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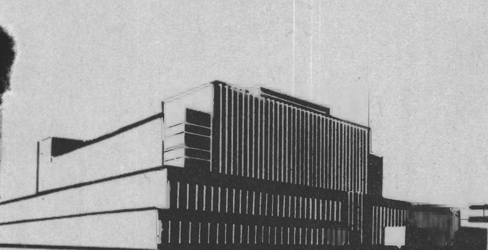

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

WOOD-CHIPPING EQUIPMENT AND MATERIALS HANDLING

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Introduction

The utilization of wood chips in manufacturing processes was confined primarily to the pulp and paper industry until a relatively few years ago, and the term "wood chip" consequently implied a wood fragment cut to pulp mill specifications. Although the pulp and paper industry remains the largest user of wood chips, a growing number of other industries are also using them. As a result, the term wood chip is now loosely applied to a variety of wood fragments. Each industry or user has its own specifications, which may be quite broad or very specific.

Chips are produced by cutting the wood, breaking it, or some combination of these two basic methods. The process of chipping is essentially one of breaking down large or irregular solid wood pieces into fragments more or less uniform in size and shape.

Increasing wood utilization resulting from development of new products has increased the demand for chipping equipment. This demand has brought about improvements in existing machines as well as the development of new machines. The Forest Products Laboratory has been active in research leading to these new products and has investigated equipment suitable for the production of chips to meet various specifications. One of the prime chip specifications has been bark content, which restricted the use of chips until satisfactory bark-peeling machines were developed. Bark-peeling machines and methods now available are described in Forest Products Laboratory Report No. 1730.

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Before making a selection of chipping equipment, it is advisable to establish chip specifications for the intended use. Although several types of machines may be capable of producing chips suitable for a specific use, only one type of machine may be suitable for another kind of chip.

Chip Uses and Requirements

The predominant use of chips is for the production of pulp. This industry has demanded bark-free chips of uniform size. There have been no set standards as to size, except that chips too large to pass through a screen with 1-1/2- or 2-inch openings and those small enough to pass a 5/16- or 1/4-inch screen normally are rejected. Each mill has its own objective size, varying from about 1/2 to 1 inch in length.

As pulp mills have expanded their purchases of chips from sawmills, they have developed more detailed chip specifications. In general, these limit bark content to less than 1 percent, specify the desired chip length, and set limits on the percentage of oversize and fines. The pulping utility of planing mill chips and chips or coarse sawdust produced by sawmill headsaws is being investigated. (44).

A long-standing, but declining, use for wood chips is for fuel. There are no specifications for this material. Major considerations are handling and burning. Preferably, fuel should be dry and not packed to the extent it retards burning, or should be fine enough to burn in suspension. Recent sawmill barking installations have reduced the use of wood, but increased consideration of bark chips for fuel.

A relatively new and increasingly important user of chips is the particle board industry. It uses a wide range of wood particle sizes and shapes with considerable variation in the allowable bark content. The chips may be produced by cutting the wood, breaking it, or some combination of the two. The final product may be faced with veneer or with thin chips called flakes or shavings.

Considerable quantities of chips are now used in agriculture. Chip products include poultry litter, cattle bedding, mulch, compost, and soil amendant, (1-34-37).[2] There are no limitations on bark percentage, but other specifications vary considerably. Very fine

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[2] Underlined numbers in parentheses refer to Literature Cited at the end of the article.

material that creates dust when disturbed is undesirable. Also, chips containing splinters or sticks that might injure livestock are unsuitable for bedding; thin chips with considerable surface and ability to absorb moisture are preferred. For soil improvement, small chips and sawdust, which compost in less time than coarse chips, are preferred. These and other considerations, as well as the individual farmer's preferences, result in a wide variety of agricultural chip specifications (5, 30).

Chips are also used by the metallurgical industry in refining ore and manufacturing steel. For some processes large chips are used that would be considered oversize by a pulp mill. For other processes, chips approach the size of sawdust. Bark is acceptable in some instances and undesirable in others.

Chemically treated chips are used for gas filtering and refining. They should be relatively long and thin, and may have some bark on them.

Although there are a large number of other uses for chips ranging from wood hydrolysis to home barbecuing, their production considerations are essentially the same as those just mentioned.

Raw Material Source of Chips

Round pulpwood in lengths from 4 to 32 feet is the major source of chips. All other sources supply wood left over or not utilized by other manufacturing processes (9). Sawmills provide the largest supply of chips from these sources (7). Development of efficient log barkers has rapidly increased the production of pulp chips from sawmills (16-38)

Particle board chips are produced from wood left over in furniture plants, sawmills, sash and door plants, veneer plants (25), and similar industries. Some chips are also made from round wood, such as pulpwood or wood left over after logging (18).

Almost all wood leftovers, including thinnings developed in growing a timber crop to trimmings from industry or construction projects, can be chipped. Limiting factors mainly concern the economics of handling and marketing the chips. (4)

Chipping Equipment

A variety of equipment is used to produce wood fragments. These machines can be divided into two major categories--those using knives and those using hammers, otherwise known as cutting machines and fracturing machines.

Knife-cutting Machines

Cutting machines, those with knives ground to a sharp edge, are commonly referred to as chippers or knife hogs. The three principal types are the disk, cylinder, and V-type (13-19).

Disk chipper machines have a steel disk attached at right angles to a shaft. A number of knives, usually varying from 3 to 12, are attached radially to the disk in slots that permit them to extend beyond the face of the disk. As the disk rotates, the attached knives pass a single bed-plate or square-edged stationary knife, sometimes referred to as an anvil. A spout that holds the wood during chipping extends from the stationary knife outward. On chippers used by the pulp and fiber industry, the spout is generally at an angle of 30° to 60° to the disk. Some chippers used by the particle board industry to produce flakes have the spout at an angle of 90° to the disk.

