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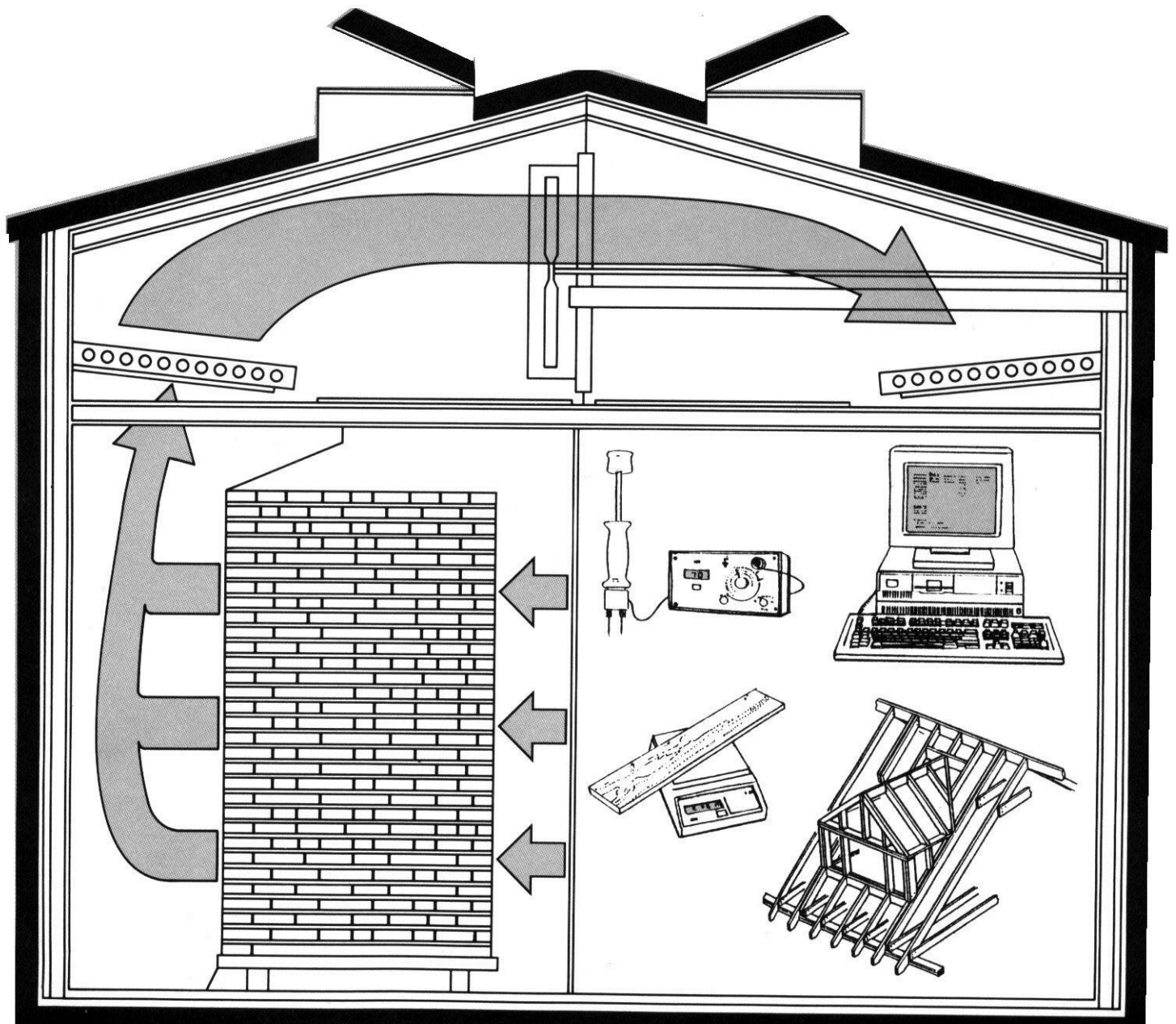
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# Dry Kiln Operator's Manual



# Dry Kiln Operator's Manual

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<sup>1</sup>The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

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# Preface

The purpose of this manual is to describe both the basic and practical aspects of kiln drying lumber. The manual is intended for several types of audiences. First and foremost, it is a practical guide for the kiln operator—a reference manual to turn to when questions arise. It is also intended for mill managers, so that they can see the importance and complexity of lumber drying and thus be able to offer kiln operators the support they need to do their job well. Finally, the manual is intended as a classroom text—either for a short course on lumber drying or for the wood technology curriculum in universities or technical colleges.

This manual is a revision of the 1961 edition by Edmund F. Rasmussen. Forest Service staff who contributed to that original edition were Raymond C. Rietz, Edward C. Peck, John M. McMillen, Harvey H. Smith, and A.C. Knauss. It is a credit to these men that the 1961 edition has been in wide use and demand for the past 28 years. It is also to their credit that even though the manual is out of date in many parts, we were able to use the basic framework of the original edition to build on.

The Forest Products Laboratory staff involved in this revision were William T. Simpson (who wrote the introduction and had overall responsibility for coordination), R. Sidney Boone, James C. Ward, and John L. Tschernitz. Each person was responsible for revising certain chapters or parts of chapters. This assignment of responsibilities is indicated on the chapter-opening pages. Chapters 5 and 7 of the original manual were combined in this revision. Chapter 11, Energy in Kiln Drying, is a new chapter and was written by John L. Tschernitz. In addition to this assignment of chapters, there were many formal and informal meetings among us to exchange ideas.

***The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.***

# Acknowledgments

Many people helped in the revision. We visited many mills to make sure we understood current and developing kiln-drying technology as practiced in industry, and we thank all the people who allowed us to visit. Professor John L. Hill of the University of New Hampshire provided the background for the section of chapter 6 on the statistical basis for kiln samples. Kiln manufacturers were also very helpful in spending time with us and providing photographs and schematics of drying equipment. In particular, we wish to thank Coe Manufacturing Company, Hemco (Harvey Engineering and Manufacturing Corp.), Irvington–Moore, Nyle Corporation, Uraken Canada, Ltd., and Wagner Electronic Products, Inc., for their help. We also thank Professor Charles J. Kozlik, retired from Oregon State University, for arranging and accompanying several of us on a plant tour in the Northwest.

