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# WOOD FLOUR

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## WOOD FLOUR

By

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### Introduction

Wood flour, which is wood in very fine particle form, is produced from selected dry wood waste by several types of grinders and sized by mechanical or air screening methods. The flour must conform to various specifications as to distribution of particle sizes, species included, resin content, color, specific gravity, foreign matter, absorptiveness, or other specifications, depending on use, and is employed chiefly in the manufacture of linoleum, explosives, and plastics, with numerous other uses consuming the remainder. Total consumption, which amounted to 49,000 tons in 1939, is not large. Production is concentrated in the East near the large centers of consumption and convenient to concentrations of suitable waste wood. Consumers' requirements are rather exacting, so that rigid specifications differing widely according to use make the manufacture of wood flour a business requiring technical skill and specialized knowledge.

The term "wood flour," for which no clear-cut definition has been adopted, is applied somewhat loosely to wood reduced to finely divided particles approximating those of cereal flours in size, appearance, and texture. A specific method of production is not implicit in the name "wood flour."

The characteristics of very small wood particles are dependent on the method of preparation. The chemical methods used for paper pulp production loosen or remove the material binding the wood cells together, so that the resulting particles are characteristically whole single cells or fibers retaining their original form to a large extent, but somewhat modified chemically. Mechanical methods of pulp production leave the chemical nature of the wood unaltered, but in making groundwood pulp the fibers separated by the wet abrasive action are more or less battered or broomed out at the ends, while cell fragments and fiber bundles (two or more unseparated cells) are more frequent than in chemical pulp. In dry mechanical reduction, by cutting, abrading, or crushing, the wood particles characteristically are fragmented cell bundles, which may, on further reduction, separate into battered fragments of single cells. Wood flour, being produced by mechanical reduction, is of this nature.

## Wood Flour Use

The properties of wood flour are such that it is used in the following categories, singly or in combination:

1. As an absorbent
2. As a chemical reactant
3. As a chemically inert filler
4. As a modifier of physical properties
5. As a mild abrasive
6. As a décor

Specific applications in the various categories are numerous; a few citations will suffice to illustrate typical applications. Absorbent qualities may be utilized in cleansers to remove unwanted liquids or semiliquids (water, oils, greases) from such articles as delicate machinery parts, jewelry, and furs, or to carry cleansing, toxic, or other chemical agents to the object in controlled quantity. In the manufacture of dynamite, the extreme sensitivity of the explosive agent can be reduced to safe levels by immobilizing the liquid nitroglycerin by absorption in a solid medium. Kieselguhr (a fine earth) was formerly used, but has been replaced by vegetable fiber media, such as wood or straw flours, the vegetable absorbent contributing other benefits as a result of its combustibility at the same time.

As a chemical reactant, wood flour or any other carbonaceous absorbing medium used in dynamite contributes to the reaction during explosion, the combustion of the absorbent utilizing some of the excess oxygen released during the explosion and adding to the force thereof. The chemically reactive property of wood flour is utilized also in incense, for combustion. The presence of natural resins sometimes influences the proportions of materials it is compounded with, notably in linoleum manufacture.

In the majority of the uses of wood flour combustion is not involved, and the wood flour plays a chemically inert role, serving as a diluent or filler to reduce the amount of the more expensive ingredient needed, as in the manufacture of linoleum and plastics (the major uses of wood flour) and in patching materials, cements and glues, casting or molding materials, phonograph records, unbreakable dolls, and other uses. The choice of wood flour as a filler may be based solely on economy in cost, but frequently other properties enter into its choice.

Although chemically inert in most applications, wood flour is active in modifying the physical properties of any material throughout which it is dispersed. The low density of the parent wood and the fluffy character of the derived wood flour reduce the density of heavy plastics and similar dense products when used as a filler. The inclusion of wood flour modifies strength characteristics and is particularly effective in increasing the impact resistance of plastics, rendering them less brittle, reducing cooling stresses, and minimizing shrinkage. Wood flour provides opacity to transparent plastics and provides color control, as, for example, when used in linoleum.

In foundries, wood flour acts as an anti-bind agent, and in ceramics it modifies porosity when used as burn-out material. In special paints, the sound-insulating properties of wood flour are utilized, while in electrical equipment the electrical insulating qualities may be improved by the presence of wood flour. Thermal conductivity will be modified by the presence of wood flour, though its use primarily for this purpose is uncommon.

