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フィリッピンの森林事情について

――林産業を中心として――

海外技術協力事業団
Overseas Technical Cooperation Agency

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調査統計課

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1. MOISTURE CONTENT OF WOOD IN RELATION TO AIR HUMIDITY

Wood in the tree (green wood) contains much water, frequently more water than wood. It is very common for the water content of green wood to amount to 1/3 or 1/2 of the total weight and it can be higher. Air also contains water in varying amounts which is referred to as humidity. The "relative humidity" of the air is expressed as a percentage and refers to the degree of saturation of the air. For example, when the relative humidity of the air is reported as 80 percent, it means that the air contains 80 percent of the total amount of water it can hold at that temperature. The relative humidity of air is continually changing, not only from day to day but even from hour to hour, but most of the time it is less than 100 percent. When the relative humidity is lower than 100 percent the air absorbs water from any source that will give up water. The lower the relative humidity, the more thirsty the air becomes and the more rapidly it tries to absorb water from its surroundings.

When green wood is exposed to air at less than 100 percent relative humidity, the air absorbs moisture from the wood, rapidly or slowly according to the relative humidity. Thus the process of seasoning the wood begins and it continues as long as the air is dryer than the wood. When the moisture content of the wood comes down to about 30 per cent, (percentage based on the oven-dry weight of the wood), the wood begins to shrink. Thereafter the shrinkage will continue as long as drying continues.

But wood will not give all its water to the air because wood also has an affinity for water. Very dry wood will absorb water from air at high relative humidity just like dry air will absorb water from green wood. If the humidity of the air remains constant, the moisture content of the wood will eventually come into balance with it and, in doing so, will swell or shrink in proportion to the amount of water it absorbs from or gives off to the air. For each relative humidity there is a corresponding wood moisture content. This is called the "equilibrium moisture content" or "EMC" of the wood. The temperature of the air also has an influence on the EMC of the wood at a given humidity but this is not enough to require discussion here. Following are a few examples of the relation between the equilibrium mosture content of wood (EMC) and the relative humidity of the air surrounding it:

Relative humidity of the air (at a temperature of 70°F)	Approximate moisture content of wood in equilibrium
percent	percent
90	21
80	16
70	13
60	11
50	9
40	8
30	6
20	5
10	3

The humidity of the air can change quickly as the air temperature changes but the moisture content of wood in ordinary sizes cannot change quickly. Therefore, after wood has once reached approximate equilibrium with the average humidity of the surrounding air, its moisture content does not change appreciably with the hourly or even the daily changes in relative humidity of the air. It is in a constant state of trying to accommodate to the rapid changes in humidity but because of its slowness, never is able to attain complete equilibrium until humidity changes cease - which practically never happens under normal living conditions.

Although dry wood does not respond to hourly or daily changes in the relative humidity of the air, it does respond to long-continued or seasonal changes. For example, in long periods of dry weather, the average relative humidity of the air is considerably lower than during long periods of wet weather. Wood that has reached approximate equilibrium during wet weather will therefore, lose moisture and shrink during extended periods of dryness until it reaches approximate equilibrium with the average new conditions. When the wet season comes again the wood will reabsorb water from the air and swell again as it seeks equilibrium. This constant struggle to attain equilibrium with the air continues as many years as the wood is exposed to changing humidity.

To obtain best service from articles made of wood for use in buildings, therefore, it is important that the wood be seasoned to the right moisture content before the articles are made. Failure to do so may result in much dissatisfaction. The "right" moisture content is determined by the conditions under which the wood will be used.

For general use in the Philippines, where the buildings are open to the free circulation of air and no artificial heating is used, lumber for furniture manufacture should be seasoned to about 12 percent moisture content before the furniture is manufactured. This is close to or slightly below the average moisture content the wood will attain in normal service and no trouble should be encountered from shrinking or swelling later.

In the United States and Canada, however, it is best to season wood to about six to eight percent before making it into furniture because, in heated houses during cold weather, air humidities are very low and the moisture content of the wood may go as low as five or six percent. In the summertime in these countries, however, the windows are open, the humidities are higher and the moisture content of wood furniture may go as high as 10 percent. If the wood is between these extremes at the time of manufacture there will be less shrinking and swelling in service than if the manufacturing is done when the wood is at some other moisture content.

The seasonal changes in relative humidity of the air are very much less in the Philippines than in the United States and Canada. Much more care is required, therefore, in seasoning wood for products to be exported to these countries than products to be used in the Philippines. This is why wood products that give entirely satisfactory service in the Philippines may shrink and crack excessively when exposed to the extremely dry air of a North American house in winter.

Some species shrink or swell less than others with a given change in moisture content and, to that extent, may be preferred. The design and construction of the product, of course, also have much to do with its performance in service.

2. SOME FACTS ABOUT KILN-DRIED WOOD

Kiln-dried wood is wood that has been seasoned in a heated kiln until its moisture content has been reduced to the desired level. If the kiln is good and has been operated properly and if the drying is carefully done, well-seasoned lumber will be produced. There are, however, numerous misconceptions and false beliefs about kiln-dried lumber, some of which are touched upon in this note.

1. How dry is kiln-dried lumber? A skilled kiln operator with good equipment can dry lumber to any predetermined moisture content between about 20 percent and bone dry, according to what is desired. For making furniture and similar articles for use in the Philippines, a moisture content of about 12 percent is desirable. But for the manufacture of furniture in the United States the wood should be dried to about 6 per cent because wood articles in the United States have lower average moisture content in service than similar articles in the Philippines. However, lumber to be shipped to the United States and subsequently redried in that country can be dried to the moisture content agreed upon between the buyer and the shipper.

2. Does kiln-dried lumber remain at the moisture content to which it was dried? No, its moisture content does not stay constant but can become higher or lower in accordance with the relative humidity of the air surrounding it. For example, lumber that has been kiln dried to 6 percent and subsequently exposed to air whose relative humidity averages higher than 30 percent will absorb moisture from the air. The higher the relative humidity of the air, the more moisture will be absored. The moisture content of wood always tries to attain a balance with the relative humidity of the air surrounding it.

3. Does kiln drying kill insects? Yes the temperatures normally employed in kiln drying will kill insects and any wood that has been properly kiln dried will contain no live insects when it comes from the kiln. As soon as the lumber is cool, however, it may be attacked by insects just like other dry lumber that has not been kiln dried.

4. Does kiln drying make lumber weaker or stronger? If the kiln is operated properly, kiln drying does not change the natural strength of the lumber but if excessively high temperatures are used they may reduce the strength of the wood and cause other damage.

5. What are the essentials of good kiln drying? Good kiln drying requires correct control of the temperature, the relative humidity and the air circulation within the kiln according to the species, thickness and condition of the lumber being dried. Incorrect control of these factors can cause many defects, such as warping, splitting, checking, collapse or case hardening and greatly reduce the value and usefulness of the lumber. Good kiln drying requires good equipment and a skilled operator. Unskilled operator can do more harm than good. Much study and practice are required to develop a good kiln operator.

6. May all species of wood be dried together? It is not good practice to mix species in drying. Some species are more easily damaged and require much greater care than others. When such species are mixed together in the same kiln charge, the drying conditions will have to conform to the requirements of the species most difficult to dry. This will be too slow for the other species. If the drying is done as rapidly as the easiest species permits, the slow-drying species will be damaged. Even when the wood is all of the same species the kiln operator must use discretion because there are differences in the rate of drying of heartwood and sapwood, quarter sawn and flat sawn, and other factors to consider.

7. May all sizes be dried together? Since thick lumber dries more slowly than thin lumber and must be dried with greater care, it is not good practice to dry mixed sizes in the same charge. If for any reason mixed sizes are dried together, the kiln should be operated as required by the largest size. The thinner sizes will then not be damaged but more time will be required than when they are dried alone.

8. In what way is kiln drying better than air drying? Air drying is dependent upon the weather but kiln drying can be under conditions controlled to give best results. Kiln drying is quicker and saves the yard space, the extra handling and the drying losses involved in air drying. It also permits drying to lower moisture contents than air drying.

9. Should lumber be air dried before kiln drying? Preliminary

air drying is not necessary but lumber that has been air dried or partially air dried can be kiln dried more quickly and requires somewhat less care than lumber green from the saw. The kiln capacity in amount of lumber dried per month is greater and the kiln cost per thousand board feet is less when using air-dried lumber. However, the cost of air drying and extra handling must be added to the kiln costs in determining the total drying costs. These costs are avoided when kiln drying green from the saw. Which method is more economical or preferable depends upon local conditions and requirements.

10. How can moisture changes in kiln-dried lumber be prevented or reduced?

(a) Storing the lumber or the article made from it in a storeroom where the relative humidity of the air is maintained at the required level will avoid moisture changes as long as the correct humidity is retained. But if the humidity changes, the moisture content will begin to change. The dried lumber should not be piled on the floor but on racks about 18 inches above the floor so that the air can circulate beneath the pile. Dried lumber should not be stored in a new building until its walls and floors have thoroughly dried and reached equilibrium with the air.

(b) Wrapping the lumber or finished article in moisture-barrier paper or plastic can greatly reduce the rate at which the moisture content of the wood will change but will not prevent the change entirely.

(c) Coatings of varnish or paint on all surfaces of a piece of wood can reduce the rate of moisture change but not prevent the change. Finishing one side only, of course, retards moisture changes in that side only but the unfinished side is not benefited.

(d) The best way to avoid the ill effects of moisture changes in an article of wood is to have the wood dried to the proper moisture content before the article is made.

3. THE FIBER-SATURATION POINT OF WOOD

A growing tree contain large quantities of water, sometimes more water than wood. Some of this water held loosely in the wood within the fiber openings and in all other available interstices. It is called free water. The rest, which is called bound water or hygroscopic water, is absorbed into the walls of the cells or fibers of the wood. In green wood the bound water keeps the cells or fibers swelled to their maximum size.

When the tree is cut into lumber and the lumber begins to dry, it is the free water that evaporates first. Theoretically, all the free water should have evaporated before any of the bound water leaves the wood, but this does not occur under ordinary conditions. It is usual for the free water to have left the surface layers or the ends of a board and evaporation of bound water to have begun there before any considerable amount of the free water has escaped from the center of the board.

If we assume, however, that the drying proceeds theoretically, a point will be reached when all the free water has left the wood but all of the bound water remains. The moisture content at this theoretical point is called the fiber-saturation point. It is important to remember that this point marks the beginning of shrinkage and other behavior of wood as a result of further loss of moisture below this point.

As long as the moisture content of wood is above the fiber-saturation point, changes in moisture do not cause shrinkage or swelling, nor affect the strength of the wood. But at all moisture contents below the fiber-saturation point, any further loss of moisture results in shrinkage while any increase in moisture content causes swelling. Below the fiber-saturation point also, most of the strength properties of wood increase with further drying or decrease as the moisture content increases (up to the fiber-saturation point). When a given piece of green wood dries, the outer surfaces lose moisture first thus creating differences in moisture content in the different portions of the wood, with the surface being the driest. The exposed surface, therefore, reaches the fiber-saturation point while the inner portion is still above that point. If moisture loss proceeds further, the cells or fibers near the surface will begin to shrink but not those towards the center portion. This produces a tendency for the wood to check at the surface. Likewise, the ends of a board usually dry faster than the center so that shrinkage and checking can also begin at the ends before the center has come down to the fiber-saturation point.

To prevent the occurrence of these defects, it is important to avoid establishing too low a moisture content in the surface zones while that in the center is still high. This can be done in kiln drying by controlling the relative humidity which, of course, requires much skill. In air drying, such control is impractical because the weather is not under control.

The density of wood (weight per unit volume) decreases rapidly with the loss of water above the fiber-saturation point, but not so rapidly below that point. Why? Shrinkage, which starts to take place as a result of further drying below the fiber-saturation point, reduces the volume of the wood and for any amount of moisture loss there is a corresponding reduction of the volume of the wood. Density, being the ratio of the weight of the wood to its volume, will be less affected by the loss of the moisture where the volume is correspondingly reduced than where the volume remains constant as with wood having a moisture content above the fiber-saturation point.

Many studies have been made in attempts to determine the exact fiber-saturation point, but the findings of different researchers are not entirely in agreement. There is much evidence to indicate that the point, for most woods, is in the neighborhood of 25 to 32 percent moisture content, although there is also evidence showing that it is lower for some species and higher for others. It is generally assumed to be about 30 percent unless known to be different. Even though the fiber-saturation point cannot be located accurately, the fact remains that it is an important concept in trying to understand and explain the behavior of wood with changes in its moisture content.

4. CHEMICAL ANALYSIS OF WOOD

Chemically, wood is a complicated material. It consists mainly of two principal chemical groups, cellulose and lignin, but along with these are a great many other materials in smaller amounts, including hemicelluloses, gums, resins, waxes, fats, tannins and an endless variety of other organic and mineral compounds. In its natural condition, wood also contains large amounts of water. In the standing tree, for example, there may be more water than wood substance. In the air-dry condition, the water may constitute only 1/6 to 1/8 of the total weight. In discussing the chemical composition, however, all percentages are based on the moisture-free wood.

The principal ingredient of wood, the cellulose group, usually constitutes about two thirds of the total weight of the moisture-free wood but varies considerably among different species. The cellulose of wood is fibrous in character and is principal source of the world's supply of paper products. It is also made into rayon and can readily be converted into films, certain kinds of sugar, explosives, and other derivatives.

Lignin makes up about one fourth of the weight of wood. This appears to be the cementing substance that holds the cellulose together. In producing most kinds of paper the lignin is largely removed and usually is wasted or burned as fuel. In a small way, however, some lignin is converted into the flavoring compound, vanilla and other chemicals. Many chemists are searching constantly for profitable ways to use lignin but, thus far, with very limited success. It is expected, however, that eventually lignin will prove commercially valuable on a large scale.

When wood is burned, most of it is converted into gaseous compounds and disappears, leaving behind what is called ash. The ash contains all the non-volatile, inorganic ingredients of the wood, including compounds of silica, potassium, calcium, manganese, and many others, some in exceedingly small amounts. In early times the potassium salts in wood ashes were used with animal fats in the home production of soap.

The remaining portion of wood (in addition to the celluloses, lignin and ash) is made up of a wide variety of compounds, usually in small amounts individually but they can, together, amount to as much as 1/5 of the weight of the wood. They are sometimes collectively called extractives because most of them can be extracted from the wood with solvents. They may also be called at the Institute in this preliminary survey. Data from 32 more or less common species are given in the accompanying table, which shows the range of percentages of the different ingredients thus far found in the survey.

A number of species in the table show ash contents of about 0.5 percent or below. The highest ash content, 3.96 percent, is shown for liusin and it is interesting to note that most of this is silica. There is some evidence that high silica content increases the resistance of wood to certain marine borers. High silica content has been suggested as a reason for rapid dulling of saws in sawing some species but there is no evidence indicating the amount of silica required to affect the sawing properties noticeably. It seems probable that other factors than silica content have an equally important effect on saws and possibly also on marine-borer resistance.

The alcohol-benzene extractive contents of manggachapui and narig are the highest shown in the table. Examples of low extractive content, using alcohol-benzene mixture as a solvent, are liusin and tuai. In hot-water-soluble content, katmon and taluto can be considered high while liusin and Benguet pine are low.

From the papermaking point of view, the low lignin contents of African tulip, taluto, and Moluccan sau seem favorable. There are many other factors to consider in this regard, but low lignin content is an advantage since less chemicals would be needed for its removal.

The pentosan content of hardwoods is generally higher than that of the softwoods. The high content of alkali-resistant pentosans in ordinary hardwood sulfate pulps reduces their suitability for manufacture into alpha pulp. However, considerable interest has been shown in the development of high-alpha pulp from hardwoods by the sulfate process, using a pre-hydrolysis step in order to remove the hemicelluloses in the form of sugars.

Table I

Philippine Broadleaved and Coniferous Woods
Used for the Analyses in Table II

Common name	Scientific name	Status
Broadleaved:		
African tulip	Spathodea campanulata Beauv.	Plantation
Almon	Shorea almon Foxw.	Commercial
Apitong	Dipterocarpus grandiflorus Blanco	Commercial
Apitong, round-leaved	Dipterocarpus orbicularis Foxw.	Commercial
Bagtikan	Parashorea plicata Brandis	Commercial
Binuang	Octomeles sumatrana Miq.	Non-commercial
Guijo	Shorea guiso (Blanco) Blume	Commercial
Ipil	Intsia bijuga (Colebr.) O. Ktze.	Commercial
Ipil-ipil	Leucaena glauca (L.) Benth.	Plantation
Katmon	Dillenia philippinensis Rolfe	Commercial
Lauan, red	Shorea negrosensis Foxw.	Commercial
Lauan, white	Pentacme contorta (Vid.) Merr. & Rolfe	Commercial
Liusin	Parinarium corymbosum (Blume) Miq.	Non-commercial
Malapanau	Dipterocarpus kerrii King	Commercial
Malugai	Pometia pinnata Forst.	Commercial
Manggachapui	Hopea acuminata Merr.	Commercial
Manggasinoro	Shorea philippinensis Brandis	Commercial
Mayapis	Shorea squamata (Turcz.) Dyer	Commercial
Molave	Vitex parviflora Juss.	Commercial
Moluccan sau	Albizzia falcata (L.) Back.	Plantation
Narig	Vatica mangachapoi Blanco	Commercial
Narra	Pterocarpus indicus Willd.	Commercial
Panau	Dipterocarpus gracilis Blume	Commercial
Paper mulberry	Broussonetia papyrifera (L.) Vent.	Plantation
Raintree	Samanea saman (Jacq.) Merr.	Plantation
Taluto	Pterocymbium tinctorium (Blanco) Merr.	Non-commercial
Tangile	Shorea polysperma (Blanco) Merr.	Commercial
Toog	Combretodendrom quadrialatum (Merr.) Merr.	Commercial
Tuai	Bischofia javanica Blume	Non-commercial
Coniferous:		
Almaciga	Agathis philippinensis Warb.	Commercial
Pine, Benguet	Pinus insularis Endl.	Commercial
Pine, Mindoro	Pinus merkusii Jungh. & De Vr.	Commercial

Table

Proximate Chemical Analysis

(Results in percentages of

Common name	Ash	Solubility in: Alcohol benzene	Hot-water (leached)	Hot-water (unleached)
	Percent	Percent	Percent	Percent
Broadleaved:				
African tulip (a)	1.71	3.7	4.4	8.3
Almon	0.31	5.2	2.0	4.3
Apitong	1.52	8.2	2.1	6.3
Apitong, round-leaved (a)	0.89	3.5	1.9	3.5
Bagtikan (b)	1.23	3.1	1.5	2.9
Binuang	1.76	1.8	4.5	5.0
Guijo (b)	1.19	4.2	1.7	3.7
Ipil (a)	1.25	5.4	3.9	7.4
Ipil-ipil (b)	0.75	5.9	2.7	6.2
Katmon (a)	1.94	4.1	6.0	9.8
Lauan, red (b)	0.31	3.9	2.2	4.2
Lauan, white (b)	0.84	3.9	1.7	2.8
Liusin (a)	3.96	1.6	1.2	1.9
Malapanau (a)	0.77	4.0	2.6	4.4
Malugai (a)	1.17	2.4	3.4	5.8
Manggachapui	0.54	10.7	—	5.7
Manggasinoro (a)	1.25	3.3	1.0	2.4
Mayapis (a)	0.35	4.5	2.3	4.3
Molave	1.39	9.4	3.4	9.1
Moluccan sau	0.93	3.0	1.7	2.9
Narig (b)	0.77	10.7	2.1	5.8
Narra	1.37	4.3	3.5	5.9
Panau (b)	0.54	5.2	1.7	3.0
Paper mulberry (a)	1.53	3.5	2.4	5.1
Raintree (a)	1.94	7.1	4.6	8.6
Taluto (a)	2.50	2.2	9.8	11.0
Tangile (a)	0.27	3.7	1.3	2.5
Toog	2.48	3.5	0.9	2.5
Tuai	1.07	1.4	4.2	5.8
Coniferous:				
Almaciga	0.30	1.5	1.4	2.1
Pine, Benguet	0.28	2.0	1.4	1.5
Pine, Mindoro	0.48	4.5	2.5	3.0

(a) Average from 2 trees.
(b) Average from 3 trees.

Note: All others are results from a single tree.

II

of Some Philippine Woods

weight of moisture-free wood)

One percent NaOH	Lignin	Holo-cullulose (by diff.)	Pentosans	Silica
Percent	Percent	Percent	Percent	Percent
17.7	17.6	72.6	16.1	0.07
14.6	29.9	62.6	13.7	----
21.1	28.9	60.3	16.5	1.02
13.1	29.3	64.4	15.2	----
11.9	27.7	66.5	15.2	----
19.6	33.0	58.5	16.6	0.05
14.3	28.8	64.0	14.2	0.10
21.2	22.0	67.5	18.4	0.00
20.5	26.4	64.2	20.6	----
26.1	25.2	62.8	13.6	0.54
16.0	33.7	59.9	10.7	----
13.2	28.6	65.0	15.0	----
19.9	27.8	65.4	13.6	3.38
15.2	25.7	64.5	15.7	----
14.4	26.7	66.3	14.9	----
17.9	36.0	----	12.2	----
12.1	26.6	67.9	15.6	0.91
14.8	32.8	60.0	11.9	----
16.5	32.6	53.2	10.1	----
13.6	16.6	77.8	13.5	----
23.2	20.8	65.6	14.7	----
15.9	29.1	61.7	15.3	----
16.0	27.5	65.1	14.9	----
21.1	22.7	70.0	20.0	0.21
26.7	25.3	61.1	17.9	1.19
23.9	18.2	67.3	17.6	0.09
13.1	35.2	59.5	10.7	----
17.9	37.4	55.7	12.7	1.76
29.4	42.0	51.3	9.7	----
14.3	34.2	62.2	8.4	----
11.4	33.3	63.0	12.0	----
17.5	28.5	64.0	11.3	----

5. VENEER CUTTING

Veneer is a thin sheet of wood of uniform thickness. It is commonly cut into thicknesses from 1/64 to 3/16 inch, although thicknesses outside this range are sometimes cut for special uses. The principal use of veneer is in the production of plywood which is made by gluing together several sheets of veneer, usually an odd number, with the grain direction of adjacent sheets at right angles to each other.

Veneer may be cut in several ways. Sawing, the oldest method, is now used for only a very few species which cannot be cut satisfactorily by better methods. It is slow and wastes a large volume of the wood in the saw kerf. Slicing, the second method, is used to cut expensive veneer for decorative applications and to cut low grade veneer for such uses as containers and battery separators. Slicing is relatively slow and a relatively large part of the wood is lost in flitch preparation. Rotary cutting, the third method, is used for about 90 percent of all veneer that is cut. The production rate with rotary cutting is high and waste is less than by other methods. Variations of rotary cutting are back-cut and half-round stay-log cutting. They use the rotary lathe to simulate slicing. Their greatest use is in cutting decorative veneer when matching is desired.

Since almost all veneer in the Philippines is rotary cut, this discussion will apply to that method, although the principles involved apply in general to slicing also.

Species of wood that are of high density or contain hard knots or hard non-woody material must usually be heated before they can be cut into satisfactory quality veneer. Heated veneer bolts cause additional problems in the cutting operation. Production costs increase, certain parts of the lathe warp because of uneven heating from contact with the heated bolt, heart checks and ring shakes in the veneer bolt increase in size with heating, and more accurate lathe set-up and operation are necessary. Most commercial Philippine species fall into a second group which can be cut with the wood unheated. The species in this group can be further divided into two subgroups. The larger subgroup contains species whose veneer quality can be improved more or less by heating the veneer bolt. The smaller subgroup contains species whose veneer quality is lowered more or less by heating the veneer bolt. Most of the species in this smaller subgroup have low specific gravity and strength and tend to have fuzzy surface after most machining operations on the wood.

Veneer quality is affected greatly by the quality of the bolt from which it is cut and by the lathe condition, set-up, and operation. Lathe set-up is the factor which can be controlled more precisely. Important parts of the set-up are: 1) the conditions of the knife and nosebar; 2) the position of the knife; and 3) the horizontal and vertical distances between the knife and nosebar edges. These parts of the lathe set-up are illustrated in drawings at the end of this Technical Note.

The condition of the knife and nosebar depends on their sharpness angles and the condition of their edges. Commonly used sharpness angles are 20 degrees for the knife and 85 degrees for the nosebar. The 20 degrees is a compromise between a smaller angle which would give more efficient cutting action and a larger angle which would reduce damage to the knife edge and increase its life between grindings. Research work at the Canadian Forest Products Laboratory (see reference 1) has shown that a micro-bevel about 0.015 inch wide with a sharpness angle of 30 degrees (see drawing), hand-honed on a newly ground knife edge, increases the useful life of the knife edge. The best sharpness angle for the nosebar is not known; it is generally agreed that the edge should be sharp when thin veneer is cut, and more or less rounded when thick veneer is cut. The condition of the knife and nosebar depends on the care and skill of the grinder and lathe operators. The edges should be perfectly straight, with the knife edge as sharp as possible.

The knife should be set in the knife carriage so that the centers of the chucking spindles are in the plane determined by the movement of the knife edge during cutting. This plane will be horizontal if the lathe has been set on a level base. The knife edge is sometimes set slightly above this position to allow for the small lowering of the edge which occurs as it is honed at intervals during its use. Also, spindle bearings which are loose from wear will allow the spindles to raise slightly when cutting starts; setting the knife edge a little high will compensate for this movement.

The angle between the beveled face of the knife and the plane determined by the movement of the knive edge during cutting is the knife angle. This is a critical lathe adjustment; there is an optimum angle (which varies somewhat with species and veneer thickness) at which the best quality veneer can be cut, and a range of angles at which good quality veneer can be cut. The optimum angle is usually between 89 and 91 degrees; the range of angles is usually about one degree. With the optimum knife-angle setting, the forces acting on the knife edge during cutting are balanced and the edge is stable. If the forces are unbalanced by a knife angle which is too small the knife edge will move during cutting and the veneer thickness will vary regularly in waves one to six feet long. If the knife angle is too large, the unbalanced condition will result in veneer whose thickness varies in waves about 3/4 inch long. These are known as thick-and-thin veneer and corrugated veneer, respectively; either condition is unsatisfactory for making high quality plywood.

The knife can be set in place and its angle adjusted with fair accuracy by using ordinary machinist's tools. A good spirit level and a block of wood whose thickness is equal to the lathe spindle radius are adequate for setting the knife edge at the proper height. An accurate protractor and the spirit level can be used to set the knife angle. A special instrument for direct reading of the knife angle can be manufactured and attached to some types of lathes without much trouble.

The position of the nosebar edge in relation to the knife edge is critical. The action of the knife by itself would be a combination of cutting and wedging-splitting. Splitting of the wood ahead of the knife edge is undesirable, since a split will follow the grain of the wood and produce a rough surface. The nosebar controls splitting by compressing the wood at the knife edge. The location and amount of this compression are important, and are determined by the vertical and horizontal distances, respectively, between the knife and nosebar edges.

The adjustment of the vertical distance (opening) is not critical, since the force exerted by the nosebar is not confined to a single line, but is distributed in the wood in a fan-shaped pattern. The vertical opening should be about 20 to 30 percent of the veneer thickness.

The horizontal distance is a critical adjustment. The optimum opening varies with veneer thickness and the density and hardness of the wood. An opening which is too large will not give enough compression and the veneer will be rough and loose cut (see tightness below). An opening which is too small will over-compress and crush the wood to produce veneer which is too thin and will increase the wear on and power consumption by the lathe.

The vertical and horizontal knife-nosebar openings (VND and HNB in diagrams) can be set accurately with a set of machinist's leaf-type feeler gauges used in conjunction with an ordinary carpenter's square. A special instrument for setting the horizontal opening to an accuracy of 0.0001 inch was designed at the U. S. Forest Products Laboratory and is available commercially.