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# Introduction

The modern dry kiln is a unique product of research, development, and experience. It is the only practical means now in wide use for rapid, high-volume drying of lumber to conditions necessary for maximum serviceability in housing, furniture, millwork, and many other wood products. As part of our charge to help further the efficient utilization of our nation's timber resource, Forest Service research and development in lumber drying has made a significant contribution to the technology. The Forest Products Laboratory (FPL) has been conducting research in lumber drying since it was established in 1910. Early work by Harry Tiemann (*The Kiln Drying of Lumber: A Practical and Theoretical Treatise*, J.B. Lippincott Company, Philadelphia, PA, 1917) at FPL established lumber kiln-drying technology and the first lumber dry kiln design. Tiemann's book can really be considered the first drying manual. Several other FPL drying manuals followed before the 1961 manual by Rasmussen.

A well-designed and properly operated dry kiln can in a few days or weeks turn green lumber fresh from the forest into a dry, stable material necessary for successful industrial enterprises in today's highly competitive markets. The more critical the drying requirements, the more firmly the dry kiln becomes established as an integral part of the lumber mill, the furniture factory, or the millwork plant. For many wood products, kiln-dried lumber is essential.

Dried lumber has many advantages over green lumber for producers and consumers alike. Removal of excess water reduces weight and thus shipping and handling costs. Proper drying confines shrinking and swelling of wood in use to manageable amounts under all but extreme conditions of relative humidity. Properly dried lumber can be cut to precise dimensions and machined more easily and efficiently; wood parts can be more securely fitted and fastened together with nails, screws, bolts, and adhesives; warping, splitting, checking, and other harmful effects of uncontrolled drying are largely eliminated; paint, varnish, and other finishes are more effectively applied and maintained; and decay hazards are eliminated if the wood is subsequently treated or protected from excessive moisture regain.

Efficient kiln drying of lumber is therefore of key importance in the utilization of our forest resource. On one hand, it helps to assure continued markets for wood products by increasing their service life, improving their performance, and contributing to consumer satisfac-

tion. On the other hand, it helps to conserve our forest resource by reducing waste in manufacture and extending service life and usefulness of products. Both are essential in using timber wisely, which has long been an accepted tenet of forest management policy.

The full benefits of modern kiln-drying technology can be gained only when certain prerequisites are observed. Mill management must recognize the importance of efficient operation to quality of product, and operators must be well trained and encouraged to apply the best techniques. Quality should not be sacrificed for quantity in the production of kiln-dried lumber. The high value of our timber resource makes it uneconomical to do so.

Terms used in this manual to describe dry kilns and their components, drying characteristics of wood, and kiln operational procedures are generally accepted and used throughout the industry. For clarification and to help the newcomer with common terminology, a glossary of terms is included after the last chapter.

# Glossary

This glossary includes generally accepted definitions of a limited number of terms currently used in wood-drying literature. It also includes closely related terms that are not fully defined in their special application to present-day drying in most dictionaries or glossaries.

The following abbreviations are used throughout this manual.

Btu	British thermal unit
COD wt	Calculated oven-dry weight
DB	Dry bulb
EMC	Equilibrium moisture content
fbm	Board feet (foot board measure); although it is not used in this manual, MBF is a commonly used term for thousand board feet
FSP	Fiber saturation point
MC	Moisture content
OD wt	Oven-dry weight
RH	Relative humidity
sp. gr.	Specific gravity
WB	Wet bulb
WBD	Wet-bulb depression
wt	Weight

**Absorption, liquid**—The taking in or imbibing of a liquid.

**Adsorbed water**—In context of wood drying, adsorbed water is held in wood substance by hygroscopic or molecular attraction. (Syn: bound water)

**Air, entering**—Heated air just as it enters the kiln loads of lumber.

**Air, fresh**—Air brought into the dryer to replace vented air.

**Air, laminar**—In kiln drying, airflow across the lumber, parallel to the stickers, which is very smooth and layered, with no eddies or swirls; generally considered a condition in which velocity is too low to produce an optimum drying effect.

**Air, leaving**—Air just after it leaves the kiln loads of lumber. It is usually at a lower temperature than the entering air.

**Air, short circuiting of**—See Short circuiting of air.

**Air, turbulent**—In kiln drying, airflow across the lumber, parallel to the stickers, which is not layered and has fluctuations creating definite eddies and swirls; generally considered preferable to laminar flow for optimum drying.

**Air binding**—The presence of air (generally in pockets) in steam coils and traps, which interferes with the normal flow of steam and condensate.

**Air drying**—See Drying, air.

**Air reversal**—Changing the airflow to flow in the opposite direction through a load of drying lumber or products.

**Air travel, length of**—The distance between the entering- and leaving-air sides of the kiln charge.

**Air velocity**—The speed at which air moves, generally measured in feet per minute.

**Air volume**—The total amount of air occupying or moving through a given space, generally measured in cubic feet.

**Anemometer**—An instrument for measuring air velocity.

**Annual growth ring**—The growth layer put on a tree each year in temperate climates, or each growing season in other climates; each ring includes springwood and summerwood.

The glossary was compiled by R. Sidney Boone,  
Research Forest Products Technologist.

**Baffle**—A piece of canvas, metal, or wood used for deflecting, checking, or otherwise regulating the flow of air.

**Load**—A rigid or flexible panel placed to minimize the amount of air short-circuiting over, under, and between the kiln loads of lumber or other wood products.

**Balance**—An instrument used for measuring mass or weight and often used in weighing moisture content sections and kiln sample boards.

**Bark**—Outer layer of a tree, which consists of a thin, living inner part and a dry, dead outer part that is generally resistant to moisture movement.

**Bastard sawn**—Lumber in which the annual growth rings make angles of 30° to 60° with the surface of the piece.

**Blue stain**—See Stain, blue.

**Bolster**—A piece of wood, generally a nominal 4 in. in cross section, placed between stickered packages of lumber or other wood products to provide space for the entry and exit of the forks of a lift truck.

**Bow**—The distortion in a board that deviates from flatness lengthwise but not across its faces.

**Boxed heart**—The term used when the pith falls entirely within the outer faces of a piece of wood anywhere in its length. Also called boxed pith.

**Bright**—A term applied to wood that is free from discolorations.

**British thermal unit (Btu)**—The amount of heat necessary to raise 1 lb of water 1 °F in temperature.

**Bulb**—The temperature-sensitive part of a thermostatic control system.

**Control**—The sensing part of the controlling system, located in the kiln, which contains a temperature-sensitive liquid, gas, or electronic sensor.

**Controlling dry**—The bulb that controls the dry-bulb temperature.

**Controlling wet**—A bulb, kept completely covered at all times with a clean, water-saturated wick or porous sleeve, which automatically controls the wet-bulb temperature.

**Double-end control**—Control bulbs, usually located in each longitudinal half of the kiln, which control kiln temperatures for their respective zone, independent of each other.

