven into hubs by automatic hammers; equalized in length.

III. **Rims and felloes** are either bent or sawn to proper form.

In the first case, the bolts are steamed or boiled; then bent and pressed in an iron pattern when hot; then cased up and dried; then bored to receive the spokes; rounded on the inside with a slight elevation left around the hole; planed, and finally sandpapered.

In the second case, very wide plank is required. Sawn felloes are obtained either by a set of concave saws, having the required curvature, or by a band scroll saw which follows the pencil marks of a pattern made for each piece on the plank.

IV. **Axles** are turned on a lathe according to a steel pattern spanned in the lathe; are gained to receive bolsters and hounds; and have the thimble skeins driven on by hydraulic pressure.

V. **Shafts and poles** are sawn from plank $1\frac{1}{2}$ to $2\frac{1}{2}$ inches thick and $8\frac{1}{2}$ to 12 feet long; are heated and bent, cased, dried, rounded, and belt polished.

VI. **Waggon box boards** are from 12 to 16 feet long, and from 13 to 17 inches wide. No defects are allowed, except a small knot showing on one side.

(C) FEW ESTABLISHMENTS MAKE ENTIRE WAGGONS. Usually shafts, spokes, hubs, rims, axles, &c. are made in factories close to the woods, while other factories closer to the cities or to railroad centers put the waggons together after buying their component parts.

The requirements of firms engaged in the manufacture of agricultural implements are similar to those of the waggon works, in raw material as well as in machinery.
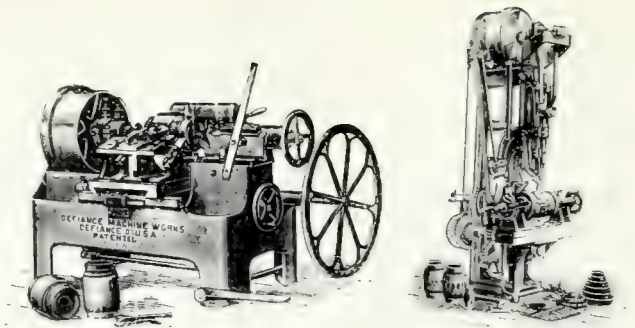
Hub lathe. Defiance Machine Works, Defiance, Ohio.

Hub mortising machine. Defiance Machine Works, Defiance, Ohio.
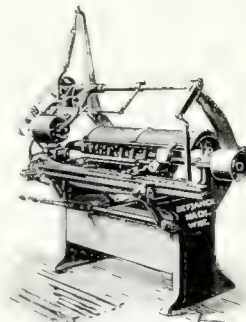
Spoke lathe. Defiance Machine Works, Defiance, Ohio.
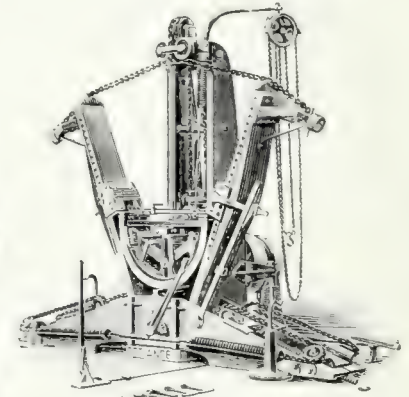
Felloe and hound bender. Defiance Machine Works, Defiance Ohio.
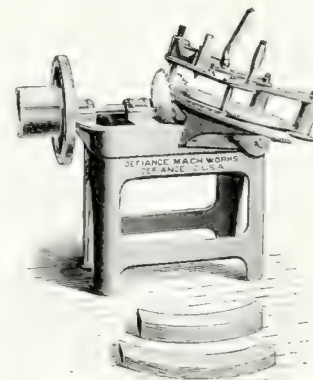
Concave felloe saw. Defiance Machine Works, Defiance, Ohio.
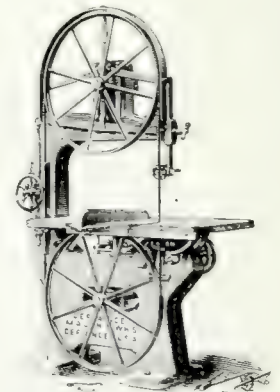
Band scroll saw. Defiance Machine Works, Defiance, Ohio.
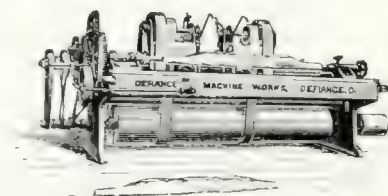
Inside axle tree lathe. Defiance Machine Works, Defiance, Ohio.
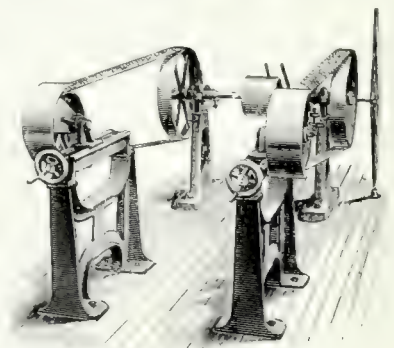
Double belt polisher for shafts and poles. Defiance Machine Works, Defiance, Ohio.

PARAGRAPH XXVI.

SHINGLE MILL.

(A) MATERIAL. Breasted, shaved, rived, or rifted shingles (meaning hand-made) are used in the backwoods only. In the Southern Appalachians, shaved shingles made of chestnut cost $2 per 1,000 pieces, while so-called boards, two feet long and six inches wide, split from white oak, cost $3 per 1,000 pieces. Rived cypress shingles are split with the tangent (not with the radius) along the Southern coast.

For machine-made shingles are used:—

On the Pacific Coast, red and white cedar.
In the Lake States, white pine, white cedar, spruce, Norway pine, and hemlock.
In the South, cypress, longleaf pine, and shortleaf pine.
1,000 feet b. m. in the log yield 11,000 shingles.

(B) DURABILITY. The durability depends on the climate, on the pitch of the roof, and on the size of the face which the shingles offer to the weather; it is said to be for:—

White pine, rived, 20 to 25 years.
White pine (heart), sawn, 16 to 22 years.
White pine (sap), sawn, 4 to 17 years.
Chestnut, rived, 20 to 25 years.
Cedar, sawn, 12 to 18 years.
Spruce, sawn, 7 to 11 years.

The manufacture of rived sugar pine shakes in the Sierra Nevada.

(C) SPECIFICATIONS. The usual size of sawn shingles is:—16 inches or 18 inches long; 4 inches wide; $1/_{16}$ inch thick at small end; $1/_2$ inch thick at butt end. A bundle of shingles contains 250 pieces, is 20 inches long and has 24 tiers.

A carload of white pine shingles, weighing 22,000 pounds, contains 70,000 16-inch shingles; a large car of red cedar shingles contains 170,000 pieces.

One thousand shingles cover 100 square feet of roof, each showing 14.4 square inches to the weather.

A rule for the number of shingles required for a roof is:—Ascertain number of square inches in one side of roof; cut-off the last figure, and the result is the number of shingles required for both sides of the roof. In this case, each shingle shows 20 square inches to the weather.

Shingles are usually laid to show 4 inches of their length, which arrangement yields, in 16-inch shingles, a quadruple layer of shingles on the roof. The higher the grade of the shingles and the steeper the roof, the larger is the weather face permissible.

(D) MACHINERY. The machinery (Challoner Co., of Oshkosh, Wisc., leading manufacturers) used in a shingle plant consists of:—

I. **Drag saw,** either driven from a countershaft or acting directly from the piston, cutting the logs into shingle lengths.

II. **Bolter,** a circular saw cutting the round blocks into bolts, the thickness of which equals the width of thes shingle. Bolts split with an axe yield a better grade of shingles but cause a large waste of timber. A knot saw may be used after bolting to remove knots, rot, sap, &c.
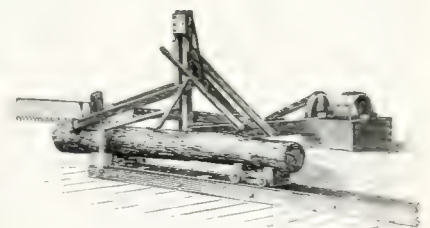
Drag saw. Defiance Machine Works. Defiance, O

III. Shingle machine, constructed in a variety of forms: –
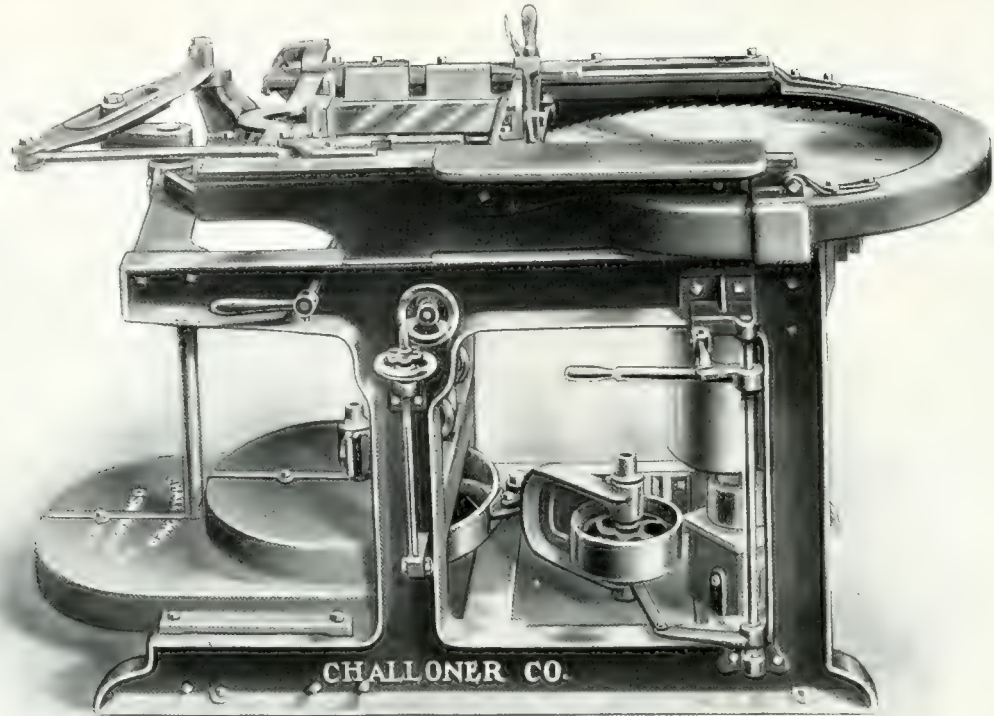
Single block shingle machine. Challoner Co., Oshkosh, Wisc.
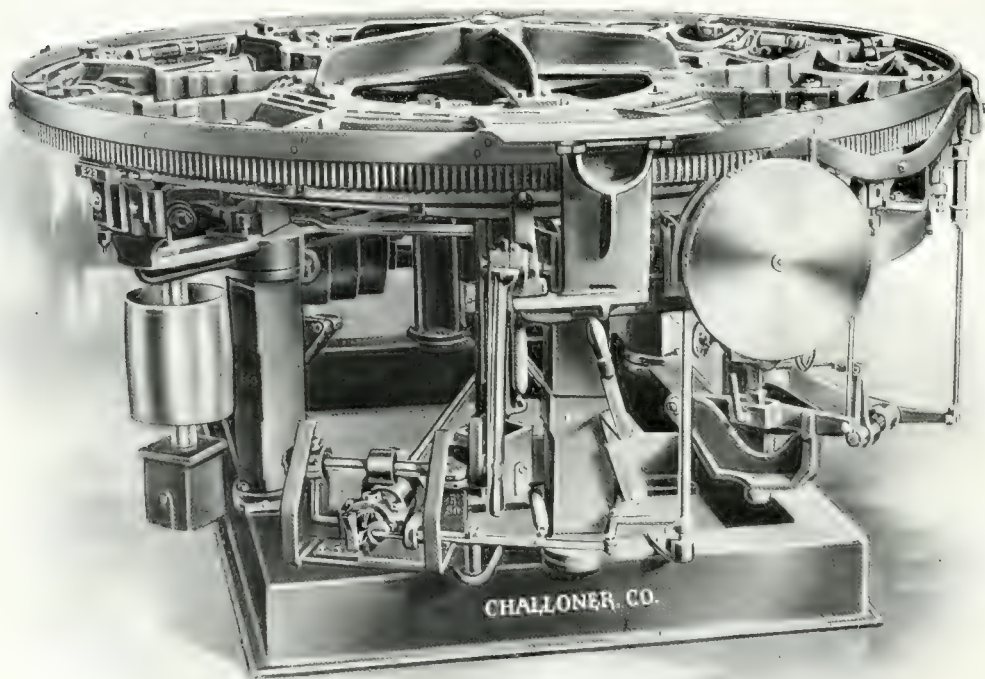
Two-block rotary shingle machine. Challoner Co., Oshkosh, Wisc.

(a) A KNIFE IS SPANNED in a sash frame moving up and down and severing a shingle at each stroke from steamed bolts. This system, furnishing "cut shingles," is not much used.

(b) THE SHINGLE SAW MACHINE uses a circular saw lacking the loose collar and screwed onto the fast collar. The gauge at the center of the saw may be very heavy while the gauge at the rim is from 15 to 20 only.

The shingle blocks are fastened into either a sliding frame or a rotating frame and are tilted automatically, before each feed movement of the carriage, so as to alternate edge and butt cuts.

The sliding frame is either hand fed or power fed. A machine takes from one to ten blocks at a time.

IV. The jointer is meant to give a rectangular shape to the shingle. It is either a single or a double rip saw (two saws 4 inches apart) or a wheel jointer consisting of a steel wheel carrying, close to the circumference, 4 to 8 knives radially or almost radially set and of a hood covering the machine and connected with a blowpipe to remove shavings. The shingles are placed opposite an opening in the hood and pressed by hand against the knives, which make about 500 to 800 revolutions per minute.

V. The shingle packer, used for 16-inch and 18-inch shingles, consists of a bench and two slotted and overhanging steel rods. The attendant pressing the rods down by hand or foot packs the shingles tightly with their fine ends overlapping.

VI. Shingle planers, fancy butt shapers and dry kilns are found in up-to-date plants. After kiln drying, bundles require tightening up.
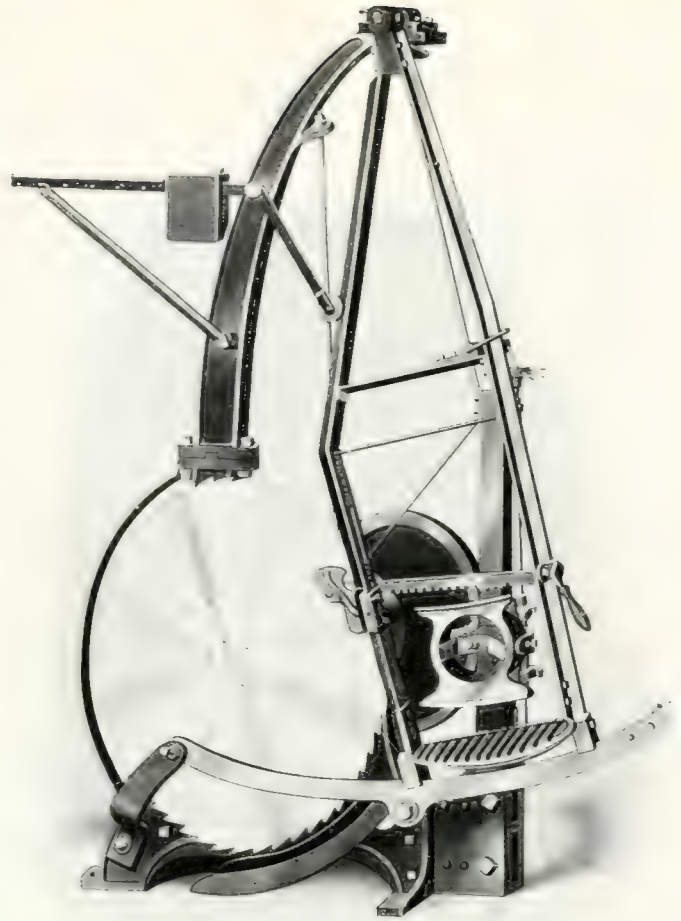
Pendulum swing saw for heading and shingles.
Peter Gerlach Co., Cleveland, Ohio.