In addition to the modification of physical qualities imparted by wood flour intimately incorporated into the primary material, certain physical qualities of wood flour are exhibited when used in loose admixture or alone. As a mild abrasive, wood flour is useful in soaps and in the cleaning of furs. It is used also in the polishing, by tumbling, of small objects such as buttons, and in removing the flash from and polishing molded plastic articles.

In addition to the decorative value of plastic articles incorporating wood flour, this material is used decoratively in the production of "oatmeal" and "velvet" wallpapers, where the sprinkling of wood flour, colored as desired, onto a prepared paper surface provides decoration by design and by texture.

### Species Used

The species considered most desirable for wood flour are the white pines (Eastern, Western, and sugar pine), aspen, spruce, hemlock, and to a limited extent, balsam fir and paper birch. Basswood is acceptable for some uses, and flour from maple is made in relatively small quantities. Cottonwood, yellow-poplar, and willow are sometimes used for special grades, and some redwood flour has been produced. Strongly acid species, such as oak, and the many species with dark heartwood are considered undesirable for many uses from the standpoint of chemical activity or coloration. Bleaching is not practiced because of the subsequent deleterious effects of residual bleaching agent; hence naturally light-colored flour is required for dynamite, where color is used as an index of age<sup>1</sup>, and for inlaid linoleum and plastics, where light-colored products must be produced. The darker flours, and those containing some bark, can be used in the darker or the cheaper printed linoleums, the dark plastics, and in cleaning compounds in which color is unimportant. Abroad, spruce, pine, and fir are used in Scandinavia, and in Great Britain some use is made of teak, beech, mahogany, and cedar.

### Variation in Wood Flour

Wood flour, broadly considered, is neither a uniform nor a standardized product. Variation in resin content occurs within a species and thereby appears in the product, and the species used, though relatively few in number, have somewhat different characteristics. Variation in manufacturing methods results in particles of different structure and shape, some granular, some fibrous, while maximum particle size and proportions of the smaller particles may differ widely for flours of supposedly like fineness, depending somewhat on the raw material and the manufacturing process used. A few samples of screen analyses of wood flour are given in table 1 to illustrate the variations encountered in material having the same trade designation as to size (40 mesh), which is the number of the sieve in the Standard Screen Scale through which particles will pass.

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<sup>1</sup>This requirement could be eliminated by marking the date of manufacture on the dynamite. Distinctive dyes could be incorporated to identify various dynamite strengths or brands.

Table 1.--Sample distributions of particle size in 40-mesh wood flours as indicated by percentages passing through screens of increasing fineness

Sieve No.	Amount passing through sieve		
	Sample A	Sample B	Sample C
	Percent	Percent	Percent
40	100	100	100
50	98	62	55
60	76	40	30
80	38	31	18
100	11	25	10
150	6	18	7
200	--	12	5

A wide range in particle size is unavoidable, since the efficient reduction of wood to flour-like particles involves a principle common to the reduction of all aggregates to finer particle size. Any crushing or shattering treatment accorded a mixture of variously-sized pieces is only slightly selective as to size, for the small pieces are subdivided in common with the larger pieces as they come in contact with the machine parts or are caught between larger particles being crushed, a procedure that could be limited only by removing the finer particles from the mass as soon as they have reached the desired size and before they are subjected to further milling action. Even such a procedure, however efficient, would not prevent the formation of particles smaller than the desired size, since fragmentation is not uniform and may produce superfine particles. The equal subdivision of particles slightly over the desired size also would produce extra-fine particles, as would the knocking off of the corners of large pieces. The variation in particle size parallels the variation in the initial stock, therefore non-uniformity of raw material results in the power-wasting production of unnecessarily fine particles. A variation in particle size is an unavoidable result of the processing of material en masse.



## General Conditions in the Industry

As a result of the variability of wood flour, consumers who have adapted their processes to give the desired results with the product of a given wood flour manufacturer continue to use that particular product, and some large consumers have installed their own wood flour machinery. Because of this situation, coupled with the exacting requirements and competition for raw material, the wood flour industry is not easy to break into, and mortality among such ventures has been rather high.