**Dual control**—Two bulbs of a Y-shaped control system. They are usually located on each kiln wall directly opposite each other and control the temperature of the entering air regardless of the direction of air movement.

**Recorder**—The temperature-sensitive part of a system that records but does not control kiln conditions.

**Recorder-controller**—A bulb attached by means of a capillary tube to a recording-controlling instrument.

**Zone control**—A bulb or sensor that controls the temperature within a zone.

**Bypass pipe or duct**—A pipe or chamber that permits air, steam, or water to be diverted from their regular channels.

**Cam**—A rotating plate so cut that the edges act as a guide for a pin rolling along the edge. In drying control instruments, the pin is employed to control temperatures and/or moisture conditions in the drying chamber.

**Cambium**—The one-cell-thick layer of tissue between the bark and wood that repeatedly subdivides to form new wood and bark cells.

**Capacitance, electrical**—The property of an electrical conductor or configuration of conductors that allows it to store potential energy in the form of an electrical field.

**Capillary action**—The combination of solid-liquid adhesion and surface tension by which a liquid is elevated in a vertical tube or moved through a cellular structure.

**Casehardening**—A condition of stress and set in wood in which the outer fibers are under compressive stress and the inner fibers under tensile stress, the stresses persisting when the wood is uniformly dry.

**Casehardening, reverse**—A final stress and set condition (in lumber and other wood items) in which the outer fibers are under a tensile stress and the inner fibers are under a compressive stress as a result of over-conditioning.

**Cell**—A general term for the minute units of wood structure, including wood fibers, vessel segments, and other elements of diverse structure and function, having distinct cell walls and cell cavities.

**Charge**—See Kiln charge.

**Chart, recorder**—A sheet, usually circular, on which a graphic record of kiln temperatures is transcribed.

**Check**—A lengthwise separation of the wood that usually extends across the rings of annual growth and parallel to the wood rays. Checks result from drying stresses.

**Surface**—A check starting on a wide-grain surface and extending into the interior of a board.

**End**—A check starting on an end-grain surface and extending along the length of a board.

**Internal**—Checks originating in the interior of a piece of wood or extensions of surface and end checks.

**Circulation, air**—The movement of air within a kiln by either natural or mechanical means.

**Direction of**—The direction of movement of air through the kiln charge, expressed as longitudinal, transverse, or vertical.

**Forced**—The movement of air within a kiln by mechanical means.



Longitudinal—Air movement through the kiln charge to be expressed as front to rear or rear to front.

Natural—The movement of air within a kiln by natural means. Reversible. Capable of change in the direction of air movement.

Transverse—Air movement through the kiln charge from wall to wall to be expressed as right to left or left to right.

Vertical—Air movement through the kiln charge from top to bottom or bottom to top.

**Co-generation**—The simultaneous generation of electricity and low-pressure steam for on-site use, such as in drying.

**Coil header (or manifold)**—A pipe fitting to which a number of pipes are connected on one side.

**Coil, intermittent operation of**—The alternate opening and closing of the valve that controls steam flow into the coil.

**Coil, pipe**—One or more runs of pipes, the function of which is to heat the air in the kiln.

Booster—A supplementary coil, usually located between tracks of a multiple-track kiln, used to add heat to air that has already moved across a trackload of lumber.

Ceiling—A coil placed near the kiln ceiling to warm the ceiling and roof, thus preventing moisture condensation.

Double-end—Coils usually extending half the length of the kiln from both ends and usually operating as separate units.

Multiple-return-bend header—A coil usually with the discharge header located below the supply header, the pipes running back and forth with a 180° elbow at the bends.

Plain header (horizontal or vertical)—A coil consisting of a supply and discharge header at opposite ends with the pipes running from one to the other.

Single-return-bend header (horizontal or vertical)—A coil with the discharge header usually located under or on the side of the supply header, the pipes running from the supply header to a 180° bend and back to the discharge header.

**Coil radiating surface**—The entire uninsulated surface area of a heating coil.

**Collapse**—The severe distortion or flattening of single cells or rows of cells in wood during drying, often evidenced by a caved-in or corrugated appearance of the surface of the piece.

**Compression failure**—Rupture of the wood structure resulting from excessive compression along the grain. It may develop as a result of bending in the living tree or during felling. In surfaced lumber, compression failures appear as fine wrinkles across the face of the piece.

**Compression wood**—Abnormal wood formed on the lower side of branches and inclined trunks of softwood trees. It has relatively wide, eccentric growth rings with little or no demarcation between springwood and summerwood and more than normal amounts of summerwood. Compression wood shrinks more than normal wood longitudinally, causing bow, crook, and twist.

**Condensate**—Water formed by the cooling of steam.

**Conditioning**—See Stresses, relief of.

**Conditioning treatment**—A controlled high temperature-high relative humidity condition used in a dry kiln after the final stage of drying to bring about a uniform moisture distribution in the boards and to relieve drying stresses.

**Conduction, heat**—Transmission of heat through or by means of a conductor.

**Controller**—An instrument that automatically controls kiln temperatures.

**Convection, heat**—Transfer of heat from heating coils to lumber by means of air.

Course, lumber—A single layer of lumber.

**Crib**—A stickered kiln truckload of lumber usually stacked onto kiln trucks and kiln bunks to make a load 6 to 10 ft wide, 10 to 16 ft high, and as long as the lumber being stacked.

**Crook**—A distortion of a board in which the edges deviate from a straight line from end to end of the board.

**Cup**—A distortion of a board in which there is deviation from flatness across the width of the board.

**Cycle, heating**—The time intervening between successive openings of a control valve.

**Cycle, temperature**—The time between the maximum and minimum temperatures during a heating cycle.

**Decay**—The decomposition of wood substance by fungi.

Advanced (or typical)—The older stage of decay in which the destruction is readily recognized because the wood has become punky, soft and spongy, stringy, ringshaked, pitted, or crumbly. Decided discoloration or bleaching of the rotted wood is often apparent.

Incipient—The early stage of decay that has not proceeded far enough to soften or otherwise perceptibly impair the hardness of the wood. It is usually accompanied by a slight discoloration or bleaching of the wood.

**Defects, drying**—Any irregularity occurring in or on wood, as a result of drying, that may lower its strength, durability, or utility value.

**Degrade, kiln**—A drop in lumber grade that results from kiln drying.

**Dehumidification kiln**—See Kiln, dehumidification.

**Density**—The weight of a body per unit volume.

**Depression, wet-bulb**—The difference between the dry- and wet-bulb temperatures.

**Desorption**—The loss of adsorbed (hygroscopic) moisture from wood to the surrounding air.

**Desuperheater**—A device for removing from steam the heat in excess of that required for saturation at a given pressure. In kiln drying, atomized water injection is often used to eliminate the superheat from the steam employed for humidification.