PARAGRAPH XXVII.
LATH MILL.

The usual length of laths is 4 feet; the weight per 1,000 is 500 pounds; 50 laths form one bundle. One thousand laths cover 70 square yards, and a cord of slabs yields 3,000 laths.

All softwoods, further yellow poplar, cottonwood and linden form the raw material for laths.

The lath mill is attached to the sawmill. It decreases the waste in the mill, by converting slabs and offal into commodities. Unfortunately, there is a continuous and heavy overproduction of lath.

Chestnut and also hemlock when used green result in brown stripes showing through the plaster on the wall.

Before adding a lath mill to the sawmill, the owner should learn the effect which such addition will have on the rate of fire insurance.

The machinery used in the lath mill consists of:—

(A) SLAB RESAW, by which the last board is cut out of the slab. It contains a circular saw and feed works pressing the slab into the saw; or a horizontal band saw, with chain feed above and rolling bed below.

(B) LATH BOLTER, consisting of a single or double cut-off circular saw.

The lath bolter has the function of cutting the raw material coming from the slab resaw, the edger, or the trimmer down to proper lath length.
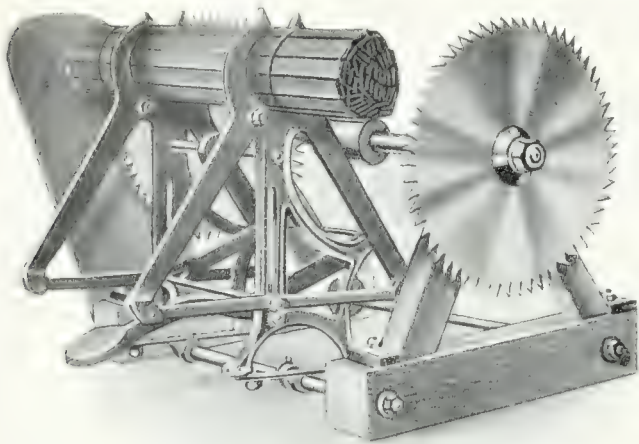
Combination lath bundling machine and trimmer.
M. Garland Co., Bay City, Mich.   Lath machine. Wheland Machine Works, Chattanooga, Tenn.
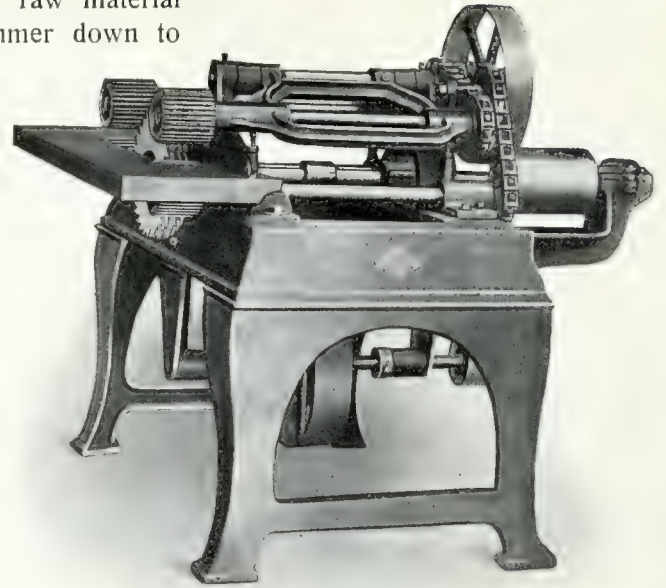
(C) LATH MACHINE, which is either an ordinary gang rip saw having up to six small circular saws and an automatic feed, or a cutterhead and knife machine. The latter machine makes the so-called "grooved" lath.

Whilst ordinary lath is laid to the wall with interstices of an inch between adjoining pieces, the grooved lath is laid solid. The grooves are dove-tailed into the face of the mill cull boards used for the purpose.

(D) LATH BUNDLING MACHINE, which presses the laths together by a foot or hand lever and facilitates binding.

Very frequently the lath bundling machine is combined with a trimmer or equalizer, consisting of two cross-cut saws pressed against the bundle in the moment of binding. The green lath must be yard-dried or kiln-dried before shipping.

PARAGRAPH XXVIII.
NOVELTY MILLS.

Novelty mills have sprung up, in recent years, all over the Northeast, manufacturing trays, wooden dishes, wooden wire, rules, pen-holders, flasks, skewers, spools, toys, and thousands of playthings of the hour.

The variety of the raw material used is as great as the variety of the goods manufactured. Still, birch seems to be the acknowledged leader for novelty makes. The Defiance Machine Works, of Defiance, Ohio, are the leading manufacturers in a long series of novelty machinery.

Wooden dishes, wooden wire, turnery wares, and shoe pegs may deserve particular mention.

(A) WOODEN DISHES:—

I. Material. Yellow poplar is used for large wooden trays. Second growth white pine (cuts taken between whirls) is used in New England. Maple is preferred for small oval wood dishes, turned out by a special machine automatically.

II. Manufacture of oval dishes. These oval dishes are obtained from sawn blocks, scaling from 6 inches by 8 inches to $7\frac{1}{4}$ inches by $9\frac{1}{2}$ inches.

The dishes are cut with the grain from the side face. Blocks are thoroughly boiled. The cutting knife, revolving circularly, makes 25 dishes to the inch and 75,000 per day.

Two-facing knives shave the block clean between every two cuts, carving out true edges.

A screw-fed carriage automatically feeds the block into the knives. No skilled labor is required. The attendant merely removes the remnants of a spanned block and places a new block in the carriage.

(B) WOODEN WIRE. Wooden wire is used for mattings, screens, inner rack of ladies' hats, &c. The raw material consists of willow, basswood and poplar plank.

A series of planing knives, in the form of sharp rimmed, fine steel cylinders, plies in a sliding frame over the plank, severing at each stroke a series of wires having the length of the plank.

A straight planer knife follows in the wake of the fine cylinders, removing the irregularities left on the plank.

(C) TOOL HANDLES, INSULATOR PINS, BOBBINS, SPOOLS, SHOE LASTS, &c., are turned on an automatic turning lathe. The thread of insulator pins and brackets (locust) is obtained by an automatic thread-cutting machine.

Shoe lasts are cut from ironwood, beech, birch, or ash. They are blocked out roughly, to begin with, by a circular or by a band scroll saw. The raw blocks are air-dried and kiln-dried before being spanned into an automatic turning lathe. The point of the foot requires trimming on a special shaping machine.

Thread cutting machine for insulator pins. Defiance Machine Works, Defiance, Ohio.

Handle turning lathe. Trevor Mfg. Co., Lockport, N. Y.
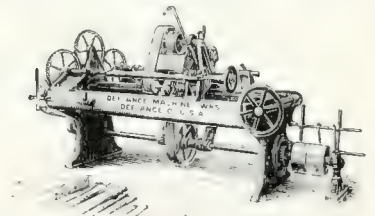
Copying lathe. Defiance Machine Works, Defiance, Ohio.

(D) WOODEN SHOE PEGS are used to fix the "uppers" to the shoe sole and to construct the heel. The pegs are automatically fed from a pegging machine.

Pegs are $3/8$ inch to $7/8$ inch long, square with a prismatic head.

The raw material consists of birch and hard maple.

I. The blocks are cut into discs, $3/8$ to $7/8$ inch thick, by a circular saw.

II. The discs are pointed in a pointing machine, which plows parallel grooves, lengthwise and crosswise, into the discs.

The distance between two furrows equals the width of the peg.

III The splitting machine severs, by the gradual strokes of a knife (first stroke down to $1/2$, second stroke down to $3/4$ of thickness of disc), the disc into strips of pegs and, playing crosswise, into individual pegs. After each stroke of the knife the disc is moved toward it by the width of one furrow. During the operation the disc is held in a leather frame.

IV. The wet, red pegs are then bleached by applying sulphuric acid; then dried in heated drums; then cleaned from splinters and irregularities by sifting.

PARAGRAPH XXIX.
MATCH WORKS.

Wooden matches are either round or square.

(A) ROUND MATCHES are made on a machine resembling the wooden wire machine described in the preceding paragraph, under "B."

The fine circular planes through which the wood is being forced cause a compression of the fibre so that the matches are unfit for impregnation with paraffine.

The wood is air-seasoned before using. The weight of a double-acting machine is 900 lbs. It is attended by two workmen, is driven by one horse-power, and yields 5,000,000 round matches per day.

(B) SQUARE MATCHES are made from blocks 16 inches to 24 inches long which, after steaming or boiling, are peeled on a rotary veneer machine into layers having the thickness of a match.

I. The veneers are automatically clipped into sheets having a length of 6 feet and a width equaling 5 to 12 match lengths. These sheets are heaped up in packs containing 50 to 80 tiers.

II. A knife system, with spur-knives, plays in a vertical sash and cuts from each tier, at each stroke, 5 to 12 matches. The pack, after each stroke, is moved forward the thickness of a match.

The machine is attended by one man, requires one horse-power, weighs 1,500 lbs., and has a daily capacity of 25,000,000 square matches.

III. The matches are then dried and cleaned by sifting.

(C) THE TREATMENT THERE-AFTER is identical for round and square matches, consisting of:—

I. Causing the match pegs to lie parallel, by rocking them in an oscillating drawer.

II. Fixing about 2,250 matches at a time in a clasp or frame.

III. Dipping the clasp (for fine matches) wholly into paraffine and the tips thereafter into a chemical compound which forms the inflammable head. The compound consists of one or more oxidizing substances often mixed with a particle of some explosive, so as to allow of ignition by friction on any rough surface.
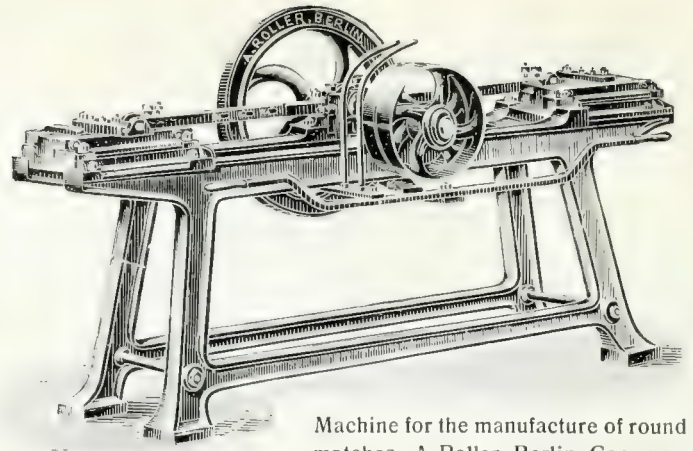
Machine for the manufacture of round matches. A. Roller, Berlin, Germany.
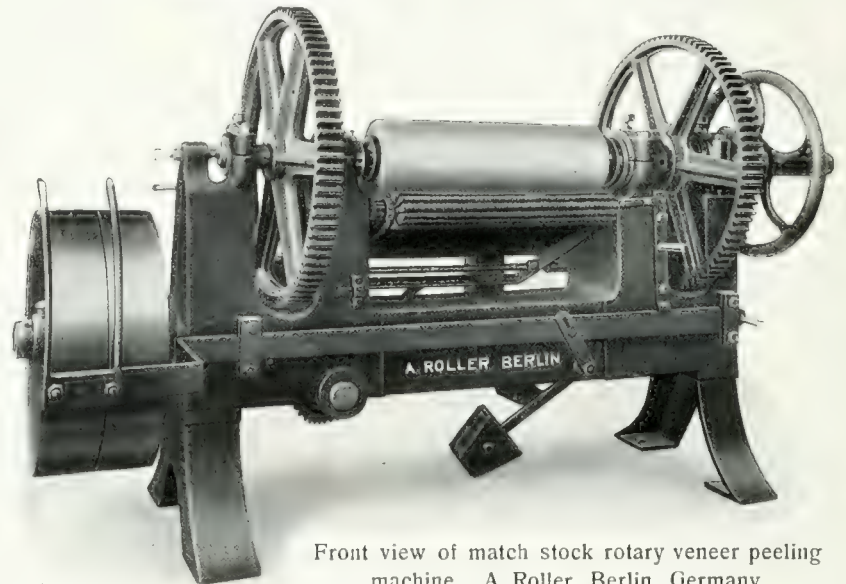
Front view of match stock rotary veneer peeling machine. A. Roller, Berlin, Germany.
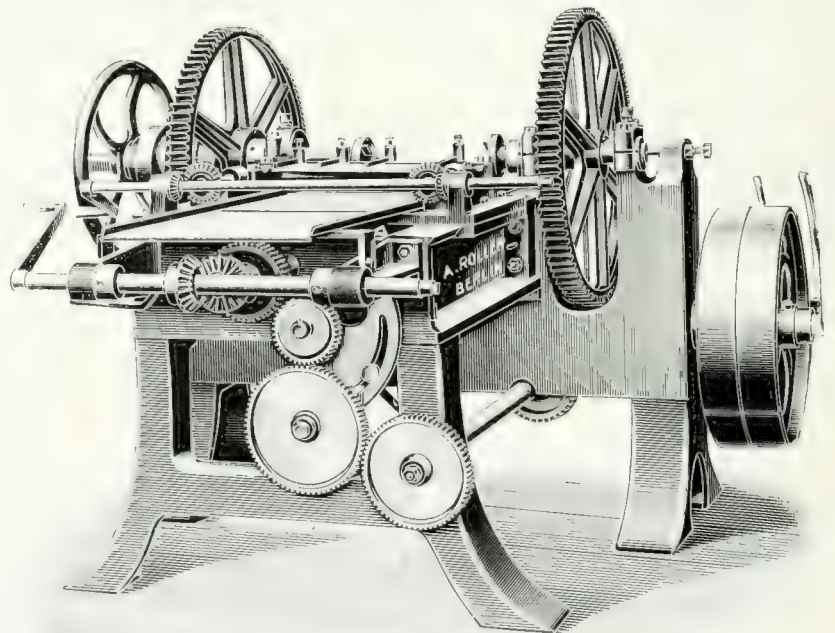
Rear view of match stock rotary veneer peeling machine. A. Roller, Berlin, Germany.

(D) IN MODERN MATCH WORKS, A. Roller's "Automaton" performs, attended by four helpers, the various functions given under "C." More than that:— The machine fills the matches into matchboxes automatically.

The raw matches are fed into the machine (illustrated at the bottom of this page) at A; are taken up by an endless bed I (the bed consisting of 26 strands) and heated at B; they are dipped in parraffine at C, and receive the inflammable head at D; they are dried by air at E and G, and by steamheat at F. They are finally dropped into boxes, 26 boxes being filled simultaneously.

The main driving pulley, requiring $2\frac{1}{2}$ horse-power, is at K.

