

Review Paper

Pakistan J. Sci. Ind. Res., Vol. 19, Nos. 5-6, October-December 1976

SEASONING AND DIMENSIONAL STABILIZATION OF WOOD

M. ASLAM

PCSIR Head Quarters, Karachi

(Received February 18, 1977)

Classification of Woods. The division of commercial timbers into two great classes, softwoods and hardwoods, rests on a botanical distinction. The softwoods or coniferous timbers are derived from the comparatively small class of cone-bearing trees, mostly with evergreen needles or scale-like leaves, known as conifers or Coniferae. The conifers form extensive forests in cool temperate regions and in mountainous districts, and supply the bulk of the world's commercial timber. The structure of their wood is of a simple, primitive type, distinctly different from that of the hardwoods. Softwood timbers are generally well suited for constructional use and they are comparatively soft and easy to work, light in weight but strong enough for most practical purposes.

The hardwoods are furnished by the great group of broad-leaved trees which include the vast majority of species in the forests of the world today. The structure of the hardwoods is more complex and their technical properties show a much wider range of variation than is the case with the softwoods. It should be clearly understood that softwood and hardwood are now universally recognized conventional technical terms for the two main classes of timber defined above. The fact that some coniferous timbers are indeed hard, and some broad-leaved trees furnished a comparatively soft grade of wood does not affect the use of the terms in their

special technical sense.

The Structure and Properties of Wood. A tree grows by the process of laying down a cone-shaped sheath of timber over the whole of the exterior of the trunk and the nature of the wood which is produced varies from season to season within the year and from year to year with the life of the tree, so that we have quite a complicated picture of development.

Starting at the centre (or the pith), the tree grows outward, adding a growth ring each year. This growth ring usually is composed of two types of cells: springwood, formed in the period of rapid growth in the spring, and summerwood, formed in the period of slow growth, usually in the summer.

These two types of cells have different densities and properties, and are one source of variability in the tree (Fig. 1). The ratio of springwood to summerwood is dependent on species and environment, but commonly varies from one growth ring to the next. Shown also in Fig. 1 is a knot within the cross-section. This knot, originally the base of a living branch, is a serious source of weakness in structural lumber.

The basic structural element of wood, the fiber, is generally aligned longitudinally with the tree trunk. Figure 2 shows a typical section of a coniferous tree for illustration of the microscopic structure of the wood. The main message of this drawing is that

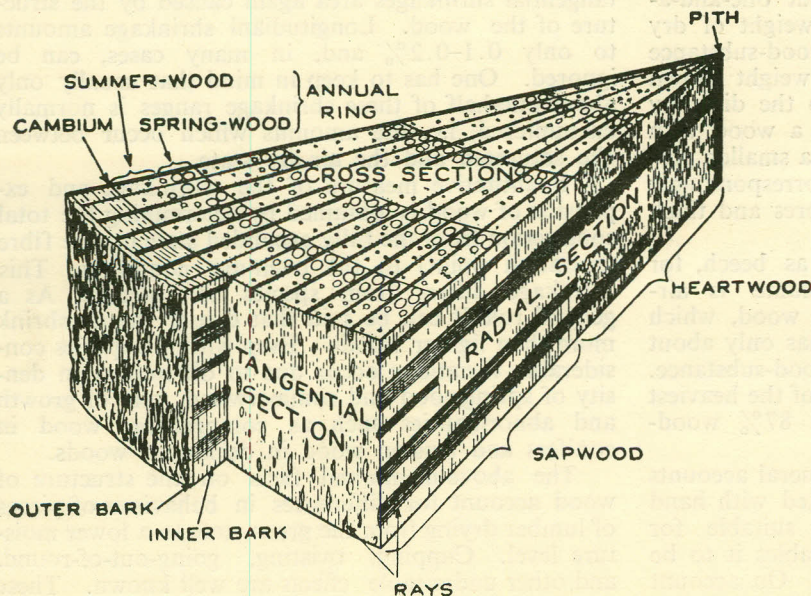


Fig. 1. Diagrammatic drawing of a wedge-shaped segment cut from a five-year-old stem of a hardwood, showing the principal structural features.

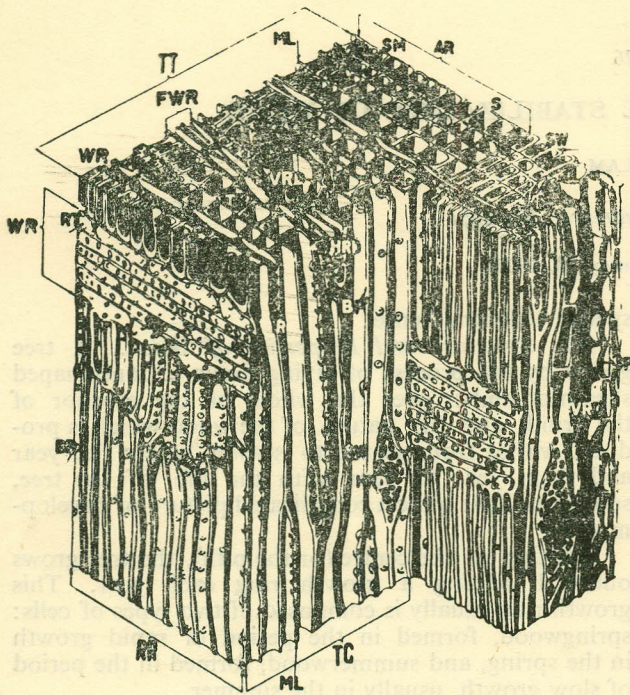


Fig. 2. A drawing of the microscopic structure of a coniferous tree.

the wood structure may be considered as a composite bundle of tubes. In a material of this construction, the longitudinal compressive and the tensile strength may be expected to be high, the transverse values to be lower, and shear between the tubes to be a plane of relative weakness.