**Dew point**—The temperature at which steam or water vapor begins to condense.

**Diamonding**—A form of warp in which the cross section assumes a diamond shape.

**Diffuse-porous wood**—A hardwood in which the pores tend to be uniform in size and distribution throughout each annual ring or to decrease in size slightly and gradually toward the outer border of the ring.

**Diffusion**—Spontaneous movement of heat, moisture, or gas throughout a body or space. Movement is from high to low points of temperature or concentration.

**Direct fired**—A method of heating a dry kiln where the hot gases produced by burning gas, oil, or wood waste are discharged directly into the kiln atmosphere.

**Dry-bulb temperature**—The temperature of the air indicated by any type of thermometer not affected by the water vapor content or relative humidity of the air.

**Drying, air**—Process of drying lumber by natural conditions in a yard or in an open unheated shed.

**Drying, precision kiln**—Process of drying wood in which controlled procedures are followed in order to obtain a stress-free product that has a desired moisture content and has suffered a minimum loss in strength.

**Drying in transit**—The partial or complete kiln drying of lumber by a drying facility located between the shipping and fabrication points.

**Drying rate**—The amount of moisture lost from the lumber per unit of time.

**Duct, air**—A rectangular, square, or circular passage-way to conduct air.

**Electrodes**—In testing wood for moisture content, devices made of an electrical-conducting material for connecting wood into the electric circuit of an electric moisture meter. In high-frequency heating, metal plates used to apply the electric field to the material being heated.

**Insulated**—In testing wood for moisture content, special electrodes for use with resistance-type electric moisture meters that are coated with an insulating material to limit or control the point of contact between the electrode and the wood.

**End check**—See Check, end.

**End coating**—A coating of moisture-resistant material applied to the end-grain surface to retard end drying of green wood or to minimize moisture changes in dried wood.

**Equalization**—Bringing the pieces of lumber in a kiln charge to nearly uniform moisture content. See Treatment, equalization.

**Equilibrium moisture content**—The moisture content at which wood neither gains nor loses moisture when surrounded by air at a given relative humidity and temperature.

**Evaporation**—The change from the liquid to the vapor form.

**Extractives**—Substances in wood that are not an integral part of the cellular structure and can be removed by solution in hot or cold water, ether, benzene, or other solvents that do not react chemically with wood substance.

## Fan

**Centrifugal fan**—A device for moving air by means of a rotating wheel or impeller, which gives a centrifugal action to the air being moved. Frequently used for pressure venting.

**Deck fan**—Fan mounted with fan impeller horizontally oriented in a horizontal panel opening, such as a floor or ceiling opening.

**Disk or propeller fan**—An axial-flow fan with the air flowing through the impeller parallel to the shaft upon which the impeller is mounted. The impeller blade is designed to deliver about the same volume of air in either direction of rotation.

**Pitch**—The angle a fan blade is set with respect to the axis of the propeller fan shaft.

**Shroud**—Flanges around the wall opening for a disk fan impeller that give support to the wall and provide protection for the impeller and personnel.

**Fiber, wood**—A comparatively long ( $\leq 1/25$  to  $1/3$  in), narrow, tapering hardwood cell closed at both ends.

**Fiber saturation point**—The stage in the drying or wetting of wood at which the cell walls are saturated with water and the cell cavities are free from water. It normally applies to an individual cell or group of cells, not to whole boards. It is usually taken as approximately 30 percent moisture content, based on the weight of oven-dried wood.

**Flat-sawed**—Lumber sawed in a plane approximately perpendicular to a radius of the log. See Grain.

**Flitch**—A portion of a log sawed on two or more sides and intended for remanufacture, as into lumber or veneer.

**Fluctuation, steam pressure**—Variation of steam pressure.

**Flue, vertical**—A vertical space, usually 6 in or less in width and extending the length and height of a kiln truckload or package of lumber.

**Grain**—The general direction of the fibers in wood or lumber. When used with qualifying adjectives, it has special meanings concerning the direction of the fibers or the direction or size of the growth rings. Specific terms for fiber and growth ring direction are as follows:

Cross grain—Grain deviating from a line parallel to the sides of the piece.

Diagonal grain—A form of cross grain resulting from sawing at an angle with the bark of the log.

Interlocked grain—A form of spiral grain in which the fiber direction gradually alternates from right-hand to left-hand spiral and back again in adjacent groups of annual rings.

Spiral grain—A form of cross grain that results during the growth of the tree; the fibers take a spiral course about the trunk instead of the normal vertical course.

Straight grain—Grain parallel to the sides of the piece.

Coarse grain—wood in which the growth rings are wide or have major differences in density and color between springwood and summerwood.

Edge grain (or vertical grain)—The grain in lumber produced by quartersawing so that the edges of the growth rings are exposed on the widest faces of the piece, and the rings form angles of 45° to 90° with the widest faces.

Fine grain—Wood in which the growth rings are narrow and inconspicuous.

Flat grain—The grain in lumber produced by flat sawing so that the tangential faces of the growth rings are exposed on the widest faces of the piece and the rings form angles of less than 45° with the widest faces.

**Green lumber (or grass green)**—Lumber cut from freshly felled trees.

**Growth rate**—The rate at which a tree has laid on wood, measured radially in the tree trunk or in the radial direction in lumber. The unit of measure in use is the number of annual growth rings per inch.

**Hardwoods**—Woods produced by one of the botanical groups of trees that have broad leaves in contrast to the needles or scalelike leaves of the conifers or softwoods. The term has no reference to the actual hardness of the wood.

**Heartwood**—The wood extending from the pith to the sapwood, the cells of which no longer participate in the life processes of the tree. Heartwood may be infiltrated with gums, resins, and other materials that usually make it darker and more decay resistant than sapwood.

## Heat

Conduction—The transfer of heat within a material or from one material to another in contact with it.

Consumption—In kiln drying, the total heat required to heat the wood and the kiln structure and to evaporate the water from the wood, as well as heat losses, including venting.

Convection—The transfer of heat to or from a material by reason of the mass movement of a fluid or gas in contact with it. In kiln drying wood, air is generally used as the medium of exchange.

Exchanger—Normally a device for transferring heat from one fluid or gas to another without allowing them to mix. Examples: fin pipes, radiators.

Latent heat of evaporation—The heat required to change water into steam without a temperature change and at constant pressure; for example, water at 212°F and at atmospheric pressure changes to steam at the same temperature by adding 970.3 Btu/lb.