Until about 1950, it was common practice to use inclined spouts and gravity feed, which was a decided disadvantage in early attempts to use portable disk chippers in the woods (20-35-43). Among the first attempts to change the spout angle was an installation that tilted the disk so the spout was horizontal (15). When chippers with horizontal spouts were developed, power feed works were also developed. These were followed by horizontal spout chippers fed by belt conveyors, which are now extensively used by sawmills.

The newest development is a chipper with two feed spouts, one horizontal for slabs and edgings, the other inclined for trims and shorts.

Design developments in the placement of knives on the disks, knife angles, and the like, have contributed a great deal to the success of the horizontal-spout chippers (42). These machines have alleviated conveyor and handling problems, thus facilitating sawmill and portable applications.

Cylinder chippers resemble enlarged planer or jointer heads. A steel cylinder on a shaft has recesses to hold knives. Cutting edges of the knives are parallel with the surface of the cylinder. The knives rotate past a bedplate or anvil. Placement of the knives varies from single knives extending the length of the cylinder to narrow knives placed in a staggered pattern around the cylinder. An advantageous feature of these machines is the wide feed spout or throat in relation to machine size.

Depth of recess ahead of the knives and position of the bedplate determine the shape and size of chips produced. Cutting near the underside of the cylinder produces thin chips or shavings, while cutting higher up on the cylinder provides thicker chips. Variation in the size and shape of chips is also attained by using serrated and toothed knives. This flexibility has resulted in the predominance of the cylinder-type chipper for production of agricultural chips used for livestock bedding, poultry litter, and the like (34). Another factor for its popularity, is the ease with which it adapts to portable and mobile operation (10, 17-40). Machines of this type are also being used to produce good-quality chips for the pulp and paper industry.

V-type chippers have been used by sawmills for many years to produce fuel. Uniformly high-quality chips were not required, so no special attention was given to sharpening of knives or maintenance. As a result, this machine is more commonly referred to as a wood hog. The knife-carrying head, resembling two short cones joined at their apexes, has knives extending radially from the center toward the rim of the cones. The head assembly rotates past a V-shaped throat plate in the same manner as in the previously described chippers. Frequently, these machines have two to four bedplates. The angle of the throat plate has an effect on the type and shape of chips produced. The number of bedplates also affects chip quality.

One of the advantages of the V-type chipper is the large throat opening in relation to the machine's size or bulk. This is an important consideration on portable chipper operations. Machines of this type are used to produce chips for fiberboard plants (2-3). Although cylinder chippers are more commonly used for brush disposal, these machines are also used and are equally suitable.

Wood Fracturing Machines

The principal difference between wood fracturing machines and cutting machines is that wood chips or particles are made by blunt- or dull-edged cutters. As a result, the wood particles or chips are not cleanly cut, but are broken on the end-grain sections. Side sections are mostly broken along the grain and present about the same side surface as chips from knife machines. Machines of this type are referred to as wood hogs, hammermills, chip shredders, and rechippers.

Most of these machines employ free-swinging hammers attached to a cylinder. The hammers are extended from the drum by centrifugal force during operation. There is considerable variation in the size and shape of the hammers. On some, the striking end is wedge shaped, so that action is similar to chopping with a blunt ax. Other machines utilize square-cornered hammers, and one type uses stationary sections between which the hammers rotate. On some types, the bedplates are similar to those on knife machines.

Bars, grates, and screens are commonly used in hammer-type machines. Thus wood fragments are thereby recirculated until they are reduced to sizes that pass through the screens. With very fine screens, extremely small particles, such as wood flour, are produced. These machines are also used to reduce oversized pulp chips, rejected in screening, to acceptable sizes for which purpose they are referred to as rechippers. A similar combination of knife chippers and hammermills is also used in the particle board industry. Most of the chips used in the extraction industry are produced by this type of machine.

Chipping Machine Power Requirements

Machines that produce chips by cutting and splitting require considerably less power than those that break or crush wood. Thus, knife-type machines require the least power per volume of wood chipped. Other machines that employ a combination of cutting and breaking action require considerably more power, with the amount dependent upon the ratio of the two actions, the species of wood, and the size of the chips produced. In general, more power is required to produce small chips than coarse ones.

Horsepower requirements for cutting machines depend upon chip length, chip thickness, shear strength, and hardness of the wood (11-31-32). Chip length determines the number of knife cuts required per cubic foot of wood. This varies directly with the diameter of the wood and can be determined by the formula

$$\log y = a + b \log x$$

where y is the number of cuts per cubic foot and x is the log diameter. Number of cuts can also be calculated by the formula

$$\text{No. cuts} = \frac{6912}{\pi D^2 \text{ chip length in inches}}$$

Plotted values for these formulas are shown in figure 1.

Chip thickness and width determine the number of shear planes or the total square inches of surface sheared parallel to the grain. The shear strength of wood varies with species and with moisture content (40), the shear strength of green, being less than that of dry wood. Specific gravity is indicative of shear strength, hence dense hardwoods require more power to chip than softwoods.

Hardness is related to the knife pressure required to sever wood fibers before other pressures cause shearing. This varies according to species and growth conditions, but is also indicated by specific gravity.

Horsepower-seconds required to chip a cubic foot of wood in commercial disk chippers were measured by H. W. Rogers (36) for a number of species. Data on specific gravity, exact species, and condition of the chipper knives are lacking. Specific gravity values from the Wood Handbook (41) in relation to Rogers' data indicate a reasonably good correlation. The plottings and computed regression are shown in figure 2. Since Rogers did not obtain specific gravities, the values plotted must be considered approximate for chippers with a spout angle of 52°.

Machines differing from the ones used during the above study will no doubt yield different values. Such variations include knife angle, sharpness of the knives, and spout angle.

Wood strength factors affecting the horsepower requirement of machines that break or fracture wood are primarily shear, impact bending, tensile strength, and moisture content. The size of the wood fragments produced is an important factor affecting power requirements. More power is required to produce fine particles than to produce coarse ones.

Chipping Machine Production Rates

Production rates of chipper machines are controlled by the size of raw material, size of chips produced, and cutting rate of the equipment.

Although volume of production may be expressed by several standards, the most reliable and stable ones are cubic feet of solid wood and weight in tons.