Many of the familiar properties of wood are due to the fact that a large proportion of its bulk consists of air contained in the cavities of its cellular structure. The actual wood-substance forming the cell walls is a hard, dense material having a specific gravity of approximately 1.5, i.e. about one-and-a-half times the weight of water. The weight of dry wood depends on the proportion of wood-substance to air-space, and the wide range of weight shown by different kinds of timber is due to the diversity of their cellular structure. Obviously a wood with large pores and thin cell-walls contains a smaller proportion of wood-substance and is correspondingly lighter in weight than one with small pores and thick cellwalls.

In a wood of medium weight such as beech, for example, approximately half the volume is air-space and half wood-substance. Balsa wood, which is one of the lightest known timbers, has only about 7% of its volume consisting of solid wood-substance. At the other extreme *lignum vitae*, one of the heaviest commercial timbers, contains about 87% wood-substance.

The cellular structure of wood in general accounts for the ease with which it can be worked with hand and machine tools. It renders wood suitable for use as a heat-insulating material and enables it to be compressed and bent without breaking. On account of its porous nature wood holds paint and glue better

than most materials and can be impregnated with preservatives to increase its durability.

Moisture in Wood. One of the important properties of wood to be noted is its considerable affinity for water. In a living tree one finds, besides the water which is required to keep the wood substance completely saturated, a large portion of 'free' water which fills the hollow spaces of the wood structure. If freshly-cut wood is left in the atmosphere, this 'free' water disappears first before any of the moisture of the cell-wall is lost. The point at which no 'free' water remains is called the fibre saturation point (FSP). For most species this point is in the vicinity of 25% or above. Wood of any moisture content above the FSP, if brought into a dry atmosphere, will begin to shrink as soon as the fibre saturation point has been reached. Dry wood brought into an atmosphere saturated with moisture will absorb water and swell until the FSP is reached. In an atmosphere of constant relative humidity wood reaches an equilibrium moisture content.

The process of shrinking when the wood dries below saturation point is caused by the contraction of cell-walls. The length of the cells is affected very little by the moisture content, consequently shrinkage in the longitudinal or fibre direction is small. This is explained by the fact that the cell-walls consist of long crystallites (ordered regions) arranged parallel or only slightly inclined to the long axis of the cells. Water can be present only between these crystallites. Upon its removal, the crystallites draw closer together causing shrinkage to occur mainly in cell diameter. This process is reversed when dry wood takes up water. Consequently the dimensions of wood change mainly across the grain.

Shrinkage across the grain is not uniform. It is considerably greater in tangential than in radial direction. On the average, tangential shrinkage is nearly twice as great as radial shrinkage. For Canadian woods the range of radial shrinkage is from 1.7 to 6.7%. The differences between radial and tangential shrinkages are again caused by the structure of the wood. Longitudinal shrinkage amounts to only 0.1-0.2% and, in many cases, can be ignored. One has to keep in mind that usually only about one-half of these shrinkage ranges is normally encountered, i.e. the amounts which occur between the saturated and the air-dry state.

A quantitative measure of the shrinkage and expansion of wood is obtained by determining the total contraction from the fully expanded state (at the fibre saturation point) to the oven-dry condition. This shrinkage differs from species to species. As a general rule it can be said that denser woods shrink more than lighter woods. Even within a species considerable variations occur due to differences in density of springwood and summerwood, rate of growth and abnormalities such as compression wood in conifers and tension wood in deciduous woods.

The above-mentioned facts on the structure of wood account for differences in behaviour of pieces of lumber drying from the green state to a lower moisture level. Cupping, twisting, going-out-of-round, and other undesirable effects are well known. These are illustrated in Fig. 3.

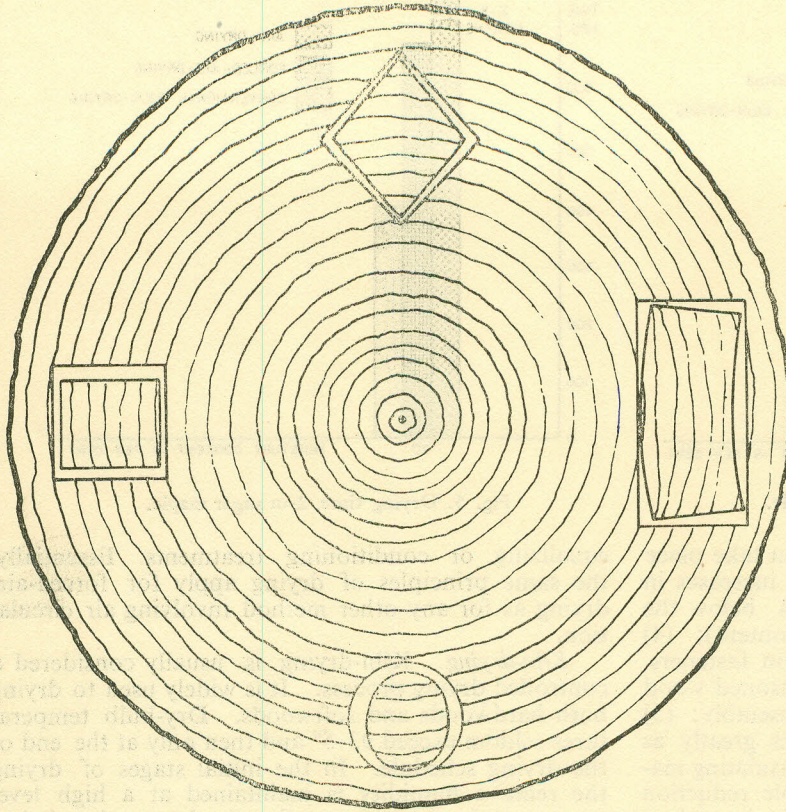


Fig. 3. Diagram illustrating shrinkage of wood across the grain. Clear space represents, in each case, shrinkage in drying from green to oven-dry condition.