The machine is 6·920 meters (27 feet) long and 2·275 meters (9 feet) high. Its weight is 7 tons and its daily capacity is 50,000 boxes of safety matches.

(E) THE RAW MATERIAL for matches is derived from cottonwoods, linden, sapwood of yellow poplar, white pine, spruce or cedar. A white, soft and long fibre is required.

The leading manufacturer for match machinery is A. Roller, Berlin, Germany.

An excellent description of match manufacture is found in Indian Forest Memoirs, Economic Ser., Vol. II, Part 1.

In California, a cheap grade of matches is produced from Port Orford Cedar by a process similar to the shoe-peg process described in paragraph XXVIII, under "D."
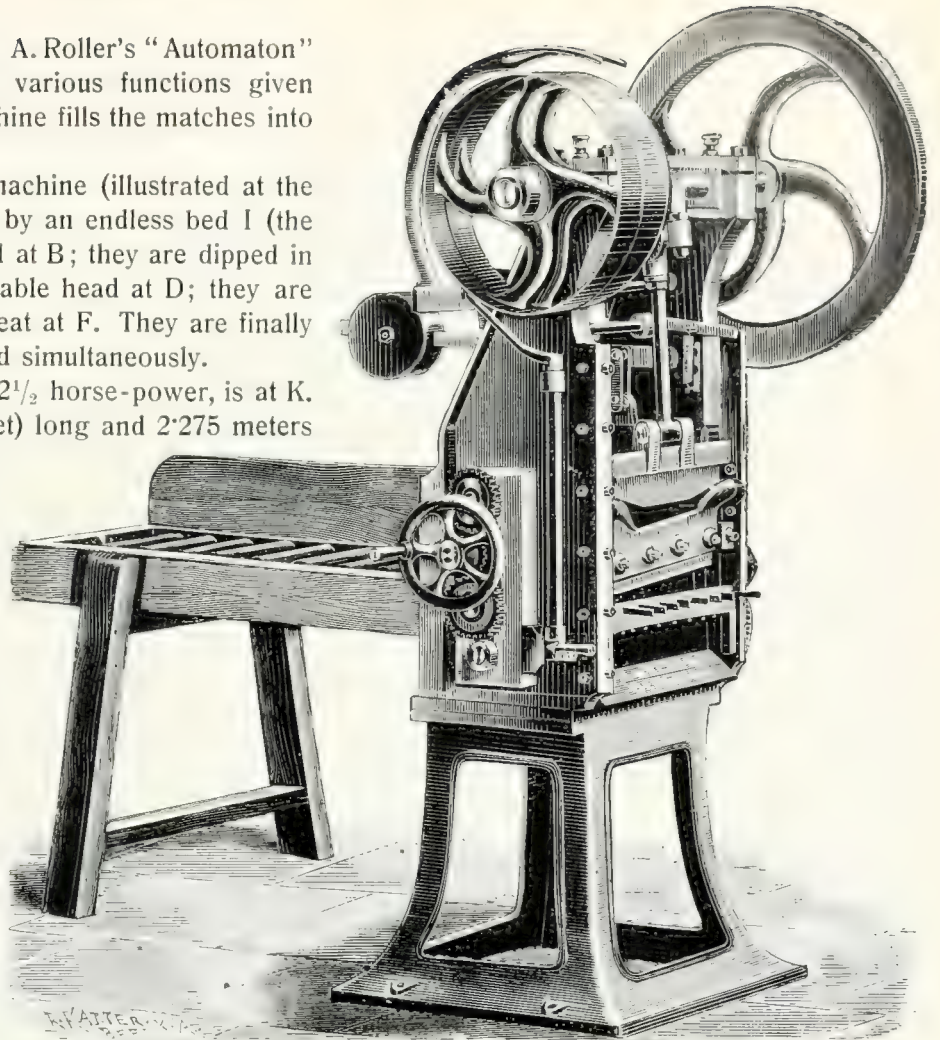
Cutting machine, dissecting the veneers into square matches. A. Roller, Berlin, Germany.
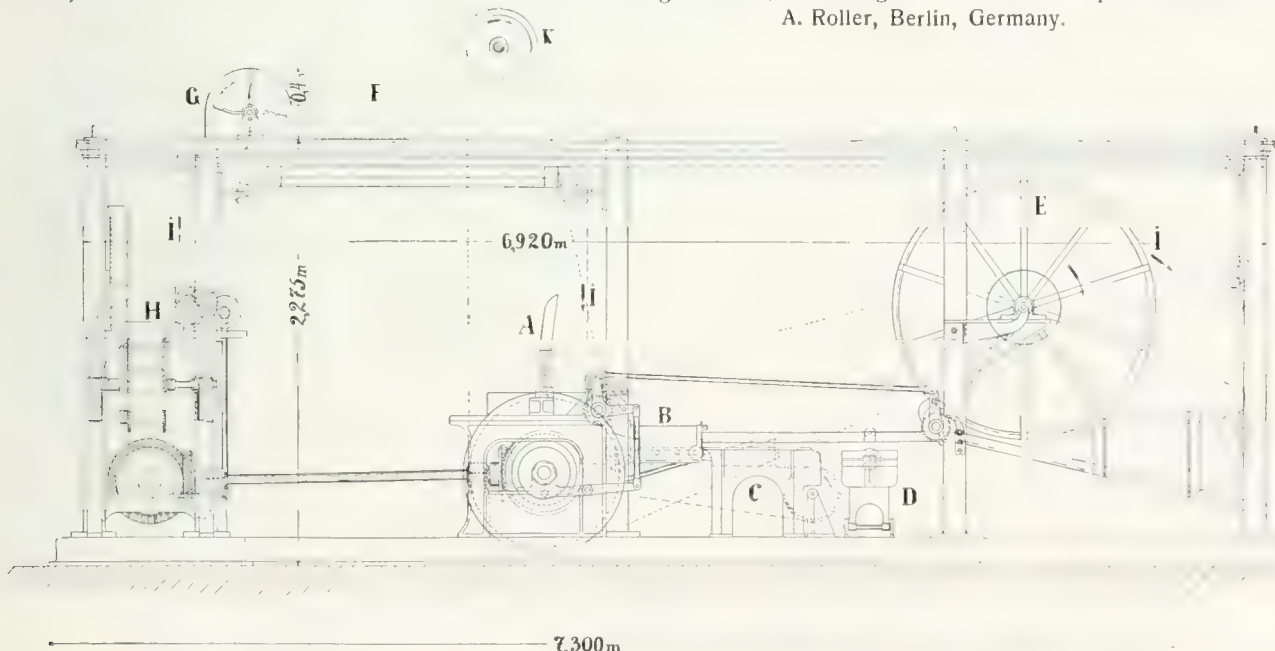
Side view of the "Automaton" match machine. A. Roller, Berlin, Germany.

PARAGRAPH XXX.

EXCELSIOR MILL.

(A) GRADES OF PRODUCT. The following grades of excelsior are distinguished:—

First grade:—Fine wood wool, thickness from $1/500$ inch to $1/64$ inch.

Second grade:—Common fine wood wool.

Third grade:—Mattress stock.

The greatest demand is for stock $1/100$ inch thick and from $1/32$ to $1/8$ inch wide.

(B) USAGE. Excelsior is used for upholstering and for packing (glassware, furniture, confectionery, &c.). It is preferred to straw owing to its greater elasticity and to its lack of dust. It is easily colored. A limited amount of excelsior is woven into mattings and rugs.

(C) KINDS OF WOOD. Basswood is best; balm of gilead, cottonwood, and yellow poplar come next. Birch, gum, pine, and spruce are used also. Frequently the core of blocks peeled on the rotary veneer machine is made into excelsior. One cord of basswood yields 1,500 pounds of excelsior.

(D) PROCESS OF PREPARATION. The wood is peeled, cut into 38-inch blocks, and the blocks split into slabs 5 to 6 inches thick. These slabs are thoroughly air-seasoned under cover, and finally cut into two lengths of 18 inches each.

(E) MACHINERY. Excelsior machines are, usually, small, upright knife machines manufactured, amongst others, by the American Sawmill Machinery Co., Hackettstown, N. J. The modern machine, however, (made by Kline, Alpena, Michigan) is an eight-block horizontal machine consisting of:—

I. **Two sliding steel frames** carrying eight tool heads into which the knives and the comb-like spurs are spanned. The sliding frames are moved by powerful cranks and pitmans on maple slides.

II. **Two stationary frames**, above the sliding frames, each having four sets of rolls; each set pressing by its rotation a wood block downward against the knives.

III. **Conveyors for the shavings,** falling through the sliding frames.

The operator—one man attends the machine unaided—feeds the wooden blocks from above into the stationary frames, whilst the machine is running at full speed. The comb-like spurs are cutting fine, parallel lines into the bottom face of the blocks; and the knives sever at each feeding stroke a thin layer of wood from the blocks.

Eight-block horizontal excelsior machine, made by Kline, Alpena, Michigan.

Additional machinery consists of automatic knife grinders, baling presses, cut-off saws, barkers, &c.

The price of the machinery for a modern excelsior plant is about $2,000. About 30 horse-power are required.

The daily capacity of an eight-block machine is 4,000 pounds of fine wood wool, or 10,000 pounds of mattress stock.

Excelsior is, usually, a by-product, and not the main product of a manufacturing plant.

PARAGRAPH XXXI.

GROUND WOOD PULP MILLS AND CHEMICAL FIBER MILLS.

(A) HISTORICAL REMARKS. Up to the year 1854, paper was made from cotton, linen and hemp fiber, precipitated from a mush in the shape of a matting. The use of mechanically ground wood (pulp) dates back to 1854.

Since 1867 wood has been further refined by chemical processes which separate the wood into thinner strings of cells and free it from rosin, tannin, albumen, gums, &c.

In the United States there were at hand in 1890, 82 mills; in 1909, 253 mills (counted by the census).

Rags, manila, straw, and waste paper, used as raw material for paper, still vie in value with the wood used as raw material.

Japanese paper is made of the inner bark of a mulberry tree, Brussonetia, and of the shoots of Edgeworthia.

For highest grades of writing paper, cotton and linen are used.

In 1900, close to 2,000,000 cords of wood were consumed, of which quantity three fourths were spruce and one fourth poplar and miscellaneous. The average value per cord was $5.

In 1909, over 4,000,000 cords of wood were consumed, and the average value had risen to $8.62.

The participation in the total consumption of the various species, domestic and imported, during 1909, appears from the following census tabulation: —

Kind of wood	Value per cord (Dollars)	Quantity (Cords)	Per cent of participation
Spruce: — Domestic	9·32	1,653,249	41·3
Imported	11·34	768,332	19·2
Hemlock	6·30	559,657	14·0
Poplar: — Domestic	7·96	302,876	7·6
Imported	7·94	25,622	0·6
Balsam	8·28	95,366	2·4
Pine	6·25	90,885	2·3
White fir (concolor)	5·34	37,176	0·9
Cottonwood	(1)	36,898	0·9
Beech	7·21	31,390	0·8
All other species	6·81	151,179	3·8
Slab wood and other mill waste	4·66	248,977	6·2
Summary ...	8·62	4,001,607	100·0

(1) The value of cottonwood is not given; its use has declined rapidly of late years.

(B) STATISTICAL REMARKS. One cord of wood yields one ton of ground pulp wood (mechanical fiber) or one half ton of chemical fiber. In the so-called "news grade" 70 per cent of pulp is mixed with 30 per cent of chemical fiber.

An average fiber mill produces 75 tons a day.

A modern pulp plant requires annually at least 6,000 cords of wood; a modern fiber plant at least 25,000 cords.

The price of the product f. o. b. factory is, approximately: —

<div style="text-align:center">

For ground wood pulp .. ... $15 per ton
For soda fiber .. .. $36 per ton
For sulphite fiber ... ... $47 per ton

</div>

(C) THE PLANT:—

I. The chemical fiber plant requires an investment of about $10,000 per ton of daily production. Unlike a sawmill, a fiber plant cannot be shifted when the nearby supply of raw material is exhausted.

II. A fiber plant must be located:–

(a) CLOSE TO WATER; water is not so much used for motive power as for the washing of the fiber;

(b) CLOSE TO CHEAP WOOD SUPPLY; wood must be plentiful and uniform, of a long, straight fiber, readily interlacing and white;

(c) CLOSE TO CHEAP COAL, since the coal consumption per pound of fiber amounts to at least $^{3}/_{16}$ of a pound of coal. So much coal is required for heating, drying, and bleaching, that all excepting 15 per cent of the machinery should be driven free of charge.

(D) PROCESS OF MANUFACTURE. The manufacture is either purely mechanical (ground wood pulp) or also chemical. In the latter case, the soda process, the sulphite process, and the sulphate process are distinguished. The electric process, though very promising, is still in early infancy.

The mechanical process, applicable to spruce particularly, has consumed in the United States, in 1909, altogether 1,246,121 cords out of a total quantity of 4,001,607 cords.

The sulphite process was applied to 2,183,984 cords (mostly spruce, hemlock, balsam, fir).

The soda process was applied to 571,502 cords (notably pine and hardwoods).

The sulphate process is said to be particularly adapted to pine and larch.

The principle of manufacture is:– Grinding and beating of wood in water until it forms a fluid pulp; allowing water to run off through screens, leaving a matted stratum of wet fiber; bleaching; drying; pressing.

I. Ground wood fiber:–

(a) The log is cut (by a drop frame wood saw) into bolts one foot long and 5 inches thick. The bark is removed, and the knots are usually bored out;

(b) The bolts are fed into pockets and pressed against millstones of 26 inches face by 54 inches

Overhead drop frame wood saw, made by M. Garland Co., Bay City, Mich.
D is the log to be cut; C, the cut piece of wood; A is the drop saw frame; F, G, H, friction and geared log chain drive, which can be stopped at any desired point and started at will.
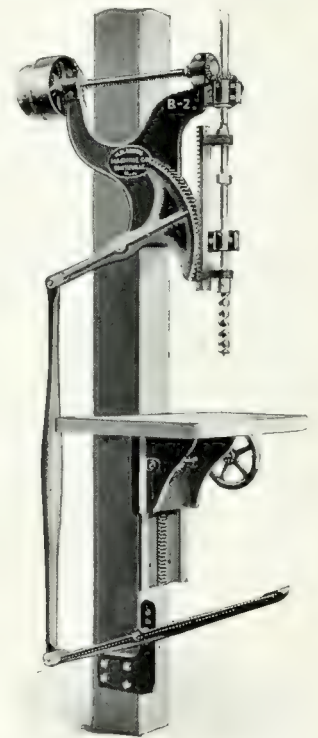
Vertical knot boring machine.
H. B. Smith Machine Co.,
Smithville, N. J.

diameter which turn slowly under constant influx of water. The bolts must be ground in the direction of the fiber. Two, three, and four pocket grinders are found, weighing from 5 to 10 tons;

(c) The fluid pulp is carried through screens, retaining the long splinters, which are transferred to a pulp engine for further mechanical refining;

(d) The fiber may be ground or lacerated a second time both in stampers and rotary mills;

(e) The pulp is separated according to its fineness by rocking screens of different mesh which allow the water to run-off. The screened product is taken up by endless belts of cloth (in the so-called "wet machine") which carry it as a thin matting through a series of pressure rolls (pressure either hydraulic or spring pressure);

(f) The mattings are dried by super-heated steam, by pressure or in the air. Pulp is shipped in rolls about 3 feet long and 1½ feet in diameter. It is not paper but merely the leading raw material for ordinary paper.