The industry, as a whole, depends for its existence largely on the favorable price ratio between wood flour and other equivalent material. To maintain this favorable ratio, and to compete with low cost flour exported from Scandinavia, where the industry originated, maximum economy in investment, labor, power, and raw material charges must be had. Low investment, labor, and power costs are engineering and managerial problems. Raw material must be available at a low cost and in a form requiring minimum power and handling charges, such as sawdust and shavings. Conversion of wood waste to flour as an adjunct to the waste-producing plants has not had notable success, since the manufacturing process is so unlike ordinary woodworking methods and the marketing of the product involves a sales technique and a clientele entirely separate from that involved in the usual wood products. Processing of waste, then, seems best accomplished at specialized plants where primary interest is centered on effective management and technical control to maintain production of wood flour at peak efficiency.

## Manufacture of Wood Flour

### Raw Material Sources

The chief source of low-cost raw materials is the waste of other wood-processing industries. Although the total waste produced in wood-using industries is tremendous, stringent economic and technical requirements at present disbar all but a small portion of it for making into wood flour. Species acceptable for wood flour are few in number: the wood must be free of bark in most cases; it must be dry to permit reduction to flour; it must be readily collected and in small pieces to avoid extra sizing operations; and the resulting bulk precludes long transportation hauls or frequent rehandling.

The various limitations stated, added to the economic necessity of using dry material of small size, restrict the sources of raw material supply to fairly large planing mills and woodworking plants using large quantities of dry wood of a preferred species (or equipped to segregate their waste by species), and to only such sources of carload lots of waste as are not much more than 100 miles from the wood flour plant to minimize haulage. (A transportation charge on waste of \$0.25 per 100 pounds can be borne in periods of good prices for flour.)

## Manufacturing Processes

The methods of producing wood flour may be listed as :

1. By reclamation or segregation
  - (a) Recovery of dust from sanders, with or without screening to size
  - (b) Screening of sawdust to segregate the finer particles
2. By attrition (abrasion)
3. By impact fragmentation (cutting and shock)
4. By crushing

Sander dust is derived from dry wood, and, if the species is acceptable, is suitable in applications where the presence of particles of the sanding abrasive is not damaging. Screening to size may be necessary. If air separation is employed for screening, it is possible to eliminate practically all of the abrasive. The screening of sawdust yields a granular product suited for fur cleaning, for example, but the percentage of fine particles of flour size in sawdust is rather small (4 percent 80 mesh or finer); hence such processing can be efficiently conducted only as an incidental adjunct to what is primarily a sawdust business.

Sander dust and sawdust provide wood flour merely as reclamation or segregation processes. The processing of wood with the primary expressed objective of making wood flour was first suggested in 1897 (9) and led to the establishment of the first wood flour factory in 1906, in Norway, in which the flour was produced by attrition in stone mills similar to those used for grinding cereals. In the common stone mill, a revolving circular stone of the proper grit, with a flat upper surface, is surmounted by a stationary stone that is slightly concave on the lower surface, provided with shallow grooves for distributing the material being ground and also provided with a central opening through which the raw material is introduced between the stones. As the rotation of the lower stone abrades this material to finer size, the reduced material works outward toward the perimeter and is further reduced in size as the gap between the faces of the stones diminishes. The finished product, its fineness controlled by the spacing of the stones, discharges over the periphery of the lower stone and is collected for packaging. In this process, the initial size of the raw material approximates that of sawdust (which can be used directly), so that a preliminary reduction is necessary for larger material, such as shavings. Because of the heat generated by the abrasion it is necessary to introduce a small (controlled) quantity of water or steam between the stones to prevent overheating resulting in charring or combustion, but too much water would result in an excessive moisture content of the flour. Some of the finest sizes of wood flour can be produced by this method, but power consumption is relatively high, requiring cheap power. Most of the wood flour produced abroad is made with stone mills, chiefly in Scandinavia, where water turbines drive the mills.



A more modern type of mill, the single or the double attrition mill, is also used for producing wood flour by abrasion. In these mills, corrugated metal disks, revolving in opposite directions either in the horizontal or vertical plane, grind the material between two disks (double attrition mill), or between a single disk and a similarly abrasive casing (single attrition mill). A steel burr roller type of mill also is used, in which the material is ground between a series of burrs, or toothed rollers, operating in pairs and revolving in opposite directions, successive rollers having finer teeth. This type of mill is effective for producing the coarser meshes of wood flour, but is unsuitable for producing the finer meshes. In general, steel-tooth attrition mills present some difficulties in maintenance of tooth sharpness, a matter that is of minor importance or entirely absent with other grinding methods. The grooves of stone mills require occasional deepening.