The Physical and Chemical Composition of Wood. The structure of wood, so far as it can be studied by the naked eye or with the aid of the microscope, does not always provide a complete explanation of the properties of wood in general, or of the differences between one species and another. It is sometimes necessary to consider also the physical and chemical composition of wood in relation to its properties and uses. This is rather a complex subject and can only be referred to very briefly.

Wood substance is of a colloidal nature and may be compared with other common substances in this class, for example gelatin and cotton. Like these, wood substance is hygroscopic: it swells when it absorbs moisture from the air and shrinks when it dries. It resembles cotton, and differs from gelatin, in having a fibrous structure. The major chemical constituents of wood-substance are cellulose, lignin and hemicellulose. Cellulose is the principal component of all vegetable tissues, and it is the addition to it of lignin which gives wood its characteristic strength and hardness. The relative proportions in which the major constituents are present and the way in which the molecular units are bound together play an important part in determining the properties of different timbers.

Roughly speaking, the strength of wood increases with its weight or density, but this is by no means the only factor concerned. The outstanding toughness of some woods and the adaptability of others for bending are attributed to some peculiarity in the composition, of their cell-walls. Similarly, the refra-

ctory nature of certain hard woods, which causes a rapid dulling of saws and machine cutters, can be traced to the presence of inorganic components such as silica in the wood. In an earlier paragraph reference has been made to various chemical substances which are found in the cell cavities of the wood as distinct from the actual material of the cell-walls. These substances commonly include various kinds of gum, resin, tannin, dyestuffs, and, in certain cases, minerals such as silica or calcium carbonate. On the chemical composition of wood depend many of the most important properties of timber, for example, its natural durability when exposed to the weather, its resistance to the corrosive action of chemicals, its varying degree of inflammability, and its value for fuel. Wood cellulose provides the raw material for the manufacture of pulp and paper products, artificial silk (rayon), some types of plastic and lacquer, and wood alcohol. Other materials which can be extracted from wood include turpentine, rosin, dyestuffs and tanning materials.

Seasoning of Wood

Drying of Wood. The living tree holds many gallons of water in the cells of its wood. A 16-ft southern pine log 15 in in dia, for example, may weigh as much as 1250 lb and contain about 47% or 70 gallon water. Most of this water must be removed by seasoning to make lumber and other wood products.

There are a number of important reasons for seasoning: (1) reduces the likelihood of stain, mildew, or decay developing in transit, storage or use: (2) the

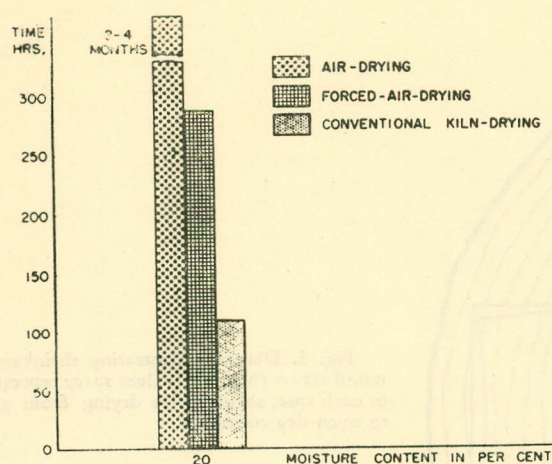


Fig. 4. Drying time, 1-in sugar maple.

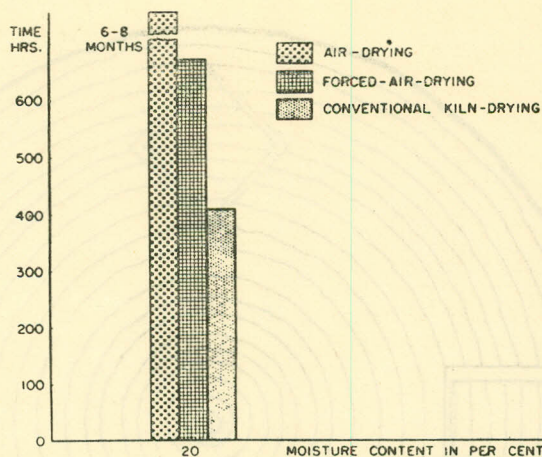


Fig. 5. Drying time, 2-in sugar maple.

shrinkage that accompanies seasoning can take place before the wood is put to use; (3) wood increases in most of its strength properties as it dries below the fibre-saturation point (30% moisture content); (4) the strength of joints made with common fasteners, such as nails and screws, is greater in seasoned wood than in green wood seasoned after assembly; (5) the electrical resistance of wood increases greatly as it dries; (6) dry wood is better thermal insulating materials than wet wood; (7) the appreciable reduction in weight that accompanies seasoning is important in reducing shipping costs.

Ideally the temperature and relative humidity during drying should be controlled; if wood dries too rapidly it is likely to split, check, warp, or honey-comb because of shrinkage stresses.