Wet machine for ground wood pulp. Trevor Mfg. C., Lockport, N. Y.

The actual price of mechanically ground wood pulp depends entirely on the amount of water retained in it. When the product is shipped over long distances, it becomes necessary to use a large amount of heat for the efficient expulsion of the water adhering to the fibre. Aside of this requirement, the pulp mill can get along without any heat and without any power other than that furnished by a waterfall.

The ground wood pulp is more mealy and less interlaceable than the chemically prepared fiber; it contains lignin as well as cellulose; exposed to the sun, it soon turns to a brownish tint.

Pulp grinder. Trevor Manufacturing Company, Lockport, N. Y.

II. Soda process. This process consists of:—

(a) Removing bark in a "barker," consisting of knives spanned into a rapidly rotating disc;

(b) Grinding and dissecting the bolts into fragments about $1/24$ inch by 1 inch in size;

(c) Charging the ground material into annealed and welded steel digesters (of about 15 feet diameter and of 50 feet height) containing a solution of caustic soda;

(d) Boiling by live steam under a pressure of 125 pounds;

(e) Blowing the product against a target;

(f) Repeated washing and screening;

(g) Bleaching with chlorate of lime;

(h) Fishing the product thus obtained from a stream of water by endless screens and by endless belts of flannel cloth, in the "fourdrinier," and drying it between heated rollers;

(i) Reclaiming caustic soda by boiling in vacuum vats and by melting in the "incinerator."
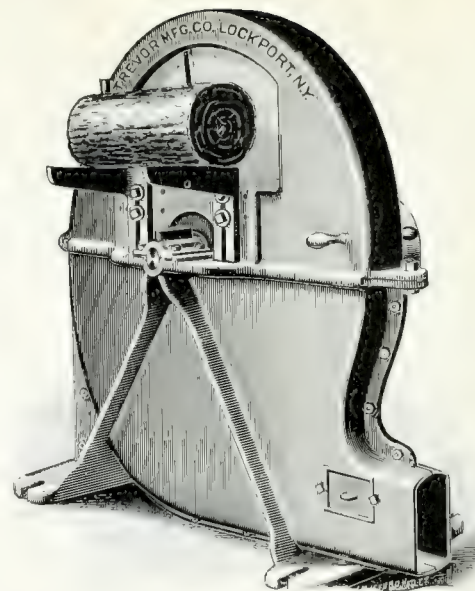
Barker for pulpwood. Trevor Mfg. Co., Lockport, N. Y.
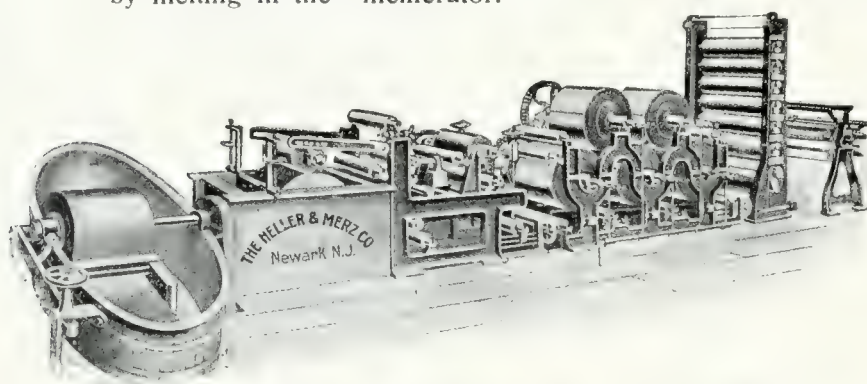
Miniature of beater, fourdrinier, and calender made by Heller & Merz Co., Newark, N. J.
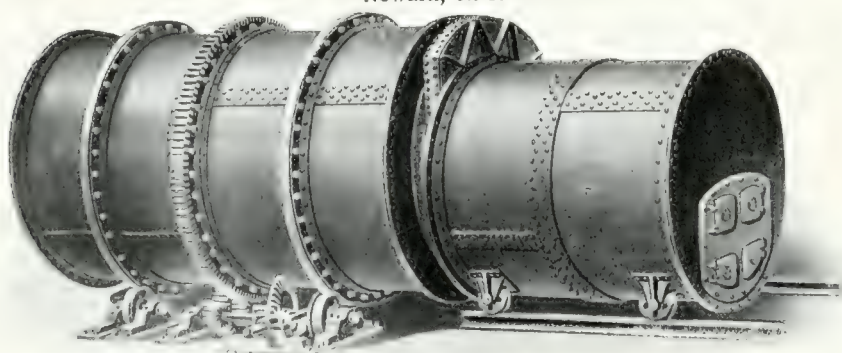
Incinerator used in regaining caustic soda, made by Manitowoc Engineering Works, Wisconsin.

Sulphite digester, made by Manitowoc Eng. Works, Wisc.

III. Sulphite process. It differs from the soda process notably in the points "c," "d," "e," and "g."

The wood fiber is first cooked without chemicals and then boiled for 60 hours in lead-coated digesters with calcium sulphite, a cheap chemical usually prepared at the mill itself.

No or only little bleaching is required, the fiber being fairly free from color when leaving the digester.

The expense of manufacture per ton of sulphite fiber is said to be as follows:—

Two cords of spruce	ℳ 19·00
Coal	ℳ 3·00
Sulphur	ℳ 3·30
Lime	ℳ 0·70
Labor, inclusive of office force	ℳ 12·00
Wear and tear	ℳ 4·50
Interest on investment	ℳ 3·00
Total	ℳ 45·50

The sulphite process offers the following advantages over the soda process:—

(a) It is simpler (less bleaching; no regaining of chemicals);

(b) It does not interfere with the strength of the fiber;

(c) It yields a larger output of fiber per cord.

IV. Sulphate process. This process is adopted in spruce mills originally arranged for the caustic soda process; further for pine and larch as raw materials. The chemical used is sodium (or magnesia) sulphate, the price of which is only one third that of caustic soda. The process, which results in violent reactions, is particularly strong. It is also known as the Krafft process.

V. Electric process. The electric current is used to obtain from an 8 per cent solution of common salt ($Na\ Cl$) its composing parts, viz., caustic soda and hydrochloric acid.

These substances, alternatingly acting upon the wood prepared in the manner described under II, "a," and "b," dissolve the lignin and destroy the incrustations of the fiber, so that pure cellulose remains in the digesters.

Two digesters are used, connected with the positive and the negative electrode of the current respectively. The process is said to be faster and cheaper than the sulphite process. No bleaching required.

PARAGRAPH XXXII.

TEXTILE FABRICS.

Garments made of paper have long been used in Japan and in China, in default of other material for clothing. In Western countries the only articles of clothing made of paper, until recently, were "starched articles," like collars and cuffs. Now, however, numerous inventors are endeavoring to introduce woven paper fabrics.

(A) FINE AND STRONG PAPER is cut into strips $\frac{1}{10}$ inch wide. The strips are twisted or spun into yarns, to be used in weaving. Usually, the yarn is used in connection with cotton yarn, the paper yarn enwrapping the cotton yarn for toweling, curtains, mattings, screens, &c.

In conjunction with wool, the paper yarn is used to manufacture heavier and warmer material fit for wearing.

(B) XYLOLIN, a substance made of wood and fit for exclusive use in weaving, has been patented by Emil Claviez (Saxony, Germany). Xylolin is non-shrinkable and impervious to water.

Yarns made of xylolin (known as sylvalin yarns or as lizella yarns) are being manufactured, on a large scale, in the German spinneries owned by Prince Henkel-Donnersmark and by the Elberfelder Farbwerke.

(C) WOOD YARN, as so far obtained, is inferior to cotton yarn in strength and in the possibility of laundering. In the future, nevertheless, wood used for a raw material in the textile industries may advance as much as it has advanced in its use with the paper industries.

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PARAGRAPH XXXIII.

TANNING MATERIALS AND TANNERIES.

(A) OBJECT OF TANNING. Tannage tends to render the skin permanently supple and durable by impregnation with tannin.

(B) THE METHODS OF TANNAGE EMPLOYED nowadays are:—

1. "Tawing" by means of alum salts.
2. "Shamoying" by means of certain oils or acids of oils.
3. "Tawing" by salts of chromium.
4. "Vegetable tanning."

Chromium tannage has many advantages; it is superseding vegetable tannage in many instances. In the sole leather, belt leather, and harness leather industries, vegetable tanning material is still preferred. Forest utilization is concerned in vegetable tannage alone.

(C) VEGETABLE TANNING MATERIALS:—

I. **Tanning materials used** in the United States, by over 600 tanneries, are:—

Hemlock bark ...   800,000 cords, worth $ 9·00 per cord

Oak bark   ...   ...   300,000 cords, worth $10·90 per cord

Vegetable (notably chestnut) extracts, 200,000 tons, worth $28·00 (in chestnut) per ton.

Chestnut wood averages 8 per cent and chestnut oak bark 12 per cent of tannic acid, approximately. Sumach leaves and mangrove bark, rich in tannic acid, are used on a small scale.

II. **Important are the importations** into the United States of foreign tanning materials, particularly rich in tannic acid, notably of:—

Quebracho wood (containing 24 per cent tannin, from Argentina, Chile, Peru).

Quebracho extract.

Divi-divi, bean pod of Caesalpinia coriaria (containing 45 per cent tannin).

Catechu (cutch, terra japonica), a cake obtained from boiled leaves, fruit, and wood of Acacia catechu.

Gambier, obtained like catechu from Uncarica gambir (exported from Singapore).

Myrobalans, the dried fruits of various species of the genus Terminalia (from East India).

Kino, a gum bled from many tropical trees, e. g., from Pterocarpus (Malabar-kino), from Butea (Bengal-kino), from Eucalyptus (Australian kino).

Valonea, the cup of the acorn of Quercus aegilops (from Mediterranean countries).

III. **Tannin percentages of dressed bark** are, after experiments given in Sargent's 10th Census report:—

Mangrove	31·0 %	...	Burr and red oak ...	4·6 %
Cal. Chest. oak ...	16·5 %	...	Chestnut	6·7 %
Live oak	10·5 %	...	Douglas fir	13·8 %
Chestnut oak... ...	6·2 %	...	Eastern hemlock ...	13·1 %
Spanish oak	8·6 %	...	Western hemlock ...	15·1 %
Black oak	5·9 %	...	Eastern spruce	7·2 %
White oak	6·0 %	...	Engelmann spruce ...	16·0 %

(D) TANBARK IN PARTICULAR:—

I. **Notes** on tanbark obtained from chestnut oak, and from hemlock.

(a) THE CORKY OUTER LAYERS of bark do not contain any tannin. The inner layers (phloem and bark cambium) are rich in tannin.

(b) FRESH BARK contains on an average 45 per cent water and shrinks heavily during the drying process.

(c) WHILE CHESTNUT OAK BARK MUST BE PEELED IN SPRING immediately when the sap begins to rise (April-May), hemlock bark may be peeled at any time from May to September, peeling best in July. Peeling of oak bark in the "second sap," towards June 15th, is not advisable.

(d) CHESTNUT OAK TREES IN THE BOTTOMS peel earlier than those higher up on the slopes.
The bark on the uphill side of a tree is thinner than the bark on the downhill side.

(e) TREES EXPOSED TO THE WEATHER (isolated, on unprotected slopes) have shorter boles but heavier bark than those growing under the reversed conditions.
Dying trees will not peel.

II. Peeling process: –

(a) GIRDLE THE TREE about four feet above the ground; remove bark from stump and roots; fell the tree in such a way as to leave the bole well raised above the ground.

(b) NOTCH (WITH AXE) A LINE along the tree and rings around the tree every four feet. Have two men with "spuds" peel the ringed sections, and see that the pieces peeled are as wide as possible and, as near as possible, four feet long. Large pieces will dry well and will save expense in handling. Handling costs more than peeling.

A bark spud.

(c) LEAN THE PEELED PIECES against the felled bole, flesh side in, as high above ground as possible, and see that the air circulates freely aro und them.

(d) SEE THAT THE BARK IS AS LITTLE SHADED as possible. Peel before leaves are out. Never leave bark to dry in a moist gully. Never place flesh of bark flat on a solid object. Three days of dry and windy weather will cure the bark when it is properly peeled and "stood up." Fully cured bark will break, without long slivers, square across its face. Bark is sure to deteriorate if a long rainy season sets in.

(e) THE MINIMUM DIAMETER OF TREES and branches to be peeled depends on the price of bark and the price of stumpage. Far from the roads, it does not pay to peel pieces of less than 10 inches diameter.

Chestnut oak tree cut for tanbark on Biltmore Estate, North Carolina. The bark is placed to cure against the tree from which it came.

(f) THE CURED BARK is carried to the sledding roads, is sledded to the waggon roads, and is waggoned to the depot.

(g) THE EXPENSE OF OAK BARK PEELING, in the Southern Appalachians, is per cord of 2,240 lbs.: –

Cutting and peeling and curing ... $1·25 to $1·50
Carrying and sledding... ... ... 90c to $1·45
Sleds and sledding roads... ... ... 15c to 30c

(h) WHITE OAK BARK imparts to the leather a gray color, and yellow oak bark imparts a bright yellow color. Both these kinds are little used.

(C) TANNING EXTRACTS IN PARTICULAR:—

I. Tannin extracts are manufactured from bark (oak and hemlock), chestnut wood, quebracho, mangrove, and oak wood. Quebracho wood contains 24 per cent; chestnut wood 8 per cent; white oak wood 4 to 6 per cent of tannin.

II. **The bark or else the wood** is shredded in a chipper and the tannin extracted (not entirely) by steam or hot water. The liquid obtained is condensed in the vacuum.
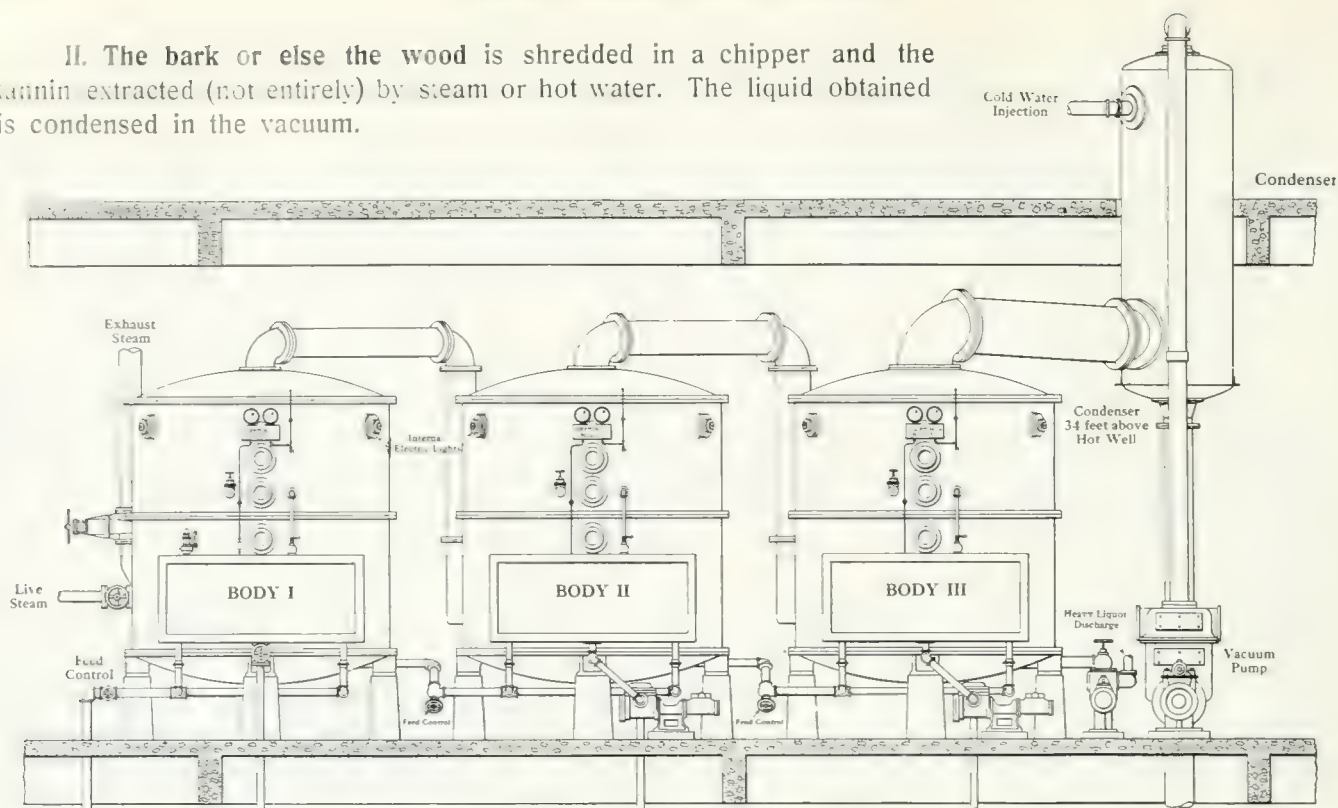
Triple effect Zaremba evaporator for condensation of tannic acid. Zaremba Co., Buffalo, N. Y.