The effective distance between knife and nosebar edges is the resultant of the vertical and horizontal openings. It is commonly called the <u>nosebar opening</u> (or clearance) and may be expressed in terms of the veneer thickness being cut. The percent <u>nosebar compression</u> is the difference between veneer thickness and nosebar opening expressed as a percent of veneer thickness. Acceptable nosebar compressions are about 12 to 22 percent.

Veneer quality is evaluated by thickness, thickness uniformity, smoothness, and depth of the lathe checks in the veneer (tightness). Other important quality factors, which cannot be controlled by the lathe operator, are the color, figure, and presence of natural defects in the veneer.

The thickness of the veneer as it comes from the lathe should be the one at which the knife carriage feed gears are set, if the gears operate correctly. A smaller thickness would indicate that the nosebar compression was too great. Variations in veneer thickness, which should not exceed about plus and minus four percent of the average thickness, are usually caused by an incorrect knife angle.

Tightness of the veneer and the smoothness of its surface can be estimated visually with good accuracy by an experienced lathe operator. The lathe check depths (an inverse measure of tightness) in well-cut veneer should not exceed 30 to 50 percent of the veneer thickness. Thin veneer can be cut smoother and tighter than thick veneer.

Finally, high quality plywood cannot be made from poorly cut veneer. Plywood quality can be improved at the cost of extra care and time in the operations which follow cutting, but the quality increase which can be brought about is limited.

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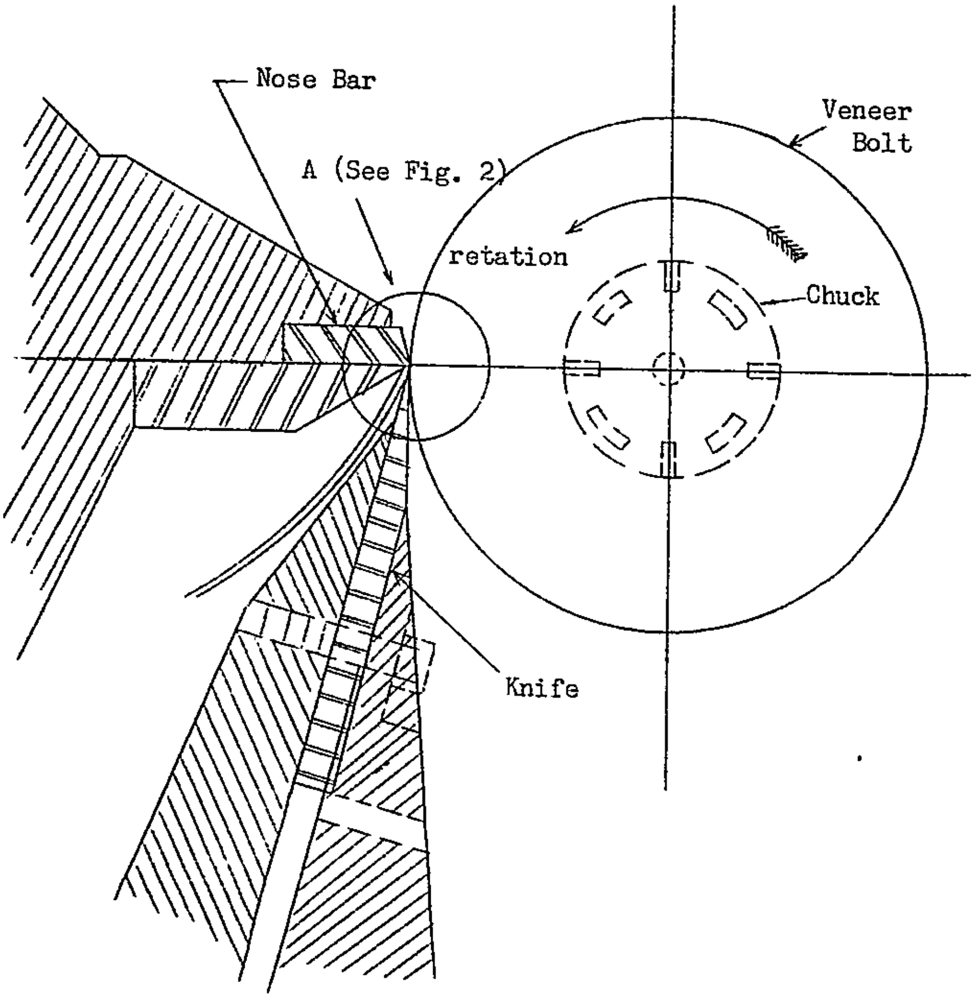

FIG. 1. DIAGRAM SHOWING CROSS SECTION OF PRESSURE BAR, NOSE BAR, KNIFE BAR, KNIFE, AND LOG DURING ROTARY VENEER CUTTING, TO ILLUSTRATE TERMINOLOGY.

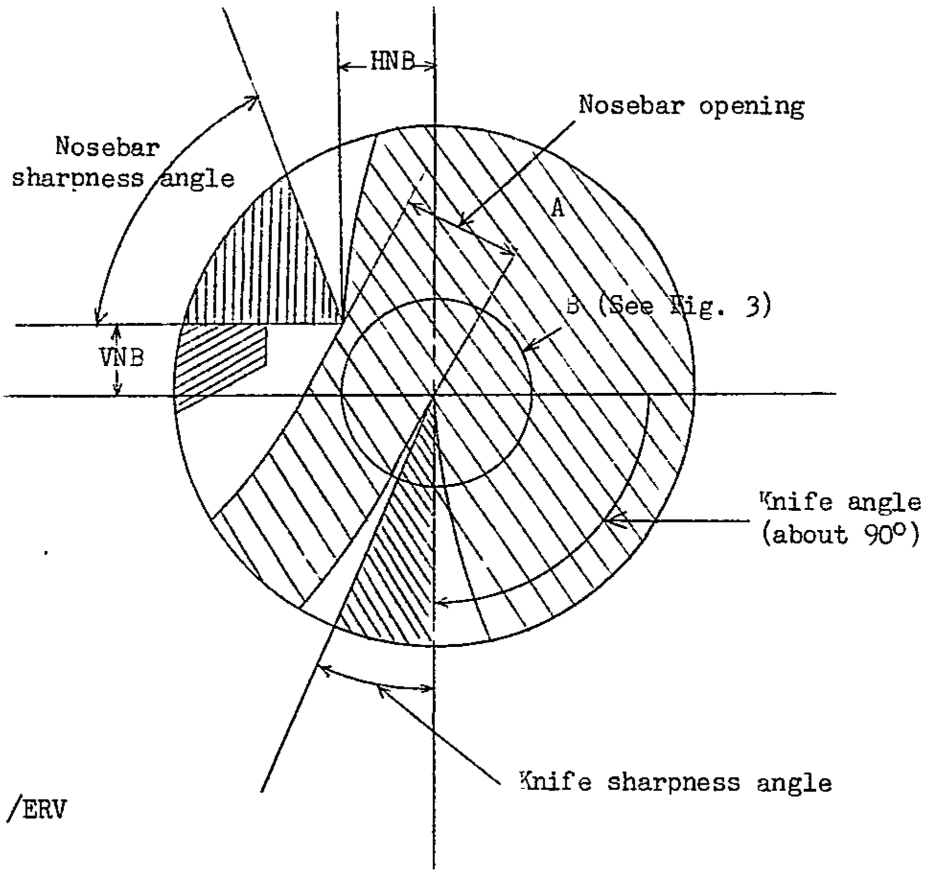

FIG. 2. CROSS SECTION OF NOSEBAR AND KNIFE DURING ROTARY VENEER CUTTING

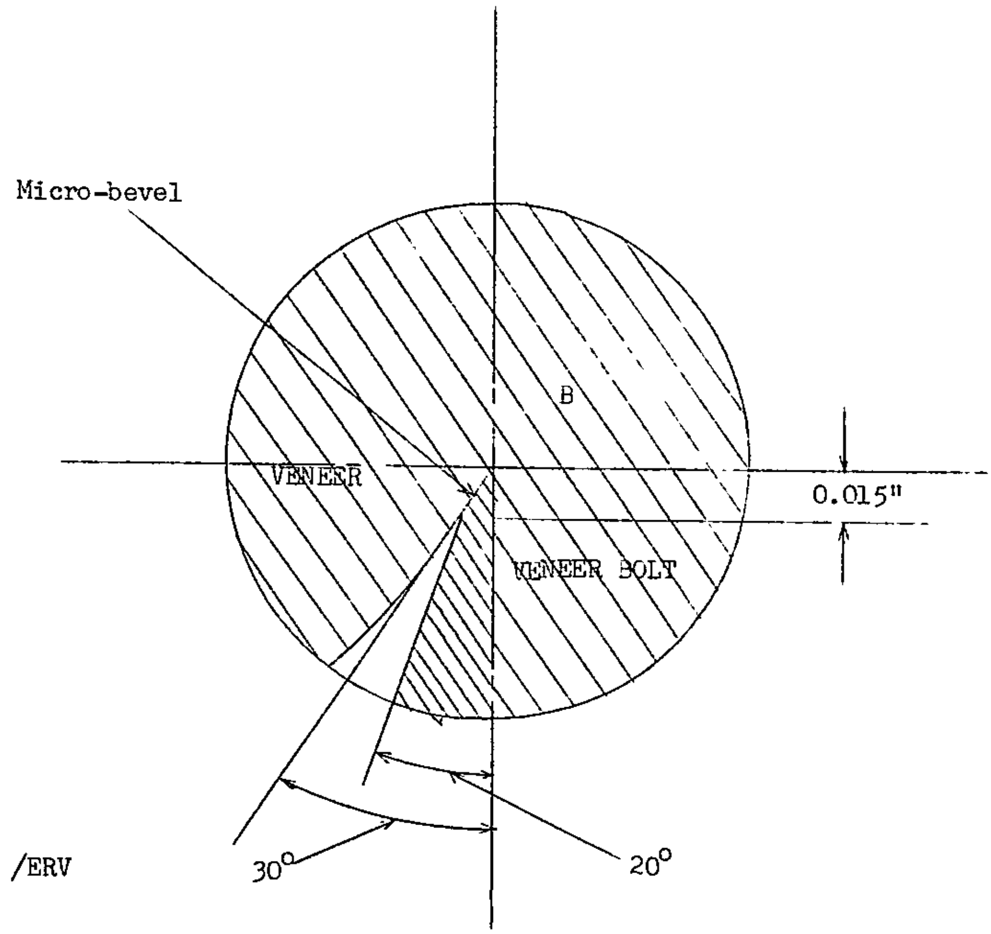

FIG. 3. CROSS SECTION OF KNIFE DURING ROTARY VENEER CUTTING

6. PULP AND PAPER MAKING FROM HARDWOODS

The principal source of pulp is wood, which, according to common usage, is classified into softwoods or conifers and hardwoods or broadleaved species.

Conifers now account for 85 to 90 percent of world pulp production. The rest comes from hardwoods and other cellulosic raw materials. The dominance of conifers arises, in part at least, from their longer fibers which make for strong pulp.1/ Hardwoods generally have shorter fibers than conifers and produce pulps which have lower tearing resistance and folding endurance but possess good burst and tensile strength. The addition of hardwood pulps to the fiber constituents of the paper will often improve the formation, smoothness and printing qualities of the paper from softwood pulps.

In manufacturing pulp in the Philippines, the scarcity of conifers makes it necessary to utilize the hardwoods, which are available in abundance. A common feature of tropical hardwood forests is the lack of homogeneity. The number of wood species in the Philippines is estimated to be more than 3,500 although the majority of these are not commercially important. In any Philippine forest, therefore, there are likely to be many species of wood standing together. It is seldom that a natural hardwood stand of any size is found consisting of one or two species only. This makes it imperative that any process to be considered for pulping such hardwoods should be able to use them in mixtures, with a minimum or absence of sorting out of the various species.

The wood may be brought to the mill by water, rail, trucks or tractors. After storage in the yards or ponds, the logs are cut to suitable lengths and the bark is removed. Except for wood which is to be ground, the logs must be further reduced in size by chippers.

Several processes are available for converting hardwoods to pulp. Brief descriptions, together with the uses of the corresponding pulps, are given below. Groundwood or mechanical process:- This is the simplest and, where the cost of power is low, the cheapest process of all. In principle, it

1/ Bamboos, abaca and ramie also have long fibers and make strong pulps.

consists of pressing the wood (by hydraulic or other means) against a revolving grindstone. A stream of water softens the wood and cools the stone at the same time. The pulp yield is up to 95 percent of the weight of the wood.

For this process the most suitable woods are light colored and of low or medium density. High extractive content, high density, and dark color are objectionable.

Groundwood pulp is used in newsprint and other printing papers. For newsprint, the normal groundwood-pulp portion is 80 to 85 percent when coniferous wood is used and the remainder is chemical pulp. When using groundwood pulp from hardwoods the proportion of chemical pulp must be increased because of the lower strength characteristics of hardwood pulp.
Chemical methods:- The wood chips are digested or "cooked" with chemicals under pressure and high temperature in rotary or stationary digesters, in order to release the fibers by removing all or most of the non-cellulosic materials, principally lignin. Different chemicals are used in the different chemical processes.

a. Sulfite or acid process. - The cooking liquor consists of a mixture of calcium, or magnesium, or ammonium bisulfite and sulfurous acid. The resulting pulp is relatively light colored and easily bleached in comparison with pulps produced by the other processes. The strength is sufficient for such purposes as newsprint, magazine paper, greaseproof, glassine and fine papers. This process is widely used also to produce dissolving pulps, such as are employed in the manufacture of rayon and cellulose films of various kinds.

Hardwoods containing appreciable amounts of resins and tannins are not suited for this process. It is not usually feasible to digest mixtures of various species by this method. Also, it is not usually practical to recover the chemicals from the spent liquor of the calcium-base process, the most common of the sulfite processes. This makes a serious waste-disposal problem.

b. Soda process.- Caustic soda in solution is used as the digesting chemical. Soda pulp is commonly used in the manufacture of printing and writing papers because of its desirable qualities of softness, absorbence, smoothness, opacity and bulk. The pulp yield is lower and the strength is less than that of sulfate pulp from the same wood. The chemicals in the spent pulp liquor can be recovered, greatly reducing the problem of waste disposal.

c. Sulfate process.- Caustic soda and sodium sulfide are used in the cooking liquor. Yields up to 55 percent are obtained. The pulp has exceptional strength and the unbleached pulp is used in the production of wrapping and bag papers and linerboards for fiber boxes. The dark-colored pulp produced by this process requires multi-stage bleaching if light-colored paper is required.

With this process it is generally possible to pulp mixtures of various species. A chemical recovery system, as in soda mills, makes it possible to recover the chemicals in spent liquor for reuse and to generate steam during their recovery. Without recovery, the cost of chemicals in the soda and sulfate processes would be excessive. Recovery also greatly reduces the waste-disposal problem.

Semichemical methods:- The raw material is subjected to relatively mild chemical action using one of the chemicals mentioned previously. This softens the wood but does not defiberize it. The chemical treatment is followed by mechanical fiberizing in an attrition mill or otherwise. The yield and quality of these pulps lie between those of the mechanical and the chemical pulps. The waste-disposal problem depends in large part on the chemicals used.

a. Chemigroundwood process.- The debarked logs are impregnated with a neutral sulfite liquor (mixture of sodium sulfite and sodium bicarbonate) by vacuum and pressure treatment in a closed vessel. Then the chemically treated logs are ground in the same manner as in the normal groundwood process. The pulp yield is up to 90 percent. The advantages of the chemigroundwood over the conventional groundwood process include greater production, less power consumption, and excellent pulp strength. The color of the pulp is likely to be darker but it is usually readily lightened by use of a small amount of bleaching agent. The pulp can be used in the manufacture of newsprint, book, toweling, tissue, and corrugating grades.

b. Cold caustic soda.- The chips are soaked in caustic soda solution at normal atmospheric pressure and temperature for a few hours after which they are fiberized in disc mills. Yields of up to 80 percent are attained. The pulp is yellowish. Among its uses are for newsprint, toweling, corrugating, and insulating papers and building boards. Both high and low density hardwoods can be handled by this method. Another attractive feature is its relative simplicity as compared with other semichemical processes. Recently this method has been shortened by the use of hydrostatic pressure, which effects quick chemical impregnation of the chips in seconds or in a few minutes, instead of hours. The process is adaptable to continuous operation.

c. Neutral sulfite semichemical.- The chips are partially digested with a neutral sulfite liquor (mixture of sodium sulfite and sodium bicarbonate) under pressure and high temperature in rotary, vertical, or continuous digesters, after which they are fiberized in disc refiners. The yield is from 70 to 85 percent. The unbleached pulp has a tensile strength close to that of the corresponding sulfate pulp and is used in corrugating boards. The bleached pulp is suitable for glassine, greaseproof, printing and fine papers.

Before pulp can be used for paper making, it must undergo several treatments. The pulp must be screened to remove coarse particles and washed to remove adhering chemical solutions. To develop the required paper strength properties, the pulp is beaten or refined in beaters, jordans, or conical or disc refiners. Chemical additives like dyes, rosin, alum, and fillers are usually added in the beater to impart their special desired properties to the pulp.

REFERENCES: Much information about the manufacture of pulp and paper can be found in the numerous books on the subject, including the following:

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7. TANNIN CONTENT OF PHILIPPINE BARKS

Tannins are complex organic compounds found in varying amounts in the bark of trees, in wood and in the leaves, roots, fruits, flowers or stems of many other plants. They are found in all parts of the world but only plants with reasonably high tannin content are used commercially for tannin production. In general, tannins are amorphous substances with astringent taste that have the property of precipitating gelatin from solution and of forming strongly colored solutions and precipitates with iron salts. The tannins consist largely of polyphenols and are of two main groups, the hydrolyzable tannins (pyrogallol group) and the condensed tannins (catechol group). They can be distinguished from each other by their reaction with formaldehyde-hydrochloric acid solution. The catechol tannins are highly reactive with formaldehyde in acid solution forming condensation products. They are thus potential raw materials for the production of waterproof adhesives, if and when it becomes possible to control the reaction in a commercially acceptable manner. The pyrogallol tannins form little or no condensation products with formaldehyde but do form colored compounds with iron salts. Most sources of tannin contain both groups but usually one group predominates.

Tannins are ordinarily obtained from barks by leaching with cold or hot water. The solution thus formed, at suitable concentration, can be used directly for tanning hides and skins into leather. However, tannins at present are chiefly produced in extract form and extract factories exist in most countries where suitable raw materials are available in sufficient quantity. Extracts are produced in the form of concentrated liquids containing about 40 percent tannin, in the form of solid blocks, or as a powder containing about 60 percent of tannin. Tannin also appears in commerce in the form of dried bark, leaves, or fruits, according to the source from which it is obtained.

The principal use of tannins is in the tanning of hides and skins into leather, using water solutions obtained by extraction from the original plant source. These extracts contain both groups of tannins. Tannins of different origins serve to produce different types of leather such as light or dark-colored or hard or soft leather. In most cases, tannins from different sources are blended to produce the type of leather desired. The tannins from kamachile bark and from mangrove barks have been used extensively in the Philippines. The tannin from kalumpit bark has been used in leather tanning but is not popular.

Mangrove is the general name given to trees and shrubs growing in tidal forests. The most commonly used mangrove species in the Philippines are bakauan and tangal (Rhizophora and Ceriops). Only a few tanners in the Philippines are at present using mangrove bark but, since there are such large quantities of mangrove bark available, it is desirable that this local material should be fully utilized. The disadvantage of mangrove bark is that it produces a dark reddish color in the finished leather, but by blending it with other tanning materials, including synthetics, this can be overcome. Mangrove bark extract is now being imported into the Philippines from other countries.

Among the uses to which tannins are put, other than for tanning hides and skins or possible preparation of wood adhesives, are: (a) in deep oil-well drilling, in combination with caustic soda, to reduce the viscosity of the drill mud; (b) for the preservation of fishing nets; (c) for boiler-water treatment; (d) as mordants for dyes in paper and textile manufacture; (e) in ink manufacture; (f) in certain rust preventives; and (g) as nicotine tannate in insecticides.

No Philippine wood has been found thus far that contains a substantial amount of tannin, but it is possible that such woods exist among the 3,500 or more tree species found in the Islands. The barks of many Philippine trees, however, contain tannin in commercial quantities, including not only kamachile, the mangrove group, and kalumpit, but many others, among them even the common red lauan and white lauan barks. Not all of these tannins, however, would be acceptable to the leather tanners or could be produced cheaply.

One of the projects of the Forest Products Research Institute is to survey the tannin content and character of the barks of Philippine woods, in the hope of finding some that have commercial usefulness. In studying the possible usefulness of a bark as a source of tannin, the first step is to make the following qualitative tests to indicate whether there is enough tannin present to be interesting and whether it is mainly pyrogallol tannin or catechol tannin.

Gelatin test.- This is made by mixing into the bark extract solution a few drops of a 1 percent gelatin solution, containing 10 percent sodium chloride. This forms a precipitate with the tannin and the amount of the precipitate gives a rough approximation of the tannin content.

<u>Stiasny reaction</u>.- The reaction between the tannin solution and formaldehyde-hydrochloric acid solution gives a tannin-formaldehyde precipitate, the amount of which is a direct measure of the amount of tannins that could react with formaldehyde to form a thermosetting-resin adhesive.

<u>Pyrogallol test</u>.- This is made by adding a one percent solution of ferric ammonium sulfate to a bark extract solution. A resulting blue-black color indicates the presence of pyrogallol tannins.

There is no accurate, convenient method for determining the exact amount of tannins present but a good approximation is obtained by removing the tannins from solution with hide powder. This is the official method of the American Leather Chemists' Association and is the method generally used. Actually the amount of tannin in bark is variable and widely different values may be obtained from different samples of bark from the same species. No single analysis can be depended upon to represent any species correctly and the results of different chemists may vary considerably, depending in part on the quality of the samples analysed. Nevertheless, the analytical data, if obtained on truly representative samples, indicate the general magnitude of tannin content to be expected from a species under normal conditions.

The yield of tannin from barks can be greatly decreased if the barks are taken from logs that have been a long time in water or if the bark has been dried slowly and allowed to ferment or become moldy.

Qualitative tests for tannins have been made at the Institute on barks from about 185 wood species. Quantitative analyses have been made on 25 of the species with higher yields, with the results shown in the attached table. The species of the mangrove group show tannin contents ranging from less than 10 percent to more than 30 percent. Commercial mangrove bark is usually a mixture from several species and its tannin content can vary accordingly. The table also shows that considerable amounts of tannin could be produced from some of the other species listed but, before commercial production would be practicable, it would have to be shown that they can be marketed in sufficient quantities and at high enough prices to make the operation profitable.

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Tannin Content of Some Philippine Barks

As Determined by F.P.R.I.

SPECIES	Relative amounts of gelatin precipitate	Tannin-formaldehyde precipitate Percent 3/	Tannin content Percent 3/	Pyrogallol test
1. Agoho (*Casuarina equisetifolia*)	medium	16.7	14.4	negative
2. Anabiong (*Trema orientalis*)	medium	13.4	8.1	negative
3. Bakauan-babae (*Rhizophora mucronata*) 1/	medium	12.0	8.8	negative
4. Benguet pine (*Pinus insularis*)	medium	10.8	12.1	negative
5. Bolong-eta (*Diospyros pilosanthera*)	medium	6.3	4.8	negative
6. Busaing (*Bruguiera gymnorrhiza*) 1/	large	20.6	13.0	negative
7. Buta-buta (*Excoecaria agallocha*) 1/	trace	13.4	6.9	negative
8. Gapas-gapas (*Camptostemon philippinense*) 1/	small	12.4	6.7	negative
9. Guijo (*Shorea guiso*)	medium	11.3	4.3	negative
10. Kalumpit (*Terminalia microcarpa*)	large	5.2	20.0	positive
11. Kamachile (*Pithecellobium dulce*)	large	30.5	31.8	negative
12. Kupang (*Parkia javanica*)	medium	15.9	9.2	negative
13. Langarai (*Bruguiera parviflora*) 1/	large	19.0	8.4	negative
14. Lanutan-bagyo (*Gonystylus macrophyllus*)	small	10.1	11.8	negative
15. Lauan, red (*Shorea negrosensis*)	large	14.8	4.2	negative

16. Lauan, white (*Pentacme contorta*)	medium	11.3	7.0	negative
17. Mahogany (*Swietenia macrophylla*)	medium	15.1	17.4	negative
18. Manggasinoro (*Shorea philippinensis*)	trace	15.5	10.1	negative
19. Pagatpat (*Sonneratia alba*)1/	large	20.5	18.6	negative
20. Pototan (*Bruguiera sexangula*)1/	small	19.3	19.8	negative
21. Saging-saging (*Aegiceras corniculatum*)1/	large	22.6	12.9	negative
22. Sakat (*Terminalia nitens*)	medium	1.9	26.6	positive
23. Tabau (*Lumnitzera littorea*)1/	large	23.5	14.5	negative
24. Tabigi (*Xylocarpus granatum*)1/	large	26.1	21.9	negative
25. Tangal (*Ceriops tagal*)1/	large	25.0	31.3	negative

1/ Species so marked belong to the mangrove group.
2/ Percentage tannin-formaldehyde precipitate on the basis of oven-dry unextracted bark.
3/ Percentage tannin based on oven-dry bark. These are averages of duplicate determinations by the hide-powder method on bark from a single tree.

8. CHARCOAL FROM WOOD

When wood is heated sufficiently in the presence of air, it will ignite and burn to ashes. In the absence of air, however, if the wood is heated above 270 deg. C(518 deg. F), water and other volatile materials will be driven from the wood without burning, and charcoal will remain. This process is called destructive distillation. If the escaping volatiles are passed through a condenser, a crude liquor containing water, tars, oils, acetic acid, methyl alcohol and numerous other chemical compounds may be recovered but a substantial portion will remain uncondensed and may, if desired, be burned as fuel for heating additional wood. Unfortunately, the cost of saving and refining the chemicals from wood decomposition is usually more than the products can sold for an' it is seldom that these by-products can be recovered profitably. The general custom is to allow them to go to waste but the uncondensed combustible gases are sometimes burned to provide heat for charring. The principal product and usually the only profitable commercial product of destructive distillation is charcoal.

Wood charcoal has been oroduced and used by man from prehistoric times and has long been an article of commerce in practically all countries. There are many ways to produce charcoal. Small quantities can be obtained, of course, by merely picking off the charred portion of partly burned wood after a fire has died out.

<u>The pit method</u>.- Charcoal is made in some countreis by the pit method in which a pile of wood is thoroughly ignited and, when judged sufficiently hot, is covered with leaves or sod and then with soil to exclude practically all air, leaving openings for the escape of smoke and for the entrance of controlled small quantities of air. When, in the judgment of the operator, the charring is complete, all openings are tightly closed and the pile is allowed to cool. By this method, some of the wood is burned to produce the heat required to get the charring started and keep it going and the charcoal may contain considerable quantities of dirt from the soil cover.

<u>The kiln method</u>.- This is a refinement of the pit method in that the charring is done in some form of kiln or oven, of which there are many varieties and sizes. For example, an

ordinary oil drum, set in a bank of earth or a hillside, can be used, if provided with a means of covering the top and leaving an outlet for smoke, and a means of letting air into the bottom, under control. Larger kilns of metal in various designs are used, some portable and some not. Kilns of clay, brick, or concrete blocks are also common, some of which will hold very large quantities of wood. All these kilns are operated on the same principle as the charcoal pits, namely, burning part of the wood to heat the rest and closing all vents when charring is complete, to let the mass cool before opening to the air.

The yield of charcoal by this general method of production varies with the skill of the operator, the kind, size, and condition of the equipment, and the dryness of the wood but, with good equipment and good operation, yields equivalent to about one third of the original weight of the wood (on the moisture-free basis) may be obtained. Unskilled operation may burn too much of the wood or leave too much uncharred. Uninsulated sheet metal kilns allow rapid loss of heat and require more wood to be burned to maintain the high temperature required. Leaky kilns allow air to enter after the kiln is closed and this consumes charcoal. In charring green wood, more heat is required to drive off excess water than when seasoned wood is used and more of the wood is consumed to provide it.

