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Manufacturing and Marketing Eastern Hardwood Lumber Produced by Thin Kerf Band Mills

Daniel L. Cassens

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The Author

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Foreword

In 1995, I purchased an LT40 hydraulic Wood Mizer sawmill with my inheritance. I have used the mill for sawing salvaged timber cut from my own woodlands, for custom sawing, and for dozens of demonstration events for Purdue University. Some of the lumber is kiln-dried and sold to custom and weekend woodworkers.

Over the years, I have had a wide variety of technical training and experience growing timber, harvesting it, sawing it on the Wood Mizer, and either putting it to use or passing it on to others to use. This handbook is a compilation of the knowledge I gained from my training and experience. I hope you will find the publication useful.

Daniel L. Cassens

October 2011

Wood-Mizer Products, Inc., has become the world leader in sawmills, with over 30,000 mills in use in more than 110 countries. We thank Wood-Mizer Products, Inc., for their support in producing and promoting this book to individuals who have a keen interest in this great industry.

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Safety

There is always a risk of being hurt when using mechanical equipment and handling logs and lumber. Therefore the safety recommendations of equipment manufacturers should be studied and followed. Individuals should wear their own personal protective equipment such as a hard hat, ear protection, safety glasses, and steel-toed shoes.

The Occupational Safety and Health Administration (OSHA) is the department of the U.S. Government with the responsibility to ensure safety and a healthful work environment. OSHA standards that may be useful are Sawmills 29 CFR1910.265, Logging 29CFR1910.266, Personal Protective Equipment 29CFR1910.132 to 1910.138, and Lockout/Tagout 29CFR1910.147. Other standards, as appropriate, should be consulted.

Dedication

I dedicate this handbook to four individuals who have influenced my life. First are my parents, Ludwig Preibisius Cassens (1913 – 1981) and Ethel Alvina Hinrichs (1914 – 1992), and my wife Victoria (Vicki) Jean Vinkovich Cassens.

Two of my grandparents immigrated as young children from Ostfriesland, Germany, and the other two were born to previous immigrants from the same region–all in the 1870s. They and many others settled in Whiteside County located in northwest Illinois because of the fertile farm land. My parents worked as farmers all of their lives, and towards the end of their working career were able to purchase a small farm. When my father finished eighth grade he had been told to stay home and work. Dad always regretted not being able to continue his formal education. I believe that as a result he sent my older brother Robert and me to the University of Illinois. Both of us finished Ph.D.'s and have had long professional careers at land grant institutions.

With the passing of my mother, I received a small inheritance. I wanted to do something special that I would not otherwise do and that would remind me of both parents. The choices came down to two: a Civil War officer's commission signed by Abraham Lincoln or a Wood Mizer sawmill. The first item would hang on the wall and look pretty. The second would convert salvaged timber from our woodlands into usable products. One would result in my doing nothing, and the other—although I did not know it at the time—would result in endless, outdoor physical activity, every minute of which I would enjoy.

At this point my wife entered the picture and set my priorities straight, as she has so often done . She knew me to be an outdoors person and physically active. To her the choice was obvious, and it should be the mill equipped with hydraulics and not one I would have to manually load. Thank you, Vicki. The mill and the people I have met since its purchase in December 1995 have improved both of our lives. I am pleased to have had the technical training and practical experience to prepare this handbook.

I also dedicate this handbook to Don Laskowski, cofounder of Wood Mizer Products, Inc., which recently finished its 25th year. Don is a brilliant inventor and business person. He is also a very sharing person and humanitarian at the world level. In the early days of the company, he always had time to talk with customers and helped numerous institutions by offering educational discounts. He was genuinely concerned about the success of his customers and worked to that end. Thank you, Don. Without his efforts, there would be no need for me to write these pages.

Acknowledgments

Many individuals have contributed directly and indirectly to the content and the appearance of this document.

First, I acknowledge all of the individuals who have shared with me their knowledge of wood. It is this knowledge, parts of which I have retained, used, or experienced while pursuing my own timber ownership and management activities, woodworking projects, and sawmilling interests that I have put into writing and photographed for this document.

Next, I recognize deserving Purdue University employees. Before retiring, Sandy Morris, secretary in the Department of Forestry and Natural Resources, worked for me for over 20 years. The original text for this document was written the old fashioned way, using pen and paper. Sandy had the wonderful ability to translate my scribbles into an electronic format. We used to call it typing!

Chip Morrison, graphic designer in the College of Agriculture, Agricultural Communications Service, is responsible for many of the photographs and charts. More important than words and pictures, the way the document is put together is what will hopefully make it a worthwhile and useful book. After Chip moved on to another job Tim Thompson picked up and saw the document through layout.

I thank Tracey Simmerman, the current secretary, for picking up the drafts of each chapter and carrying them forward through the Forest Service editorial process and to the final format. Without prior knowledge of the ability and patience of these individuals, I simply would not have even attempted this document.

Jane Wolf Brown, editor in the College of Agriculture, Agricultural Communications Service, was responsible for editing the entire document on several occasions. She is commended for turning the words into real English. Thank you, Jane. After Jane's retirement, Rebecca Goetz assumed her responsibilities and is to be thanked for her continued encouragement, editing, and coordination.

Daniel Warner, Manager of the Purdue University, Wood Research Laboratory, is acknowledged for preparing many of the samples pictured and for contributing his broad experience of working with wood.

I thank Chris Sigurdson, Department Head of Purdue University's Agricultural Communications Service, for working with me in developing the project and, most importantly, for agreeing to allow his excellent employees to work on this extensive project.

In addition, I thank Purdue University—specifically, Rob Swihart, Head of the Department of Forestry and Natural Resources—for allowing me to spend the time required to complete this project.

I also thank a number of individuals affiliated with other organizations for their contributions.

Larry Osborn, Research Associate, Wood Technology and Forest Products, Appalachian Hardwood Center, West Virginia University, reviewed the document and changed many items that needed improvement. It is very time consuming to review a document of this size. I thank Larry for making this unselfish contribution.

I recognize the Creative Services Staff of the Northeastern Area State and Private Forestry, Forest Service, U.S. Department of Agriculture. Just as I thought the book was about through the writing and editing phase, Roberta Burzynski entered my life. Initially, I was not quite willing to accept many of her suggestions, but she eventually made her points and this document is much improved and organized thanks to her efforts. Roberta invested months of her time in this document. She somehow was able to not only make many grammatical corrections, but to also digest all of the information, tie it together in a flowing way, and finally to ask questions where the text was not clear. Thank you, Roberta. Juliette Watts is to be thanked for creating or converting to electronic format the many illustrations throughout the text.

Finally, the Wood Education Resource Center (WERC), USDA Forest Service Northeastern Area State and Private Forestry, is recognized in three ways. First, I recognize the professional contributions of Ed Cesa, Deputy Director of WERC. Since Forest Service approval of the project, Ed has always been there and in a very timely fashion worked out any details that needed attention. Second, Ed also reviewed the document making many suggestions for improvement. The quality and level of the personal and professional involvement recognized above are efforts that individuals make out of pride and professionalism. Money cannot buy this level of commitment; however, money is important in keeping the entire system "up and running." Last, I sincerely thank WERC for their monetary support of this project.

WERC

Wood Education and Resource Center

The Wood Education and Resource Center (WERC) is administered by the Northeastern Area State and Private Forestry of the Forest Service, U.S. Department of Agriculture. WERC's mission is to facilitate networking and information exchange with the forest products industry, in order to enhance opportunities that sustain forest products production. WERC's programs support managerial and technical innovation that keep businesses competitive, and provide state-of-the-art training, technology transfer, and applied research. The center consists of offices, training facilities, and a rough mill in Princeton, WV, and serves the 35 States in the eastern hardwood region of the United States.

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Chapter 1.

Introduction: Why Thin Kerf Band Mills?

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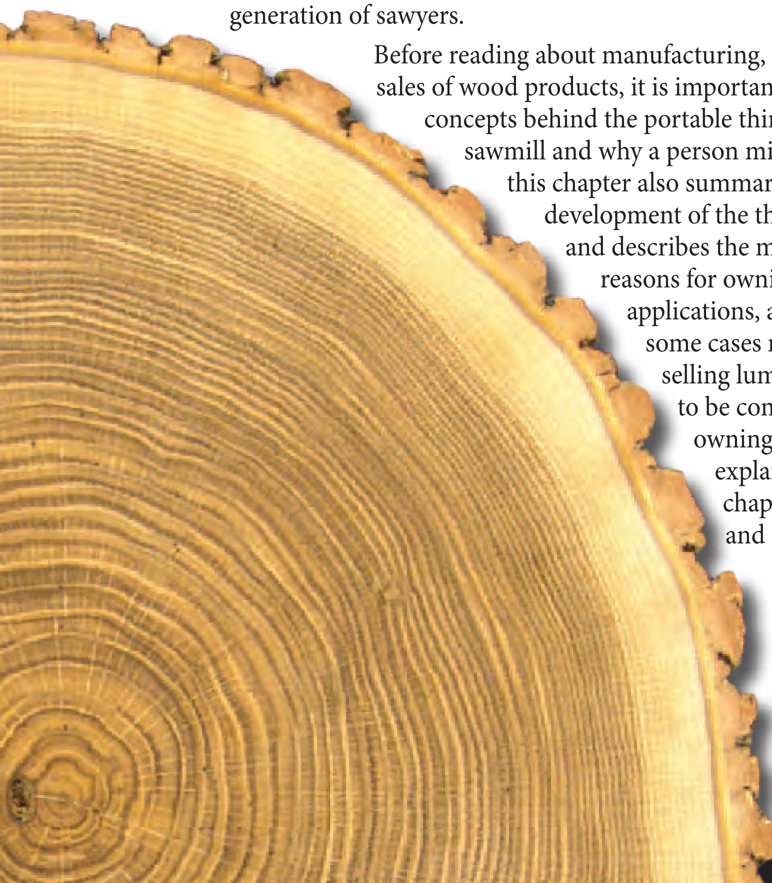
Chapter 1.
Introduction: Why Thin Kerf Band Mills?

The relatively new portable thin kerf band saws are very versatile and have low initial and running costs compared with standard larger mills. The simple equipment can be operated and maintained by one person, to process one tree or a stack of logs. Damage from hitting foreign objects in logs is usually limited to the cost of a blade at the most, which can be recovered with just one or a few boards from the more valuable species. These machines have essentially replaced the “community” circle sawmills that were once so common.

Tens of thousands of the new machines have been sold by a wide variety of manufacturers, and an entire generation of new sawyers has developed. Unlike the owners of large existing mills, who pass information and contacts from one generation to the next, this new generation of sawyers has no knowledge, or very little knowledge, about lumber and how it is processed and marketed. This handbook is intended to serve as a basic reference guide for this new generation of sawyers.

Before reading about manufacturing, marketing, and sales of wood products, it is important to consider the concepts behind the portable thin kerf band sawmill and why a person might own one. So, this chapter also summarizes the development of the thin kerf band saw, and describes the many and varied reasons for owning one, applications, and markets. In some cases marketing and selling lumber do not need to be considered in owning a mill, as explained later, in the chapters on marketing and sales.



Development of the Thin Kerf Band Sawmill

Thin kerf saw technology has always been of interest to wood manufacturers, and as raw material prices increased, substantial developments occurred in circle gang saws. Reduced saw plate thicknesses resulted in increased yield. These saws were rapidly adopted for processing large cants into boards and pallet parts. The savings were substantial.

As this development was being successfully adopted, the concept of holding the work piece (log or cant) stationary and moving a thin kerf band saw through it continued to be refined. This concept allowed for a much thinner kerf to be removed, and for substantial savings in raw materials, as well as equipment costs. Power requirements were also reduced. Mounting the equipment on a trailer made it portable, thus eliminating the need for loading and transporting heavy, bulky logs.

As thin kerf band saw technology developed, a portion of the traditional sawmill industry began to adopt it. This trend continues as equipment manufacturers develop heavy duty, higher production machines. Savings in kerf thickness is probably the main reason for adoption by the traditional sawmill industry. Other traditional manufacturers are looking at thin kerf mills as "satellite" operations to increase production, particularly on smaller logs of valuable species.

Due to its simplicity, relatively low investment cost, low maintenance, raw material savings, and ease of operation, thin kerf band saw technology has a very bright future.

Reasons for Owning a Thin Kerf Band Sawmill

Individuals buy thin kerf sawmills for a wide variety of reasons. First and foremost, thin kerf sawmills produce lumber. For many, this lumber costs no more than the effort of processing and the cost for depreciation of the mill. After proper drying, the lumber can be consumed for manufacturing furniture, cabinets, and other wood items, or used for special building projects, including houses, cottages, barns, and bridges. The portable thin kerf sawmill technology is perfect for producing odd sizes not available commercially, especially for restoration projects. Processing salvaged timber from old buildings is yet another application.

Forest landowners have opportunities to use portable thin kerf band saws, as well. Dead and dying trees, thinnings, and other mostly commercially valueless trees can be salvaged. Many trees are also available after violent storms, such as tornadoes, ice storms, and hurricanes. More valuable trees could also be processed. The material can be used by the mill owner on the property, and an owner with entrepreneurial abilities can find markets for at least a portion of it.

Timberless entrepreneurs and some arborists can find opportunities to salvage otherwise valueless urban trees, or those from land clearing activities, ranging from new developments, to road construction, and to other right-of-way clearings. Trees from clearing activities are essentially forest grown trees. By traditional wood industry standards, most urban trees will not produce substantial quantities of high-grade lumber when compared with forest trees. Portions of these trees, however, are certainly usable for a variety of products ranging from furniture to barn siding to pallet cants. Some homeowners have even arranged for their favorite tree (one that died or had to be removed) to be milled into lumber and then processed into furniture. Urban trees are often available for free or for the hauling.

Custom sawing is another opportunity. It returns quick cash and helps the owner and operator become more visible in the immediate community. Custom sawing services are in particularly high demand after trees are felled by storms. Some operations have been able to saw on a full-time contract basis for large mills.

Others have seen this new technology as an opportunity to produce grade lumber and deliver it to the commercial market. Competing directly with the traditional industry in this manner may be hard. On the other hand, the number of small woodlots that are not considered economically feasible to harvest by the traditional industry are ideal for smaller operators.

Thin kerf mills can also be used to process small volumes of noncommercial species, many of which have beautiful color and grain patterns.

To see the color and grain pattern of commercial and miscellaneous species found in the eastern temperate forest, see Cassens (2008).

Applications and Markets

The list of possible applications for the thin kerf band mill is almost endless. The entrepreneur who is considering the purchase of a thin kerf mill, or who already has one, needs to very carefully consider and write down exactly what their objectives are and how they will be reached. If the objective is internal consumption, then marketing and sales expertise may not be critical. If the objective is external sales, then every effort needs to be extended to learn about lumber and its potential markets and what it takes to fill them.

In the market, the thin kerf mill operator will be competing directly with whoever is already filling the need. The competition may be experienced, well positioned, well financed, and very capable. To compete in the traditional markets the entrepreneur must first understand the types of markets, their size, and how they function. An understanding of the marketing process and sales techniques for the hardwood industry is also mandatory. When unique niche markets can be identified, they are ideal for these smaller machines.

About this Handbook

This handbook was prepared to be as inclusive of topics related to thin kerf band mills as possible. Following this introductory chapter are two chapters that discuss the eastern hardwood resource (Chapter 2) and wood quality (Chapter 3). Armed with this information the reader is ready to calculate the potential economic advantages of processing timber into products.

The reader will learn how lumber, logs, and trees are graded, and how to calculate potential value for hardwoods (Chapters 4, 6, 7). How softwoods are graded and stamped to meet building code requirements is discussed next (Chapter 5). Detailed information on identifying trees and logs suitable for fine face veneers is also included (Chapter 8). Veneer logs have the highest value.

Different techniques that can be used to process logs into lumber are discussed (Chapter 9), as well as the amounts of residues generated and options for their use (Chapter 10). How to dry and store lumber (Chapter 11) and protect it from insects (Chapter 12) and discoloration or even decay (Chapter 13) are also covered.

Understanding the existing market structure (Chapter 14) and how the existing traditional industry moves lumber and other sawed products from the mill to intermediate and end users is critical before attempting to develop markets for products (Chapter 15). Finally, this handbook explains how to approach a customer in a professional and efficient manner (Chapter 16).

Most of the information presented has been gleaned from my association with the traditional hardwood sawmill and face veneer industry for over 30 years, my experience operating a thin kerf band mill for over 15 years, and owning forest land. This practical information and personal operating experience, along with technical training from three leading land grant universities, results in a well-rounded body of information.

Throughout this handbook, I refer to “traditional mills or operations.” This terminology is used to differentiate the more permanent existing companies, both large and small, from the new generation of operators with portable thin kerf band sawmills. Very few aspects of the traditional industry, however, are fixed and consistent. Many companies perform multiple functions, and these functions and techniques can change with changing market conditions. With just a few exceptions, traditional hardwood operations are small compared with the corporate world of manufacturing. Personal relationships remain very important in this industry. Traditional sawmills and yards compete, but they also interact with each other.

Nearly all of the information presented is pertinent to larger operations, as well as to smaller ones. The basic product, lumber, does not change. Only the size and scope of the processing facility changes. Long-standing firms have had the time to develop experience within their ranks. The new generation of sawyers has not had this opportunity. This handbook aims to fill that void.

References

Cassens, Dan. 2008. *Lumber from Hardwood Trees.* Purdue University Cooperative Extension Service. CD-FNR-406.

Chapter 2.

Eastern Hardwood Resource

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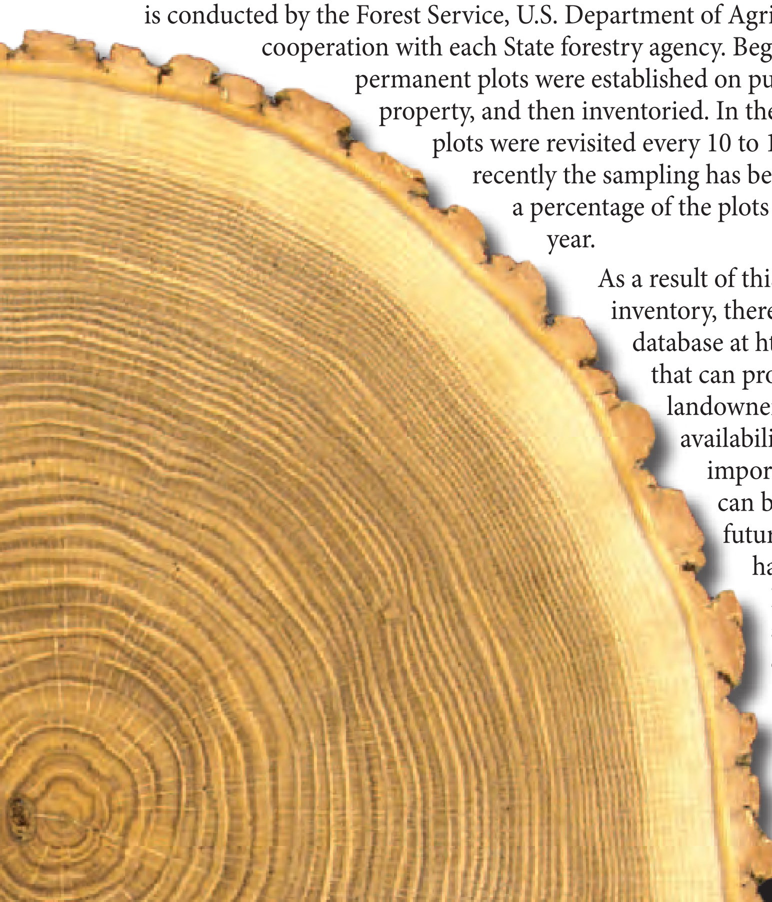
Chapter 2.
Eastern Hardwood Resource

Hardwoods grow throughout the Eastern United States and Southern Canada. With the exception of some protected areas, all of the old growth was removed before World War II. Much of the land was cleared for agriculture, and much of the remaining forest land was abused. In spite of these issues and due to forest management techniques that slowly developed after the initial cut, hardwood timber is now a tremendous resource.

This chapter describes the significance and vitality of the hardwood resource in the United States.

Forest Inventory

A statistical-based forest inventory has been conducted at regular intervals in the United States since 1953. Some earlier data are also available. The inventory is conducted by the Forest Service, U.S. Department of Agriculture, in cooperation with each State forestry agency. Beginning in 1953, permanent plots were established on public and private property, and then inventoried. In the past, all of the plots were revisited every 10 to 12 years, but more recently the sampling has been changed so that a percentage of the plots is inventoried each year.



As a result of this annual forest inventory, there is a tremendous database at http://fia.fs.fed.us that can provide insight into landownership and the availability of species. More importantly, past history can be used to predict future growth and harvest trends. Inventory data is available at the county level.

The database is so large that it can be difficult to find the exact information needed. Before beginning, determine exactly what you want. It is important to understand exactly what is meant by some of the terms used, which are carefully defined. Some of the more important terms and definitions appear in Box 2-1.

A nationwide report summarizes the data, and the trends are published periodically. The two most recent reports are the source of the information highlighted in this chapter (Smith and others 2001, 2009).

Forest Land Area

Forest land area in the United States increased by 3 percent between 1987 and 2007. Since 1920, forest land area has been relatively stable, increasing and decreasing over the years within a relatively narrow range.

About 33 percent of the U.S. land area, or 751 million acres, is forest land. This amounts to about 72 percent of the area estimated as forested in 1630 (1.04 billion acres). Of all U.S. forest land, 33 percent is federally owned. This proportion of Federal to other forest land has remained relatively stable since about the 1950s.

In 2007 about 10 percent of all U.S. forest land (about 75 million acres, up from 52 million acres in 1997) was reserved from commercial timber harvest in wilderness, parks, and other legally reserved classifications. Tens of millions of acres of additional publicly owned forest land is administratively withdrawn from timber harvest under existing management plans.

Timber Land Area

In 2007 about 68 percent of all forest land (514 million acres, up from 504 million acres in 1997) is classified as timberland—forest land capable of producing in excess of 20 cubic feet of wood per acre per year and not legally withdrawn from timber utilization. Of forests in the East, 95 percent are classified as timberland, as well as 83 percent of the Pacific Northwest subregion, about 47 percent of the Rocky Mountain region, and 9 percent of Alaska.

About 12 percent (63 million acres) of timberland in the United States is of planted origin—mostly softwood species. Nearly three quarters (45 million acres) of all planted timberland is in the South.

Timber Inventories

Growing-stock volume on U.S. timberland increased by 7 percent between 1987 and 1997. Between 1953 and 2007, net volume per acre increased by 37 percent. Average volume per acre rose by 125 percent between 1953 and 2007 in the North, 95 percent in the South, 39 percent in the Rocky Mountain region, and 6 percent in the Pacific coast region.

About 57 percent of the volume of growing stock is in softwoods, and the

Box 2-1. Definitions of Terms for U.S. Forest Service Survey Data

Forest land. Land at least 120 feet wide and 1 acre in size with at least 10 percent cover (or equivalent stocking) by live trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between forest and nonforest lands that have at least 10 percent cover (or equivalent stocking) with live trees and forest areas adjacent to urban and built-up lands. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 120 feet and continuous length of at least 363 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if they are less than 120 feet wide or 1 acre in size. Tree-covered areas in agricultural production settings, such as fruit orchards, or tree-covered areas in urban settings, such as city parks, are not considered forest land. Note: This definition does not apply to the data for western Texas, western Oklahoma, and interior Alaska, which, to date, have not had field verification of reported estimates that are based solely on remote sensing (Smith and others 2009).

Growing stock. A classification of timber inventory that includes live trees of commercial species meeting specified standards of quality or vigor. Cull trees are excluded. When associated with volume, it includes only trees 5.0 inches d.b.h. and larger (Smith and others 2009).

Saw log. A log meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound, and straight, and with a minimum diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods, or the log may meet other combinations of size and defect specified by regional standards (Smith and others 2009).

Sawtimber trees. Live trees containing at least one 12-foot sawlog or two noncontiguous 8-foot logs that meet regional specifications for freedom from defect. Softwood trees must be at least 9.0 inches d.b.h., and hardwood trees must be at least 11.0 inches d.b.h. (Smith and others 2001).

Timberland. This term is used for forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. Note: Areas qualifying as timberland are capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included. (Smith and others 2009).

remaining 43 percent is in hardwoods; however, 90 percent of the hardwood growing stock is in the eastern United States. The Pacific coast region accounts for 43 percent of all softwood growing stock, and the North has 11 percent. The balance is divided between the South and the Rocky Mountain region.

The net growing-stock volume of U.S. hardwoods increased by 15 percent between 1997 and 2007, and by 91 percent between 1953 and 1997. Since 1953, the net volume of U.S. hardwoods increased by 119 percent, and the volume of hardwoods in diameter classes 19 inches or greater tripled—from 26 to 81 billion cubic feet.

Growth and Removals

In general, domestic timber production has been declining since the early 1990s, while consumption has been relatively stable. The gap between production and consumption has been filled with rising imports.

In 2006 growing-stock removals totaled 15.5 billion cubic feet or just 2 percent of total growing-stock inventory. This amount represents a decline of nearly 3 percent from 1996 but a 9-percent increase from 1976. Softwoods accounted for 63 percent of the growing-stock removals, and hardwoods accounted for the balance. Private owners, including industrial and non-industrial private forest owners, accounted for 14.2 billion cubic feet, or 92 percent of growing-stock removals. Removal of growing stock from National Forests decreased 54 percent from 1996 to 2006.

The balance between net growth and removals provides an estimate of sustainability of timber harvest. The growth-to-removal ratio (net growth divided by growing-stock removals) during 2006 for the United States was 1.72, indicating that growth exceeded removals by 72 percent.

The predominant use of both softwoods and hardwoods continues to be for lumber. Sawlogs provided for 48 percent of timber product output in 2006, veneer logs 8 percent, and pulpwood 29 percent. The remaining 15 percent was used for fuelwood and other products. Hardwood timber product output declined 21 percent between 1996 and 2006, and softwood output was down by 1 percent over the period. A major cause of hardwood product output decline was regional reduction in harvesting hardwoods for fuel wood in the southern and northern regions. Since that time, interest in the use of wood as an energy source has been renewed and is dependent on fossil fuel costs, subsidies, and government mandates.

On a tonnage basis, the weight of wood products consumed in the United States each year is roughly equal to the weight of all plastics, Portland cement, and all metals consumed (Bowyer and others 2003).

Hardwood Species Availability

The Forest Service inventory presents data for growing stock and sawtimber as well. This category includes live trees with an 11-inch and larger diameter at breast height (d.b.h.). Table 2-1 shows the net volume of hardwood sawtimber (International rule) and percent of each species on timber land throughout the eastern United States. Red and white oak constitute the largest available volume, or nearly 40 percent of the total. Hard and soft maple follow the oaks in terms of availability. Yellow-poplar, cottonwood and aspen, hickory, and sweetgum follow, in order. Walnut, yellow birch, basswood, and black cherry are species with some of the smallest volumes available. If substantial demand develops for these species with smaller available quantities, the price could be driven up rapidly.

Table 2-1. Net Volume of Hardwood Sawtimber on Forest Land in the Eastern United States (U.S. Department of Agriculture, Forest Service, 2009)

Species	Volume[1]	%
Ash	47,861	4.3
Basswood	18,819	1.7
Beech	24,298	2.2
Blackgum and tupelo	30,589	2.7
Cherry	26,301	2.3
Cottonwood and aspen	42,712	3.8
Hickory	61,709	5.5
Maple, hard	64,790	5.8
Maple, soft	90,318	8.1
Red oak, select	98,008	8.7
Red oak, other	163,532	14.6
Sweetgum	58,024	5.2
White oak, select	118,281	10.6
White oak, other	68,622	6.1
Walnut	8,202	0.7
Yellow birch	10,298	0.9
Yellow-poplar	115,222	10.3
Other	73,328	6.5
Total	**1,120,918**	**99.7**

[1] Millions of board feet based on International ¼-inch rule. For more information about the International Log Rule, see the chapter entitled "Log and Tree Scaling Techniques."

Hardwood Species Characteristics

For more information, see *Lumber from Hardwood Trees* by Dan Cassens. The CD covers all the "hard to find" facts about our nation's 35 most attractive hardwoods and includes photography of large wood panels for the most common species. These panels show the range of lumber characteristics from perfect, clear lumber to lower grades. Additional photography shows standing trees, character marks for selected species, and manufacturing equipment.

Commercial hardwood trees covered include ash, aspen, basswood, beech, birch, black cherry, black walnut, cottonwood, hackberry, hard or sugar maple, hickory, red oak, sassafras, soft maple, sycamore white oak, and yellow poplar. Other species covered include black gum, black locust, boxelder, buckeye, butternut, catalpa, chestnut, coffeetree, dogwood, elm, holly, honey locust, magnolia, mulberry, osage orange, persimmon, sweetgum, and willow.

Featured sections include:

- Decay Resistance: Properties of various species
- Mechanical Properties: Different properties of various species
- The Production Process: Hardwood lumber processing from start to finish
- Purchasing and Selling: Who to contact when buying or selling hardwood lumber
- Shrinkage: Characteristics due to relative humidity
- Steam Bending: Ability of different woods to bend
- Understanding Lumber: Different characteristics, terms, definitions, and sawing techniques on all species
- Wood Machining: Species responses to planing, shaping, turning, and boring
- Extensive references about hardwood lumber

For more information, you can find it online at The Education Store for Purdue Extension:
https://mdc.itap.purdue.edu/item.asp?item_number=CD-FNR-406

Summary

Each American consumes the equivalent of an 18-inch diameter 100-foot tree for wood and paper products each year (Southern Forest Products Association and Southeastern Lumber Manufacturers Association 1999). So the total U.S. requirement is about 300 million good-sized trees. Some Americans believe that meeting this demand is destroying the forests. Forest data presented in this chapter demonstrate that not only are U.S. forests replacing the volume of wood consumed each year, they are growing about 75 percent more. This "excess growth" is available for use. Traditional uses such as sawlogs, pulp, and panel products will continue, but the future also looks bright for better utilization of low grade material for energy.

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Chapter 3.

Wood Quality and Characteristics

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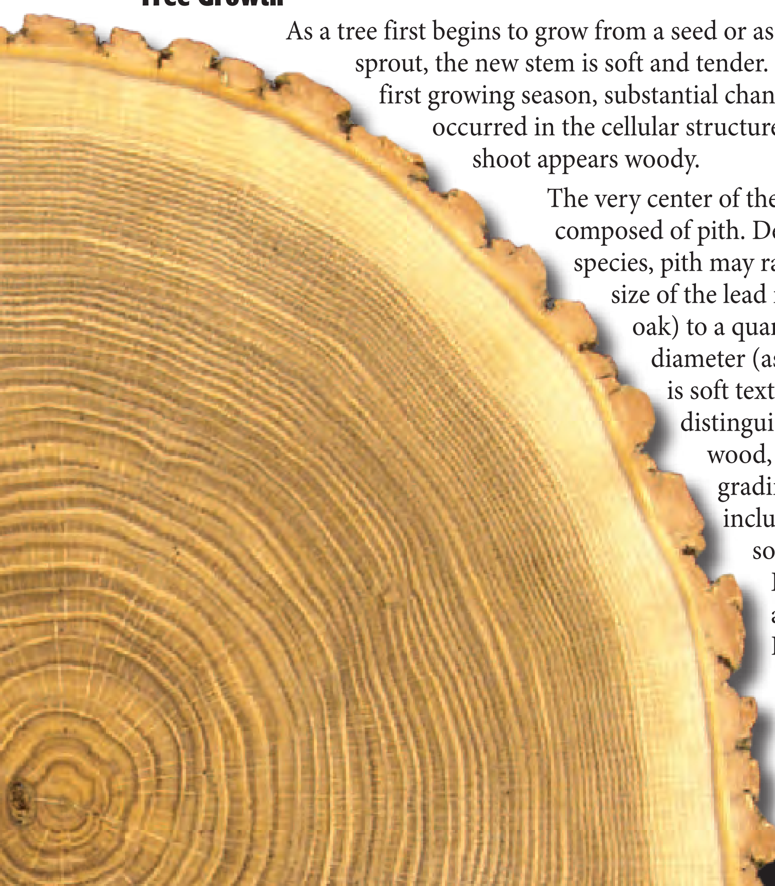
Chapter 3. Wood Quality and Characteristics

Hardwood trees are biological organisms that we see and enjoy everyday, but we seldom consider the complex nature of how they grow and of the many different uses that are often based on each species' unique features. Furthermore, the wood produced by each species is equally complex, but substantially different in its characteristics from one species or group of species to another. Without fully understanding the complexity and variability of wood, people have been successful in adopting it for many uses. An understanding of some of the basic characteristics and properties of wood, however, can help solve problems when they arise in current applications, help identify new uses or substitutes, and enable an even greater appreciation of the resource.