III. **While in France the sappy branches** and young shoots of chestnut are preferred, in America the heart wood and especially the butt is considered best.

IV. **The wood is cut 4 feet** to 5 feet long. The South uses a cord of 160 cubic feet $= 1\frac{1}{4}$ cords of 128 cubic feet in the chestnut wood business.

V. **Clear water,** cheap transportation, and cheap fuel are required for successful manufacture. Only sound wood is used. Worm holes in chestnut, however, do not interfere with its tannic value.

VI. **Liquid extracts** exposed to air or exposed to heat spoil rapidly.

VII. **Chestnut extract is shipped** in barrels of 56 gallons capacity or in tank cars. More rarely, it is condensed to a solid form and shipped in sacks.

VIII. **The price of chestnut extracts** is $1\frac{1}{4}$c to $1\frac{1}{2}$c per pound.

IX. **Rarely in the United States,** but usually in France, chestnut extract is bleached so as to prevent it from imparting a dark color to the leather.

X. **One cord (160 cubic feet)** of chestnut wood yields one barrel or 500 pounds of extract containing about 25 per cent tannin, and worth $6.50 to $8.00.

(F) CRITERIA OF A GOOD METHOD OF LEATHER MANUFACTURE are:—

I. **The weight of the leather produced.** Since leather is sold by the pound (excepting army orders), the tanner tries to press into the hide the maximum amount of tannin, tannin being cheaper than hides.

Beyond a certain point, this extravagance of impregnation fails to increase the wearing qualities of leather and is therefore useless to the buyer.

II. **The color of the leather produced** and the adaptability of the leather to coloring.

III. **The possibility of the tannin being washed out** through wear and tear.

IV. Quickness in filling orders and amount of investment required.

V. Cheapness of manufacture. The best leather is produced slowly only by use of materials rather poor in tannin.

(G) STATISTICAL NOTES:—

I. One ton (2,240 pounds) of hemlock bark will tan 300 pounds of sole leather or 400 pounds of upper leather; 4 to 5 pounds of good oak bark are required to produce 1 pound of sole leather.

One acre of hemlock forest is said to yield about 7 cords of bark, and 1,500 board feet of timber are said to carry, on an average, 1 cord of bark.

One acre of hardwood forest will yield, on an average, not to exceed one-half cord of chestnut oak bark. The form height for chestnut oak bark ranges between 0·10 and 0·18.

II. One hundred pounds of dry hides yield 150 to 185 pounds of leather; 100 pounds of green hides yield 60 to 80 pounds of leather. The cost of the hide amounts to from 50 to 75 per cent of the cost of production.

III. The number of tanneries in the United States has greatly decreased from the year 1880 (5,628 plants) to the year 1910 (597 plants). The small tanneries using old fashioned and wasteful methods have been outclassed by the large and intelligently conducted modern plants. The leather trust controls over 100 of the largest plants. The tendency of the tanneries is a gradual shifting towards the waterfront.

IV. "Hides" are obtained from oxen, cows, and horses; "kips" from yearling cattle; "skins" from calves, sheep, goats, and pigs.

Calf skin is used for upper leathers of shoes; sheep skin for cheap shoes, linings and gloves; goat skin for fine upper leathers and gloves.

Hides are often split, and the so-called grain and flesh splits are used in place of goat and calf skins. The best and strongest leather is obtained from the back of the animal close to the spine.

(H) MANUFACTURE. The old fashioned methods used from time immemorial consisted of rinsing the skins; scraping-off the flesh; treating the hair with lime; placing alternating layers of crushed oak bark and of skins in rough vats. The time consumed in this process of manufacture frequently exceeded a year. The best leather, however, is produced in this way.

The modern process in manufacturing sole, belt, and harness leather is:—

I. Soak in soft water (heated to less than 70 degrees F.) to remove salt and blood and to restore the original softness and pliability of the skin. Remove blood, dirt, flesh, and fat from inner side of hide.

II. Loosen hair either by liming green hides in milk of lime for three to six days or by sweating dry hides at 70 degrees in a closed room, inviting a partial decomposition of the hair sheath. The sweating is preferred for acid hemlock tannage.

III. Remove on the "beam," by hand or machine, the hair and the lime.

IV. Prepare the liquors in the leech house. Cold water extracts only part of the tannin from either bark or wood. Very hot water may extract all, extracting with it, however, undesirable coloring matters and killing the fermenting microbes. Aside from the mechanical imbedding of molecules by impregnation, a chemical action (fermentation) is supposed to take place in the case of bark tannage, due to the presence of microbes in the bark, chemically binding the tannin to the albumen and gelatine of the skin.

V. The tannage itself is either "acid hemlock tannage," or "non-acid hemlock, oak, and union tannage."

(a) ACID HEMLOCK TANNAGE CONSISTS OF:—

    1. Coloring in a dilute solution of tannin.

    2. Placing skin for 2 to 4 days in a sulphuric or lactic bath (of 10 to 30 per cent) by which the hide is swelled to a great thickness.

    3. Placing the hide in a strong, concentrated solution of tannin.

(b) Non-acid hemlock tannage, oak tannage, and union tannage ($^2/_3$ hemlock bark, $^1/_3$ oak bark) consists of:—

1. Treating (coloring) the hide, to begin with, to weak solutions of 4 to 13 per cent of tannin, during 10 to 15 days.
2. Gradually increasing, during the next 150 days, the concentration of the liquors. If a hide is at once hung in a strong liquor, its outer layers only are tanned. The hide will not swell, and the inner layers will fail to be impregnated.

VI. The operations finishing the process of manufacture are:— Washing; scouring-off the so-called bloom; stuffing (which means bathing in grease); drying; dampening and rolling under pressure; re-drying; glossing on a brass bed by brass rollers.

PARAGRAPH XXXIV.
MANUFACTURE OF CHARCOAL IN CHARCOAL KILNS (PITS).

(A) DISTILLATION OF WOOD. The destructive distillation of wood, conducted under reduced admission of air, yields chemically the following proportion of substances:—

1. Twenty-five per cent of non-condensable gases, viz.:—

carbon, monoxide	marshgas	propene
carbon dioxide	acetylene	ethylene

2. Forty per cent of condensable vapors, viz.:—

acetone, furfurol	acetic acid	crotonic acid
methyl alcohol	formic acid	capronic acid
methylamine	butyric acid	propionic acid

3. Ten per cent of tarry liquid, viz.:—

tar	xylol	cresol	pyrene
creosote	cumol	phlorol	chrysene
toluol	methol	naphthalene	paraffine

4. Twenty-five per cent of solid residue, viz.:—

charcoal	inorganic salts

(B) THE KILN OR PIT PROCESS. In the kiln process of destructive distillation of wood, the substances given above under 1, 2, and 3 are allowed to escape unused.

Modern technology succeeds in condensing and utilizing several of these substances by the process described in the next following paragraph (XXXV).

Still, the majority of the charcoal commercially used is produced by the old and wasteful charcoal kiln.

(C) CHARACTERISTIC QUALITIES OF CHARCOAL:—

1. Charcoal has per cubic foot a larger heating power than wood. A ton of charcoal, in modern machines, generates 2,000 horse-power.
2. Owing to its lesser weight, it is very cheaply transported.
3. Its freedom from sulphur and phosphates makes it valuable for metallurgic work (Swedish charcoal iron).

(D) THE WORK AT THE KILN:—

I. For use in kilns, wood must be thoroughly seasoned, free from heavy knots. The billets must have equal length.

The kilns should be charged with but one species and but one assortment of wood at a time.

II. The works consists of:—

(a) PREPARATION OF GROUND NEAR water by leveling and hoeing the soil, by removing roots and stones, by raising the center of the circle to be occupied by the kiln about 10 inches over its circumference.

The diameter of the circle is from 15 feet to 30 feet usually. The best soil is loamy sand, which secures proper regulation of the draft.

The site should be protected from wind. Twigs are woven into a wind screen on the windward side, if necessary.

(b) ERECTING THE "CHIMNEY" by placing three or four poles of even height at one foot distance from a central pole, fastening them to the central pole by withes.

The chimney is cylindrical if kiln is lighted from above, and pyramidal if kiln is lighted from below. The chimney is filled with inflammable substances (dried twigs, charcoal, &c.).

Small charcoal pit ready to receive a coating of beech mold and a covering of dirt, preparatory to charring.

(c) CONSTRUCTING THE KILN PROPER.

The kiln has a parabolic form. It consists of two or more tiers of billets placed more or less vertically, the bark turned outward, the big end downward, the finest pieces near the chimney and near the circumference, the largest pieces half way between.

These tiers are topped by a cap, consisting of smaller billets placed slopingly. A cylindrical chimney extends through the cap. A pyramidal chimney is closed by the cap.

In the latter case a lighting channel is left on the ground running radially on the leeward side from the base of the pyramidal chimney to the circumference. This channel, too, like the chimney, is filled with inflammable material.

(d) STUFFING ALL IRREGULARITIES, interstices, cracks, &c., showing on the outside of the kiln with small kindling.

(e) COVERING THE KILN by two draft-proof layers so as to exclude or restrict the admission of air.

1. The vegetable layer, $\frac{1}{4}$ to $\frac{3}{4}$ foot thick, made of green branches, grass, weeds, leaf mold and moss.
2. The earth layer, 2 inches to 6 inches thick, consisting of loam, charcoal dust, &c.

If the kiln is lighted from below, a belt about 1 foot high running around the circumference on the ground is left without the earth cover until the fire is well started.

The earth layer and the vegetable layer are thoroughly joined by beating with a paddle.

In large kilns a wooden frame (the armor) consisting of T sections is used to prevent the cover from sliding down.

It presents also a safe footing for the attendant to work on.

Small charcoal pit at the completion of the charring process.

III. **The kiln is lighted** early in the morning on a quiet day. A cylindrical chimney is closed on top from above as soon as the fire is well started in the cap.

A lighting channel, in the case of a pyramidal chimney, is similarly closed.

IV. **The regulation of the fire** and of the draft are the most important functions of the attendant who guides the fire evenly and gradually from the cap down to the bottom.

The means of guidance are: —

    (a) To check draft, increased earth cover;
    (b) To increase draft, holes of about 1 inch diameter punctured through the cover with the paddle reversed.

If the wind is strong, all holes are closed and the earth cover is increased.

Cracks forming in the cover must be closed at once.

Large charcoal pit in Austria, ready to receive the covering.

In dry weather the kiln is continuously sprinkled.

The kiln may explode if the cover is too heavy and the draft too strong.

The color of the smoke escaping through the punctures indicates, by turning blue and transparent, the completion of the charring process above the punctures.

The old punctures are then closed, and another row of punctures is made about two feet below the closed holes.

V. **Refilling is required** where dells are forming irregularly, while the kiln gradually shrinks to one half of its original volume.

For refilling, the cover over the dell is quickly removed, all holes having been closed beforehand, and the dell is rapidly filled with new wood.

VI. **When the bottom holes show the proper color of smoke**, the charring process is completed. All holes are then closed, and the kiln is allowed to cool.

The duration of the charring process is from six days to four weeks, according to size of kiln. The contents vary between four and sixty cords.

VII. **Beginning at the leeward side**, the kiln is gradually uncovered. The crust of earth, cut into fragments, is thrown on again. The earth, trickling down, quenches the fire. After another twelve to twenty-four hours, preferably at night, the coal is taken out, in patches or pockets, slowly and carefully, so as to prevent the flames from breaking out. Water must be ready at hand to quench incipient fires.

(E) STATISTICAL NOTES. The loss of weight in the charring process is 75 per cent. The loss of volume is 50 per cent. Two cords of hardwood yield one ton of charcoal.

In America charcoal is sold by the bushel, a bushel weighing about 25 pounds.

The expense for labor incurred in erecting the kiln and in producing the coal is 60 cents per ton of product.

(F) APPENDIX. In Norway, Sweden, and Russia kilns of trapezoid form are built of peeled logs 18 to 30 feet long. The logs are lying horizontally in the heap which has the appearance of an American "skidway."

The lighting channel runs lengthwise on the ground.

The covering (branches below, mud above) is pressed against the vertical walls of the heap by slabs or by small horizontal poles held in place by pilings or by posts.

The fire is conducted from the small towards the big end of the trapezoid.

PYROLIGNEOUS ACID, WOOD (METHYL) ALCOHOL, AND THEIR MANUFACTURE.

(A) RAW MATERIALS. These are, preferably, broad-leafed species—beech, maple, birch—which must be thoroughly seasoned. Birch is inferior to beech and maple. Elm imparts to the product an undesirable odor.

Heavy material is preferable, it is said, to small stuff.

(B) DISTILLATION. The process consists in a dry distillation of the wood, differing from the charcoal kiln process merely by preventing the resulting gases from escaping.

The distillation takes place in large horizontal iron cylinders, usually over 40 feet long by 6 feet in diameter, into which the wood is run on steel trucks. After closing the cap of the cylinders (admission of air reduces the output of pyroligneous acid) the cylinders are slowly heated to a red heat. The gases forming are led, by long worm pipes, through a condenser.

Not all of the gases formed allow of condensation. The uncondensable gases are conducted to the fire room.

At the bottom of the cylinder, tar is forming and is let out frequently by a system of pipes into a collecting basin. Conifers yield more wood-tar than do hardwoods.

(C) FURTHER TREATMENT. The gases, condensed to a liquid a large proportion of which is water, are conducted to the still house.

The main components of the liquid are wood-tar (heaviest), pyroligneous acid (medium weight) containing wood-vingear and wood-alcohol, and wood-oil (lightest).

By gravity alone, these constituents are separated, to begin with, the liquid flowing from one tank into the other.

All containers must be made either of wood or of copper.