<u>The retort or oven method</u>.- By this method, the wood is placed in a large steel cylinder or retort with a tightly closing door and means for the escape of tar and gases. This is heated from outside without admitting air. The wood is loaded on cars which run on a track thus making it easy to move the charge into and out of the retort. With this method, the temperature can be controlled more closely than by the other methods and none of the charge is consumed to furnish carbonization heat. When the charge has been heated to the right temperature a chemical reaction begins that gives off heat (exothermic reaction). In general, very little additional heat from outside is necessary to complete the charring. It is possible, therefore, when using the retort method, to give the charge a preliminary drying and warming in a separate chamber, using the waste heat of the flue gases from the oven furnaces. This shortens the time and reduces the exterior heating required in the charring retort.

The volatiles given off during the charring process are usually passed through a condenser which separates the condensable portion containing chiefly water, methyl alcohol, acetic acid, oils and tars. These may be separated further and refined into salable products but usually that is not profitable. The non-condensable gases may be burned under the ovens for heating the wood to the charring temperature or for the preliminary drying process.

There are numerous variations in details of the retort process and equipment, some of which are patented. Several processes have been developed which operate continuously. In one such process, a vertical retort is filled with short pieces of wood. Then the charring process is started by heating the wood from below until it begins to produce its own heat. The carbonization temperature is maintained by recycling the hot wood gases. As the charring proceeds, more wood is fed slowly into the top and charcoal is gradually removed through grates at the bottom and placed in large cans for cooling. Such retort processes are effective, but require rather high initial investment.

Since the retort cannot be moved at reasonable cost, it should be located within reach of an adequate supply of wood as well as in a place convenient for shipping the charcoal to market.

The hardness, density and shipping or handling properties of charcoal depend in part upon the nature of the wood charred. Heavy, dense woods usually produce hard, heavy charcoal that does not break up badly or develop too much fine powder in handling and shipping. The lighter woods generally produce the softer and more friable charcoals that break up easily when handled or shipped and produce more fine powder that is largely wasted. By crushing the charcoal, mixing with binder (such as starch), and pressing in rotating or reciprocating molds, fine or soft charcoal or mixed charcoals can be made into briquettes of more or less uniform quality and good salability.

Sawdust cannot be made into charcoal by the ordinary methods because heat cannot be made to penetrate rapidly into a large mass of sawdust. Many attempts have been made to devise methods for charring sawdust by keeping it moving in small quantities through a heated zone in a pipe or other closed container. Two or three methods of this kind have been demonstrated in the pilot-plant stage recently. It is hoped that such a method may eventually prove practical so that large tonnages of sawdust that now are little used may find profitable utilization.

Sawdust charcoal would probably have to be converted into briquettes before it could be marketed in large quantities.

Wood charcoal finds use for domestic heating and cooking, recreation (picnic) cooking, in metal smelting, in chemical manufacturing processes and for various other uses. In the Philippines, several hundred tons of charcoal are consumed each month in the manufacture of calcium carbide.

The quality of charcoal for industrial use depends in part on the percentage of volatile materials it contains, its hardness or crushing strength and the impurities it may contain such as ash and dirt. The ash content depends on the basic ash content of the wood and bark from which it is made. Charcoal produced at high temperatures will be lower in volatile matter and higher in fixed carbon content than charcoal produced at lower temperatures. For some uses, the percentage of volatile matter permitted in the charcoal is limited by the user's specification.

The crushing strength of wood charcoal parallel to the fiber direction of the original wood is much higher than that prependicular to the fiber direction, and both values vary considerably among charcoals produced from different wood species. High-volatile charcoal generally tends to be harder, stronger, heavier, and much easier to ignite than low-volatile charcoal. Generally the yield for low-volatile charcoal is less, partly because the weight of the volatile portion is lost and, in the kiln method, because some fixed carbon is consumed in driving off the excess volatile matter. Charcoal hardness decreases with a rise in moisture content but it recovers its original hardness after drying. It can absorb up to about three times its own weight of water, so that it is advisable to protect charcoal from rain.

Fresh charcoal from the kiln or retort may ignite spontaneously due to the rapid absorption of oxygen by the charcoal, which is an exothermic reaction. It is always a good practice to allow the fresh charcoal to stabilize before storing it.

Wood charcoal made at low temperature is a poor conductor of heat. Its conductivity increases with the temperature at which the charcoal is made.

The equilibrium moisture content of wood charcoal varies with the prevailing relative humidity in any given locality. For relative humidities between 80 and 90 percent, its equilibrium moisture content varies from about 10 to 14 percent.

Additional information about charcoal production and uses may be found in the numerous publications on the subject, including:

1. Anonymous, 1950, "Charcoal from portable kilns and fixed installations", Food and Agriculture Organization of the United Nations, Rome, Italy.

2. Beglinger, E., 1957, "Charcoal production in kilns", Report No. 1277, U.S. Dept. Agri., Forest Service, Forest Products Laboratory.

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9. VENEER DRYING

The water present in the fresh-cut heartwood veneer of Philippine woods usually amounts to between 35 and 60 percent of the total weight of the green veneer. This is equivalent to moisture contents of 54 to 150 percent based on the oven-dry weight of the wood. In some woods, higher or lower moisture contents may be found. Excess water is undesirable and most of it must be removed before the veneer is satisfactory for most uses. Wet veneer cannot be glued properly with most glues and is easily attacked by insects, fungi and staining organisms; the shrinkage which will take place in wet veneer as it dries out during service can cause serious warping in the glued product.

Moisture will move naturally from green or wet wood to the surrounding air, up to a certain limit[1/]. The rate of this

1/ See FPRI Technical Note No. 1.

movement can be increased greatly by increasing the temperature of the wood and the temperature and rate of circulation of the air. Accelerating and controlling this moisture movement are the basic aims in veneer drying.

The three methods most used in drying veneer are air drying, drying in kilns which have been designed primarily for lumber, and drying in mechanical veneer dryers.

Air drying is the least efficient of these three methods because of the relatively low temperature, the erratic air circulation, and the varying weather conditions. Its use is limited to situations in which other drying facilities are inadequate.

Kiln drying is more efficient because of the higher temperature and rate of air circulation, and because the air temperature and relative humidity can be controlled fairly well. However, as is the case with air drying, kiln drying is used normally only to supplement standard veneer-drying equipment.

Mechanical veneer dryers are the most efficient because of the high air temperatures and circulation velocities that can be maintained, and because they utilize a continuous process as opposed to a batch process. Furthermore, veneer dried in a mechanical dryer generally has less buckle than air-dried or kiln-dried veneer. Mechanical dryers are of three types: the platen type (e.g., Merrit-Solem), the screen type (James), and the roller type (Coe). The roller type is most common in the Philippines and the following discussion will apply to it.

The drying time of veneer may be divided into two distinct periods. The location of the dividing line between the two periods varies, but it is usually somewhere between 25 and 40 percent moisture content. During the first period the moisture content is high enough that no shrinkage occurs; drying in this period causes problems only in unusual species. Shrinkage does occur during the second period, and it is this shrinkage that causes drying defects such as checks, splits, and end waviness.

Water loss from the end grain of wood is much faster than the loss from tangential and radial surfaces. Therefore, in veneer drying, the ends of the veneer sheet enter the second period sooner than the center of the sheet, and shrinkage occurs at the ends before it does at the center. This difference sets up stresses in the veneer which are relieved in one or both of two ways. The ends of the veneer will split when the stress exceeds the strength of the wood, or the wood at the ends of the sheet will acquire a tension set[2] when its strength is not exceeded. Subsequent drying of the unchecked veneer will bring the ends and center of the veneer sheet to the same moisture content. The shrinkage of the ends is then less because the tension set has produced a sheet whose ends are slightly wider than its center. The result is usually waviness on the ends to accommodate this extra width.

The shrinkage of wood varies greatly with the grain direction in the wood, somewhat with species, and slightly with drying conditions. Shrinkage parallel to the grain of the wood is negligible; radial shrinkage averages about 80 percent of the tangential[3] shrinkage, and both are very much greater than shrinkage parallel to the grain. In drying rotary-cut veneer to about eight percent moisture content, the length will not decrease a significant amount, the thickness will decrease about four percent, and the width will decrease about five percent, but these values differ somewhat with different species. These shrinkage differences contribute to the formation of the drying defects warping and checking. Because grain direction variations from place to place within a single sheet of veneer are the usual condition, and because shrinkage varies with grain direction, shrinkage also varies within the sheet. The result may be warping and checking.

Drying defects are much less troublesome in thick (1/10-inch) than in thin (1/20-inch) lauan veneers, because the thicker veneer has greater strength and stiffness. The strength is generally greater than the stresses which tend to cause splitting and checking; the stiffness is generally great enough to overcome the tendency to warping and end waviness.

The aim of the veneer dryer operator is to dry the largest possible volume of veneer to the desired moisture content in a given time, and at the same time to minimize the number of drying defects. In general, these two objectives are in

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2/ Tension set is the setting or "fixing" of the fibers of the wood in an expanded condition (i.e., less than normal shrinkage will accompany subsequent drying).

3/ Radial and tangential refer to the corresponding directions in the round tree or log.

opposition; drying defects are usually more numerous in veneer which has been dried faster. Then, to dry veneer in which the occurrence of drying defects must be minimized, volume must be sacrificed. For cases in which drying defects are not so important, or are not so likely to occur, production volume can be emphasized. The volume can be increased in several ways.

First, the drying temperature can be increased. It has been found that increasing the dryer temperature by 20 degrees F. (11 degrees C.) will increase the dryer capacity by 10 to 15 percent. This capacity increase would be greater for temperatures which were low before the temperature increase. The relationship was found to be logarithmic. However, the dryer temperature is limited by the available boiler pressure, or by the safe working pressure of the steam distribution lines.

Second, the air velocity within the dryer can be increased. This is fixed in most dryers, but in cases in which it can be varied, doubling the air velocity would decrease the drying time some 10 to 20 percent.

Third, the opening in the dryer venting stack may be increased. This allows a greater volume of moisture-laden air to leave the dryer and be replaced by relatively moisture-free air, which may cause faster drying. This new air must of course be heated to the drying temperature. If the dryer is operating near its maximum temperature, as limited by the available steam pressure, then an increase in the opening of the venting stack will tend to reduce the maximum temperature.

Proper control in the veneer drying operation requires considerable skill and experience. The average moisture content at which the veneer should be when it comes from the dryer is established by gluing requirements and the intended use of the product; it is usually between 6 and 12 percent. Moisture content variations about this average are always present but the smaller the variations the better.

In general, the time required to dry veneer depends on the rate of drying and the total amount of water which must be removed from the veneer for it to reach the desired moisture content. The total to be removed depends on the thickness and the green and dry moisture contents of the veneer; the rate of removal depends on the drying temperature, the air velocity, the amount of moisture in the drying air, and the drying characteristics of the species. The total amount increases with veneer thickness and green moisture content, and the rate increases with the temperature and velocity of the drying air.

The drying time, of course, must be such that the veneer comes out of the machine at the desired moisture content.

In order to work effectively, the dryer operator must have accurate information on the drying characteristics of the veneer, the dryer temperature, the drying time, and the dry moisture content of the veneer being dried. Knowledge of the drying characteristics is necessary to estimate the temperature-time combination which will give the desired dry moisture content. Then the moisture content of the first few pieces dried can be measured; if it is not correct the drying time must be changed. Knowledge of the drying characteristics of the veneer again is necessary to estimate the correct drying-time change. The dry moisture content must be checked from time to time with a reliable moisture detector to insure continued correct drying.

Veneer drying research at F.P.R.I. has shown that the large differences in required drying time among Philippine species are attributable much more to green moisture content differences than to drying rate differences. Green moisture contents from 55 percent (bagtikan) to 145 percent (mayapis) have been found in the species studied to date. The bagtikan was dried in almost half the time that was required to dry the mayapis. It has also been found, in the species studied thus far, that doubling the veneer thickness increased the required drying time by an average factor of about 2.7, all other things being equal. In other words if, under a given set of drying conditions, 1/12-inch veneer was dried in 10 minutes, than 1/6-inch veneer of the same species, dried under the same conditions, would require about 27 minutes to dry.

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10. PROTECTING BUILDINGS FROM TERMITE AND FUNGUS DAMAGE

Great damage is done to wood in the Philippines and other countries by termites and fungi. No accurate estimate can be made of the value of ruined wood products or the annual cost of making necessary repairs but it undoubtedly amounts to millions of pesos per year. Some of this annual loss may be unavoidable but the major part of it could be prevented or greatly reduced if proper precautions are taken.

The following brief consideration of the termites and the fungi with the short description of their respective groupings as agents of wood deterioration may aid in understanding the methods to be used to defeat them.

Termites

Termites are primarily wood-feeding insects which from colonies and live in the dark1/. The members of the colony are divided into three castes - the reproductives (the queen, king, and adults) which perpetuate the colony, the soldiers which repel intruders, and the workers which provide the food and are the ones most destructive to wood.

There are more than 50 species of termites in the Philippines. Only about 6 species, however, may be found doing serious damage to the woodwork of buildings. The others are mostly found in the forest. Based on their habitat, these insects may be divided into two main groups - the subterranean

1/ There are some species of termites which travel and forage in the open.

or ground-dwelling termites and the non-subterranean or wood-dwelling termites.

The subterranean termites, as their name implies, live and establish their primary colonies in the ground and from this home base they make tunnels in the soil or earthen shelter tubes over other materials in their search for food, which is mostly wood. They may also make secondary nests in the wood they eat. They need an adequate supply of moisture which they ordinarily obtain from the soil but may also obtain it from wet spots in the building or from any other available source.

The non-subterranean termites include species which live in the fresh wood of living trees and others, - the drywood termites which live in the dry woodwork of buildings and do not establish ground contact. The very small amount of moisture needed by the drywood termites is obtained from the wood they eat. They enter wood and establish their initial colony in it soon after their swarming flight. Their presence in wood may be detected by their fine, granular excretal pellets which they push out of their hidden galleries.

Fungi

Fungi are low forms of plants which differ from ordinary green plants by having no roots, stems or leaves and by their inability to synthesize their food from the nutrients in the soil. They are filamentous (threadlike) in structure, but they often produce fruiting bodies like the visible parts of a mold, mushrooms, or "conks" which are equivalent to the seed-producing parts of other plants. They grow well in damp and warm places.

There are hundreds of species of fungi and they are present almost everywhere but, for the purpose of this discussion, we are concerned only with those that inhabit wood and depend on it for their food. These may be divided roughly into two groups: those that cause decay and weakening of the wood and those whose principal effect is staining or discoloration of the wood with little or no effect on strength.

The characteristics or evidence of fungal decay in wood are as follows:

1. The affected wood often appears water soaked and the color becomes dark or reddish brown but may also be whitish or streaked in different colors.

2. Both sapwood and heartwood may be affected but usually the sapwood deteriorates more rapidly.

3. Narrow black or dark-colored zone lines may be present.

4. The affected wood becomes light in weight and brittle and the texture varies from a spongy mass to a cracked, shrunken mass of easily crushed material.

5. The odor of wood with active growth of decay fungi usually is like that of a mushroom.

The characteristics of fungal stained wood are as follows:

1. The color of the affected wood becomes blue-grey, dark brown, green, or blackish, at times, pink, yellow, or orange. Often generally distributed; sometimes wedge-shaped in cross-section.

2. The discoloration is almost entirely confined to the sapwood and it may even be superficial.

3. There is no readily noticeable weakening of the affected wood.

Protective Methods

The most important precaution to take in protecting wood from decay fungi, staining fungi, and subterranean termites is to use sound dry wood and keep it dry. These three groups of organisms require a plentiful supply of moisture and they cannot live without it. Therefore, in putting up a new building or repairing a damaged one, take every precaution against the accumulation of moisture in the wood. Observe the following rules:

1. See to it that no untreated wooden structural member is put in contact with or close to the soil. Construct sound concrete foundations, footings, and floor slabs and place such woodwork as posts, sills, jambs, and studdings upon them. Builders frequently allow woodwork such as posts and door frames to extend through concrete floors to the soil. This is a disastrous mistake and should never be permitted.

2. Remove all woody debris such as stakes, slabs, scrap lumber, stumps, etc. from the soil under and around the building.

3. Keep the building site well drained and remove all unnecessary obstructions to good ventilation beneath or around the building.

4. Use designs that will keep wood dry. All forms of construction that will trap moisture in wood should be avoided. Provide roofs with considerable overhang at eaves and gable ends to protect exterior woodwork against rain wetting.

5. Provide for easy inspection of the woodwork in the substructure of the building.

6. Use preservative-treated or naturally-durable wood as much as possible.

7. In areas where cases of severe termite infestation are prevalent, treat the soil of the building site with one of the following soil poisons in oil solution or in water emulsion. Treatment should be applied after the building site has been leveled but before pouring the concrete foundation and slab floor.

a) aldrin, 1.0 percent
b) lindane, 1.0 percent
c) chlordane, 2.0 percent
d) dieldrin, 1.0 percent
e) heptachlor, 5.0 percent

The rate of application should be about 5 gallons of the chemical solution or emulsion per 10 square feet of soil under the building and for every 10 linear feet around foundation walls.

<u>What can be done against drywood termites?</u>

Drywood termites are more difficult to control than the subterranean termites because they do not require access to a water supply. The simple method of keeping the wood dry does not interfere with the work of these wood destroyers. The following methods, however, will help in minimizing their attack:

1. Use pretreated or naturally durable heartwood lumber as much as possible.

2. Use wire screen, 18 to 20 meshes to the inch, on all doors, windows, and other openings in order to prevent or retard the entrance of winged termites.

3. Paint or varnish woodwork. Drywood termites ordinarily do not bore through paint or varnish to enter wood. They usually enter through nail holes, cracks, and crevices in wood. For this reason, these entrance points should be thoroughly brushed or sprayed with a good insecticidal solution or effectively closed.

Repairing damaged structures

In repairing structures that have been damaged by fungi or subterranean termites, observe the same precautions as are recommended for new buildings. That is, remove all seriously damaged wood and replace with dry sound wood, prevent all wood contact with the soil and if this is unavoidable, use wood with the proper preservative treatment. Remove all debris, provide good drainage and ventilation, correct all defects of any kind that allow moisture to accumulate in the wood, and treat the soil, cracks, and crevices of the concrete slab floor and foundations under the building. If a few subterranean termites are left in the building they will die after the wood has dried unless they have access to additional moisture. If there are many of them, however, they may build tubes downward toward the soil in search of moisture. These should be watched for and destroyed whenever found.

In removing decayed wood in preparation for making repairs, it is desirable, when possible, to cut back two feet beyond the obviously decayed wood.

Drywood termites are difficult to eradicate, especially when the infestation is far advanced and many structural members are affected. The following moisture should be considered:

1. Replacement and repair.- Infested structural members where permanent strength is desired need replacement with preservative-treated or naturally durable wood.

2. Heat treatment.- Infestation in limited areas in flooring and similar woodwork is sometimes controlled by a 10-minute exposure to infrared heat radiation. Widespread infestations, however, require other methods of treatment.

3. Chemical treatment.- Like the heat treatment, this method of control is only applicable to limited scale infestation and is not dependable in severe and extensive cases of termite attack. This treatment consists in either brushing insecticidal

solution on the surface of the affected wooden members, injecting insecticial solution or blowing insecticidal dust into drilled holes reaching the termite galleries in the wood.

4. Fumigation or gas treatment.- Heavily infested buildings, especially in other countries, are sometimes fumigated with either methyl bromide or hydrogen cyanide to eradicate drywood termites. Fumigation work is undertaken only by licensed and experienced fumigators because the chemicals used are extremely poisonous to man.

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11. WHAT IS MEANT BY HARDWOODS AND SOFTWOODS

The terms "hardwoods" and "softwoods" are commonly used commercially and in many technical publications to distinguish between two groups of tree species. They do not mean, however, that all "hardwoods" have hard wood or that all "softwoods" have soft wood for such is not the case. Some hardwoods are hard, such as molave, yakal and many other Philippine species while other hardwoods are relatively soft, including gubas, ilang-ilang and others.

There are several differences between the hardwoods as a group and the softwoods-

Botanically the terms refer to two great groups of trees or seed-bearing plants, the Angiosperms (hardwoods) whose seeds are enclosed in an ovary or pericarp and the Gymnosperms (softwoods) whose seeds are naked or exposed.

The wood of the Angiosperms is called porous because it contains tube-like water-conducting groups of cells referred to as "vessels" which run vertically in the tree. On a cross section of a tree they appear as pores. In some species these pores can be seen by the unaided eye but in other hardwood species they can be seen only with the aid of a magnifying glass or microscope. In some species the vessels or pores are open while in other species they are closed with pithlike growths called tyloses. The structure of the hardwoods is more complex than that of the softwoods.

The woods of the Gymnosperms, (softwoods) on the other hand do not contain the water-conducting vessels and do not show pores when viewed in the cross section. The softwoods have tracheids instead of pores, which perform the dual function of conducting water and providing mechanical support for the tree. It is easy for the skilled technician with the aid of a magnifying glass or microscope to determine whether a piece of wood is from the softwood or hardwood group.

In general, the hardwoods are broad-leaf trees while the softwoods have needle-like or scale-like foliage but there are exceptions to this rule. For example, almaciga (a softwood or Gymnosperm) has broad leaves while agoho (a hardwood or Angiosperm) has needle-like or scale leaves.

Generally, the hardwoods shed their leaves in winter in cold climates while the softwoods do not but there are exceptions to this rule for even in cold climates some hardwoods remain "evergreen" while some softwoods shed their needles in winter.

In the North Temperate Zone of Europe, Asia and America, most hardwoods are without leaves during the entire winter, which may be as long as five or six months, while in the tropics, although several hardwoods shed their leaves at some period during the year, a new crop of leaves quickly appears and they are without leaves for a short time only.

In the North Temperate Zone the softwoods or conifers predominate and constitute the principal commercial species, while in the tropics the hardwoods predominate.

In the Philippines the softwoods (Gymnosperms) constitute a relatively small group, consisting principally of the following species:

Almaciga (Agathis philippinensis)
Benguet pine (Pinus insularis)
Mindoro pine (Pinus merkusii)
Malakauayan (Podocarpus philippinensis)
Malaalmaciga (Podocarpus blumei)
Igem (Podocarpus imbricatus)
Pasuig (Podocarpus amarus)
Dalung (Phyllocladus hypophyllus)
Lokinai (Dacrydium elatum)
Mountain yew (Taxus wallichiana)

Philippine hardwoods (Angiosperms) include the Philippine mahogany group, the apitong group and more than 3000 other species. Thus, in the Philippines, the lumber industry, the plywood industry, the furniture industry and most other wood-using industries must be based mainly on the hardwoods. The pines, almaciga and malakauayan are valuable woods industrially and highly desirable but the quantities available limit the extent to which industries can be based upon them.

Perhaps the discussion of this subject can be understood better with the aid of the accompanying table which illustrates the botanical system of classifying wood species and subdividing them into families, genera and species. Since there are more than 3500 tree species in the Philippines, the table can show only a very small fraction of the hardwoods but it shows all the commercially important softwoods of the Philippines.

SOFTWOODS

Families	Genera	Species
Araucariaceae	Agathis	Almaciga (Agathis philippinensis)

SOFTWOODS

Families	Genera	Species
Pinaceae Pine family	*Pinus*	Benguet pine (*Pinus insularis*) Mindoro pine (*Pinus merkusii*)
Podocarpaceae	*Podocarpus*	Malakauayan (*Podocarpus Philippinensis*)

HARDWOODS

Families	Genera	Species
Anacardiaceae	*Koordersiodendron*	Amugis (*Koordersiodendron pinnatum*)
	Dracontomelon	Dao (*Dracontomelon dao*)
	Mangifera	Pahutan (*Mangifera altissima*)
Combretaceae	*Terminalia*	Binggas (*Terminalia citrina*) Kalumpit (*Terminalia microcarpa*)
Ebenaceae	*Diospyros*	Ebony (*Diospyros ferrea*) Kamagong or mabolo (*Diospyros discolor*)
Dipterocarpaceae	*Anisoptera*	Dagang (*Anisoptera aurea*) Palosapis (*Anisoptera thurifera*)
	Dipterocarpus	Apitong (*Dipterocarpus grandiflorus*) Panau (*Dipterocarpus gracilis*)
	Hopea	Manggachapui (*Hopea acuminata*)
	Parashorea	Bagtikan (*Parashorea plicata*)
	Shorea	Tangile (*Shorea polysperma*) Red lauan (*Shorea negrosensis*) Guijo (*Shorea guiso*) Yakal (*Shorea astylosa*)
	(and others)	
Leguminosae	*Intsia*	Ipil (*Intsia bijuga*)

Families	Genera	Species
	Koompassia	Manggis (*Koompassia excelsa*)
	Pahudia	Tindalo (*Pahudia rhomboidea*)
	Pterocarpus	Narra (*Pterocarpus* spp.)
	Sindora	Supa (*Sindora supa*)
	Wallaceodendron	Banuyo (*Wallaceodendron celebicum*)
	(and others)	
Verbenaceae	*Teijsmanniodendron*	Dangula (*Teijsmanniodendron ahernianum*)
	Vitex	Molave (*Vitex parviflora*)
	(and others)	

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12. THE CRACKING OR CHECKING OF WOOD CARVINGS

Some Philippine carved wood products sold to the United States and other countries develop cracks, especially those that arrive there during the middle of winter and are placed in houses that are heated. The cracking results mainly from the rapid loss of moisture and the shrinking caused by this moisture loss when wood is moved from a humid climate to a dry climate. When the outer zones or the end surfaces of a carving dry much more rapidly than the inner portion, they shrink faster than the inner portion which puts the outer wood in a stretched condition. If the stretching or tensile stress is too great, the wood will crack to relieve the tension.

Cracking or checking is influenced by a number of factors including:

(a) The dryness of the wood when exposed to the low-humidity conditions: Wood always tries to reach a moisture content in equilibrium with the relative humidity of the air surrounding it.1/ Air-dry wood in the Philippines may have a moisture content of 14 to 17 percent but in heated houses in northern United States during cold winter weather it may have a moisture content as low as 5 or 6 percent. If the wood to be exported has a high moisture content, the danger of its cracking when exposed to such low relative humidity is very great.

If from the time it leaves the Philippines the further drying of wood is effected slowly and carefully, cracking can be greatly reduced and often entirely avoided. After the wood dries to the moisture content it will finally attain in the United States there is little danger of further cracking. But if the drying takes place rapidly, the danger of cracking is greatly increased. Carvings from the Philippines that arrive in the United States at the beginning or in the middle of winter are more likely to crack than those that arrive in the States in the late spring or summer, after the heating season is over and the indoor relative humidities are much higher than in winter.

(b) The size of the carving: Thick, heavy carvings are more likely to crack than thinner ones. Wide carvings are more likely to crack than narrow ones of the same thickness.

(c) The way in which the wood is cut: Carvings made from "quarter-sawn" boards (boards cut parallel to the radius of the tree) are less likely to crack than carvings made from "flat-sawn" boards (boards cut approximately perpendicular to the radius or tangential to the circumference of the tree). End

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1/ This subject is discussed more adequately in Technical Note No. 1 "The moisture content of wood in relation to air humidity".

surfaces are more likely to crack than side surfaces. In carvings made from blocks containing the center or pith of the tree, cracking is almost certain to take place before the wood reaches the low indoor moisture contents prevailing in the United States during cold weather.