Diameter or cross-sectional area of the raw material determines the length required per cubic foot. Figure 3 shows the number of lineal feet per cubic foot of wood by diameter. The length of chips determines the number of cuts per cubic foot and can be calculated as follows:

$$\text{No. cuts per cu. ft.} = \frac{\text{lineal feet per cu. ft. x 12}}{\text{chip length in inches}}$$

Machine rates are governed by the number of cuts per unit of time. The number of knives spaced around the circumference of a disk or drum multiplied by the revolutions per minute determines the cuts per minute. This value, divided by the number of cuts per cubic foot, determines the production per minute. When a number of pieces small in diameter, such as edgings and slabs, are fed at one time production must be computed for the total cross-sectional area. For example, four sticks of 2-inch wood are equivalent to one stick of 4-inch wood and nine sticks of 2-inch wood equal one 6-inch stick. A study of southern pine sawmill waste (39) shows that slabs and edgings vary from 0.001 to 0.080 cubic foot per lineal foot. Sixty percent vary from 0.016 to 0.040, or the equivalent of round wood 1.7 to 2.7 inches in diameter.

In some areas, the cord is still used as a unit of measurement. Figure 4 shows the conversion factors used in changing lineal feet and cubic feet to cords. Figure 5 converts lineal feet per minute to cords per hour.

The most satisfactory unit of measurement is the ton. Generally, prices are computed on a dry-weight basis. Data on dry weight of various species are given in the Wood Handbook (41). Using these data and accompanying tables, it is only necessary to determine the moisture content from chip samples in order to determine dry weight. By applying these data, cubic feet per minute can be converted to tons per hour.

Production rates for hammermills and similar machines depend a great deal on the size of chips produced. Since conditions vary so widely, production rates should be obtained from equipment manufacturers for specific conditions of operation.

Factors Affecting Machine Selection

Following are some of the factors to consider in selecting a chipping machine for a specific purpose:

1. Type of chip to be produced.
2. Utilization of chips.
3. Size, shape, and character of raw material.
4. Volume of material per hour required.
5. Permanent, portable, or mobile operation.
6. Amount of dirt, grit, and tramp iron likely to be encountered.
7. Height of feed spout and method of feeding.

Weight is an obvious consideration in mobile equipment, but production rate is equally important (35). The output of chips must be balanced with the transportation system and the delivery of rough wood by the logging crews. Other special applications require consideration of factors not normally necessary.

Handling Raw Material

Raw material for chipping can be classified as round wood, sawmill slabs and edgings, veneer clippings, furniture plant and similar trimmings, brush, and other.

Round Wood

Included in the round wood classification are pulpwood, veneer cores, logs, and forest thinnings. All are generally chipped into pulp chips with the exception of forest thinnings which, because of bark and handling problems, are usually chipped into agricultural chips. However, barking and handling problems are currently being resolved and more of this material will probably go into pulp chips in the future.

Handling costs are related to the number of pieces, up to the weight limitations of the handling equipment. The time and motion required for a man or machine to pick up a 6-inch log and place it on a conveyor is approximately the same as required for a 2-inch log of the same length, yet the volume is nine times greater.

This basic consideration is very important in determining the lengths to which material should be cut. Cutting material in long lengths, tree lengths, or bundling it are possible solutions for handling problems. The use of binder twine, plastics, and similar material will make it possible to chip bundles without injury to knives.

Many permanent chipper installations are a bottleneck to lower logging and handling costs, because they were designed for short wood and use gravity-fed chippers which cannot handle long wood. Conveyor systems generally represent a relatively small percentage of the total installation cost, but usually cause a high percentage of the down time. Careful planning and investment in conveyor systems is well justified.

Sawmill Slabs, Edgings, and Trim

Wood left over from the manufacture of lumber is handled according to two basic methods, depending upon the barking system in use. The predominant method is to bark the log, after which all leftover material goes to the chipper. Where log barkers are not used, slabs and edgings are salvaged and processed in slab barkers. In this latter case, material may be chipped at the mill where it is collected, or hauled to a central point for chipping.

Belt conveyors are commonly used to convey barked material to the chipper. No particular complications are involved at mills cutting 100 percent softwoods or 100 percent hardwoods. Mills cutting a mixture of these, however, have a problem, since most purchasers want the two segregated. Mills have two alternatives; either segregate the logs and saw them in separate batches, or use a diversionary conveyor system. When softwood logs are being sawn, the slabs and edgings go to chipper A. If a hardwood log is rolled onto the carriage, the hinged conveyor is raised and slabs and edgings are diverted to chipper B, to storage, or the burner. This method is illustrated in figure 6.

Mills without log barkers are faced with three alternatives in order to utilize slabs and edgings for chips. First, markets must be found for chips that include bark. Such markets are now scarce except for agricultural chips.

The second alternative is to market unbarked slabs and edgings. Some of the larger mills that have log barkers and chippers also have slab barkers, and will purchase unbarked slabs from nearby smaller mills. There are also centralized chipping plants that depend entirely on purchased slabs (6).

A third alternative is to install a slab barker and sell clean slabs and edgings, or add a chipper and sell chips. When slab chippers are used, considerable thought should be given to the method of sawing. If a log that yields 10 boards 1-inch thick is live sawn as in a sash gang saw, it will yield 2 slabs and 20 edgings. Thus, 22 pieces must be handled going into the barker and rehandled as they come out. If the same log is turned three times, then the yield will be 4 slabs and not more than 12 edgings for a total of 16 pieces.

Decisions on sawing methods must be based on the following considerations:

1. The larger the number of pieces chipped per ton of wood, the larger is the percent of fines, slivers, and rejects.

2. Sawing production decreases with an increase in number of turns per log. The amount is directly dependent upon turning equipment used and increased number of headsaw cuts. A pine log turned three times and sawn into 1-inch lumber requires about 1-1/3 times as many cuts as a live-sawn log of the same diameter.