Reduction of wood by impact is accomplished in "hammer" mills, sometimes referred to as "beater" mills. Within a horizontal cylindrical or sometimes conical space within the casing of such mills, a shaft is revolved at high speed. A series of disks or spiders fitted to this shaft provides anchorage for free-swinging hammers, which may consist of sharp-cornered rectangular bars pivoted at one end on pins near the rims of the disks, or they may consist of plain or toothed rings retained by similar pins. In operation, centrifugal force keeps the hammers or rings yieldingly extended to a position wherein they clear the surrounding casing slightly. The type of hammer or ring used varies with the material being ground, hence the ring type, best suited to brittle materials, is not used for grinding wood. Hammers may be of the yoke or bar type, extending the full length of the grinding chamber, but for wood it is desirable to use relatively narrow hammers, face width sometimes being as low as one-eighth inch. Hammer width and velocity should be such that the air cushion developed by the face of the hammer will not force the particles aside before they can be struck by the hammers. Lower velocities and wider hammers may be used for coarse grinding or during the initial breakdown of the raw material. In operation, material to be ground is introduced to the grinding chamber through a spout discharging at the end or along the length of the chamber near the beginning of the upper half of hammer rotation, where it meets the rapidly rotating hammers. The faces, edges, and corners of the hammers cut and shatter the material and throw it forcibly against the casing, whence it undergoes additional impact and rebounds into the path of succeeding hammers, repeating this cycle until it enters the lower half of the casing, consisting of a half-cylinder or half-cone of perforated metal, spaced bars, or louvers. Further reduction takes place in the layer of material retained on the screen, particles sufficiently ground dropping through into the collecting system, the larger particles either remaining on the screen until reduced enough or recirculating, being carried around into the upper half of the chamber for additional grinding. The effectiveness of hammer mills in grinding to fine meshes (100 percent passing through 100 mesh, or finer) is reduced by the low inertia and high air resistance of very fine wood particles, resulting in a movement of the particles out of the path of the hammers or in a low differential between the velocity of the hammers and the velocity of air-borne particles moving within the grinding chamber. This condition does not occur in either the attrition type of mill or in the crushing type.

Pulverization by crushing is usually accomplished by passing the material between a moving roller and a stationary surface or anvil, high unit pressure at the line of contact producing the breakdown of material. Meshes as fine as 350 to 400 have been reported attainable with these pulverizers. (The embrittlement of wood flour by impregnating with urea is envisioned in a recent patent (21) as a means of readily grinding the naturally tough wood fibers to an extremely fine powder in ball or tube pulverizers.) In the roller pulverizer, a vertical spindle carries at its upper end a spider from which long journals in swinging bearings are suspended, the bottom end of each being fitted with a roller. Concentric with the spindle and at the level of the rollers, the ring-shaped anvil or "bull" ring is placed. As the spider rotates with the shaft, the rollers are thrown outward against the bull ring by centrifugal force. Material to be ground is scooped up by a "plow" in advance of each roller which directs the material between the roller and the ring, where the grinding takes place. The ground material is removed from the grinding zone by an air current and oversize particles are returned for regrinding. Better grinding conditions are maintained by this early removal of the fine particles.

#### Sizing of the Product

The use of air in handling wood flour is primarily for classifying or sorting the ground material by size. For any given upward air velocity, there is a rate at which the air resistance of a particle of specific size balances its weight, larger sizes settling out. The same principle is also operative in centrifugal action. By these means it is possible to classify the wood flour into one fraction meeting size requirements and a second fraction ("tailings") of oversize particles that are returned concurrently to the input side of the grinder. The finished product is removed by passing the air stream (usually in a closed circuit) into a cyclone, any excess air discharging through bag filters to remove the last fine particles. Recovery is practically 100 percent.