(d) The species of wood used: Different species of wood vary in their tendency to shrink or swell with a given change in moisture content and some of them will shrink $1\frac{1}{2}$ to 2 times as much as others under the same conditions. In general, lightweight woods shrink less than heavy woods under the same conditions but there are exceptions to this rule. Most lightweight woods, though, are not particularly attractive in color or figure. Also some of the woods that are most attractive in appearance are heavy and have high shrinkage. Philippine woods that have low or moderate shrinkage but at the same time are attractive in color or figure are rain-tree (Samanea saman) (which is commonly called "acacia" in the Philippines or "monkey pod" in Hawaii) and narra (Pterocarpus indicus or P. vidalianus). These woods will generally crack less in drying to low moisture contents than woods with high shrinkage values, under the same conditions. Other species undoubtedly have good properties for the purpose but their shrinkage tendencies have not yet been determined.

The foregoing discussion covers the principal causes of checking or cracking in carvings and makes some suggestions that could help in minimizing the defect but it offers no sure cure for the trouble because there is no simple and practical way that is certain to prevent it. Cracking can be greatly reduced, however, and usually avoided, if the reasons for the cracking are understood by the carvers, the merchandizers and the customers and if each does what he can to avoid it.

What the carver can do

1. As much as possible, use wood that has low shrinkage properties.

2. Use designs and sizes that are least likely to crack.

3. Avoid the use of blocks containing the center or pith of the trees.

4. See that the wood is thoroughly dry before carving, or at least before it is sold to customers or foreign dealers.

5. Experiment with removing excess wood from the center of large carvings by boring or chiseling. (This method should be approached cautiously for it is not known to have been worked out successfully.)

What the dealer or jobber can do

1. Assist the carvers in getting wood that is most suitable in species and dryness for their purposes. This may have to be brought in from other parts of the Philippines.

2. Know the dryness of the carvings obtained from the carvers and handle them accordingly.

3. Dry slowly to a low moisture content carvings that are intended for sale in the United States and other countries with similar low humidities.

4. Maintain a storage room where suitable humidity is maintained to keep the carvings at about 8 percent moisture content while waiting sale or shipment to the States but do not put carvings in this room until they have dried down to about 13 percent.

5. Wrap each carving in suitable plastic film or in asphalt lined paper. This will slow down the rate of moisture change.

6. Ship out carvings that are as near as practical to the moisture content they will attain in service.

7. Issue a warning slip with each carving telling the buyer how to care for it so as to avoid cracking.

What the purchaser can do

1. Avoid placing carvings purchased from local Philippine dealers immediately in places where the relative humidity is low or allowing them to remain for long periods in direct sunshine. In other words, avoid rapid drying of the carvings. Carvings that arrive in the United States in winter should not be brought immediately into dry heated rooms but should be kept in more humid places until the heating season is over. Some drying of the carvings will take place during the summer but it will not be so rapid as in winter and there will be less danger of cracking during the second winter than during the first. Never leave wood carvings (or other wood items) close

to a hot radiator.

2. By the skillful use of wrappings that retard the passage of moisture from the wood he can slow down moisture changes.

Treatments and Coatings

There is the possibility of using coatings and treatments that will slow down the rate of drying or otherwise will stabilize the wood and reduce the tendency to check during severe drying. No such treatment is known to have been so thoroughly explored that it can be recommended as yet. The following are mentioned, however, for the information of those who may wish to experiment:

(a) Green wood soaked for some days in polyethylene glycol-1000, a wax-like material that is soluble in warm water (about 104°F) is said to have its tendency to check greatly reduced. This chemical is very costly at present and is not available for sale in the Philippines. Wood so treated does not take ordinary finishes very well and, if finished at all, requires a special finishing material. Information about experiments with this material on gunstocks can be found in an article entitled, "Chemical treatment curbs shrink and swell of walnut gunstocks" by Mitchell and Wahlgren, in the Forest Products Journal, Volume IX, page 437, December 1959. No experiments with polyethylene glycol-1000 are known to have been made to date in the Philippines.

(b) Paint, shellac, or varnish finishes are not often desired on carvings but when they can be tolerated they will slow down the rate of moisture change and thus can be helpful in reducing checking. In order to be effective, however, they must be applied to all surfaces, ends and edges of the carving, not just one or two sides. Such coatings do not prevent the escape of moisture but they reduce the rate of change.

(c) Coating all surfaces of the wood repeatedly with a drying oil, such as boiled linseed oil, and allowing it to dry thoroughly between coatings can retard the rate of drying of the wood but this will change the appearance of the carving and for that reason may usually be unacceptable. In general, coatings of linseed oil have been found less effective in retarding moisture changes than paints. Since linseed oil is not produced in the Philippines, the use of lumbang oil may be tried instead.

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13. ADHESIVES FOR WOOD, THEIR CHARACTERISTICS AND SELECTION FOR PARTICULAR USES

An adhesive, in general, is "a substance that causes bodies to adhere to each other". Adhesives for wood are compounds or mixtures of compounds for gluing wood to wood or, sometimes, to other materials. They may be of natural origin such as animal glues, fish glues, casein glues, starch glues and others, or they may be based primarily on synthetic products, such as the synthetic resin glues. All commercial wood adhesives must be able to make joints that are at least as strong as the wood. In addition, some resistance to moisture is generally required and, in numerous cases, the glue joint must be able to resist repeated soakings in water or even boiling in water, without serious weakening. The total number of individual glues or glue formulas that may be used with wood is very large but they may be grouped into classes by origin and properties as shown in the accompanying diagram. Within each class shown in the diagram there may be wide variations in formulation or source, as well as in properties.

The starch glues, as a group, are low in cost but they are the least water resistant. They are easy to use, make strong joints and generally will set without heat but most of these glues lose strength rapidly under continued or frequent exposure to water or to relative humidities about 80 percent. They are not suitable for use in the tropics except for very temporary or limited purposes. They are not known to be in commercial use in the wood industries in the Philippines.

Blues correctly formulated from soy-bean meal, peanut meal and other plant products of high protein content have generally higher moisture resistance than the starch glues. They are frequently used in the United States for manufacturing softwood plywood of limited moisture resistance but they will not usually last long when continuously exposed to wet conditions or high relative humidities. They are especially vulnerable to a combination of warmth and dampness and for this reason are less suitable for use in the tropics where relative humidities and temperatures are generally higher than in the temperate zone. These glues can be formulated to set cold or in hot presses.

Glues made from proteins of animal origin except blood and casein glues are generally of low moisture resistance. Ordinary hide and bone glues or fish glues lose strength completely when they absorb water. For some, the glue mixture is warmed before application while others are applied cold. They set without heat and are not suitable for use with heat. The water resistance of a hide glue can be increased substantially by the addition of formalin or certain other chemicals but hide glues are relatively high in cost and this degree of water resistance can be provided more cheaply by other glues. Water-resistant hide glues, therefore, find exceedingly limited commercial use. The casein glues, which are made from the casein produced from skimmed milk, if properly formulated, have high dry strength and good water resistance. They are used extensively in the United States and are commonly sold at retail in small packages for household use. In this form they are sometimes available in the Philippines. There is also some commercial wood gluing with casein glues in the Philippines. Casein glues can be formulated for use in hot presses or to set without heating.

Blood glues, (dry, soluble, whole-blood powder), made from animal blood, are formulated to set cold or in hot presses. They possess moderate resistance to moisture. They are not well suited for gluing solid wood but when properly used in making plywood they produce joints that remain strong after considerable soaking in water. However, blood glues have been largely replaced in commercial operations by the synthetic-resin glues. No blood glues are known to be in commercial use in the Philippines, but some dry soluble whole blood may be used with urea glue.

Synthetic-resin glues, as shown in the diagram, are of two general classes: (a) those that do not soften when heated after they have been cured (thermosetting) and (b) those that soften or become plastic when heated (thermoplastic). The thermoplastic glues are useful in certain kinds of products where convenience in use is of particular importance and where maximum strength under adverse conditions is not required. For maximum strength and durability under severe use conditions, thermosetting glues are generally more suitable and dependable.

The thermosetting resin glues, when properly formulated and used, have high resistance to moisture but some are more resistant than others. The urea-resin glues are generally cheaper than the other glues of this group and, for that reason, more extensively used. They may be formulated for use with hot presses or electronic heating or for use without heat. In the manufacture of plywood with a moderate degree of water resistance, urea glues are usually diluted or "extended" with considerable quantities of wheat flour or other similar starches, primarily to lower the cost of the glues. Also, small amounts of inert fillers such as finely powdered coconut shell or walnut shell may be incorporated in the glue to improve its spreadability or to control glue penetration into the wood. The dilution or filling of the glues adds to their attractiveness for commercial use, especially in the manufacture of plywood.

Urea glues, when formulated for cold setting, are sometimes used for gluing solid wood, as in the production of furniture and other laminated wood products. When so used, they should not be extended with any starch. The urea glues are considered on the border line of resistance to warmth and moisture for use in the tropics for these purposes. They might be used with reasonable success for such minor products where maximum safety and dependability are not required but they should not be used for producing large laminated beams or arches whose weakening or failure would entail loss of life or excessive costs for replacement. Plywood or other products glued with urea resins are not dependable for long life when used under continued or frequent exposure to the weather, to wet conditions or to high relative humidities and temperatures.

The most water-resistant glues that are readily available for commercial use at present are the thermosetting, synthetic-resin glues based on resorcinol, phenol or melamine resins or blends of phenol and resorcinol resins. The phenol resins and, possibly to some extent, melamine resins are the glues now used in the production of boil-proof, water-proof, exterior-grade or "marine" plywood. The phenol and resorcinol resins and the blends of these resins are the primary glues for producing laminated products of maximum durability but here their varying temperature requirements influence their commercial adaptability. Phenolic-resin glue is sometimes impregnated into very thin sheets of paper and used as a film glue for hot pressing. This form is especially suitable for gluing thin veneer which is difficult to spread with wet glue or which is easily penetrated and stained by wet glue. As a group, these adhesives of the waterproof class are more costly than the other resin glues which generally limits their use to products for which other glues are not acceptable.

The phenolic-resin glues require relatively high setting temperatures in the hot-plate press but this is not a serious disadvantage in plywood production where the heat is required to penetrate through thin sheets of wood. But in the production of laminated beams and arches, especially those of large size or wide curvature, the high-temperature requirements of the phenol-resin glues at the innermost glue line of the beam or arch assembly cannot be met by hot presses. The glue can be set in specially designed kilns capable of producing and maintaining the temperatures and humidities required but these are expensive and the long heating periods required can cause damage to the wood. For this reason, the resorcinol-resin glues or glues made from mixtures of resorcinol and phenol resins are preferred. These glues, particularly the resorcinols, can be set at normal indoor temperatures often found in the tropics and, at most, require only moderate heating that can be provided easily without expensive equipment. The mild temperature requirements of the resorcinol group of glues tend to offset their higher first cost.

The selection of a glue for a particular use should be based on availability, cost, convenience in use and requirements of the product to be glued. For commercial operations, all these factors are important but, for limited amounts of gluing on a small scale, convenience in using may be more important than the fittest cost of the glue.

Most plywood in the Philippines is now being made with urea-resin glues extended with wheat flour and, for export, must pass certain specified tests for moisture resistance. The small amount of "exterior" or "marine" plywood produced is glued with phenolic-resin glue.

Laminated timbers in the Philippines are being glued with casein glues where maximum durability is not required or with resorcinol-resin glues or phenol-resorcinol blends where such glues are specified or where maximum durability is required.

Furniture in the Philippines is manufactured almost entirely in small shops where convenience in gluing is a prime requirement. As a result, animal hide glues, urea glues, packaged casein glues or polyvinyl-resin glues are used, for the most part.

The foregoing practices may change with market demands, the relative availability and cost of the different glues or improvements in glue formulations.

In a brief statement such as this technical note, many aspects of the subject are inadequately covered and there are exceptions to some of the generalizations made. Furthermore, the whole field of glue formulation is in a state of constant change and improvement and new glues, or variations in old products may reasonably be expected. For a more adequate coverage of the subject, the reader is referred to the publications of manufacturers of the respective glues, to current technical journals and to the references listed below.

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CLASSIFICATION OF WOOD ADHESIVES

(a) by origin

Natural

Plant

1. Starch base
   - a) cassava
   - b) other plant products of high starch content
2. Protein base
   - a) soy bean
   - b) other plant products of high protein content

Animal

1. hide
2. animal bones (including fish bones)
3. blood
4. casein
5. other animal products of high protein content

Synthetic

Thermosetting

1. urea resin
2. melamine resin
3. phenol resin
4. resorcinol resin
5. other thermosetting resins

Thermoplastic

1. polyvinyl resin[s]
2. other thermopla[stic] resins

(b) by resistance to moisture (when properly formulated and used)

low moisture resistance

- starch glues
- animal hide and bone glues
- polyvinyl resin glues

moderate moisture resistance

- modified hide glues
- soy bean glues
- peanut-meal glues
- other glues of plant protein origin
- casein glues
- blood glues

high moisture resistance

- urea-resin glues

maximum moistur[e] resistance

- phenol resin gl[ues]
- resorcinol resi[n] glues
- melamine resin glues

14. SAPWOOD AND HEARTWOOD

When a cross section of a tree is viewed, such as the end of a log, an outer zone of light-colored wood will usually be seen next to the bark as indicated in Fig. 1. This light-colored wood is called the "sapwood" of the tree. It is composed partially of living tissues whose main function is to carry food and water to the different parts of the tree and to serve as a reservoir of stored food.

Surrounded by the sapwood zone, as shown in Fig. 1, there is a central zone called "heartwood". This is usually, but not always, darker in color than the sapwood. In some species, the borderline between the two zones is difficult or

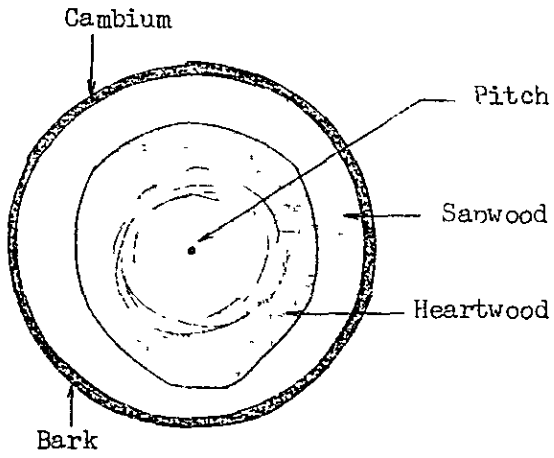

Fig. 1. End view of a log showing sapwood and heartwood

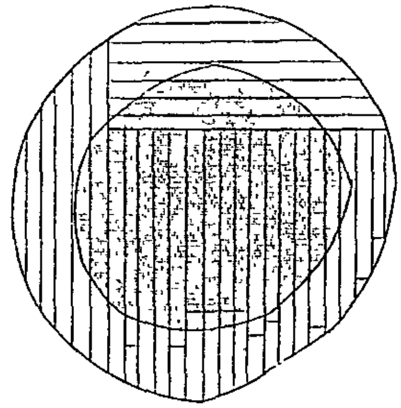

Fig. 2. Boards cut from a log may be all sapwood, all heartwood or contain both heart and sapwood

even impossible to locate. These are sometimes called "sapwood species", meaning that they have no noticeable heartwood. The heartwood consists of dead tissues and does not participate in the life activities of the tree but it continues to serve as a support of the standing tree.

In the beginning, when the tree is very small, it consists entirely of sapwood but as the tree grows larger and puts on new layers of sapwood beneath the bark, "as the result of the activity of a growing layer, the cambium", life gradually ceases in the central portion and the central sapwood becomes heartwood. The pith of the tree (see Fig. 1) generally disappears. Year after year, as the tree grows older and increases in size, the heartwood zone also increases in size but always is surrounded by the sapwood zone. The thickness of the sapwood zone depends mainly upon the wood species. In some species the sapwood may be less than an inch thick while in others, the "sapwood species", it may occupy all or most of the cross section.

As the age of the tree increases there is a tendency for resins, gums, tannins, coloring matter and other so-called "extraneous materials" to accumulate in the heartwood but very little in the sapwood. The nature of these "extraneous materials" or "extractives" varies greatly among different wood species. The heartwood of some species contains materials that are toxic or repellent to fungi and insects, which account for the resistance of the heartwood to these destructive organisms. In other species the extractives of the heartwood do not contain protective chemicals. In such species the heartwood has little greater resistance, if any to decay fungi than the sapwood.

As mentioned above, the sapwood of the tree contains very little of the extractive materials that characterize the heartwood but it contains the sugars, starches and other nutrients of the tree, some of which are foods for fungi and insects. The sapwood, therefore, has low resistance to decay fungi under damp conditions of use, is easily discolored by staining fungi and readily attacked by several kinds of insects. Starch appears to be particularly attractive to powder-post beetles (bukbok). Sapwood that is kept thoroughly dry does not stain or decay but may be attacked by "bukbok". The absence of these nutrient chemicals, particularly starch, from heartwood makes it unattractive to bukbok and, therefore, generally free from their attack even in species that do not contain toxic chemicals in the heartwood. Staining fungi find nothing of value in heartwood and, therefore, do not discolor it. Wood-decaying fungi, however, depend on the wood substance itself and, under conditions favorable to their growth, attack both sapwood and heartwood in all species that do not contain toxic or repellent extractives in the heartwood.

The general characteristics and properties of sapwood and heartwood are compared in the accompanying table.

While the foregoing statements and those in the table are generally correct, there are occasional exceptions. For example, sometimes trees contain rings or irregular areas within the heartwood that did not change from sapwood to heartwood. These areas are sometimes called "included sapwood" or "inner sapwood" and they appear to retain the general properties of sapwood even though surrounded by heartwood. Whether they continue to function in the life processes of the tree is not apparent.

There is also false heartwood which is sometimes found within the sapwood zone. This is dead wood caused by a wound or a diseased condition. It is usually too small to be significant in the utilization of the wood but may be excluded as defective because of its color.

When the log is cut into lumber, some of the boards may be all sapwood, some may be partly sapwood and partly heartwood, and some may be all heartwood as indicated in Fig. 2. Boards containing sapwood are perfectly acceptable for many purposes and sapwood is usually preferable to heartwood if the wood is to be impregnated with preservatives. When lumber is selected for high natural resistance to decay and insect attack, however, it should be remembered that this property exists only in the heartwood. The sapwood of even the most durable species is low in decay and insect resistance. When thoroughly impregnated with suitable preservatives, however, sapwood can be made as durable as heartwood and, in most species, even more durable.

It is sometimes assumed that heartwood is stronger than sapwood but this is not correct and frequently the reverse is true. The wood very near the pith of the tree, in the heartwood zone, is frequently less dense and more defective and therefore weaker than the wood in the outer heartwood zone or in the sapwood. The strength of wood depends to a large degree on its density or specific gravity, moisture content, straightness of grain and freedom from defects, and not upon the change from sapwood to heartwood. The relationship between density and strength is particularly close, so much so that density is considered to be a good indication of strength, the denser woods being the harder and stronger.

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T A B L E

SAPWOOD AND HEARTWOOD COMPARED

Sapwood	Heartwood
The outer zone of the tree	The inner zone of the tree
Light colored	Usually darker in color than sapwood but not always
"Living" wood	No longer living
Contains sugars, starches and other nutrients of the tree	Does not contain nutrient chemicals
Does not contain toxic or repellent chemicals	Many species contain toxic or repellent chemicals in varying amounts but they are lacking in other species
Easily discolored by staining fungi	Not discolored by staining fungi
Attractive to bukbok	Resistant to bukbok
Not durable under adverse conditions	Highly durable in some species, intermediate in some species, not durable in others
Strength at least as great as in heartwood	Outer heartwood as strong as sapwood, inner heartwood often weaker
Usually penetrable by preservatives	Penetrable on some species, highly resistant to penetration in others
Extraneous materials mostly absent	Extraneous materials generally present

15. RELATIVE ECONOMY OF TREATED AND UNTREATED WOOD

The economic advantage of the use of treated wood has been proven in many countries and has recently aroused the interest of wood-users in the Philippines. In semi-permanent and permanent construction, where durability is a primary consideration, the use of treated wood can usually be shown to effect substantial savings. In temporary construction, on the other hand, where cheap, untreated, non-durable species can serve the purpose satisfactorily, any extra cost of preservatives and treatments would obviously be an unnecessary loss of money. In such cases preservative treatment would not be advantageous.

The relative economy of the use of treated and untreated wood can be compared by spreading the total costs of the different materials over the number of years they are expected to serve. This gives a figure called "annual charge" which is a yearly payment made to defray a debt at an interest compounded annually for the length of the service life of the material. The total costs to be compared include the first cost of the material, installation costs, and the cost of maintenance and interest on the investment throughout the service life. In some instances, the maintenance cost of the treated and untreated material might not differ much but any difference would generally be in favor of the treated wood since it would require less maintenance than the untreated. In comparing their costs, maintenance cost should be included whenever accurate data are available.

The annual charge may be computed by the formula:

$$A = P \frac{r(1 + r)^n}{(1 + r)^n - 1} \quad ------ (1)$$

Where: A = Annual charge
P = First cost in place (cost of delivered material and installation cost)
r = Interest rate expressed as a decimal
n = Expected length of service

Table 1 shows the annual charge per peso of cost of a material for different interest rates computed from formula 1.

For example, for a telephone company making a choice between the use of treated and untreated apitong poles in a line requiring 1,000 poles, the first cost in place of a single untreated pole is assumed to be P32.00 (P25.00 cost of poles plus P7.00 installation cost) and it would possibly last 5 years. A treated pole in place would probably cost P80.00 (P25.00 cost of pole, P48.00 cost of treatment, plus P7.00 installation cost) and should last 30 years in service[1]. Assume also that the capital was borrowed at an interest rate of 6 percent.

Table 1 shows that, at 6 percent interest, a timber with a service life of 5 years would have an annual charge of P0.23740 for every peso of cost and one that lasts 30 years would have an annual charge of P0.07265. The annual charge for the untreated pole, which cost P32.00 in place, is 32 times 0.23740 or P7.60. The treated pole, which cost P80.00, has an annual charge of 80 times 0.07265 or P5.81. The lower annual charge of the treated pole shows that it is the more economical material to use. Using treated poles in this case would mean a total saving of P1,790.00 per thousand poles per year without taking into account the fact that replacement of poles in service costs more than the first installation and that there would be six replacements of the untreated poles to one replacement of the treated poles.

Some wood-users may decide to buy untreated timbers and have them treated. In this case it would be desirable to determine how much may be spent for treatment without increasing the annual charge of the structure. With the use of formula 1 and knowing the number of years the untreated wood will last and the number of years added due to treatment, the allowable cost for treatment can be estimated by equating the annual charge of the untreated wood to the annual charge of the treated wood. The first cost of the treated pole in this case is the cost of the untreated pole in place plus the allowable cost for treatment (y). The equation would be:

$$P(A_1) = (P + y)(A_2)$$

$$(P + y) = \frac{P(A_1)}{A_2}$$

$$y = \frac{P(A_1)}{A_2} - P \text{ - - - - - - } (2)$$

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1 The costs given are market prices for a 30-foot pole at the time of writing. These prices of course are subject to considerable variation.

Where: A_1 = Annual charge per peso of cost of the untreated material

A_2 = Annual charge per peso of cost of the treated material

y = Allowable cost of treatment without increasing the annual charge

Using the values of the foregoing example, the maximum amount the company could spend for treatment without increasing the annual charge may be determined. Taking the values of A_1 and A_2 from the table, the allowable cost of treatment would be:

$$y = \frac{32(0.23740)}{0.07265} - 32$$

$$= P72.57$$

Since the cost of treatment (see first example) would amount to P48.00, which is less than the maximum allowable cost of treatment (P72.57), the use of the treated pole is economically justifiable (without taking into consideration the extra costs of replacing poles in service).

Wood-users may ask how long treated wood should last to have the same annual charge as the untreated wood or how long should the treated wood serve to compensate for the additional cost of treatment. From formula 1, n, (the number of years the treated wood must last to have the same annual charge as the untreated), can be obtained by the formula:

$$n = \frac{\text{Log } A - \text{Log } (A - Pr)}{\text{Log } (1 + r)} \quad --- \quad (3)$$

To avoid the tedious computation by the use of this formula, the table can again be used. Having obtained the annual charge of the untreated pole, equate this to the cost of the treated pole multiplied by the annual charge per peso of cost of the treated pole in place, represented by x.

$$7.60 = 80\ (x)$$

$$x = \frac{7.60}{80} = P0.09500$$

Referring to table 1, the annual charge of P0.09500 per peso of cost at 6 percent interest gives a figure of about 17 years. This means that if the treated pole will serve 12 years more than the untreated, the treatment will have paid for itself. The number of years each pole will serve more than is required to pay for the treatment are the savings which make its use the more economical.

A great deal of savings accrue from increasing the service life of the timber aside from the reduction of the annual charges. The use of short-lived untreated poles necessitates frequent renewals, especially when employed under conditions favorable to decay and insect attack as in power and telecommunication lines. Each replacement would usually cost considerably more than the original installation cost because the cost of renewal must include the cost of removing the old as well as the cost of erecting the new pole plus the cost of removing and re-installation of the insulators and wires. Furthermore, over a period of years, it is to be expected that the price of the untreated poles will be higher each time a new purchase is made. Therefore, the annual charge for each new group of untreated poles will be higher than that of the previous group. Added to these are the inconveniences to users and the reduction of income to the company brought about by the interruption of service. In actual practice, all these costs must enter into the computations.

The foregoing computations and values for treated and untreated poles should be understood as examples only. Conditions fluctuate from year to year and the source and availability of the materials also affect the cost. Furthermore, different localities and services have different labor and installation costs.

The usefulness of the above formulas is not limited to poles. They may be used just as readily to compare the economy of treated and untreated wood in other structures such as bridges, culverts, fences, piers, piling and other wood structures of various kinds. These formulas may also be used to compare the economy of different competitive structural materials with wood or with each other.

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ANNUAL CHARGE PER PESO OF COST OF MATERIAL IN PLACE

Years service of material before renewal (n)	Interest rate 4%	5%	6%
1	1.04000	1.05000	1.06000
2	0.53020	0.53780	0.54544
3	0.36035	0.36721	0.37411
4	0.27549	0.28201	0.28859
5	0.22463	0.23097	0.23740
6	0.19076	0.19702	0.20336
7	0.16661	0.17282	0.17914
8	0.14853	0.15472	0.16104
9	0.13449	0.14069	0.14702
10	0.12329	0.12950	0.13587
11	0.11415	0.12039	0.12679
12	0.10655	0.11283	0.11928
13	0.10014	0.10646	0.11296
14	0.09467	0.10102	0.10758
15	0.08994	0.09634	0.10296
16	0.08582	0.09227	0.09895
17	0.08220	0.08870	0.09544
18	0.07899	0.08555	0.09236
19	0.07614	0.08275	0.08962
20	0.07358	0.08024	0.08718
21	0.07128	0.07800	0.08500
22	0.06920	0.07597	0.08305
23	0.06731	0.07414	0.08128
24	0.06559	0.07247	0.07968
25	0.06401	0.07095	0.07823
26	0.06257	0.06956	0.07690
27	0.06124	0.06829	0.07570
28	0.06001	0.06712	0.07459
29	0.05888	0.06605	0.07358
30	0.05783	0.06505	0.07265

Based on the formula: $A = P \dfrac{r(1 + r)^n}{(1 + r)^n - 1}$

Where: A = Annual charge
P = First cost of materials in place
r = Interest rate expressed as a decimal
n = Expected length of service

16. THE DENSITY AND SPECIFIC GRAVITY OF WOOD

The density and specific gravity of wood are valuable indices of its physical and mechanical characteristics. Generally, the denser the wood is, the higher are its strength properties, the more difficult it is to season and the harder it is to saw and nail.

The terms density and specific gravity are so frequently confused that it is worthwhile to define them specifically.

<u>Density</u>

Density refers to the mass or weight of a substance per unit volume and is expressed in such terms as grams per cubic centimeter, kilograms per cubic meter, or pounds per cubic foot.