Loss—The amount of heat lost by transmission through the building walls, roof, doors, floor, and vents.

Radiation—The transfer of heat by waves through space by reason of a temperature difference existing between two bodies. In common terminology in kiln drying, all forms of heat transfer are often lumped into one term—radiation of heat.

Sensible heat—In kiln drying, the amount of heat required to raise the kiln and lumber to drying temperature. (Syn: enthalpy)

Total heat—The latent heat of the water vapor in the air-water vapor mixture plus the sensible heat of the mixture.

Transfer coefficient—An experimentally derived number for a particular system that quantifies the rate of heat exchange between two zones.

**High-temperature drying**—Use of dry-bulb temperatures of 212°F or more.

**Honeycombing**—Checks, often not visible on the surface, that occur in the interior of a piece of wood, usually along the wood rays. See Ring failure.

**Humidity, absolute**—The weight of water vapor per unit volume of space.

**Humidity, relative**—**Ratio** of the amount of water vapor present in the air to that which the air would hold at saturation at the same temperature. It is usually considered on the basis of the weight of the vapor, but for accuracy it should be considered on the basis of vapor pressures.

**Hygrometer**—An instrument for measuring relative humidity, often consisting of dry-bulb and wet-bulb thermometers.

**Hygroscopicity**—The property of a substance that permits it to adsorb and retain moisture.

**Hysteresis**—The tendency of wood exposed to any specified temperature and relative humidity conditions to reach equilibrium at a lower moisture content when absorbing moisture from a drier condition than when losing moisture from a wetter condition.

**Implosion**—The caving in of kiln doors and/or walls because of a sudden marked decrease in pressure below atmospheric within the kiln. Normally occurs at kiln startup with very cold lumber or when restarting after fan failure early in a run.

**Indirect fired**—A method of heating a dry kiln where a hot fluid (steam, water, or oil) flows into the kiln in pipes and gives off its heat to the kiln atmosphere through a suitable radiating surface.

**Infiltration, cold air**—The uncontrolled and inadvertent entry of cold air into the dryer through cracks in the walls and ceiling, or leaky doors, or openings other than the fresh-air intake.

**Juvenile wood**—The initial wood formed adjacent to the pith, characterized often by lower specific gravity, lower strength, higher longitudinal shrinkage, and different microstructure than mature wood.

**Kiln**—A heated chamber for drying lumber, veneer, and other wood products in which temperature and relative humidity are controlled.

Automatically controlled—A dry kiln in which drying conditions are controlled by the action of thermostats.

Compartment—A dry kiln in which the total charge of lumber is dried as a single unit. At any given time, the temperature and relative humidity are uniform throughout the kiln.

Conventional-temperature—A kiln for drying lumber and other wood products typically operated in the range of 110 to 180°F.

Dehumidification—A type of kiln in which the moisture removed from the lumber, or other wood product, is condensed out of the circulating air, which is reheated instead of being exhausted to the atmosphere.

Elevated-temperature—A kiln for drying lumber and other wood products typically operated in the range of 110 to 211°F.

Forced-circulation—A dry kiln in which the air is circulated by mechanical means.

High-temperature—A kiln for drying lumber and other wood products operated at temperatures above 212°F.

Low-temperature—A kiln for drying lumber or other wood products typically operated in the range of 85 and 120°F.

Manually controlled—A dry kiln in which drying conditions are controlled by the manual operation of valves and ventilators.

Multiple-track—A dry kiln equipped with two or more tracks.

Natural-circulation—A dry kiln in which air circulation depends on the power of gravity and the varying density of air with changes in its temperature and moisture content.

Package-loaded—A trackless compartment kiln for drying packages of stickered lumber or other wood products. The dryer usually has large doors that can be opened so that the kiln charge can be placed in or removed from the dryer by forklift trucks.

Progressive—A dry kiln in which the total charge of lumber is not dried as a single unit but as several units, such as kiln truckloads, that move progressively through the kiln. The temperature is lower and the relative humidity higher at the entering end (green end) than at the discharge end (dry end).

Reversible-circulation—A dry kiln in which the direction of air circulation can be reversed at desired intervals.

Side-loaded—See Package-loaded.

Single-track—A dry kiln equipped with one track.

Track-loaded—A compartment kiln for drying stickered lumber that is stacked on kiln trucks, which are rolled into and out of the kiln on tracks.

Vacuum—A compartment kiln in which lumber is dried at less than atmospheric pressure either continuously or intermittently during the drying cycle.

**Kiln charge**—The total amount of lumber or wood items in a dry kiln.

**Kiln charge, mixed**—Same as kiln charge but composed of more than one species or thickness of lumber or wood items.

**Kiln drying**—Process of drying lumber in a dry kiln.

**Kiln leakage**—The undesirable loss of heat and vapor from a kiln through badly fitted doors and ventilators or through cracks in the walls and roof.

**Kiln run**—The term applied to the drying of a single charge of lumber.

**Kiln sample**—A section 30 in or more in length cut from a sample board and placed in the kiln charge so that it can be removed for examination, weighing, and testing.

Controlling—Some of the wettest samples used to control the drying. The number depends on the total number of samples used and the composition of the kiln charge.

Driest—The kiln sample with the lowest moisture content.

Fastest drying—The kiln sample that loses the largest amount of moisture in a given period.

Pocket—A space provided for the kiln sample in the kiln packages of lumber.

Slowest drying—The kiln sample that loses the least amount of moisture *in* a given period.

Weight, current—The weight of a kiln sample at given times during the drying process.

Weight, final—The weight of a kiln sample after the completion of drying.

Weight, green (initial, original)—The weight of a kiln sample prior to kiln drying regardless of its moisture content.

Wettest—The kiln sample with the greatest amount of moisture.

**Knot**—That part of a branch that has become overgrown by the body of a tree. The shape of the knot depends on the angle at which the branch is cut.

**Laminar air**—See Air, laminar.

**Loading, cross-piled**—Lumber piled on kiln trucks and placed in a dry kiln with the long axis of the load perpendicular to the length of the kiln.

**Loading, end-piled**—Lumber piled on kiln trucks and placed in a dry kiln with the long axis of the load parallel to the length of the kiln.

**Longitudinal**—Generally, the direction along the length of the grain of wood. A longitudinal section may be a plane either tangential or radial to the growth rings.

**Lumber, kiln-dried**—Lumber that has been dried in a dry kiln to a specified moisture condition.

**Lumber, shipping-dry**—Lumber and other wood products that have been air or kiln dried to a sufficiently low moisture content to prevent stain, mold, and decay in transit; generally taken to be 25 percent moisture content or less.