Air-drying. Air-drying is a process of piling sawmill products outdoors to dry. Control of drying rates is limited and great care must be used to avoid degrading the wood. Drying time is a function of climatic conditions; in damp coastal areas wood dries slowly, whereas in the arid regions it dries rapidly.

Forced-air-drying. Whereas improved piling methods can result in better air circulation, further reduction in drying time can be achieved by use of circulating fans, a technique commonly referred to as forced-air-drying. Forced-air-drying times as compared with conventional kiln-drying schedules for 1 and 2 in maple may be seen in Figs. 4 and 5, respectively. These times are from experimental work carried out in Ottawa during the summer months.

Currently the terms predrying, fan-drying, accelerated air-drying and low-temperature-drying are loosely used to describe one operation.

It is contended that the term 'forced-air-drying' should be used to describe mechanically induced circulation of air through lumber stacks without any control of humidity or temperature; whereas 'low-temperature-drying' should be used to describe drying with the addition of heat up to 43.5°C when the objective of the heat is either to accelerate drying or to maintain a desired wet bulb depression. This method is suitable for drying to moisture contents in the 10-15% range. It does not lend itself to

equalizing or conditioning treatments. Essentially, the same principles of drying apply for forced-air-drying as for any other method involving air circulation.

Kiln-drying. Kiln-drying is usually considered a controlled drying process. It is widely used to drying both hardwoods and softwoods. Dry-bulb temperatures seldom exceed 93.5° and then only at the end of the drying schedule. In the initial stages of drying the relative humidity is maintained at a high level to control the moisture gradient in the wood and thus prevents splitting and checking. Modern kiln installation use forced-air circulation, instrumented to give good control of both dry and wet-bulb temperatures. Most kilns are equipped with automatic control instruments. The kilns are vented to exhaust the moisture evaporated from the wood. Most installations are steam-heated, although furnace-type kilns using gas or oil for fuel are now being built. Many species, especially hardwoods, are first air-dried to about 20% moisture content, then kiln-dried to the moisture content at which they will be used.

High-temperature Kiln-drying. Another method of drying which uses temperatures above the boiling point of water is generally known as high-temperature-drying. The principal advantage of this method is increased kiln production which in turn allows faster marketing of the products.

Past experience shows that most softwoods and some low-density hardwoods in the green condition may be successfully dried using high temperatures in the 104-115° range. A substantial reduction in drying time (Fig. 9) has been realised on an experimental basis in drying spruce without developing any serious defects.

On the other hand, it has been found that most hardwood species must be predried before high temperature can be used in order to prevent serious degrade such as checking, collapse, honey-combing, and discoloration. Comparative drying times using various methods for drying 1-in yellow birch are shown in Fig. 7. Some refractory hardwoods such as oak should not be subjected to high-temperature drying at all, since they develop serious degrade.

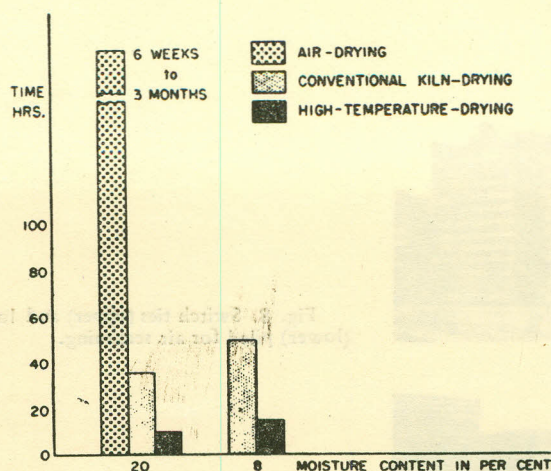


Fig. 6. Drying time, 1-in white spruce.

Air Seasoning

With most treating methods, the presence of any considerable amount of free water in the cell cavities may retard or even prevent the entrance of the preservation liquid. Thus, the application of a superficial oil treatment as by brushing, to green or wet is ineffectual, even with the pressure processes it is impossible to impregnate freshly cut wood satisfactorily, unless such artificial conditioning treatments as steaming and vacuum, boiling under vacuum, or vapour-drying are resorted to prior to the actual injection of the preservative.

The most common method of preparing green lumber and timber for treatment is to pile it out of doors and allow it air season. Unseasoned wood that is exposed to the open air, but protected from rain, will gradually dry out until it comes into approximate equilibrium with the average relative humidity of the air.

The seasoning yard should be located on well-drained ground which is open to the wind. Low, damp sites are poorly suited for drying and also encourage decay. Unless there is good air drainage, damp air may settle in the yard, especially at night, and retard seasoning. The yard should be kept clean and sanitary at all times. No weeds, waste wood, or other debris should be allowed to accumulate, and storm water should be drained away promptly. The seasoning piles should be raised 1½-2 ft above the ground on permanent foundations of well-treated wood, concrete, or other suitable material and should be well ventilated beneath. They should also be spaced far enough apart to be accessible for inspection or other purposes.

An excellent method of piling lumber is shown in Fig. 8, in which the lumber is properly stacked and spaced, good foundations keep the material well off the ground, and the piles are sloped for drainage. Roofs over the piles would be further improvement.

Since no definite rules can be laid down to determine the most advantageous seasoning time, each operator must decide upon the best practice for his particular location, climatic conditions, and kind of timber.