Density depends heavily on the current moisture content. Green wood, for instance, has a higher density than air-dry wood of the same species. As the moisture content of the green wood decreases, the density decreases until the fiber saturation point (30 percent is the assumed moisture content) is reached. Further drying below that point causes shrinkage of the wood which tends to compensate for the weight of water lost and thus may result in increasing the density despite the loss of moisture.

<u>Specific gravity</u>

Specific gravity refers to the relative density of any substance in comparison with a standard density, usually that of distilled water at 4°C, which is taken as unity. Water is taken as a standard medium because one cubic centimeter at 4°C weighs exactly one gram which makes for convenience in calculation.

The specific gravity of wood is the ratio of the weight or density of a given volume of wood to the weight of the same volume of water at a temperature of 4°C. Density referred to here is based on weight oven dry and volume at current moisture content. However, the specific gravity of wood is usually computed from the volume of the wood when green (before any shrinkage has taken place) and the weight of the wood when oven dry (moisture free). The dimensional constancy of wood under these two basic conditions assures replication, thus the calculated specific gravity is reliable and can be compared with published figures obtained under the same conditions. Sometimes, however, as in making strength tests on wood, the specific gravity is based on the volume of the wood at the time of test which may be in the green or in the air-dry condition. Whatever basis is used should be made clear in published data.

Specific gravity is expressed decimally, such as 0.37.

This figure would mean that a given volume of the wood weights 0.37 times the weight of the same volume of water.

Specific gravity is at its lowerst when its computation is based on the weight when oven dry and volume when green and is at its highest when based on the weight and volume when oven dry. As wood dries or seasons below the fiber-saturation point, there is a gradual increase in specific gravity due to the shrinkage in drying.

Since most woods are lighter than water, even when green, most specific gravity values are less than unity. Thus the specific gravity of tangile averages about 0.47 based on oven-dry weight and volume when green. Some woods, however, are heavier than water even when oven dry and their specific gravity values exceed unity. Mancono, for example, has a specific gravity of about 1.41 on the basis of oven-dry weight and air-dry volume (about 15 to 17 percent moisture content).

The specific gravity of wood is a direct indication of the amount of wood substance in a given volume, but it is also an inverse indication of the amount of air the wood contains. The volume occupied by wood substance alone is considerably less than the volume occupied by wood in the usual form in which it grows. The specific gravity of wood substance is about 1.53 as determined in water, but no wood is known to have specific gravity that high. Practically all wood contains some air space but the higher the specific gravity is, the less air space the wood contains.

The specific gravity of wood is not only different for different species but it also varies somewhat within any species and even within the cross section of a single tree. In general, the wood at the center of a tree has a lower specific gravity than the wood near the outside of the tree or in the intermediate zone. The wood near the top of the tree is also weaker and of lower specific gravity than the average wood lower down in the tree. This is not strange because the wood near the top of a growing tree is center wood and, if the tree continues to grow in height and diameter, it will eventually be covered by wood of higher specific gravity.

Specific gravity is not a reliable indication of resistance to decay fungi or insects. Some very light woods are high in decay and insect resistance and some are low in these qualities. Similarly some woods of high specific gravity are high in resistance to decay and insects and others are not. In general, it appears that the resistance of durable woods to fungi and insects results from the presence of certain extractives in the wood which are toxic or repellent to the destructive agents. If these extractives are present in sufficient quantities they may increase the specific gravity somewhat but in general, their quantity is limited.

For most common uses, woods of intermediate specific gravity are preferred but for limited special uses the very heavy or the very light woods may prove useful. The usefulness of wood is also influenced by numerous other characteristics such as color, figure, texture, odor, taste, machining properties, finishing properties, durability, permeability, and others.

In surveying the mechanical and physical properties of Philippine woods, the FPRI has already made specific gravity determinations on many species. The accompanying table gives average specific gravity and density values for about 80 species that have been tested thus far, including most of the species in common commercial use.

HOW TO DETERMINE SPECIFIC GRAVITY

Two facts about a piece of wood must be determined in order to compute its specific gravity. These are its volume (commonly in the green condition) and its weight when oven dry.

Volume of the green wood may be determined by actual measurement or by weighing the amount of water displaced when the wood specimen is submerged in a weighed container of water. This is done by placing a container of water of suitable size on one pan of a balance and placing weights on the other pan to balance it. Then the piece of wood whose volume is to be determined is impaled on a fine-pointed tool held in a clamp on a ring stand and forced below the surface of the water. The additional weights required on the other pan to bring the system again into balance are equal to the weight of the water displaced by the wood, assuming of course that no water is absorbed by the wood during the weighing. Absorption can be avoided by soaking the wood in another container of water for awhile before weighing. The weight of the displaced water in grams is equivalent to the volume of the wood in cubic centimeters. For maximum accuracy, however, the water temperature would be taken and a temperature correction applied in the calculations.

The oven-dry weight of the wood is determined by placing the specimen in a temperature-controlled oven maintained at a temperature of about 102°C. Small specimens can be dried moisture free in 24 to 48 hours under such conditions. The moisture-free or oven-dry condition is reached when successive weighings show no further loss in weight.

The specific gravity is then calculated by dividing the oven-dry weight of the wood in grams by the grams of water displaced by the wood. Or, if the volume of the wood has been determined by measurement, the oven-dry weight is divided by the volume in cubic centimeters. This id done because 1 cc. of water (at the correct temperature) weighs 1 gram. When English units of measurement and weight are used, conversion factors must be employed because, in the English system, no such simple relation exists between weight and volume of water as in the metric system.

The above method is usually employed where a more exact specific gravity value is required. A practical method of estimating the specific gravity of wood which requires less time and equipment is by the flotation method. This method is less accurate than the standard laboratory process but it is useful for producers and suppliers seeking a quick specific gravity test to guard against the use of under-weight material and at the same time, avoid the rejection of wood of acceptable specific gravity. This method is accurate enough to detect up to 90 percent of stock which should be rejectable for light weight.

The method consists of determining the submerged proportion of a piece of wood with parallel sides when it is floated in water. The piece of wood to be tested is cut to 1-inch square in cross-section and 10 inches long and is marked into 10 equal divisions of 1-inch. When the test piece is floated on end in a narrow vessel of water, its specific gravity at the current moisture content can be determined by noting the length of the submerged portion of the piece, expressed as a decimal fraction of the total length.

HOW TO DETERMINE DENSITY

Density is determined simply by weighing the specimen and determining its volume, then expressing the result in terms of weight per unit of volume and stating the condition of the wood. Thus density may be expressed in pounds per cubic foot when green or when air dry. With lumber, density is sometimes expressed as pounds per thousand board feet "shipping dry", which means at a moisture content of about 20 percent.

Density figures on U.S. woods are sometimes published as pounds per cubic foot at 12 percent moisture content. The green values may also be given in a parallel column.

The approximate density of wood at an assumed moisture content can be calculated from the specific gravity, using a formula such as

$$Dm = S\ (1 + \frac{m}{100})$$

in which D = density in grams per cc
m = moisture content assumed
S = specific gravity based on green volume and oven-dry weight

At an assumed moisture content of 20 percent, the formula would be

$$D_{20} = S\ (1 + 0.2)$$

The result, in grams per cubic centimeter, can be converted into any other units desired by using the proper conversion factors. The value obtained by this formula is only approximate because the formula does not take into consideration the shrinkage in volume in drying from the green condition to 20 percent moisture content. This could be taken care of by a more complicated formula if the volumetric shrinkage of the species is known.

Density values for moisture contents above 30 percent would be correct but, for moisture contents below 30 percent, the density values obtained by this formula will be somewhat low.

Although calculations such as the foregoing could be made for the weight of lumber per thousand board feet in the shipping dry condition, it is not safe to rely on them for that purpose. Lumber may be cut over-size or under-size and the volume of the commercial quantity called 1000 board feet may vary considerably on that account. Transportation companies and lumber shippers are accustomed to using average weights per thousand board feet obtained by weighing actual shipments.

AVERAGE DENSITY AND MEAN SPECIFIC GRAVITY OF SOME WOODS FROM THE WET REGIONS OF THE PHILIPPINES

Common and scientific name	Moisture content at test (percent)	Mean specific gravity[1]	Density (lbs/cu.ft.) based on	
			Wt. & volume at test	Wt. & volume at 12 percent M.C.
AFU (Anisoptera brunnea Foxw.)	106.5	0.54	69.6	41.4
AGOHO (Casuarina equisetifolia L.)	56.7	0.83	81.2	66.8
ALMACIGA (Agathis philippinensis Warb.)	97.0	0.44	54.1	33.2
ALMON (Shorea almon Foxw.)	106.5	0.39	50.2	29.3
ANANG (Diospyros pyrrhocarpa Miq.)	82.6	0.62	70.4	47.8
ANANG-GULOD (Diospyros inclusa Merr.)	72.1	0.68	73.0	53.4
ANILAU (Columbia serratifolia Cav. DC.)	160.2	0.37	60.1	27.4
ANONGO (Turpinia ovalifolia Elm.)	158.0	0.36	58.0	26.7
APANANG (Neotrewia cumingii Muell.-Arg. Pax and K. Hoffm.)	94.3	0.55	66.7	41.9
APANIT (Mastixia philippinensis Wang.)	115.0	0.49	65.7	37.3
APITONG (Dipterocarpus grandiflorus Blanceo)	84.0	0.63	72.3	49.0
APITONG ROUND-LEAVED (Dipterocarpus orbicularis (Foxw.)	95.1	0.58	70.6	44.4
ATA-ATA (Diospyros mindanaensis Merr.)	64.5	0.69	70.9	54.4
BAGTIKAN (Parashorea plicata Brandis)	106.7	0.48	61.9	36.5

1 Based on weight when oven dry and volume when green. Data released for publication gave the specific gravity values to three decimal places, but for convenience they were rounded off to two decimal places in this Technical Note.

BALAKAT-GUBAT (Sapium luzonicum Vid. Merr.)	153.0	0.38	60.0	28.5
BALIKBIKAN (Drypetes bordenii Merr. Pax and K. Hoffm.)	69.4	0.75	79.3	59.9
BATINO (Alstonia macrophylla Wall.)	106.6	0.60	77.4	46.2
BINGGAS (Terminalia citrina Gaertn. Roxb.)	66.9	0.74	77.1	58.5
BOKBOK (Xanthophyllum excelsum Blume Miq.)	92.9	0.63	75.8	48.8
BOLON (Alphonsea arborea Blanco Merr.)	66.0	0.70	72.5	55.1
DAGANG (Anisoptera aurea Foxw.)	121.7	0.54	74.6	41.1
DALINGDINGAN (Hopea foxworthyi Elm.)	73.3	0 62	67.0	47.8
DANGKALAN (Calophyllum obliquinervium Merr.)	78.6	0.60	66.9	46.5
DITA (Alstonia scholaris L. R. Br.)	131.0	0.38	54.8	28.0
DUKTULAN (Syzygium luzonense Merr. Merr.)	86.1	0.62	72.0	48.4
GUBAS (Endospermum peltatum Merr.)	191.1	0.31	56.3	22.5
GUIJO (Shorea guiso Blanco Blume	72.8	0.70	75.4	54.8
HAGAKHAK (Dipterocarpus warburgii Brandis)	96.4	0.52	63.7	39.9
HIMBABA-O (Allaenthus luzonicus Blanco F.--Vill.)	132.8	0.43	62.5	31.9
IPIL (Intsia bijuga Colebr. O. Ktze.)	95.9	0.68	83.2	53.1
IPIL-IPIL (Laucaena glauca L. Benth.)	79.1	0.73	81.6	58.2
KALANTAS (Toona calantas Merr. and Rolfe)	92.1	0.56	67.1	43.0
KAMATOG (Erythrophloem densiflorum Elm. Merr.)	74.8	0.69	75.2	54.6
KATILMA (Diosphyros nitida Merr.)	67.8	0.70	73.3	55.5
KATONG-MATSIN (Chisocheton pentandrus Blanco Merr.)	127.0	0.52	73.7	39.5

KATURAI (Sesbania grandiflora L. Pers.)	180.1	0.40	69.9	29.6
KUBILI (Cubilia cubili Blanco Adelb.)	116.5	0.49	66.2	36.9
KUPANG (Parkia javanica Lam. Merr.)	223.6	0.34	68.7	25.5
LAMOG (Planchonia spectabilis Merr.)	103.6	0.55	69.8	42.3
LANIPAU (Terminalia copelandii Elm.)	106.3	0.47	60.5	35.5
LANUTAN BAGYO (Gonystylus macrophyllus Miq. Airy-Shaw)	109.5	0.50	65.4	38.0
LANUTAN, VIDAL'S (Bombycidendron vidalianum Naves Merr. and Rolfe)	93.2	0.53	63.9	40.8
LANUTAN, YELLOW (Polyalthia flava Merr.)	111.4	0.51	67.4	38.9
LAUAN, RED (Shorea negrosensis Foxw.)	97.7	0.46	56.8	34.7
LAUAN, WHITE (Pentacme contorta Vid. Merr. and Rolfe)	122.0	0.42	58.2	31.2
LIUSIN (Parinarium corymbosum Blume Miq.)	63.5	0.74	75.5	58.5
MAHOGANY BIG-LEAVED (Swietenia macrophylla King)	138.0	0.45	66.8	33.5
MALABAYABAS (Tristania decorticata Merr.)	46.8	0.94	86.1	77.5
MALABULAK (Gossampinus malabarica DC. Merr.)	252.0	0.27	59.3	19.4
MALAPANAU (Dipterocarpus kerrii King)	88.2	0.58	68.1	45.1
MALATAPAI (Alangium longiflorum Merr.)	89.3	0.64	75.2	49.5
MALIBAYO (Berria cordifolia Willd. Burr.)	118.4	0.57	77.8	43.8
MALUGAI (Pometia pinnata Forst.)	100.3	0.56	70.0	43.1
MANARING (Lithocarpus soleriana Vid. Rehd.)	81.8	0.63	71.4	48.8
MANGGACHAPUI (Hopea acuminata Merr.)	82.7	0.63	71.9	48.8

MANGGASINORO (*Shorea philippinensis* Brandis)	133.5	0.39	56.8	29.0
MAYAPIS (*Shorea squamata* Turcz. Dyer)	139.6	0.37	55.3	27.7
MIAO (*Dysozylum euphlebium* Merr.)	71.8	0.66	70.7	51.5
MOLAVE (*Vitex parviflora* Juss.)	68.8	0.71	74.8	56.0
NARIG, THICK-LEAVED (*Vatica pachyphylla* Merr.)	86.6	0.62	72.1	48.5
NARRA (*Pterocarpus indicus* willd)	119.1	0.50	68.4	37.8
PANAU (*Dipterocarpus gracilis* Blume)	83.2	0.63	72.0	48.8
PANGLONBOIEN (*Syzygium simile* Merr. Merr.)	105.1	0.56	71.6	43.0
PIANGA (*Madhuca obovatifolia* Merr..Merr.)	96.0	0.60	73.3	46.4
PINE, BENGUET (*Pinus insularis* Endl.)	65.9	0.59	61.1	46.0
RAINTREE (ACACIA) (*Samanea saman* Jacq. Merr.)	154.8	0.49	77.8	36.9
SAKAT (*Terminalia nitens* Presl.)	97.1	0.57	70.2	43.5
SANTOL (*Sandoricum koetjape* Burm.f. Merr.)	107.3	0.46	59.6	34.8
SPANISH CEDAR (*Cedrala odorata* L.)	169.0	0.38	63.8	28.6
TAINGANG-BABUI (*Gonocaryum calleryanum* Baill. Becc	81.9	0.63	71.5	49.0
TANGILE (*Shorea polysperma* Blanco Merr.)	92.8	0.47	56.5	35.9
TEAK (*Tectona grandis* L.f.)	118.2	0.49	66.7	37.4
TOOG (*Combretodendron quadrialatum* Merr. Merr.)	94.0	0.57	69.0	43.8
TUAI (*Bischofia javanica* Blume)	124.4	0.53	74.2	40.3
TULO (*Alphitonia philippinensis* Braid)	139.9	0.40	59.8	29.6
YAKAL-GISOK (*Shorea gisok* Foxw.)	54.6	0.81	78.2	64.7
PAHUTAN (*Mangifera altissima* Blanco	104.7	0.55	70.2	72.5

17. POINTERS ON MANUFACTURING FURNITURE FOR SHIPMENT TO THE UNITED STATES

Much furniture made in the Philippines and exported to the United States or taken home from the Philippines by U. S. residents gives trouble from checking, warping or opening of joints after it has spent one or two winters in the United States. The cause of these defects is the drying of the wood during the winter time in heated buildings. Wood in the living tree may be 1/2 water, or even more. When cut into lumber and exposed to the air most of the water evaporates and the moisture content of the wood finally attains an approximate balance with the relative humidity of the air. After that point of equilibrium is reached, the wood attempts to keep its moisture content in balance with the relative humidity of the air. That is constantly changing, however, and so rapidly and frequently that the wood cannot keep up with it. The best the wood can do is to remain approximately in equilibrium with the average relative humidity of the air.

In the Philippines the average relative hudidity is high in comparison with the humidities prevailing in most of the United States. Wood furniture in buildings in the Philippines normally has a moisture content close to 15 percent which does not change greatly throughout the year because Philippine buildings are not heated and the windows are usually kept open. In the United States, the average relative humidites of the outdoor air vary somewhat in different parts of the country, being fairly low in Arizona, New Mexico, Nevada and similar climates in other States and fairly high along the Gulf of Mexico, the Atlantic Coast and the North Pacific Coast. In practically all parts of the United States, however, even during summer weather, the average relative humidity is lower and the moisture content of air-dry wood is lower than in the Philippines. The moisture content of wood in buildings during the late summer time in much of the United States may get as high as 9 or 10 percent. It may be somewhat higher than this along the Gulf of Mexico and considerably lower in dry western climates like that of Arizona. During winter, when outdoor temperatures are low and buildings are heated, the indoor relative humidities become very low and the moisture content of wood furniture under some conditions may drop as low as 4 or 5 percent.

If a piece of furniture from the Philippines, with a moisture content of 15 percent, is moved into a heated building in the United States in the late fall or winter, it will lose moisture rapidly in trying to get in balance with the low relative humidity prevailing. The loss of moisture causes the wood to shrink considerably which frequently results in checking, warping, or opening of joints, to the great dissatisfaction of the owner.

Wood shrinks considerably in drying from about 30 percent moisture content to lower moisture content values and the greater the loss of moisture the greater the shrinkage. Boards shrink in width and thickness but do not shrink significantly in length. The shrinkage in width is less in boards cut in the direction of the radius of a log (radial shrinkage) than in boards cut in the direction at right angles to the radius (tangential shrinkage). Some species of wood shrink considerably more than others with the same moisture loss and thus are more likely to give trouble.

Another factor that enters into the behavior of wood in drying is the ability of wood to adjust itself in some degree in tensions or stresses set up as it shrinks. Thus, if wood is dried carefully and slowly it can usually be dried with little or no checking. This is basic in successful kiln drying. If it is dried unevenly or too rapidly, however, the shrinkage stresses become so severe that they are more than the wood can resist and they are relieved by checking or warping.

The design, construction and finishing details of a piece of furniture also have an influence on its behavior during drying. Design and construction details that permit slight movement of the wood as it shrinks are less likely to result in checking and warping than those that resist all movement. Finishing all surfaces of the wood increases the possibility of avoiding checking or warping in comparison with the normal practice of finishing the exposed surfaces only. Lacquer, varnish, paint and wax finishes do not prevent moisture changes but tend to make the changes take place more slowly. If a table top is finished on the exposed surface but has no finish on the under surface, loss of moisture will be more rapid from the under surface. This will favor uneven drying as well as more rapid drying and encourage the development of internal stresses which favor warping and checking.

The foregoing discussion, although incomplete and technically inadequate, points to some of the important factors that influence the performance of wood furniture and gives the reasons for some of the precautions recommended.

Some furniture manufacturers understand the importance of low moisture content in furniture for shipment abroad and they may be able to dry their lumber to 6 or 8 percent moisture content before manufacturing it into furniture. But wood dried to such a low moisture content in the Philippines will begin to absorb moisture immediately and gradually will come back toward

15 percent. If the low moisture content is to be retained, therefore, the furniture must be manufactured and shipped out of the country promptly so that it does not have time to come back to normal Philippine moisture content. If the manufacturer has storage facilities, however, where the relative humidity of the air is maintained at 40 to 50 percent, either by heating or dehumidifying the air, the wood of the furniture can be held at a relatively low moisture content suitable for export. Unless a concern is equipped to dry the rough lumber to 5 to 8 percent, to store the finished product under suitable conditions and to provide protection against reabsorption of moisture during cargo shipment, it is not advisable that it should undertake to export furniture to the United States.

Most furniture manufacturers in the Philippines are not equipped for kiln drying or for humidity control in store rooms. They try to get their lumber reasonably dry but do not always attain even that objective.

The species of wood from which the furniture is made has an important influence on its behavior. Some species shrink less than others in drying and in this respect are preferable for furniture. Narra is one of the best of the native Philippine woods in this respect. The so-called acacia (rain tree or monkey-pod wood), which is found to a limited extent in the Philippines, has even lower shrinkage than narra. This wood is seldom made into furniture other than small coffee tables but is commonly found in novelties and carvings of various kinds and these, when made of this species, seldom give trouble in the United States. Other species can be and are used, of course, but the greater the shrinkage the greater the care required.

18. DETERMINING THE MOISTURE CONTENT OF WOOD

All wood in service contains water, even wood that has been dried. The amount of water in any piece of wood depends on its degree of dryness or, as commonly stated, its moisture content. This, in turn, depends upon the conditions to which the wood is exposed in service. In the lumber trade and in wood technology in general, the moisture content of wood is expressed as a percentage of the weight of the wood when oven dry. A piece of wood cut from a newly felled tree or from a log in the sawmill may contain as much water as wood. In that case it would be said to have a moisture content of 100 percent, meaning that water is present to the extent of 100 percent of the weight of the oven-dry wood. Different species of trees differ in the amount of water their wood contains and, even in a single tree, the moisture content may vary in different parts. In some species the sapwood portion of the "green" or freshly cut wood may have a moisture content as high as 200 percent, in which case, water constitutes two thirds of the total weight. In other species the moisture content of the heartwood may be as low as 35 or 40 percent.[1]

The moisture content of wood is determined by weighing a small piece of wood, then drying it in an oven maintained at a temperature of approximately 103 degrees Centigrade until its weight becomes constant, as shown by repeated weighings. The moisture content is then calculated by dividing the loss in weight by the weight of the oven-dry sample, using the following formula:

$$\text{Percent M.C.} = \frac{W_1 - W_2}{W_2} \times 100$$

In this formula, W_1 means initial weight and W_2 means oven-dry weight. Multiplying by 100 converts the result from a decimal into percentage.

In the determination of the moisture content of lumber in a pile, it is impractical to determine the moisture content of each piece in the pile. Obviously, therefore, it will be nçessary to pick at random a few representative pieces from the pile from which the small moisture sample can be prepared. The number of boards taken for sampling should depend upon the size of the pile and the accuracy of estimates desired.

The moisture content of moderately dry wood can be readily determined by certain electrical instruments called "moisture meters". These meters give good results when maintained in correct adjustment and used properly, with suitable species correction factors, by skilled operators. They can be very misleading otherwise. Species corrections for resistance-type moisture meters for a number of Philippine commercial species are available from the Forest Products Research Institute.

When using the oven-drying method of determining moisture content of boards, moisture samples are cut at least two feet

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1 Although the moisture content of green wood varies widely, all species approach the same moisture content when used in buildings, depending on the average relative humidity of the surrounding air. In the Philippines the moisture content of dry wood in buildings averages in the vicinity of 15 percent. See Technical Note No. 1, "The Moisture content of wood in relation to air humidity".

from one end of each sample board selected. Moisture samples cut too close to the end of a board are not reliable as a measure of the average moisture content of the board. These moisture samples should be about one inch or less in length along the grain and should include the entire width of the board and as soon as each moisture sample is severed from the board it should be freed from slivers and immediately weighed on a good balance accurate to one-tenth gram. This gives the green weight. The accuracy of the result obtained depends largely upon the accuracy of the weighing. The size of specimens also affects the accuracy and the smaller the specimens used, the greater is the need of accuracy in weighing.

If an oven is to be used, any suitably designed oven with thermometer well so that a thermometer can be provided to indicate temperature during the drying period will suffice. The temperature should, however, be kept as nearly as possible within two degrees of 103 degrees Centigrade. The specimens should be separated from each other in the oven so that the hot air can circulate freely around all sides of each specimen. The length of time the specimens must remain in the oven depends in part on the size of the specimens and also on the drying conditions. Ordinarily 24 to 48 hours should be sufficient. The specimens may be weighed after 24 hours and then again after a few more hours. If there is no further loss in weight, they have reached "constant weight". The final weighing gives the "oven-dry" weight from which the moisture content can be calculated.

Example: Once the oven-dry weight is obtained, the moisture content of the particular specimen can be determined by the formula given above. Suppose that a specimen had a green weight of 12.90 grams while its oven-dry weight was 11.82 grams, then its moisture content is calculated as follows:

$$M.C.\% = \frac{12.90 - 11.82}{11.82} \times 100$$

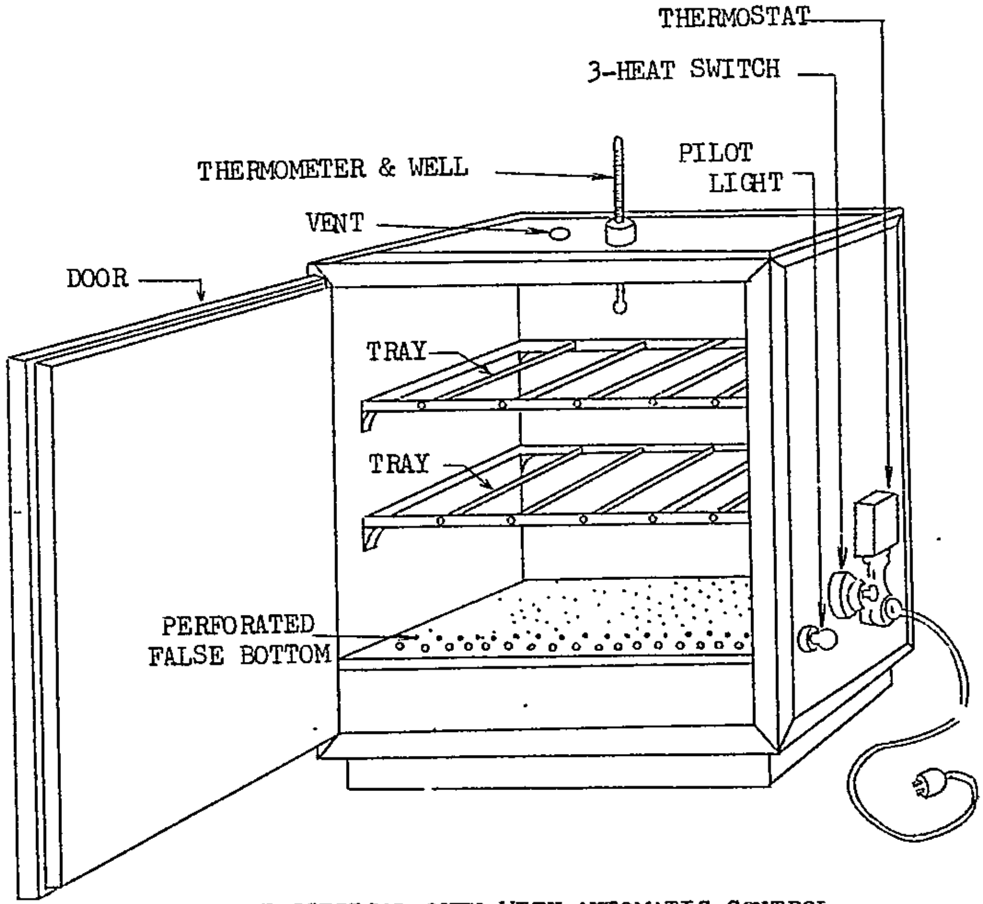
$$= \frac{1.08}{11.82} \times 100 = 9.1 \text{ percent}$$

Construction of an Oven

A simple electric- oven may be constructed as a double-wall box primarily from aluminum or copper sheets and asbestos cement boards. The walls, which should be insulated with fiber-glass wool, may be made by laying the aluminum or copper sheets on "dexion" frames or high density wood frames, although "dexion" frames are more preferable for longer service. The outside walls should be welded with the inside walls to form solid walls at all sides, top, and bottom of the box.