The pyroligneous acid, freed from wood-tar and from wood-oil, is then treated with lime. Lime neutralizes the pyroligneous acid, by forming acetate of lime, and frees the wood-alcohol.

The neutralized liquid is then distilled, wood-alcohol going over first, water next, and acetate of lime remaining as a syrup. This syrup is boiled down, in open pans, to the consistency of a sugar, the grey acetate of lime of commerce.

(D) THE PLANT. The plant consists of two buildings:—

I. The retort house contains a series of iron retorts which can be opened and sealed at either end. Cars loaded with dry wood enter at one side; cars loaded with glowing charcoal are drawn from the other side, after the lapse of 48 hours. The charcoal cars are allowed to cool in a double set of air-proof sheet iron sheds. Immediately above the retorts are found the open pans in which the acetate of lime is condensed.

II. The still house, situated at a safe distance from the retort house, contains the main condenser, a series of wooden tanks and a number of copper stills. Its basement is used for a barrelling room.

(E) OUTPUT. One cord of air-dry beech yields 2,000 pounds of liquids, 14 gallons of tar, and 1,000 pounds (50 bushels of 20 pounds each) of charcoal, worth 5c to 6c per bushel.

The 2,000 pounds of liquids furnish 190 pounds of acetate of lime (worth $9\frac{1}{2}$c per pound, and 9 gallons of 96 per cent wood-alcohol, worth 50c per gallon.

(F) USE. Acetate of lime is used in the manufacture of acetone, gunpowder, acetic acid, and of the salts of acetic acid.

Wood-alcohol is used largely in the manufacture of varnishes, dyes, celluloid, and especially for denaturizing the true ethyl-alcohol. It is poisonous.

(G) STATISTICS. In the United States during 1909, 116 distilling etablishments consumed 1,150,000 cords of hardwoods, costing $3·32 per cord upon an average.

The products obtained were	Total output	Result per cord
Charcoal	53,000,000 bushels	46·1 bushels
Wood alcohol	8,500,000 gallons	7·4 gallons
Acetate	150,000,000 pounds	131·0 pounds

PARAGRAPH XXXVI.
TRUE OR ETHYL ALCOHOL AND ITS MANUFACTURE.

(A) PRINCIPLE UNDERLYING THE PROCESS. Wood heated under pressure in the presence of acids yields sugar (dextrose). This sugar, freed from the acid admixture and allowed to ferment under the influence of yeast, is transformed into ethyl alcohol.

(B) RAW MATERIAL. Cottonwoods, linden, yellow poplar are said to be superior to the heavy hardwoods as well as to conifers. Unless sawdust is available, the wood is prepared as if it were to be used in the manufacture of chemical fiber.

(C) PROCESS. The acid used does not enter into any chemical combination with the wood. It merely acts by its presence and is said to be most efficient when in statu nascendi. Sulphuric acid, sulphurous acid, hydrochloric acid or a mixture of these and similar acids are used.

The temperature of the lead-coated vats containing acid and wood is gradually raised to about 250 degrees F. Hydraulic pressure in also applied, either before or after the heating process. As a matter of fact, the partial conversion of cellulose into sugar seems to be due to pressure, not to heating. The acid is then neutralized and the temperature reduced to about 85 degrees F. By the addition of yeast (fed on phosphates of potash and of ammonia) a violent fermentation of the sugar is started, ending within 36 hours, when the yeast has dropped down to the bottom of the vat while the sugar has been converted into alcohol.

The liquid is distilled and redistilled, yielding alcohol of any desired concentration.

The refuse remaining – merely a small percentage of the raw material seems convertible into sugar – might be used as fuel for the boilers.

Classen claims, after his method, to obtain at least 30 per cent dextrose from absolutely dry wood. After T. Kœrner, not more than 6 per cent of the weight of air-dry wood can be thus converted.

(D) OUTPUT. One hundred pounds of dry-wood are said to actually yield about five pounds of 90 per cent alcohol. The process of manufacture is far from being perfect. A number of chemists, notably Classen, are hard at work to further improve and to cheapen the process. Cheap alcohol – a fuel, a source of light, and a source of technical energy – manufactured from wood will be a boon for household, industry and forest.

PARAGRAPH XXXVII.
ARTIFICIAL SILK MADE FROM CELLULOSE.

(A) HISTORY. Artificial silk was first prepared by Hilaire de Chardonet in 1884. To-day, many patents and numerous factories to exploit them exist in the Old Country.

(B) QUALITIES OF PRODUCT. Artificial silk has an exquisite shine and is easily colored. Artificial silk is thicker, less flexible, more brittle, and weaker than natural silk. It distends perceptibly in water. The tearing strength of silk obtained from nitro-cellulose is only 35 per cent of that of true silk, its toughness only 45 per cent.

Under the microscope, the thread produced by the silkworm shows a hollow cross section, whilst that of artificial silk is solid. Chemically, there is no difference between the composition of natural and

of artificial silk. Silk is a peculiar variety of cellulose; all plant matter containing cellulose, and notably all wood fiber may be used for the manufacture of artificial silk.

The adaptability of the various American forest trees to the production of artificial silk remains to be studied.

The price of artificial silk approximates $1·35 per lb.; whilst the price of natural silk varies between $4·00 and $6·00 per lb.

Artificial silk is used on a daily increasing scale in silk weavings. New methods and modifications of manufacture continuously increase its chances to become a substitute for natural silk.

(C) PROCESSES OF MANUFACTURE. There are three main processes in use, namely:—

I. A solution of nitro-cellulose, a compound of nitric acid and cellulose in ether or alcohol, is pressed through minute capillary pipes, appearing in long, silky threads. The methods of Vivier and Lehner reduce or entirely destroy the inflammability of the product.

II. Cellulose is dissolved in a mixture of copper oxide and ammonia. This solution forms a waxy mass which is pressed through minute capillary openings and appears in the form of supple, long, silky threads, immediately entering a bath of sulphuric acid. Here cellulose is set free, now a solid thread, while blue vitriol and sulphate of ammonia result at the same time. The threads are spun exactly like threads of natural silk.

III. Viscose process. A combination of cellulose and sodium, treated with carbon-bysulphide, yields a glutinous, cartilaginous substance of great pliability, first produced in 1892 and named "viscose."

Exposed to the influence of the atmosphere, carbon-bysulphide is set free, gradually, through evaporation.

From the substance remaining, from which the sodium is removed by washing, a peculiar variety of cellulose is obtained, technically known as "viscoid."

Viscose can be treated to coloring matter, and the viscoid retains the color thus imparted.

When a solution of viscose is forced through minute, capillary pipes, finer threads may be obtained than those produced by the silkworm. These threads, deprived by rapid evaporation of the carbon-bysulphide adhering to them, or else passed to the same effect through a solution of chloride of ammonia, are so fine that they cannot be used individually, and that strands of them must be used for spinning and weaving.

Viscose silk is no more inflammable than is cotton.

PARAGRAPH XXXVIII.

MANUFACTURE OF OXALIC ACID.

(A) PRINCIPLE. Any wood heated to about 400 degrees F. in the presence of caustic substances yields, among many other products of disintegration, a large percentage of oxalic acid.

(B) RAW MATERIAL. Any wood finely ground or pulverized, and especially sawdust and mill refuse, is well adapted to the process,—oak as well as beech, pine, chestnut, &c. Cottonwood is said to form a poor raw material.

(C) PROCESS. A mixture of caustic soda, caustic potash, and sawdust is heated, under continuous stirring, in open pans ($\frac{1}{2}$ foot deep and 6 feet square). The temperature is gradually raised to 480 degrees (not over) F., remaining at that figure for about $1\frac{1}{2}$ hours. The melted mass, consisting of oxalate of sodium and of carbonate of potassium, is thrown into water and allowed to cool, when the oxalate forms a dough of minute crystals. This dough is freed from water by centrifugal power, then treated with lime and thereafter with sulphuric acid, with the result that gypsum is precipitated from a solution of oxalic acid.

(D) OUTPUT. One hundred parts of wood yield up to 80 parts of oxalic acid. The quantity of the output depends on the proper mixture of caustic soda and potash, and on the proper regulation of the temperature.

(E) USE. Oxalic acid is used in calico printing, in bleaching, and in polishing metals. Some of its salts are used in photographic developing.

PARAGRAPH XXXIX.

THE MAPLE SUGAR INDUSTRY.

In the sap of all broad-leafed species considerable quantities of sugar are found. This quality is commercially important, however, only in the case of hard maple. In 1900 there were produced 51,000,000 pounds of maple sugar and about 3,000,000 gallons of maple syrup.

New York, Vermont, and New Hampshire are leaders in this industry. Seventeen per cent of all granulated sugar made in the United States is said to be obtained from the maple tree.

Vermont protects its maple sugar industry from counterfeits by State inspection and official stamp.

(A) TAPPING THE TREES: —

I. **The trees are tapped** from middle March to middle April. Cold nights alternating with warm days are necessary for best results.

II. **A hole is made, with an auger,** $1/4$ to $1/2$ inch in diameter, slightly slanting towards the entrance, to a depth of 2 inches, at a point 2 to 3 feet above ground. Holes on that side of the tree toward which it leans are said to be most productive. Holes 10 feet above ground do not yield any sap.

III. **A wooden or galvanized iron spout** (3 to 8 inches long, with a hook at the end to suspend the bucket) is inserted into the hole. A bucket is hung by its handle from the hook at the end of the spout.

IV. **The buckets** are emptied at least once a day, as the sap ferments rapidly. The sap, poured into large tanks resting on sleds, is quickly taken to the sugar shed. The buckets must be kept clean.

V. **The production per tree is 25 gallons of sap** per season. The season lasts not longer than four weeks. The trees are not affected by tapping, either in quality or vitality. A new hole is made every year.

(B) BOILING PROCESS. Immediately after gathering, the sap is boiled down in open pans over an open fire.

I. **Manufacture of sugar.** The sap is boiled in an evaporator to the consistency of wax, poured into forms, and stirred to prevent formation of large crystals. Crystalization takes about 12 hours. Fifty quarts of sap yield 2 lbs. of sugar.

II. **Manufacture of syrup.** The sap is boiled down to a lesser consistency and at once canned or bottled. Forty gallons of sap yield one gallon of syrup.

In a Vermont sugar bush. Workman in the act of inserting the sap spout.
(Photograph supplied by Vermont Agr. Exp. Station.)

Evaporator in the sugar house. (Photograph supplied by Vermont Agr. Exp. Station.)

PARAGRAPH XL.

NAVAL STORES, THEIR PRODUCTION AND MANUFACTURE.

(A) STATISTICS. In 1909 the United States produced 29,000,000 gallons of spirits of turpentine, worth $12,600,000; 3,300,000 barrels of rosin or colophany, worth $12,600,000. In 1911, the prices of turpentine and rosin had much increased.

One acre of turpentine orchard yields in three years' tapping 25 gallons of spirits of turpentine and 800 pounds of rosin.

Two hundred boxes yield in a season one barrel of crude rosin (280 lbs.) worth, in 1911, $8 for "dip" and $4 for "scrape." A barrel of rosin yields six gallons of spirits of turpentine.

Orchards are leased at $2 to $3 per acre for three years.

(B) METHODS OF ORCHARDING:—

1. Southern method (also Austrian method).

(a) SPECIES USED:—Longleaf pine; Cuban pine; short leaf pine, notably Pinus echinata (small trees preferred); in 1911 also Pinus taeda; in Austria, Pinus austriaca.

(b) OPERATIONS OF THE FIRST SEASON:—

1. *Boxing:*—The tree is cut into, 8 inches above ground, with a narrow, thin-bladed "boxing axe." Usually two boxes to a tree, on opposite sides. Width of box is 14 inches; depth horizontally 4 inches, vertically 7 inches; height of the tip above the lip about 10 inches. Boxing takes place in January and February.

2. *Cornering:*—Immediately after boxing the tree is "cornered." Cornering implies the removal of two triangular strips of bark and sapwood above the box, running as high as the tip. The resulting grooves act as gutters for the rosin.

Near the base of the tree, litter and debris are removed so as to reduce the danger from fire.

3. *Hacking:*—Hacking or chipping begins in early March and is continued until October. The "hack" is a bent-bladed, sharp instrument which is drawn obliquely across the tree, producing a series of V shaped grooves in the outer layers of sapwood above the box and the corners. The points of the V's stand in a vertical line over the tip. The surface thus scarified is called a face. The chipping removes a layer of sapwood $1/_2$-inch to $1^1/_4$-inch deep. Shallow chipping secures larger yields of dip (less dry face) and smaller death-rates of trees worked for rosin. The face of the first season is from 18 inches to 24 inches high and always remains as wide as the box.

4. *Collecting:*—The virgin dip accumulating in the box during the first season is dipped out seven or eight times; the rosin, hardened on the face, is scraped off towards fall.

In the turpentine orchard.

Hack with handle and weight.

Taking the dip from a box in a turpentine orchard.
(Reproduced from "Scientific Americ

(c) OPERATIONS OF SUBSEQUENT SEASONS:—In the following seasons, the face is gradually carried upward until the working becomes unprofitable.

The output of dip, now called yellow dip, decreases from year to year, with the increase of distance between the freshly hacked face and the box. The scrape preponderates over the dip.

Longleaf pine may be tapped for an indefinite number of years, if periodic intermissions permit the trees to recuperate. Usually, the campaign extends over three to four years.

The number of faces made on a tree depends on its diameter. A tree of 22 inches diameter receives three faces; a tree of 16 inches diameter receives two faces, whilst smaller trees receive one face only. A strip of bark about 8 inches wide separates the faces sidewise.

II. French method (Hugues system):–

(a) SPECIES USED:– Pinus maritima, which grows on the sand dunes fringing the Western shore of France, is exclusively treated to this method.

(b) OPERATIONS:–

1. *Remove the rough bark* around the tree to prevent pieces of bark from falling onto the face.
2. *In early March make a scar* close to the ground 4 inches wide and $1^1/_4$ feet high, removing $^2/_5$ inch of sapwood. The instrument used is a bent-bladed, crooked-handled axe.

Long-leaf pines bled, for a long number of years, by the box system, near New Berne, North Carolina.

3. *Insert a toothed collar,* made of zinc or iron, into an incision cut with a sharp curved knife at the bottom of the scar.
4. *Hang a glazed earthen pot* on a nail immediately under the lip of the collar. The pot is $5^1/_2$ inches deep, $5^1/_2$ inches wide at top and 3 inches wide at bottom.
5. *Extend the 4-inch scar* week by week upward until October, taking each time a thin layer of sapwood off the old face. The final length of the face reached in a number of years is up to 30 feet.
6. *The collar and cup* are moved each spring to the top of the preceding year's face.

The nailhole in the pot allows rainwater to run off, since water is lighter than crude rosin.
The pot is often covered with a wooden lid, the face itself by rough boards.

III. Dr. Charles H. Herty's gutter method:–

(a) APPLICABILITY:– The method can be applied to bled or unbled trees. It has been tried by the U. S. Forest Service since 1902 in the Southern pineries, and is being adopted gradually by all intelligent operators.

(b) OPERATIONS OF THE FIRST SEASON:—

1. *Use cornering axe* to provide two flat cheeks 8 inches above the ground forming an angle of about 120 degrees; each is half as high as it is long; total width about 14 inches. Two men, right and left handed, cut 3,000 such faces per day.
2. *Make two incisions* at base of faces, one for each cheek, one at least an inch higher than the other. Tool used is a broad-axe having a 12-inch straight blade.
3. *Insert galvanized sheet iron gutters* into the incisions. Gutters are 2 inches wide and 6 inches to 12 inches long, bent to proper form (angle 120 degrees) by a tilting-bench contrivance. The lower gutter projects by $1^1/_2$ inches over the mouth of the upper, the projection forming a spout.