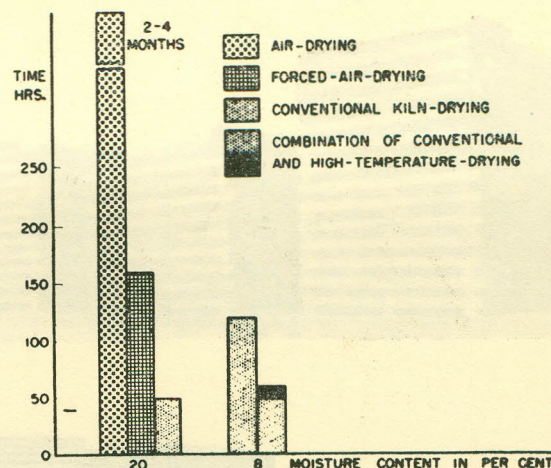


Fig. 7. Drying time, 1-in yellow birch.

To reduce degrade in air-dried hardwood lumber, follow proper stacking and spacing procedures. Here are the different types of degradations and the causes:

Split. (1) Two few stickers, (2) lack of roofing or poor roofing, (3) stickers not flush with ends of boards.

Check. (1) Lack of roofing, (2) board edges exposed at bunk spaces, (3) stickers not flush with ends of boards, (4) drying too rapid due to excessive exposure of lumber stacks.

Warp. (1) Poor sticker alignment, (2) poor bunk alignment, (3) lack of sufficient stickers, (4) foundation out of level, (5) thick and thin lumber in same course in stack.

Stain. (1) No chemical dip, (2) use of green or wide stickers, (3) base of piles too low, (4) grass and weeds growing between stacks, (5) poor yard location.

Dimensional Stabilization

It is obvious that dimensional instability is detrimental in some applications of wood. Consequently attempts to reduce (if not eliminate) this property have been undertaken. A practical measure for the effectiveness of treatments meant to increase dimensional stability is the antishrink-efficiency (AE) defined as follows:

$$AE = \frac{\text{Swelling of untreated sample}(\%) - \text{Swelling of treated sample}(\%)}{\text{Swelling of untreated sample}(\%)} \times 100$$

Treatments which will increase dimensional stability be divided into four groups:

(1) Painting, i.e. covering the surface with a moisture-resistant film using oil paint, varnish, resin, etc. One might include here treatment which leads to a coating of the interior surface of wood.

(2) Swelling of the wood to its maximum dimension and keeping it in this swollen state: the materials used to bring out this change remain in the wood. This process is often referred to as 'bulking'.

(3) Changing the wood chemically, e.g. by replacing the hydroxyl groups of the cellulose by less

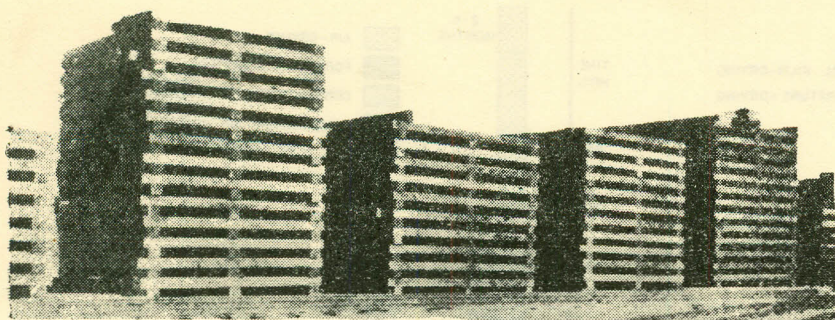


Fig. 8. Switch ties (upper) and lumber (lower) piled for air seasoning.

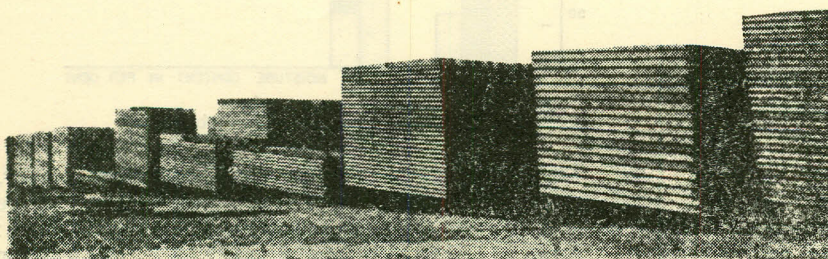
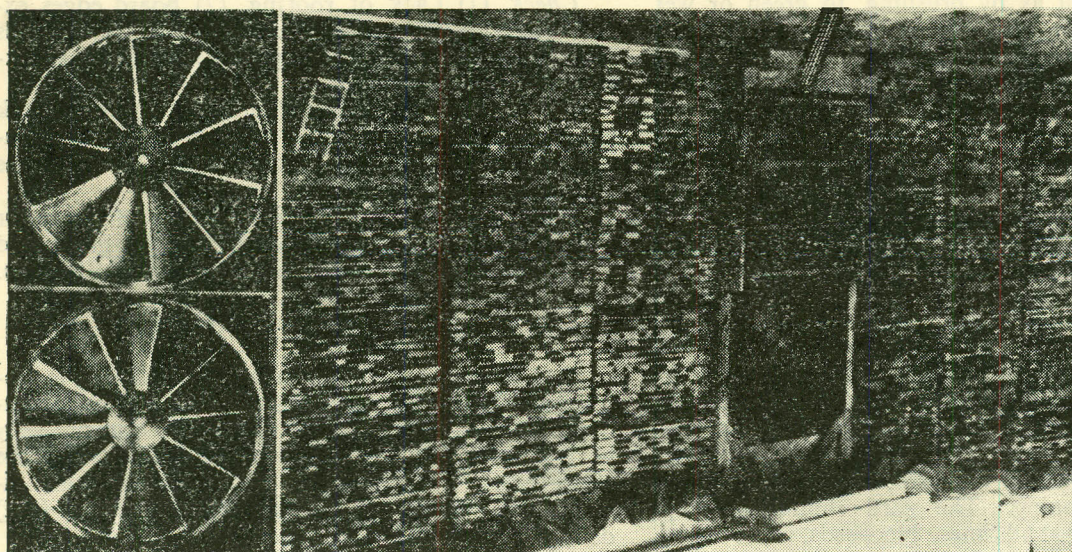


Fig. 9. An example of forced-air-drying.



hydrophilic group such as acetyl or nitro groups. These groups are not only less hydrophilic but also more bulky than the ones they replace and, consequently, cause a certain amount of 'bulking'.