3. Most slab barkers remove a higher percentage of bark from slabs than edgings.

4. Mechanical handling equipment for slabs and edgings may or may not be available.

5. The grade of logs and the value of the lumber based on board width or grade are also determining factors. (8).

Sawing methods have an effect on the number of pieces to be chipped. Methods of handling these pieces affect chip production costs.

Veneer Trimmings

Trimmings in veneer mills generally require very little handling. They are usually diverted directly from chippers or other machines to mechanical conveyors. The major consideration is that conveyor and chipper capacity be adequate to prevent stoppages and lost time of production equipment.

Furniture Plant and Similar Industries

Considerations involving use of chippers in furniture and related industries are similar to those affecting their use in veneer mills. Since it is difficult to produce good pulp chips with knife chippers from short trims and because the material is dry, most of it is used for particle board. Such material is therefore generally processed by hammermills. These machines are available in low-capacity sizes, and chips are easier to convey than trimmings. Therefore, consideration should be given to the economics of using several small machines rather than one larger machine.

Brush and Logging Slash

There are two objectives for chipping material left over from the harvesting or thinning of forests. They are utilization and disposal. The reduction of fire hazards is the major reason for disposal. The presence of bark, leaves, and dirt makes utilization of this material difficult. Cost of assembling, handling, barking, and cleaning makes utilization uneconomical under present conditions. The development of economical handling and cleaning methods is necessary.

Chipping for disposal, particularly along logging roads and right-of-way clearing for new road construction, can often be justified. Slash burning operations are costly and restricted to periods of safe burning. There is also the risk that fires will get out of control, with resultant damage and possible lawsuits. These considerations were responsible for developing portable chippers. Material must be assembled for either burning or chipping, and crews must be hired to burn or chip the material. Cost of assembling raw material and chipping, therefore, can be justified on many disposal operations (18, 22, 33).

Chip Handling

One of the major advantages of chipping is that chips can be easily handled by mechanical equipment. Air streams and belts are the most common methods of conveying chips within the plant (28). Chain conveyors and bucket lifts, which are used infrequently are more likely to cause additional breakage of wood resulting in slightly higher percentages of fines than other types. Abrupt changes in the direction of air-stream conveyors can also cause chip breakage.

All types of chippers create a movement of air, but it is greater with knife-cutting machines than with others. The addition of fins on the back side of chipper disks increases the flow of air. Knife chippers, particularly those of this type, need no auxiliary equipment other than air pipes to convey chips short distances. It is common practice to convey chips to screens or storage bins merely by utilizing air from the chipper.

Long-distance conveying to railroad cars and storage bins is accomplished with high-velocity air or belts. Selection of equipment depends a great deal on the volume of chips, distance, lift or height of elevation, and plant layout.

Railroad cars and truck trailers or vans are used for transporting chips from sawmills and concentration yards (12). Special high-sided gondola cars are preferred in some parts of the country. In other areas, the use of boxcars is prevalent. There is some objection to open-top vehicles, particularly in heavy industrial areas, because dirt, cinders, and other foreign matter are deposited on the chips in transit. Generally, however, open-top vehicles are easier to load. The type of hauling equipment to be used influences the selection of conveying and loading systems at the chip-producing plant.

Chip Storage

Chip storage is temporary and not a serious problem at chip-producing plants, but it is an important consideration at chip-using plants. Producing plants need only sufficient storage facilities to prevent plant shutdowns while their transportation equipment is away on hauls or fails to arrive on time. Storage facilities, therefore, usually consist of bins of limited capacity.

Chip-consuming plants use bins, silos (23-29) and outdoor open piles. There has been an increase in outdoor bulk-pile storage during recent years (14). On the West Coast, outdoor storage is used in areas with annual rainfall up to 75 inches (26). Studies in the South (27) indicate that 5,000 to 10,000 cords of chips can be stored per acre, depending upon the height of pile.

An investigation of temperatures in hogged fuel and sawdust (21) shows that the highest temperatures occur in the upper part of open piles. The maximum reached in Douglas-fir hogged wood was 185° F. in 45 days; in sawdust the highest was 180° F. in 120 to 160 days. Temperatures decreased toward the bottom of the pile and also as the storage time increased beyond the initial heating period. These temperatures are well below the ignition point for wood.

In similar research being conducted on storage piles of pulp chips in the South, chip deterioration also is under study. If deterioration is a problem, studies will be made on piles sprayed with water, as is currently done with logs and pulpwood.

Chip Quantity Measurement

A number of different standards are used in marketing wood chips. The unit used in the Pacific Northwest is 200 cubic feet of chips. The Cunit used in eastern Canada and the Northeast, is 100 cubic feet of solid wood. Other standards are used elsewhere. In general, these are intended to have a relationship to the amount of solid wood in a standard or nonstandard cord of pulpwood. In the South, a unit may vary from 180 to 250 cubic feet of chips.

The present trend is toward standardization based on weight (9-24). In some areas in the South, for example, the term "a unit of 5,000 pounds" is used. Most chip producers and sellers now use the standard ton as a base unit. Generally, the price stated is on the basis of a ton of green chips at a specified moisture content. The price for pulpwood chips, however, is generally based on the "bone-dry weight" (ovendry), the species of wood, and average green moisture content. The basic reason for this approach is the close relationship between a bone-dry ton of wood and the weight of pulp produced by a particular pulping process. Pulp yield varies far less when wood is bought on a weight basis than when bought by the cord. These same general considerations also apply to other chip products.