The top should be provided with two through-perforations between 1/2 and 3/4 inch in diameter. One of them will serve as a thermometer well and the other as a vapor vent. There should be a door at the front, which should be well fitted in the opening to minimize heat leakage.

To connect the heating coils, which are placed at the bottom of the oven, to the 3-heat switch, the pilot light, and the thermostat, as seen in the sketch, usually a number of perforations through the right side wall of the oven are provided.



ELECTRICAL OVEN WITH AUTOMATIC CONTROL

Inside the oven, two drying trays to hold specimens may be made of any suitable wire mesh or iron grills to allow hot air circulation around the wood. To protect the heating coils from chance falling of slivers from the drying wood and the eliminate fire hazards, a false bottom should be provided just above the heating coils. This false bottom should be made of perforated asbestos cement board. The perforations may have a diameter of about 1/8 inch and the distance between perforations may be about two inches.

19. LAMINATED WOOD, ITS MANUFACTURE AND USES

The mounting demand for glued laminated wood constructions, the improvements in glues and the development of gluing techniques are making the wood-laminating industry grow in importance.

Glued laminated wood consists of boards or laminae bonded together, either in straight or curved form, with their grain directions parallel to each other. Laminated wood is fundamentally different from plywood because in the latter the adjacent veneers or plies are almost always glued with their grains at right angles to each other.

A wood lamination may be of any desired thickness and length provided that it can be bent to the required curvature without any evidence of failure. It could be made of short pieces jointed end to end to form longer laminae, or of narrow pieces glued edge to edge to form wider ones. These factors permit a vast choice in design features, limited only by the service demanded of the laminated products. To obtain a satisfactory glued-laminated assembly, several requirements must be fulfilled. Following is a discussion of some of those requirements.

Seasoned wood is vital in wood lamination. Wood must be dried uniformly to a moisture content approximately equal to that expected in service. A difference of not more than 5 percent moisture content, for example a range of 6 to 11, or 10 to 15 percent, between laminations in a single assembly is recommended. This will avoid serious moisture content changes within the assembly and help to avoid the glue-line stresses induced by moisture changes while in service.

Flat-grain or plain-sawn lumber shrinks and swells more in width than vertical-grain or quarter-sawn[1] lumber of the same size. In a laminated assembly this difference in shrinkage between the two adjacent boards can result in severe glue line stresses. To minimize this, lumber for laminated constructions should be segregated into plain-sawn and quarter-sawn lots. It is advantageous not to mix flat-grain and vertical-grain boards in any laminated assembly.

It is always advisable to rough-surface lumber for laminating as a first step. Although of secondary importance, rough surfacing helps to disclose natural and seasoning defects, aids in the separation of wood according to grain, sapwood and heartwood, and facilitates the elimination of undesirable pieces. It helps attain boards of uniform thickness. A double surface planer is adaptable for this operation.

When long laminations are desired from shorter pieces, the boards are end-jointed. The plain-scarf, hooked-scarf, finger- and serrated-scarf joints are commonly used. When wider laminations are required, edge gluing is done. Some types of tongue- and groove-joints have been used to facilitate edge alignment but they involve greater loss of effective gluing surface than plain joints.

The final surfacing of the stock before assembly gluing is one of the most important operations in the manufacture of laminated wood products. The quality of the finished product depends largely on the accuracy and care with which this operation is conducted. For maximum glue joint strength and durability, the mating faces must be cleanly machined and accurately fitted.

Final surfacing can best be done first on a jointer and then on a cabinet planer equipped with well-fitted cutter head mounted on ball bearings. The surfacing operation must be a light cut not more than 1/16-inch at a pass through the planer. Knife marks must hardly be visible on the finished surfaces. Feed rates and cutterhead speed resulting in 20 to 30 knife marks per inch have been found satisfactory.

The success in manufacturing glued laminated products also depends much on the use of the right glue and following the right gluding procedures. Most commonly used for this purpose

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1 These terms refer to the direction of the growth rings of the tree with reference to the faces of the board. If the smaller of the two angles formed between the growth rings and the wide face of the board is less than 45 degrees, the board is classed as flat sawn. If the smaller angle is greater than 45 degrees the board is classed as quarter sawn.

in the Philippines are resorcinol or phenol-resorcinol, fortified ureas and casein glues. The more durable resorcinol or phenol-resorcinol resin glues would be the best choice for laminated timbers for exterior service in the Philippines because the moisture conditions are too high to permit the use of casein glues. The use of urea-resin glues is questionable because of the observed reductions in strength of glue joints subjected to somewhat high temperatures and humidity conditions prevailing in this country. Each type of glue has a recommended procedure for preparation and application. To attain strong and durable glue joints, these recommendations must be followed carefully.

Various means are used in applying pressure to the laminated assembly. Hydraulic and screw presses may be used for pressing straight members glued with room-temperature-setting glues. With adjustable jigs and pull-down or draw-up clamps, retaining clamps serve best for pressing curved members. The use of screws or nails has not been thoroughly investigated but, in general, nailing as a means of applying pressure is not recommended for high-strength laminated members. However, for some kinds of work nail gluing has been found practical. For laminated assemblies (glued with elevated-temperature-setting glues) requiring transfer from the gluing room to the curing chamber, heavy presses are impractical to use because of their heavy weight. Instead, light presses and retaining clamps are used.

To attain intimate contact between glued surfaces, uniform pressure must be applied to laminated assemblies. Since it is hard to locate clamps close together and simultaneously apply uniform pressure directly to all points on the glue joint-area, caul planks are placed between the clamps and the glued assembly while pressing. For straight laminated assemblies, thick cauls are suitable. In case of curved members of short radius of curvature, two or more thin cauls on each face of the assembly are more effective.

Unless chemical reaction and loss of solvent in the glue are completed, the laminated assembly is inadequately cured. For adequate curing, some glues require ordinary room temperature while others demand higher temperatures. Manufacturers of modern glues always recommend both curing time and temperature for their glues.

Glued laminated assemblies must be machined to final dimension only after they are fully cured. This will prevent occurrence of sunken joints which are objectionable where good surface appearance is a requisite.

Under continuously dry conditions, such as in the interior of buildings or in the case of equipment, furniture and fixture used inside buildings, where the wood is protected from exposure to extreme conditions of weather and atmosphere, the glue joints will last as long as the wood if proper glue is used and the and the gluing is well done. Good joints could be attained with animal hide, casein and polyvinyl resin glues and unextended cold-setting urea-resin glue. Due to the humid conditions and often times high temperatures which prevail in most parts of the Philippines, the use of casein, animal hide, polyvinyl resin or even urea glues is of doubtful reliability and may not furnish the length of service required of certain structure. Until further research has established the reliability of these glues under Philippine conditions their use in important structures is not recommended.

Laminated wood products may be used for implement parts, bridges and marine equipment which are subjected to cycles of soaking or wetting and drying, and variations in temperature. The glue for such uses must be highly resistant to water, heat and decaying organisms. These can be met by resorcinol or phenol-resorcinol resin glues with their corresponding cold catalyst or hardener. The wood also must be naturally durable or made so by adequate preservative treatment. For large or irregular shaped products, the preservative treatment may have to be applied before gluing but where the size and shape of the finished products permit, preservative treatment may be applied after gluing and finishing to final dimensions.

Glued laminated wood has some very distinct advantages over other materials of construction. Among these are the following:

(a) Properly designed glued laminated wood structures have greater strength per unit weight than steel.

(b) They have higher safety qualities as in cases of sudden shock and stresses.

(c) They are slightly affected by heat and cold and are themselves excellent insulators against these extremes. If constructed with large cross-sections, these structures are, even if untreated, much more fire-resistant than steel.

(d) They take varnish and paint readily, and being already beautiful in themselves, furnish excellent architectural effects. when used as materials of construction.

Some species of wood are more difficult to glue satisfactorily than others. For this reason, a survey of the gluing properties of commercial Philippine woods has been started at the Forest Products Research Institute to determine which species, if any, require special precautions in gluing. A urea formaldehyde resin glue in powder form with HGE cold catalyst and a phenol-resorcinol glue in liquid form with FM 124 cold catalyst are being utilized. Preliminary results of the study on almon, apitong, dagang, manggasinoro, mayapis, red lauan, round-leaved apitong, white lauan, tangile and thick-leaved narig indicate the suitability of these species for laminating. The study is being continued.

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20. PHILIPPINE MAHOGANY

Philippine mahogany is a distinctive trade name for the premier Philippine commercial woods which are light reddish to reddish-brown in color and show ribbon-grain or mahogany figure. It is commercially important because of its beauty, workability, versatility, relatively low price and abundance in various sizes and forms. Uses for it range from fine cabinet work to the rugged planking of sea-going vessels, particularly in modern home construction. The Forest Products Research Institute has found it suitable for veneer and plywood, and its waste or residue promising for pulp and papermaking.

As regards wood quality, uses and beautiful finish, Philippine mahogany is similar to the tropical American mahogany (Swietenia macrophylla King), the West Indian mahogany (S. mahagoni Jacq.) and the African machogany (Kaya ivorensis A. Chev.). Its inherent beauty in color, grain and figure, fine texture, the ease of working it and its high-finishing property altogether have earned for it an enviable position not only in the American lumber market but also in the international trade.

In international trade, it is a "must" to use the prefix "Philippine" to the word mahogany. In the use of this term, Philippine mahogany has always maintained and justfied its long-established fair competition in the international market and this has been duly recognized by the U.S. Federal Trade Commission since 1931 and repeatedly affirmed by it in 1932, 1934, 1947, 1957 and 1960. With this reputation, the international market has absorbed increasing quantities of Philippine mahogany. In 1957, Philippine mahogany lumber exports amounted to 57,727,000 board feet shared by more than ten countries as follows:

1.	United States	67	percent
2.	Okinawa	10	"
3.	Hongkong	3	"
4.	Hawaii	2	"
5.	Canada	1.5	"
6.	England	0.9	"
7.	Formosa	0.6	"
8.	Belgium	0.5	"
9.	Denmark	0.3	"
10.	Guam	0.2	"
11.	Others	14.0	"

Also in 1957, log exports amounted to 880,988,000 board feet (valued at 47,127,726) shared by only eight countries as follows:

1.	Japan	89	percent
2.	United States	4	"
3.	Taiwan	3.3	"
4.	Korea	2.4	"
5.	England, Italy, Australia and Germany	1.3	"

Phillippine mahogany, therefore, has been a supporter of the Philippine economy. Next to copra and sugar as export products, its annual dollar earning is the highest and helps greatly in replenishing the dwindling dollar reserves of the country. As an industry, it provides employment to about 4 percent of the country's population. This will continue to benefit the Philippines so long as the potential standing timber of Philippine mahogany, 267 billion board feet, is properly managed on a sustained-yield basis.

Species and Brief Notes on Philippine Mahogany

Philippine mahogany, according to the grading rules of the United States National Hardwood Lumber Association, consists of seven species of the Dipterocarpaceae. These are classified into two groups, namely:

a. Philippine red or dark red mahogany (red lauan)
   Species: red lauan, tangile and tiaong

b. Light red Philippine mahogany (white lauan)
   Species: almon, mayapis, white lauan and bagtikan

1. Red lauan (Shorea negrosensis Foxw.)

Tree features

Tree.- Large, buttressed.
Bole.- Straight, cylindrical, very slightly-tapered.
Crown.- Small, irregular, open, with few large branches.
Leaves.- Simple alternate, elliptic ($1\frac{1}{2}$ to $2\frac{1}{2}$ inches wide and $4\frac{1}{4}$ to $6\frac{1}{2}$ inches long), upper surface smooth and dark green stellate hairs along veins beneath, base rounded, apex acuminate.
Bark.- Dark brown to reddish black, flakes off in rectangular scales (2 to 4 inches long and $\frac{1}{4}$ to $\frac{1}{2}$ inch wide).
Inner bark.- Reddish, stringy.

Wood features

Sapwood.- Straw color, 2 to $2\frac{1}{2}$ inches thick.
Heartwood.- Brick red.
Wood.- Homogeneous, coarse-textured, slightly lustrous, distinctly ribbon-grained when quarter-sawn, takes stains very easily, finishes highly, works easily with common tools, has high glue-, paint- and nail-holding capacity, but not resistant to decay.
Uses.- Most uses of American mahogany, furniture, cabinets, general house construction, veneer and plywood, sash, boat planking and decking.
Supply.- Abundant, estimated standing timber 45.8 billion board feet.

2. Tangile (Shorea polysperma (Blco.) Merr.)

Tree features

Tree.- Large, seldom strongly-buttressed
Bole.- Like red lauan in form.
Crown.- Dense, widely spreading, irregularly conical and dome-shaped.
Leaves.- Simple, alternate, ovate-lanceolate (2 to $5\frac{1}{2}$ inches long and $1\frac{1}{4}$ to 2 inches wide), shiny, upper surface dark green, lower surface light green, base rounded, apex long-acuminate.
Bark.- Light red, 2 to $2\frac{1}{2}$ inches thick, sheds off in irregularly-shaped scales.
Inner bark.- Red, stringy.

Wood features

Sapwood.- Straw color, 1½ to 2 inches thick, distinct from heartwood.
Heartwood.- Red to dark brownish-red.
Wood.- Fine-textured, cross-grained, fairly lustrous, beautifully ribbon-figured when quarter-sawn, seasons well, checks negligibly, moderately hard, weighs about 36 pounds per cubic foot, has high glue-, and nail-holding capacity, lasts long indoors, but not resistant to decay.
Uses.- All uses of red lauan.
Supply.- Abundant, estimated standing timber 49.3 billion board feet.

3. Tiaong (Shorea sp.)[1]

Tree features

Tree.- Large, resembles red lauan more than tangile.
Leaves.- Oblong to elliptic (1¼ to 2-3/8 inches wide and 2½ to 5½ inches long), smooth except midrib with few fairs, stipules larger than those of tangile.
Bark.- Reddish, 13/32 to 1 inch thick, not powdery to the touch as tangile, sheds in small flakes similar to guijo and apitong.
Inner bark.- Red, stringy.

Wood features

Wood.- Tangile-like, lighter color, softer, lighter weight (32 pounds per cubic foot), cross section has fewer resin ducts appearing as numerous broken lines than those appearing as solid lines in tangile.
Uses.- Same as tangile.

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1 The botanical name of tiaong has not been definitely established up to the present time. It was formerly known as Shorea teysmanniana Dyer, but according to Foxworthy, the description of S. teysmanniana by Symington, based on sterile botanical specimens, does not fit the Philippine species known as tiaong. He placed it under tangile (S. polysperma (Blco.) Merr.), although there are certain differences between the two species. Tamesis and Auilar treated it as an undetermined species belonging to the genus Shorea but separate from tangile (S. polysperma).

Supply.- Abundant in Laguna and Quezon; reported in several provinces including Mindanao (Agusan and Davao); estimated standing timber 0.7 billion board feet.

4. Almon (Shorea almon Foxw.)

Tree features

Tree.- Large.
Bole.- Regular, almost cylindrical, very evenly-shaped.
Crown.- Flat, irregular.
Leaves.- Simple, alternate, elliptic to ovate ($3\frac{1}{2}$ to 4-3/4 inches long and $1\frac{1}{2}$ to $2\frac{1}{2}$ inches wide), apex acuminate, base rounded, paperlike, blade flat or slightly convex.
Bark.- Smooth, ridgeless, light brown in young trees below 15 inches diameter; furrows long with flat ridges between them, dark brown or darker in older and bigger trees.
Middle bark.- Thin, with pitted dark brown layer.
Inner bark.- Light brown to slightly yellowish beneath the ridges.

Wood features

Sapwood.- Straw color, light brown transition.
Heartwood.- Light pink to light red.
Wood.- Cross-grained, coarse-textured, ribbon-figured when quarter-sawn, weighs 36 pounds per cubic foot.
Uses.- Furniture, various kinds of interior work, boat planking and decking, patterns, all other uses requiring moderately hard and comparatively light wood with beautiful "ribbon figure", plywood, lumber, rotary and quarter-sliced veneers.
Supply.- Abundant, estimated standing timber 6.4 billion board feet.

5. Mayapis (Shorea squamata (Turcz.) Dyer) Synonym: S. palosapis (Blco.) Merr.

Tree features

Tree.- Large, strongly buttressed.
Bole.- Form similar to red lauan.

Crown.- Dense, spreading, flatly conical.

Leaves.- Simple, alternate, oblong, ovate or elliptic, 4 to 8 inches long and 3 to 4 inches wide, upper surface smooth, lower surface hairy and rough, apex shortly acuminate, base cordate, thinly leathery, blade concave, closely similar to almon leaves which are smaller and with finer hair on the lower surface.

Bark.- Prominently ridged, 5/16 to 5/8 inch thick, brown to dark brown, gray when exposed to strong sunlight and black when wet.

Inner bark.- Stringy, brown to pink, with vertical white band beneath the furrows.

Wood features

Sapwood.- Light-colored, 1 to 2 inches thick.

Heartwood.- Red.

Wood.- Varies from sufficiently red to be able to pass as red lauan or tangile to light red to be taken for white lauan, glossy, lightest among Philippine mahogany (31 pounds per cubic foot), with volatile resin, resin ducts empty, log cross section shows concentric rows of resin ducts.

Uses.- Furniture, cabinets, cigar boxes, patterns, veneer and plywood.

Supply.- Abundant, estimated standing timber 46.5 billion board feet.

6. Bagtikan (*Parashorea plicata* Brandis) Synonym: *P. malaanonan* (Blco.) Merr.

Two species: (1) *P. plicata*, leaves whitish beneath, and (2) *P. warburgii*, leaves hairy and brownish beneath.

Tree features

Tree.- Large.

Bole.- Cylindrical.

Crown.- Irregular, vase-shaped.

Leaves.- Elliptic to ovate (2-3/8 to 6 inches long and 2 to 3-1/8 inches wide), upper surface light green, whitish beneath.

Bark.- Brown to almost black but grayish when exposed to sunlight, convex-faced ridges and furrows discontinuous, cambium white.

Wood features

Sapwood.- Light gray, 3/4 to 1½ inches thick, rather indistinct from heartwood.
Heartwood.- Grayish-brown.
Wood.- Cross-grained, moderately coarse-textured, moderately hard, moderately heavy (40 pounds per cubic foot), seasons well, works and holds nails like most woods of equal density, glues and takes stains very satisfactorily, strongest among the lauans.
Uses.- Furniture, cabinets, interior finish, ship and boat planking, patterns, veneer and plywood.
Supply.- Abundant, estimated standing timber 7.0 billion board feet.

7. White lauan (*Pentacme contorta* (Vidal) Merr. & Wolfe)

Two species: (1) *P.* contorta, found throughout the country, leaves less than 6 inches long, and (2) *P. mindanensis*, confined only to Agusan, Lanao, Zamboanga and Basilan, leaves over 6 inches long.

Tree features

Tree.- Large, more strongly buttressed with age.
Crown.- Flat, irregular, open.
Leaves.- Simple, alternate, ovate (length 4 to 5¼ inches, width about half the length), smooth, apex acuminate, base rounded, dark green, with 6 pairs of prominent and further apart secondary nerves that differentiate white lauan from other species.
Bark.- Brown to almost black, gray when exposed to sunlight, distinct longitudinal ridges throughout the bole in young trees and, in very old trees, less ridges and more scaly, concave-faced ridges more or less continuous, cambium yellow.

Wood features

Sapwood.- Light gray, 2 to 3½ inches thick, indistinct from the heartwood.
Heartwood.- Grayish when fresh, light pink when dry.

Wood.- Cross-grained, moderately coarse-textured, comparatively light (35 pounds per cubic foot), moderately hard, seasons well, very stable once dried.

Uses.- Boat planking and decking, furniture, cabinets, practically all uses of red lauan and tangile.

Supply.- Abundant, estimated standing timber 102 billion board feet.

Useful Guides in Wood Identification

To those who are engaged or concerned in the identification of Philippine mahogany, the following keys may be helpful:

A. Key to Philippine Red Mahogany

1. Wood, dark reddish-brown to brick red, coarse-textured; bark ridged, over 3/8 inch (10 mm.) thick ---------------------- Red lauan (Shorea negrosensis)

1' Wood, light red to reddish-brown, finer-textured than above; bark not ridged --------------------------- 2

2. Resin ducts in continuous line, filled with white resin; bark powdery and smooth to the touch -------------------------- Tangile (*Shorea polysperma*)

2'. Resin ducts in broken line, filled with white resin; bark not powdery, shedding in irregular flakes -------------- Tiaong (*Shorea* sp.)

B. Key to Light Red Philippine Mahogany

1. Wood, light red to reddish color ---------------- 2

2. Resin ducts filled with white resin, pores oblong in shape ----------------------- Almon (*Shorea almon*)

2'. Resin ducts empty, pores circular in shape ---------------------------------- Mayapis (*Shorea squamata*)

1'. Wood, light to gray in color ------------------ 3

3. Wood, grayish with reddish tinge ----------- White lauan (Pentacme contorta)

3'. Wood, grayish with a brown cast; heavier and harder than above ------------ Bagtikan (Parashorea plicata)

C. Card-sorting Key to Philippine Mahogany

The Forest Products Research Institute has devised a card-sorting key for the convenient and reliable identification of Philippine mahogany. This is now available from the Institute.

Keys A and B are bracket keys. To use either key, first examine the wood to be identified, noting its striking diagnostic features. For example, using A, compare these wood features with the features enumerated in number 1 on the left hand side and if they do not agree, make another comparison with the features in number 1'. If the features enumerated in 1' agree with the wood features, follow the broken line to the right up to number 2. On the left hand side find the corresponding number 2 and compare the wood features with the diagnostic features enumerated in this number, and if these features do not agree, compare the features enumerated in number 2' with the wood features. Should the wood and the enumerated features agree or tally with each other, follow the broken line to the right and you will find the common and scientific names of the wood being identified. In this particular case, the identification is tiaong (Shorea sp.).

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21. PAPER AND ITS IMPORTANCE IN DAILY LIVING

The word "paper" originated from papyrus, a cross-woven mat of Egyptian reeds (*Cyperus papyrus*) which was pounded into a hard thin sheet and used in ancient times as a writing material. Paper is the name now given to all kinds of matter or felted sheets of fibers formed on a fine wire screen from a water suspension.

Basically the fibers in a sheet of paper form a definite self-supporting structure or matrix due to their felting or bonding properties. The degree of bonding between the fibers in a sheet depends upon the fiber dimensions and their shape, the relation between these dimensions, their surface area relative to their mass, their chemical composition, flexibility and the mechnaical and chemical processing treatments given to them. The strength of the paper depends largely on the number of bonds between the surfaces of the adjacent fibers. The fiber to fiber bonding may be improved by mechanical treatment such as beating, rubbing, bruising, pounding or refining. This develops a gelationous surface condition so that when the fibers are felted and dried, the contact areas between them become cemented and the fiber matrix set.

Importance of Paper

The consumption of paper is often considered as an index of the industrial progress and standard of living of a nation. The statement that the higher the standard of living and the more progressive the nation, the larger is the amount of paper consumed might be called the "Paper Law."

However, paper is one of the commodities that has just been taken for granted. Few individuals recognize the importance that paper plays in our everyday life. Almost at all times of the day, we come in contact with paper, in one way or another, in its various forms, uses and applications. Paper is so essential and so closely connected with our daily lives that if it should suddenly disappear from the face of the earth the effect on communication, education, government, industry and commerce would be paralyzing. The status of paper has greatly changed from a purely cultural product used for books, newspapers and writing paper to a basic product, which, like steel, can be produced, modified and adapted for a multitude of uses. Bags and wrapping papers are widely used in the marketing of merchandise; corrugated and solid fiber boxes are replacing wooden crates for shipping many commodities; paper overlays are being used for veneer, plywood, lumber and hardwood panels; paper milk containers are now becoming standard in many countries, and a thousand more other uses.

Paper is one of the most versatile materials and has thousands of uses. We have paper money, bank books, checks, business records, certificates, bonds and stocks, Blueprints and specifications for houses, factories, machines, automobiles, etc. are made usually on paper.

As a result of constant research, hundreds of new and better paper products with different properties and applications are being developed. The future of paper and its uses is probably limited only by man's ingenuity. The quality of paper products has been modified and improved through the addition of resins, waxes, and sizing materials or in combination with plastics, glass fibers, metals and other materials; and by coating with resins, lacquers, glue or casein with or without fillers of clay or other mineral pigments.

Because of its lightenss, low cost, and availability, paper is used for packaging and shipping. Without paper containers it would be difficult to mass produce and distibute various materials and products. Paper has now truly become one of civilization's most useful products.

Kinds of Paper

There are hundreds of grades or classes of paper and paperboards each with distinct characteristics, properties and uses. The list is too long for all the kinds of papers to be included in this Note. Hence, only the major groups or classification of papers will be described.

Bond and writing papers

These papers closely resemble each other and are often used interchangeably. However, it may be stated that bond papers are generally of better quality than ordinary writing papers. Some properties of these papers may differ widely but generally they are similar in opacity and brightness, and both must have good printing and erasing qualities and also good quality for writing with ink. Bond paper was originally used where strength, durability and permanence are essential requirements such as in government bonds, legal documents, currency papers, certificates and insurance policies. However, the use of bond papers is extended to other fields such as in business forms, letterheads, data sheets, advertising pieces and collection books where strength and permanenece are not so important. Bond papers may be made entirely from rags, or bleached chemical pulp from wood, bamboos and agricultural fibrous materials or from mixtures of these pulps.

Writing papers are used principally for pen-and-ink writing, letterheads, tablets, stationery, notebooks, many types of ruled or printed forms, and sometimes for printing purposes. The principal differences between bond and writing papers are that the latter are not as strong as the former, and usually they have close formation and, generally, exhibit smooth, flat finish. Writing papers are made entirely from rag pulp, or chemical wood pulp, and mixtures of these pulps. Mechanical wood pulp is also sometimes added to the mixtures.

Printing paper

Printing paper is any kind of paper suitable for printing. This group includes book paper, newsprint, bristol, ledger, and lithographic. As mentioned above writing and bond papers are sometimes used for printing.

1) Book papers may be coated or uncoated. Both kinds are used in the printing of magazines, books, pamphlets, folders and brochures. These are usually made from various mixtures of mechnical and chemical wood pulps, straw, esparto and reclaimed

paper pulps. Mineral fillers, size and dyes are also added.

Uncoated book papers may be made in antique, eggshell, machine, English or supercalendered finishes, as well as other fancey finishes. Color, cleanness, formation, bulk, opacity and finish are important properties. Always the strength must be sufficient for the requirements of the printing processes to be employed.

In the case of coated book paper, the base paper is coated either on one or both sides with white mineral pigment mixed with adhesives. The pigments used are clay, barium sulfate, calcium carbonate, calcium sulfate and titanium dioxide, while the adhesives normally are casein, starch and glue. Practically all coated book paper is supercalendered and the finish ranges from a dull finish to a high gloss.

2) Newsprint paper, as the name implies, is the grade of paper generally used for newspaper. It is also used for other printing of which mail-order catalogues are good examples. The composition of the paper is largely groundwood pulp with some chemical wood pulp.