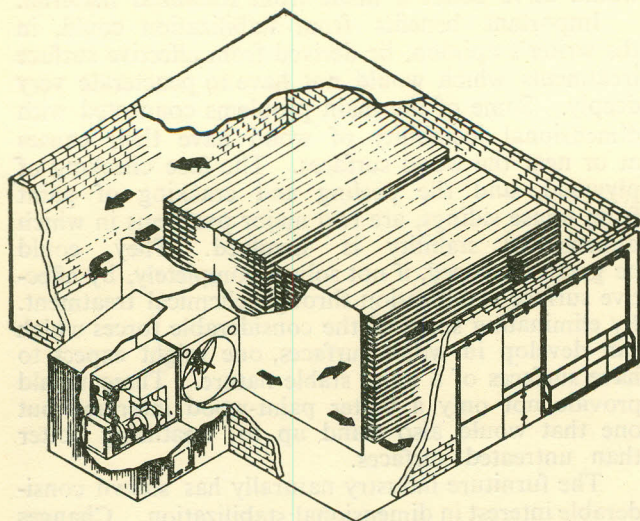
(4) Preventing the entrance of water into the fine structure of the wood by setting up cross-links between the chain molecules of the cellulose.

All of these methods are being used to certain degree, however, each method has its limitations.

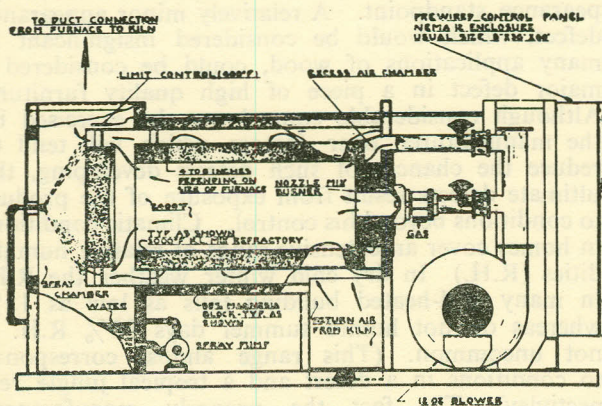
Painting. Coating of paints or other water repellent substances are effective against 'free' water. A plywood panel covered with a good film of oil paint consequently would not be exposed to 'free' water such as rain drops splashing against it. On the other hand, these films are very permeable to water vapour. Consequently, in an atmosphere of

relative humidity, water vapour exerts the same swelling effect on a painted panel as on an unpainted one. The only difference would be that the painted panel would reach an equilibrium moisture content at a much slower rate. This is of great practical importance since, in the majority of cases, extreme atmospheric conditions prevail only for relatively short periods. Slowing of the rate of water absorption may often be sufficient to prevent extreme dimensional changes. Since extreme changes cause most of the undesirable effects of instability, paints and other water repelling materials have their value as dimensional stabilizers.

Bulking. Bulking, that is the swelling of wood to its maximum dimension and keeping it at this dimension, can be brought about by the deposition



*Vapo-Aire Package System
Furnace for Direct-Heated Kilns*



Typical Cutway Showing Internal Construction

Fig. 10. An example of high temperature Kiln-drying.

of many substances such as sugars, glycerol, glycols, salts, etc. inside the wood structure.

Best dimensional stability results were obtained with treatments that imparted a polyethylene glycol retention from 20 to 30% (of the weight of dry wood) in the thin, critical areas around the receiver and barrel groove. Only a small proportion of the chemical penetrates the thick part of the butt, where a high level of stability is unimportant, so proper treatment does not have a significant effect on the weight of the finished stock.

The treatment currently favoured by industry consists of soaking the green, precarved stocks for 45-60 days in a 30% (by weight) solution of polyethylene glycol-1000 maintained at around 24°. Soaking time can be substantially reduced by elevating the temperature.

Polyethylene glycol-100 curbs shrink, swell and warp by building the wood fiber walls, attacking the problem at its very roots. The chemical diffuses into the microscopic, lattice-like structure of the individual fibre walls, where the natural moisture

of the turgid wood fibres is displaced by large molecules of the stabilizing agent. Fibre walls thus supported-bulked are permanently restrained from changing in dimension with variations in moisture content.

This simple, effective antishrink treatment has slight effect on the colour, gluing, or physical properties of wood. However, because of the nature of the process involved, it is fully effective only on fresh-cut, green wood.

As an added dividend, it was found that stocks made of exceedingly wild-grain woods, including walnut burls, could be seasoned to flawless perfection following chemical stabilization.

Moreover, properly treated precarved stocks are so stable that they can be kiln-dried from the dripping wet condition to 6% moisture content in less than 26 days, including three days for equalizing and conditioning, and improvement over the 60-90 days it normally takes to properly kiln-dry the untreated walnut blanks.