**Lumber storage room**—A room maintained within specified equilibrium moisture content limits so that lumber stored in it will not gain or lose moisture beyond fixed limits.

**Makeup air**—Ambient air that replaces vent air used to exhaust water vapor being released within the dryer.

**Meter, moisture**—An instrument used for rapid determination of the moisture content in wood by electrical means.

**Mineral streak**—An olive to greenish-black or brown discoloration of undetermined cause in hardwoods, particularly hard maples; commonly associated with bird pecks and other injuries; occurs in streaks usually containing accumulations of mineral matter.

**Moisture content of wood**—Weight of the water contained in the wood, expressed as a percentage of the weight of the oven-dried wood.

Average—The percentage of moisture content of a single piece of wood or the sum of the moisture contents of a number of pieces divided by their number.

Core—The moisture content of the inside part of a moisture section remaining after a shell one-fourth the thickness of the section has been removed.

Determination of—The testing of lumber to determine the amount of moisture present. This is usually expressed in terms of percent of the oven-dry weight.

Find—The moisture content of the wood at the end of kiln drying.

Green—The moisture content of wood in the living tree or freshly sawn wood.

Initial—The moisture content of the wood at the start of kiln drying.

Shell—The moisture content of the outer one-fourth of the thickness of a moisture section.

**Moisture distribution**—The variation of moisture content throughout a piece of wood, usually from face to face but sometimes from end to end or from edge to edge.

**Moisture gradient**—A condition during drying in which the moisture content uniformly decreases from the inside toward the surface of a piece of wood. Also a term used specifically to denote the slope of the moisture content distribution curve.

**Moisture gradient, reverse**—A condition following moisture regain in which the moisture content is higher at the surface than inside the wood.

**Moisture meter**—See Meter, moisture.

**Moisture range**—The difference in moisture content between the driest and wettest boards or samples.

**Moisture section**—A cross section, 1 in. in length along the grain, cut from a kiln or random sample and used to determine moisture content.

Initial weight of—The weight of a moisture section immediately after being cut from a kiln sample or board.

Oven-dry weight of—The weight of a moisture section after being oven-dried to a constant weight.

**Mold**—A fungal growth on lumber taking place mainly at or near the surface and, therefore, not typically resulting in deep discolorations. Growths are usually ash green to deep green in color, although black is common.

**Old growth**—Timber in or from a mature, naturally established forest. When the trees have grown during most if not all of their individual lives in active competition with their companions for sunlight and moisture, the timber is usually straight and relatively free of knots.

**Oven-dry**—A term applied to wood dried to constant weight in an oven maintained at temperatures of from 214 to 221°F.

Pervious wood—A wood through which moisture moves readily.

### **Piling**

Box—The flat piling of random-length boards on kiln trucks so that the ends of the completed load are in vertical alignment. The longest boards are placed on the outside of the load, and the shorter boards are

alternately placed with one end even with one end of the load or the other.

**Edge**—Piling lumber so that the broad face of the board is vertical.

**Flat**—Piling lumber so that the broad face of the board is horizontal.

## Pipe

**Condensate**—The pipe on the downstream side of heating coils and steam traps that carries condensate back to the boiler.

**Feed**—Usually the pipe conducting steam from the control valve to the heating coils.

**Fin**—A heating pipe with many finlike projections that increase the radiation surface.

**Plain**—A heating pipe with a smooth outer surface.

**Steam-spray**—A pipe with numerous holes or nozzles through which steam is ejected to increase the relative humidity in the kiln.

**Pit**—A relatively unthickened part of a wood cell wall where a thin membrane may permit liquids to readily pass from one cell to another. A “bordered” pit has an overhanging rim that is not present in a “simple” pit.

**Pitch**—The mixture of rosin and turpentine or other volatiles produced in the resin canals of pines and other conifers. Term also applied to mixtures of nonvolatile liquids or noncrystalline solids and volatile oils in other species.

**Pocket**—An opening, extending parallel to the growth rings, that contains or has contained pitch.

**Streak**—A well-defined streaky accumulation of pitch in the wood of certain softwoods.

**Pith**—The small, soft core occurring in the structural center of a tree trunk, branch, twig, or log.

**Plainsawed**—Another term for flat-sawed or flat-grained lumber.

**Platen pressdrying**—Contact heating of wood between heated metal plates to affect drying while under restraint.

**Plenum chamber**—The space between the lumber stack and kiln wall for air circulation on the pressure side of a fan or blower in which the air is maintained under pressure.

**Pore**—The cross section of a specialized hardwood cell known as a vessel. See Vessels.

**Predryer**—A type of low-temperature dryer. Stickered loads or unit packages of lumber or other wood products are placed in a large building provided with fans, heating system, and vents such that air of a given temperature and humidity can be circulated through the lumber.

**Pressdrying, platen**—See Platen pressdrying.

**Psychrometer**—An instrument with both wet-bulb and dry-bulb thermometers for determining the amount of water vapor in the atmosphere.

**Psychrometric char**—A table or graph used to relate the absolute humidity, relative humidity, and dry- and wet-bulb temperatures.

**Quartersawed**—Lumber sawed so the wide faces are approximately at right angles to the annual growth rings. See Grain.

**Radial**—Coincident with or generally parallel to a radius of the tree from the pith to the bark. A radial section is a lengthwise section in a plane that passes through the pith.

**Radiation**—A term often used in kiln drying to describe heat transfer from heating coils to lumber. In this common use, it is understood to include both convection and radiation heat transfer, although the former is the most important in kilns.

**Balanced**—Construction and arrangement so as to ensure equal radiating surface and uniform temperatures throughout the kiln.

**Excessive**—A greater amount of radiation than required.

**Flexible**—The arrangement of the heating system into small coils equipped with hand valves that, when opened or closed, permit rapid adjustment of the radiating surface to meet the required needs.

**Raised grain**—A roughened condition of the surface of dressed lumber in which the hard summerwood is raised above the softer springwood but not torn loose from it.

**Rays, wood**—Strips of cells extending radially within a tree and varying in height from a few cells in some species to 4 in or more in oak. The rays primarily serve to store food and transport it horizontally in the tree.

**Redry**—A process in which material that has been dried but is at a moisture content level higher than desired is returned to the dryer.

**Refractory**—In wood, implies difficulty in processing or manufacturing by ordinary methods, difficulty in drying, resistance to the penetration of preservatives, or difficulty in machining.

**Relative humidity**—See Humidity, relative.

**Resin canal (or duct)**—Intercellular passages that contain and transmit resinous materials. They extend vertically or radially in a tree.