Air screening or separating is applicable to any type of grinder, especially when a very fine-meshed flour is being made. The original practice of mechanical screening, using modern rotating, vibrating, or oscillating screens of wire or cloth, however, has not been displaced by air screening. It is still widely and effectively used in the industry in conjunction with all types of mills. There is some danger, however, that any slivers produced in the hammer type of mill (not in attrition mills) may pass through the screen. Such slivers are considered a defect in the flour for use in plastics (10). The final screened product of the two types of screening may show some differences. In air separation, a broomed-out particle of given dimensions and weight may have sufficient surface area to be air-borne, whereas a smooth, compact particle of the same dimensions would have more weight in relation to surface area and therefore settle into the tailings and be reground to smaller size, although both would pass through a mechanical screen. The air-separated flour is reported to have a somewhat higher percentage of fines, as typified by the particle-size distributions shown in table 2 for 80-mesh flour.

Table 2.--Distribution by particle size -- 80-mesh wood flour

Classification process	Sieve number				
	80	100	200	300	400
	Percentage passing through screen				
Air separation	100	98	85	70	60
Mechanical screening	100	96	78	60	0

The final screened product, whether mechanically or air-screened, is packed in paper or cloth bags holding 75, 100, or 112 pounds of flour.

#### Processing Efficiency

The bagging of the flour is the culmination of a process reputed to depend for its efficiency and financial success upon the application of "trade secrets," which in all probability reduce to aggressive merchandizing, maintenance of uniform processing conditions, elimination of ineffectual labor by convenient arrangement of plant, efficient handling of materials, maintenance of output at or near the machine capacity, and reduction of fire hazard. For highest efficiency, machinery should be selected to suit the raw material, the end product, and the capacities desired. If a high ratio of reduction is required, reduction in two or more stages in series is most efficient, thus shavings would be reduced to not smaller than 20 mesh in a hammer mill discharging directly into another mill where it may be ground to 80 to 100 mesh. Pre-sizing to finer than 20 mesh is not considered economical. High peripheral speeds (12,000 to 16,000 feet per minute) should be sustained in hammer mills for effective grinding, and the feed should be adjusted to and maintained at the level giving maximum effective output. This is attained with a recirculating load of 20 percent in hammer mills or 50 percent in attrition mills. A larger "run-around" results in lower production and power wastage in recirculating the material, which merely moves through the machine without grinding. A smaller run-around indicates a sub-capacity feed rate, with the production of an unnecessarily large proportion of fines. Other practices contributing to efficient operation are the proper maintenance of machinery and protection of plant and equipment from damage.

## Plant Protection

Damage to grinders could result from the presence of foreign matter, such as nails and stones, in the material being ground. Electromagnetic devices are available for removing magnetic materials, but are inoperative on nonmagnetic metals or stones. Gravity-operated traps are sometimes used in the feed line, and one type of hammer mill incorporates a trap which catches and retains the foreign matter separated by centrifugal action after its introduction into the machine. It should be quite feasible, however, to employ air feed at the input spout to achieve air separation of dense foreign matter of any type. The presence of foreign matter is feared as a cause of sparks that might start fire within the grinders, but this danger is over-emphasized. Overheating in attrition mills is possible, but combustion occurs when the flour is exposed to the atmosphere on leaving the mill. In hammer mills, high velocities and dense concentrations of flour prevent combustion, one hammer mill manufacturer demonstrating this by introducing a handful of nails, a box of ordinary strike-anywhere matches, and finally a shovelful of glowing furnace coals into a mill in operation, without causing fire. Closed-circuit mills may be operated with an inert atmosphere, such as carbon dioxide, to eliminate the oxygen necessary to combustion.

A very real danger of fire exists in wood flour plants, however, from external causes, and the resulting fires may be disastrous. Under certain conditions, wood flour is explosive in its combustion, and in any event is highly inflammable. The Bureau of Mines (19) has found that the conditions for explosive combustion exist when the concentration of airborne dust is such that the particles are surrounded by sufficient air for combustion to raise all particles to the ignition temperature and spaced closely enough to permit propagation of flame from one particle to the next, greater or lesser concentrations not meeting these requirements are not explosive. Losses from fire may add 15 percent to overhead costs of the business, when fire does not wipe out the plant completely, hence reduction of hazard is worth constant attention. Motors and switches should be nonsparking and completely enclosed, and static generated in belts or elsewhere should be eliminated (26) through safe grounds. Sprinkler systems, nonsparking floors and enforced no-smoking rules are desirable. Inch-deep accumulations of grinder dust on rafters, exposed stud bracing, shelves, and in unused corners of the floor offer good odds for rapid spread and complete gutting by any fire which gets started. Plant cleanliness is therefore of paramount importance. Air conditioning to remove dust would be a wise procedure for protection of the investment entailed by a good wood flour plant. Cleanliness throughout is desirable to prevent contamination of flour. One English manufacturer uses pneumatic bag cleaning, uses a special truck for delivery, and goes so far as to carry special slippers in the truck for use inside the truck to prevent carrying in grit or shavings that would adhere to the bags and possibly contaminate the flour during emptying of bags.