3) Bristol - is the term given to the group of papers or paperboards, 0.006 of an inch in thcikness or thicker. The principal types under this group are called index bristol, mill bristol, wedding bristol, bogus bristol and folder stock.

Index bristols are used mostly for index records, index cards and business and commercial cards. They must have good writing and erasing qualities, stiffness, durability and permanence.

Mill bristols are used principally for show cards and other advertising media where stiffness and good printing surface are important characteristics.

Wedding bristols are high-grade bristols used principally for cards, announcements and menus. These are made by pasting two or more sheets together to form different thicknesses and plies. Important characteristics are color, cleanness, finish and must have "snap."

Bogus bristols may be solid or the different layers may be of different stock and colors. They are used for various ticket purposes and cheap, stiff printing cards. The composition of bogus bristols usually consists of mixtures of overissue news, blank or unprinted news, and various other kinds of waste papers and bleached sulfite pulp.

Folder stock is used primarily for the manufacture of folders for business filing. Significant properties include serviceability, tearing resistance, folding endurance and uniform thickness. Non-curling and a uniform high finish withou mottle are also important properties.

4) Ledger papers as indicated by the name are mainly used as filler leaves for ledger books. They are usually surface-sized and treated to permit erasure of writing ink. Since ledgers are used for keeping records, paper with a high degree of durability and permanence is required. Other important properties include good writing and erasing qualities, good water resistance, uniform surface and smoothness.

5) Lithographic papers are prepared for use in the lithographic printing process. They may be coated either on one side or both sides and must have a uniform ink-receptive surface which does not allow the ink to come off. Important qualities are cleanness, uniform formation, freedom from fuzz, bright white color and a flat sheet.

Wrapping and bag papers

These two grades of paper are so analogous and similar in properties that in many cases they may be used interchangeably. Both papers are produced primarily for packaging. As such, they must have the property of retaining the contents of a package intact and in good condition until the package reaches its final destination. Strength, pliability and ability to protect the packaged product are the most important points considered for these kinds of paper.

Most wrapping and bag papers are made from unbleached kraft pulp, although to a certain extent, some are made from bleached pulps. In both cases, strength and good sizing are the main requirements, although other properties may be imparted to the paper through the use of various additives, coating or treatment with waxes, depending upon the end-use. There are various uses for these papers such as shipping sacks, grocers' bags, meat wrappers, soak wrappers, decorative wrapping and hundreds of other uses.

Paper towels and toilet tissues

These papers can be classified under one group as they possess some common characteristics. Important properties of these papers are softness, absorbency and strength. Both papers are creped to impart the required softness and absorbency. Paper towels usually have a wet strength sufficient to withstand use without disintegration. On the other hand, toilet tissues must have the property of being easily disintegrated in water.

Due to modern high sanitary standards, the market for toilet tissues and paper towels has expanded grately. The basic advantages derived from the use of these papers in addition to their sanitary attributes, are convenience, economy, efficiency and service.

Paperboards

Paperboard is a general term which includes all sheets made of fibrous materials on paper machines or wet machines, 0.012 inch or more in thickness. However, certain grades of paper boards are also included in this classification which are 0.006 of an inch or over in thickness such as corrugating board, lightweight chip, certain linerboards, etc.

Paperboards are classified in accordance with the industries for which they are produced namely, boxboards, container baords and paperboard specialities.

1) Boxboards are the paperboards used for fabricating boxes such as folding and set-up boxes and cartons. They must have a fair degree of strength, be capable of bending without cracking and possess a good surface for printing.

2) Container boards are used for the manufacture of corrugated and solid fiber shipping containers.

Corrugated containers usually consist of two linerboards used for the inner and outer facings with the corrugated material in-between. The corrugated construction provides a cushioning effect. It possesses high tensile strength and is rigid, yet may be folded without rupture when scored.

Solid fiberboard is made by joining, with a suitable adhesive, an outer liner, one or more filler members or layers and an inner liner. The adhesives normally used are starch and silicate of soda.

3) Paperboard specialties comprise a number of kinds of boards especially made for particular purposes. Following are several grades of specialty boards, although there are actually many more:

a. Binder board is a solid board with thickness ranging from 0.03 to 0.30 inch. This is mainly used for the binding of books and is usually lined with cloth, paper or leather.

b. Electrical pressboard is a dense board with thickness ranging from 0.03 to 0.25 inch. This is used for insulation in electrical industries and hence, must be free from conducting particles.

c. Imitation pressboard is somewhat similar to electrical pressboard but lacks its high density and dielectric property. This is used principally for notebook covers.

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22. DIFFERENTIATION OF RED LAUAN (SHOREA NEGROSENSIS FOXW.) AND TANGILE (S. POLYSPERMA (BLCO.) MERR.)

Red lauan and tangile belong to the genus Shorea of the Dipterocarpaceae. They are the sources of the Philippine red mahogany famous in the international trade. Both species are abundant in Philippine forests and have straight and cylindrical bole of merchantable size.

Botanically, red lauan and tangile are distinctly different species. Red lauan's crown is small, irregular, open and made up of a few large branches. The leaves are simple, alternate, elliptic (1-1/2 to 2-1/2 inches wide and 4-1/4 to 6-1/2 inches long), smooth and dark green above, but hairy along nerves beneath. The bark is 1/2 to 1 inch thick, dark brown to reddish black, prominently ridged and shallowly furrowed on the upper portion of the trunk, and sheds in thick and irregular flakes (2 to 4 inches long and 1/4 to 1/2 inch wide). The inner bark is stringy in texture, dull tan or reddish in color.

Tangile has a wide spreading, irregularly dome-shaped and dense crown, covering 1/3 to 1/2 the length of the bole. The leaves are simple, alternate, ovatelanceolate (2 to 5-1/2 inches long and 1-1/4 to 2 inches wide), shiny, leathery, dark green above and lighter green beneath. The bark is light red, and sheds in thin, irregular, and small to medium-sized flakes. In old trees, the fresh bark is somewhat powdery and smooth to the touch. The inner bark is red and stringy in texture.

The woods of red lauan and tangile are so closely similar that red lauan is often sold in the market as tangile. Depending solely on the general characteristics of their woods, either of these species may be taken for the other even by experienced foresters. Because of certain requirements in the international trade as well as specifications in various construction or building contracts, it becomes necessary to determine their identity whenever they are specified in the bill of materials to safe-guard against possible unpleasant litigation or financial loss. Results of a study in the Institute of the woods of these two species show that it is possible to differentiate one from the other, based on materials from Quezon, Camarines, Cagayan and Agusan.

As seen by the naked eye or with a 20-x hand lens, three diagnostic features could be used to distinguish red lauan from tangile. These are the burning splinter test, number of pores per sq. mm., and percentage of solitary pores per unit area.

Splinter test

Match-sized splinters, about 5 cm. long of the dry heartwood are burnt slowly to almost the whole length. Red lauan produces charcoal or partial ash, and tangile light brown or brown ash.

Pore count

Pores or vessels can be seen with the naked eye on a clean-cut cross section of most hardwoods. Otherwise a 20-x hand lens can be used. Because of the similarity of the nature and size of the pores of red lauan and tangile, a difference in their distribution is of some diagnostic value. The method of counting the pores per unit area is a practical approach towards identifying these species although it has some limitations depending on the source of the material.

A four quadrat die with a circular area of 20 sq. mm. and a 20-x hand lens are used in determining the number of pores per sq. mm. and the percentage of solitary pores. An impression is made by hammering lightly the die on a cleanly-cut cross section of the wood. Counts are made per quadrat of the circle with the use of the hand lens. These are averaged to show the number of pores per sq. mm. Tangile shows consistently higher average values for the two features mentioned than red lauan as indicated below:

Diagnostic features	Red lauan	Tangile
1. No. of pores/sq. mm	1.3 to 3.6 ave. 2.3	1.6 to 5.4 ave. 2.8
2. Percentage of solitary pores	39 percent	64 percent

Best results in the differentiation of red lauan and tangile are obtained by the laboratory method using a microscope equipped with a calibrated stage micrometer. With the low and high power objectives, fiber length and diameter measurements are taken from 100 wood fibers obtained by macerating wood splints with equal parts of 30 percent hydrogen peroxide and 60 percent glacial acetic acid. Likewise, 100 measurements (under the low power objectives) for each of the maximum tangential diameter of pores on the cross section and ray height on the tangential section, and observation for the presence of oxalate crystals are carried out from either temporary or permanent mounts or section slides. Average values of tangile are consistently lower than those of red lauan as shown below:

Diagnostic features	Red lauan	Tangile
	microns[1]	microns[1]
1. Maximum tangential diameter of pores	233.31-472.50 ave. 311.9	199.98-415.3 ave. 280.3
2. Fiber length	722.20-2488.6 ave. 1703	507.70-2145.0 ave. 1336.9
3. Fiber diameter	17.14-60.0 ave. 33.4	16.44-50.0 ave. 26.8
4. Ray height	184.56-2214.7 ave. 1071.7	276.84-2060.9 ave. 891.6
5. Oxalate crystals	absent	present

1 One micron is one thousandth of a millimeter.

The most significant diagnostic feature of these two species is the presence of oxalate crystals in the vertical parenchyma of tangile and its absence in red lauan.

So far, the practical and satisfactory methods for separating the woods of red lauan and tangile are the burning splinter test and the microscopic observation for the presence of oxalate crystals.

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23. OCCURRENCE OF SILICA INCLUSION IN PHILIPPINE WOODS

Silica is the name ordinarily given to the chemical substance known as silicon dioxide (SiO_2). Ordinary sea sand is composed mostly of silica.

Silica in wood is classified as inclusion or vitreous. The former refers to cell inclusions smaller than the lumina of the cells in which they occur. Under the microscope or hand lens they appear to have wrinkled or uneven surfaces and refractive index of 1.434. The latter refers to silica deposited as a lining on cell walls or a complete filling in the lumen of the containing cell and with a refractive index greater than 1.5. These small deposits are microscopically visible provided they are present in quantities in excess of 0.05 percent based on oven-dry weight of the wood. On this basis, the terms silica-accumulating and silica-free have been adopted to describe the presence and absence, respectively, of silica in wood.

The importance and significance of silica inclusions in certain woods have been recently recognized on account of a number of associated practical problems of which the following are typical:

(a) Diagnostic value of siliceous inclusions as an aid to wood identification

The occurrence of siliceous inclusions in wood in certain species, genera, and families, has proven to be of significant diagnostic value, to a certain extent, in identifying closely related species. This may be used as promising criterion in separating closely allied genera or species because silica inclusions are readily recognizable by their characteristic properties. In a study conducted by the Forest Products Research Institute on similar woods of the Sapotaceae commonly found in the market, it was possible to differentiate bansalagin (Mimusops parvifolia R. Br.), which is silica-accumulating, from duyok-duyok formerly Mimusops calophylloides Merr., but now Manilkara merrilliana H. J. Lam, which is silica-free. Similarly, bagomaho formerly Sideroxylon fragrans Elm., but now named Planchonella firma Dub., a silica-accumulating species, was segregated from Ahern mangkas (Sideroxylon ahernianum Merr.) which is silica-free. In the Dipterocarpaceae, silica-free kalunti (Shorea kalunti Merr.) was differentiated from silica-accumulating manggasinoro (Shorea philippinensis Brandis).

(b) Siliceous inclusions and working qualities

Siliceous timbers are generally hard to saw and some of them dull the teeth of saws rapidly. However, the amount of silica required to affect the sawing properties noticeably has not yet been determined. The sawing problem is far from satisfactorily explained because other researches found that there are timbers wanting in silica inclusions, yet, they cause severe dulling of saws. On the other hand, some timbers which contain silica inclusions are converted easily into lumber or finished products and no complaints as to dulling of tools have been reported. It seems probable that other factors than silica content have an equally important effect on saws and other wood working tools. But one thing stands out clearly. The presence of silica inclusions in wood has been associated with the dulling of saws and wood-working tools. The Forest Products Research Institute has been following up observations along this association.

(c) Resistance of wood with silica inclusions to marine borers

Teredine resistance of some siliceous timbers was observed in 1932 by Gonggrijp who suggested that a silica content of 0.50 percent of the dry weight of the wood is sufficient to confer resistance. As an example, Australian turpentine (*Syncarpia laurifolia* Ten.) with a silica content of 0.59 percent has a world-wide reputation for marine borer resistance. However, the presence of silica in some species is not the only factor that gives them resistance to the attack of teredine borers. Probably other extraneous toxic materials present contribute to the resistance of the wood. Despite this, it is important to have at hand a list of our local siliceous woods and their resistance to marine borers. With this information on the right species to be used in marine timber installations, the cost of replacements and damage due to marine borers may be substantially reduced.

The species, shown in the accompaning tables, were studied by microscopic methods and some were chemically analyzed. Table 1 shows the local species found by microscopic observations to be as siliceous as Australian turpentine, if not more so, based on the size, occurrence and distribution of their silica inclusions. In Table 2, the silica content of 161 species are listed. Thirty-three species were found to exceed the 0.59 percent silica content of the Australian turpentine.

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Table 1. List of local species studied by microscopic examinations which are as siliceous as, or more siliceous than, Australian turpentine based on the size, occurrence and distribution of silica inclusions.

Species	Locality
1. Afu (Anisoptera brunnea Foxw.)	Quezon
2. Apitong (Dipterocarpus grandiflorus Blanco)	Quezon
3. Bagomaho (Planchonella firma Dub.)	Capiz
4. Malabaniti (Madhuca sp.)	Mindoro, Palawan
5. Bansalagin (Mimusops parvifolia R. Br.)	Bataan, Camarines, Cotabato, Palawan
6. Banokbok (Pouteria luzoniensis (Merr.) Baehni)	Tapiantana Islands
7. Basilan apiton (Dipterocarpus basilanicus Foxw.)	Basilan
8. Bataan tagatoi (Palaquium bataanense Merr.)	Ilocos Sur
9. Bayit (Walsura aherniana Perk.)	Sorsogon
10. Betis (Madhuca betis (Blco.) Macbr. & Merr.)	Cagayan, Mindoro, Rizal
11. Betis-bundok (Madhuca monticola (Merr.) Merr.)	Palawan
12. Broad-leaved apitong (Dipterocarpus speciosus Brandis)	Albay, Basilan
13. Dugarag (Aphanamixis velutina Elm.)	Agusan
14. Edkoyan (Madhuca leerii (Teijsm. & Binn.) Merr.)	Zamboanga
15. Hagakhak (Dipterocarpus warburgii Brandis)	Agusan, Cagayan, Camarines
16. Kalalang (Chrysophyllum roxburghii G. Don)	Palawan
17. Lahas (Palaquium obovatum (Griff.) Engl.)	Davao
18. Malaanonang (Shorea polita Vid.)	Agusan
19. Malabetis (Madhuca oblongifolia (Merr.) Merr.)	Camarines
20. Malak-malak (Palaquium philippense (Perr.) C. B. Rob.)	Bataan, Batangas, Laguna
21 Malapanau (Dipterocarpus kerrii King)	Agusan, Quezon, Samar

Table 1. (Continuation)

Species	Locality
22. Malikmik (Palaquium cuneifolium Merr.)	Quezon, Zambales
23. Malobon (Madhuca burckiana (Koord.) H. J. Lam)	Agusan, Cagayan
24. Manggasinoro (Shorea philippinensis Brandis)	Quezon
25. Mindanao palosapis (Anisoptera mindanensis Foxw.)	Zamboanga
26. Panau (Dipterocarpus gracilis Foxw.)	Ilocos Sur, Quezon, Zambales, Agusan, Cagayan, Laguna
27. Pianga (Madhuca obovatifolia (Merr.) Merr.)	Camarines
28. Round-leaved apitong (Dipterocarpus orbicularis Foxw.)	Camarines Norte
29. Salakin (Aphanamixis cumingiana (C. D.C.) Harms)	Bulacan
30. Tailedleaf panau (Dipterocarpus caudatus Foxw.)	Camarines
31. White nato (Pouteria macrantha (Merr.) Baehni)	Lanao

Table II. Silica content of certain Philippine woods. (Underscored common names are the species found to exceed the 0.59 percent silica content of the Australian turpentine).

Species	Percent silica	Locality
1. Anubing (Artocarpus ovata Blanco)	5.93	Laguna.
2. Kalios (Streblus asper Lour.)	4.82	Laguna
3. Kalulot (Artocarpus rubrovenia Warb.)	4.11	Bataan
4. Gumihan (Artocarpus elastica Reinw.)	3.96	Davao

Table II. (Continuation)

Species	Percent silica	Locality
5. Amdil (Paratrophis glabra (Merr.) v. Steen.)	3.58	Davao
6. Liusin (Parinari corymbosa (Blume) Miq.)	3.49	Laguna
7. Bio-bio (Artocarpus multifidus Jarr.)	3.33	Davao
8. Pianga (Madhuca obovatifolia (Merr.) Merr.)	2.87	Laguna
9. Pakak (Artocarpus treculiana Elm.)	2.57	Camarines
10. Bayuko (Artocarpus fretessii Teijsm. & Binn.)	2.20	Palwan
11. Balakat-gubat (Sapium luzonicum (Vid.) Merr.)	2.20	Laguna
12. Kubi (Artocarpus nitida Trec.)	1.85	Bataan
13. Toog (Combretodendron quadrialatum (Merr.) Merr.)	1.80	-
14. Alagasi (Leucosyke capitellata (Poir.) Wedd.)	1.80	-
15. Tuai (Bischofia javanica Blume)	1.76	-
16. Dagang (Anisoptera aurea Foxw.)	1.70	-
17. Afu (Anisoptera brunnea Foxw.)	1.43	Quezon
18. Malkubi (Artocarpus subrotundifolia Elm.)	1.38	Samar
19. Nangka (Artocarpus heterophylla Lam.)	1.13	Sulu
20. Malatapai (Alangium longiflorum Merr.)	1.04	Laguna
21. Apitong (Dipterocarpus grandiflorus Blanco)	1.02	Quezon
22. Manggasinoro (Shorea philippinensis Brandis)	1.00	Quezon
23. Kapok (Ceiba pentandra (L.) Gaertn.)	0.99	-
24. Matang-arau (Melicope triphylla (Lam.) Merr.)	0.98	Laguna
25. Salakin (Aphanamixis cumingiana (C. DC.) Harms)	0.92	Bulacan
26. Kalimatas (Phaeanthus ebracteolatus (Presl) Merr.)	0.89	Laguna
27. Lanutan-bagyo (Gonystylus macrophyllus (Miq.) Airy Shaw)	0.84	-
28. Binggas (Terminalia citrina (Gaertn.) Roxb.)	0.80	-
29. Katmon (Dillenia philippinensis Rolfe)	0.78	Laguna

Table II. (Continuation)

Species	Percent silica	Locality
30. Malaanonang (*Shorea polita* Vid.)	0.74	Agusan
31. Bayit (*Walsura aherniana* Perk.)	0.74	Sorsogon
32. Bukagan (*Artocarpus anisophylla* Miq.)	0.64	Palawan
33. Dugarag (*Aphanamixis velutina* Elm.)	0.60	Agusan
34. Duktulan (*Syzygium luzonense* (Merr.) Merr.)	0.52	Laguna
35. Agusan kangko (*Aphanamixis agusanensis* Elm.)	0.45	Agusan
36. Palosapis (*Anisoptera thurifera* (Blco.) Blume)	0.42	Bataan
37. Magabuyo (*Celtis luzonica* Warb.)	0.42	Laguna
38. Kangko (*Aphanamixis perrottetiana* (C. DC.) Harms)	0.37	Camarines
39. Agogoi (*Chisocheton tetrapetalus* (Turcz.) C. DC.)	0.37	Agusan
40. Igyo (*Dysoxylum decandrum* (Blco.) Merr.)	0.37	Camarines
41. Katong-matsin (*Chisocheton pentandrus* (Blco.) Merr.)	0.36	Palawan
42. Apanang (*Neotrewia cumingii* (Muell.-Arg.) Pax & K. Hoffm.)	0.35	Laguna
43. Malabulak (*Salmalia malabarica* (DC.) Schott & Endl.)	0.35	Laguna
44. Malakalumpang (*Sterculia ceramica* R. Br.)	0.35	Laguna
45. Sasa (*Walsura villamilii* Merr.)	0.33	Zamboanga
46. Ata-ata (*Diospyros mindanaensis* Merr.)	0.25	-
47. Hamindang (*Macaranga bicolor* Muell.-Arg.)	0.24	Laguna
48. Taingang-babui (*Gonocaryum calleryanum* (Baill.) Becc.)	0.23	Laguna
49. Tangisang-bayauak (*Ficus variegata* Blume)	0.22	Bataan
50. Malakamanga (*Reinwardtiodendron celebicum* Koord.)	0.19	Davao
51. Ilang-ilang (*Cananga odorata* (Lam.) Hook. f. & Th.)	0.18	Laguna
52. Hulas (*Pseudotrophis mindanaensis* Warb.)	0.18	Davao
53. Upas (*Antiaris toxicaria* (Pers.) Lesch.)	0.16	Cagayan
54. Bolong-eta (*Diospyros pilosanthera* Blanco)	0.16	Laguna
55. Taluto (*Pterocymbium tinctorium* (Blanco) Merr.)	0.15	Laguna

Table II. (Continuation)

	Species	Percent silica	Locality
56.	Lanutan-dilau (Polyalthia flava Merr.)	0.15	Laguna
57.	Balsa (Ochroma pyramidale (Cav.) Urb.)	0.14	Laguna
58.	Anonang (Cordia dichotoma Forst.)	0.13	Laguna
59.	Ipil (Intsia bijuga (Colebr.) O. Ktze.)	0.13	Laguna
60.	Bani (Pongamia pinnata (L.) Merr.)	0.13	Palawan
61.	Anang (Diospyros pyrrhocarpa Miq.)	0.12	Laguna
62.	Governor plum (Flacourtia jangomas (Lour.) Raeusch.)	0.12	Laguna
63.	Kupang (Parkia roxburghii G. Don)	0.11	Abra
64.	Dap-dap (Erythrina orientalis (L.) Murr.)	0.11	Bataan
65.	Himbaba-o (Allaeanthus luzonicus (Blco.) F.-Vill.)	0.10	Davao
66.	Sakat (Terminalia nitens Presl)	0.08	Laguna
67.	Teak (Tectona grandis L. f.)	0.08	Laguna
68.	Rimas (Artocarpus cummunis J. R. & G. Forst.)	0.08	Ilocos Sur
69.	White lauan (Pentacme contorta (Vid.) Merr. & Rolfe)	0.07	Quezon
70.	African tulip (Spathodea campanulata Beauv.)	0.07	-
71.	Kaliantan (Leea philippinensis Merr.)	0.05	Laguna
72.	Binuang (Octomeles sumatrana Miq.)	0.05	Laguna
73.	Rarang (Erythrina subumbrans (Hassk.) Merr.)	0.05	Laguna
74.	Almon (Shorea almon Foxw.)	0.05	Zamboanga
75.	Mayapis (Shorea squamata (Turcz.) Dyer)	0.05	Camarines
76.	Kalunti (Shorea kalunti Merr.)	0.04	Zambales
77.	Dolalog (Ficus variegata Blume var. sycomoroides (Miq.) Corner)	0.04	-
78.	Katilma (Diospyros nitida Merr.)	0.04	-
79.	Binunga (Macaranga tanarius (L.) Muell.-Arg.)	0.03	-
80.	Yakal (Shorea astylosa Foxw.)	0.03	-
81.	Bayok (Pterospermum diversifolium Blume)	0.03	Laguna
82.	Kamagong (Diospyros philippensis (Desr.) Gurke)	0.02	-
83.	Paper-mulberry (Broussonetia papyrifera (L.) Vent.)	0.02	-

Table II. (Continuation)

Species	Percent silica	Locality
84. Gapas-gapas (*Camptostemon philippinense* (Vid.) Becc.)	0.00	Quezon
85. Pagatpat (*Sonneratia alba* J. Sm.)	0.00	Quezon
86. Pahutan (*Mangifera altissima* Blanco)	0.00	Laguna
87. Vidal lanutan (*Bombycidendron vidalianum* (Naves) Merr. & Rolfe)	0.00	Laguna
88. Anang-gulod (*Diospyros inclusa* Merr.)	0.00	Laguna
89. Banalo (*Thespesia populnea* (L.) Soland.)	0.00	Laguna
90. Kubili (*Cubilia cubili* (Blanco) Adelb.)	0.00	Laguna
91. Big-leaved mahogany (*Swietenia macrophylla* King)	0.00	Laguna
92. Spanish cedar (*Cedrela odorata* L.)	0.00	Laguna
93. Bagarbas (*Hydnocarpus sumatrana* (Miq.) Koord.)	0.00	Laguna
94. Malubago (*Hibiscus tiliaceus* L.)	0.00	-
95. Bagtikan (*Parashorea plicata* Brandis)	0.00	Quezon
96. Narig (*Vatica mangachapoi* Blanco)	0.00	Agusan
97. Tangile (*Shorea polysperma* (Blco.) Merr.)	0.00	Laguna
98. Potkipot (*Abarema angulata* (Benth.) Kosterm.)	0.00	Quezon
99. Ayangile (*Acacia confusa* Merr.)	0.00	Zambales
100. Malatanglin (*Adenanthera pavonina* L.)	0.00	Quezon
101. Salingkugi (*Albizia saponaria* (Lour.) Blume)	0.00	Samar
102. Alibangbang (*Piliostigma malabaricum* (Roxb.) Benth. var. *acidum* (Korth.) de Wit)	0.00	Laguna
103. Thailand shower (*Cassia siamea* Lam.)	0.00	Manila
104. Siping-siping (*Cynometra bifoliolata* Merr.)	0.00	Davao
105. Makapil (*Dalbergia mimosella* (Blco.) Prain)	0.00	Bataan
106. Firetree (*Delonix regia* (Boj.) Raf.)	0.00	Quezon
107. Earpod (*Enterolobium cyclocarpum* Griseb.)	0.00	Laguna
108. Kamatog (*Erythrophloeum densiflorum* (Elm.) Merr.)	0.00	Cagayan
109. Tiri (*Gleditsia rolfei* Vid.)	0.00	Davao
110. Kakauati (*Gliricida sepium* (Jacq.) Steud.)	0.00	Laguna

Table II. (Continuation)

	Species	Percent silica	Locality
111.	Batete (*Kingiodendron alternifolium* (Elm.) Merr. & Rolfe)	0.00	Sulu
112.	Manggis (*Koompassia excelsa* (Becc.) Taub.)	0.00	Palawan
113.	Tina-tinaan (*Indigofera zollingeriana* Miq.)	0.00	Bataan
114.	Ipil-ipil (*Leucaena leucocephala* (Lam.) de Wit)	0.00	Laguna
115.	Basilan bahai (*Ormosia basilanensis* Merr.)	0.00	Zamboanga
116.	Tindalo (*Afzelia rhomboidea* (Blco.) Vid.)	0.00	Ilocos Norts
117.	Prickly narra (*Pterocarpus vidali nus* Rolfe)	0.00	Cagayan
118.	Akle (*Serialbizia acle* (Blco.) Kosterm.)	0.00	Ilocos Suz
119.	Katurai (*Sesbania grandiflora* Pers.)	0.00	Jolo
120.	Supa (*Sindora supa* Merr.)	0.00	Sibuto
121.	Sandalaitan (*Sophora tomentosa* L.)	0.00	Palawan
122.	Sampalok (*Tamarindus indica* L.)	0.00	Manila
123.	Banuyo (*Wallaceodendron celebicum* Koord.)	0.00	Cagayan
124.	Tukang-Kalau (*Aglaia clarkii* Merr.)	0.00	Palawan
125.	Gisihan (*Aglaia laevigata* Merr.)	0.00	Bataan
126.	Kuling-manuk (*Aglaia luzoniensis* (Vid.) Merr. & Rolfe)	0.00	Cotabato
127.	Magsayap (*Aglaia stellato-tomentosa* Merr.)	0.00	Palawan
128.	Maranggo (*Azadirachta excelsa* (Jacq.) Jacobs)	0.00	Palawan
129.	Kalantas (*Toona calantas* Merr. & Rolfe)	0.00	Cagayan
130.	Bauai (*Epicharis foxworthyi* (Elm.) Harms)	0.00	Palawan
131.	Amau (*Dysoxylum pauciflorum* Merr.)	0.00	Laguna
132.	Tarublang (*Epicharis angustifoliola* (Merr.) Harms)	0.00	Palawan
133.	Lanzones (*Lansium domesticum* Corr.)	0.00	Davao
134.	Bagelunga (*Melia dubia* Cav.)	0.00	Quezon
135.	Santol (*Sandoricum koetjare* (Burm. f.) Merr.)	0.00	Rizal

Table II. (Continuation)

	Species	Percent silica	Locality
136.	Pingan-pingan (Vavaea heterophylla Merr.)	0.00	Camarines
137.	Panigib (Walsura brachybotrys Merr.)	0.00	Misamis
138.	Urisep (Walsura multijuga King)	0.00	Lanao
139.	Tabigi (Xylocarpus granatum Koen.)	0.00	Quezon
140.	Upling-gubat (Ficus ampelas Burm. f.)	0.00	Cagayan
141.	Balete (Ficus balete Merr.)	0.00	Abra
142.	Kalukoi (Ficus callosa Willd.)	0.00	Bataan
143.	Basala (Ficus callophylla Blume)	0.00	Palawan
144.	Pasapla (Ficus concinna Miq.)	0.00	Manila
145.	Basikong (Ficus botryocarpa Miq.)	0.00	Palawan
146.	India rubber (Ficus elastica Roxb.)	0.00	Manila
147.	Upli (Ficus melinocarpa Blume)	0.00	Camarines Sur
148.	Alangas (Ficus heteropoda Miq.)	0.00	-
149.	Aplas (Ficus irisana Elm.)	0.00	-
150.	Hagimit (Ficus minahassae (Teijsm. & de Vr.) Miq.)	0.00	Laguna
151.	Tibig (Ficus nota (Blco.) Merr.)	0.00	-
152.	Agopid (Ficus obscura Blume)	0.00	Agusan
153.	Dungo (Ficus pubinervis Blume)	0.00	Ilocos Sur
154.	Agaien (Ficus microcarpa L. f.)	0.00	-
155.	Hauili (Ficus septica Burm. f.)	0.00	Abra
156.	Agamid (Ficus cordatula Merr.)	0.00	Palawan
157.	Baleteng-inon (Ficus sumatrana Miq.)	0.00	Zambales
158.	Isis-bato (Ficus tinctoria Forst. f.)	0.00	Palawan
159.	Malanangka (Parartocarpus venenosus (Zoll. & Mor.) Becc. subsp. papuanus (Becc.) Jarr.)	0.00	Mindoro
160.	Agus-us (Paratrophis philippinensis (Bur.) F.-Vill.)	0.00	Laguna
161.	Kuyos-kuyos (Taxotrophis macrophylla (Blume) Boer.)	0.00	Cebu

24. USEFUL FIBERS FROM BARKS OF PHILIPPINE WOODS

It has been estimated that about eight percent of the total volume of a tree trunk is bark. It is also estimated that the annual cut of the commercially known and most exploited Philippine mahogany alone is about 4,716,981 cubic meters. Based on these estimates the bark of the annual cut of the Philippine mahogany alone is about 377,358 cubic meters.