**Ring, annual growth**—See Annual growth ring.

**Ring failure (or separation)**—A separation of the wood during drying. Occurs along the grain and parallel to the annual rings, either within or between rings; called honeycomb and ring check in some localities. See Shake.

**Ring-porous wood**—Wood in which the pores of the earlywood (springwood) are distinctly larger than those of the latewood (summerwood) and form a well-defined zone or growth ring.

**Sample**—See Kiln sample.

**Sample board**—A board from which one or more kiln samples will be cut, or a board taken from a kiln truck-load during drying for the purpose of cutting a moisture section.

**Sap**—The moisture in green wood, which contains nutrients and other extractives in solution.

**Sap stain**—See Stain, blue.

**Sapwood**—The layer of wood near the outside of the log that is actively involved in the life processes of the tree. Usually lighter in color than the heartwood.

**Sapwood stain**—See Stain, blue.

**Seasoning**—Removal of moisture from green wood, and in some cases relief of stresses, in order to improve its serviceability. (Syn: drying)

**Second growth**—Timber that has grown after the removal, whether by cutting, fire, wind, or other agency, of all or a large part of the previous stand.

**Sensible heat**—See Heat, sensible.

**Set**—A localized semipermanent deformation in wood caused by internal tensile or compressive stresses.

Compression—Set, occurring during compression, that tends to give the wood a smaller than normal dimension after drying. Usually found in the interior of wood items during the last stage of drying but sometimes in the outer layers after overconditioning or rewetting. Also caused by external restraint during rewetting of dried wood.

Tension—Set, occurring during tension, that tends to give the wood a larger than normal dimension after drying. Usually occurring in the outer layers during the first stages. Also caused by external restraint during drying of wet wood.

**Shake**—A separation along the grain, the greater part of which occurs between and within growth rings. Found in stumps and ends of freshly cut logs and green lumber. See Ring failure.

**Short circuiting of air**—The movement of air through other than desired channels. Usually results when a kiln charge is improperly loaded and/or baffled.

**Shrinkage**—The contraction of wood caused by drying the material below the fiber saturation point.

Longitudinal—Shrinkage along the grain.

Radial—Shrinkage across the grain, in a radial direction.

Tangential—Shrinkage across the grain, in a tangential direction.

**Sinker**—A log that sinks or has low buoyancy in water.

**Sinker stock**—Green lumber or other green sawmill products that will not float in water. Sinker stock may be sawn from sinker logs that were water-logged during ponding or from freshly cut logs containing wetwood. The green moisture content is abnormally high, and

the lumber tends to dry slowly and is prone to develop checks and honeycomb.

**Softwood**—Wood produced by one of the botanical groups of trees that, in most species, have needle or scalelike leaves.

#### **sorter**

Drop—A mechanical lumber-sorting device that sorts lumber for thickness, width, and length by dropping them into separate compartments accordingly.

Edge—A mechanical lumber-sorting device consisting of grooves or slots in which the lumber is placed on edge. Lines of live rolls, arranged under the slots, carry the lumber to the desired bin or compartment.

Tray—A mechanical lumber-sorting device consisting of a series of trays one above the other into which the lumber is ejected by either mechanical or electrical signaling devices.

**Specific gravity**—The ratio of the oven-dry weight of a piece of wood to the weight of an equal volume of water (39°F). In drying, specific gravity values are usually based on the volume of the green wood.

**Split**—A lengthwise separation of the wood, caused by the tearing apart of the wood parallel to the wood rays.

**Spray line**—A plain pipe of varying sizes and lengths that is drilled with holes of various sizes and spacing through which steam is injected into the kiln.

**Springwood (earlywood)**—The part of the annual growth ring that is formed during the early part of the season's growth. It is usually less dense and mechanically weaker than summerwood.

**Stain**—A discoloration in wood that may be caused by such diverse agencies as micro-organisms, metal, or chemicals. The term also applies to materials used to impart color to wood.

Blue (sap stain, sapwood stain)—A bluish or grayish discoloration of the sapwood caused by the growth of certain dark-colored fungi on the surface and in the interior of the wood, made possible by the same conditions that favor the growth of other fungi.

Chemical—A general term including all stains that are due to color changes of the chemicals normally present in the wood, such as pinking of hickory and browning of some softwoods, particularly the pines.

Chemical, brown—A chemical discoloration of wood, which can occur during the air drying or kiln drying of several softwood species, caused by the concentration and modification of extractives.

Iron-tannate—A bluish-black surface stain on oak and other tannin-bearing woods following contact of the wet wood with iron, or with water in which iron is dissolved.

Mineral—An olive to greenish-black or brown discoloration in hardwoods, particularly maple, caused by bird peck or other injury and found either in mass discoloration or mineral streaks. The mineral associ-

ated with such streaks is frequently calcium oxalate, which has a tendency to dull machining knives.

**Sticker**—A gray to blue or brown chemical stain occurring on and beneath the surface of boards where they are in contact with stickers (also fungal sap stain when found only in the sticker area).

**Water**—A yellowish to blackish surface discoloration caused by water that dripped onto the wood during drying.

**Weather**—A very thin grayish-brown surface discoloration on lumber exposed for a long time to the weather.

**Steam**—The vapor into which water is converted when heated.

**Exhaust**—Steam that has already passed through a steam engine or machine.

**Flash**—The reevaporation of hot water produced by excess heat when the water is discharged to a lower pressure.

**Live**—Steam obtained directly from the boiler.

**Superheated**—Steam at a temperature higher than the saturation temperature corresponding to the pressure.

**Steam binding**—The presence of steam in the drain line between the heating coil and trap, which temporarily prevents the drainage of condensate and air from the coil.

**Sticker**—A wooden strip placed between the courses of lumber in a kiln load and at right angles to the long axis of the boards to permit air circulation.

**Alignment**—The placing of stickers in a pile, package, or truckload of lumber so that they form vertical tiers.

**Spacing**—The distance between stickers measured from center to center.

**Stress, drying**—An internal force, exerted by either of two adjacent parts of a piece of wood upon the other during drying, caused by uneven drying and shrinkage, and influenced by set.

**Tensile**—Stress in the outer layers of wood during the early stages of drying when the layers are trying to shrink but are restrained by the still-wet interior region; also, the stress in the interior layers later in drying as they try to shrink and are restrained by the set outer shell.

**Compressive**—Stress found in the interior region of wood during the early stages of drying, caused by the shrinking of the outer shell; also, stress in the outer layers later in drying caused by the shrinking of the interior.