## Economics of Wood Flour Production

### Investment and Productive Capacity

Investments will vary to some extent with type of equipment installed and will depend, naturally, on total capacity. Attrition mills, lower in maintenance and power costs than hammer mills, are higher in first cost. Complete milling and screening equipment for a plant producing one ton of 40-mesh flour per hour would cost between \$5,000 and \$8,000, exclusive of buildings, trackage, power supply, etc., but including motors, accessories, and installation costs. Roller crushers cost about 10 percent more than hammer mills of equal capacity; mills of double capacity cost only about 75 percent as much per unit of capacity as the smaller ones, but production per horsepower-hour is less in the larger sizes.

Capacities of the same equipment when producing other mesh sizes vary inversely with the mesh, thus the capacity at 40 mesh is but half that at 20 mesh. At fine meshes (100 or finer), one grinder manufacturer considers that power consumption and output vary as the square of the ratio of meshes, thus 200 mesh would require four times the power required for 100 mesh, or  $\left(\frac{200}{100}\right)^2 = 4$ . If the power consumption of grinding only, apart from machine losses, depends on the total cleavage area involved in reducing from a larger size, a doubling of power for each halving of particle dimension would be indicated since cleavage area (assuming cubical particles) is  $3L^2 \left(\frac{L}{l} - 1\right)$  where  $L$  is the initial length of side, and  $l$  is the length after subdivision. If  $L$  is taken as 1 and  $l$  as  $1/2, 1/4, 1/8, 1/16 \dots$ , the total cleavage area (the quantity in parentheses in the foregoing formula) relative to the area involved in the first halving, will be 1, 3, 7, 15 ..... The increases in cleavage area, the successive differences, will be 2, 4, 8 .... Although this 2, 4, 8 ... progression agrees with the inverse ratio mentioned previously, it is based only on the energy absorbed by the cleavage areas.

Frictional losses in the machine -- in bearings, in internal air resistance, and between machine and material -- together with the energy consumed by internal friction in the material and in recirculating it are probably constant and therefore dependent in the aggregate on grinding time. Grinding time for constant power, or power for constant flour output, may increase faster than the indicated ratio (approaching the squared ratio of the meshes) due to energy absorbed for nongrinding movement of the material, as in the fanning action of hammer mills where the air cushion ahead of each hammer moves the smaller particles out of the hammer path, or in the cushioning effect in attrition or roller mills where particles smaller than the actual gap between machine parts lie between the layers of particles in actual contact with the machine parts and are moved without reduction in size.



Total power requirements are reported to be about 125 horsepower-hours per ton of white pine shavings reduced to 40 mesh, or 16 pounds per horsepower-hour, a rate which may go as low as 10 pounds per horsepower-hour with coarse raw material, high moisture content, or inefficient grinder operation. At 80 mesh, production is about 5 pounds per horsepower-hour, and at 100 mesh it is about 4 pounds per horsepower-hour.

#### Operating Costs

The cost of power for grinding will depend on the mesh and the power rate. With electricity at 1 cent per kilowatt hour, and figuring conservatively that line and motor losses will reduce effective power to 1 horsepower per kilowatt, total power costs for 40-mesh flour would amount to \$1.25 to \$2.00 per ton. For 80-mesh flour, the power cost would be about \$4.00 per ton, increasing to \$5.00 per ton of 100-mesh flour. Maintenance and upkeep of equipment will be about 1 to 1.5 cents per horsepower-hour, while overhead varies between 10 and 25 percent, depending largely on fire losses. In 1929, the delivered cost per ton of \$26.29 for linoleum grade flour was distributed thus: raw materials 32.5 percent, factory expense 36.6 percent, general and administrative expense 4.9 percent, interest 4.0 percent, and transportation 22.0 percent (31).