This chapter briefly describes the important characteristics of trees and wood.

Tree Growth



As a tree first begins to grow from a seed or as a root or stump sprout, the new stem is soft and tender. By the end of the first growing season, substantial changes have occurred in the cellular structure, and the young shoot appears woody.

The very center of the stem is composed of pith. Depending on species, pith may range from the size of the lead in a pencil (as in oak) to a quarter inch or so in diameter (as in walnut). Pith is soft textured, easily distinguished from solid wood, and in lumber grading it cannot be included in clear or sound cuttings. Examples of pith are shown in Figure 3-1.

Figure 3-1. Examples of a large chambered pith in walnut (left) and a solid pith in yellow-poplar (right). Pith runs the entire length of the stem but, due to irregularities, it usually weaves in and out of a board.

To the outside of the pith is a series of continuous layers of wood (Figure 3-2). Each year, a new layer of wood is formed, hence the term annual ring or growth increment. To the outside of the annual rings is the cambium, which is responsible for the formation of additional rings (wood) of tree growth as well as additional phloem and bark.

The cambium (Figure 3-2) may be viewed as a thin cylinder of just one to a few generative cells surrounding the woody portion of the stem and protected

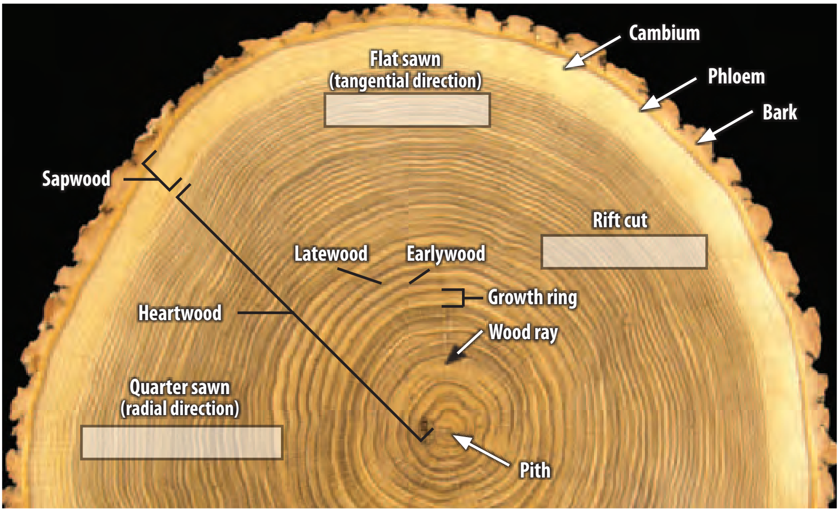


Figure 3-2. Cross section of a log showing several important features.

by layers of phloem. It cannot be seen by the naked eye. Each growing season the cambium forms a layer of wood and a much thinner layer of bark. The wood cells (xylem) become thick-walled and lignified; each new layer of inner bark (phloem) pushes the older, nonfunctional bark outward as the stem enlarges. Successive cork cambia are formed in the older portion of the bark to produce outer layers of suberized cork cells and lignified stone cells. Tissues outside the cork cambia die. They are eventually sloughed off. The activity of the cork cambium gives trees their characteristic bark patterns.

Water from tree roots is conducted upward through the outer portion of the woody cylinder by tensions created in the crown and distributed to the cambium and other living cells. Food in the form of sugar, synthesized in the leaves, is transported through the living inner bark to the cambium, where cell division takes place. Sugars are also conducted radially and stored, mostly as starch, in the horizontal rays. Rays (Figures 3-2, 3-4, 3-6, 3-8, 3-10) are so named because they radiate outward from the pith. They may be very fine and unnoticeable to the eye, as in gum or aspen, or they may be rather broad, as in oak, to produce the ray fleck pattern so characteristic of quartered oak. End checking of logs and lumber usually occurs at the interface of a ray and adjacent longitudinal tissue. For more information on end checking, see the chapter entitled "Wood Moisture and Drying."

Height and lateral growth of trees occur through the meristimatic regions of the buds on the limb tips. In these regions new cells are added during each growing season; the cells elongate, thus adding height and breadth to the tree. A spike driven in a tree at 4 feet above ground level will remain there regardless of how high the tree grows or how wide its branches may extend, since height growth occurs at the tips of the branches. Growth in trunk diameter is due to cambial activity.

Knots result when a limb is formed by the tree. The limb is an integral part of the tree, has its own cambium for diameter growth, and has a meristimatic branch tip or tips for elongation. Each year a continuous growth increment is laid down simultaneously over the limb and the main tree bole by their respective cambia. The result is a sound, tight knot. If the limb dies, the main tree cambium continues to grow and surrounds the dead limb thereby resulting in a "loose" or dead knot. Eventually the limb falls off of the tree, the cambium and new wood is formed over the top of the dead branch stub and generally clear wood is formed, at least on young vigorous trees with relatively small branches.

Annual Rings

Annual rings or growth rings are one of the most noticeable characteristics in many woods. They can also indicate substantial information about the history of the tree and properties of the wood. In American hardwood species, there is enough difference between the beginning and end of a growth increment to clearly differentiate it and to permit counting the "rings" to determine a tree's age. Some hardwoods, such as sweetgum, tupelo, and soft maple, however, have growth increments that are not very distinct; but with careful examination, the rings can still be counted. The width of a growth increment may vary from a few cells in width to as much as an inch in some fast growth woods (Figures 3-3 and 3-4). For some species, such as oak, ash, elm, and others, the growth increment is composed of an easily distinguishable

Figure 3-3. These two pieces of red oak are 5 to 5½ inches wide. The one on the bottom contains three complete and two partial rings. It is a fast-growing southern species called water oak. The top piece is average growth northern red oak and has 30 rings.

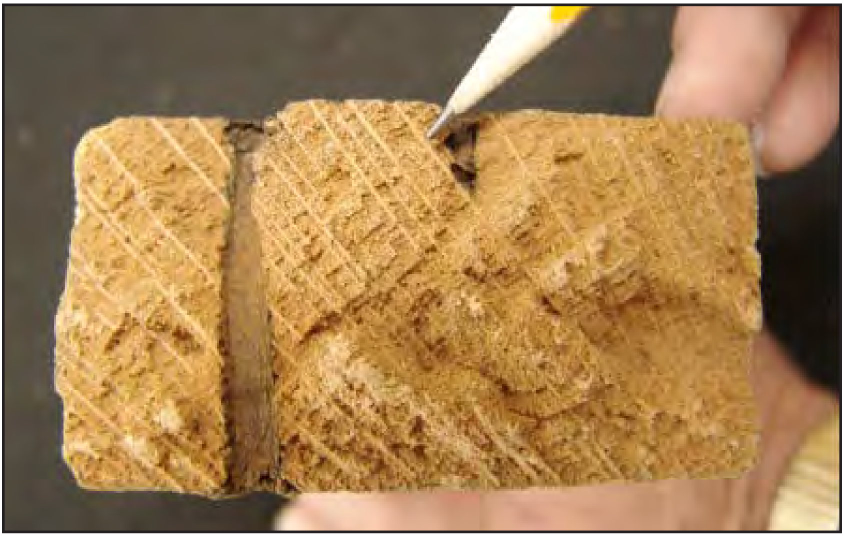


Figure 3-4. Very slow growth white oak 2 by 4 taken from an 1870s house. Only large weak earlywood cells are present making it nearly impossible to count the rings. The brash break occurred because of the very slow growth rate in a ring porous wood. The diagonal light colored lines are the wood rays.

earlywood zone and a latewood zone (Figure 3-5). Earlywood is formed during the first part of the growing season and is sometimes called springwood. Latewood, formed after the earlywood, may be called summerwood. Latewood in these species is generally darker in color and composed of relatively small, thicker-walled cells and, thus, is denser than the earlywood. Southern pine and Douglas-fir are two common softwoods with distinct earlywood and latewood.

Figure 3-5. Earlywood and latewood within an annual ring.

On the basis of the annual ring cross-sectional characteristics, the hardwoods can be divided into three general categories: ring porous, semi-ring porous, and diffuse porous (Figure 3-6 and Table 3-1). Understanding these three general categories is extremely helpful in wood identification.

The ring porous woods have an easily identified earlywood or springwood zone characterized by large diameter pores, which can easily be seen with the unaided eye, at the beginning of each growth increment. The pore diameter then more or less abruptly changes to a smaller size and remains at about that size to the end of the ring. Ring porous woods include oak, ash, elm, and others often noted for their showy grain pattern (Figure 3-7).

Table 3-1. Growth ring pattern of various hardwoods

Ring porous	Semi-ring porous	Diffuse porous
Ash	Butternut	Alder, red
Catalpa	Persimmon	Aspen
Cherry[1]	Walnut	Beech
Chestnut, American	Yellowwood	Birch
Coffeetree, Kentucky		Blackgum and tupelo
Elm		Buckeye
Hackberry and sugarberry		Cherry[1]
Hickory and pecan		Cottonwood
Honeylocust		Dogwood
Locust, black		Holly
Mulberry		Magnolia
Oak		Maples (all)
Osage-orange		Oak, live
Sassafras		Sourwood
		Sweetgum
		Sycamore
		Willow
		Yellow-poplar

[1] At the beginning of the growth ring, cherry has one distinct row of larger pores with subsequent pores uniform in size. Thus, it is classified as ring porous but appears diffuse porous to the unaided eye.

A. Ring porous red oak, shown in flat sawn (left), quarter sawn (center), and rift cut (right) boards.

B. Semi-ring porous walnut, shown in flat sawn (left), quarter sawn (center), and rift cut (right) boards.

C. Diffuse porous hard maple, shown in flat sawn (left), quarter sawn (center), and rift cut (right) boards.

Figure 3-6. Examples of longitudinal (top) and end grain (bottom) characteristics in hardwood. For each category, three different sawing and grain patterns are shown.

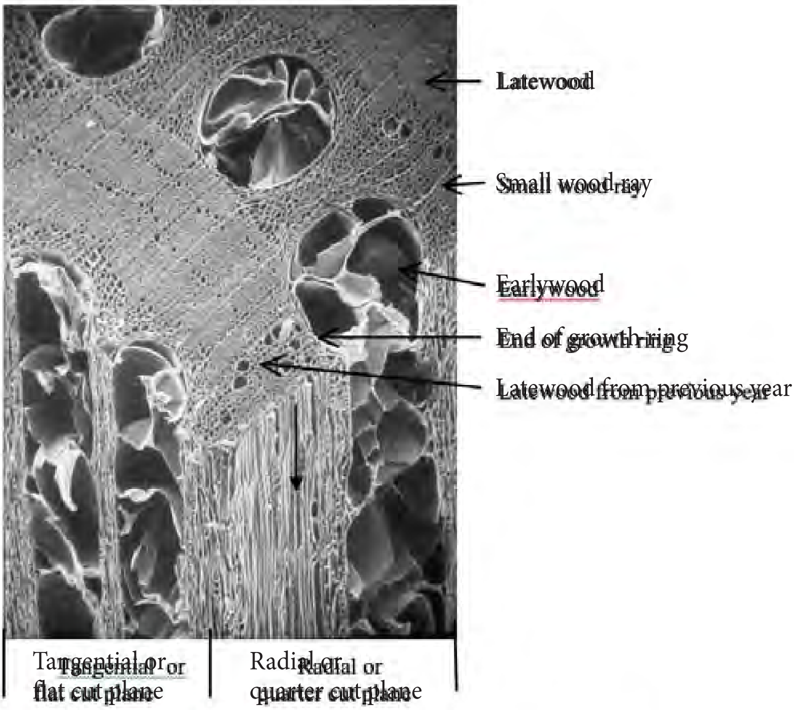


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Figure 3-7. Scanning electron micrograph of ring porous white oak shows the transition between the large earlywood pores and the small dense cells in the latewood from the previous year.

In diffuse porous woods, the pores are uniform in size across the entire growth ring and generally too small to be seen without the use of a hand lens. Diffuse porous species include maples, gums, and yellow-poplar. Earlywood and latewood zones are not discernible (Figure 3-8).

Within the growth increment of a semi-ring porous wood, the pores are initially large and then gradually decrease in diameter throughout the ring. Examples of semi-ring porous woods include walnut and butternut.

The cell structures in softwoods are much more regular and uniform than in the hardwoods. As a result, softwoods do not typically exhibit showy grain patterns. Figure 3-9 is a scanning electron micrograph of southern yellow pine for comparison. Earlywood and latewood are shown.

In ring porous or coarse grained woods the width of the annual ring can have a very important impact on the stiffness of a member. Slow-growth trees have a higher percentage of earlywood and thus large diameter, thin-walled, and weak cells. Fast growth trees have a high percentage of dense latewood with thick-walled cells. Thus, fast-growth wood of these species is substantially stronger than slow growth wood. Figure 3-4 shows a slow growth white oak 2 by 4 with a brash and very weak break. Because diffuse porous hardwoods are uniform in cell distribution across the entire growth ring, their strength properties are not affected by growth rate.

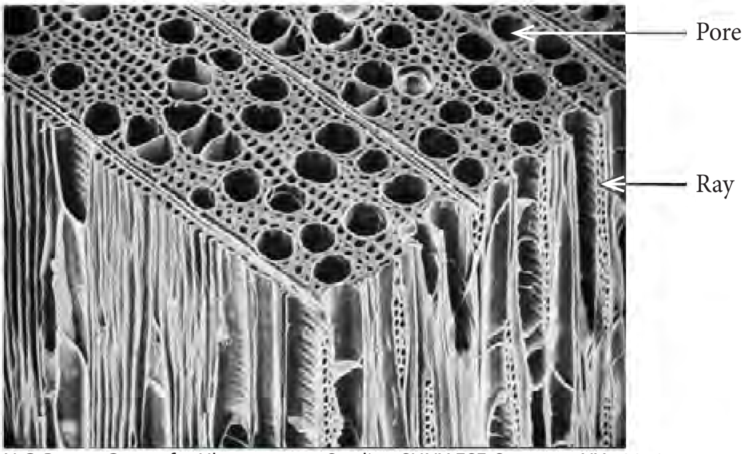

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Figure 3-8. Scanning electron micrograph of yellow-poplar, a diffuse porous wood. The pores are a fairly constant size throughout the growth ring.

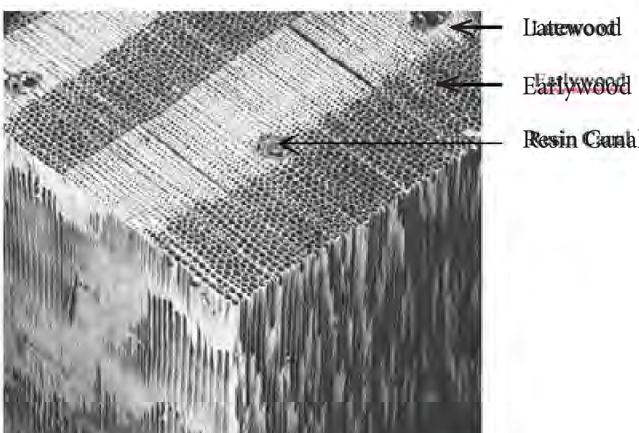

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Figure 3-9. Scanning electron micrograph of southern yellow pine, a softwood, shows earlywood and dense latewood. Note the uniformity of the cell structure.

Distinct Surfaces in Wood

The presence of four distinct surfaces in wood is also an important characteristic. The most obvious of these is the cross section or the surface exposed when wood is cut across the grain (Figure 3-2). The cross section is important since it reveals the annual rings and thus information about growth rate. Veneer log buyers are particularly interested in the freshly cut cross section wetted with water, as it provides additional information about wood color, mineral stain, gum spots in cherry, and bird peck. The wet surface makes many small characteristics stand out. It is also a key surface for identification of wood using cell structure.

Another distinct surface is the tangential surface (Figures 3-2, 3-6, 3-10) that is produced when a board is cut parallel to the bark or tangent to the log surface. The lumber is called flat sawn. This is the most common way of producing lumber today, and it results in a characteristic U- or V-shaped grain pattern—at least with coarse-grained hardwoods, such as oak, ash, elm, hickory, and pecan. The characteristic U- or V-shaped pattern results whenever the saw cuts across a growth ring.

A third surface is the radial surface (Figures 3-2, 3-6, 3-10) that is exposed when a cut is made from the pith or very center of the log on a perfect radius to the bark. Lumber cut in this way is known as quartered lumber. Quartered oak exposes large, showy ray flecks, and it was highly prized for furniture and other decorative purposes around the turn of the 20^{th} century. Quartered oak is once again a very popular item. Sycamore is another wood that can be quartered to show large ray flecks. Some softwood species, such as southern pine and Douglas-fir, are quartered to expose a "vertical grain pattern" and used for flooring because of the high resistance to wear. Since quartersawn lumber, especially from small logs, results in substantial waste during the sawing process, it commands a premium price.

Rift cut lumber and veneer occur when the saw line intersects the wood rays at about a 45° angle (Figure 3-10). Neither the characteristic U- or V-shaped growth ring pattern of flat sawn stock nor the quartered ray fleck is seen. In oak the growth rings can be seen as pencil stripes and the ends of the rays appear along the length of the board.

Shrinkage and mechanical properties are defined in terms of radial and tangential surfaces in wood. In reality, however, very few perfectly quartered or flat sawn boards are produced. The saw cut usually ends up at some angle between these two primary planes.

Heartwood and Sapwood

The presence of a distinctive heartwood in some species or its near total absence in others is another important characteristic. In older trees of most species, heartwood is located near the center of the stem. In mature oak, walnut, and cherry, for example, heartwood may compose most of the stem

Figure 3-10. From top to bottom: Flat sawn (tangential direction), rift cut, and quarter sawn (radial direction) boards. Ray fleck shows in the quarter-sawn board

(Figure 3-2), whereas in other species such as hard maple and ash, heartwood may compose only a small portion of the stem.

Heartwood is composed of dead cells and thus serves only as mechanical support to the tree. Due to the accumulation of various chemicals or extractives, the presence of a dark and characteristic color of heartwood, such as in walnut, cherry, old growth sweetgum, and oak, greatly enhances their value. In some hardwoods, such as cottonwood, the heartwood and sapwood show no or very little difference in color. This does not indicate an absence of heartwood but it does show that all species do not accumulate dark-colored extractives.

Because of the high value of walnut heartwood, the presence of sapwood can lower the value of lumber and veneer. Most larger operations that process walnut steam the green lumber. The steaming process darkens the sapwood. Sapwood in walnut is not limited by the National Hardwood Lumber Association (NHLA 2011) grading rules, if sold and specified as "steamed walnut." In the veneer process, the light-colored sapwood portion on much of the veneer is clipped and discarded. As a result logs with a high percentage of sapwood are discounted in value. Fast growth, open grown walnut tends to have a high percentage of sapwood.

Sapwood is located in a cylinder outside the heartwood but inside the bark. Sapwood is light in color, and at least the outer portion contains living cells that transport water from the roots to the tree crown. Very few if any differences exist in the mechanical properties of sapwood and heartwood; however, sapwood is usually much more porous and thus accepts preservative treatment more easily and will dry more quickly. Molds and stains will discolor sapwood faster than they will heartwood. Heartwood may have a slightly higher weight per unit volume than sapwood does, due to the presence of significant amounts of extractives in some species.

Because of its light color, the sapwood of some species is sought after. Hard maple and birch are examples, and the NHLA (2011) rules provide a special grade for "sap" material. As in many things, a combination of appearance, properties, and consumer preference determines value.

Research has shown that some species, such as maple, birch, and ash, do not form a true heartwood. However, these species can still develop a central core of dark colored wood. This heartwood results when a branch dies and the inner growth rings are exposed to the air and microorganisms, or when wounds are large or slow to heal. This process is called compartmentalization. For these species, healthy, fast-grown trees will have wide sapwood compared with slow growing trees, which take longer to heal over injuries, such as branch stubs and wounds.

Natural Durability

Lumber and other wood products that contain moisture contents in excess of 30 percent is subject to wood decay. Wood decay is the actual deterioration of the cellulose, or lignin, or both. Cellulose and lignin are the two most common components of wood. Fungi have microscopic hyphae that secrete enzymes to dissolve the wood substance, so they can use it as a food source. Hyphae are root-like structures that spread from cell to cell. Some wood extractives are toxic or at least repel decay and insects, thus making the wood of certain species more durable than others (Table 3-2). Where the extractives do not have a toxic or repellent effect, the heartwood is no more resistant than the sapwood.

Yellow-poplar is an anomaly. It is currently listed as having no resistance to decay. The old growth material was once used for windows and door frames, siding, and other applications where it was occasionally wetted. It performed very well. When available lumber is used in similar applications today, decay problems are likely to develop. Younger trees of this species contain large amounts of sapwood and the heartwood of most younger trees is lighter-colored and is not considered decay-resistant.

The natural decay resistance of wood is a fascinating subject. The amount of "resistance" to decay is impossible to quantify. Woods, such as black locust, white oak, and cedar, have a reputation for resistance. Resistance can vary from tree to tree, however, and the second or young growth timber of redwood, western red cedar, and cypress is not as durable as the old growth. Resistance can also vary depending on the severity of exposure. Wood that is in contact with soil, or that is consistently wet will decay faster than wood that is only occasionally wet. Warm weather also promotes decay. Naturally decay resistant woods are probably most suitable where a moderate decay hazard exists or where very long term use is not expected. Remember, young timber has substantial sapwood, and sapwood has no resistance to decay. Properly pressure-treated material should be used where a severe decay or insect hazard exists.

Table 3-2. Decay resistance of the heartwood of common species (U.S. Department of Agriculture, Forest Service, 1999)

Resistant or very resistant	Moderately resistant	Slightly or nonresistant
Baldcypress, old growth	Baldcypress, young growth	Alder, red
Catalpa	Douglas-fir	Ash
Cedar	Larch, western	Aspen
Atlantic white	Pine, longleaf, old growth	Beech
Eastern redcedar	Pine, slash, old growth	Birch
Incense	Pine, eastern white, old growth	Blackgum and tupelo
Northern white	Redwood, young growth	Buckeye
Port-Orford	Tamarack	Butternut
Western redcedar		Cottonwood
Yellow		Elm
Cherry		Basswood
Chestnut		Firs, true
Cypress, Arizona		Hackberry and sugarberry
Honeylocust		Hemlock
Juniper		Hickory and pecan
Locust, black[1]		Magnolia
Mesquite		Maples (all)
Mulberry, red[1]		Pines (other than those listed)2
Oaks, white[2]		Spruce
Osage-orange[1]		Sweetgum
Redwood, old growth		Sycamore
Sassafras		Tanoak
Walnut		Willow
Yew, Pacific[1]		Yellow-poplar

[1] Exceptionally high decay resistance.
[2] More than one species included, some of which may vary in resistance from that indicated.

Spiral and Interlocked Grain

Wood is made up of cells. Wood cells are shaped like soda straws—roughly round, long, and thin-walled. Most cells (except ray cells) are oriented in a more or less longitudinal direction, essentially parallel to the long axis of the tree stem. In some cases, however, the cells may be arranged in a noticeable spiral about the stem (Figure 3-11). Lumber sawn from these logs will have a cross or diagonal grain pattern. The lumber is typically low in strength and stiffness, tends to twist upon drying, and is difficult to machine.

Figure 3-11. Spiral grain can be seen on this white oak log.

Interlocked grain is similar to spiral grain in some respects. In this case, the grain spirals in one direction for 1 to several years and then reverses direction (Figure 3-12), which results in interlocked grain. Woods with interlocked grain are the gums, sycamore, elm, and many tropical woods. Woods with interlocked grain are difficult to split, may shrink longitudinally more than normal upon drying, and often warp excessively. From a positive standpoint, interlocked grain on quartered lumber can reflect light in varying patterns resulting in a ribbon stripe figure. I have seen this effect in some old growth, quarter sawn red gum (sweetgum).

Abnormal Wood

In both hardwoods and softwoods, depending on age and location in the tree, wood can be found that is not representative of most wood for that species. This wood is called abnormal wood.

Figure 3-12. Interlocked grain in sweetgum. Note how the wood did not split uniformly but developed a wavy pattern.

Juvenile Wood

One type of abnormal wood is juvenile wood. Juvenile wood is that material formed near the center or pith of the tree; it is prevalent in softwoods. It also occurs in hardwoods, but little information is available concerning it. Juvenile wood is characterized by wide growth rings, with shorter, thin-walled cells, and fewer latewood cells, thus resulting in a lower density and reduced strength values. There is also a tendency toward greater spiral grain. The shrinkage characteristics of juvenile wood are different from the shrinkage of normal wood, thus increasing warp problems. The change from juvenile wood to normal wood is gradual, thus making identification of juvenile wood difficult.

Reaction Wood

Reaction wood is another type of abnormal wood. This wood often forms in leaning trees that are partially bent by a storm or other disturbance. Reaction wood is formed in an attempt by the tree to straighten itself. This abnormal wood may also be formed as a tree bends toward a light source. Reaction wood is particularly troublesome because the board may otherwise be defect-free and appear as a desirable piece.

In softwoods, reaction wood is called compression wood (Figure 3-13). It is formed on the lower side of leaning trees. The part of the growth ring with reaction wood is usually wider than the rest of the ring, has a high proportion of latewood; and as a result, the tree develops an eccentrically shaped stem, and the pith is not centered. Compression wood, especially the latewood, is usually dull and lifeless in appearance. It presents serious problems in wood

Figure 3-13. Compression wood is found on the lower side of leaning softwood trees.

manufacturing since it is much lower in strength than normal wood of the same density and tends to shrink excessively in the longitudinal direction. Sometimes it is the cause of structural failures in critical applications, such as ladders. The softwood lumber grading rules restrict the extent of reaction wood in lumber.

In hardwood trees, reaction wood is called tension wood and forms predominately toward the upper side of a leaning tree (Figure 3-14). Tension wood is usually not as evident as compression wood. It may form irregularly around the entire stem; and as a result, there is less tendency for the pith to be off center. Tension wood is often difficult to detect. It may have a silvery appearance, and at other times, cannot be visually detected. However, crooked and sweepy logs should be suspect. When machined, a fuzzy or woolly surface may result, particularly in green wood. During the finishing process, stain is sometimes absorbed irregularly by tension wood, leaving a blotchy appearance. Due to abnormal longitudinal shrinkage, warping is also a problem with tension wood, and during drying it may collapse. The mechanical properties of tension wood are generally less than those for normal wood. Tension wood can deform the work piece as it is being sawed resulting in thick and thin lumber.

Figure 3-14. Tension wood is found in the upper side of leaning hardwood trees and branches. This is an extreme example.

Growth Stress in Logs

All standing trees and cut logs contain a certain amount of internal stress that can create problems for smaller mills that are not capable of holding the partially cut log or cant firmly in place. As boards are cut free, the log or cant moves and, if some correction is not made for this movement, the next piece of lumber will be thick and thin as a result of the log—not the mill.

In the simplest explanation, the outside of a tree or cut log is in tension, and the core is in compression (Figure 3-15). The zero point for stress is somewhere between 0.50 and 0.70 radii from the pith to the bark.

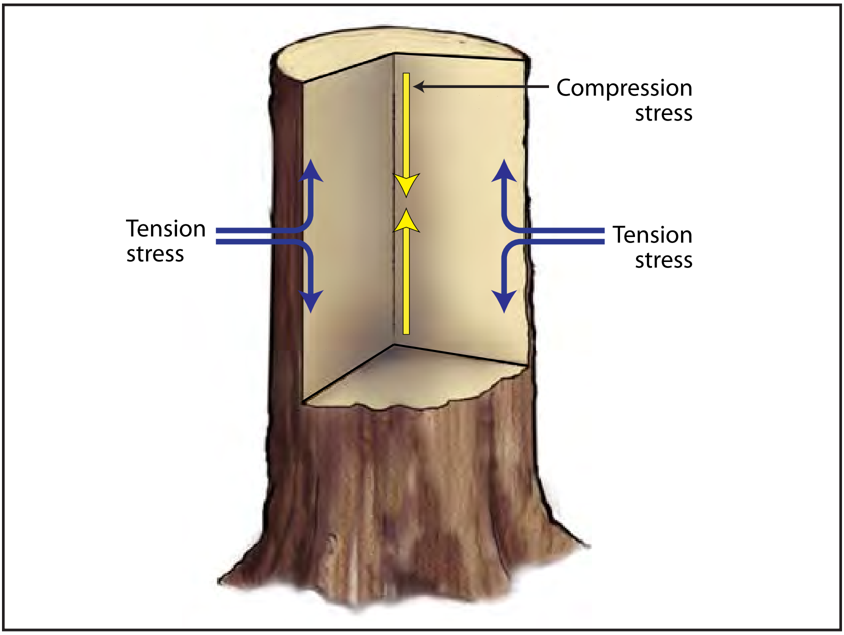

Figure 3-15. The tree stem shows tension in the outer portion and compression in the central part. In a board cut loose from the surface, both ends will be bowed outward.

Small logs tend to have the same amount of stress as large logs. So, stress in a large log is spread over a wide area, and releasing it one board at a time generally does not result in serious distortion of the remaining work piece. In a small log, however, the removal of a slab or board can substantially change the stress balance and result in unacceptable distortion.

Stress is exhibited in a number of different ways. Examples include splitting in logs, as well as distortion of slabs, boards, and the remaining work piece (Figures 3-16 and 3-17). Small fast growth timber of yellow-poplar and ash seems to be the most prone to stress problems. Longer logs create more problems than shorter logs do. If the log or cant cannot be held straight as it is processed, the sawyer must make several adjustments. First sawing around the log one or two boards at a time will gradually release the stress and help prevent thick and thin lumber. Where deviations occur, a shim cut can be made before cutting the next full thickness board. The last board produced will likely need to be turned 180° and resized. The back or bottom of the last board will contain the summation of all of the distortions that occurred in the pieces cut above it. Another approach is to cut oversize cants and then resize them, thus removing any distortions that may develop.

Gang sawing, where the log or cant is processed into boards all in one pass will also help to eliminate thick and thin lumber. The stress is relieved uniformly across the diameter of the log, all at one time.

Figure 3-16. The release of growth stress resulted in a board that is bowed up towards the outside of the log and a work piece that is bowed down.

Figure 3-17. This high quality walnut veneer log has severely degraded due to the release of growth stress.

Nomenclature

In the hardwood industry, the different species are referred to by their common names, such as red oak and sweetgum. This system has proven to be perfectly satisfactory, particularly when only a limited number of species or species groups is available. However, a more precise system commonly used by researchers and in many references is available. With this system, the important parts are the genus and species names. For example, the scientific name for true white oak would be *Quecus alba* L. "*Quercus*" refers to the genus, "*alba*" refers to the species, while L. stands for Carl Linnaeus, the famous botanist who first described and named the species in the 1700s. The first letter of the genus name is always capitalized, while the species name is written in lower case. Scientific names are always underlined or italicized. There are several commercial species of white oak trees. Each has the same genus name, *Quercus*, but a different species name. Once the lumber is cut, however, it is all referred to as white oak since there are only minor or no differences in the wood of the various white oaks. Since common names often vary from one section of the country to another, scientific names can be used where necessary, to precisely describe the species in question.

Much confusion exists over the terms "hardwood" and "softwood," probably because they are not directly associated with the hardness or softness of the wood. Some true hardwoods, such as cottonwood, aspen, and basswood, have softer or lighter wood than do the common softwoods, such as Douglas-fir, larch, and southern pine.

Softwood refers to those trees in North America commonly called pines, spruces, larch, fir, hemlock, redwood, yew, cypress, Douglas-fir, and cedar. These trees have needle- or scale-like leaves and generally, but not always, maintain them throughout the year. As a result, it seems logical to refer to them as evergreens. Or, since they bear scaly cones to produce seeds, they are also called conifers. Lumber from these species is most commonly used for construction purposes.

Hardwood, on the other hand, refers to those species that generally, but not always, have broad deciduous leaves. Their leaves change color in fall and drop to the ground in temperate climates. Some of the more common hardwood species are oak, gum, ash, elm, hickory, walnut, cherry, maple, birch, aspen, and cottonwood.