In the lumber industry, this bark is almost entirely unutilized and is disposed of as waste, thus posing a problem of waste disposal.

The barks of some trees contain high percentage of resins, some in tannins, others in waxes and other chemicals. This enormous amount of bark is a potential raw material for the manufacture of adhesives, charcoal, hardboards and other structural boards, and other related products.

A study has been conducted on bark utilization at the Forest Products Research Institute. Logs of white lauan (Pentacme contorta (Vid.) Merr. & Rolfe) with moisture content of 77 percent and bagtikan (Parashorea plicata Brandis) with moisture content of 88 percent were found to yield from 7 to 10 percent bark by volume. Fractionation of this bark yielded 47 percent of fibrous elements for white lauan and 43 percent for bagtikan, and the rest, consisted of assorted corky and woody elements.

Bark and its Composition

Though only the exterior covering of the trunk and branches of a tree is technically known as bark the word is often loosely used to designate all the tissues lying outside the wood. Bark consists of an outermost corky layer called epidermis, a layer of manufactured-food-conducting tissues called phloem, and a zone between these two layers known as cortex. In several species, a layer of fibrous strips called "bast fiber" forms an inner bark. Oils, resins, tannins, waxes, and phenolic substances may also be present in the bark. When extracted from the barks of some tree species, these materials are useful for the manufacture of certain chemical and medicinal products.

The bark of some woods is processed into various useful products. In chip or pulverized form, bark is used in the growing of certain plants. The ground bark particles alter the "water-air relationships," lower the bulk density, improve the friability and act as a protective mulch of the soil. When mixed with suitable chemicals, it may be a useful fertilizer. In the making of structural fiber boards, roofing and some grades of paper some manufacturers remove only part or perhaps none of the bark from wood.

Incidentally, the most common, yet the oldest and lowest-grade use of unprocessed bark, is for fuel in some factories as well as in millions of rural Filipino homes. Certain barks of the commonly used Philippine timber-producing species have bark fibers while the others have bast fibers.

Bark Fibers

Some barks contain from 60 to 90 percent of thickly matted fibers that are strong, tough and durable. These can be utilized for a number of purposes. The bark fibers of paper mulberry (*Broussonetia papyrifera* (L.) Vent.), for example, have been successfully used in the manufacture of hand-made papers, parasols and decorative papers in Thailand and Japan. This tree is now cultivated locally. The matted fibers from the bark of kalulot (*Artocarpus rubrovenia* Warb.) and abutag have been used locally by natives for clothing and G-strings. The barks of these species are comparable in structure to that of paper mulberry and so likewise might be useful raw materials for a hand-made paper industry of the Philippines. It is likely that there are other Philippine species which can produce similar fibers.

Bast Fibers

"Bast fibers" are obtained mostly from dicotyledonous plants. They occur in that portion of the fibro-vascular area of phloem which is around the woody, central portion and just under the outer bark. They usually occur in bundles with their ends overlapping so as to produce continuous filaments or strips throughout the length of the tree. In some cases, the filaments are interlaced as in malabuho (*Sterculia oblongata* R. Br.).

Bast fibers are inherently strong and durable, and are commonly extracted by simple retting. In most instances, they are primarily processed for the manufacture of ropes, baskets, hats, mats, etc. Bast fibers possessing sufficient bending strength, folding endurance, toughness, and durability are used for making wild-hog traps, fish lines, clothes lines, twines, sacks for storing rice, strings, cordage and textile fabrics for cords, strainers, mosquito nets, etc.

The most important tree species that produce bast fibers of the best quality belong chiefly to the Thymelaeaceae, Tiliaceae, Malvaceae, Sterculiaceae and Moraceae.

Fibers of salago (Wikstroemia spp.), alagasi (Leucosyke capitellata (Poir.) Wedd.), bani (Pongamia pinnata (L.) Merr.), Vidal lanutan (Bombycidendron vidalianum (Naves) Merr.), malubago (Hibiscus tiliaceus L.), anabo (Abroma augusta (L.) L. f.), and malabuho (Sterculia oblongata R. Br.) are very strong and generally used for rope making. The bast fibers of ramie (Boehmeria nivea (L.) Gaudich.) and lata or upas-tree (Antiaris toxicaria (Pers.) Lesch.) are perhaps more suitable for cloth making.

Salago and malabuho bast fibers are exceptionally good. Salago fibers can be used for making strong paper, and would seem to be particularly useful constituents for bank note and check paper. The exquisitely silky and strong fibers of malabuho are good materials for weaving elegant bags, wallets, and hats for both men and women.

At present, small establishments engaged principally in the local fiber business export some of their products to foreign countries including Japan, United States, and Europe, for good prices. The demands by these countries for the products of the local industries are ever-increasing so this foreign trade will continue to help the Philippine economy.

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25. MINIMIZING DECAY HAZARDS IN LUMBER YARDS

The danger that lurks in the use of lumber infected with wood-destroying fungi[1/] is not generally appreciated by wood users. The casual observer does not readily recognize incipient decay in wood which can be easily mistaken for sound lumber. Perhaps unknowingly, lumber dealers may occasionally sell as sound lumber, wood having incipient decay when mixed with sound or clear lumber.

Many people regard this infection as a minor superficial defect which can be largely removed by surface planing. This, however, is not the case. Infected wood, even in the early stage, is already permeated with the destructive hyphae of wood-decaying fungi. When this infected piece is used in a place of high decay hazard, it will not last long in service. As a consequence, this necessitates expensive repairs and replacements with attendant inconvenience and unnecessary expense to the user.

Stored lumber that is stained and infected by molds is likewise objectionable. It is likely to harbor wood-decaying fungi because the conditions that favor stain fungi also favor decay fungi.

Recent findings by the Forest Products Research Institute disclose that decay in stored lumber occurs sometimes in lumber yards because of primitive and unsanitary storage conditions

1/ See FPRI Technical Note No. 10, Protecting Building from Termite and Fungus Damage.

and improper handling practices which make for high decay hazards. The following recommendations will reduce these decay hazards:

1. Site. - It is preferable to locate the yard in well drained high level ground, and not adjacent to wind obstructing objects such as tall trees and buildings. High solid wall inclosures are objectionable because they obstruct air movement inside the yard thereby promoting humidity which is favorable to decay.

2. Sanitation. - The elementary rules of sanitation should be observed. Wood waste scattered all over the premises invariably harbors wood decaying fungi as well as insects. It may contain fungal infection and should be disposed of promptly and properly. Regular and frequent cleanups of debris are far more desirable than one large yearly cleanup. The use of sawdust to fill up low ground is undesirable. Soil containing rotted woody materials can be a constant source of infection for the lumber stored in the yard.

Infected timber should never be used for the foundation or skids of piled lumber because fungus strands can move freely from infected wood to moist clean lumber if the two come in contact.

Weeds which impede air movement and promote high humidity in the air beneath the piles should be eradicated and kept under control.

3. Foundations. - The piles or stacks should be placed on good solid foundations. Concerte or brick piers and durable or adequately treated timber for horizontal stringers are preferable. Adobe stones are not desirable for foundations because they readily absorb water and take a long time to dry. The height of the foundations should not be less than 18 inches from the bottom of the stringers to the surface of the ground to permit ample ventilation beneath the piles and keep the soil beneath as dry as possible. The foundations for shed piles should be similar to those recommended for yard piles.

4. Layout. - The arrangement of the stacks in the yard should be such that the air moves through each one of them regardless of wind direction. Adequate alleys and spaces must be provided between piles and rows of piles so as to provide air movement freely.

5. Piling. - The most critical period in storing fresh sawn lumber is the first few weeks after delivery. It is at this stage that the surface of the lumber is moist enough for the germination of fungal spores that might have alighted on it to initiate decay. Hence, the faster the lumber is dried the less chance for fungal infection to occur, but in doing so due consideration must be given to the possibilities of warping and checking. This can be attained by proper spacing of the piles and the separation of the lumber in the pile by stickers to promote drying within the pile. The stickers should be of sound and dry material, preferably heartwood, and must be handled in a sanitary manner. Fresh lumber should never be piled for storage on top of old lumber. It must be piled separately.

6. Pile roofs and sheds. - A good pile roof has always been considered an important feature of good air seasoning practice. A roof protects the upper courses and, to a lesser extent, the lower part of the pile from rain. Rain-water penetrating the pile may retard drying of the lumber besides rendering it susceptible to fungal infection. To provide maximum protection, the roof should extend beyond the ends and sides of the piles and should be pitched so that the water will run from front to rear and drip off at the edge. The roof of the sheds should be kept in good repair and provided with gutters and downspouts.

The lumber stored in the sheds should never be allowed to project beyond the roof because the drip from rain may run back along the projecting pieces into the center of the solid-piled stock. Once wetted, the pile will retain the moisture for prolonged periods permitting fungal infection to set in.

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A P P E N D I X

WOOD DESTROYING TERMITES
THEIR ECONOMIC SIGNIFICANCE & CONTROL

By Faustion C.Francia and Antonio J.Valino [1]

Termites are insects which we call "anay" or "unos" in the Philippines. They are small in size. The common wingless forms are usually no longer than a quarter of an inch. Most of them are whitish in color.

These insects spend most of their lifetime in galleries in the soil or in wood where they live in colonies characterized by a social organization and by division of labor among the members. Thus, they have three castes-the reproductives, the workers, and the soldiers-which develop from the young termites or nymphs.

INTRODUCTION

The reproductives in a termite colony develop wings and, at a certain season of the year, especially during the rainy season, take to flight in order to establish new colonies. For a brief period during this flight, they are attracted to and swarm around lighted lamps or electric lights. They soon shed their wings, pair off (a male and a female), and seek suitable places either in the ground or in wood, depending on their habits, to make a nest and reproduce. If they succeed, this nest eventually becomes a colony populated by numerous young termites and the parent female termite becomes physogastric and is usually termed "queen" while the parent male termite remains in its original size and is called "king".

Only a small percentage of the colonizing reproductives succeed in starting new colonies because, aside from the mortality which results from long exposure in the attempt to find suitable breeding places, many of them fall prey to house lizards, bats, ants, spiders, and other predators.

A termite queen has been known to lay several thousand eggs a day and may live for a considerable period of time.

1/ Senior and Junior Forest Products Technologist, respectively, Forest Products Research Institute, College, Laguna.

The queen, even before its death, may be supplemented in producing eggs by one or more reproductives. Thus, a termite colony may remain active for many years.

The workers function as the food providers of the entire colony and are the ones that destroy wood. In some termite species, the worker caste is absent and the nymphs or young secure the food with which to provide themselves and the other members of the colony.

Termites feed on the cellulose of wood. The ability of these insects to feed on wood is made possible by the presence, in their digestive organs, of microorganisms, mostly flagellated protozoa, that aid in digesting the wood. These protozoa multiply and are distributed among the termites through feeding.

The soldiers serve as the guardians of the colony. They repel intruders, particularly ants, by means of their well-developed, greatly elongated mandibles or by means of their pointed or truncated heads. Soldiers of some species exude a substance that is repellent to ants.

Except when they are on their wings, termites seldom show themselves out of their galleries and are therefore rarely seen. Their presence is nevertheless easy to detect. The existence of earthen shelter tubes on the surface of wooden structures or the accumulation of small fecal pellets below or at the base of any woodwork is the tell-tale of their depredations.

The different species of termites may be divided into two main groups - the subterranean termites and the non-subterranean termites - based on their habitat or place in which they establish their colonies.

SUBTERRANEAN TERMITES:

The subterranean termites are popularly known as "anay" in the Philippines. They are mainly ground-dwelling in habitat, but they often extend their colonies to wood on the surface of the ground and even up into the upper stories of buildings. This extension is indicated in part by the presence of earthen tubes through which the termites travel to and fro. There may also be hidden tunnels or galleries within the wood which are not seen. Subterranean termites need an adequate moisture supply which they ordinarily obtain from the soil but may also obtain it from wet spots in buildings. When a portion of or the entire shelter tube is broken, it is immediately repaired by the termites, otherwise, the termites in the upper sections of the tube will try to find their way down and if access to the ground is completely cut off, they will eventually die.

There are 42 known species of subterranean termites in the Philippines but much of the damage to buildings and structures is caused by the four common species, namely, Coptotermes vastator Light, Microcerotermes los banosensis (Oshima), Macrotermes gilvus (Hagen), and Nasutitermes luzonicus (Oshima).

Coptotermes vastator, the Philippine "milk" termite, can be distinguished from other species by the milky secretion of the soldiers when disturbed. This secretion comes out of a pore or gland at the front of the head of the termite soldier. This species is by far the most destructive of all Philippine subterranean termites and is frequently encountered in the woodwork of buildings, especially where pine or similar lumber is used. The attack on wood in contact with the ground is done by tunnelling inside and throughout the length of the wood. To reach wood above the ground, they build earthen tubes over other materials like stone, concrete, etc. or may pass through cracks and crevices in these materials. The pathway inside the tube is usually lined or spotted with whitish excreta. A secondary nest is often located in the infested wood.

Microcerotermes los banosensis, the Los Banos termite, is characterized by the rectangular shape of the head of its soldiers. Its nest is hard, honeycombed, of earthen and excretory material, and frequently located partly above the ground, usually at the base of dead tree trunks, stubs, or posts. Its narrow, almost cylindrical runways or shelter tubes are often inconspicuously located. For this reason, severe dammage to the woodwork of buildings is often effected before its attack is noticed. It builds a dark-brown secondary nest in wood in the same manner as Coptotermes vastator.

Macrotermes gilvus, the mound-building termite, is widely distributed in the Philippines. Inside its mound are sponge-like structures called, "fungus gardens", wherein a species of fungus is grown for food. Although this termite feeds principally on fungus, it frequently attacks abandoned logs, fence posts, stakes, lumber, woodwork of buildings, paper, and even clothing left on the ground. It builds broad earthen tubes on the trunks of trees to feed on the outer dead layer of the bark or on dead wood.

Nasutitermes luzonicus, the Luzon point-headed termite, can be recognized by the pointed, brownish-black head of its soldiers. It constructs tubes and nests which are often located on the trunks of trees or in large crevices in wood or masonry. They occasionally climb buildings and feed on the surface or between piles of lumber but they seldom cause severe damage.

The others of the 42 known species of subterranean termites in the Philippines are mostly found in the forests and seldom cause damage to man-made structures.

NON-SUBTERRANEAN TERMITES:

The non-subterranean termites include species which live in the fresh wood of living trees and others which live in the dry woodwork of buildings. They do not build earthen shelter tubes. Those that live in the fresh wood of living trees such as avocado, ipil-ipil, madre-cacao, santol, guava, bitungol, etc. often cause the death of these trees. Their infestations gain foothold in dead knots, limbs, exposed roots or injuries on the trunks, and often extend to the living sapwood and dead heartwood. Their galleries are usually lined with moist, brownish excreta. There are five known species of termites that attack living trees in the Philippines. Of these, Neotermes grandis Light, and N. malatensis (Oshima) are very common.

The termites that attack and inhabit the dry woodwork of building are called "drywood" termites. They are popularly known as "unos" in the Philippines. These insects can live in and feed on wood with as little as three percent moisture content and can withstand excessive aridity or dryness by staying close to each other, utilizing excretory moisture and feeding on their dead. They do not require contact with the soil or any other source of moisture than the wood they eat.

Two species of drywood termites - Cryptotermes dudleyi Banks and C. cyanocephalus Light - cause serious damage to woodwork of buildings in the Philippines. These two species have soldiers with brownish-black, truncated heads but they can be distinguished from each other by the relatively larger size of the individual member of C. dudleyi species and by the low, broad, and longer mandibles of its soldiers.

C. dudleyi occurs not only in the Philippines but also in Central and South America, Indo-Malaya, Papua, and Australia.

In other countries, this species is frequently associated with other drywood termite species. In the Philippines, a colony of C. dudleyi has been found in a wood chunk also heavily infested by C. cyanocephalus. C. cyanocephalus, considered native to the Philippines, is now also reported in Java. World commerce has been greatly responsible for the wide distribution of these destructive pests because they can be unknowingly transported from one country to another in lumber, plywood, boxes, furniture and other wooden articles.

ECONOMIC SIGNIFICANCE

Termites are by nature wood feeders and are one of the most important biological agents of wood deterioration. If only they would confine their activities to the forests, breaking down what would have been perennial stumps, snags, and dead trees, or in the soil, keeping it in constant circulation and rendering it permeable to air and moisture, they could be highly beneficial insects.

Some people even find them useful. It is reported that many mountain tribes dig up termites in the soil or collect them while swarming and cook them for food. Also in many places of the country, termite nests are collected and the termites in them fed to chickens, turkeys, and other poultry.

Unfortunately, termites are indiscriminating in their habits. They are beneficial in the forests but outside of the forests they do enormous damage to wood structures and wood products.

Much wood is destroyed whereever termites are found. The damage they cause to buildings and other cellulose-containing possessions of man (poles, posts, furniture, books, stationery, clothes, living crops, trees, etc.) amounts to millions of pesos per year in the Philippines. Much of this tremendous amount of damage results from the ignorance of wood-users and builders alike about the habits of the different species of termites and their failure to take proper precautionary measures.

A survey made recently to determine the causes of termite infestation in buildings on the forestry campus, College, Laguna, and in various housing projects in Manila and Quezon City, revealed that faulty construction practices such as wood in contact with the ground cracks in masonry, voids in hollow blocks, use of susceptible untreated lumber, and faulty plumbing in bathrooms and toilets were responsible in many cases for inviting serious attack by termites.

CONTROL MEASURES

AGAINST SUBTERRANEAN TERMITES:

1. Good construction practices - It is important that wood be put out of the reach of termites. A first step in this direction is to construct sound concrete foundations and floor slabs, and to place all woodwork such as posts, sills, jambs, studdings, etc. upon them. Wooden staircases should rest upon sound concrete landings that can easily be inspected.

The use of metal shields laid on top of foundations is only partly effective and often ineffective due to improper placement. Making small trenches all around the top of foundations and filling them with creosote or oil, although it has been recommended, is not convenient or sightly and requires regular inspection and maintenance of the oil level. Furthermore, this method aside from being unsightly, does not afford protection to wood in other lower parts of the building.

Naturally durable wood, like the heartwood of molave, narig, yakal, tindalo, dungon, ipil, and akle is strongly resistant to termites but the sapwood of even the durable species is not resistant unless treated. Wood thoroughly treated with a good preservative is also resistant to termite attack and may be used to advantage. Both treated and naturally durable wood are costly but, in the long run, are more economical than cheaper untreated non-durable wood which requires frequent replacement.

All wooden debris such as slabs, shavings, waste lumber and wood stakes should be removed from the soil under the building. Shrubbery and trees or their branches should not come in contact with the building.

Good sanitation and efficient drainage are very important. Lumber, old furniture, wooden boxes and other materials stored under the building should not lie on the ground nor remain undisturbed for a considerable period of time. Keep wood well above the ground, not in contact with it; have plenty of space beneath if possible; and provide for easy inspection. Even instruction to children on the economic significance of termites and the necessity of reporting or destroying termite tubes whenever found, can be of help.

2. The use of soil poisons. - A supplement to good construction methods is the use of soil poisons sprayed on the surface of the soil or mixed with the soil under the building, prior to the construction of the building. The effectiveness of the protection will depend in a large measure on following recommended concentrations and dosages and on the thoroughness of the treatment.

Soil poisons may also be applied around foundations of existing buildings or injected into cracks in foundations and concrete slabs and in voids in hollow blocks.

Among the chemicals that have been used and found effective in termite control work on the forestry campus and in various places in Manila are the following:

1) Aldrin, 0.5 to 1.0 percent in oil solution or in water emulsion.

2) Lindane, 1.0 percent in oil solution or in water emulsion.

3) Chlordane, 2.0 percent in oil solution or in water emulsion.

4) Dieldrin, 0.5 to 1.0 percent in oil solution or in water emulsion.

5) Heptachlor, 5.0 percent in oil solution or in water emulsion.

The rate of application should be about 5 gallons of the chemical solution per 10 square feet of soil under the building, applying a little more of the solution to the soil under the bathroom and in other critical areas. Also apply 5 gallons of the solution per 10 linear feet to soil around foundation walls. Again the thoroughness of the treatment is emphasized.

3. The use of poison dusts. - Insecticidal dusts are often used in checking active infestations. Any of the following dusts - white arsenic, 10 percent DDT, 5 percent dieldrin, and 5 percent heptachlor - blown by means of a dust gun into the mounds, nests, tunnels or earthen tubes will bring about the cessation of termite activity in them or their

abandonment for a considerable period of time.

AGAINST DRYWOOD TERMITES:

1. Preventive control. - To prevent drywood termite infestation, the following steps should be considered:

1) Inspection of second-hand lumber before using. - Second-hand lumber or old seasoned lumber intended for use should be carefully examined for evidences of infestation such as excretal pellets and small plugged holes. Infested usable lumber should be kiln-dried or steam-heated to at least $150^{o}F$ for 2 hours. Otherwise, such lumber should never be used in buildings. Discarded lumber from infested buildings should be burned.

2) Screening of doors, windows, and other openings. - The use of a wire screen, 18 to 20 meshes to the inch, on all doors, windows, and ventilation openings will retard the entrance of winged termites into the building through these openings.

3) The use of treated or naturally durable wood. - Sapwood lumber of all species is generally susceptible to the attack of drywood termites and as much as possible should not be used without treatment in structures where permanent strength is desired. Among the local timber species whose heartwood is very resistant to drywood termite attack are akle, dungon, guijo, ipil, manggachapui, molave, saplungan, and yakal. Sapwood lumber can, however, be made resistant by proper preservative treatment such as pressure treatment with Wolman salts, Boliden salts, pentachlorophenol, or other good preservative, dipping lumber for 3 minutes or longer in a 5.0 percent oil solution of pentachlorophenol or three-coat brush application of the same solution to all surfaces.

Spray, brush, or dip treatment gives only superficial protection and subsequent surfacing and cutting of the treated lumber will remove the protective chemical coating. Even pressure-treated lumber will have its resistance reduced whenever cutting exposes untreated interior wood.

4) Painting or varnishing wood-work. - Painting or varnishing woodwork will be of help in protecting those surfaces from drywood termite attack if the termites have not already entered but, for full protection, the finish would have to be applied to all surfaces. Drywood termites ordinarily do not

bore through paint or varnish to enter wood. They usually enter through nail holes, cracks, and crevices in wood. For this reason, these entrance points should be thoroughly brushed or sprayed with a good insecticial solution or effectively closed.

2. Remedial control. - where infestation has already taken place, but is not too extensive, it can be stopped by one of the methods that follow:

1) Replacement of infested wood. - If the infestation is severe but localized and the wood can be replaced, the infested pieces should be removed and burned immediately.

2) Heating of infested pieces. - Killing termites present in furniture can be effected by heating the articles for about 2 hours at 150°F in a dry kiln or other suitable heater. Infestation in limited areas in flooring and similar woodwork can also be stopped by a 10-minute exposure to infrared heat radiation. If the infestation is widespread, however, heating one or two spots cannot be expected to control the entire colony.

3) Injection of insecticides into infested materials.- Where other methods seem impractical to apply, injection of liquid insecticide or blowing insecticidal dust into the termite galleries by means of a syringe, spray gun, or dust bellows is recommended. Auger holes into the galleries to permit injecting the insecticide should be made to hit the termite tunnles in the wood. Seal the holes with putty or other suitable material after treatment.

Among the insecticidal oil solutions that have been used and found effective are: 6.0 percent DDT, 2.0 percent chlordane, 5.0 pentachlorophenol, 0.5 percent dieldrin, and 0.4 percent lindane. Where liquid insecticides are not desirable, one ounce of any of the following insecticidal dusts - Paris green, 10 percent DDT, 5 percent dieldrin, and sodium fluosilicate - finely powdered, is sufficient to treat 15 to 30 holes.

4) Fumigation. - Methyl bromide and hydrogen cyanide(HCN) fumigation of entire buildings is sometimes practiced in other countries for getting rid of drywood-termite infestation. Two and one half pounds of methyl bromide or 2 pounds of HCN is used to fumigate 1000 cubic feet of space. Fumigation is, however, very dangerous because the gas is extremely poisonous to all animal life, and should be undertaken only by experienced and licensed professional fumigators. The treated building

must remain unoccupied until the poison has dissipated. People have died from failure to observe these precautions.

Constant vigilance is necessary with all termites even after all other precautions have been taken, to detect the first sign of new attack and take proper action.

CAUTION!

The chemical mentioned in this article are poisonous to man and animals and should not be applied where they might contaminate food and drinking water nor stored in places within the reach of children and pets. They should be handled with care.