#### Transportation

The cost of rail shipment of wood flour is somewhat more than for sawdust, wood flour being so classed and taking a higher rate when 75 percent of the material passes through 60 mesh. When less than 75 percent passes through a 60-mesh screen, the material is classed (for rail transportation purposes) as sawdust. This distinction is not recognized by the State of Wisconsin, where any dust produced by a saw is legally deemed sawdust, regardless of fineness or mesh. While this conception is true, of course, it does not form a logical basis for proportioning rates to value of the product or to the hazards incurred during transportation, since fire danger depends on particle size rather than the method of production. Aside from interpretation of what constitutes wood flour, the transportation of the flour involves no inherent difficulties.

#### Prices and Grades

The flour is delivered to the purchaser in bags at f.o.b. prices ranging from \$20 to \$25 per ton for 40 mesh to \$35 to \$40 per ton for 100 mesh (and correspondingly higher, up to \$35 per ton, for finer meshes or special grades), prices varying with quality, grade, and source. One of the largest domestic producers supplies graded flour in three grades, called Granularmetric, Technical, and Nontechnical.

Granularmetric flour, as its name suggests, is closely controlled as to size and proportion of fines, color, and resin content, and is difficult to produce. It is a superior grade of technical flour, the

technical grade including flour made to definite specifications as to mesh, species, color, specific gravity, resin content, absorptiveness, character of fibre, or other properties. Specifications as to the various characteristics are the least exacting for the nontechnical wood flour, the common grade, which may permit a mixture of several similar species and greater variation in the proportions of the particle sizes present.

Generalized specifications of wood flour for various types of use are tabulated in the appendix.

### Production and Imports

Statistics are not available as to the quantities of the various grades or meshes of flour produced, or of production by species. The amount of granularmetric flour is relatively small. The bulk of the flour produced is of the nontechnical grade and enters such products as linoleum, certain plastics and other molded articles, composition flooring and shingles or roofing, and the like.

Figures for domestic production and imports, available up to 1939, are given in table 3.

Table 3.—Estimated United States consumption of wood flour from 1928 to 1939

Year	: Domestic : : production :	: Imports :	: Total :
	: <u>Tons</u> :	: <u>Tons</u> :	: <u>Tons</u> :
1928	: 32,755 :	: 7,245 :	: 40,000 :
1930	: 57,970 :	: 4,530 :	: 62,500 :
1932	: 15,342 :	: 4,658 :	: 20,000 :
1934	: 19,565 :	: 1,915 :	: 21,480 :
1937	: -- :	: -- :	: 32,000 :
1939	: -- :	: -- :	: 49,000 :

Wood flour of foreign manufacture is subject to an import duty of 25 percent ad valorem, reduced March 7, 1931 by presidential proclamation (31) from the 33-1/3 percent established by the Tariff Act of 1922. With the advent of the war, shipments from foreign sources -- Scandinavia, Holland, and Germany -- dropped sharply, and no foreign flour has been received since 1940. Since then, domestic production has increased to make up for the lack of foreign supplies and increased domestic requirements.

#### Probable Trends in the Industry

With the cessation of hostilities in Europe, it is to be expected that foreign wood flour will reappear in the American markets as soon as adequate shipping space becomes available. Such imports will help supply the increasing demand for wood flour for use in plastics and for whatever new uses may develop. The foreign flour, made chiefly in stone attrition mills, probably will be especially suitable for the plastics industry because of its quality and fineness. The surface finish of plastics improves as the filler becomes finer, and the demand for better finishes will accentuate the demand for finer meshes. Flour as fine as 250 and 300 mesh is now used occasionally, while a large amount of 150 mesh is used where 80 mesh was considered satisfactory five years ago. The European wood flour in the past has been considered superior in quality to domestic flour, but there are no technical reasons why domestic flour cannot be equally well made, other than a possible lower resin content in the species used. Where resin content is important, minor changes in the formulations into which the flour enters usually can be made to permit equally effective use of domestic flour. Continued importation of European flour may ultimately resolve itself on an economic rather than a technical basis.

The course of the wood flour industry in the United States in the post-war period may be expected to be one of gradual expansion and considerable stability, unless over-expansion occurs or Canadian production results in severe competition. The likelihood of general displacement of wood flour by mineral or other organic fillers at ruinously competitive prices is small, although some small-scale shifts may occur where other fillers provide special qualities for specific purposes, as in the better flow characteristics of phenolic resins when soybean filled (22). Since almost all wood flour is used as a secondary material in the products into which it enters, the general conditions of the wood-flour industry should parallel those of the consuming industries. Barring a general economic decline, the wide diversity of products into which wood flour enters should guarantee a good degree of stability.