There is no point in treating unshaped blanks if the objective is to attain a high level of dimensional stability in the finished stock, because most of the chemical will be in the outer portions of the blanks which are cut away during subsequent shaping and inleting.

Another advantage of chemical stabilization is that treated wood can be finish-carved, hand-inletted, and checkered more easily than untreated wood. The treatment also permits sanding and finishing the stock to a flat, mirror-smooth surface, in contrast to the ashboard effect common in stocks containing burl and grain distortions that present alternating hard and soft areas.

The chemically stabilized stocks may well outperform any substitute material thus far developed and at the same time retain the natural warmth, beauty, durability, and other desirable properties of the fine hard-woods long prized by sportmen. Treated stocks are now commercially available in developed countries, several others are known to be experimenting with the process, and the military is also interested.

So far as is known, the only other commercial application of polyethylene glycol to wood is in the production of wood carvings. Green wood turnings and carvings of all sorts—bowls, lamp bases, gavels, furniture legs, totem poles, etc.—lend themselves to the antishrink treatment.

Several years ago Stamm suggested the use of polyethylene glycols (carbowaxes) as bulking agents. These are waxy substances which are water-soluble up to a certain molecular weight. Green wood, soaked in concentrated polyethylene glycol solutions, can be dried and finished without serious interference from dimensional changes. Antishrink efficiencies up to 80% have been obtained with polyethylene glycol treatments. The methods, however, is rather costly and confined to pieces of small dimensions.

Chemical Modification. Derivatives of cellulose such as cellulose acetates and cellulose nitrates are very resistant to the penetration of water vapour. Everyone is familiar with the transparent handles of many tools which frequently consist of cellulose acetate. Cellulose nitrate film base and lacquers are known for

their indifference to water. The process by which cellulose acetate is formed, has been shown to be applicable to thin wood sections and veneers. Experiments at the Ottawa Laboratory, Forest Products Research Branch, have shown that veneers can be acetylated either by treatments with liquid acetic anhydride or in an atmosphere of acetic anhydride vapour. Antishrink efficiencies of more than 75% can readily be obtained by these treatments.

Acetylation of lumber by treatments with solutions of acetic anhydride in onswelling solvents, e.g. toluene, have been reported. The major objection to these treatments is their cost. Vapour phase treatments with phenylisocyanate have also been found effective. With phenylisocyanate decreasing in price, this method might find some practical application in the future. Other cellulose derivatives have also been tried. Many of these have shown a certain effectiveness, but their cost is considered prohibitive for large scale application. Furthermore, vinyls and methacrylates which can be made to polymerize in wood change the cellulose of the wood by joining or 'graft-polymerizing' to it. This is a very active field of investigation at present.

Cross-linking. Cross-linking is a widely used principle in the technology of materials consisting of large molecules, especially when these molecules are long chain-like structures cellulose molecules. The setting up of cross-link across the chains greatly alters the properties of the resulting materials. When applied to cellulose and wood, cross-linking can be expected to increase dimensional stability by preventing the entry of water between the cellulose chains. A very simple and inexpensive compound such as formaldehyde reacts with cellulose by setting up short bridges (so-called methylene between the neighbouring cellulose chains. Unfortunately, this reaction requires an acid catalyst which is very detrimental to the cellulose of the wood. The resulting cross-linked material, although greatly improved with regard to dimensional stability, may become too brittle to be of practical value in many applications. Many other means of cross-linking have been tried but so far none of these have proved satisfactory.

Some treatments which are applied to make wood more dimensionally stable combine several of the above mentioned principles. Impregnating wood with soluble substance which afterwards are rendered insoluble, e.g. by radiation, can be considered a combination of surface coating, bulking and chemical modification. Even graft-polymerization might be involved in some cases.

Since the problem is so complex, no single available method can be considered ideal. However, is complete stabilization still the problem? In many applications, wood in its natural state serves well and would not be more useful if it had been given a stabilizing treatment. Roof joints, floor joints, 2×4 ft and many other items would not serve any better in treated rather than untreated form, when installed under proper conditions. On the other hand, components such as door and window sills, door frames, doors and drawers of cabinets, as well as some highly specialized articles (e.g., shoe lasts)

would serve better if made from stabilized material.

Important benefits from stabilization could, in the writer's opinion, be derived from effective surface treatments which would not have to penetrate very deeply. Some of the main problems connected with dimensional instability of wood have their causes at or near the wood surfaces. The face checking of plywood, and the peeling and cracking of paint from house sidings, are two major problems in which dimensional stability is involved. They could be greatly reduced, if not solved completely, by effective surface stabilization through chemical treatment. By eliminating some of the considerable forces which can develop in wood surfaces, one might expect to have surfaces of a more stable nature. These would provide not only a better paint-wood interface but one that would also stand up to weathring better than untreated surfaces.

The furniture industry naturally has shown considerable interest in dimensional stabilization. Changes in dimensions of wood with changes in atmospheric conditions can affect the serviceability of the product not only in structural performance but also from appearance standpoint. A relatively minor appearance defect, which would be considered insignificant in many applications of wood, could be considered a major defect in a piece of high quality furniture. Although considerable control can be exercised by the manufacturer over factors which will tend to reduce the chances of such defects developing, the ultimate defects result from exposure of the product to conditions beyond his control. Climatic conditions in homes cover an extensive range of relative humidities (R.H.) In dry cold winter weather the R.H. in many well-heated building falls as low as 15% whereas on hot humid summer days 90% R.H. is not uncommon. (This range almost corresponds to conditions in a desert and a tropical jungle respectively). The fact the properly manufactured furniture generally stands up well in spite of these extremes commends both its raw materials and the skill of the manufacturer. Nevertheless, occasional failures do occur and for this reason it would appear desirable to dimensionally stabilize wood or wood components for certain applications.