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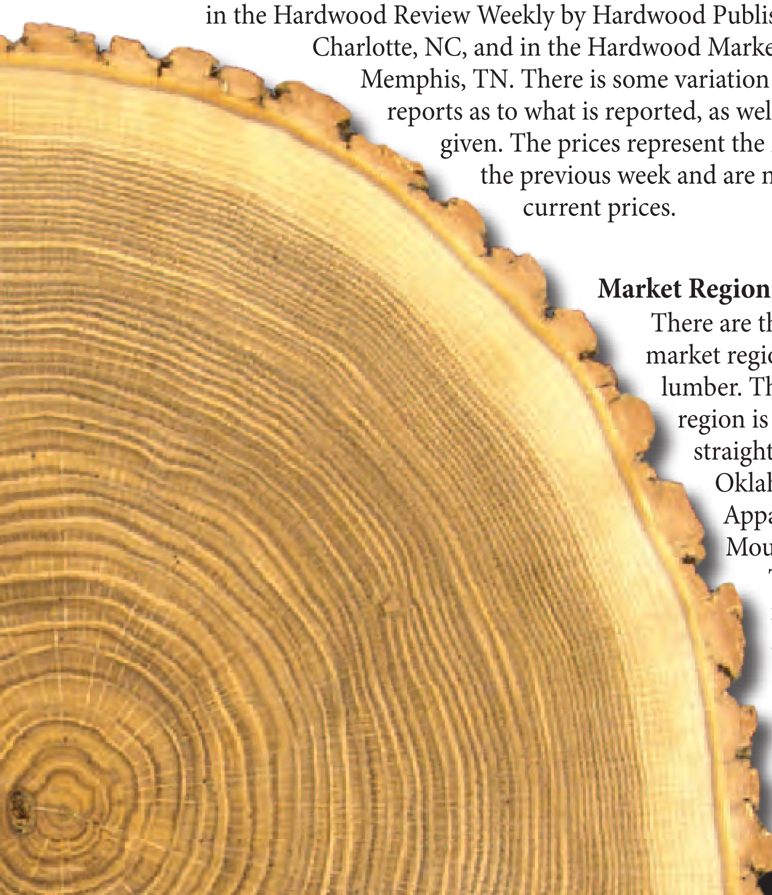
Chapter 4.
Hardwood Lumber Pricing and Grading

Lumber grades determine price. Pricing and grading are two of the most important functions in hardwood lumber manufacturing. Grading may appear complicated to the newcomer in the industry, but with training and experience, the logic of the system becomes clear. Pricing, likewise, is involved.

This chapter first describes how lumber is priced, and then outlines the grading system. Examples show how to grade sample boards using standard grades.

Pricing Hardwood Lumber

The price of wholesale, green, and kiln-dried hardwood lumber by geographic region and other lumber items such as pallet stock, railroad ties, upholstered frame stock, flooring, board road, and cypress are reported weekly in the Hardwood Review Weekly by Hardwood Publishing, Inc., in Charlotte, NC, and in the Hardwood Market Report in Memphis, TN. There is some variation between the two reports as to what is reported, as well as the prices given. The prices represent the market trend for the previous week and are not intended to be current prices.



Market Regions

There are three broad market regions for hardwood lumber. The southern region is roughly a straight line from north Oklahoma to the Appalachian Mountains, except in Tennessee where it dips around the south end of the Appalachians, and then up the coastal plain to southern Virginia. The northern region is north from southern Iowa across central Illinois and Indiana, and then through Canada north of Lake Erie and Ontario, across central New York and New Hampshire. The Appalachian region lies between the other two. The Hardwood Review Weekly breaks the northern and southern portion of the Appalachian region into smaller geographic areas for some species. The regions do not represent biological or political boundaries but are more or less understood by the industry as being distinctly different. Growth rates or wood texture and the amount of sapwood are probably two of the major differences between the regions. Species vary somewhat as well. Grading practices for the same species can also vary. In general, for the same species and item, southern hardwoods are the least expensive, while northern hardwoods are the most expensive, and Appalachian hardwoods are intermediate. These price relationships, however, can change with market demand.

Species and Species Groups

Lumber prices are reported for each species or species group (Table 4-1). The lumber thickness is given in quarters, such as 4/4, which represents 1-inch thick lumber, or 8/4, which represents 2-inch thick lumber. Typically overthickness for 4/4 lumber is 1/16 to ⅛ inch and for 8/4 thick lumber is about ¼ inch. The overthickness allows for shrinkage and sawing variation. The overthickness is extremely important; the amount should be well understood by both seller and buyer and determined before the lumber is produced. Next, the hardwood lumber grades by thickness are presented.

Lumber Grade and Thickness

The common lumber grades are these:

First and Seconds (FAS)

FAS One Face (abbreviated as F1F or just 1F)

Selects

No. 1 Common

No. 2A Common

No. 2B Common

No. 3A Common

No. 3B Common

The designation “A” means the cuttings have a clear face, while “B” indicates the cuttings are required only to be sound. When the notation is simply No. 2 Common, it is assumed to be No. 2A Common. The notation FAS/1F means FAS One Face and better lumber, so it includes the FAS grade as well. Not all grades are listed for all species, as can be seen in Table 4-1. Lumber grades are followed by kiln-dried and green lumber prices.

Table 4-1. Lumber prices in dollars per thousand board feet for Appalachian white oak reported by the Hardwood Review Weekly for the week of April 15, 2011 (Hardwood Publishing, Inc. 2011)

Thickness	Grade	Kiln-Dried Gross Tally		Kiln-Dried Net Tally		Green
4/4	FAS/1F	1,580	(1,490–1,665)	1,700	(1,600–1,790)	**1,065 +15**
	No.1 Common	1,000	(925–1,065)	1,075	(995–1,145)	585
	No.2 Common	795	(740–850)	855	(795–915)	**430 -10**
	No.3 Common	610	(575–660)	655	(620–710)	**380 -10**
5/4	FAS/1F	1,875	(1,785–1,955)	2,015	(1,920–2,100)	**1,175 +10**
	No.1 Common	1,110	(1,050–1,160)	1,195	(1,130–1,245)	**615 +5**
	No.2 Common	920	(870–965)	990	(935–1,040)	**545 -5**
	No.3 Common					**490 -10**
6/4	FAS/1F	**2,270 +10**	(2,180–2,365)	**2,440 +10**	(2,345–2,545)	**1,325 +10**
	No.1 Common	1,310	(1,260–1,380)	1,410	(1,355–1,485)	615
	No.2 Common	975	(930–1,030)	1,050	(1,000–1,110)	
8/4	FAS/1F	**2,695 +10**	(2,550–2,865)	**2,900 +10**	(2,740–3,080)	**1,485 +15**
	No.1 Common	1,480	(1,380–1,535)	1,590	(1,485–1,650)	650
	No.2 Common	1,030	(985–1,080)	1,110	(1,060–1,160)	

Seasoning

In Table 4-1, the price for 4/4 FAS/1F white oak averaged about $1,065 per thousand board feet for green stock in the prior week. The price increased by $15 per thousand board feet. In the past, Select and F1F grades were priced separately and just somewhat less than FAS. Many operations are selling lumber such as Selects and better, or F1F and better, at one price.

The Hardwood Review Weekly also reports the average and range of prices for kiln-dried lumber by gross and net tally. The use of gross and net tally is a confusing issue to those not directly involved in the wholesale hardwood industry. Lumber shrinks as it dries. When 1,000 board feet of green lumber are kiln-dried, only about 930 board feet will be tallied when the same lumber is removed from the kiln. The loss in volume is commonly understood to be in the 6 to 7 percent range.

When lumber is sold on gross tally, the price is based on the original 1,000 board feet. When lumber is sold on net tally, the price is based on the smaller quantity of 930 board feet, so the price per thousand board feet is higher. Large wholesale buyers and sellers understand gross tally and commonly use it. An issue can develop when smaller purchasers, who do not understand the difference, simply pick the lowest price being offered per thousand board feet and do not ask how the lumber is tallied. In this case it is likely to be gross tally, and if the buyer measures the lumber the volume stated will not be present.

Depending on supply and demand, as well as other conditions such as inventory, space, future market expectations, and cash flow needs, sellers will adjust the price being asked up or down, and buyers may also try to negotiate the price down. Asking the buyer to take a portion of a less desirable but still useful item, as well as paying freight costs and payment terms is also negotiable. When lumber is in tight supply it can change ownership more than once in the same day and not even move from its storage location. A wholesaler explained that he had sold a load of lumber in the morning, had calls for more of the same item, and unknowingly (until the paper work was processed) purchased the same load of lumber from another wholesaler at a higher price, and then sold it again—all in the same day.

Retail prices for kiln-dried hardwood lumber are not systematically collected and reported; however, Dominion Enterprises in Essex, CT, does an informal survey of distribution yards for each issue of Woodshop News. Retail prices for a different species, kiln-dried, FAS, surfaced two sides lumber are reported in each issue. Trends for past years are also reported. Typically, these are the highest prices that could be received at the retail level.

Table 4-2 shows wholesale green and kiln-dried lumber prices (not surfaced) as reported by the Hardwood Review Weekly, and kiln-dried surfaced on two sides retail prices as reported by the Woodshop News. Kiln-drying adds only modest costs at the wholesale level. However, when small quantities of 100 board feet or so, are sold at retail, prices about double from wholesale prices, regardless of species.

Table 4-2. Wholesale green and kiln-dried lumber prices (not surfaced) as reported by the Hardwood Review Weekly (Hardwood Publishing, Inc. 2011) and kiln-dried surfaced on two sides retail prices as reported by the Woodshop News (Dominion Enterprises 2010, 2011)

Species Green	How drying affects lumber value			
	Wholesale[1]		Retail kiln-dried[2]	
	Dollars per MBF Green	Dollars per MBF Kiln-dried (KD) Net Tally	Dollars per MBF	Dollars per 100 BF
Ash	765	1,225	2,662	307
Cherry	1,245	2,150	5,063	538
Eastern white pine[3]	—	—	—	365
Hard maple Sap/Btr	1,470	1,360	3,612	441
Hickory	660	1,255	2,400	320
Oak, red	870	1,340	2,687	301
Oak, White	1,045	1,690	3,425	383
Walnut	2,265	3,340	5,079	561
Yellow poplar	535	810	1,984	228

[1] Southern Appalachian stock FAS/F1F truckload quantities
[2] Average for Northeast, Southeast, and Midwest United States
[3] 4/4 D & Better Selects

Grading Hardwood Lumber

Most of the hardwood lumber purchased in North America for remanufacture into other products is graded according to the Rules for the Measurement and Inspection of Hardwood and Cypress published by the National Hardwood Lumber Association (NHLA 2011). Prices reported for hardwood lumber are directly tied to these grade rules. The rules are written with the volume user in mind. Sometimes they are modified to better fit the needs of the buyer and seller.

The original version of these rules was published in 1898 to help sellers and buyers establish a basis on which lumber at the producer's location could be sold without examination by the buyer. Through the years, the rules have been modified to better fit existing lumber supplies and end uses. The rules have also been translated into French, Italian, European and Mexican Spanish, and Mandarin Chinese. Check with the NHLA for current versions and translations of the rules.

The NHLA grades for hardwood lumber appear complicated and difficult to apply upon initial inspection. For the most part, however, they are strictly mathematical and quantitative. The more subjective part of lumber grading is to determine what is and what is not a defect. With some practice, however, this too becomes more exact.

This section provides an abbreviated overview of the NHLA rules. It is intended for those individuals who must understand hardwood lumber grading concepts and terminology in order to purchase, sell, or use the material. It is not intended to teach someone how to become a professional lumber grader.

The rules are full of exceptions for different grades and species. Although extremely important in determining grade, few of these exceptions are covered here. The reader is encouraged to study the published rules book, as well as the NHLA Inspection School Training Manual (National Hardwood Lumber Association 2006), to obtain a more detailed understanding of the rules.

Standard Terms and Grade Requirements

An understanding of a number of standard terms is essential in grading hardwood lumber. A few of the more important terms are defined in Box 4-1.

Hardwood lumber grades generally are based on the size and number of cuttings or individual pieces that can be obtained from a particular board when it is cut and used in a manufacturing process. Manufacturers usually are interested in the amount of clear material available in a board. Therefore, the cuttings are normally clear. Sound cuttings are allowed in some of the lower grades, however, and this material is often used where appearance is not critical.

Box 4-1. Definitions of selected standard terms used in hardwood lumber grading[1]

Surface measure (SM)	Width of the board in inches and fractions of inches times length in whole feet divided by 12. The surface measure is rounded to the nearest whole number.
Board foot (BF)	Width of the board in inches times length in feet times the thickness in inches divided by 12 or it is equal to the SM times the thickness.
Cutting	A portion of a board obtained by cross-cutting, by ripping, or by both. Diagonal cuttings are not permitted. Note: In lumber grading the cuttings, are only visualized; no cross-cutting or ripping actually takes place.
Cutting unit	One inch by 1 foot or 12 square inches of board surface. The unit is used to determine whether or not a board has enough clear surface to make a certain grade. The number of units in a cutting is equal to the width in inches and fractions of an inch times the length in feet and fractions of a foot.
Clear face cutting	A cutting having one clear face (ordinary season checks are admitted) and the reverse side sound (see below).
Sound cutting	A cutting free from rot, pith, shake, and wane. Texture is not considered. It will admit sound knots, bird pecks, stain, streaks, or their equivalent, season checks not materially impairing the strength of the cutting, pin, shot, and spot worm-holes. Other holes ¼ inch or larger are admitted, but shall be limited as follows: one ¼ inch in average diameter in each cutting of less than 12 units; two ¼ inch or one ½ inch to each 12 units on one side only of a cutting.

[1] National Hardwood Lumber Association (2011).

Table 4-3 lists the requirements for the more common standard hardwood lumber grades. Lumber is generally graded from the poorest side of the piece. For F1F and the Selects grade, however, one side must grade FAS and the reverse side No. 1 Common. The reverse side of the cutting is not required to be sound. The F1F grade is similar to the Selects grade, but F1F grade lumber must be 6 inches wide. Special wane restrictions apply to each of these two grades (Box 4-2).

Board sizes

Several factors are used to aggregate boards into different standard grade classes (Table 4-3). The easiest of these to apply is size. FAS lumber must be at least 6 inches wide and range from 8 to 16 feet long.

Number of cuttings

Next, only a certain number of cuttings is allowed, depending on board size. For example, in FAS, the number of cuttings allowed is determined by dividing the surface measure (SM) by 4 and dropping all fractions.

Table 4-3. Standard hardwood lumber grades and their minimum requirements[1]

Minimum Requirement	FAS[2]	F1F[2,3]	Selects[3]	No. 1 Common	No. 2A No. 2B[4]	No. 3A	No. 3B
Width	6 in+	6 in+	4 in+	3 in+	3 in+	3 in+	3 in+
Length	8 ft–16 ft	8 ft–16 ft	6 ft–16 ft	4 ft–16 ft	4 ft–16 ft	4 ft–16 ft	4 ft–16 ft
Number of cuttings allowed	$\frac{SM}{4}$ Not over 4	$\frac{SM}{4}$ for FAS side $\frac{SM+1}{3}$ for No. 1 Common side	$\frac{SM}{4}$ for FAS side $\frac{SM+1}{3}$ for No. 1 Common side	$\frac{SM+1}{3}$ Not over 5	$\frac{SM}{2}$ Not over 7	No limit	No limit
Minimum size of cuttings	4 in by 5 ft 3 in by 7 ft	4 in by 5 ft or 3 in by 7 ft FAS side 4 in by 2 ft or 3 in by 3 ft No.1 Common side	4 in by 5 ft or 3 in by 7 ft FAS side 4 in by 2 ft or 3 in by 3 ft No.1 Common side	4 in by 2 ft 3 in by 3 ft	3 in by 2 ft	3 in by 2 ft	1½ in or wider to contain 36 sq. inches
Yield amount required in clear face cuttings	$\frac{10}{12}$ 83 1/3 %	$\frac{10}{12}$ FAS side $\frac{8}{12}$ No. 1 Common	$\frac{10}{12}$ FAS side $\frac{8}{12}$ No. 1 Common	$\frac{8}{12}$ 66 2/3 %	$\frac{6}{12}$ 50%	$\frac{4}{12}$ 33 1/3%	$\frac{3}{12}$ 25% sound cuttings

[1] National Hardwood Lumber Association (2011).

[2] See Box 4-2 for additional restrictions for grades FAS and F1F.

[3] The reverse side of the cuttings for both the FAS and No. 1 Common sides are not required to be sound for the grades of F1F and Selects.

[4] The grade No. 2A Common requires clear face cuttings. Grade No. 2B Common meets all of the requirements of No. 2A, except that the cuttings are sound as defined in sound cuttings (Box 4-1).

Minimum size of cuttings

The next factor is the minimum size of cuttings allowed. For FAS, the cuttings must be at least 4 inches wide by 5 feet long, or 3 inches wide by 7 feet long. If the board does not have clear face cuttings of at least this size, a lower grade must be considered. The minimum sizes for lower grades are narrower and shorter.

Clear face

Last, a certain percent of the board is required to be in clear face cuttings. For the FAS grade this is 10/12, that is, at least 83⅓ percent of the board is in clear face cuttings. The number of cutting units in each cutting must be calculated. Fractions in 12ths (e.g., 10/12) are used by graders so that the numerator of the fraction (10 in this case), when multiplied times the surface measure of the board, gives the actual number of units required to make the grade.

Steps in Grading a Board

Several steps are involved in grading a board:

- Determine the species.
- Determine the surface measure of the board.
- Determine the poor side of the board.
- Estimate the grade.
- Calculate the number of cuttings allowed.
- Lay out the cuttings on the board surface.
- Calculate the number of clear face cutting units.
- Consider other rule limitations.
- Assign grade.

With practice, these steps become automatic. For instructive purposes, it is beneficial to go through each step. After description of the steps, example calculations for grading three sample boards are given.

Determine the species

Lumber is normally separated and sold based on species. Some species, such as Ash and birch are graded by the standard rule. Plain red and white oak are graded standard except for a consideration of mineral stain. The unique characteristics of some species result in modifications of the rules. For example, in cherry, small knots or their equivalent not exceeding ⅛ inch in diameter shall be admitted in the cuttings. Gum streaks and spots are admitted without limit.

Walnut is one of the more interesting and expensive species, and it is often purchased in small quantities. Every board is likely to be closely scrutinized. The grades for walnut and butternut vary substantially from the standard grades. FAS will admit pieces 6 and 7 feet long, as compared with the standard 8-foot length. The minimum width for FAS is 5 inches, as compared with the standard 6 inches. The minimum size cuttings are decreased in all of the grades. As a result, any particular grade in walnut and butternut will not yield the size and probably surface area of clear material, as compared with lumber graded with the standard rules.

Determine the surface measure of the board

Surface measure (SM) is a measure of the surface area or size of the board. The surface measure is simply the width of the board in inches and fractions multiplied by the length in whole feet divided by 12 (calculation 1 in the examples). Fractions are rounded up or down to the nearest whole number. When the fraction is one-half, it is rounded up one time and down the next time. The surface measure is used to determine the number of cuttings allowed. Lumber graders can manually use a scale stick to quickly determine the surface measure (Figures 4-1 and 4-2), or the process can be automated using scanning technology (Figure 4-3).

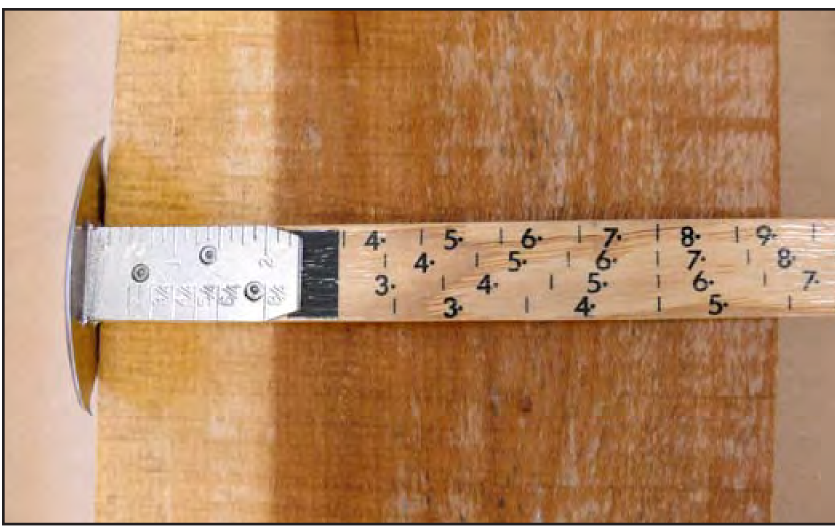


Figure 4-1. The standard tool in hardwood lumber grading is the scale stick, which is used to obtain the surface measure of each board.

Figure 4-2. In larger operations, the lumber is handled by machine. As the board is examined by the grader, the surface measure is read from a series of scales placed behind it.

Figure 4-3. Surface measure can also be determined electronically, as in this state-of-the-art operation.

Determine the poor side of the board

The lumber grade is determined from the poor side of the piece, except for the Selects and F1F grades. The poor side is the side with the lower grade, or if both sides have been graded, it is the side with the least number of cutting units.

Estimate the grade

At this point, the grade of the board is assumed, and the board characteristics are compared with those given in Table 4-3.

Calculate the number of cuttings allowed

The first characteristic to determine is the number of cuttings permitted for the assumed grade. The number of cuttings is equal to the surface measure divided by the appropriate factor (calculation 2 in the examples). An FAS board measuring 12 inches wide by 12 feet long has a surface measure of 12 feet. Therefore, for FAS the surface measure of 12 is divided by 4; 3 cuttings are allowed. The larger the board, the greater the number of cuttings allowed. Some limits apply. An extra cutting is also allowed in some cases. This extra cutting allows a board to be placed in a higher grade, providing a specified increased yield can be achieved (Table 4-4).

Table 4-4. Surface measure needed and additional yield required to take an additional cutting of boards with three different grades[1]

Requirements for one additional cutting	Grade of board		
	FAS	No. 1 Common	No. 2A and No. 2B Common
Surface measure needed to take one additional cutting	6–15 ft Surface measure	3–10 ft Surface measure	2–7 ft Surface measure
Additional yield required when taking one additional cutting	Surface measure × 11 91 2/3%	Surface measure × 9 75%	Surface measure × 8 66 2/3%

[1] National Hardwood Lumber Association (2011).

Lay out the cuttings on the board surface

The objective is to obtain the largest amount of surface area in the cuttings given the limited number allowed and their minimum size (calculation 3 in the examples). This step requires some skill. In the upper grades, the cuttings are generally required to be clear, and the reverse sides of the cuttings are required to be sound.

Calculate the number of clear face cutting units

The number of cutting units available in the cuttings that were visually laid out above is calculated (calculation 4 in the examples). To calculate the number of units in each cutting, the width (in inches and fractions of an inch) is multiplied by the length (in feet and fractions of a foot). The number of units for each cutting is totaled. If the total exceeds the minimum number required, then the board meets the requirement for the cutting units needed for the grade. If the total does not exceed the minimum number of cutting units required for the grade, then the next lower grade is considered.

The number of units needed depends on the size or surface measure of the board and the percent or fractional yield required by the grade (calculation 5 in the examples). An FAS board measuring 12 inches wide by 12 feet long has a surface measure of 12 feet. Therefore, for the 10/12 clear face cuttings required for the FAS grade, the number of units required is determined by multiplying the 12 feet of surface measure times 10. Thus, 120 cutting units are needed to make the grade. The board has a total of 144 units (12 *SM* × 12).

Consider other rule limitations

In some situations additional restrictions must be considered. The FAS grade has several additional restrictions (Box 4-2), which must be considered in addition to the factors discussed above.

Assign the grade

The grade of the board and surface measure are usually recorded at this point.

Box 4-2. Additional restrictions for the FAS grade. With the exception of wane, these same restrictions apply to the FAS face of both F1F and Selects grades.[1]

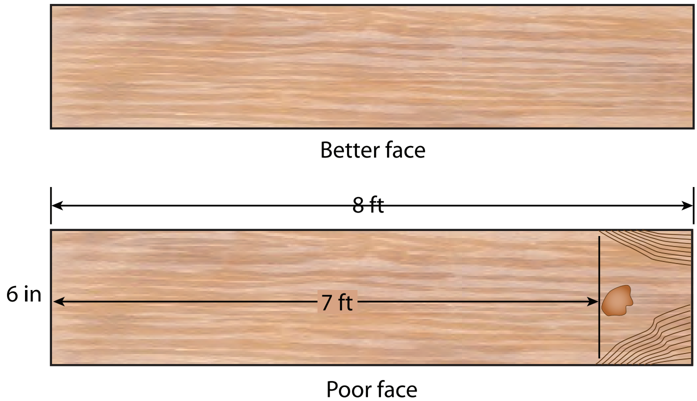
Pith	Pith is the soft textured tissue located in the very center of a cross section of a tree. If a board is cut from this portion of a tree or log, the pith will then appear along the length of the board. The length of pith in the FAS grade is limited. In total, it shall not exceed a number equal to the surface measure expressed in inches. Thus, a board with 12 feet of surface measure shall not contain more than 12 inches of pith.
Wane	For FAS, wane is allowed up to one-half the length on one or both edges. For F1F, the length of wane on the No.1 Common side is the same as FAS. In addition, the sum of the width of the wane from both edges cannot exceed 1/3 of the total width of the piece. For Selects, 6 in. and wider, wane is restricted on the No. 1 Common side just as for the No. 1 Common side of F1F. For 4 in. and 5 in. wide pieces, the width of wane is restricted on both sides just as for the No. 1 Common side of F1F, but the total length of wane on both edges, when added together, cannot exceed ½ the length.
Splits	The maximum total length of splits is limited to twice the surface measure of the piece expressed in inches except when 1 foot or shorter. Splits may diverge up to 1 inch to the lineal foot, except when one foot or shorter. Splits shorter than one foot are not covered by this rule.
First Lineal Foot	Within one lineal foot from the ends of the boards of standard length there shall be 50% or more clear-face. And another 25% sound wood. The remaining 25% may contain defects, sound or unsound.
Knots	The average diameter of any knot shall not exceed in inches one-third the surface measure of the piece.
97% Rule	This rule admits pieces 6 inches and wider of 6 feet to 12 feet surface measure that will yield 97% in two clear-face cuttings of any length, full width of the board.

[1] National Hardwood Lumber Association (2011).

Calculating Standard Grades for Sample Boards

The calculations performed in grading different quality boards are given in the following three examples.

Example calculations for FAS grade board



1. Calculate the surface measure (SM).

$$SM = \frac{\text{width in inches x length in feet}}{12} \text{ or } \frac{\text{6ft x 8in}}{12} = 4$$

2. Number of cuttings permitted for FAS
   Number = $SM \div 4$ or $4 \div 4 = 1$

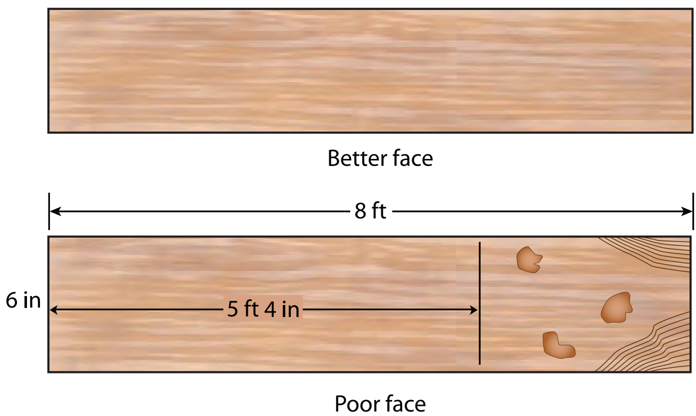
3. Minimum cutting size for FAS
   The minimum cutting size is 4 in × 5 ft or 3 in × 7 ft.
   The 6 in × 7 ft cutting shown on the poor face qualifies.

4. Calculate the number of units available.
   Width in inches and fractions times length in feet and fractions:
   6 in × 7 ft = 42 units

5. Units needed for FAS are
   $SM \times 10$ or $4 \times 10 = 40$

Board meets requirements for the FAS grade.

Example calculations for No. 1 Common grade board



1. Calculate the surface measure (SM).

   $$SM = \frac{\text{width in inches x length in feet}}{12} \text{ or } \frac{\text{6ft x 8in}}{12} = 4$$

2. Number of cuttings permitted for No. 1 Common
   Number of cuttings = SM + 1 ÷ 3 or 5 ÷ 3 = 1

3. Minimum cutting size for No. 1 Common
   The minimum size of cutting is 4 in × 2 ft or 3 in × 3 ft.
   The 6 in × 5 ft 4 in cutting shown on the poor face qualifies.

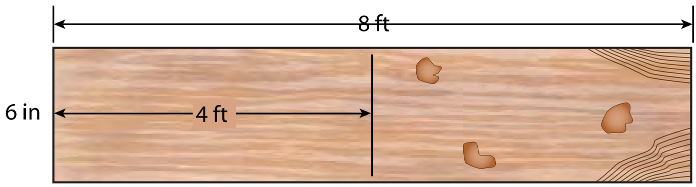
4. Calculate the number of units available.
   Number of units = width in inches and fractions × length in feet and fractions or 6 in × 5 ft 4 in = 32 units

5. Units needed for No. 1 Common
   Units = SM × 8 or 4 × 8 = 32

Board just meets requirements for the No. 1 Common grade.

Example calculations for No. 2A Common grade board

Better face



Poor face

1. Calculate the surface measure (SM).

   $$SM = \frac{\text{width in inches x length in feet}}{12} \text{ or } \frac{\text{6ft x 8in}}{12} = 4$$

2. Number of cuttings permitted for No. 2A Common
   Number of cuttings = SM ÷ 2 or 4 ÷ 2 = 2

3. Minimum cutting size for No. 2A Common
   The minimum size of cutting is 3 in × 2 ft
   The 6 in × 4 ft cutting shown qualifies.

4. Calculate the number of units available.
   Number of units = width in inches and fractions × length in feet and fractions or 6 in × 4 ft = 24 units

5. Units needed for No. 2A Common
   Units = SM × 6 or 4 × 6 = 24

Board just meets requirements for the No. 2A Common grade.

Sales Code

The Rules for the Measurement and Inspection of Hardwood and Cypress (NHLA 2011) contain a detailed section titled, National Hardwood Lumber Association Sales Code, revised August 2011. The sales code is binding between buyer and seller only when it is specifically stated in the contract that it shall govern. The bulk of the code discusses good business practices, common sense, and the courtesies buyers and sellers should extend to each other if a long-term relationship is to exist. The sales code also discusses which options exist when a dispute over a lumber shipment develops. The NHLA rules book should be consulted for details, and questions should be directed to the NHLA Chief Inspector in Memphis, TN.

Inspection Service

In addition to maintaining and publishing the hardwood and cypress inspection rules, the NHLA also offers an inspection service. Professional lumber graders employed by the NHLA are available to inspect lumber on a fee-plus-expenses basis. They are available upon request to both members and nonmembers.

The graders will grade lumber as specified in written orders to them, using the NHLA rules as a basis. They will provide a certificate giving pertinent information about the parcel. The accuracy of the certificate is guaranteed by the NHLA. If a dispute over a lumber shipment arises, the national inspector can also be employed to grade the lumber, and the dispute would be settled based on the regulations given in the sales code if it applies.

Training Programs

Numerous lumber grading short courses are offered around the country. These programs are about 3 days long and are sponsored by a university, government agency, or private company, in cooperation with the NHLA. The instructor is usually—but not always—an NHLA inspector. For information on future programs, contact the NHLA at 901-377-1818. Their Web site is located at http://www.natlhardwood.org.

In the short course, some time is spent reviewing the rules, and the balance of time is spent practicing grading the boards (Figure 4-4). Thus, at the end of the program the registrant has a good understanding of the rules and should be able to accurately grade boards, but has not had time to develop the speed required in production situations. The NHLA offers an intensive 14-week training course at its headquarters in Memphis for those individuals who want more in-depth training.

Figure 4-4. Typical hardwood lumber grading short courses emphasize hands-on experience.

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For More Information–Pricing

Hardwood Market Report, Memphis, TN.
www.hmr.com

Chapter 5.