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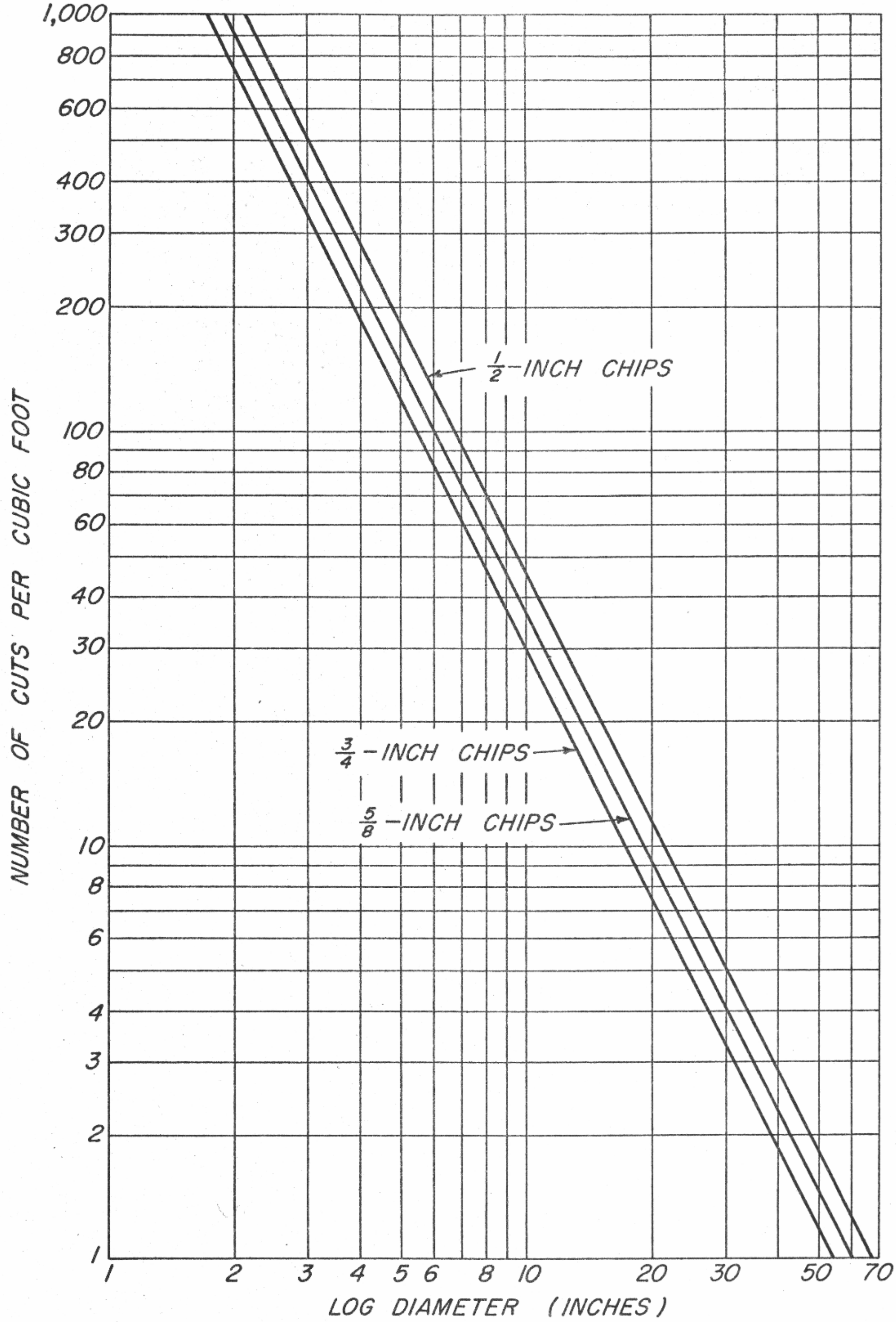

Figure 1. --Chipper cuts required per cubic foot of wood.