Problems encountered by the furniture industry which are related to dimensional stability include the following: sticking drawers and doors; sunken glue-joints in veneered lumber panels; telegraphing of headers and edge strips on veneered particle boards panels, loosing of dowelled, mortised, and various other types of joints; splitting of solid wood components such as chair seats; end splits in the cores of veneered lumber panels which are not end-banded; warping of doors and other panel components which are not firmly held by rigid frame; and the development of fine cracks and checks on the surface of highly finished veneered panels.

Most, if not all, of these problems could be overcome by dimensionally stabilizing the wood components. However, the cost of treating the large volume of wood involved in many instances would be prohibitive. On the other hand, the volume of wood requiring treatment to overcome some of the problems, such as sticking drawers, would be relative-

ly small and in these applications treatment might prove to be quite practical. However, the greatest benefit at the current stage of development of wood stabilization techniques might be derived from surface treatment where applicable. Such treatments, for example, applied to surface veneers could greatly reduce, if not eliminate, the development of surface checks and splits, a problem which has been of major concern to the industry for a considerable time.

In conclusion, it can be said that dimensional stabilization of wood is an ideal state which may be difficult to reach completely. However, partial solutions such as the slowing of the rate of dimensional changes by surface coatings, and the dimensional stabilization of surfaces by chemical modification or impregnation are realistic research aims which appear to be well within reach and which promise very rewarding results.

to show how it is independent of human con-
sideration and communication of experience. In
order to support this argument, the first part of the
book deals with those particular factors of quantum
physics which most directly show the necessity
of a complementary mode of description in atomic
physics. To avoid misunderstandings due to the
usual ontological way of thinking, the necessity
of Wigner's interpretation of the quantum for-
malism is shown by presenting the essential elements
of the discussion between Bohr and Einstein regard-
ing the epistemological problems involved when
describing atomic phenomena. The subsequent chap-
ters show how complementary is a rather challeng-
ing ontological philosophy. The final chapter pro-
poses that the independence of the phenomena-
logical and conceptual levels of experience is a ne-
cessary condition for the child's acquisition of lan-
guage as well as for all kinds of interaction of language
and mind. This condition is believed to be bound
up with a fundamental complementarity of language
itself.

Practical Electrochemistry, C. J. Mooney and J. D. R.
Thomas, 104 pp. Methuen, 1975. Price: £ 2.50.

Many complex mixtures can now be resolved
using gas and/or thin layer chromatography. How-
ever, certain types of molecules, notably the light
molecular-weight and easily denatured proteins, can-
not be separated effectively by these techniques.
Facile and rapid protein separation is currently
important and it is in this respect that electro-
phoresis has bestowed remarkable benefits in me-
dical, biochemistry, and biology. Electrochemis-
try can also be used for all manner of separation of charged
species and provided suitable complexing electro-
lytes are employed, for unchanged species in
the last respect, useful separation of carbohydrates
have been made with buffer electrolyte systems.

The basic requirements for separation by electro-
phoresis is some kind of inert support saturated with
a conducting electrolyte. Frequently buffered on
which the charged species of the sample move at
different rates towards the appropriate electrode under
the influence of an applied electric field. One im-
portant electrochemical technique, however, namely
electrochromatography, depends on the various protein
factors being placed in their respective pH zones.
Another technique which involves an eventual ma-
nipulation is that of polyacrylamide gel electro-
phoresis where migration of protein molecules is
aided according to the point of the support

fluid process involving is something that has
in the realm of the intelligible for it depends upon
factors like amount, acceptability, and preservation
of natural nutrients like vitamins especially vita-
mins A and D which are likely to be destroyed through
the direct treatment. Another important aspect
is the destruction and restoration of enzymes for
which chemical treatment and ionizing radiation
might be the answer.

But in the present-day era of mass production
the story would not be the answer. More trans-
formation of food products is a problem and the book
discusses (pp. 114-28) phenomena wherein which is
assuming greater importance progress in and a
comparative table of the different methods has been
given by the author. Other valuable sections are
the calculation of heat-exchange performance (pp.
234-40), duct heating and cooling (pp. 247-52) and
analysis of heat treatment (pp. 282-94). The
discussion of the process of physical operations
(pp. 227-46) should prove very valuable to food in-
dustry in Pakistan as it provides a summary of the
latest information on the subject. In the indigenous
pharmaceutical systems, for example, the concen-
tration of various compounds from juices and ex-
tracts is of considerable importance. This is very
well discussed and illustrated (pp. 224-25). A very
enlightened discussion of adsorption in food industry
is given at the end.

The treatment is, of course, didactic as the book
is meant to serve as a textbook. The diagrams are
neatly produced and the printing is superb.
The author, who are associated with the Department
of Food Science, Agricultural University, Wageningen
The Netherlands have made a valuable addition to
the technology of food industry.

Kamal M. Habib

Quantum Physics and Ordinary Language, T.
Barnett, 61 pp. Macmillan, London, 1974. Price:
£ 1.95.

The concept of complementarity, well known in
connection with the wave and particle explanations
of subatomic behaviour, refers to the coexistence
of two theories whose partial accounts of the facts
will together give a more complete view. In this
book the author seeks to show that this condition
of complementarity can be applied in a more general
way to the interaction of quantum physics and ordi-
nary language. It is this wrong idea for plain
people and for scientists who are concerned with
the meaning of quantum physics and the conceptual