Softwood Lumber Grading

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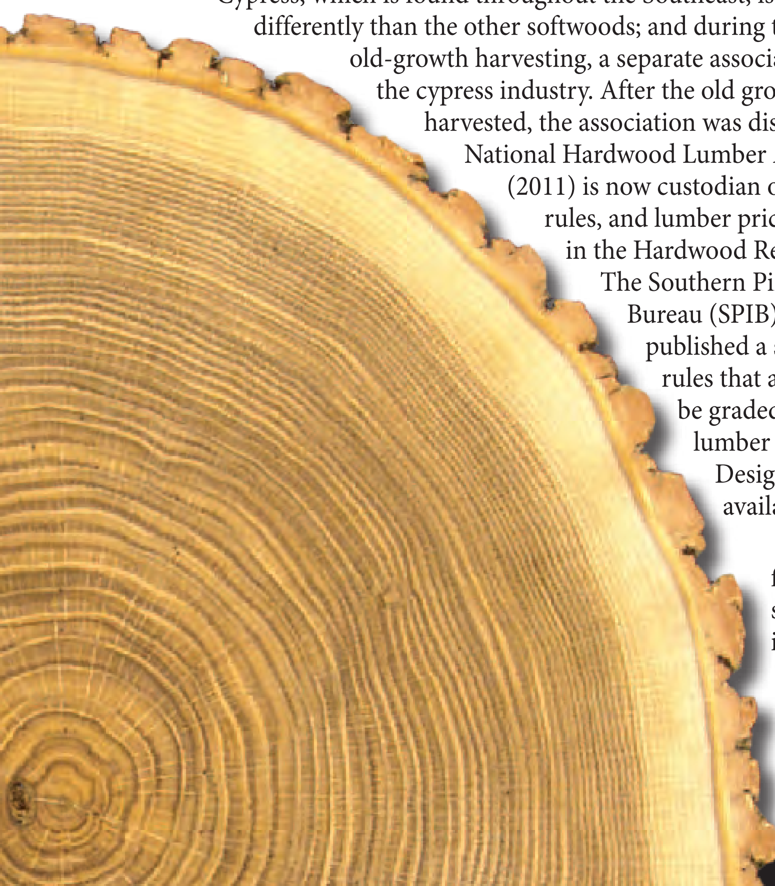
Chapter 5.
Softwood Lumber Grading

The primary focus of this handbook is hardwood lumber and related products; however, softwood lumber is addressed briefly. The softwoods (numerous pine, cypress, fir, cedar, and spruce species) are intermixed with the hardwoods or grow on sites adjacent to the hardwoods in nearly all regions of the eastern United States and Canada, except the central Midwest. Traditionally mills processed both hardwoods and softwoods, but changing markets and processing efficiencies forced larger mills to process either one or the other. This is especially true in the southern pine region. Smaller portable mills, however, may process both softwoods and hardwoods, especially for local applications and when custom sawing.

This chapter focuses on softwoods, which are handled, graded, priced, sawed, and distributed differently than hardwoods.

Cypress, which is found throughout the Southeast, is handled differently than the other softwoods; and during the period of old-growth harvesting, a separate association represented the cypress industry. After the old growth timber was harvested, the association was disbanded. The National Hardwood Lumber Association (2011) is now custodian of the grading rules, and lumber prices are reported in the Hardwood Review Weekly. The Southern Pine Inspection Bureau (SPIB) recently published a second set of rules that allow cypress to be graded as dimension lumber (SPIB 2002a,b). Design values are also available.



The market for factory and shop softwood lumber is similar to that for grade hardwood lumber.

Softwood stock is separated by species and grade, and sawed for thickness on the quarter scale, just as hardwoods are. The lumber moves into processing facilities to be converted into items such as windows, doors, and moulding.

Another market segment includes boards, which are sold by species, grade, and nominal dimensions, such as 1 by 4 and 1 by 6. Other items include posts, beams, and timbers; deck grade lumber; fencing; shingles and shakes; as well as milled-to-pattern stock.

The most important market category in terms of volume is framing or dimension lumber. This is the material purchased at local lumber yards and used for housing and other light-frame construction purposes. For this application, an entire new set of regulations can come into play in addition to the grading rules themselves, Anyone dealing with softwood lumber should understand the system and how it works.

Before proceeding with a discussion of framing or dimension lumber, a review of the market reports and traditional distribution system is useful.

Market Reports

Two publications report softwood prices and market trends: Random Lengths published in Eugene, OR, and Crow's Market and Price Service published by RISI in Bedford, MA. A review of either of these reports will indicate the complexity of the system just by the number of items listed. These weekly publications report on what the market did in the previous week. The reports include lumber, panel stock, plywood, oriented strandboard, and particleboard.

Distribution System

The distribution process for large quantities of softwood lumber moving through the traditional system is not as complicated as that for the hardwoods, but it still can have a number of steps (Figure 5-1). First, major softwood mills do not typically sell lumber direct. Wholesalers are commonplace and are

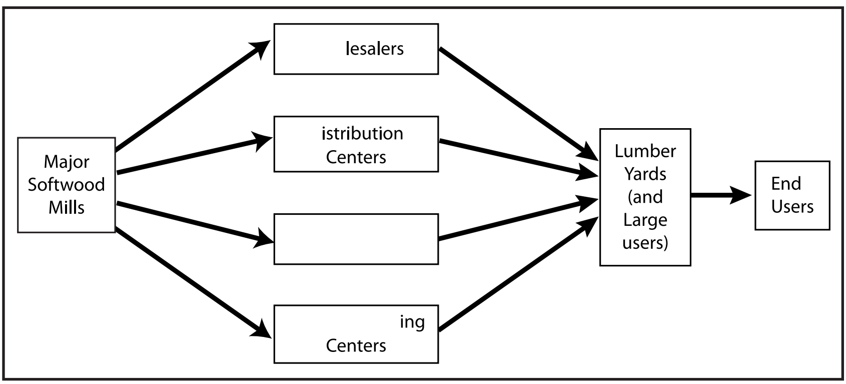


Figure 5-1. Common avenues of distribution for softwood lumber products.

responsible for moving large quantities of lumber from the sawmill to retail yards and secondary manufacturers. Large softwood corporations will also move lumber directly to distribution centers that distribute lumber on a more local basis. Other major outlets include wood-treating facilities and remanufacturing centers. Both distribution and remanufacturing centers are usually located in metropolitan areas, hold substantial inventory, and are thus able to respond to local demands.

Framing and Dimension Lumber

Most softwood lumber sold in North America is used in construction as dimension material, such as 2 by 4s and 2 by 6s or timbers defined as being 5 by 5 inches or larger. As part of a structure, each piece of lumber carries a certain amount of load. Softwood grades for dimension and timbers have been established according to engineering methods that determine how much load each piece is capable of supporting. These load values are then used in the design of a structure. A specific procedure has been established by which this extremely important process is completed. The process requires the use of grade stamps on each piece of lumber. If a structure fails, people can be hurt or even killed, and someone will likely be found liable. The grade stamp serves to identify the mill responsible for the lumber.

Softwood Grading System

It is important to understand how the softwood grades were established and administered. At the very top of the hierarchy is the American Lumber Standard Committee, Incorporated (ALSC). This Committee developed Voluntary Products Standard PS20-70 (superseded by PS20-05), under procedures established by the U.S. Department of Commerce (2005). At the same time, the National Grading Rule Committee developed the first National Grade Rule for Softwood Dimension Lumber. Technical procedures and processes used to establish the lumber grades are published by the American Society for Testing and Materials (ASTM 2002, 2006). The Forest Service's Forest Products Laboratory, U.S. Department of Agriculture, in Madison, WI, developed much of the test data used to establish allowable design values and helps to monitor various activities.

Seven rule-writing agencies publish rules as approved by the Board of Review of the American Lumber Standard Committee and certified for conformance to the American Softwood Lumber Standard PS20-05. These agencies are regional or species-specific and include the following:

Standard Grading Rules for Northeastern Lumber, published by the Northeastern Lumber Manufacturers Association, P. O. Box 87A, Cumberland Center, ME 04021

Standard Grading Rules, published by the Northern Softwood Lumber Bureau, P. O. Box 87A, Cumberland Center, ME 04021

Standard Specifications for Grades of California Redwood Lumber, published by the Redwood Inspection Service, 405 Enfrente Drive, Suite 200, Novato, CA 94949

Standard Grading Rules for Southern Pine Lumber, published by the Southern Pine Inspection Bureau, 4709 Scenic Highway, Pensacola, FL 32504

Standard Grading Rules for West Coast Lumber, published by the West Coast Lumber Inspection Bureau, P.O. Box 23145, Portland, OR 97281-3145

Western Lumber Grading Rules, published by the Western Wood Products Association, 522 Southwest Fifth Avenue, Portland, OR 97204-2122

Standard Grading Rules for Canadian Lumber, published by the National Lumber Grades Authority, 406-First Capital Place, 960 Quayside Drive, New Westminster, BC V3M 6G2

More than 95 percent of all softwood lumber consumed in the United States is produced by mills using rules certified under the ALSC system, and was graded by mills using the services of an ALSC-accredited agency.

Occasionally, hardwoods such as yellow-poplar are used for dimension lumber in building construction, and other species such as oak are used for heavy timbers. Hardwoods used in construction are subjected to the same requirements as the softwoods. The Northeastern Lumber Manufacturers Association (NLMA 2006) maintains the available rules for hardwoods.

Inspection and Supervision

Once the grades are established, they must be applied. In addition to the rule writing agencies listed above, several other agencies (accredited by the Board of Review of the American Lumber Standard Committee) are available to inspect and provide mill supervisory services. Each agency is somewhat specialized in what it is approved to inspect and has its own grade stamp and logo that appear on every piece of lumber it inspects. More frequently, however, an agency provides supervisory services to a mill and allows the mill to use the grade stamp in the agency's absence. The grade stamp remains the property of the agency, and it can be recalled if the mill using it fails to accurately grade its lumber. Loss of a stamp makes it nearly impossible for a mill to market softwood framing or dimension lumber. Nonstructural lumber, such as boards, selects, and factory products, are exempt from the grade stamp in most cases. Contact the American Lumber Standard Committee, P.O. Box 210, Germantown, MD 20875-0210, phone 301-972-1700, for the most current lists of rule writing and grading agencies.

The grade stamp is extremely important to building inspectors, as it is required by all building codes. The code is usually enforced at the county level, where a building permit is required before any construction can begin. When a building is inspected, the inspector will look for a grade stamp on the lumber. This grade stamp is the only way for the inspector to determine if the lumber used in the structure is acceptable. The building can be rejected if the lumber is not grade stamped. The level of code enforcement can vary by county.

Therefore, be certain to check with the county building inspector and permits office to determine exactly what is required. Past experiences may not predict future expectations. There may be some State and local exceptions when the lumber is produced and used for one's own building projects.

Understanding the Softwood Grade Stamp

Grade stamps are used in the softwood industry as a means for the seller to provide the buyer, building inspector, or other interested parties with five pieces of important information:

1. Grading agency trade mark,
2. Mill identification number,
3. Lumber grade designation,
4. Species or species group, and
5. Moisture content or seasoning at the time of surfacing.

Figure 5-2 shows the information that a typical grade stamp is required to contain (ALSC 2006). Figure 5-3 is an actual grade stamp. The trademark designation normally takes the form of an inspection agency's logo. There are several inspection agencies that have been approved by the ALSC. The following is a discussion of the five pieces of information contained in each grade stamp.

Trademark®		Grade designation
Mill identification	Species	Seasoning

Figure 5-2. A softwood grade stamp provides several types of information.
Trademark—identity of agency quality supervision.
Mill identification—product manufacturer name, brand, or assigned mill number
Grade designation—grade name (number or abbreviation).
Species—name or abbreviation of individual species or species combination.
Seasoning—moisture content classification at time of surfacing

S-Dry—19% maximum moisture content
MC 15—15% maximum moisture content
KD—kiln dried to moisture content indicated in grading rules
S-GRN—over 19% moisture content (unseasoned)
HT—designation for heat treated—while not a seasoning designation, the abbreviation HT may be found in conjunction with the seasoning information.

Figure 5-3. Example grade stamp showing Southern Pine Inspection Bureau (SPIB) as the agency, the grade as No. 1, kiln-dried (KD) to 19 percent moisture content, heat treated (HT), and producing mill number 406. The species is not given but implied, as SPIB deals exclusively with Southern Pine lumber.

Grading Agency

The grading agency is usually identified by its trademark. The American Lumber Standard Committee approves each agency, and a complete list is available on its Web site at www.alsc.org.

Mill Identification Number

Each grade stamp contains a number that indicates the producing mill or identifies an individual inspector and the grading agency. This number provides a means to trace the lumber back to the original producer. The name of the producing mill is sometimes provided, but it is not required.

Lumber Grade Designation

Following are several structural lumber grades in common use, from the highest to the lowest.

Select structural
No. 1
No. 2
No. 3
Stud
Construction
Standard
Utility

In addition, dense grades are sometimes recognized for southern pine. Dense grades apply to those pieces with no less than six growth rings per inch and one-third or more of each ring is summerwood; or no less than four rings per inch, and one-half or more of each ring is summerwood (SPIB 2002a).

Summerwood is the darker-colored, dense portion of an annual growth ring. The dense terminology is applicable only to Select Structural, No. 1, and No. 2 grades. A similar but somewhat more involved system has been established for Douglas-fir and western larch. For these species, the terminology is medium grain, close grain, and dense (WWPA 2005).

Lumber may be purchased by including one grade and all higher grades, such as in No. 1 and Better. Select Structural grade through No. 3 grade lumber is sold in sizes of 2- to 4-inches thick and 2 inches and wider. Stud grade is sold in sizes 2 to 4 inches thick and 2 inches and wider. Construction, Standard, and Utility grades are restricted to 2- to 4-inches thick and 2- to 4-inches wide.

The No. 2 and Stud grade are probably the two most commonly used specifications for general construction purposes. Lower grades can be used, but their appearance to many people is less than desirable. Higher grades command a premium price and are usually used where the higher strength design values can be taken advantage of.

Each of the grades given above has a set of "allowable design stress" values associated with them. These design stress values cover the properties of bending, tension parallel-to-the-grain, compression parallel-to-the-grain, compression perpendicular-to-the-grain, shear parallel-to-the-grain, and modulus of elasticity. These design stresses allow the designer or engineer to accurately and safely select the proper grade and size of member for a specific load situation.

Rather than designing a structure from the basic design values, builders and others often use span tables. The tables provide a means to determine what species and size and grade of lumber should be used to carry a particular load given the span and member spacing. Lumber trade associations often have copies of span tables available on their Web sites or for a nominal fee.

In addition to dimension lumber and timbers, there are numerous softwood products, such as heavy decking, factory lumber, lumber intended to be cut up in a remanufacturing process, and items intended for specialty applications, such as cross arms, machine stress rated lumber, scaffold plank, stadium grade, drop siding, bevel siding, and moldings. There are often separate grade rules that specify product sizes and profiles for each of these products.

Species or Species Group Identification

In the softwood grades, some species may be specifically identified on the stamp. Examples include ponderosa pine and redwood. More likely, the stamp would indicate that two or more species may be present in the shipment, for example, southern yellow pine could include loblolly, longleaf, shortleaf, and slash pine. The species designation spruce-pine-fir could include any of two different species of true firs, five different species of spruce, and three different species of pine. The mechanical properties of all these species covered by one grade stamp are so similar that, for practical purposes, they are lumped into one group.

Moisture Content or Seasoning

The moisture content of lumber is important when it comes to proper utilization. Some species of wood, when first cut from the log, may contain as much as one-half of their weight as water. Lumber is normally dried to a specified moisture content for several reasons. First, the removal of water greatly reduces the weight of the lumber, thus making it easier and less expensive to handle and ship. As lumber is dried and maintained below a certain moisture content, it becomes stronger and more resistant to stain and decay. More importantly, lumber is dried to a moisture content consistent with the environment in which it will be used. Table 5-1 shows the recommended moisture content values for various wood items at the time of installation. Lumber dried to a moisture content that is equivalent to the location of its use will not shrink and swell appreciably.

Table 5-1. Recommended moisture content in percent for various wood items at time of installation (U.S. Department of Agriculture, Forest Service, 2010)

Use of wood	Moisture content in percent, by region					
	Most areas of United States		Dry southwestern areas		Damp, warm coastal areas	
	Average[1]	Individual pieces	Average[1]	Individual pieces	Average[1]	Individual pieces
Interior: Woodwork, flooring, furniture, wood trim, laminated timbers, cold-press plywood	8	6-10	6	4-9	11	8-13
Exterior: Siding, wood trim, framing, sheathing, laminated timbers	12	9-14	9	7-12	12	9-14

[1] To obtain a realistic average, test at least 10 percent of each item. If the amount of a given item is small, several tests should be made. For example, in an ordinary dwelling having about 60 floor joists, at least 10 tests should be made on joists selected at random.

Softwood lumber is available at three different moisture content or seasoning levels: S-GRN, S-DRY or KD 19, and MC 15 or KD 15.

S-GRN indicates that the moisture content of the lumber was 19 percent, or more, at the time of surfacing. The lumber is considered green or unseasoned.

S-DRY or KD 19 indicates that the maximum moisture content in the lumber is 19 percent.

MC 15 or KD 15 indicates that the maximum moisture content is 15 percent. If only KD appears, it indicates that the lumber was kiln dried to a moisture content indicated in the grading rules.

Drying lumber is expensive; and in the drying process, more defects develop. This system of indicating how dry the wood is, allows the purchaser to specify a range of moisture content levels. Lumber dried below 15 percent and stored in open sheds will simply regain moisture in most areas of the United States except the arid southwest.

HT refers to heat treatment of wood to comply with requirements for its use as a global packaging or shipping material. The green wood is heated until the minimum core temperature is 56 °C (about 133 °F) and held at that temperature for at least 30 minutes.

Lumber Inspection Procedures

Grading Agencies

Large stationary softwood mills usually purchase the services of one of the grading agencies approved by the American Lumber Standard Committee. The mill has its own graders, who are issued a grade stamp to use. The grading agency supervises the grading process at the mill, and the mill must pay a fee for the service provided. If the mill fails to conform to established practices, the grading agency reclaims its stamp.

Owners or producers of small quantities of softwood or hardwood lumber to be used in construction can call for a "certificate inspection." The lumber is grade-stamped, and a certificate is issued in regards to the inspection. The lumber is now eligible to be used in building construction. When a certificate inspection is requested, the grading agency will arrange for their first available or closest inspector to travel to the location of the lumber. A week to 10 days advance notice is preferred. If the location is close to a major softwood lumber producer, it may be beneficial to determine which grading agency the producer is using. By using the same grading agency, travel costs and time might be reduced.

The owner of the lumber should be prepared to turn and move the boards for the inspector. Also, presorting the lumber by widths and lengths is important. Additional sorting by estimated grade will further speed up the process. For small quantities it may be easier to use a combined grade, such as No. 2 and better. The lumber may be rough or surfaced. Lumber having a moisture content in excess of 19 percent will be marked "S-GRN." Air-dried lumber or that with a moisture content of less than 19 percent will be stamped "S-DRY."

Grading Rules

Sawyers should be certain that they follow the size requirements set forth by the rule writing agencies for different species. In order to finish to the sizes required, lumber must be cut oversized to allow for shrinkage during drying, planing, and sawing variation. The Standard Grading Rules for Northeastern Lumber (NELMA 2006) and the Western Lumber Grading Rules (WWPA 2005) specify that, for dry or green lumber, 80 percent of the footage be at least ⅛ inch thicker than the standard surfaced size with the remainder at least 3/32 inch thicker. Width shall be at least ⅛ inch wider than the standard surfaced widths. The rules for southern pine measuring 1¼ inches to 4½ inches thick are the same, except the lumber must be dry. Minimum rough widths (dry) of southern pine lumber of nominal thickness of 4½ inches and less are ⅜ inch less than nominal for widths of 2 through 7 inches, and ⅝ inch less for widths 8 inches and wider.

Anyone contemplating producing lumber that will be graded and stamped by a softwood agency should be careful to fully research all of the details before sawing. First, purchase the softwood grading rules book, which applies to the species or species group of interest. Thoroughly review the pertinent parts of the book. Second, once you have a written plan on how to proceed, contact the appropriate softwood lumber grading agency to discuss the plan with them and to make certain that your lumber will meet all of the requirements, such as thickness, widths, and lengths, moisture content, and possible other items. Checking out all of the details before sawing can avoid great aggravation and possible waste of material.

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Chapter 6.

Log and Tree Scaling Techniques

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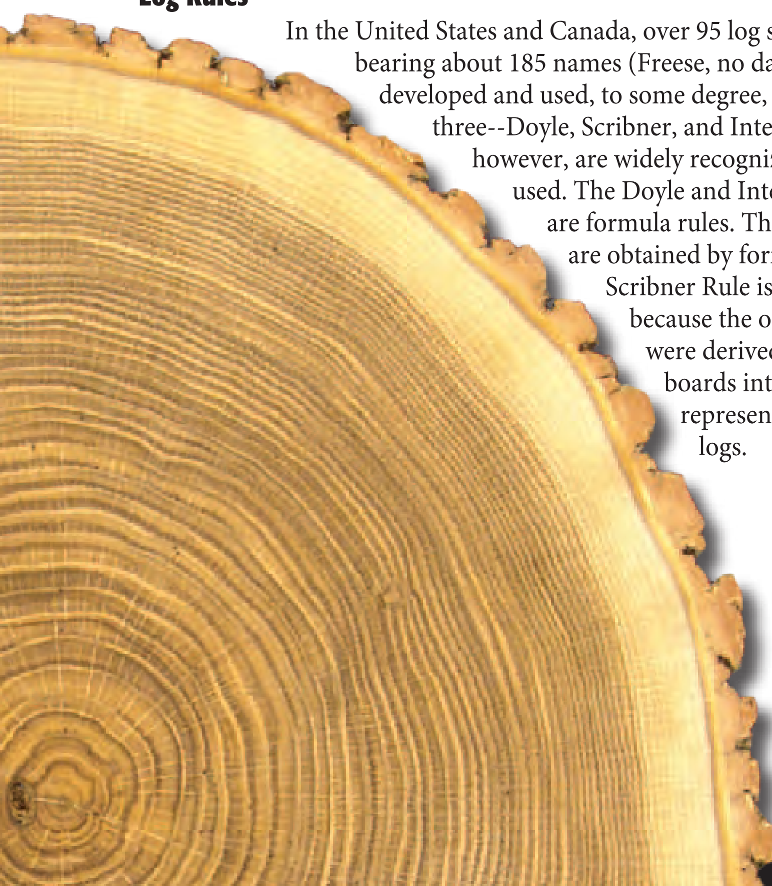
Chapter 6.
Log and Tree Scaling Techniques

Buying and selling logs and standing trees based on an estimate of the number of board feet they contain is an everyday practice in the lumber industry; however, it can be a confusing practice. Log and tree scaling essentially are estimating the final board footage expected. Different individuals will likely obtain somewhat different estimates. The final volume of lumber produced also depends on the sawing process and the equipment used, and will vary substantially depending on many factors.

This chapter should help the reader better understand log and tree scaling. Tables and formulas used to estimate the board-foot volume of **logs** and **trees** by three of the most commonly used log rules are provided. Background information concerning the various rules and scaling techniques is also provided.

Log Rules

In the United States and Canada, over 95 log scaling rules bearing about 185 names (Freese, no date) have been developed and used, to some degree, over time. Only three--Doyle, Scribner, and International--however, are widely recognized and currently used. The Doyle and International Rules are formula rules. That is, the values are obtained by formula. The Scribner Rule is a diagram rule because the original numbers were derived by fitting boards into perfect circles representing the ends of logs.



Doyle Rule

The Doyle Rule (Table 6-1) is the most widely used, especially on private timber in the East and South. The formula is simple and easy to remember:

Board feet Doyle = $(D - 4)^2 \times (L/16)$

D = Diameter inside bark at the small end in inches

L = Log length in feet

This formula says to subtract 4 inches from the diameter for slabs and edgings, square the result, and adjust for log length. Log taper is ignored. The edgings and slab allowance are too large for small logs and too small for large logs. As a result, the rule seriously under-scales small logs and over-scales large logs.

The earliest known version of this rule still in existence is a second edition (Doyle 1837). No copy of the first edition published in 1825 is known; however, it is likely that the rule dates to 1825.

Scribner Rule

The Scribner Rule (Table 6-2) was first published in 1846 by J. M. Scribner. This diagram rule is for 1-inch lumber in widths of 4, 6, and 8 inches, with ¼-inch kerf allowance. Log taper is again ignored. Volumes increase only when log diameter increases in such a way that board width increases or additional boards can be added (Freese, no date). This version of the rule is not commonly found or used, but a portion is reproduced in Table 6-2A for the reader's information and convenience.

Because of the diagramming process for the Scribner Rule (Table 6-2B), irregular increases in board foot values result from one diameter class to the next. Furthermore, Scribner Decimal C (Table 6-2B), the most prevalent form of the rule, rounds the predicted volume to the nearest 10 board feet (Anonymous 1980). Because of these factors, Scribner volumes change erratically as a step function, with log diameter and length. For example, a 10-inch diameter log, for all lengths from 8 feet through 12 feet, contains 30 board feet. Several variations of the rule have been published by Bruce and Schumacher (1950).

Because of the irregularities of the rule, the following formula to correct the deficiencies was proposed (Bruce and Schumacher 1950):

Board feet Scribner = $(0.79D^2 - 2D - 4)L/16$

D = Diameter inside bark small end in inches

L = Log length in feet

Table 6-1. Doyle log rule, board feet (Wenger 1984)

Diameter of log, small end, inside bark (inches)	Length of log in feet												
	6	7	8	9	10	11	12	13	14	15	16	17	18
	Contents of log in board feet												
6	1	2	2	2	2	3	3	3	4	4	4	4	4
7	3	4	4	5	5	6	7	7	8	8	9	10	10
8	6	7	8	9	10	11	12	13	14	15	16	17	18
9	9	11	12	14	16	17	19	20	22	23	25	27	28
10	13	16	18	20	22	25	27	29	31	34	36	38	40
11	18	21	24	28	31	34	37	40	43	46	49	52	55
12	24	28	32	36	40	44	48	52	56	60	64	68	72
13	30	35	40	46	51	56	61	66	71	76	81	86	91
14	37	44	50	56	62	69	75	81	87	94	100	106	112
15	45	53	60	68	76	83	91	98	106	113	121	129	136
16	54	63	72	81	90	99	108	117	126	135	144	153	162
17	63	74	84	95	106	116	127	137	148	158	169	180	190
18	73	86	98	110	122	135	147	159	171	184	196	208	220
19	84	98	112	127	141	155	169	183	197	211	225	239	253
20	96	112	128	144	160	176	192	208	224	240	256	272	288
21	108	126	144	163	181	199	217	235	253	217	289	307	325
22	121	142	162	182	202	223	243	263	283	304	324	344	364
23	135	158	180	203	226	248	271	293	316	338	361	384	406
24	150	175	200	225	250	275	300	325	350	375	400	425	450
25	165	193	220	248	276	303	331	358	386	413	441	469	496
26	181	212	242	272	302	333	363	393	423	454	484	514	544
27	198	231	264	298	331	364	397	430	463	496	529	562	595
28	216	252	288	324	360	396	432	468	504	540	576	612	648
29	234	273	312	352	391	430	469	508	547	586	625	664	702
30	253	296	338	380	422	465	507	549	591	634	676	718	760
31	273	319	364	410	456	501	547	592	638	683	729	775	820
32	294	343	392	441	490	539	588	637	686	735	784	833	882
33	315	368	420	473	526	578	631	683	736	788	841	894	946
34	337	394	450	506	562	619	675	731	787	844	900	956	1,012
35	360	420	480	541	601	661	721	781	841	901	961	1,021	1,081
36	384	448	512	576	640	704	768	832	896	960	1,024	1,088	1,552
37	408	476	544	613	681	749	817	885	953	1,021	1,089	1,157	1,225
38	433	506	578	650	722	795	867	939	1,011	1,084	1,156	1,228	1,300
39	459	536	612	689	766	842	919	995	1,072	1,148	1,225	1,302	1,378
40	486	567	648	729	810	891	972	1,053	1,134	1,215	1,296	1,377	1,458

Formula: $(D-4)^2 \frac{L}{16}$

Table 6-2. Scribner log rule

A. Scribner log rule, board feet (Anonymous 1980)

Diameter of log, small end, inside bark (inches)	Length of log in feet				
	12	14	16	18	20
	Contents of log in board feet				
6	12	14	18	22	24
7	18	24	28	32	34
8	24	28	32	40	44
9	30	35	40	45	50
10	40	45	50	55	65
11	50	55	65	70	80
12	59	69	79	88	98
13	73	85	97	109	122
14	86	100	114	129	143
15	107	125	142	160	178
16	119	139	159	178	198
17	139	162	185	208	232
18	160	187	213	240	267
19	180	210	240	270	300
20	210	245	280	315	350
21	228	266	304	342	380
22	251	292	334	376	418
23	283	330	377	424	470
24	303	353	404	454	505
25	344	401	459	516	573
26	375	439	500	562	625
27	411	479	548	616	684
28	436	509	582	654	728
29	457	539	609	685	761
30	493	575	657	739	821
31	532	622	710	799	888
32	552	644	736	828	920
33	588	686	784	882	980
34	600	700	800	900	1,000
35	657	766	876	985	1,095
36	692	807	923	1,038	1,152
37	772	901	1,029	1,158	1,287
38	801	934	1,068	1,201	1,335
39	840	980	1,120	1,260	1,400
40	903	1,053	1,204	1,354	1,505

Table 6-2.

B. Scribner decimal C log rule, board feet (Anonymous 1980)

(Board foot volumes in tens with zeroes omitted, no taper considered)

Diameter of log, small end, inside bark (inches)	Length of log in feet													
	6	7	8	9	10	11	12	13	14	15	16	17	18	20
	Contents of log in board feet													
6	0.5	0.5	0.5	0.5	1	1	1	1	1	1	2	2	2	2
7	0.5	1	1	1	1	2	2	2	2	2	3	3	3	3
8	1	1	1	1	2	2	2	2	2	2	3	3	3	3
9	1	2	2	2	3	3	3	3	3	3	4	4	4	4
10	2	2	3	3	3	3	3	4	4	5	6	6	6	7
11	2	2	3	3	4	4	4	5	5	6	7	7	8	8
12	3	3	4	4	5	5	6	6	7	7	8	8	9	10
13	4	4	5	5	6	7	7	8	8	9	10	10	11	12
14	4	5	6	6	7	8	9	9	10	11	11	12	13	14
15	5	6	7	8	9	10	11	12	12	13	14	15	16	18
16	6	7	8	9	10	11	12	13	14	15	16	17	18	20
17	7	8	9	10	12	13	14	15	16	17	18	20	21	23
18	8	9	11	12	13	15	16	17	19	20	21	23	24	27
19	9	10	12	13	15	16	18	19	21	22	24	25	27	30
20	11	12	14	16	17	19	21	23	24	26	28	30	31	35
21	12	13	15	17	19	21	23	25	27	28	30	32	34	38
22	13	15	17	19	21	23	25	27	29	31	33	35	38	42
23	14	16	19	21	23	26	28	31	33	35	38	40	42	47
24	15	18	21	23	25	28	30	33	35	38	40	43	45	50
25	17	20	23	26	29	31	34	37	40	43	46	49	52	57
26	19	22	25	28	31	34	37	41	44	47	50	53	56	62
27	21	24	27	31	34	38	41	44	48	51	55	58	62	68
28	22	25	29	33	36	40	44	47	51	54	58	62	65	73
29	23	27	31	35	38	42	46	49	53	57	61	65	68	76
30	25	29	33	37	41	45	49	53	57	62	66	70	74	82
31	27	31	36	40	44	49	53	58	62	67	71	75	80	89
32	28	32	37	41	46	51	55	60	64	69	74	78	83	92
33	29	34	39	44	49	54	59	64	69	73	78	83	88	98
34	30	35	40	45	50	55	60	65	70	75	80	85	90	100
35	33	38	44	49	55	60	66	71	77	82	88	93	98	109
36	35	40	46	52	58	63	69	75	81	86	92	98	104	115
37	39	45	51	58	64	71	77	84	90	96	103	109	116	129
38	40	47	54	60	67	73	80	87	93	100	107	113	120	133
39	42	49	56	63	70	77	84	91	98	105	112	119	126	140
40	45	53	60	68	75	83	90	98	105	113	120	128	135	150

The rule is fairly consistent on 16-foot or shorter logs under 28 inches in diameter.

The Scribner Rule was widely used, especially by the Forest Service, in the Lake States and the western United States. Recently, it has been replaced by a cubic volume measurement system. The Spauling or Columbia Pine Log Rule closely approximates the values given for the Scribner Rule. In the West, east-side and west-side (Cascades), the Scribner Rule is also in use.

International Rule

The International Rule (Table 6-3) was developed by Judson F. Clark in 1900 while working for the Province of Ontario (Anonymous 1906). It is probably the most accurate of the current rules but is not widely accepted. It is based on a carefully researched analysis of the losses occurring during the conversion of sawlogs to lumber and is one of the few rules incorporating a basis for dealing with log taper. Based on studies of northeastern tree species, Clark made a conservative taper assumption of ½-inch change in diameter for every 4 feet of log length. The initial rule was based on a kerf of ⅛ inch and is called the International ⅛-inch Kerf Rule. The basic formula for a 4-foot log is as follows:

Board feet International (4-foot log) = $(0.22D^2 - 0.71D)$

D = Diameter inside bark small end in inches

The formula is expanded for longer lengths up to 20 feet by adding ½ inch in diameter for every 4-foot section and applying the basic formula.