4. *Fasten with a nail an earthenware cup* of a capacity equaling that of a box ($5\frac{1}{2}'' \times 3\frac{1}{2}'' \times 7''$) in such a way that its rim stands $\frac{1}{2}$ inch below the spout, and that the nailhole is as far as possible from the spout. The nailhole should be 2 inches below the rim of the cup.

5. *Chipping as in method I;* cups emptied from time to time into collecting buckets.

(c) OPERATIONS OF SUBSEQUENT SEASONS:—Next season, the uppermost chipped channels receive incisions and gutters as per (b), 2 and 3, above. The cup is moved to the upper end of the face made in the previous year.

(d) EQUIPMENT. Equipment required for 10,000 faces is:—

10,500 cups (cost $1\frac{1}{4}$ c each = \$131·25).

Gutter strips made from 1,886 pounds of galvanized iron, 29 gauge (cost of material \$103·27; cost of cutting and shaping gutters \$4).

10,000 sixpenny nails (costing \$1·05)

Freight charges are about \$304.

Labor at the trees requires an outlay of \$80.

(e) RESULTS:—Dr. Herty justly claims financial superiority of this method over the old Southern method, due to an increased output of turpentine.

Dr. Charles H. Herty's gutter method.

The Herty method also restricts the damage to the trees by fire, by storm, and by insects.

Some operators guide the rosin into the cups by means of a wire. The drops of rosin descend along the wire more rapidly than along the face.

IV. The airtight jar method. (Compare "Scientific American" October 28, 1911.)

(a) THIS METHOD IS APPLICABLE to all conifers, and to all trees regardless of size. It does away with the danger from fire and with permanent injuries to the trees.

(b) INSTEAD OF AXES, augers are used. Two holes, $\frac{3}{4}$ inch wide, are bored into the tree close together at the mouth, and then diverging with an upward trend into the tree, towards the heart.

(c) THE HOLES ARE COVERED BY A METAL-LID, inserted into a shallow groove of $2\frac{3}{4}$ inches diameter bored over the two smaller and deeper holes. The metal-lid connects, by a hollow, rectangular arm, with a metal-cap similar in size to the metal-lid, which cap, threaded at the inside to receive a glass jar to be screwed into it, should hang horizontally. The thread must be so exact as to be airtight, when the jar is screwed on.

By this means, the tree is prevented from closing the wound inflicted. The rosin oozing from the wound is prevented from oxidizing and crystallizing so as to remain liquid.

The jar is emptied whenever it is filled with rosin, to be replaced immediately for a new run.

(d) THE METHOD CAN BE APPLIED, at the same spot on the same tree, for an indefinite number of years.

The airtight jar method (Photo from "Scientific American.")

(C) MANUFACTURE OF NAVAL STORES FROM PINE PRODUCTS:—

I. From rosin of longleaf pine, &c., obtained by orcharding:—

(a) MELTING crude rosin in order to separate, from the liquid constituents, pieces of bark, wood, &c.

(b) DRY DISTILLATION of the liquids in a copper distilling apparatus, heated usually from an open fire beneath the apparatus; but preferably by superheated steam.

(c) THE GASES ARE COOLED in a worm and condenser, forming a layer of turpentine which is redistilled frequently.

(d) THE ROSIN (COLOPHONY), now of a light yellow color escapes through a pipe in the bottom of the still.

II. From the wood of the various species of pine:—

(a) CUT OR SAW THE WOOD into kindling sizes.

(b) FILL IT (from above) INTO A GAS-PROOF BRICK STILL ROOM some 15 feet high and 6 feet through, holding from 2 to 6 cords of wood. The top and bottom of the still are funnel shaped and provided with pipes. The still is surrounded by the fire room.

(c) AFTER CLOSING THE UPPER FUNNEL, apply heat very gradually. Within 24 hours turpentine begins to escape through the top pipe which leads through a worm into a condenser. When the gases appear dense and thick, the top pipe is closed and the gases (now largely containing pyroligneous acid) are forced through the bottom pipe to be condensed in another condenser. Light (at a later stage dark) tar is let out through this same pipe. The fires are checked when the tar begins to flow freely.

(d) THE PROCESS TAKES, for heating, 3 days; for cooling, 8 days. Charcoal is left in the still room. Proper regulation of temperature is most essential.

(e) ONE CORD OF RICH PINE kindling yields about 25 gallons of tar, 1 gallon to $1\frac{1}{2}$ gallons of machine oil, $\frac{1}{2}$ to 1 gallon of turpentine, some pyroligneous acid and $\frac{1}{2}$ cord of charcoal.

III. From stumps and roots of Pinus palustris and of Pinus resinosa:—

(a) THE STUMPS, LEFT IN THE GROUND FOR A FEW YEARS, then extracted by stump lifters, taken to the plant and allowed to season further in the yard, are sawed up by a circular saw, sliced by a hog, and ground by a grinder.

(b) THE MASS OF SMALL IRREGULAR PARTICLES thus obtained is charged, four cords at a time, into upright iron cylinders, at least four cylinders belonging to a "circuit." Then live steam is forced, for 90 minutes, through the circuit, the steam taking up the spirits of turpentine as it passes from the first to the last cylinder. In the first cylinder, it finds old chips almost exhausted by previous extractions; and in the last cylinder, it finds fresh chips full of turpentine.

(c) STEAM AND WATER IS WITHDRAWN from the exhausted chips by the vacuum pump, and the wood is dried simultaneously.

(d) NEXT, the cylinders containing dry wood free from turpentine are filled with naphtha, a solvent which, passing from one cylinder to the other, withdraws the crude rosin found in the wood.

(e) THE SOLVENT IS SEPARATED from the rosin and thus regained by fractional distillation. The wood fiber left in the cylinders is used to feed the boilers.

(f) THE OUTPUT per 4,000 pounds of stumps (costing $4\frac{1}{2}$ per cord of 4,000 pounds delivered at the plant) is:—

> 15 gallons crude spirits of turpentine worth a few cents less than the product of the turpentine orchards.
> 300 pounds of E grade crude rosin, worth $6·80 per barrel of 280 pounds.

IV. Use of naval stores:—

(a) SPIRITS OF TURPENTINE are used for colors, paints, varnishes, asphalt laying, solvent for rubber.

(b) COLOPHONY, the rosin of the trades, is used for glue in paper manufacture, varnishes, soap making, soldering, manufacture of sealing wax.

V. Wood-tar obtained from conifers is lighter than water (owing to spirits of turpentine therein contained); made of broadleafed species it is heavier than water. It contains toluol, xylol, cumol, naphthaline, paraffine, phenol, kreosol, pyrogallol and many other carbohydrates.

Caustic soda acts as a solvent for the aromatic alcohols contained in wood-tar. From this solution true creosote is derived.

Dry distillation of wood-tar yields:—

> Light wood-oil.
> Heavy wood-oil.
> Shoemaker's pitch.

(D) CONIFERS OTHER THAN PINES are used to a limited degree in the manufacture of naval stores.

I. Larch yields the so-called Venetian turpentine, which is obtained by boring (with $1\frac{1}{2}$-inch auger) a deep hole into the heart of the tree. The hole is closed by a plug. After a year the turpentine, entirely filling the hole, is extracted.

II. Spruce was tapped for turpentine on a large scale in the Old Country before the orchards of the South were developed. Only scrape is obtained from long and narrow faces. The scar invites red rot, badly checking the value of the timber. The output in ten years is, per acre, 73 lbs. of crude spruce rosin.

III. Fir has rosin ducts only in the bark. Blisters or bubbles of the bark filled with rosin yield the so-called "Canada balsam" and "Strassburg turpentine," collected in tin cans. The blisters are opened with the rim of the can.

IV. Douglas fir yields, when pieces rich in rosin are treated to dry distillation, aside of spirits of turpentine and of wood-alcohol,

A turpentine orchard in the spruce woods of Saxony, visited by the Biltmore Forest School.

a valuable solvent for colors. The Oregon Wood Distilling Co., of Orewood near Portland, Oregon, is conducting experiments in this line.

PARAGRAPH XLI.

VANILLIN.

Vanillin, a substitute for vanilla, which has caused the price of bean vanilla to decline rapidly and permanently, is obtained from spruce (fresh cut) by removing the bark and collecting the sap adhering to it either with sponges or with broad-bladed knives. The sap is then boiled, strained, and condensed in the vacuum pan to one fifth of its former volume.

In the cooling room, crystals of coniferine are formed from the syrup. Coniferine, when treated with potassium bichromate and sulphuric acid, is oxidized into vanillin. The syrup obtained as a by-product is distilled and used in the manufacture of alcoholic beverages.

Eighty gallons of sap yield one gallon of coniferine.

The bark itself is frequently cured (dried) and used in the tanneries.

REMARK:—In Western North Carolina, the bark of Betula lenta, the red birch of the lumberman, is used for the manufacture of true oil of wintergreen.

The bark is peeled, chipped, and subjected to dry distillation, at low temperatures. The first distillate, collected in a crude condenser, contains the oil of wintergreen of commerce.

PARAGRAPH XLII.

UTILIZATION OF FOREST FRUITS.

(A) BEECHNUT OIL. Mast years of beech occur, according to climate, every 3 to 8 years. The nuts are gradually dried, slightly roasted, peeled and cleaned of shells; then either ground, applying moderate heat, or pounded in mills by stampers. The oil oozing out is strained and placed in a cool room (in earthenware vessels), where the clean oil forms a top layer to be poured off gradually.

The residue is pressed into cakes and used as feed for stock.

Two hundred pounds of dry beechnuts yield 5 quarts of oil.

(B) OLIVE OIL. Olive oil is obtained from the fruit of Olea Europea by crude grinding and pressing processes.

(C) CHESTNUTS, pecans, walnuts, acorns. The chestnut yields, in certain sections of France and Italy, the daily bread of the natives.

The food value of American chestnuts, pecans, and walnuts is beginning to be realized.

The acorn of the white oak yields a beverage (coffee) of astringent, medical qualities.

The cups of the acorns, particularly rich in tannin, are used as a raw material in many tanneries ("Valonea" of Quercus aegilops).

(D) RHAMNUS SPECIES. The fruit of the buckthorns yields a valuable dye.

(E) NUT PINES. The Indians of California and Arizona subsist, at certain seasons, on the fruits of the Western nut pines.

(F) THE TRADE VALUE OF THE SEEDS OF WHITE PINE, Douglas fir, Abies concolor, Lawson's cypress, red oak and in fact of all seeds of American timber species, is beginning to be realized. Sylviculture, in America and notably in Germany, requires enormous quantities of American tree seeds. The various methods of "coning" are described in Schenck's Lectures on Sylviculture, paragraph XXII.

PARAGRAPH XLIII.

IMPREGNATION.

Impregnation of wood intends:—

(a) To destroy the bad hygroscopic qualities (shrinking, warping, working, permeability) of lumber and timber;

(b) To impart a desirable color to furniture woods;

(c) To cause a fireproofing of shingles, wood, and timber;

(d) To increase the durability of wood exposed to decomposition by the injection of antiseptic liquids.

(A) WATERPROOFING. The use of certain woods (beech and gum) is barred from many industries by the fact that these woods will continue to "work" after having been put in place, be it within a piece of furniture, or in the flooring of rooms.

Beech flooring is impregnated with common pine rosin (colophony) by the process of Amendt, Oppenheim, Germany. The manufactured flooring is thoroughly seasoned. It is placed loosely on steel cars and run into retorts sealed hermetically. The colophony, in molten condition, heated to 345 degrees, is forced into the wood by the pressure pump under 75 pounds pressure. The whole pressure process takes five minutes only, for each charge. Ten pounds of colophony are used per cubic foot of flooring.

If it is desired to obtain a heavier degree of impregnation (up to 20 lbs. of colophony per cubic foot of wood), the pump is allowed to work for a correspondingly longer period.

After impregnation, the liquid is pumped from the retort; but the wood is left in it for 2 to 2½ hours, so as to allow the colophony adhering to the surface of the wood to drop down, and so as to prevent by gradual cooling the formation of cracks.

By a similar process, heading and staves made of open-grained woods are rendered impermeable to liquids.

(B) COLOR-IMPREGNATION. At Memphis, Tenn., color-impregnation of various woods is made use of, in a commercial way, under foreign patents. At the Paris World's Fair, in 1900, color-impregnated furniture (notably beech bedroom furniture) attracted attention for the first time. The process is a secret.

Color-impregnation by ammoniacal fumes is used in all furniture works.

Professor Wislicenus, of the Tharandt Forest School, Saxony, uses so-called "soil gases" to impart desirable colors without changing or coating the fiber. Pine, beech, birch, larch, oak, and so on, adopt most pleasing shades of color under this process.

(C) FIREPROOFING. Among the American timber species, the lumber and timber of the sequoias (bigtree and redwood) are known to be most fireproof.

Impregnation of wood with chemicals similar to those used in the commercial fire extinguishers has been advocated here and there.

(D) ANTISEPTIC IMPREGNATION intends to bar the activities of timber-destroying bacteria, enzyms, fungi, insects (e. g., white ants), and molluscs (e. g., teredo). Its use has increased, of late years, enormously in the case of railroad ties, telephone poles, and fence posts. Five principles may be applied:—

I. Immersion:—

(a) THE OLDEST METHOD used was immersion in a strong solution of ordinary salt ($NaCl$).

Immersion into a 2 to 3 per cent solution of corrosive sublimate is used extensively in the case of telephone poles. The poles must be winter-cut, the bark must be removed and the air must be allowed to dry the poles thoroughly, before they are bathed, for 10 to 14 days, in wooden or concrete tanks containing the solution in question. The solution must be stirred from time to time. The chemical test (impregnated wood is blackened by sulphide of ammonia) shows that the liquid enters only into the outer layers of the wood. The method is known as "kyanizing."

Chloride of zinc, being cheaper, may be used in lieu of chloride of mercury. This substance, however, is more readily leached out by rain. A. Schmidt reports that pine ties had lost, after three years' use, 80 to 85 per cent of the chloride of zinc originally injected.

It is also claimed that the zinc-treated wood fiber decomposes rapidly in close proximity to iron rails or iron spikes driven into wood thus treated because of the influence of free hydrochloric acid.

In Austria, a 4 per cent solution of acid fluoride of zinc ($ZnF_2 \cdot 2HF$) is being used by the governmental telegraph lines for the impregnation of telegraph posts by mere immersion.

(b) "METALIZED" WOOD IS OBTAINED AS FOLLOWS:—Immerse the wood in a solution of sulphate of iron; then coat the wood with chloride of calcium. As a result, in the outer layers of the wood, gypsum (sulphate of lime) is formed together with chloride of iron. The wood becomes, simultaneously, impermeable to water and adopts a metalic shine.

II. Boiling:—

(a) BOILING OF BUILDING MATERIAL in salt water or in a solution of borax was customary in olden times. It seems to be, nowadays, a method rarely practised.

(b) BOILING OF LOGS (e. g., walnut logs) with exhaust steam, resulting in the discharge of a black juice from the logs, is frequently seen abroad. The process is supposed to remove or destroy, also, the albumen and the starch contained in the wood, on which certain fungi are said to feed.