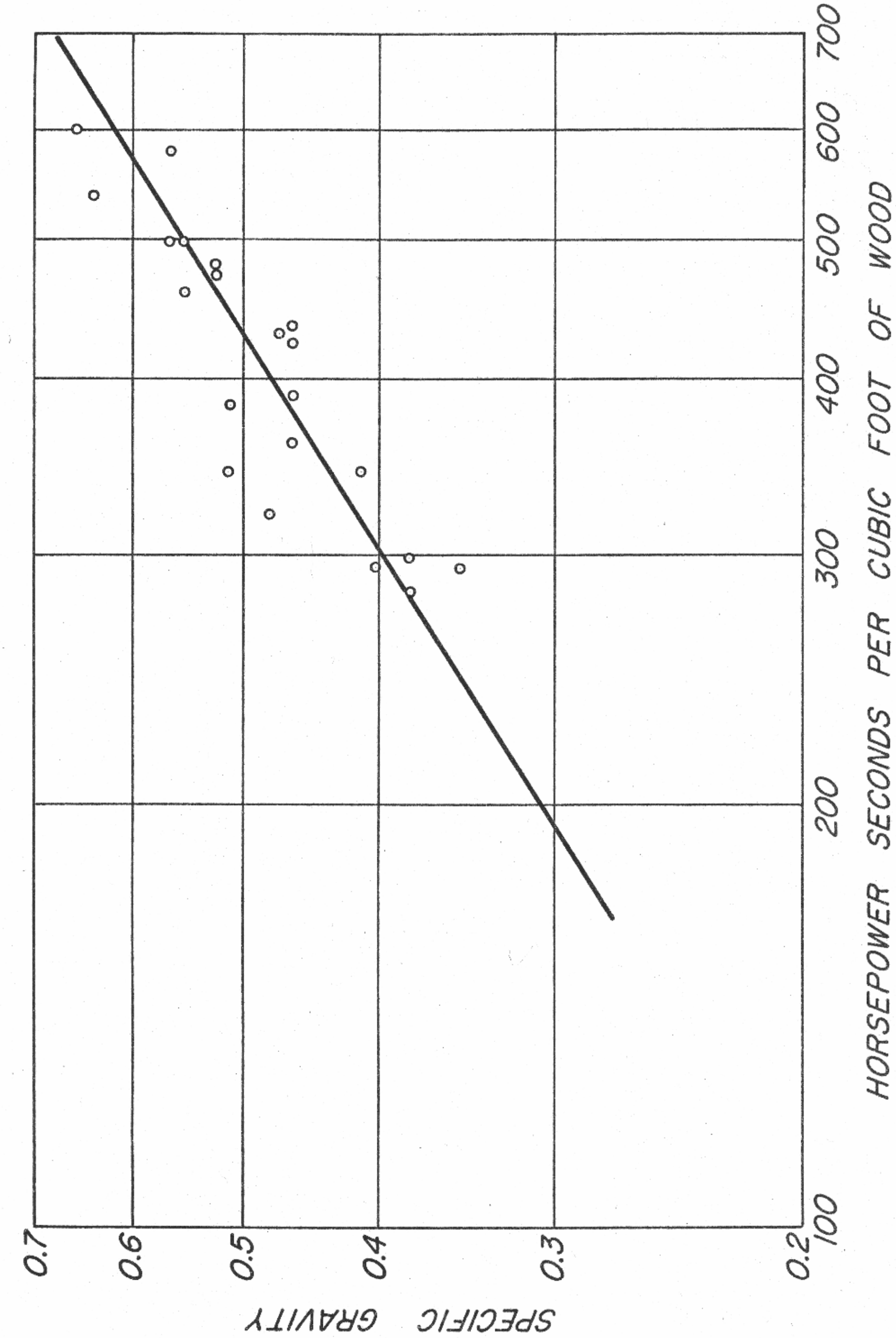

Figure 2. --Relationship of specific gravity to chipping power.

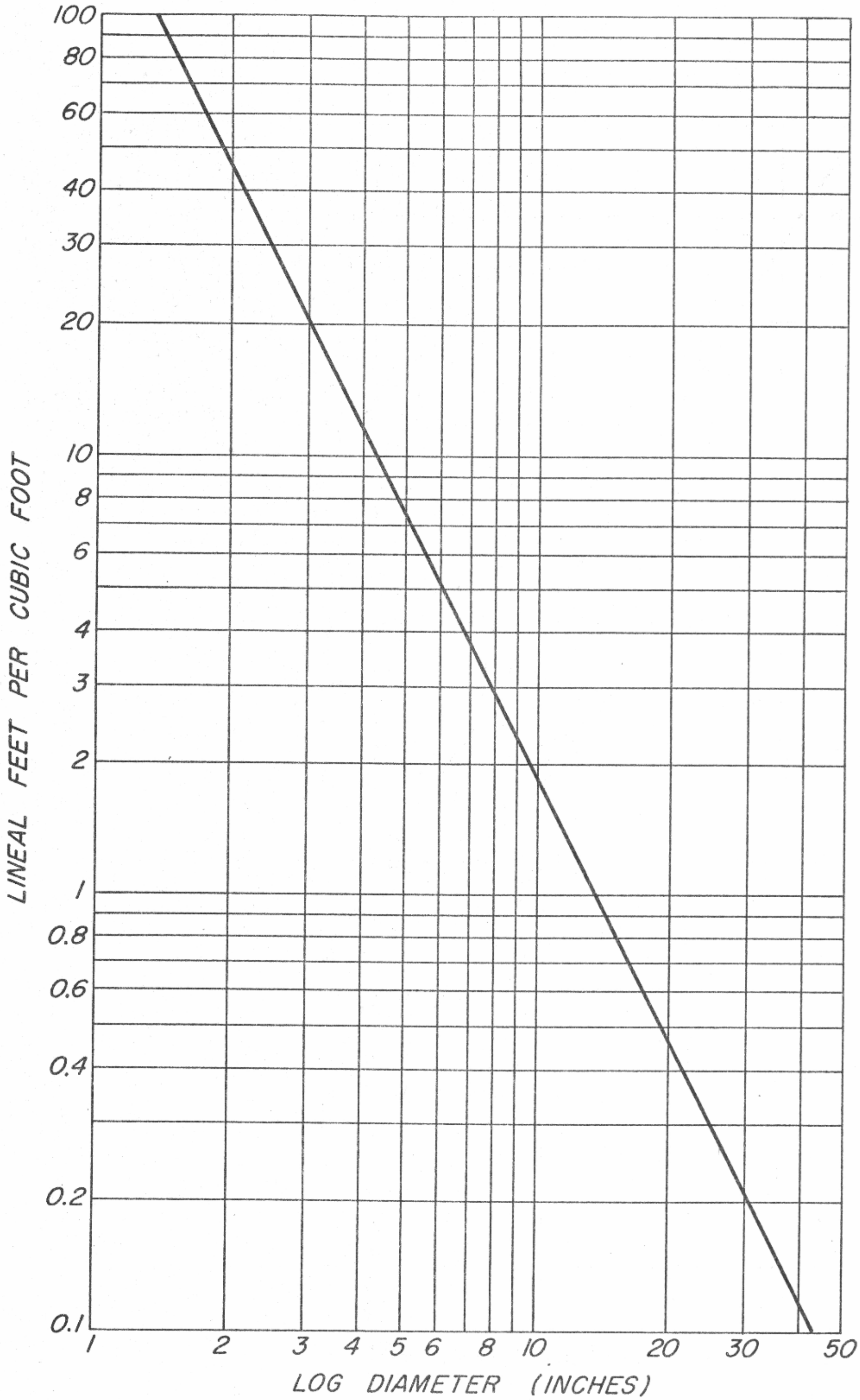

Figure 3. --Lineal feet of round wood per cubic foot.