Since many mills could not recover the volumes estimated by the International ⅛-inch Kerf Rule, in 1917, Clark modified the rule to allow for a ¼-inch kerf. The resulting rules are as follows for log lengths of 4 to 20 feet:

Board feet (for 4-foot lengths) = $0.199D^2 - 0.642D$

Board feet (for 8-foot lengths) = $0.398D^2 - 1.086D - 0.271$

Board feet (for 12-foot lengths) = $0.597D^2 - 1.330D - 0.715$

Board feet (for 16-foot lengths) = $0.796D^2 - 1.375D - 1.230$

Board feet (for 20-foot lengths) = $0.995D^2 - 1.221D - 1.719$

Table 6-3. International ¼-inch log rule, board feet (Anonymous 1980)

Diameter of log, small end, inside bark (inches)	Length of log in feet						
	8	10	12	14	16	18	20
	Contents of log in board feet						
6	10	10	15	15	20	25	25
7	10	15	20	25	30	35	40
8	15	20	25	35	40	45	50
9	20	30	35	45	50	60	70
10	30	35	45	55	65	75	85
11	35	45	55	70	80	95	105
12	45	55	70	85	95	110	125
13	55	70	85	100	115	135	150
14	65	80	100	115	135	155	175
15	75	95	115	135	160	180	205
16	85	110	130	155	180	205	235
17	95	125	150	180	205	235	265
18	110	140	170	200	230	265	300
19	125	155	190	225	260	300	335
20	135	175	210	250	290	330	370
21	155	195	235	280	320	365	410
22	170	215	260	305	355	405	455
23	185	235	285	335	390	445	495
24	205	255	310	370	425	485	545
25	220	280	340	400	460	525	590
26	240	305	370	435	500	570	640
27	260	330	400	470	540	615	690
28	280	355	430	510	585	665	745
29	305	385	465	545	630	715	800
30	325	410	495	585	675	765	860
31	350	440	530	625	720	820	915
32	375	470	570	670	770	875	980
33	400	500	605	715	820	930	1,045
34	425	535	645	760	875	990	1,110
35	450	565	685	805	925	1,050	1,175
36	475	600	725	855	980	1,115	1,245
37	505	635	770	905	1,040	1,175	1,315
38	535	670	810	955	1,095	1,245	1,390
39	565	710	855	1,100	1,155	1,310	1,465
40	595	750	900	1,060	1,220	1,380	1,540

All values are rounded to the nearest multiple of 5 board feet, and lengths over 20 feet are to be scaled as two or more logs.

Finally, Grosenbaugh (1952, p. 11) published an integrated formula for the International Rule:

$$\text{Board feet International} = 0.049\,761\,91\,LD^2 + 0.006\,220\,239\,L^2D - 0.185\,476\,2\,LD + 0.000\,259\,176\,7L^3 - 0.011\,592\,26L^2 + 0.042\,222\,22L$$

D = Diameter inside bark small end in inches

L = Log length in feet

Using the Log Rules

There is no simple answer as to the best log rule to use. Local tradition will most likely predict which rule will be used in buying and selling cut logs. The rules are fair as long as everyone uses the same rule. Most experienced operators know how much overrun to expect for a particular set of logs and mill conditions. Overrun, a common term in the sawmill industry, refers to the number of board feet produced by the mill beyond what the log scale indicated.

$$\text{Overrun in percent} = \left[\frac{\text{Lumber Tally}}{\text{Log Scale}} - 1\right]100$$

Underruns can also occur.

A large number of factors can affect overrun or underrun. Some of these include the log rule used, scaling practices, overall roughness of the logs, log taper, log diameter and length, species, slab thickness and edging practices, board thickness, random width lumber versus specified widths, length of shortest piece saved, sawing variation, kerf thickness, oversizing, sawyer experience, grade sawing versus volume sawing, and—finally—the presence of various devices that assist the sawyer, such as laser lights, computer controls, and scanning equipment. Obviously, these conditions vary with available timber, from one mill to the next, and even in the same mill, depending on the day. Nevertheless, most experienced mills have good data on the amount of overrun they can expect. This information is factored into the price that can be paid for logs.

If the objective of scaling is to estimate as closely as possible the volume of lumber to be produced from a given set of logs, the International rule would be preferred—along with some adjustment for overrun or underrun.

Comparing the Log Rules

Figure 6-1 shows the three rules, assuming that the International rule provides a correct estimate of the content of a 16-foot log by diameter. On small logs, the Doyle rule estimates only a fraction of the board foot content. The accuracy of the rule increases as log diameter increases. The Scribner Decimal C Rule provides a closer estimate and, like the Doyle Rule, generally improves in accuracy as log diameter increases; however, the results are erratic.

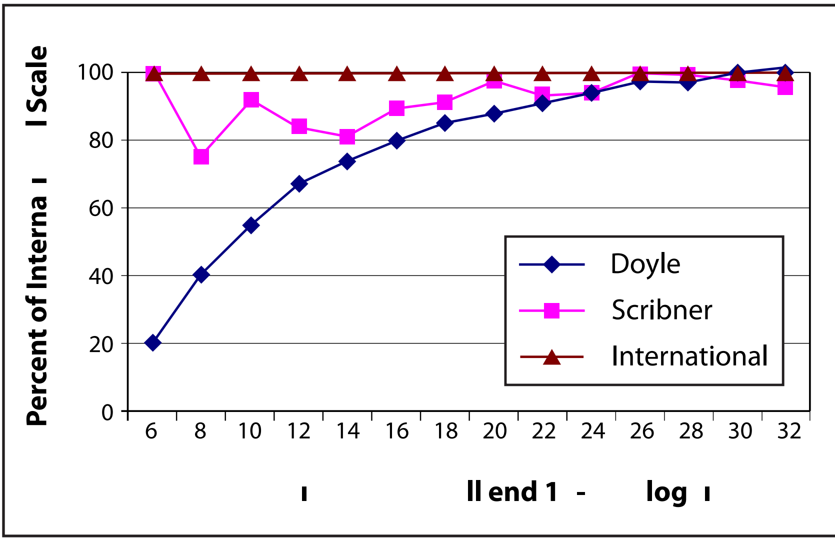


Figure 6-1. Comparison of log volumes using the Doyle and Scribner log rules, and assuming that the International ¼-inch log rule provides a 100 percent estimate of the correct volume

Log Scaling Techniques

Stick Scaling

The actual scaling or measuring of logs and the recording of the data should be done as carefully as possible. The author has seen a group of 14 knowledgeable log buyers scale 11 logs and come up with 14 different answers. The average scale was 1,544 board feet Doyle with a range from 1,434 to 1,795 board feet, or a spread of 361 board feet. After the contest, when each log was carefully examined, the agreed-upon volume was 1,589 board feet.

Besides just plain carelessness, several other factors can affect the results of log scaling. For the best results, follow this advice:

- First, determine log lengths with a tape measure. Some logs may have several inches of trim allowance. Others may be just short of a full foot measure. Being just short of a full foot measure will result in the lumber being tallied at the next lower foot length in hardwoods and the next even foot length in softwoods. Thus, correct length cannot be eyeballed consistently.

- Next, measure the diameter of the log on the small end in two directions at 90° angles to each other inside the bark. Logs are seldom perfectly round. Thus, the small and large diameters need to be averaged.
- Decide how to round fractions of an inch. Consistently rounding down results in less log scale, and could also result in the next batch of logs going to a competitor.

Does the scaling diameter truly represent the milling diameter of the log? Some logs are purposely bucked, or cut to length, close to or through branch stubs or other swollen areas likely to contain defects. The result is a "necking down" or "narrowing effect" of the log diameter. The purpose of bucking through major defects is to increase the grade yield of the log, but it is also easy to increase the scaling diameter by an inch or more.

There are also rules for scaling out defective areas such as rot, splits, and sweep. These rules are based on general geometry and are somewhat time consuming to apply. As a result, mills usually do not accept defective or crooked logs. When they do accept them, they usually scale them back by reducing the length.

Weight Scaling

In some sections of the country and particularly on small diameter low-valued logs, weight is used as a measurement system. Unlike traditional log scaling, discussed above, weight scaling is quick and easy. Each mill usually develops its own set of tables for its own specific conditions.

Determining Volume of Standing Trees

When purchasing stumpage (standing trees), the buyer must estimate the value of the usable product being offered. In high-valued hardwoods, or where a limited number of trees are involved, buyers often measure the diameter at breast height (d.b.h.), which is the diameter at 4½ feet above the ground, and deduct a certain amount for taper and bark thickness to estimate the scaling diameter at the top of the first log. The volume is then determined from a log-scale table (a Log Rule). Ocular estimates combined with local experience on taper and bark thickness are then used to determine the diameter and length of each additional log and hence the volume in the tree.

A second method for estimating stumpage that is commonly used by trained foresters requires the use of volume tables. These tables predict the gross volume of the tree, using any one of the three common log rules, based on the d.b.h., "merchantable height" in 16-foot logs, and sometimes—for added refinement—a form factor. One commonly used form factor is the Girard form class, defined as the percentage ratio between the diameter inside bark at the top of the first 16-foot log and the d.b.h. For example, a tree with a first-log scaling diameter of 16.0 inches and a d.b.h. of 20.0 inches has a form class of (16 ÷ 20 × 100) or 80 percent. Form class can vary for a given species, age, diameter, and height. For the most accurate estimates, a separate form class should be determined for each diameter class and species tallied.

Merchantable height includes that portion of a tree from stump height to a point on the stem at which merchantability for saw timber is limited by branches, deformity, or minimum diameter. For smooth stems, this minimum diameter is usually not less than 60 percent of the tree d.b.h. This is the case for the smallest sawlog trees, which are usually 10 inches in diameter. The minimum diameter for merchantable heights decreases to 40 percent for large trees that are 30 to 40 inches in diameter. This definition of merchantability or usable log length must be carefully followed.

A complete set of volume tables for the Doyle, International, and Scribner Rules based on different form classes is given by Mesavage and Girard (1956). Tables 6-4, 6-5, and 6-6 report values for form class 78, or the most commonly used class. A rule of thumb calls for a 3 percent change in volume for each unit increase or decrease in form class. That is, a form class of 79 will have approximately 3 percent more volume than that of a form class 78. If the tables given here for form class 78 do not provide good estimates for timber in your area, a higher or lower form class table should be used.

Wiant (1986) has formulated the Mesavage and Girard Form Class 78 table for each of the three log rules discussed here. Formulas for the Doyle log rules, Scribner, and International ¼ inch predicted 90 to 98 percent of table values within 2 percent. The equations for trees are presented below.

$$\text{Doyle volume} = (0.55743L^2 + 41.51275L - 29.37337) + (2.78043 - 0.04516L^2 - 8.77272L)D + (0.04177 - 0.01578L^2 + 0.59042L)D^2$$

$$\text{Scribner volume} = (17.53508L - 0.59242L^2 - 22.50365) + (3.02988 - 0.02302L^2 - 4.34381L)D + (0.51593L - 0.02035L^2 - 0.01969)D^2$$

$$\text{International ¼-inch volume} = (1.52968L^2 + 9.58615L - 13.35212) + (1.79620 - 0.27465L^2 - 2.59995L)D + (0.04482 - 0.00961L^2 + 0.45997L)D^2$$

L = Number of 16 foot logs
D = d.b.h.

Table 6-4. Gross volume of trees, Doyle log rule, form class 78 (Mesavage and Girard 1956)

D.b.h. (inches)	Merchantable height in number of 16-foot logs										
	1	1½	2	2½	3	3½	4	4½	5	5½	6
	Volume in board feet										
10	14	17	20	21	22	—	—	—	—	—	—
11	22	27	32	35	38	—	—	—	—	—	—
12	29	36	43	48	53	54	56	—	—	—	—
13	38	48	59	66	73	76	80	—	—	—	—
14	48	62	75	84	93	98	103	—	—	—	—
15	60	78	96	108	121	128	136	—	—	—	—
16	72	94	116	132	149	160	170	—	—	—	—
17	86	113	140	161	182	196	209	—	—	—	—
18	100	132	164	190	215	232	248	—	—	—	—
19	118	156	194	225	256	276	297	—	—	—	—
20	135	180	225	261	297	322	346	364	383	—	—
21	154	207	260	302	344	374	404	428	452	—	—
22	174	234	295	344	392	427	462	492	521	—	—
23	195	264	332	388	444	483	522	558	594	—	—
24	216	293	370	433	496	539	582	625	668	—	—
25	241	328	414	486	558	609	660	709	758	—	—
26	266	362	459	539	619	678	737	793	849	—	—
27	292	398	505	594	684	749	814	877	940	—	—
28	317	434	551	650	750	820	890	961	1,032	1,096	1,161
29	346	475	604	714	824	902	980	1,061	1,142	1,218	1,294
30	376	517	658	778	898	984	1,069	1,160	1,251	1,339	1,427
31	408	562	717	850	983	1,080	1,176	1,273	1,370	1,470	1,570
32	441	608	776	922	1068	1,176	1,283	1,386	1,488	1,600	1,712
33	474	654	835	994	1,152	1,268	1,385	1,497	1,609	1,734	1,858
34	506	700	894	1,064	1,235	1,361	1,487	1,608	1,730	1,866	2,003
35	544	754	964	1,149	1,334	1,472	1,610	1,743	1,876	2,020	2,163
36	581	308	1,035	1,234	1,434	1,583	1,732	1,878	2,023	2,173	2,323
37	618	860	1,102	1,318	1,534	1,694	1,854	2,013	2,172	2,332	2,492
38	655	912	1,170	1,402	1,635	1,805	1,975	2,148	2,322	2,491	2,660
39	698	974	1,250	1,498	1,746	1,932	2,118	2,298	2,479	2,662	2,844
40	740	1,035	1,330	1,594	1,858	2,059	2,260	2,448	2,636	2,832	3,027

Table 6-5. Gross volume of trees, Scribner log rule, form class 78 (Mesavage and Girard 1956)

D.b.h. (inches)	Merchantable height in number of 16-foot logs										
	1	1½	2	2½	3	3½	4	4½	5	5½	6
	Volume in board feet										
10	28	36	44	48	52	—	—	—	—	—	—
11	38	49	60	67	74	—	—	—	—	—	—
12	47	61	75	85	95	100	106	—	—	—	—
13	58	76	94	107	120	128	136	—	—	—	—
14	69	92	114	130	146	156	166	—	—	—	—
15	82	109	136	157	178	192	206	—	—	—	—
16	95	127	159	185	211	229	247	—	—	—	—
17	109	146	184	215	246	268	289	—	—	—	—
18	123	166	209	244	280	306	331	—	—	—	—
19	140	190	240	281	322	352	382	—	—	—	—
20	157	214	270	317	364	398	432	459	486	—	—
21	176	240	304	358	411	450	490	523	556	—	—
22	194	266	338	398	458	504	549	588	626	—	—
23	214	294	374	441	508	558	607	652	698	—	—
24	234	322	409	484	558	611	665	718	770	—	—
25	258	355	452	534	617	678	740	799	858	—	—
26	281	388	494	585	676	745	814	880	945	—	—
27	304	420	536	636	736	811	886	959	1,032	—	—
28	327	452	578	686	795	877	959	1,040	1,120	1,190	1,261
29	354	491	628	746	864	953	1,042	1,132	1,222	1,306	1,389
30	382	530	678	806	933	1,028	1,124	1,224	1,325	1,421	1,517
31	411	571	731	871	1,011	1,117	1,223	1,328	1,434	1,541	1,648
32	440	612	784	936	1,089	1,206	1,322	1,432	1,543	1,661	1,779
33	469	654	838	1001	1,164	1,280	1,414	1,534	1,654	1,783	1,912
34	498	695	892	1,066	1,239	1,373	1,507	1,636	1,766	1,906	2,046
35	530	742	954	1,141	1,328	1,473	1,618	1,757	1,896	2,044	2,192
36	563	789	1,015	1,216	1,416	1,572	1,728	1,877	2,026	2,182	2,338
37	596	836	1,075	1,290	1,506	1,670	1,835	1,998	2,160	2,324	2,488
38	629	882	1,135	1,366	1,596	1,769	1,942	2,118	2,295	2,466	2,637
39	666	935	1,204	1,449	1,694	1,881	2,068	2,251	2,434	2,616	2,799
40	703	988	1,274	1,532	1,791	1,993	2,195	2,384	2,574	2,768	2,961

Table 6-6. Gross volume of trees, International ¼-inch log rule, form class 78 (Mesavage and Girard 1956)

D.b.h. (inches)	Merchantable height in number of 16-foot logs										
	1	1½	2	2½	3	3½	4	4½	5	5½	6
	Volume in board feet										
10	36	48	59	66	73	—	—	—	—	—	—
11	46	61	76	86	96	—	—	—	—	—	—
12	56	74	92	106	120	128	137	—	—	—	—
13	67	90	112	130	147	158	168	—	—	—	—
14	78	105	132	153	174	187	200	—	—	—	—
15	92	124	156	182	208	225	242	—	—	—	—
16	106	143	180	210	241	263	285	—	—	—	—
17	121	164	206	242	278	304	330	—	—	—	—
18	136	184	233	274	314	344	374	—	—	—	—
19	154	209	264	311	358	392	427	—	—	—	—
20	171	234	296	348	401	440	480	511	542	—	—
21	191	262	332	391	450	496	542	579	616	—	—
22	211	290	357	434	599	552	593	647	691	—	—
23	231	318	494	478	552	608	663	714	766	—	—
24	251	346	441	523	605	664	723	782	840	—	—
25	275	380	484	574	665	732	800	865	930	—	—
26	299	414	528	626	725	801	877	949	1,021	—	—
27	323	448	572	680	788	870	952	1,032	1,111	—	—
28	347	482	616	733	850	938	1,027	1,114	1,201	1,280	1,358
29	375	521	667	794	920	1,016	1,112	1,210	1,308	1,398	1,488
30	403	560	718	854	991	1,094	1,198	1,306	1,415	1517	1,619
31	432	602	772	921	1,070	1,184	1,299	1,412	1,526	1,640	1,754
32	462	644	826	988	1,149	1,274	1,400	1,518	1,637	1,762	1,888
33	492	686	880	1,053	1,226	1,360	1,495	1,622	1,750	1,888	2,026
34	521	728	934	1,119	1,304	1,447	1,590	1,727	1,864	2,014	2,163
35	555	776	998	1,196	1,394	1,548	1,702	1,851	2,000	2,156	2,312
36	589	826	1,063	1,274	1,485	1,650	1,814	1,974	2,135	2,298	2,461
37	622	873	1,124	1,351	1,578	1,752	1,926	2,099	2,272	2,444	2,616
38	656	921	1,186	1,428	1,670	1,854	2,038	2,224	2,410	2,590	2,771
39	694	976	1,258	1,514	1,769	1,968	2,166	2,359	2,552	2,744	2,937
40	731	1,030	1,329	1,598	1,868	2,081	2,294	2,494	2,693	2,898	3,103

Numerous other volume tables have also been developed. These tables are often preferred since they take local timber conditions into account. Tables 6-7, 6-8, and 6-9 are presented as examples for Indiana (Beers 1973). These tables are particularly useful because they are in 12-foot and half-log increments. Twelve-foot lengths are common in Indiana and probably other regions of the central states. Sixteen-foot lengths are common in the South and in the Lake States. Check with a local forester or university to determine if local volume tables are available for your area.

Comparing Tree Scale, Log Scale, and Board Foot Yield from Thin Kerf Sawing

Tree and log yield numbers need to be developed for each operation and location. Board foot yields for thin kerf mills are not published, and it is important that operators develop their own data. As an example, consider the following data for five woods—grown yellow-poplar and three red oak trees. The tree d.b.h. ranged from 18 to 25 inches and averaged 22 inches. The Doyle tree scale using form class 78 was 3,060 board feet, and the Doyle log scale after the trees were harvested was 3,652 board feet or an increase of over 19 percent volume. A higher form class table could have corrected this difference, but Form Class 78 is the one commonly used. The logs from the small group of trees yielded 5,161 board feet or an overrun of 41 percent on the Doyle scale. The smallest log diameter inside bark (d.i.b.) (small end) was 11 inches with an average of 15.8 inches. The overrun is significant and mostly due to the thin kerf (about 87/1,000) used by the processing mill and good straight logs.

The Wood-Mizer research facility using the Doyle Scale reports a 61 percent overrun for an entire year of sawing and 49 percent for a portion of the following year. This facility processes millions of board feet of logs using a 110/1,000-inch kerf.

Table 6-7. Tree volume table for Indiana hardwoods, Doyle log rule, form Class 78, by 12-foot lengths (Beers 1973)

D.b.h. (inches)	Board feet (Doyle) by merchantable height in number of 12-foot logs											
	½	1	1½	2	2½	3	3½	4	4½	5	5½	6
10	3	8	11	14	—	—	—	—	—	—	—	—
11	6	15	21	25	—	—	—	—	—	—	—	—
12	10	23	32	39	45	50	—	—	—	—	—	—
13	14	32	44	55	64	71	—	—	—	—	—	—
14	19	41	57	72	84	94	103	112	—	—	—	—
15	24	51	71	90	105	119	131	143	—	—	—	—
16	30	61	86	110	129	146	161	176	188	206	—	—
17	36	72	103	130	153	175	194	212	229	252	—	—
18	44	84	119	150	180	207	229	251	273	300	—	—
19	52	97	137	174	208	241	267	294	322	351	—	—
20	61	111	156	199	238	277	308	341	373	406	—	—
21	70	129	176	225	270	316	353	393	428	466	—	—
22	81	149	198	255	305	359	401	449	488	530	578	625
23	93	168	228	289	344	405	455	508	552	598	650	701
24	105	190	257	324	386	454	511	570	620	671	728	786
25	118	212	286	360	430	505	569	635	692	747	808	869
26	133	236	318	399	479	558	630	702	765	826	896	968
27	148	261	348	435	527	613	693	771	842	909	986	1,062
28	163	285	382	478	579	670	758	843	922	996	1,084	1,172
29	181	314	418	523	630	729	825	918	1,005	1,087	1,184	1,280
30	200	340	456	571	685	791	895	997	1,092	1182	1,290	1,398
31	220	372	497	622	740	857	968	1,080	1,182	1,281	1,402	1,522
32	243	402	539	676	799	927	1,044	1,167	1,277	1,387	1,518	1,649
33	267	435	584	732	866	1,001	1,126	1,258	1,377	1,496	1,635	1,774
34	295	470	632	793	936	1,078	1,211	1,353	1,481	1,609	1,762	1,914
35	325	507	682	856	1,007	1,158	1,299	1,451	1,588	1,727	1,888	2,050
36	357	547	735	923	1,082	1,240	1,390	1,552	1,700	1,844	2,020	2,196
37	391	590	792	993	1,158	1,324	1,484	1,655	1,813	1,968	2,156	2,345
38	426	635	850	1,065	1,238	1,410	1,581	1,760	1,931	2,095	2,300	2,507
39	465	681	910	1,139	1,318	1,497	1,680	1,868	2,050	2,224	2,437	2,650
40	506	732	974	1,215	1,400	1,585	1,782	1,979	2,171	2,355	2,582	2,808

Table 6-8. Tree volume table for Indiana hardwoods, Scribner log rule, form class 78, by 12-foot lengths (Beers 1973)

D.b.h. (inches)	Board feet (Scribner) by merchantable height in number of 12-foot logs											
	½	1	1½	2	2½	3	3½	4	4½	5	5½	6
10	10	17	23	27	—	—	—	—	—	—	—	—
11	14	25	36	45	—	—	—	—	—	—	—	—
12	19	35	50	64	74	83	—	—	—	—	—	—
13	24	46	64	83	97	111	—	—	—	—	—	—
14	30	57	80	102	122	139	154	164	—	—	—	—
15	35	69	96	123	145	167	188	200	—	—	—	—
16	41	81	113	144	169	198	221	236	261	278	—	—
17	49	93	130	167	197	226	256	275	302	327	—	—
18	55	106	149	190	224	259	291	316	350	375	—	—
19	64	123	170	215	253	293	331	361	399	430	—	—
20	71	138	190	239	285	327	373	410	448	486	—	—
21	80	155	212	267	320	368	417	460	501	546	—	—
22	90	170	235	291	356	408	464	512	560	605	660	711
23	99	190	259	325	395	450	511	566	620	667	725	787
24	109	209	284	355	435	498	562	623	685	734	795	867
25	120	229	312	389	477	547	615	682	752	803	868	951
26	131	250	342	424	520	597	671	745	818	877	949	1,036
27	142	273	371	462	563	647	729	809	887	955	1,033	1,134
28	155	296	403	502	609	698	790	877	958	1,038	1,125	1,220
29	168	321	438	545	658	753	852	942	1,037	1,125	1,211	1,318
30	182	347	474	588	709	808	920	1,014	1,118	1,210	1,300	1,425
31	196	374	511	631	760	870	989	1,093	1,198	1,300	1,398	1,533
32	210	400	550	677	815	930	1,065	1,170	1,286	1,395	1,500	1,655
33	226	428	589	726	874	995	1,140	1,253	1,375	1,495	1,606	1,763
34	243	456	629	776	934	1,063	1,216	1,335	1,465	1,595	1,720	1,890
35	260	484	672	830	995	1,135	1,297	1,418	1,560	1,700	1,830	2,010
36	277	514	715	886	1,059	1,205	1,373	1,510	1,655	1,805	1,946	2,140
37	297	541	757	944	1,125	1,281	1,454	1,605	1,754	1,911	2,060	2,280
38	317	569	802	1,002	1,185	1,360	1,537	1,695	1,858	2,019	2,180	2,425
39	337	598	848	1,062	1,251	1,437	1,625	1,792	1,960	2,130	2,310	2,565
40	358	625	895	1,123	1,315	1,514	1,716	1,885	2,064	2,250	2,428	2,715

Table 6-9. Tree volume table for Indiana hardwoods, International log rule, Form Class 78, by 12-foot lengths (Beers 1973)

D.b.h. (inches)	Board feet (International) by merchantable height in number of 12-foot logs											
	½	1	1½	2	2½	3	3½	4	4½	5	5½	6
10	11	20	26	32	—	—	—	—	—	—	—	—
11	16	30	41	51	—	—	—	—	—	—	—	—
12	21	39	56	70	81	93	—	—	—	—	—	—
13	26	50	73	90	105	122	—	—	—	—	—	—
14	33	62	89	112	132	150	165	180	—	—	—	—
15	38	73	105	132	158	180	200	220	—	—	—	—
16	45	86	123	155	184	212	235	255	279	296	—	—
17	52	98	141	176	211	243	272	296	323	347	—	—
18	60	112	160	202	240	275	311	336	372	396	—	—
19	68	127	180	225	270	312	351	382	423	455	—	—
20	76	142	200	252	302	350	393	428	475	510	—	—
21	85	160	223	280	338	390	440	481	531	571	—	—
22	95	178	247	306	374	431	487	538	588	636	695	744
23	107	196	271	338	414	475	536	592	648	698	764	816
24	117	218	297	368	451	520	590	653	712	768	834	895
25	128	238	324	404	494	568	645	715	778	839	907	978
26	140	260	352	440	538	619	701	778	848	915	990	1,074
27	152	284	381	479	581	670	758	842	917	994	1,074	1,160
28	165	308	412	520	626	723	820	908	993	1,077	1,165	1,268
29	178	331	445	562	675	780	882	977	1,070	1,161	1,259	1,367
30	193	357	477	605	726	833	949	1,050	1,150	1,249	1,355	1,477
31	208	382	509	650	781	900	1,019	1,126	1,234	1,342	1,451	1,590
32	223	408	544	697	837	964	1,094	1,204	1,320	1,435	1,550	1,709
33	238	435	581	745	896	1,032	1,165	1,283	1,412	1,535	1,646	1,825
34	254	465	624	797	958	1,100	1,240	1,365	1,510	1,638	1,752	1,949
35	271	492	666	850	1,024	1,174	1,317	1,450	1,610	1,745	1,862	2,065
36	290	523	715	903	1,089	1,245	1,398	1,542	1,710	1,850	1,977	2,200
37	310	556	766	960	1,155	1,320	1,480	1,640	1,815	1,960	2,100	2,342
38	330	590	830	1,021	1,220	1,392	1,567	1,735	1,916	2,066	2,215	2,480
39	354	626	897	1,080	1,286	1,472	1,657	1,840	2,025	2,179	2,345	2,627
40	376	667	975	1,150	1,355	1,545	1,750	1,936	2,135	2,305	2,472	2,780

Equipment for Measuring Trees and Logs

There is a large variety of equipment for measuring both trees and logs. This equipment can be purchased by mail order from various forestry supply houses. Figure 6-2 shows some of this equipment. For the most accurate tree diameter measurement, use a diameter tape. These tapes are calibrated to give the tree diameter by measuring the circumference of the tree. Tree measuring sticks may also be used to estimate tree d.b.h. and merchantable volume. Log scale sticks or special folding rulers with the scale printed directly on them can be used to measure log diameter and length, and thus provide a volume estimate. Special steel tapes are also available to measure tree log length after felling. When ordering measuring tools, be certain to specify the log rule (Doyle, International, or Scribner) desired. Lumber grading rules look similar to some log scaling sticks but lumber grading rules are used to measure the surface feet in a board. Surface feet are equivalent to board feet on 4/4 lumber.

Figure 6-2. Tools for measuring trees and logs. Scale stick for measuring log volume using the Doyle Rule (top), tree measuring stick for estimating tree d.b.h. and height using the International ¼-inch log rule (second from top), tape for measuring tree d.b.h. (bottom left), folding rule for measuring log volume using Doyle log rule (bottom center), and steel tape for measuring tree and log lengths (bottom right).

Log Weights (Individual)

Like lumber, the few available log weight tables have been calculated from specific gravity, moisture content, and cubic volume of the log. Timson (1972), however, weighed 4,800 sawlogs that were accepted by six mills in Maryland, West Virginia, and Virginia. Most of the logs had a diameter inside bark of 8 to 18 inches and were 8 to 18 feet long. Statistical techniques were used to develop log weight tables by scaling diameter and log length for each of 15 species. Results for just one log length (12 feet) and three scaling diameters (12, 18, and 24 inches) by species are given in Table 6-10. Weights for other log lengths can be found in Timson (1972).

The regression equations used to develop the tables are given in Table 6-11. These equations can be programmed into a calculator or computer for ease of use. Only the species, scaling diameter, and log length are needed.

Table 6-10. Weight in pounds for 12-foot-long logs and three diameter classes, by species (Timson 1972, p. 7-21)

Species	Scaling diameter inside bark (inches), small end		
	12	18	24
Ash, white	576	1,277	2,273
Basswood	572	1,247	2,224
Beech	715	1,483	2,628
Birch	791	1,713	2,988
Blackgum	762	1,542	2,652
Cherry	591	1,363	2,488
Hickory	739	1,595	2,838
Locust, black	618	1,311	2,276
Maple, red	634	1,330	2,377
Maple, sugar	712	1,480	2,587
Oak, chestnut	771	1,651	2,920
Oak, red	762	1,672	2,991
Oak, white	734	1,594	2,859
Yellow-poplar	624	1,324	2,332

Table 6-11. Regression equations to predict log weight in pounds, using diameter and length, by species (Timson 1972, p. 5)[1]

Species	Prediction equations	R^2	Standard error of estimate (lb)
Ash, white	$W = 66.0433 - 6.8790D + 0.3433D^2L$	0.79	9.2
Basswood	$W = 125.6829 - 13.0288D + 0.3488D^2L$	.86	7.2
Beech	$W = 313.2024 - 29.4343D + 0.4372\ D^2L$	.93	7.3
Birch (yellow and black)	$W = 6.9273 + 6.5366D + 0.4086D^2L$	.85	9.8
Black gum	$W = 195.5815 - 7.8292D + 0.3826D^2L$	.82	11.1
Cherry, black	$W = 105.1938 - 18.2341D + 0.4081D^2L$	.92	6.3
Cucumbertree	$W = 38.9477 - 7.7847D + 0.3534D^2L$	.88	6.4
Hickory	$W = 190.1192 - 18.7348D + 0.4482D^2L$	.86	9.2
Locust, black	$W = 48.7871 + 2.1538D + 0.3148D^2L$	.65	9.0
Maple, red	$W = 289.0249 - 29.4911D + 0.4045D^2L$	.86	8.8
Maple, sugar	$W = 191.5229 - 12.9985D + 0.3917D^2L$	.84	11.0
Oak, chestnut	$W = 183.3447 - 15.9959D + 0.4516D^2L$	.85	9.0
Oak, red group	$W = 169.0737 - 18.7765D + 0.4736D^2L$	.89	10.1
Oak, white	$W = 224.7721 - 24.9150D + 0.4677D^2L$	.85	10.4
Yellow-poplar	$W = 144.0939 - 11.1559D + 0.3553D^2L$	.83	8.3

[1]W = log weight in pounds

D = diameter inside bark in inches at small end

L = length in feet

R^2 = This is a statistical term also called coefficient of determination. The higher the R^2 the better the equation fits the available data. For white ash, 79% of the variation is accounted for in the regression equation.