(c) FRANKS' MIXTURE CONSISTS of 95 per cent liquid manure and of 5 per cent lime. It is pumped into large vats, within which the wood is boiled for 3 to 8 days. The liquid enters to a depth of about 3 inches and darkens the wood to a mahogany tint.

(d) A METHOD CALLED "SIDERIZING" injects by a boiling process a solution of copperas (sulphate of iron). The wood thus treated is dried, and liquid glass (a hot solution of silicate of alumina) is applied to its surface. By a chemical reaction, silicates of iron are formed in the outer layers, which are insoluble in water and resist decomposition. The wood, at the same time, obtains a beautiful gloss.

III. **Use of hydrostatic pressure.** A solution of copper (blue vitriol) is used after Boucherie. It is kept in a tank 30 to 40 feet above ground. The timber, fresh cut with the bark on, is yarded on a rough log-deck underneath the tank within 10 days after felling. At the big end of each log a ring made of rope is held in place by a heading nailed or screwed to it. A hose connected with the tank by a system of pipes injects the liquid into the small cavity formed between log and heading. After a few days, drops of blue vitriol solution appear at the small end, indicating that the process is completed. The pressure being slight, only the outer sappy layers are impregnated. This method is largely applied in France, often in the woods themselves, to telegraph poles of spruce or fir. Expense, per cubic foot, 4 cents. Telephone poles treated after this method will not do in soil containing lime, for the reason that blue vitriol is leached out readily by water rich in carbon dioxide.

IV. **Use of air pressure (open tank treatment).** The open tank process is adapted to the impregnation of fence posts in particular. The wood is first heated and then allowed to cool in the preservative. When heated in the preservative, air and water are driven from the wood cells and from the intercellular spaces of the wood. When cooling, the liquid preservative enters into the spaces previously occupied by air and water, owing to the pressure of the atmosphere.

The liquid usually used is creosote, costing in the East from 12 to 15 cents per gallon.

(a) SINGLE OPEN TANK TREATMENT. (After Farmers' Bulletin No. 387):—

1. *Raise the temperature* of the creosote to 220 degrees.
2. *Put posts in tank,* submerging them 6 inches deeper than the ground line, to which the posts will be imbedded in the soil afterward.
3. *Maintain temperature* at 220 degrees for six hours.
4. *Allow liquid,* with the posts standing in it, to cool down for 12 hours.

(b) DOUBLE OPEN TANK TREATMENT:—

1. *Have one tank filled* with creosote heated to 220 degrees, and another heated to 120 degrees.

2. *Submerge posts from one to three hours* in the hotter bath 6 inches deeper than the ground line, maintaining temperature at 220 degrees all the time.

3. *Transfer the posts as quickly as possible* from

Open tank treatment of fence posts. (Photo picture from a Forest Service bulletin.)

the hotter to the cooler bath, and let them remain in the latter from 30 to 120 minutes.

By this simple method, durable fence posts may be obtained cheaply from beech, maple, boxelder, &c.

What, indeed, is the use of raising catalpa posts on valuable praerie soil, when posts of equal durability and of equal strength can be obtained cheaply and at once by the proper impregnation of ordinary woods' offall?

V. Use of steam pressure.

The wood, thoroughly air-dried, is placed on small steel cars running into long cylinders to be sealed hermetically by strong heads. If still partially green, the wood is dried, to begin with, by a steaming, heating, or vacuum process. That done, an antiseptic liquid, at a temperature of 150 to 200 degrees, is pressed by the force pumps into the wood.

  (a) THE LIQUIDS COMMONLY USED ARE:—

1. Chloride of zinc.
2. Coal tar creosote or heavy oil of coal tar (commonly designated as creosote).
3. Mixture of chloride of zinc and of creosote.
4. Gases of tar oils (so-called thermo-carbolization).
5. Heavy petroleums.

  (b) APPLICATION:—The creosoting method is used for ties, pilings, and paving blocks, particularly. Creosoted timber holds nails well; creosote is not washed out by rain. On the other hand, the darkened color of the wood is sometimes objectionable, and the cost of a thorough impregnation is high. In the case of telephone poles, the volatile character of the lighter coal tar oils is found objectionable.

A train of railroad ties ready for impregnation at the works of the American Creosoting Co.

The heavier portions of the coal tar oils are the most durable and the most effective.

  (c) VARIABLE EFFECTS:—The impregnability of timber seems to depend on its specific weight and on its contents of moisture; and does depend, undoubtedly, on many other factors not fully understood today.

The oaks show greater fluctuations in absorption of creosote than do the pines. Variable is, also, the distribution of the impregnating liquid within the wood impregnated. With the same quantity absorbed, one railroad tie may be impregnated to a depth of 3 inches and another—of the same weight and kind—to a depth of 1 inch only.

The cost of tie impregnation, in America, is given as 30 cents per tie impregnated with an average of $2\frac{1}{2}$ gallons of creosote.

The pressure in the impregnating retorts must be gauged according to the season of the year, according to the degree of moisture in the wood, and according to the particular structure of the pieces to be treated.

  (d) CREOSOTE OIL:—The quantity of creosote pressed into the wood is obtained either from gauge readings in the creosote tank, or else by comparing the weights of the impregnated ties with those of the unimpregnated ties, adding to the difference, however, the weight of the water evaporated from them and collected separately.

As regards the composition of the creosote, the following specifications hold good:—

"The creosote oil used must be the product obtained entirely from coal gas or coke oven tar, containing no admixture of any tar, oil or residue obtained from petroleum or any other source.

It must be completely liquid at 38 degrees centigrade, and not more than 2 per cent of the water-free oil should be insoluble in chloroform or in benzol.

The specific gravity of the oil at 38 degrees centigrade must be at least 1·03 and should not exceed 1·10. The distillate of the creosote oil used shall deposit, between 210 and 235 degrees centigrade, naphthaline salts upon cooling to a temperature of 20 degrees centigrade. During distillation the oil shall not show any evidence of decomposition.

The oil shall not contain more than 3 per cent of water."
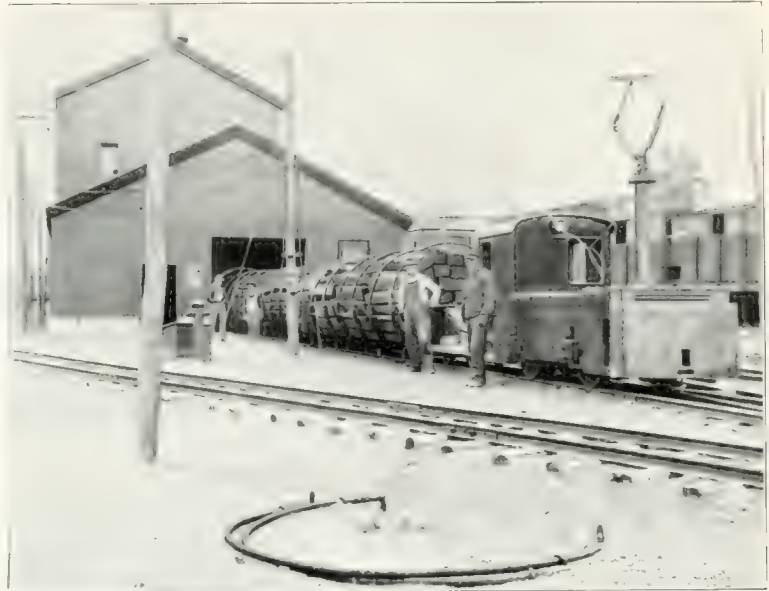
(e) RESULTS OBTAINED :—With the modern processes of creosote impregnation, the drawbacks adhering to the original method are obviated.

The material to be impregnated is no more exposed to high temperatures, prior to impregnation, since the strength of the timber is found to be greatly impaired by high temperatures. Preliminary steaming operations, also, have been found to reduce the strength of the wood by 25 per cent when a steam pressure of 20 pounds was applied for 10 hours to green shortleaf pine. Disastrous results of this character are now avoided.

As an illustration of the effect on tie impregnation with European railroads, where impregnated ties have been used for many years, the following tabular statistics are given:—

Species	Duration of ties not impregnated	Duration of ties impregnated with		
		Chloride Zinc	Cl Zn and Creosote mixed	Creosote
White Oak	12 to 15 years	16 years	18 to 20 years	25 years
Beech ...	2 or 3 years	5 to 8 years	14 to 16 years	30 to 35 years
Pine	5 to 7 years	7 to 12 years	13 to 15 years	18 to 20 years

Heartwood is not so permeable and hence not so impregnable as sapwood. Maple, birch, beech, spruce, sappy pine, &c., are more benefited by impregnation than are white oak, longleaf pine, &c. Generally the duration of the life of impregnated ties is increased at the following ratio:—Beech, 400 per cent; yellow pine and oak, 200 per cent; spruce, 50 per cent.

Obviously, every additional pound of preservative pressed into the fibre has a lesser effect on the life of the wood than the preceding pound. For every woody species the limit must be found at which additional impregnation proves unremunerative.

(f) THE PROCESSES:— The leading processes in vogue with railway engineers of the United States are the Card process, the Lowry process, and the Rueping process, described in Bulletin 131 of the American Railway Engineering and Maintenance of Way Association.

    1. *The Card process.* The timber is thoroughly air-seasoned.

        It is laid on small steel cars and run, a number of cars at a time, into a large horizontal steel cylinder. The steel cylinder is sealed hermetically. A vacuum of from 22 to 26 inches is secured, by the vacuum pump, in the steel cylinder and is maintained for one hour.

        Thereupon the impregnating liquid, consisting of 80 per cent of solution of chloride of zinc and 20 per cent of creosote oil, is admitted at a temperature of not less than 180 degrees. A pressure of 125 pounds per square inch is obtained and held within the cylinder for from three to five hours.

        Thereupon the liquid is withdrawn, and a final vacuum dries off the timber before the cars are run out of the steel cylinder.

        If it is desired to treat material that is not fully seasoned, a previous steaming process may be used.

        In order to keep the chloride of zinc solution and the creosote oil thoroughly mixed during the process of treatment, it is first agitated in the measuring tank by forcing air through pipes into the liquid.

        Within the cylinder, the liquid is continually agitated by a centrifugal pump, drawing the liquid from the top of the cylinder at three points, viz., from the center and from both ends. After passing into the centrifugal pump, the liquid is discharged through a pipe which lays along the full length of the bottom of the cylinder and is perforated through its length. The pump should handle about 1,500 gallons of the mixture per minute.

2. *The Lowry process.* Air-seasoned timber, of the same species, density, and moisture contents, is laid on tram-cars and placed within the retort cylinder. The cylinder is then filled from the charging tank with creosote oil at a temperature not to exceed 200 degrees Fahrenheit. The main line is then closed and oil from the charging tank is forced, by pressure pumps, into the retort until the timber has taken oil to the point of refusal, or a predetermined amount. The pressure within the retort is controlled so as to give a maximum penetration of the oil. Thereupon, pressure is released and the free oil in the retort is drained off. A vacuum of sufficient degree and duration is then drawn in the retort so as to recover that portion of the free oil in the timber which exceeds the specified amount. The recovered oil is drained off from the retort and the charge is withdrawn.

3. *The Rueping process.* The timber to be treated should, preferably, be thoroughly air-seasoned. Green or partially seasoned timber must be steam-dried before treatment. The timber is subjected within the steel cylinder to an initial air or gas pressure. In most cases, this compressed air is introduced direct from the compressor. The wood must be exposed to the full influence of the compressed air for a sufficient time to thoroughly fill all the cells and cavities of the wood with such compressed air. During the next step of the operation, in proportion to the quantity of impregnating liquid admitted into the cylinder, air is allowed to escape in order to make room for the required quantity of liquid.

This next step consists of the introduction of the impregnating liquid (creosote oil), under a still higher pressure, into the treating cylinder. Sufficient liquid must be introduced to completely fill the cylinder. The air escape valve must be at the highest point of the cylinder to avoid air pockets forming in the liquid.

When the material in the cylinder is completely covered with the liquid, the pressure is raised slowly, step by step, by introducing additional quantities of impregnating liquid until the pressure has reached the desired maximum securing a full penetration of the cells of the wood. The maximum pressure must be maintained until the timber will not absorb any more of the liquid.
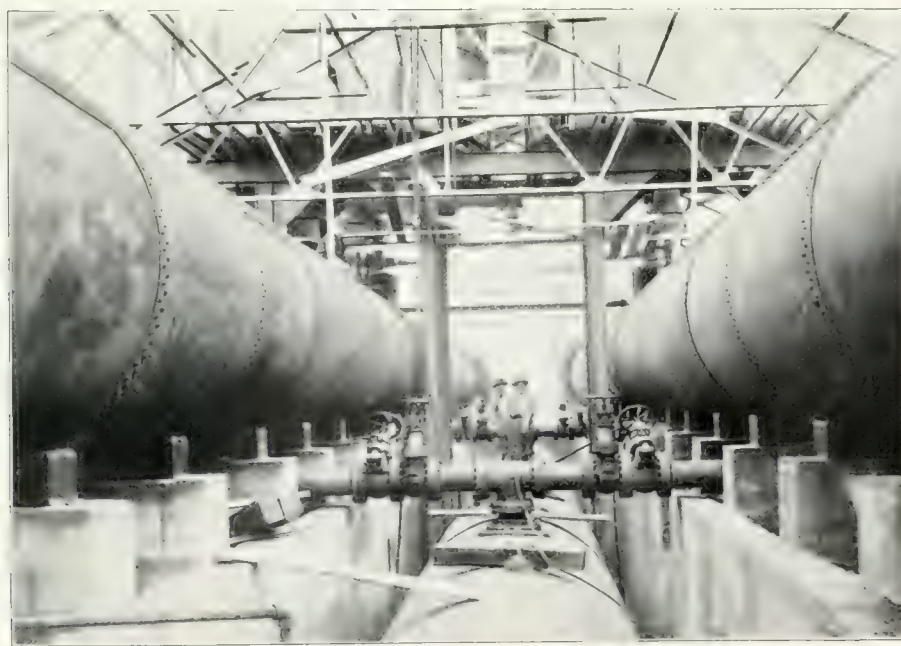
Interior of a retort house, American Creosote Co., Seattle, Washington.

The pressure is then cut off and the impregnating liquid is discharged from the cylinder.

It is not necessary to limit, in any way, the final absorption of the timber; in fact, it is better that no limit be placed on it so that, for a certainty, all parts of the timber which will take treatment are reached by the impregnating liquid.

If it is shown after the end of the run, that the final absorption is too large, then either the initial air pressure may be increased or the liquid pressure decreased.

If it is shown that the final absorption is too small, the air pressure may be decreased or the liquid pressure may be increased.

View of the booms of the American Creosote Co., at Creosote, Puget Sound, Washington.

The final absorption is dependent on the relative differences between the air pressure and the impregnating liquid pressure. By regulating the comparative height of these pressures, the final absorption can be adjusted to the specified or desired quantities.

The time required for absorption depends on the length of time at which the liquid pressure is maintained at its maximum.

The last step in the Rueping process — very characteristically — consists in the application within the steel cylinder of a vacuum. The vacuum tends to expand the compressed air within the cavities of the timber. The vacuum is maintained until, in the surface sections at least of the timber, a pressure equal to atmospheric pressure is established.

The expanding air forces a large amount of creosote oil out of the timber. Indeed, all that creosote oil may be expelled which has failed to incrustate the cell walls and which, as far as the life of the timber is concerned, is injected in vain.

The timber leaves the cylinder dry. The escape of additional compressed air, taking place during the next hours, should not cause any dripping of creosote from the material thus treated.

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