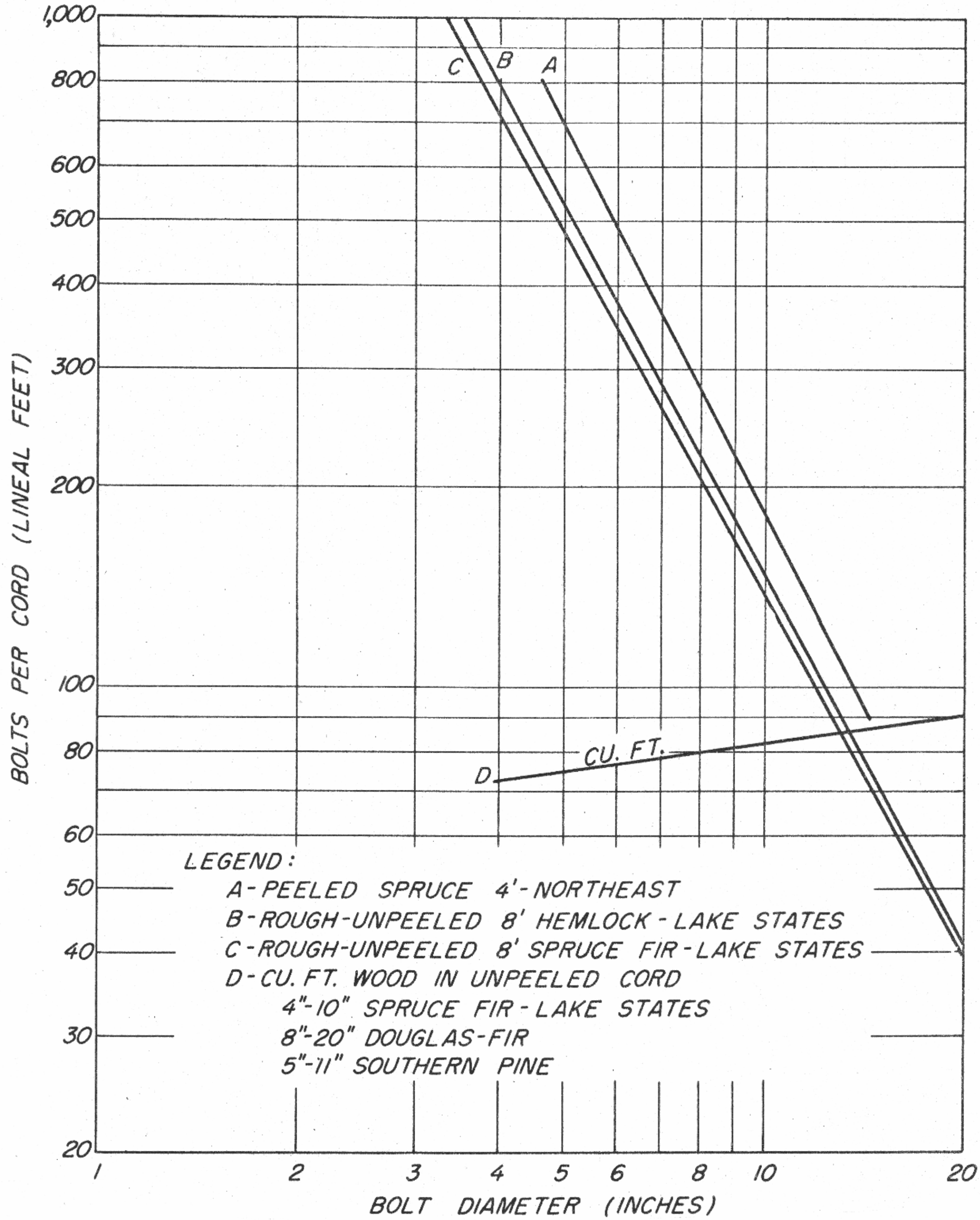

Figure 4. --Relationship of pulpwood cords to lineal feet of bolts.