Log Weight by Log Scale

The estimated green log weights by three diameter classes (12, 18, and 24 inches) per 1,000 board feet Doyle log rule are given in Table 6-12. These are probably calculated weights. Conversion factors to Scribner and International (¼ inch) rule are also given. These tables also appear in the Forestry Handbook (Wenger 1984), as well as in the Fundamentals of Logging (Allis-Chalmers 1963).

Table 6-12. Calculated weight in pounds of green logs per 1,000 board feet (Doyle log rule)[1]

Species	Log diameter (inches)		
	12	18	24
Ash, white	11,100	7,700	6,600
Aspen	10,800	7,600	6,400
Basswood	9,500	6,600	5,600
Beech	12,700	8,900	7,500
Birch, yellow	13,200	9,200	7,800
Cherry, black	10,500	7,300	6,200
Cottonwood	10,700	7,500	6,300
Cypress, southern	11,800	8,200	7,000
Elm, white	11,300	7,900	6,700
Elm, red	12,600	8,800	7,400
Gum, black	10,400	7,200	6,100
Hackberry	11,300	7,900	6,700
Hickory	14,700	10,300	8,700
Locust, black	13,400	9,300	7,900
Maple, sugar	12,900	9,000	7,600
Maple, red	11,900	8,300	7,100
Maple, silver	10,500	7,300	6,200
Oak, red	14,800	10,300	8,800
Oak, white	14,400	10,000	8,500
Poplar, yellow (tulip)	8,800	6,100	5,200
Sweetgum	10,600	7,400	6,300
Sycamore	12,000	8,400	7,100
Walnut, black	11,900	8,300	7,100
White pine	9,000	6,300	5,300
Willow	11,800	8,200	7,000

To determine the weight of logs per 1,000 board feet for Scribner and International (¼ inch) log rules, multiply the desired weight from the above table by the appropriate value in the following table:

Log diameter (inches)	Doyle to Scribner	Doyle to International (¼ inch)
12	0.81	0.67
18	0.92	0.85
24	0.99	0.94

[1]Miller, Charles I., unpublished data on file, Purdue University

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Chapter 7.

Forest Service Hardwood Log Grades, Tree Grades, and Yields

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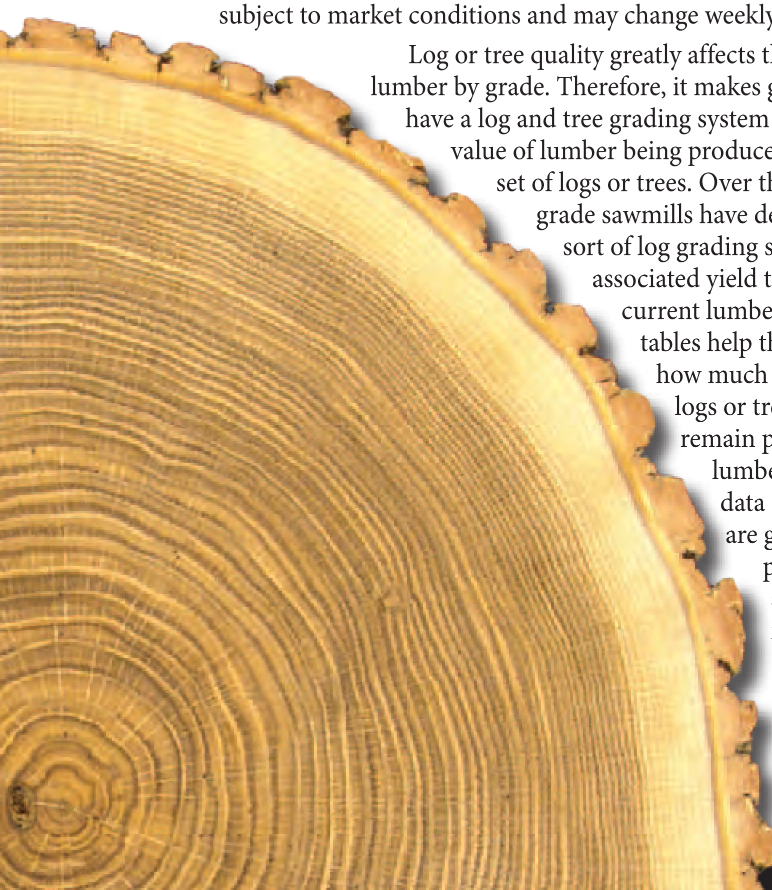
Chapter 7.

Forest Service Hardwood Log Grades, Tree Grades, and Yields

The value of wholesale green hardwood lumber can vary tremendously among species and by grade within a species. For example, the highest grade of cherry lumber could be priced at $2,420 per thousand board feet (MBF), while the highest grade of beech could have a value of $510/MBF, and the highest grade of yellow poplar, a value of $735/MBF. Within a species, the highest grade of lumber is often twice, or more, the value of the lowest grade. For example, the highest grade of walnut could be $2,065 per MBF, while the lowest grade, No. 2 Common, could be $710/MBF. At this price, the lowest grade of walnut would be worth almost as much as the highest grade of yellow-poplar. Thus, species is obviously important, but lumber grade or quality is likewise a very important factor. Wholesale lumber grades and prices are documented and well understood by the industry. As such, they represent a standard for establishing value of cut logs and standing timber. Prices are subject to market conditions and may change weekly.



Log or tree quality greatly affects the yield of lumber by grade. Therefore, it makes good sense to have a log and tree grading system that reflects the value of lumber being produced from any given set of logs or trees. Over the years, most grade sawmills have developed some sort of log grading system and associated yield tables. Based on current lumber values, these tables help the mill determine how much they can pay for logs or trees and still remain profitable. The lumber grade yield data for these systems are generally proprietary and apply only to the mill where they were collected. Volume yield can vary depending on kerf thickness, as well as slabbing, edging, and sawing techniques. These processing techniques can vary with market conditions.

This chapter describes the Forest Service log and tree grading systems and presents selected lumber yield tables by species and grade. With this information, the value of lumber in a given set of logs or trees can be estimated. The yield tables are presented as a starting point. It is important for each operator to determine how well this data represents their operation. Operators of thin kerf mills will need to adjust the numbers to better represent their increased volume. See the chapter entitled "Log and Tree Scaling Techniques," for information on overruns or underruns.

Log Grading Systems

Beginning in the 1940s, Purdue University and the Forest Service, U.S. Department of Agriculture, each developed a log grading system and associated yield data. The Forest Service extended its log grading system to standing trees in the 1970s. The Purdue University system (Herrick 1957) grades around the circumference of the tree (Figure 7-1). The system was adopted by a number of mills and receives some use today. The yield data collected was limited and is no longer available. Without yield data, the system does not fulfill the primary objective of determining potential lumber value by grading logs or trees.

The Forest Service system (Herrick 1957, Rast and others 1973) was developed at about the same time. It divides a saw log into four faces and grades each face as if it were a board (Figure 7-1). As will be seen, there is a close parallel between the hardwood lumber grades and the Forest Service log and tree grades. The system has been criticized for being too complicated because it carefully defines terms and each of the many factors that can affect the grade of a log or tree. For anyone who understands the hardwood lumber grades, however, the Forest Service log and tree grading system is intuitive.

For straight, sound logs or trees, the Forest Service system is actually quite simple. Only when all of the factors involved in log grading are considered initially, does the system become complex. Therefore, the basic system will be presented first. Additional details are provided in Box 7-A1 in Appendix 7-A. Air-dried lumber grade yields are available for eight different species, and green lumber grade yields are available for another six species (Hanks and others 1980).

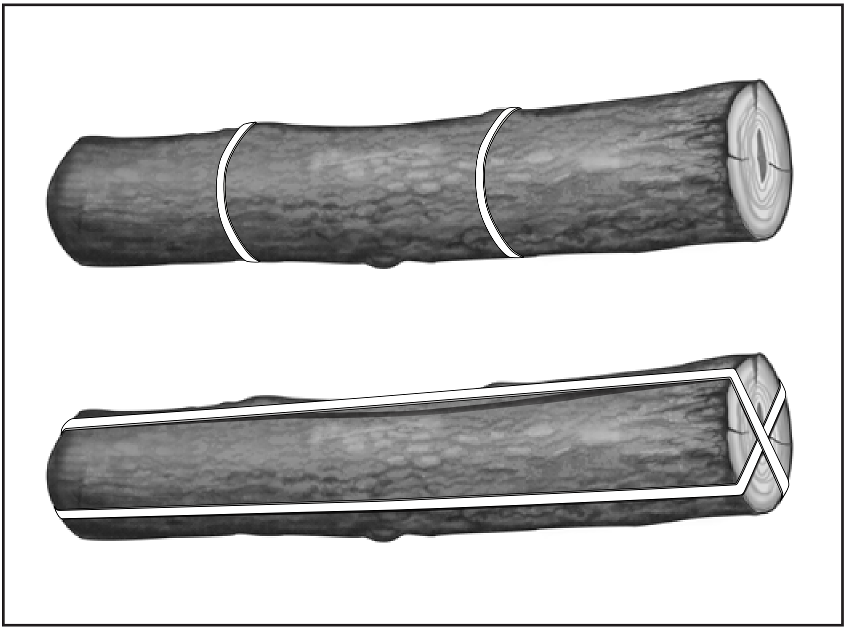


Figure 7-1. The Purdue log grading system (top) grades a log or tree around its circumference, while the Forest Service system (bottom) grades a tree or log along its length or in the direction it will be sawed.

Forest Service Log Grading System

Table 7-1 presents the Forest Service log grading system for hardwood factory lumber logs. In the grades F1, F2, and F3, the “F” stands for factory lumber logs, but it is seldom used today. The grade is based on several factors. The easiest factors to assess are whether the log is a butt or upper log, scaling diameter or diameter inside bark (d.i.b.) at the small end, and log length.

Table 7-1. Forest Service standard specifications for hardwood factory lumber logs (Hanks and others 1980, p. 2)

Grading factor		Log grade							
		F1			F2				F3
Position in tree		**Butts only**	**Butts and uppers**		**Butts and uppers**				**Butts and uppers**
Scaling diameter (inches)		[1] 13–15	16–19	20+	[2] 11	12+			8+
Length without trim (feet)		10+			10+	8–9	10–11	12+	8+
Clear cuttings on each of three best faces [3]	Length, minimum (feet)	7	5	3	3	3	3	3	2
	Number, maximum	2	2	2	2	2	2	3	No limit
	Fraction of log length required in clear cutting [4]	5/6	5/6	5/6	2/3	3/4	2/3	2/3	1/2
Sweep and crook allowance, maximum (percent gross volume)	For logs with less than a quarter of end in sound defects	15%			30%				50%
	For logs with more than a quarter of end in sound defects	10%			20%				35%
Total scaling deduction including sweep and crook		[5] 40%			[6] 50%				50%
End features: See instructions in Appendix 7-A									

[1] Ash and basswood butts can be 12 inches if they meet all other F1 requirements.
[2] Ten-inch logs of all species can be F2 if they meet all other F1 requirements.
[3] A clear cutting is a portion of a face free of defects, extending the width of the face.
[4] See Table 7-2 for actual length of clear cuttings needed.
[5] Otherwise, F1 logs with 41 – 60% deductions can be F2.
[6] Otherwise, F2 logs with 51 – 60% deductions can be F3.

Log length deserves special discussion. The Forest Service system specifies that grade 1 logs must be at least 10 feet long, because the FAS hardwood lumber grade used to require a certain percentage of long lengths. This requirement was dropped years ago; so, consideration should be given to accepting 8 foot logs in grade 1.

The additional factors that must be considered are comparable to the factors used in grading hardwood lumber. These three factors include the length of clear cuttings between defects, the number of clear cuttings allowed, and the proportion of log length required in clear cuttings.

In order to apply the rules, divide a log into four faces. Place as many defects as possible into one face. For demonstration purposes, it helps to mark the location of the four faces on the end of the log. Figure 7-2 shows a log being graded. The example is a 16-foot long butt log with a diameter inside bark or a scaling diameter of 15 inches, which qualifies as a grade 1 log. According to Table 7-1, for this diameter log, the minimum clear cutting length accepted is 7 feet, only two cuttings are allowed, and the total yield of log length must be 5/6 or 10/12.

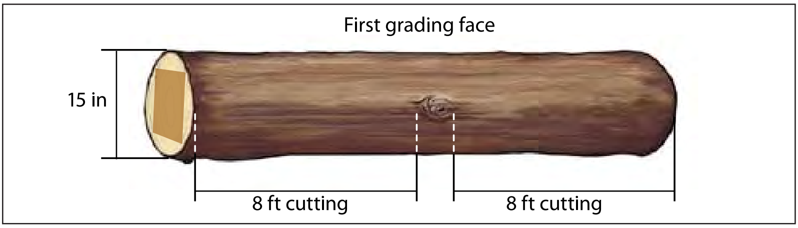
The first face (Figure 7-2A) shows two clear cuttings, each 8 feet long. From Table 7-2, 5/6 or 10/12 of the 16-foot log length is 13 feet 4 inches. The available length is 16 feet, so the first face is an easy grade 1.

The second face (Figure 7-2B) shows a 14-foot-long cutting and a 2-foot-long cutting. Only the 14-foot-long cutting qualifies, but it also exceeds the 13-foot 4-inch length requirement (Table 7-2). Therefore, the second log face is grade No. 1.

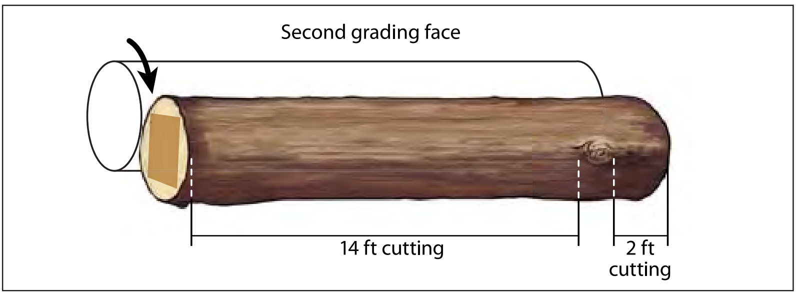
The third face (Figure 7-2C) has a 6-foot and a 10-foot-long cutting. Only the 10-foot-long cutting qualifies for grade No. 1, but it does not provide the 13 feet 4 inches of length required for grade 1 (Table 7-2). Looking to the right side of Table 7-1 under F2, 12 inches and larger diameter and 12 feet and longer, it can be seen that three cuttings, 3 feet long are allowed, and that the yield is 2/3 or 10 feet 8 inches. The grading face has 16 feet, which qualifies as grade No. 2.

The fourth log face (Figure 7-2D) has one 3-foot long cutting and two 4-foot long cuttings. All three of these cuttings qualify, and in total they exceed the 10 feet 8 inches required for grade No. 2.

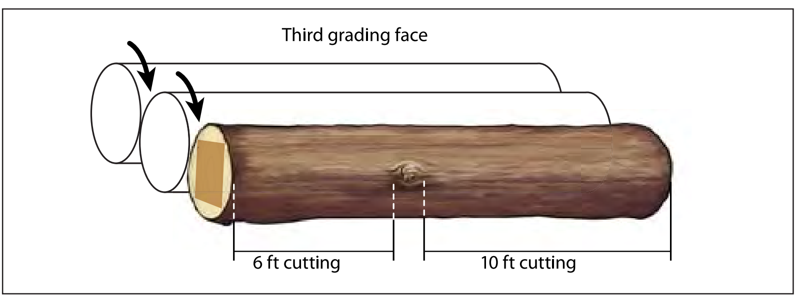
In summary, the log has two grade 1 faces and two grade 2 faces. The lowest grade face is discarded and the grade of the log is based on the lowest grade of the three remaining faces. Therefore, the log is grade 2.



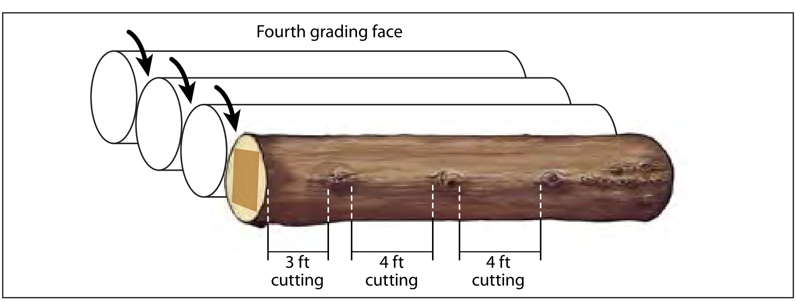
A. The first log face grades as No. 1



B. The second log face grades as No. 1



C. The third log face grades as No. 2



D. The fourth log face grades as No. 2

Figure 7-2. Example using the Forest Service system to grade four faces of a butt log, 15 inches in diameter inside bark and 16-feet long (plus trim allowance). The log is grade 2.

Table 7-2. Minimum length of clear cuttings, by log length and proportion required

Log length (feet)	Proportion and actual length in clear cuttings			
	5/6	3/4	2/3	1/2
8	6 feet 8 inches	6 feet 0 inches	5 feet 4 inches	4 feet 0 inches
9	7 feet 6 inches	6 feet 9 inches	6 feet 0 inches	4 feet 6 inches
10	8 feet 4 inches	7 feet 6 inches	6 feet 8 inches	5 feet 0 inches
11	9 feet 2 inches	8 feet 3 inches	7 feet 4 inches	5 feet 6 inches
12	10 feet 0 inches	9 feet 0 inches	8 feet 0 inches	6 feet 0 inches
13	10 feet 10 inches	9 feet 9 inches	8 feet 8 inches	6 feet 6 inches
14	11 feet 8 inches	10 feet 6 inches	9 feet 4 inches	7 feet 0 inches
15	12 feet 6 inches	11 feet 3 inches	10 feet 0 inches	7 feet 6 inches
16	13 feet 4 inches	12 feet 0 inches	10 feet 8 inches	8 feet 0 inches

What Constitutes a Defect?

What constitutes a defect is clearly the most difficult part of evaluating a log. The Forest Service (Rast and others 1973) has carefully outlined what constitutes a defect (Appendix 7-A). Mill personnel and graders learn by seeing logs processed on a daily basis and by understanding yields. For inexperienced individuals, the best method is to observe logs being cut on smaller mills with the bark still intact. In the author's experience, essentially any blemish on the log surface will result in a lumber grading defect; or it is conservative at least to assume that it does. In small logs, a blemish will likely occur on the front or, at the very least, on the back side of the first board. In large logs, with a very light blemish or overgrown limb, one or two boards may be obtained before a defect develops. In addition, and regardless of log size, there are usually other smaller defects that develop that were not evident on the log surface.

Figure 7-3 shows an oak slab with an overgrown knot. The board immediately below the blemish is clear, but the back side of the second board shows an unsound overgrown limb stub, mineral stain, and probably a grub hole. Additional information on defects is available in Agricultural Handbook 678, Defects in Hardwood Timber (Carpenter and others 1989), and in the Chapter on Hardwood Logs and Trees for Fine Face Veneer in this handbook.

Another issue in grading logs has to do with the features that can be seen on the end of the log. These features include ring shake, star shake, mineral stain, bird peck, and others. The Forest Service system divides the end of the log into quadrants that correspond with the grading faces (Appendix 7-A). The core 40 percent of the log end diameter (20% of the radius) is called the heart center, which is ignored because it usually produces low-grade lumber. The remaining portion is divided into eight quality zones. Where a defect extends into more than one quality zone, clear face cuttings cannot be taken from the overlying log surface.

The amount of scaling deduction must also be considered. The percentages allowed are presented in Table 7-1. The methods for calculations are presented in Appendix 7-B. This is a fairly complicated section of the Forest Service grading rules. In reality, most grade mills will not tolerate significant scaling defects, such as void or sweep. When they occur, logs are simply scaled back in length, diameter, or both. Should more precision be needed, however, scaling defects are well addressed by the system.

Remember that the accuracy of lumber grade prediction increases as more care is exercised in applying the Forest Service rules in their entirety. Usually it is best to study groups of at least 25 logs. The system is not intended to be applied to one or just a few logs, although it is commonly done.

Figure 7-3. Overgrown knot in a red oak slab (right). The first board from beneath the slab is clear (center), but the back side of the second board shows a large defective area (left).

Comparison with NHLA Lumber Grades

Clear cutting yields and clear cutting lengths compare closely between the Forest Service log grading requirement for each log face and the National Hardwood Lumber Association (NHLA 2011) grading rules for hardwood lumber (Cassens and Fischer 1992). For anyone who understands the hardwood lumber grading concept, the Forest Service log and tree grading rules become relatively easy to apply.

Percent of Board in Clear Area

The percent of log length required in clear cuttings and the percentage of board area required are similar (Appendix 7-C). FAS lumber and F1F and Selects lumber on the better face require that 83⅓ percent or 10/12 be in clear cuttings. Grade 1 logs will also have 83⅓ percent or 10/12 of their length in clear face cuttings.

No. 1 Common lumber requires a clear cutting yield of 66⅔ percent or 8/12, while Grade 2 logs require exactly the same percentage in clear cutting length.

Finally, No. 2 Common lumber requires 50 percent or 6/12 of the board surface in clear cuttings, while a Grade 3 log must also have at least one-half of its length in clear cuttings.

Clear Cutting Length

As presented in Appendix 7-C, the minimum clear cutting length for FAS lumber and the better side of F1F lumber and Selects is 5 or 7 feet, depending on the width of the cutting. In the log grades the smallest diameter grade 1 logs must have a 7-foot clear cutting length, while mid-sized logs require a 5-foot clear cutting length. Large diameter logs require only a 3-foot clear cutting length. With wide lumber that is produced from large diameter logs, it is often possible to take cuttings along one or both sides of a knot.

No. 1 Common lumber, which requires clear cutting lengths of 2 or 3 feet depending on cutting width, compares with Grade 2 logs, which require a minimum clear cutting length of 3 feet.

Finally, No. 2 Common lumber and Grade 3 logs both require a clear cutting length of just 2 feet.

The correlation between the NHLA lumber grading system and the Forest Service log grading system is excellent. The author has seen at least one independently developed log grading system where the mill refers to log faces as grade FAS, or No. 1 or No. 2.

Application of the System

The most important aspect of the grading system is its ability to predict the lumber grade yield and thus the value for a particular group of logs. It is important to work with groups of logs and not just one or two.

The air-dry lumber yields in percent for grade 1, 2, and 3 logs are presented in Appendix 7-D for northern red oak, white oak, black cherry, sugar maple, red maple, yellow-poplar, and basswood (Hanks and others 1980). Additional air-dried lumber grade yield tables are available for paper birch, yellow birch, black oak, chestnut oak, and scarlet oak (Hanks and others 1980). Green lumber grade yield tables are given in Appendix 7-E for red oak (lowland), white oak (lowland), and sap gum (Hanks and others 1980). Green lumber grade yields are also available for beech, cottonwood, and elm (Hanks and others 1980).

Northern red oak provides a good example of grade and value yield (Table 7-3). The Doyle Log Scale for an 18-inch d.i.b. 12-foot long log is 147 board feet (Appendix 7-F). Traditional mills may have a 15 percent overrun on this log size, so the actual volume produced is about 169 board feet—147 + (147 × 0.15). Thin kerf mills may have at least twice this overrun. The author typically expects a 35 percent overrun on the Doyle scale with a 0.087 kerf. The air-dry lumber yield of FAS plus F1F plus Selects lumber for this grade 1 log is estimated at 47 percent (Appendix 7-D). Now, 47 percent of 169 board feet is about 80 board feet of air-dry lumber. By adjusting the volume upward by 4 percent from 80 board feet to 83 board feet, the air-dried log yield is now comparable to green lumber yield. If the current market value (northern) of Selects and better green red oak lumber is $1,345, the value of Selects and better lumber for this size and grade of log should be $111.64. Table 7-3 summarizes the yield and value for the complete log. The total value of green lumber from the log is $168. Now, the costs for stumpage, logging, transportation, and milling can be subtracted; and the remainder, positive or negative, is an estimate of the gain or loss for the mill when purchasing and sawing that species, grade, and size of log.

Table 7-3. Lumber yield and assumed lumber value for a northern red oak 18-inch diameter inside bark, 12-foot long, grade 1 log

Lumber grade	Lumber yield (Percent)	Actual lumber yield (BF)		Assumed lumber value per MBF (dollars)	Total value (dollars)
		Air dried	Green [1]		
FAS + F1F + Selects	47	80	83	1,345	111.64
No. 1 Common	27	46	48	750	36.00
No. 2 Common	15	26	27	535	14.45
No. 3 Common	8	14	15	385	5.78
No. 3B Common	2	3	3	310	0.93
Total	—	169	176	—	168.80

[1] Green lumber yield = Doyle scale + overrun + 0.04 percent of Doyle Scale with overrun × percent lumber yield or [(147 + (147 × 0.15)) + (147 + (147 × .15)) (0.04)] 0.473 = 83 board feet

Tree Grading

Timber buyers each develop their own system for evaluating timber. Some may walk through a stand and make an offer based on intuition. Others may count trees of average size by species, give a value for each, and simply add the total. For high-valued timber with veneer, each tree may be measured and graded, and a price figured. As value and competition increase, additional effort must be spent to more precisely evaluate a particular stand, if overpaying is to be prevented.

The Forest Service has extended its log-grading system to standing timber (Hanks 1976). This is an appealing system because only the butt log is measured and graded, and the total merchantable height is estimated. The air-dried lumber grade yields for the entire tree can then be read directly from a table or calculated by use of regression equations. Grading details and yield tables for the tree grading system are available in Hanks (1976). Species include yellow birch, red maple, black oak, basswood, sugar maple, black cherry, paper birch, white oak, yellow-poplar, northern red oak, and chestnut oak.

Table 7-4. Forest Service hardwood tree grades for factory lumber (Hanks 1976, p. 2)

Grade factor	Tree grade 1			Tree grade 2		Tree grade 3
Length of grading zone (feet)	Butt 16			Butt 16		Butt 16
Length of grading section[1] (feet)	Best 12			Best 12		Best 12
D.b.h., minimum (inches)	[2]16			13		10
Diameter, minimum inside bark at top of grading section (inches)	[2]13	16	20	[3]11	12	8
Clear cuttings (on the three best faces)[4]						
Length, minimum (feet)	7	5	3	3	3	2
Number on face (maximum)	2			2	3	([5])
Yield in face length (minimum)	5/6			4/6		3/6
Cull deduction, including crook and sweep but excluding shake, maximum within grading section (percent)	9			[6]9		50

[1] Whenever a 14- or 16-foot section of the butt 16-foot log is better than the best 12-foot section, the grade of the longer section will become the grade of the tree. This longer section, when used, is the basis for determining the grading factors such as diameter and cull deduction.

[2] In basswood and ash, d.i.b. at top of grading section must be 12 inches, and d.b.h. must be 15 inches.

[3] Grade 2 trees can be 10 inches d.i.b. at top of grading section if they otherwise meet surface requirements for small grade 1 trees.

[4] A clear cutting is a portion of a face free of defects, extending the width of the face. A face is one-fourth of the surface of the grading section as divided lengthwise.

[5] Unlimited.

[6] Fifteen percent crook and sweep or 40 percent total cull deduction are permitted in grade 2, if size and surface of grading section qualify as grade 1. If rot shortens the required clear cuttings to the extent of dropping the butt log to grade 2, do not drop the tree to grade 3 unless the cull deduction for rot is greater than 40 percent.

Determine the Section to Be Graded

The system grades the best 12 feet in the butt 16 feet of the tree. Normally, the butt 12 feet are the best, but in the event of basal damage from fire or wounding—as an example—the upper portion of the butt 16 feet can become the grading section. Actually, any 12-foot length within the butt 16 feet may be selected for grading. Table 7-4 presents the requirements for each of the three Forest Service tree grades.

Measure Diameters

After determining the tree section to be graded, measure the d.b.h. or diameter at 4½ feet above the ground. A Grade 1 tree must be at least 16 inches d.b.h., and a Grade 2 must be 13 inches or more in d.b.h. Estimate the diameter at the top of the grading section and be certain it complies with the minimum diameter given in Table 7-4. Except for minimum-sized trees or for a tree where the top 12 feet of the butt 16 feet are graded, estimating top diameter is usually unnecessary.

Determine Cutting Lengths

Determine clear cutting lengths in each face. In Grade 1 and 2 trees, only two or three cuttings are allowed.

Calculate Clear Percent

Calculate the percentage of the face in clear cuttings. The minimum length of clear cuttings, the number of clear cuttings allowed, and the percent of clear cuttings required are all similar to those in the Forest Service log grading system. In addition, cull deduction is limited. The grade of the tree is based on the lowest grade of the three best faces. Once the tree is graded, regression equations or yield tables can be used to estimate the amount of air-dried lumber that will be produced by grade.

As an example, the coefficients for the regression equations for red oak are reproduced in Appendix 7-G. For example, the regression equation for the air dried board feet of red oak FAS lumber for tree grade 1 is as follows:

$$\text{FAS board feet} = -10.6 + 0.13317\ \text{d.b.h.}^2 - 1.5709\ \text{MH} + 0.005175\ \text{d.b.h.}^2 \times \text{MH}$$

d.b.h. = diameter breast high or 4½ feet above the ground

MH = merchantable height

Actual tree yield data for red oak appears in Appendix 7-H. Yield data for black cherry, white oak, yellow birch, red maple, black oak, basswood, sugar maple, paper birch, yellow-poplar, and chestnut oak, and complete details are in Hanks (1976).

It is the author's opinion that the yield values for the upper grades of yellow-poplar lumber are low. Conversations with the Forest Service author (Hanks 1980) indicated that there was a staining issue in the yellow-poplar lumber, and that it was considered a defect at the time of grading. In well cared for lumber, stain would not be a defect.

Calculate Tree Value

To calculate the value of a grade 1, 20-inch d.b.h. northern red oak tree with three 16-foot logs, refer to Appendix 7-H and Table 7-5. With the tables and price data given, the value of the green lumber that the tree should produce is about $345. The yield data was collected for traditional circle and band mills. Thin kerf mills, with careful slabbing and edging, could add substantially more value to the tree.

Once the value of the lumber in the tree is known, processing, hauling, logging, and stumpage costs can be subtracted to estimate potential profit or loss.

Table 7-5. Example of lumber grade yield and assumed lumber value for a Grade 1, 20-inch-d.b.h. tree, with 48 feet of merchantable height

Lumber grade	Board feet dry	Board feet green[1]	Assumed lumber value per MBF (dollars)	Total value (dollars)
FAS + F1F + Selects	123	128	1,345	172.16
No. 1 Common	105	109	750	81.75
No. 2 Common	126	131	535	70.09
No. 3 Common	42	44	385	16.94
No. 3B Common	13	14	310	4.34
Total	409	426	—	345.28

[1] Adjusted upward from dry by 4 percent

Summary

The Forest Service log and tree grading systems represent a reasonably accurate method to obtain lumber grade yield estimates or dollar values from both logs and lumber. With time, users may want to develop their own yield data or make adjustments to the Forest Service data. Practice also makes the system easier to apply.

Appendix 7-A. Special Instructions for Evaluating Defects in Forest Service Grade Sawlogs

The information in this appendix is taken from Rast and others (1973, p.16-19). Whether a log abnormality is considered a defect is summarized in Box 7-A1. Log zones referred to in this appendix are illustrated in Figure 7-A1.

Box 7-A1. Classification of abnormalities on log surface and log end, for Forest Service grade sawlogs (Rast and others 1973, p. 8).

Abnormalities	Factory Logs
Log surface	
Bulges:	
Butt	Defect
Stem	Defect
Bumps:	
High	Defect
Medium	Defect
Low	([1])
Burl	Defect
Butt scar	Defect
Butt swell	No defect
Canker	Defect
Conk	Defect
Dormant buds	([1])
Epicormic branches	([1])
Flanges	No defect
Flutes	([2])
Fork	Defect
Gum lesions	([2])
Holes:	
Large	Defect
Medium:	
Bark scarrer, fresh	No defect
Bark scarrer, old	Defect
Birds, light	No defect
Birds, heavy	Defect
Grub	([1])
Increment borer	Defect
Tap	Defect
Small	([2])
Log knots:	
Sound	Defect
Unsound	Defect
Limbs	Defect
Overgrowths:	
Knots and bark pockets	Defect
Insects	Defect
Bird peck	Defect
Bark distortions:	
Heavy or medium	Defect
Light	No defect
Seams	([1])
Splits	([2])
Surface rise	No defect
Wounds:	
New	No defect
Old	([2])
Log end	
Bird peck	([1])
Bark pocket (crotch)	Defect
Double pith	No defect
Grease spots	([1])
Grub spots	([1])
Gum spots	([1])
Loose heart	([1])
Rot	([1])
Shake:	
Ring	([1])
Wind	([1])
Soak	([2])
Spider heart	([1])
Stain	([1])
Worm holes:	
Pin, flag, and shot	Defect

[1] Defect if not confined to heart center and inner quality zone.