**Stress free**—Containing no drying stresses.

**Stress section**—A cross section of a sample that is cut into prongs of equal thicknesses, from face to face.

**Stresses, relief of**—The result of a conditioning treatment, following the final stage of drying, which causes a redistribution of moisture and a relief of the sets.

**Stresses, reversal of**—The normal change from tension in the surface and compression in the center to compression in the surface and tension in the center.

**Summerwood (latewood)**—The part of the annual growth ring that is formed during the latter part of the growing season. It is usually denser and mechanically stronger than springwood.

**Surface check**—See Check, surface.

**Tangential**—Coincident with or generally parallel to a tangent at the circumference of a tree or log, or growth rings. A tangential section is a longitudinal section through a tree perpendicular to a radius.

**Temperature**—Degree of hotness or coldness.

**Cold zone**—The lowest entering-air dry-bulb temperature in the kiln.

**Drop across the load**—The reduction in the dry-bulb temperature of the air as it flows through the load and is cooled by evaporating moisture from the load of lumber.

**Dry-bulb**—The temperature of the kiln air.

**Hot zone**—The highest entering-air dry-bulb temperature in the kiln.

**Longitudinal variation of**—The range of entering-air dry-bulb temperatures in a kiln measured along the kiln length.

**Wet-bulb**—The temperatures indicated by any temperature measuring device, the sensitive element of which is covered by a smooth, clean, soft, water-saturated cloth (wet-bulb wick or porous sleeve).

**Temperature gradient, longitudinal**—A term used to denote longitudinal temperature differences within a dry kiln.

**Tension wood**—A type of wood found in leaning trees of some hardwood species, characterized by the presence of fibers technically known as “gelatinous” and by excessive longitudinal shrinkage. Tension wood fibers tend to “pull out” on sawed and planed surfaces, giving so-called fuzzy grain. Tension wood causes crook and bow and may collapse. Because of slower than normal drying, tension wood zones may remain wet when the surrounding wood is dry.

**Texture**—A term referring to the size of wood cells. Thus, “fine-textured” wood has small cells and “coarse-textured,” large cells. Where all the cells of a softwood or all the pores of a hardwood are approximately the same size, as seen on the cross section, the wood can be called “uniform textured.” The term is sometimes erroneously used in combination with soft or hard.

**Thermocouple**—A temperature-sensing device made by soldering or fusing two dissimilar metal wires together and connecting the wires to a potentiometer or



similar device, thereby determining the temperature at the junction. Copper-constantan thermocouples are usually used in dry kiln work.

**Tracheids**—The elongated cells that make up the greater part of the wood of the softwoods; frequently referred to as fibers.

**Transverse**—The directions in wood at right angles to the wood fibers or across the grain, including radial and tangential directions. A transverse or cross section is a section through a tree or timber at right angles to the pith. It has an end-grain surface.

**Trap, steam**—A device that discharges air and condensate from steam-heating coils but limits the passage of steam.

**Treatment, equalization**—A controlled temperature and relative humidity condition used in a dry kiln at the end of drying to stop the drying of the driest boards while allowing the wettest boards to continue drying, thus reducing the moisture range between boards.

**Treatment, steaming**—Spraying steam directly into the kiln to attain a condition at or near saturation in the initial stages of kiln drying to retard the growth of mold. Also used to increase the rate of heating cold lumber. Sometimes used needlessly during other stages of drying to restore surface moisture, and often used without proper control to partially relieve stresses at the end of drying.

**Twist**—A form of warp caused by the turning or winding of the edges of a board so that the four corners of any face are no longer in the same plane.

**Tyloses**—Extensions of parenchyma cells into the pores or vessels of some hardwoods, notably white oak and black locust, prior to or during heartwood formation. They tend to prevent or greatly retard moisture movement through the vessels.

**Vacuum kiln**—See Kiln, vacuum.

**Vapor barrier**—A material with a high resistance to vapor movement, such as asphalt-impregnated paper, that is used in combination with insulation to control condensation.

**Vapor pressure**—The pressure exerted by a vapor when the rates of condensation and evaporation are in equilibrium between the liquid and vapor state.

**Ventilator (or vent)**—An opening in the kiln roof or wall, or in the blower duct work, that can be opened or closed in order to maintain the desired relative humidity condition within the kiln.

Automatic control—A ventilator that is opened or closed by a thermostat.

Linkage—The adjustable, pivoted rods connecting the vent cover to an air valve or to a hand-operated level, which facilitate the opening and closing of the vents.

Manual control—A ventilator that is opened or closed by hand.

**Vessels**—Wood cells in hardwoods of comparatively large diameter that have open ends and are set one above the other so as to form continuous tubes. The openings of the vessels on the surface of a piece of wood are usually referred to as pores.

**Virgin growth**—The original growth of mature trees.

**Wane**—Presence of bark or the lack of wood from any cause on the edge or corner of a piece.

**Warp**—Any variation from a true or plane surface. Warp includes cup, bow, crook, twist, and diamonding, or any combination thereof.

**Water, bound (adsorbed, hygroscopic)**—Moisture that is bound by adsorption forces within the cell wall; that is, the water in wood below the fiber saturation point.

**Water, free**—Moisture that is held in the cell cavities of the wood, not bound in the cell wall.

**Water box**—A water container that is mounted under the wet bulb and supplies water to the wick.

**Water pocket**—An area of unusually high moisture content in lumber; pockets are of various sizes and shapes. Also called wet pocket.

**Waterlogging**—The presence of water in steam coils, which interferes with the normal flow of steam and seriously affects the heating efficiency of the coil.

**Wet-bulb temperature**.—See Temperature.

**Wetwood**—Green wood with an abnormally high moisture content that generally results from infections in living trees by anaerobic bacteria, but may also result from water logging during log ponding. Wetwood can occur in both softwoods and hardwoods; the green lumber is usually difficult to dry without defects. Although difficult to recognize, wetwood is often characterized by a translucent, water-soaked appearance and a sour or rancid odor.

**Wood**—The hard material between the pith and the bark in the stems and branches of trees, made up of a variety of organized hollow cells and consisting chemically of cellulose, hemicelluloses, lignin, and extractives.

**Wood, reaction**—In wood anatomy, wood with more or less distinctive anatomical characteristics, formed in parts of leaning or crooked stems and in branches. Reaction wood consists of tension wood in hardwoods and compression wood in softwoods.

**Wood, refractory**—See Refractory.

**Wood, ring-porous**—See Ring-porous wood.

**Wood substance**—The extractive-free solid material of which the cell walls of oven-dried wood are composed. Wood substance has essentially the same specific gravity in all species.

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