#### Grinding and Accessory Equipment

Manufacturers of various wood flour producing equipment are listed in the following tabulation. Inclusion of any name does not imply approval of the equipment or services offered, nor does omission of any manufacturer

imply disapproval, since no study of the operating characteristics of the various makes of machines has been attempted. The services of a consulting engineer will be desirable in selecting equipment for and laying out any wood-flour plant.

Abbe Engineering Co., 54 Church St., New York 7, N. Y.  
Allis-Chalmers Mfg. Co., 1941 Ristow St., Milwaukee 1, Wis.  
American Pulverizer & Crusher Co., 1249 Macklind Ave., St. Louis 10, Mo.  
Bauer Bros. Co., 1717 Sheridan Ave., Springfield, Ohio.  
Dings Magnetic Separator Co., 524 E. Smith St., Milwaukee 7, Wis.  
Dracco Corporation, Harvard Ave. and East 116th St., Cleveland, Ohio.  
Gruendler Crusher & Pulverizer Co., 2900 North Market St.,  
St. Louis 6, Mo.  
Hocking Valley Mfg. Co., 1934 Alfred Ave., Lancaster, Ohio.  
International Engineering Co., Inc., 1200 Bolander Ave., Dayton 1, Ohio.  
Jeffrey Mfg. Co., The, 956-99 N. Fourth St., Columbus 16, Ohio.  
National Conveyors Co., 50 Church St., New York 7, N. Y.  
Orville Simpson Co., The, 1230 Knowlton St., Cincinnati, Ohio.  
Parsons Engineering Corp., 2547 E. 79th St., Cleveland 4, Ohio.  
Prater Pulverizer Co., 1827-37 S. 55th Ave., Chicago 50, Ill.  
Productive Equipment Corp., 2926 West Lake St., Chicago 12, Ill.  
Raymond Pulverizer Division of Combustion Engineering Co., Inc.,  
1315 North Branch St., Chicago 22, Ill.  
Richmond Mfg. Co., 1938 Moyer St., Lockport, N. Y.  
Sprout, Waldron & Co., Inc., 16-24 Waldron St., Muncy, Pa.  
Stedman's Foundry & Machine Works, 507 Indiana Ave., Aurora, Ind.  
United States Hoffman Machinery Corp., 105 Fourth Ave., New York 3, N.Y.  
Williams Patent Crusher & Pulverizer Co., 807 Montgomery St.,  
St. Louis 6, Mo.

#### APPENDIX

##### Generalized Wood Flour Specifications

Wood flour specifications of one of the largest manufacturers of linoleum are condensed in the following:

"Our normal specifications for wood flour, that is, those covering the material procurable prior to the war, call for a material that is nominally 80 mesh, having a maximum moisture content of 6 percent and with a weight per cubic foot of from 7 to 8 pounds. The color must be as light as possible, but, since this is a difficult property to measure, our specifications call for matching an agreed-upon sample when compared in a specified manner. The weight per cubic foot is, likewise, determined by an empirical method of filling a standard size container in an agreed-upon manner. The species of wood is not important, but it is believed that the color and weight can only be met by the better

grades of northern conifers, particularly pine. In addition, the material must be so ground that the particles are fibrous and should be free from smooth, round, rice-like grains, presumably obtained by certain methods of grinding. It is, of course, essential that the wood flour be entirely free from dark-colored specks, bark, dirt, or other foreign materials."

Wood flour used in plastics as reported by one manufacturer is exclusively white pine of a bulky nature. It is 80 mesh in size, free from bark, grit, and "shiners" (hard particles that show up in a molded piece), and contains not more than 9 percent moisture.

Wood flour for dynamite use is of light-colored softwood species. Specifications of the larger manufacturers call for white pine, spruce, and balsam fir, since a low resin content is important. The stock must be of a fibrous nature, to retain at least 65 percent of its absorbed nitroglycerin under certain conditions of temperature and pressure. Wood flour must be chemically neutral and free from dirt, grit, and foreign matter. The moisture content of the stock in the better grades is 10 percent or less.

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