[2] Refer to Defects in Hardwood Timber, Agricultural Handbook 678 (Carpenter and others 1989).

Evaluating Surface Features

A surface abnormality, if determined to extend into the log for a depth more than 15 percent of the log radius at the point of occurrence, is a log grade defect. Otherwise, it should be disregarded. All defect indicators judged to indicate log-grade defects are counted as equal, with the following exceptions in factory logs only:

1. Epicormic branches:
    a. Large (limbs more than ⅜ inch diameter at origin or bark surface): full defect on logs of all sizes, grades, and species.
    b. Small (limbs ⅜ inch diameter or less):
        i. Hard hardwoods* (except black cherry, where they are not counted as defects), all grades:
            (1) On logs less than 14 inches: full defect.
            (2) On logs 14 inches and more: one-half defect, i.e., skip every other one.
        ii. Soft hardwoods†:
            (1) Grades 1 and 2: full defect on logs less than 14 inches; one-half defect on logs 14 inches and more.
            (2) Grade 3: no defect

2. Grub holes and grub-caused overgrowths:
    a. Progressive on face.
        i. On logs 8-15 inches in diameter, each is a full defect.
        ii. On logs 16-19 inches, disregard every sixth one.
        iii. On logs 20-23 inches, disregard every fifth one.
        iv. On logs 24-27 inches, disregard every fourth one.
        v. On logs 28 inches or more, disregard every third one.
    b. Nonprogressive—aligned across face. When two or more of these defects are found in a band not more than 6 inches wide across the width of the face, they may be considered as one.

3. Bumps: High and medium bumps must be considered on all logs, although in some species‡ low bumps can sometimes be disregarded. Measurement of clear cuttings is affected as follows (Figure 7-A.2):
    a. High bump (length 3 times height or less, for example, 6 inches long and 4 inches high): Stop clear cutting at change in contour. Do not enter bump with clear cuttings.

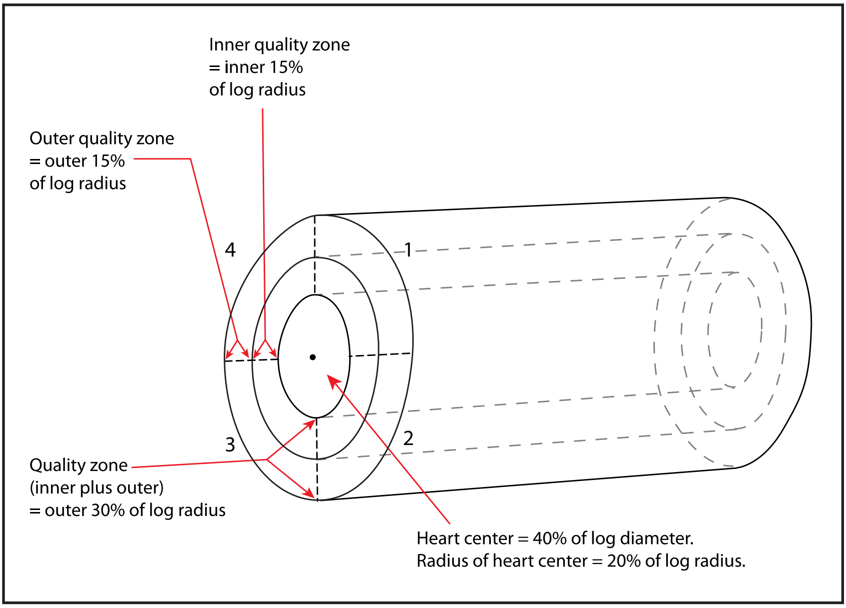


Figure 7-A.1. Log zones. Log defects are partly determined by the zones in which they are located.

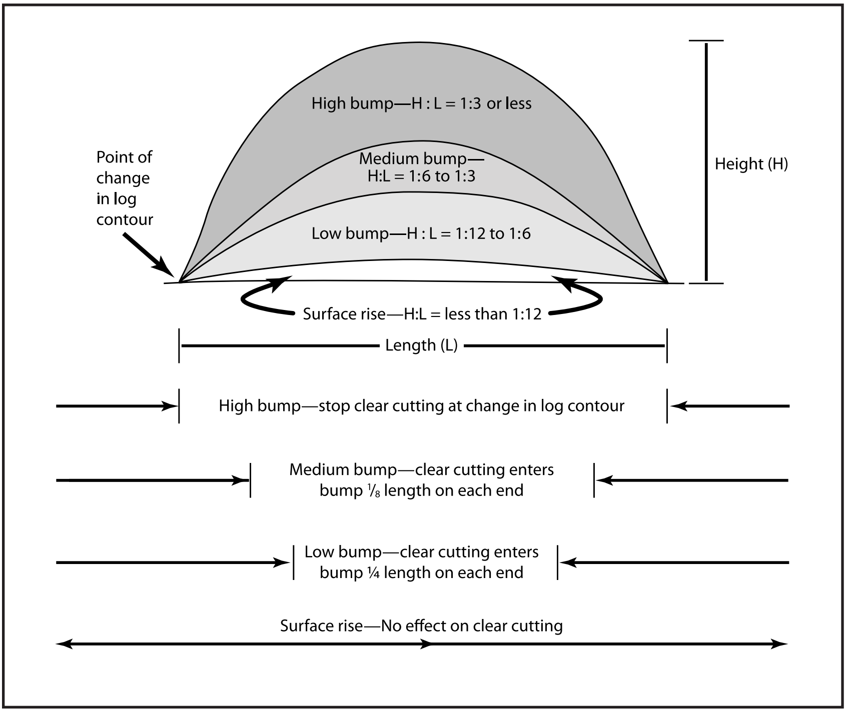


Figure 7-A.2. Bumps

   b. Medium bump (length 3 to 6 times height, for example, 12 inches long and 2 to 4 inches high): Let clear cutting enter bump one-eighth of the length on each end.
   c. Low bump (length 6 to 12 times height, for example, 12 inches long and 1 to 2 inches high): Let clear cutting enter bump one-fourth of the length on each end.
   d. Surface rise (length 12 times height or more): disregard.

4. Straight seams, frost cracks, splits extending into inner quality zone (Figure 7-A.3).
   a. Straight seams extending all or part of the length of the log that can be considered as a line dividing two grading faces can be disregarded.
   b. Straight seams not confinable to lines dividing grading faces:
      i. When full length of log, a full defect.
      ii. When extends from one end of log towards middle, extend clear cutting to include one-third of the seam length from interior end.
      iii. When completely in log, extend clear cutting from each end of log to include one-fourth of seam length from each end of seam.

5. For spiral seams, frost cracks, and splits, extending into inner quality zone, stop clear cutting where defect enters face being graded.

6. Bird peck. Individual pecks are not counted; length of pecked area is measured. A pecked area is one containing four or more pecks within 1 square foot.
   a. On lightly pecked area (fewer than four pecks per square foot), disregard.
   b. In grade 1 and 2 logs with four or more pecks per square foot,
      i. If pecks are open, disregard;
      ii. If pecks are partially or completely occluded, the pecked area is a defect. (Note: age of peck does not matter; test is whether callus tissue formed in the peck-holes.)
   c. In grade 3 logs: disregard all pecked areas.

Evaluating End Features

1. Definitions (Figure 7-A.4)
    a. Heart center. Heart center is considered to be a core with a radius equal to one-fifth the radius of the log.
    b. Quality zone. The portion of the log outside the heart center.
        i. Inner quality zone—inside half of quality zone.
        ii. Outer quality zone—outside half of quality zone.
    c. Affected area. This is defined as the area in which there are blemishes within 3 inches of each other. The total affected area, and not the area of the individual blemishes, is what determines the degrading effect.

2. Evaluation
    a. All abnormalities, regardless of type, can be disregarded in grading when they are confined to the heart center; however, they must cause scale deductions.
    b. When an abnormality is not confined to the heart center, divide the log end into quadrants conforming to the grading faces and evaluate as follows:
        i. Rot, heart check and ring shake (Figure 7-A.5). If these enter the quality zone in any quadrant and are
            (1) Confined entirely within either the inner or outer quality zone, make scale deductions as usual, but disregard as a log defect.
            (2) In both inner and outer quality zones, make scale deductions as usual but consider as a defect in the quadrant and face involved, as follows:
                (a) If it extends full length of log, no clear cutting can be taken.
                (b) If it extends only partially through the log, allow cuttings to be measured back toward the log end one-third the length of the affected area, from the point where it is estimated that the rot or shake tapers out.

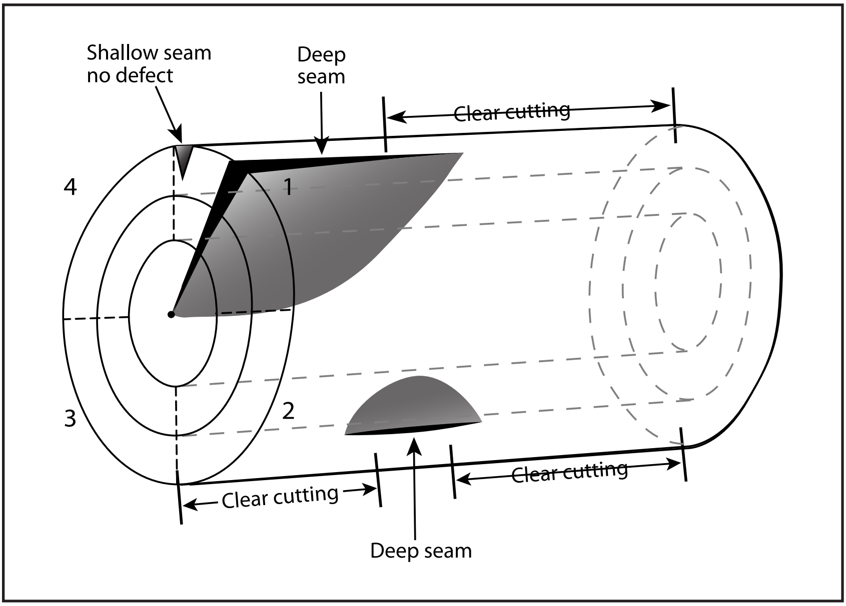


Figure 7-A.3. Straight seams, frost cracks, and splits

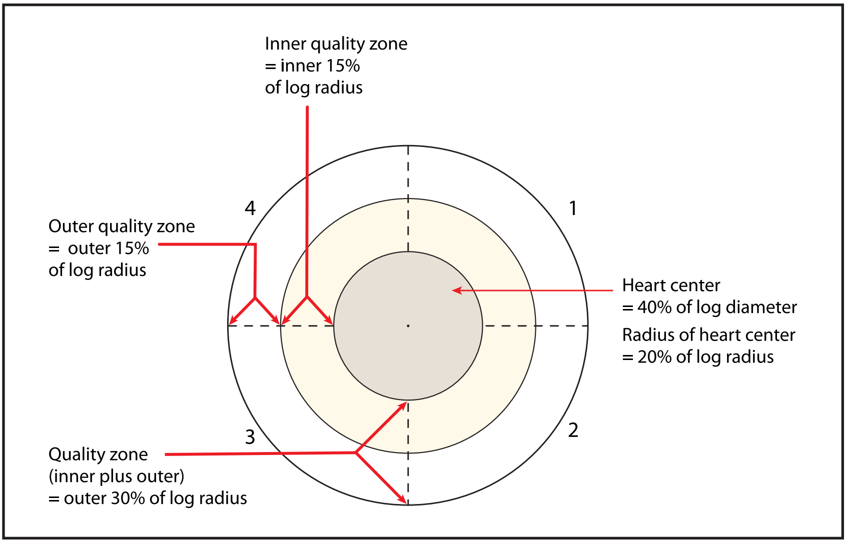


Figure 7-A.4. End features

ii. Spider heart. Defect if not confined to heart center.

iii. Spot worm holes, shot worm holes, pin worm holes, bird peck, bark pockets, grub holes, gum spots, grease spots. When enough of these are found to constitute an affected area in the quality zone and the radial measurement of this affected area is:

(1) In grade 1 and 2 logs:

(a) Less than half the radial width of quality zone, disregard.

(b) Greater than half the radius of the quality zone in three or more quadrants on one end, or two or more quadrants on both ends, degrade one grade.

(2) In grade 3 logs, disregard.

iii. Stain. Stain is considered on the scaling end only; disregard if on the large end only. The affected area in this case is the total area involved, including the heart center. When stain occurs in several solid areas that are not joined, the extent is the sum of the individual areas. Treat as follows:

(1) In grade 1 and 2 logs:

(a) If diameter of stain on scaling end is less than half the scaling log diameter, disregard.

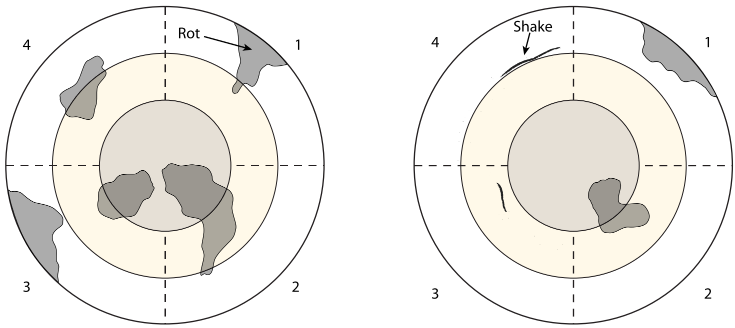
(b) If diameter of stain on scaling end is more than half the scaling log diameter, drop one grade.

(2) In grade 3 logs, disregard.

* Includes such species as sugar maple, beech, yellow birch, sycamore, hackberry, all oaks and ashes, and hickories.

† Includes such species as soft maples, basswood, yellow-poplar, gum, magnolia, willow, cottonwood, and elm.

‡ Includes such species as soft maple, tupelo, soft elm, birch, ashes, magnolias, and white oaks (white, cow, and swamp chestnut).



Defect in all four quadrants—rot in both inner and outer quality zones

No defect quadrant 1, 2, or 3 —rot or shake in only one quality zone

Defect quadrant 4—shake in both inner and outer quality zones

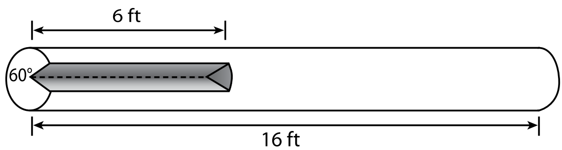
Figure 7-A.5. Rot and shake

Appendix 7-B. Methods of Determining Scaling Deductions

Examples are based on a 16-foot log with 20-inch scaling diameter (Grosenbaugh 1952, p. 16).

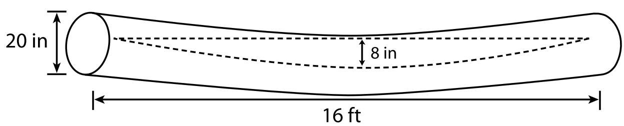
Defect section:

Percent deduction = $\frac{4}{16}$ = 25%



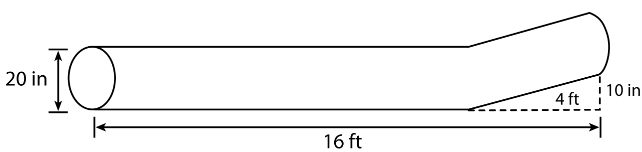
Defect section:

Percent deduction = $\left(\frac{6}{16}\right)\left(\frac{60}{360}\right)$ = 6¼%



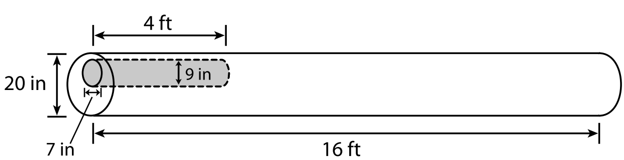
Sweep:

Percent deduction = $\frac{8-2}{20}$ = 30%



Crook:

Percent deduction = $\left(\frac{10}{20}\right)\left(\frac{4}{16}\right)$ = 12½%



Interior defect:

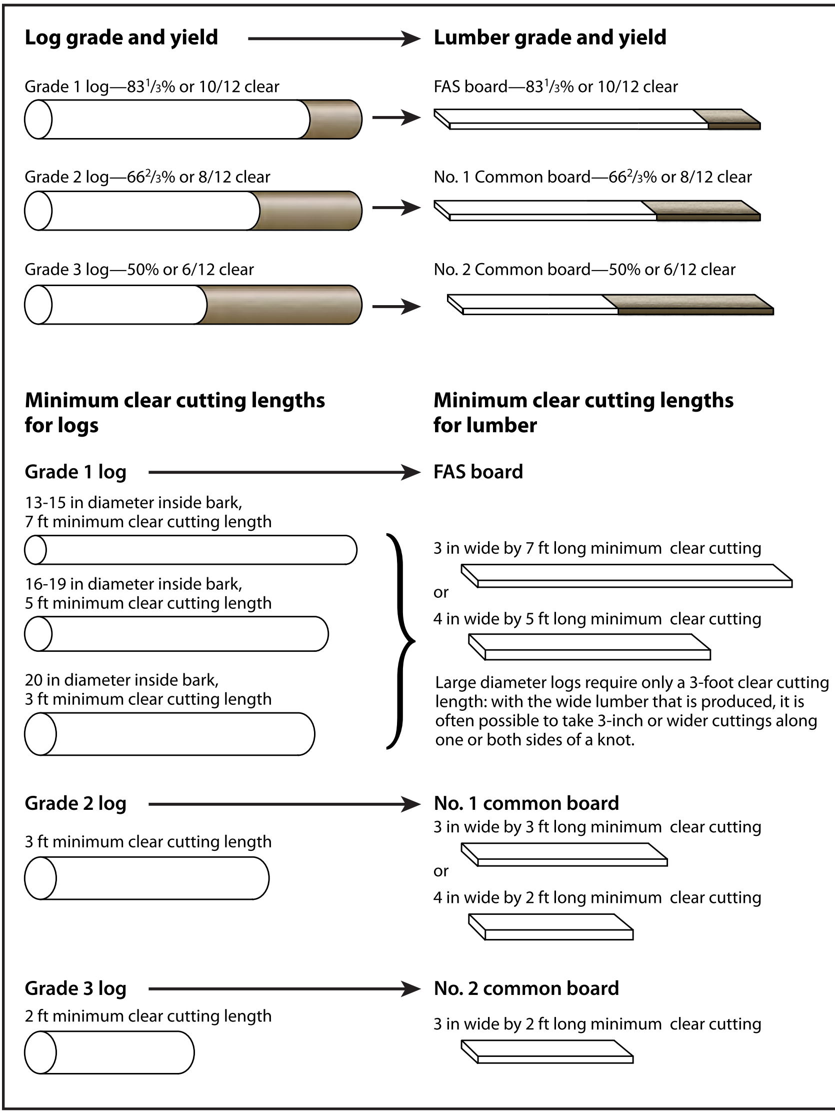
Percent deduction = $\frac{(8)\ (10)}{(20-1)^2} \times \frac{4}{16}$ = 5⅝%

In practice, each ellipse axis can be divided by (20 – 1) and rounded to nearest tenth, if desired.

Thus $\frac{8}{19}$ = 0.4, $\frac{10}{19}$ = 0.5, and (0.4) (0.5) $\left(\frac{4}{16}\right)$ = 5%

Appendix 7-C. Minimum Percent of Clear Cutting Lengths for Logs and Lumber, and Minimum Length of Individual Cuttings for Logs and Lumber

The information in this appendix is taken from Cassens and Fischer (1992, p. 4).



Appendix 7-D. Air-Dried Lumber Yields for Different Log Grades

Northern Red Oak (Hanks and others 1980, p. 50-52)

Air-dried northern red oak grade 1 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
13	40	21	23	15	1
14	43	28	18	9	2
15	44	25	22	8	2
16	41	27	22	9	1
17	51	26	17	6	1
18	47	27	15	8	2
19	54	24	15	5	2
20	51	29	14	6	2
21	46	33	14	5	3
22	51	25	15	5	3
23	53	26	13	5	3
24	48	32	10	7	3
25	57	26	9	5	3
26	41	38	14	5	2
27	42	41	12	6	—
28	54	31	11	4	1
29	46	38	8	5	2
30	40	50	5	5	—
31	72	20	5	2	—

Air-dried northern red oak grade 2 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
10	14	33	27	24	3
11	16	20	33	23	8
12	16	25	34	19	6
13	13	32	31	17	7
14	21	30	29	17	3
15	15	30	30	15	5
16	24	34	27	11	4
17	22	40	23	12	6
18	30	30	23	12	5
19	21	40	24	10	5
20	24	33	22	12	11
21	17	50	17	9	7
22	26	38	22	9	4
23	21	46	13	11	9
24	43	36	16	3	2
25	38	39	20	3	—
26	9	68	15	6	2
29	17	53	21	8	2
30	40	36	20	3	1

Air-dried northern red oak grade 3 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
8	3	5	28	42	22
9	3	13	36	36	13
10	3	9	38	37	13
11	3	14	40	32	11
12	3	15	35	35	13
13	5	23	35	25	12
14	4	21	38	22	16
15	4	28	34	24	10
16	11	27	32	18	12
17	19	30	35	10	7
18	10	25	32	13	19
19	15	20	35	22	7
20	11	29	30	16	14
21	4	36	30	13	17
22	—	13	32	48	7
23	5	40	39	12	4
24	2	28	33	19	19
25	20	53	21	6	—
26	9.	39	33	7	11
27	18	40	26	9	8
28	54	25	11	9	2

White Oak (Hanks and others 1980, p. 57, 58, 60)

Air-dried white oak grade 1 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B + Other Common
13	30	30	16	14	10
14	44	22	18	13	3
15	31	25	21	13	11
16	39	28	17	8	8
17	37	22	21	9	11
18	25	22	21	14	19
19	28	37	21	7	7
20	38	26	20	9	8
21	38	28	15	10	9
22	37	40	17	4	2
23	31	29	25	4	11
24	31	41	19	5	4
26	34	35	15	14	3
27	28	58	14	—	—
28	36	44	7	3	10
29	54	36	5	2	3

Air-dried white oak grade 2 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B + Other Common
10	5	10	41	24	20
11	10	14	27	22	27
12	9	19	29	18	25
13	8	18	30	22	23
14	9	22	30	21	18
15	12	26	33	15	15
16	17	27	29	13	15
17	13	31	28	11	17
18	12	34	25	12	17
19	16	33	28	12	11
20	13	43	28	9	8
21	17	37	29	8	9
22	16	35	21	14	14
23	5	37	39	9	15
24	15	34	39	3	9
25	10	43	23	15	8

Air-dried white oak grade 3 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B + Other Common
8	—	2	7	25	66
9	2	2	17	25	54
10	2	5	20	28	46
11	1	6	26	29	38
12	2	8	29	30	32
13	1	9	32	23	35
14	4	13	32	22	35
15	3	18	35	18	25
16	4	17	38	17	24
17	5	20	29	17	29
18	2	31	33	15	18
19	10	30	20	15	26
20	5	26	32	15	22
21	12	42	30	4	12
22	11	28	30	18	14
23	—	5	5	55	35
24	7	39	33	13	9

Black Cherry (Hanks and others 1980, p. 22-24)

Air-dried black cherry grade 1 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
13	57	16	13	8	6
14	55	18	14	10	3
15	60	16	13	8	2
16	55	19	16	7	4
17	57	22	11	7	4
18	58	21	12	4	5
19	62	17	12	6	4
20	59	19	14	6	3
21	64	18	9	7	2
22	65	11	12	5	7
24	67	19	4	1	9
25	60	21	8	8	4

Air-dried black cherry grade 2 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
10	30	23	23	16.8	8
11	15	28	26	19.8	11
12	23	26	28	16.1	7
13	22	31	26	15.9	6
14	29	32	20	12.4	6
15	28	34	22	10.1	6
16	26	35	20	8.1	11
17	28	37	21	12.0	2
18	30	41	17	8.5	3
19	24	40	21	10.4	5
20	30	36	18	11.5	5
21	51	25	15	5	5

Air-dried black cherry grade 3 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
8	2	4	30	43	21
9	3	10	36	34	17
10	3	16	41	30	9
11	4	20	39	27	10
12	5	24	37	22	12
13	8	26	38	18	10
14	14	27	34	18	7
15	7	44	30	15	5
16	14	43	22	12	10
17	13	55	14	13	5
18	21	42	19	10	9
19	—	76	12	3	9
20	55	16	16	8	4

Sugar Maple (Hanks and others 1980, p. 32, 34, 36)

Air-dried sugar maple grade 1 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
13	32	28	14	11	17
14	29	25	15	7	13
15	29	24	14	9	14
16	34	28	17	7	15
17	37	28	17	6	12
18	41	25	16	6	13
19	36	28	17	7	12
20	42	26	16	7	9
21	44	27	14	7	7
22	33	32	19	7	9
23	51	24	11	7	8
24	60	24	9	6	2
25	41	25	22	6	7
26	64	18	17	1	1

Air-dried sugar maple grade 2 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
10	9	25	10	11	35
11	11	23	21	12	33
12	12	26	22	11	29
13	10	25	26	13	27
14	12	30	25	11	22
15	16	28	25	10	21
16	14	31	27	10	19
17	17	32	25	10	18
18	15	33	25	10	18
19	23	30	26	10	10
20	23	30	22	11	15
21	29	29	18	10	14
22	27	23	26	11	13
23	29	20	30	5	16

Air-dried sugar maple grade 3 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
8	2	7	26	15	51
9	3	11	21	24	42
10	3	14	24	20	40
11	1	11	27	19	41
12	4	14	29	21	32
13	3	14	29	19	35
14	4	15	29	16	35
15	8	23	28	15	26
16	5	30	30	14	21
17	6	23	32	20	17
18	9	24	30	16	21
19	11	32	29	10	17
20	5	23	37	17	18
21	5	38	29	12	16

Red Maple (Hanks and others 1980, p. 26, 28, 30)

Air-dried red maple grade 1 log

Scaling diameter (inches)	Percent yield, by lumber grade					
	FAS + F1F + Selects	No. 1 Common	No. 2A Common	No. 2B Common	No. 3A Common	No. 3B Common
13	37	27	18	8	7	4
14	47	16	21	11	47	2
15	50	18	14	10	6	1
16	46	21	18	9	3	2
17	44	27	19	7	2	1
18	57	21	16	3	2	1
19	49	19	15	13	3	1
20	59	19	17	3	2	1
21	55	24	15	3	2	1
22	28	43	12	3	8	6
23	70	12	16	2	—	—
24	21	39	31	—	4	6
25	15	46	26	12	1	1

Air-dried red maple grade 2 log

Scaling diameter (inches)	Percent yield, by lumber grade					
	FAS + F1F + Selects	No. 1 Common	No. 2A Common	No. 2B Common	No. 3A Common	No. 3B Common
10	26	18	20	17	8	11
11	13	22	31	19	7	8
12	20	23	30	16	7	5
13	24	20	40	11	6	5
14	23	25	29	12	7	5
15	27	25	28	12	4	4
16	23	31	33	6	4	3
17	20	33	27	10	5	5
18	24	30	27	5	9	4
19	38	27	22	6	6	1
20	60	14	17	1	3	5
21	53	20	17	3	6	2

Air-dried red maple grade 3 log

Scaling diameter (inches)	Percent yield, by lumber grade					
	FAS + F1F + Selects	No. 1 Common	No. 2A Common	No. 2B Common	No. 3A Common	No. 3B Common
8	1	3	20	44	14	19
9	3	6	32	36	12	11
10	4	10	32	35	12	8
11	3	10	36	34	10	8
12	3	13	39	24	13	7
13	7	14	39	28	7	5
14	7	18	37	22	12	4
15	16	32	30	12	8	3
16	12	21	48	11	8	1
17	31	21	19	9.	17	3
18	18	39	21	7	6	9
19	—	24	46	10	2	19

Yellow-Poplar (Hanks and others 1980, p. 62, 64, 66)

Air-dried yellow-poplar grade 1 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects + SAPS*	No. 1 Common	No. 2A Common	No. 2B Common	No. 3 Common
13	14	36	26	16	8
14	21	39	32	6	3
15	17	39	34	7	3
16	24	39	25	8	4
17	19	41	27	7	5
18	24	38	28	7	4
19	28	43	23	6	4
20	30	44	18	7	2
21	26	42	19	11	3
22	18	44	29	6	3
23	22	47	20	3	8
24	22	37	36	3	3
25	34	52	11	1	2
26	5	57	30	3	5
27	7	64	21	2	6
28	2	66	29	1	3
30	8	57	27	2	7

*SAPS is no longer a recognized grade, therefore it is combined with FAS and Selects.

Air-dried yellow-poplar grade 2 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects + SAPS*	No. 1 Common	No. 2A Common	No. 2B Common	No. 3 Common
10	6	31	33	21	10
11	4	27	33	24	12
12	6	29	37	20	7
13	7	31	379	20	6
14	7	32	37	16	8
15	10	33	31	20	6
16	10	34	31	21	4
17	8	46	30	12	4
18	12	39	32	11	6
19	18	40	31	9	2
20	8	41	37	10	5
21	10	52	28	9	2
22	5	35	39	14	6
23	5	50	43	7	—
24	—	48	35	7	4
25	6	39	57	4	—
27	41	44	8	1	5

*SAPS is no longer a recognizable grade, therefore it is combined with FAS and Selects.

Air-dried yellow-poplar grade 3 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects + SAPS*	No. 1 Common	No. 2A Common	No. 2B Common	No. 3 Common
8	1	5	17	54	23
9	1	7	21	50	22
10	1	10	30	47	13
11	1	12	31	42	15
12	1	14	35	39	11
13	1	19	38	35	8
14	1	22	37	34	6
15	2	24	42	26	6
16	4	31	39	21	5
17	4	40	36	15	5
18	6	40	30	22	2
19	5	36	36	21	4
20	7	54	24	14	1
21	22	43	33	2	—
22	23	38	17	13	9
23	—	29	41	24	6
24	—	38	50	12	—
26	—	22	50	6	22
27	6	44	34	11	5

*SAPS is no longer a recognizable grade, therefore it is combined with FAS and Selects.