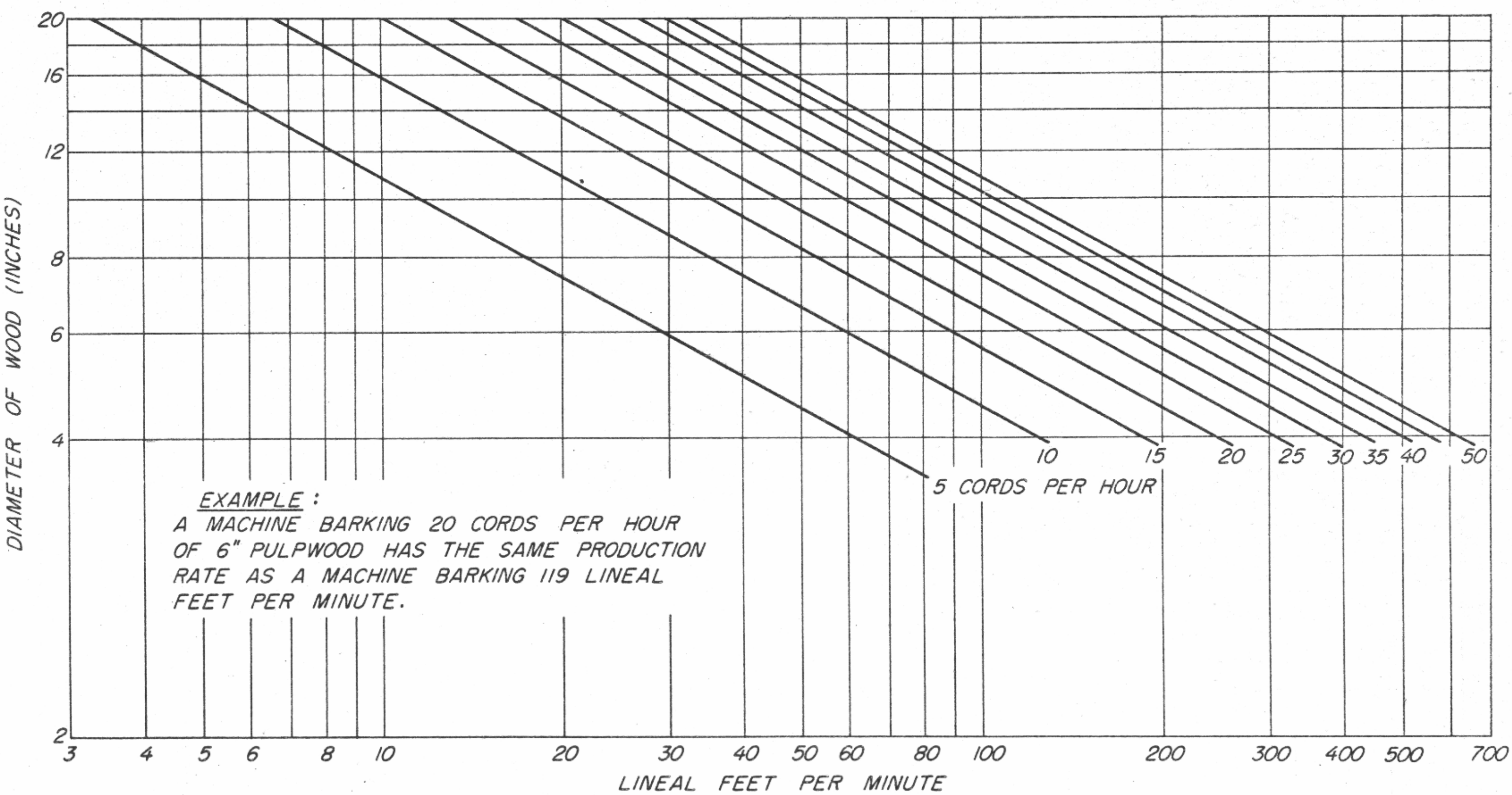

Figure 5. --Relationship of cords per hour to lineal feet per minute.

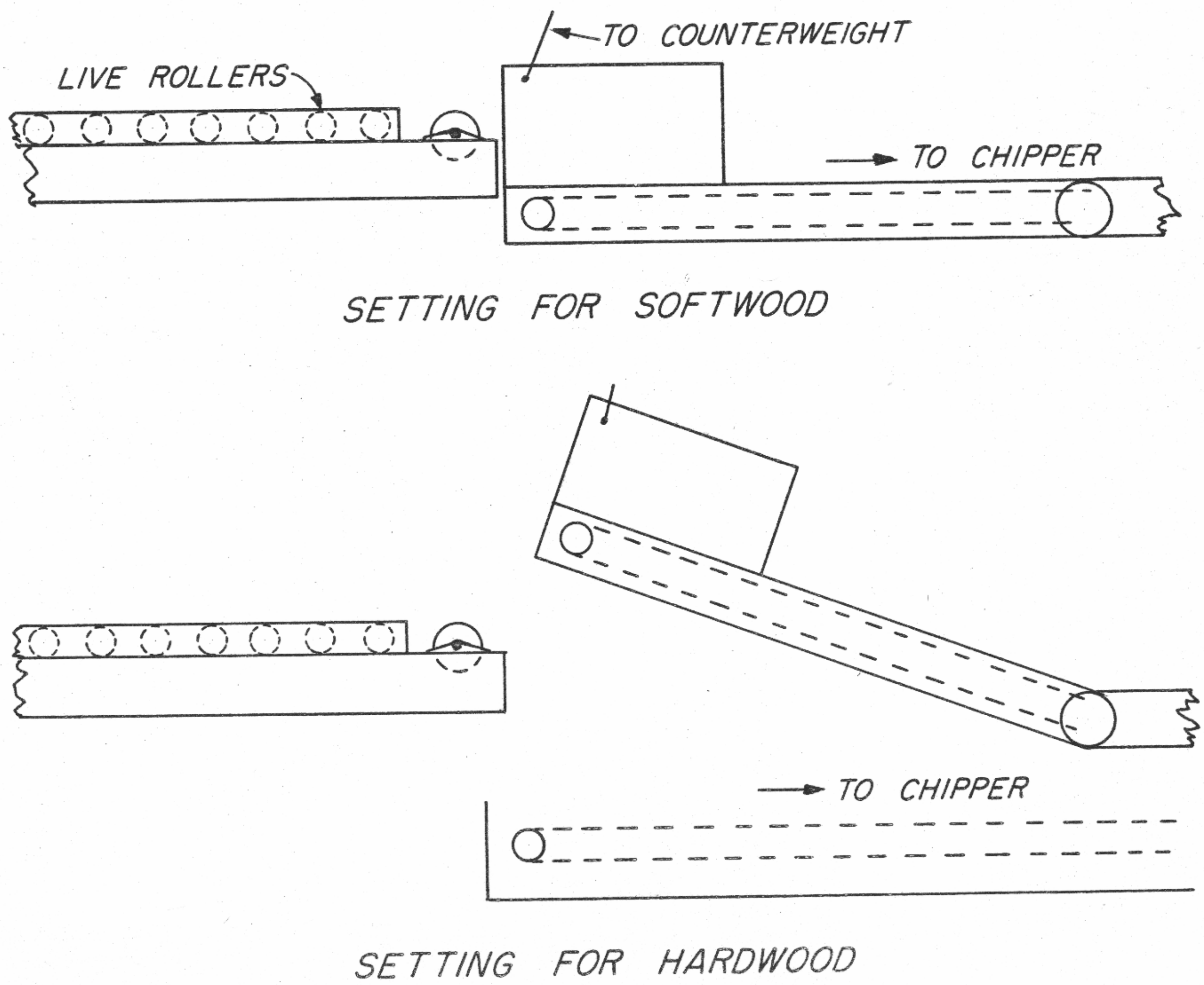

Figure 6.--A method of separating softwood and hardwood slabs. Sorting is accomplished by raising or lowering the hinged conveyor.

PUBLICATION LISTS ISSUED BY THE FOREST PRODUCTS LABORATORY

The following lists of publications based on research at the Forest Products Laboratory (Madison 5, Wis.) are obtainable on request:

Boxing and Crating

Building Construction Subjects

Chemistry of Wood and Derived Products

Fungus Defects in Forest Products

Furniture Manufacturers, Woodworkers, and Teachers of Wood Shop Practice

Glue and Plywood

Logging, Manufacture, and Utilization of Timber, Lumber, and Other Wood Products

Mechanical Properties and Structural Uses of Wood and Wood Products

Pulp and Paper

Seasoning of Wood

Structure and Identification of Wood

Wood Finishing Subjects

Wood Preservation

Since Forest Products Laboratory publications are so varied in subject no single big list is issued. Instead a list is made up for each Laboratory division as shown above. Twice a year, a list is made up showing new reports for the previous 6 months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. There is no charge for single copies of any of the reports.

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