Basswood (Hanks and others 1980, p. 10-12)

Air-dried basswood grade 1 log

Scaling diameter (inches)	Percent yield, by lumber grade			
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3 Common
12	33	32	26	9
13	44	27	17	12
14	40	29	26	5
15	48	28	17	7
16	40	30	21	10
17	50	24	14	12
18	53	17	20	10
19	54	23	12	11
20	58	28	14	—
21	36	24	32	8
22	51	27	10	13
23	51	17	16	16

Air-dried basswood grade 2 log

Scaling diameter (inches)	Percent yield, by lumber grade			
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3 Common
10	15	31	36	18
11	15	34	38	13
12	17	32	37	14
13	17	31	37	15
14	22	32	33	13
15	29	29	29	13
16	22	33	29	16
17	13	39	39	10
18	21	27	28	23
19	71	12	8	9
20	55	15	27	4
21	7	18	43	32

Air-dried basswood grade 3 log

Scaling diameter (inches)	Percent yield, by lumber grade			
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3 Common
8	1	13	59	27
9	5	23	54	18
10	4	21	58	18
11	6	23	57	15
12	6	17	56	21
13	16	20	47	17
14	16	24	40	20
15	9	21	49	22
16	26	27	30	17
17	16	21	47	15
18	20	43	30	7
19	51	2	34	12

Appendix 7-E. Green Lumber Yields for Different Log Grades

Red Oak (Lowland) (Hanks and others 1980, p. 84, 86, 88)

Green lowland red oak grade 1 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B + Other Common
13	22	32	21	8	17
14	36	27	17	8	13
15	35	30	14	6	16
16	29	31	15	10	15
17	37	28	15	8	13
18	35	32	12	4	16
19	37	34	13	7	8
20	42	27	11	5	14
21	48	27	8	3	15
22	36	35	11	5	13
23	40	33	9	4	14
24	34	41	7	3	5
25	37	37	16	5	12
26	10	43	31	4	12
27	50	24	7	4	15

Green lowland red oak grade 2 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B + Other Common
10	8	33	16	28	16
11	11	28	23	12	26
12	9	30	22	13	26
13	9	27	24	15	25
14	12	28	23	15	21
15	10	29	23	15	23
16	11	39	21	11	18
7	14	34	18	9	25
18	12	41	17	9	22
19	15	35	23	13	15
20	15	28	19	14	24
21	12	35	20	15	16
22	15	36	18	10	20
23	8	39	30	4	16
24	12	50	16	8	7

Green lowland red oak grade 3 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B + Other Common
8	—	20	8	12	60
9	3	14	20	8	54
10	2	21	21	16	40
11	2	13	33	25	29
12	1	19	32	20	32
13	1	10	22	24	43
14	2	14	24	21	39
15	1	25	30	19	24
16	—	24	24	24	29
17	4	32	32	10	23
18	8	22	22	19	29
19	1	46	21	13	18
20	2	27	31	17	23
21	—	34	26	21	18
22	—	34	41	16	8

White Oak (Lowland) (Hanks and others 1980, p. 88, 90, 92)

Green lowland white oak grade 1 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B + Other Common
13	15	33	18	13	22
14	24	31	20	8	17
15	35	28	20	9	8
16	28	29	15	10	18
17	35	29	14	8	14
18	35	33	16	7	9
19	32	35	13	5	15
20	34	40	10	3	13
21	34	38	14	4	10
22	32	39	12	3	14
23	49	37	9	4	2
24	48	39	5	3	6
25	34	54	4	1	7
26	58	24	12	—	7
27	39	37	16	—	8
28	67	12	10	1	11
29	80	11	3	1	5
30	9	41	36	3	10
31	—	70	25	3	2

Green lowland white oak grade 2 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B + Other Common
10	6	21	30	20	24
11	3	18	28	21	30
12	8	25	27	13	27
13	4	26	30	15	25
14	8	30	27	12	24
15	8	30	23	14	26
16	8	36	27	9	20
17	10	31	25	10	24
18	11	41	18	6	25
19	19	36	20	9	17
20	16	44	19	3	18
21	14	46	20	5	15
22	14	38	19	10	20
24	24	42	16	2	16
25	18	21	28	5	29
26	10	47	30	2	11
27	—	32	36	8	25

Green lowland white oak grade 3 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	3B + Other Common
8	8	20	—	52	20
9	3	13	21	33	29
10	1	18	33	15	34
11	1	18	21	14	46
12	1	15	28	13	43
13	1	14	31	17	38
14	1	8	40	12	38
15	—	20	24	15	42
16	3	21	30	15	31
17	1	15	28	10	46
18	3	24	33	11	29
19	—	15	40	9	36
20	—	17	31	10	42
21	1	25	27	14	33
22	2	16	46	8	28
23	—	18	38	14	31

Sap Gum (Hanks and others 1980, p. 81- 83)

Green sap gum grade 1 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
13	31	33	26	8	2
14	41	29	20	8	2
15	38	29	25	8	1
16	48	25	19	6	2
17	44	29	20	6	1
18	48	27	17	7	1
19	49	23	18	7	3
20	47	23	21	8	1
21	47	33	13	5	2
22	58	19	14	7	2
23	39	40	15	4	2
25	31	52	3	2	12
26	51	30	7	2	11
27	45	37	14	—	5

Green sap gum grade 2 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
10	9	28	42	12	10
11	11	25	40	20	4
12	15	28	38	13	6
13	16	29	36	15	4
14	16	32	33	14	5
15	18	36	31	13	2
16	14	38	35	11	2
17	19	41	32	8	1
18	19	41	29	8	4
19	34	32	23	7	4
20	17	28	26	3	27
21	6	41	16	13	4
23	28	39	27	6	—

Green sap gum grade 3 log

Scaling diameter (inches)	Percent yield, by lumber grade				
	FAS + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
8	—	23	56	13	9
9	5	10	42	17	26
10	3	13	50	25	10
11	1	11	49	26	13
12	2	19	48	22	9
13	3	18	54	20	6
14	2	21	46	21	9
15	5	25	50	15	6
16	7	34	42	11	6
17	2	41	42	10	5
18	5	25	44	11	15
19	—	39	39	12	10
20	—	25	73	—	2
21	7	40	33	8	12

Appendix 7-F. Board Foot Content of Different Diameters and Lengths of Logs Based on Doyle Log Rule

Information in this appendix is from Wenger (**1976, p. 258**).

Diameter of log, small end, inside bark (inches)	Length of log in feet												
	6	7	8	9	10	11	12	13	14	15	16	17	18
	Contents of log in board feet												
6	1	2	2	2	2	3	3	3	4	4	4	4	4
7	3	4	4	5	5	6	7	7	8	8	9	10	10
8	6	7	8	9	10	11	12	13	14	15	16	17	18
9	9	11	12	14	16	17	19	20	22	23	25	27	28
10	13	16	18	20	22	25	27	29	31	34	36	38	40
11	18	21	24	28	31	34	37	40	43	46	49	52	55
12	24	28	32	36	40	44	48	52	56	60	64	68	72
13	30	35	40	46	51	56	61	66	71	76	81	86	91
14	37	44	50	56	62	69	75	81	87	94	100	106	112
15	45	53	60	68	76	83	91	98	106	113	121	129	136
16	54	63	72	81	90	99	108	117	126	135	144	153	162
17	63	74	84	95	106	116	127	137	148	158	169	180	190
18	73	86	98	110	122	135	147	159	171	184	196	208	220
19	84	98	112	127	141	155	169	183	197	211	225	239	253
20	96	112	128	144	160	176	192	208	224	240	256	272	288
21	108	126	144	163	181	199	217	235	253	217	289	307	325
22	121	142	162	182	202	223	243	263	283	304	324	344	364
23	135	158	180	203	226	248	271	293	316	338	361	384	406
24	150	175	200	225	250	275	300	325	350	375	400	425	450
25	165	193	220	248	276	303	331	358	386	413	441	469	496
26	181	212	242	272	302	333	363	393	423	454	484	514	544
27	198	231	264	298	331	364	397	430	463	496	529	562	595
28	216	252	288	324	360	396	432	468	504	540	576	612	648
29	234	273	312	352	391	430	469	508	547	586	625	664	702
30	253	296	338	380	422	465	507	549	591	634	676	718	760
31	273	319	364	410	456	501	547	592	638	683	729	775	820
32	294	343	392	441	490	539	588	637	686	735	784	833	882
33	315	368	420	473	526	578	631	683	736	788	841	894	946
34	337	394	450	506	562	619	675	731	787	844	900	956	1,012
35	360	420	480	541	601	661	721	781	841	901	961	1,021	1,081
36	384	448	512	576	640	704	768	832	896	960	1024	1,088	1,552
37	408	476	544	613	681	749	817	885	953	1,021	1,089	1,157	1,225
38	433	506	578	650	722	795	867	939	1,011	1,084	1,156	1,228	1,300
39	459	536	612	689	766	842	919	995	1,072	1,148	1,225	1,302	1,378
40	486	567	648	729	810	891	972	1,053	11,34	1,215	1,296	1,377	1,458

Formula: $(D-4)^2 \frac{L}{16}$

Appendix 7-G. Coefficients for Regression Equations[1] for Northern Red Oak Tree Grades.

Information in this appendix is from Hanks and others (1976, p. 17).

Dependent variable lumber grade	Independent variables			
	Constant	D.b.h.^{2}	Merchantable height (MH)	D.b.h.^{2} × Merchantable height (MH)
Tree grade 1				
FAS	−10.6	0.13317	−1.5709	0.005175
FAS One Face	−22.6	.02716	.0842	.002815
Selects	13.7	−.01711	−.3370	.001016
No. 1 Common	57.2	−.00508	−2.7014	.009354
No. 2 Common	−78.4	.10362	3.7351	−.000884
No. 3 Common	50.3	−.04598	−.5081	.001796
No. 3B	−8.9	.02341	.1077	.000397
Tree grade 2				
FAS	−53.2	0.12214	0.9548	—
FAS One Face	38.0	−.06613	−1.0022	0.003832
Selects	3.7	—	—	—
No. 1 Common	−6.1	.01520	−.8778	.008854
No. 2 Common	−57.2	.09975	2.4582	.000878
No. 3 Common	−55.0	.11825	2.3546	−.002127
No. 3B	3.5	−.00245	−.0156	.000731
Tree grade 3				
FAS	5.9	−0.02210	−0.3208	0.001560
FAS One Face	−5.2	.02821	.0096	.000504
Selects	2.0	—	—	—
No. 1 Common	−22.6	.20603	−0.0718	.000451
No. 2 Common	−21.2	.21713	.2132	.000399
No. 3 Common	−12.0	.06393	2.1422	.000741
No. 3B	−8.3	.00011	.8556	.002338

[1] Example Regression equation:

$$\text{FAS board feet} = -10.6 + 0.13317\ \text{d.b.h.}^2 - 1.5709\ \text{MH} + 0.005175\ \text{d.b.h.}^2 \times \text{MH}$$

d.b.h. = diameter breast high or 4½ feet above the ground

MH = merchantable height

Appendix 7-H. Northern Red Oak Air-Dried Lumber Volume Yield, by Tree Diameter at Breast Height (D.b.h.), Grade, and Merchantable Logs in 16-Foot Lengths

Information in this appendix is from Hanks and others 1976, p. 53-56.

D.b.h. (inches)	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
Tree grade 1 1½ Logs					
16	28.8	48.5	32.3	37.4	2.1
17	40.6	55.8	35.1	37.3	3.2
18	53.2	63.5	37.9	37.2	4.4
19	66.4	71.6	41.0	37.1	5.6
20	80.4	80.1	44.2	37.0	6.9
21	95.2	89.1	47.6	36.8	8.2
22	110.7	98.6	51.1	36.7	9.6
23	126.8	108.4	54.8	36.6	11.1
24	143.7	118.7	58.7	36.4	12.7
25	161.4	129.5	62.7	36.3	12.7
26	179.7	140.7	66.9	36.2	16.0
27	198.7	152.3	71.3	36.0	17.7
28	218.5	164.4	75.8	35.9	19.5
29	238.9	176.9	80.5	35.7	21.4
30	260.2	189.8	85.4	35.5	23.3
Tree grade 1 2 Logs					
16	32.6	46.1	60.4	37.0	3.8
17	46.9	55.8	62.9	37.4	5.0
18	61.9	66.1	65.5	37.8	6.2
19	77.9	77.0	68.3	38.2	7.6
20	176.6	88.5	71.3	38.6	9.0
21	112.4	100.5	74.3	39.1	10.5
22	130.9	113.2	77.6	39.6	12.0
23	150.4	126.4	81.0	40.1	13.7
24	170.6	140.2	84.5	40.7	15.3
25	191.8	154.7	88.2	41.2	17.1
26	213.7	169.7	92.0	41.8	19.0
27	236.6	185.3	96.0	42.4	20.9
28	260.4	201.4	100.1	43.1	22.9
29	285.0	218.2	104.5	43.7	24.9
30	310.4	235.6	108.9	44.4	27.0
31	336.7	253.5	113.5	45.1	29.3
32	363.9	272.1	118.3	45.8	31.5
33	392.0	291.2	123.2	46.4	33.9
34	420.8	310.9	128.2	47.3	36.3
35	450.6	331.2	133.4	48.1	38.8

D.b.h. (inches)	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
Tree grade 1 2½ Logs					
16	36.3	43.6	88.5	36.6	5.5
17	53.1	55.8	90.7	37.4	6.8
18	70.7	68.7	93.1	38.4	8.1
19	89.3	82.4	95.6	39.3	9.6
20	108.9	96.8	98.3	40.3	11.1
21	129.6	111.9	101.1	41.4	12.7
22	151.2	127.8	104.0	42.5	14.4
23	173.9	144.4	107.1	43.7	16.2
24	197.6	161.7	110.3	44.9	18.0
25	222.2	179.8	113.7	46.1	20.0
26	247.8	198.6	117.1	47.5	22.0
27	274.6	218.2	120.8	48.8	24.1
28	302.3	238.5	124.5	50.3	26.2
29	330.9	259.5	128.4	51.7	28.5
30	360.7	281.3	132.4	53.3	30.8
31	391.4	303.8	136.6	54.8	33.2
32	423.1	327.1	140.9	56.5	35.6
33	455.8	351.1	145.3	58.1	38.2
34	489.5	375.8	149.9	59.9	40.8
35	524.3	401.3	154.6	61.7	43.5
Tree grade 1 3 Logs					
16	40.3	41.2	116.5	36.2	7.1
17	59.3	55.8	118.6	37.5	8.5
18	79.4	71.4	120.7	38.9	10.0
19	100.7	87.8	123.0	40.4	11.6
20	123.2	105.1	125.4	42.0	13.3
21	146.8	123.3	127.9	43.7	15.0
22	171.5	142.4	130.5	45.4	16.8
23	197.4	162.4	133.3	47.2	18.7
24	224.5	183.2	136.1	49.1	20.7
25	252.7	205.0	139.1	51.1	22.8
26	281.9	227.6	142.2	53.1	25.0
27	312.5	251.1	145.5	55.2	27.2
28	344.1	275.6	148.9	57.4	29.6
29	576.9	300.9	152.3	59.7	32.0
30	410.9	327.1	156.0	62.1	34.5
31	446.0	354.1	159.7	64.6	37.1
32	482.2	382.1	163.5	67.1	39.8
33	510.7	411.0	167.5	69.7	42.5
34	558.2	440.7	171.6	72.4	45.4
35	597.9	471.3	175.8	75.2	48.3

D.b.h. (inches)	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
Tree grade 1 3½ Logs					
20	137.3	113.4	152.4	43.7	15.4
21	164.0	134.7	154.6	45.9	17.3
22	191.8	1,570	157.0	48.3`	19.2
23	221.0	180.3	159.4	50.7	21.3
24	251.4	204.7	161.9	53.3	23.4
25	283.1	230.1	164.6	56.0	25.7
26	316.1	256.6	167.3	58.8	28.0
27	350.4	284.1	170.2	61.6	30.4
28	386.0	312.6	173.2	64.6	32.9
29	422.9	342.2	176.3	67.8	35.5
30	461.1	372.8	179.5	710	38.2
31	500.7	404.4	182.8	74.3	41.0
32	541.6	437.1	186.2	77.8	43.9
33	583.6	470.8	189.7	81.3	46.8
34	626.9	505.6	193.3	85.0	49.9
35	670.7	541.4	197.1	88.7	53.0
Tree grade 1 4 Logs					
20	151.6	121.7	179.5	45.4	17.5
21	181.1	146.1	181.4	48.2	19.5
22	212.0	171.6	183.4	51.2	21.6
23	244.5	1,983	185.5	54.3	23.8
24	278.2	226.2	187.7	57.5	26.1
25	313.6	255.3	190.0	60.9	28.5
26	350.2	285.6	192.4	64.4	31.0
27	388.4	317.0	194.9	68.1	33.6
28	427.9	349.7	197.5	71.8	36.3
29	468.9	383.5	200.2	75.8	39.0
30	511.5	418.5	203.0	79.8	41.9
31	555.3	454.7	205.9	84.1	44.9
32	600.7	492.1	208.8	88.4	48.0
33	647.5	530.7	221.9	92.9	51.22
34	697.7	570.5	215.0	97.5	54.5
35	745.3	611.4	218.3	102.3	57.8

D.b.h. (inches)	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
Tree grade 2 1½ Logs					
13	22.0	11.3	22.2	12.9	5.7
14	22.7	17.5	25.5	14.7	6.1
15	23.5	24.1	29.0	16.6	6.5
16	25.3	31.1	32.7	18.7	7.0
17	30.1	38.6	36.7	20.9	7.5
18	35.3	46.6	40.9	23.3	8.0
19	40.8	55.0	45.4	25.8	8.6
20	46.6	63.9	50.1	28.4	9.2
21	52.6	73.2	55.1	31.1	9.8
22	59.0	83.0	60.3	34.0	10.4
23	65.6	93.3	65.7	37.1	11.1
24	72.6	104.0	71.4	40.2	11.8
25	79.9	115.1	77.3	43.5	12.6
26	87.4	126.8	83.5	46.9	13.3
27	95.3	138.8	89.9	50.5	14.1
28	103.4	151.3	96.5	54.2	15.0
29	111.8	164.3	103.4	58.0	15.8
30	120.5	177.8	110.5	62.0	16.7
Tree grade 2 2 Logs					
13	19.2	16.3	43.1	28.8	6.5
14	22.0	24.3	46.5	30.2	7.1
15	27.1	33.0	50.2	31.6	7.7
16	32.7	42.2	54.2	33.2	8.4
17	38.7	52.1	58.4	34.9	9.1
18	44.8	62.5	62.9	36.6	9.8
19	51.4	73.6	67.6	38.5	10.6
20	58.4	85.2	72.6	40.4	11.4
21	65.7	97.5	77.8	42.5	12.2
22	73.5	110.3	83.3	44.6	13.1
23	81.5	123.7	89.1	46.9	14.1
24	89.9	137.8	95.1	49.3	15.1
25	98.6	152.4	101.4	51.7	16.1
26	107.7	167.6	107.9	54.3	17.2
27	117.2	183.4	114.7	56.9	18.3
28	127.0	199.9	121.7	59.7	19.4
29	137.2	216.9	129.0	62.6	20.6
30	147.8	234.5	136.5	65.5	21.8

D.b.h. (inches)	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
Tree grade 2 2½ Logs					
13	21.9	21.2	63.9	44.8	7.4
14	27.6	31.2	67.6	45.7	8.1
15	33.7	41.9	71.5	46.6	8.9
16	40.2	53.3	76.7	47.7	9.7
17	47.1	65.5	80.1	48.8	10.6
18	54.4	78.5	84.8	49.9	11.6
19	62.2	92.1	89.8	51.2	12.5
20	69.3	106.5	95.1	52.5	13.6
21	78.9	121.7	100.6	53.8	14.7
22	87.9	137.6	106.4	55.2	15.8
23	97.3	154.2	112.5	56.7	17.0
24	107.1	171.5	118.8	58.3	18.3
25	117.4	189.6	125.4	59.9	19.6
26	128.1	208.5	132.3	61.6	21.0
27	139.1	228.1	139.4	63.4	22.4
28	150.6	248.4	146.9	65.2	23.9
29	162.6	269.4	154.6	67.1`	25.4
30	174.9	291.2	162.5	69.0	27.0
Tree grade 2 3 Logs					
18	65.0	94.4	106.8	63.3	13.3
19	72.8	110.7	112.0	63.9	14.5
20	82.2	127.8	117.6	64.5	15.8
21	92.0	145.9	123.4	65.1	17.1
22	102.3	164.8	129.5	65.8	18.5
23	113.1	184.6	135.9	66.6	20.0
24	124.5	205.3	142.5	67.3	21.6
25	136.2	226.9	149.5	68.1	23.1
26	148.4	249.3	156.7	68.9	26.5
27	161.2	272.7	164.2	69.8	26.5
28	174.4	296.9	172.0	70.7	28.3
29	188.1	322.0	180.1	71.6	30.2
30	202.2	347.9	188.5	72.6	32.1
31	216.8	374.8	197.2	73.5	34.1
32	231.9	402.5	206.1	74.6	36.2
33	247.5	431.1	215.3	75.6	38.3
34	263.6	460.6	224.8	76.7	40.5
35	280.2	491.0	234.6	77.8	42.7

D.b.h. (inches)	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
Tree grade3 1 Log					
10	3.1	—	4.7	13.9	9.1
11	3.1	2.1	9.4	15.4	9.9
12	3.4	7.0	14.5	17.2	10.8
13	4.4	12.3	20.1	19.1	11.7
14	5.4	18.0	26.1	21.1	12.7
15	6.5	24.2	32.6	23.3	13.8
16	7.7	30.8	39.5	25.7	15.0
Tree grade 3 1½ Logs					
10	2.0	—	6.7	23.6	17.9
11	2.1	1.9	11.4	25.3	19.0
12	3.2	6.9	16.7	27.2	20.3
13	4.6	12.3	22.3	29.2	21.7
14	6.1	18.2	28.5	31.4	23.3
15	7.8	24.5	35.0	33.8	24.9
16	9.4	32.2	42.1	36.3	26.6
17	11.3	38.3	49.5	39.0	28.5
18	13.3	45.9	57.5	41.9	30.5
19	15.3	54.0	65.9	44.9	32.5
20	17.5	62.4	74.7	48.1	34.7
21	19.8	71.3	84.0	51.4	37.0
22	22.1	80.6	93.7	55.0	39.4
23	24.7	90.4	103.9	58.6	42.0
24	27.2	100.6	114.6	62.5	44.6
25	30.0	111.2	125.7	66.5	47.4

D.b.h. (inches)	FAS + F1F + Selects	No. 1 Common	No. 2 Common	No. 3A Common	No. 3B Common
Tree grade 3 2 Logs					
10	2.0	—	8.7	33.3	26.6
11	2.5	1.8	13.5	35.2	28.1
12	3.5	6.8	18.8	37.2	29.9
13	4.9	12.4	24.6	39.4	31.7
14	6.9	18.3	30.8	41.7	33.8
15	9.0	24.7	37.4	44.3	25.9
16	11.3	31.5	44.6	47.0	38.3
17	13.6	38.8	52.2	49.9	40.7
18	15.8	46.5	60.2	52.9	43.4
19	18.8	54.7	67.8	56.2	46.1
20	21.6	63.3	77.7	59.6	49.0
21	24.6	72.3	87.1	63.2	52.1
22	27.7	81.8	97.0	67.0	55.3
23	31.03	91.7	107.3	70.9	58.7
24	34.3	102..1	118.1	75.0	62.2
25	37.8	112.9	129.4	79.3	65.9
Tree grade 3 2½ Logs					
14	7.7	18.4	33.1	52.0	44.3
15	10.2	24.9	39.9	54.7	47.0
16	13.0	31.9	47.1	57.6	49.9
17	15.9	39.3	54.8	60.7	53.0
18	19.0	47.1	62.9	64.0	56.3
19	22.2	55.4	71.6	67.5	59.7
20	25.7	64.2	80.7	71.1	63.4
21	29.3	73.3	90.2	75.0	67.2
22	23.2	83.0	100.2	79.0	71.2
23	37.2	93.1	110.7	83.2	75.5
24	41.3	103.6	121.7	83.2	75.5
25	45.7	114.6	133.1	92.2	84.4
Tree grade 3 3 Logs					
16	14.7	32.2	49.6	68.3	61.5
17	18.2	39.8	57.4	71.6	65.2
18	21.8	47.7	65.7	75.1	69.2
19	25.8	56.1	74.4	78.7	73.3
20	29.8	65.0	83.6	82.6	77.7
21	34.2	74.4	93.3	86.7	82.3
22	38.6	84.1	103.5	91.0	87.1
23	43.4	94.4	114.1	95.5	92.2
24	48.3	105.1	125.2	100.1	97.5
25	53.5	116.3	136.8	105.0	103.0

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Chapter 8.

Hardwood Logs and Trees for Fine Face Veneer

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Chapter 8.
Hardwood Logs and Trees for Fine Face Veneer

Veneering is a fascinating industry, and successful marketing of veneer quality logs or trees depends upon the seller knowing what constitutes veneer quality logs and understanding the marketing process. Most landowners and many individuals who market timber, however, are not aware of the basic requirements for trees or logs to be considered "face veneer quality." In some instances, sellers do not understand why some logs or trees are not acceptable, others are worth little more than good sawlogs, and still others command a substantial premium. Buyers likely will not spend much time visiting tree or log offerings if they detect the seller does not understand the quality levels needed, and the material is misrepresented due to the seller's lack of knowledge. This chapter provides insight into what constitutes a veneer quality log.

Value of Veneer Logs

Hardwood veneer logs command a premium price compared with sawlogs and other fiber products of the forest. As an example, Hoover and Preston (2009) report that the prices paid for the highest quality delivered white oak sawlogs in Indiana averaged $665 per thousand board feet, Doyle Scale, in 2009. In the same report, several diameter categories and two quality classifications are used to report delivered veneer log prices. For the lower-quality classification and the smallest diameter-inside-bark (d.i.b.) class (13-14 inches), the price for white oak-veneer logs was $1130 per MBF, but it increased to nearly $3,500 per MBF for 28-inch or larger d.i.b. logs of the highest quality. Thus, it usually makes good economic sense to market high-quality logs of the appropriate species to the face veneer industry rather than process them for the green wholesale lumber market.

Attributes of Veneer

In addition to the increased economic value, the use of hardwood timber for veneer has other positive attributes. Processing a log into veneer ranging from 1/36 to 1/50 inch in thickness greatly extends the resource compared with cutting standard 4/4 lumber, which is somewhat over 1 inch thick. Veneering also allows for the production of matched grain patterns, inlays, and other artistic designs. Veneer can now be wrapped around profiles made of reconstituted wood, thus reducing the need for long, thick clear molding blanks. Veneer can also be formed over machined panels of reconstituted products for raised panels in cabinet doors. Veneered panels or parts combined with solid wood trim help make wood furniture more affordable.

Slicing Methods

In 2009 the hardwood face veneer industry was composed of only 33 slicing operations in North America. Within this industry there are no known scientific studies; and very few current publications have attempted to define log and veneer quality from an appearance aspect. These companies purchase the quality of logs as dictated by their customers, cut them into flitches (log halves or quarters), and slice them into fancy face veneers (Figures 8-1 and 8-2). Rotary cut veneer constitutes a different industry, for the most part.

Basic Requirements for All Species

Any tree or log intended for the face veneer industry must meet certain basic requirements. In addition, there are specific features that are unique to each species. Bark surface irregularities, such as overgrown branch stubs, insect damage, and old mechanical damage, will likely disqualify the log as potential veneer. In general, no surface indicators of interior defects are present in a quality veneer tree or log.

Veneer logs or the trees from which the logs are produced should be straight and well rounded. Bow and crook in a log creates an esthetic problem by causing the cathedral pattern in flat-sliced veneer to run in and out of the sheet. Tension wood is frequently present in leaning trees, and buckle can occur when the veneer is dried. Logs that are not well rounded or have an off-center pith produce veneer that has a less-than-desirable grain pattern and is likely to result in veneer buckle (Figure 8-3).

Ideally, growth rates (and thus ring width) need to be uniform across the entire cross section of the log. Thinning stands to encourage faster growth of potential veneer trees is not desirable. Growth rates of six to nine rings per

Figure 8-1. Veneer slicing operation showing the flitch or log half (back and right) being moved up and down against a stationary knife and the individual veneer sheets being stacked in the order that they are sliced.

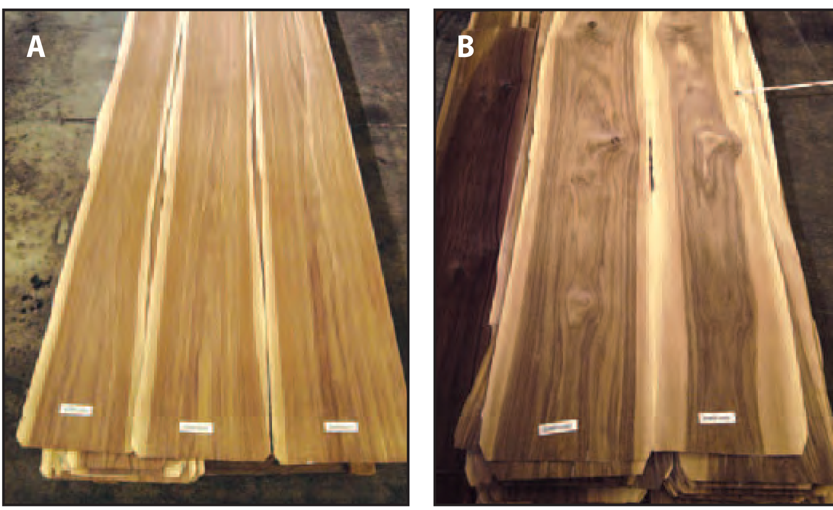

Figure 8-2. During processing for the domestic market, three sample sheets are taken from each flitch. These sample sheets are shown to potential buyers. In A, the sheet on the left is from the outside of the log, and the one on the right is from near the heart. Note the absence of defects, excellent color and uniformity, and cathedral patterns in the first two sheets on the left of this high quality flitch. In B, a much lower quality flitch with an irregular color, knots, and excessive sapwood is shown. Each flitch is bar coded as to origin, log buyer, square footage, grade, and value.

Figure 8-3. Buckle or irregular surface in walnut veneer.

inch are usually acceptable. Trees with fast growth or very slow growth rates are not preferred.

Veneer quality trees should be healthy, well-formed trees on good, well-drained timber sites. A past history of grazing, fire, or both reduces the quality and value of any potential veneer trees.

Most hardwood species grow over a wide geographic range. As such, climatic conditions, soil types, elevations, insect and disease potential, and other factors vary. Within the geographic range of each species, there are certain specific areas where buyers believe the highest quality trees generally originate. With the exception of pecan, most veneer quality timber is cut in the upper Midwest, Lake States, and Northeast section of the country. Buyers indicate that high-quality trees can come from other regions as well, but the probability is much lower.

The markets for flat-sliced veneer vary over time. Several years ago walnut was extremely popular, only to be replaced by white oak, and then cherry and maple. Now, some 30 to 40 years later, walnut is regaining popularity. Each company may have its own markets and thus affect which species they prefer to slice; however, virtually every species is sliced at one time or another.

Specific Requirements

Cherry

Cherry is currently one of the most valuable hardwood veneer species and an excellent example of the importance of geographic location. Figure 8-4 shows two 19-inch d.i.b. by 10-foot logs, each containing 141 board feet, Doyle Scale. The log on the left is from Indiana and has an estimated value of $300; the one on the right is from Pennsylvania and is valued at about $1,200. The Indiana log has irregular, darker reddish color and numerous gum spots. The Pennsylvania log has a lighter pink color and is much less prone to gum spots. On the other hand, walnut from Indiana and Iowa would likely command a premium over that from other states, and hard maple from Michigan and the Northeast would be preferred.

Figure 8-4. Geographic origin can be very important in determining veneer log value. The cherry log on the left is from Indiana and has an estimated value of about $300, while the one on the right is from Pennsylvania and has a value of $1,200. Both are the same diameter and length.

Gum in cherry (Figure 8-5) is probably the most serious defect affecting veneer quality. Gum not only disfigures the veneer, but clear finishes tend not to bridge over the spots. In addition to small spots, gum can be found in large patches, probably as a result of wounding, or even in a ring completely circling the stem. The presence of gum cannot be detected in standing trees unless a surface residue happens to be present. Buyers prefer to purchase cherry timber in those parts of the country where gum spots are least likely to be found or are at least fewer in number. These locations include the higher elevations in Pennsylvania and parts of New York and West Virginia. Cherry grown in other parts of the country almost always has some gum deposits present.

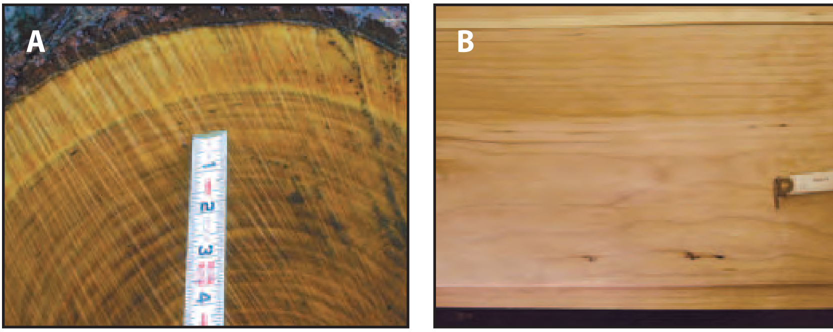

Figure 8-5. The small dark spots on the end of this cherry log are gum spots. They disfigure the otherwise clear veneer shown to the right.

Most gum deposits are caused by at least two different groups of insects—the peach bark borer and cambium miners. The most common insect is the peach bark beetle. These beetles occur throughout the range of cherry and sometimes actually kill relatively large trees. The beetle can be found in the gum exuded from the trees. The beetles attack the cambium layer, and the gum is formed in response to the insect. Peach bark beetles may build up in large numbers in tree tops after a timber harvest. The beetles then emerge and attack the residual crop trees, causing permanent gum spots in the main tree bole. Therefore, cherry veneer that is relatively free of gum spots from peach bark beetles comes from undisturbed stands that also have had little natural mortality or damage.

Cambium miners can also cause gum deposits in cherry. By carving its galleries, the cambium miner destroys a portion of the cambium, which later becomes covered over by healthy cambium growth and wood. These galleries consist of damaged parenchyma cells and insect feces. The cell damage can, but does not always, result in the production of gum. The parenchyma flecks or damaged parenchyma cells are seldom a defect in themselves. Parenchyma cells are just one type of several different cell types that make up the wood of hardwood trees. These cells are generally used for food storage and are relatively thin-walled compared with wood fibers.

“Tear drops” or brown oval to round spots (Figure 8-6) can also be found in the ends of cut cherry logs. These tear drops cause a brownish streak in the veneer itself and are objectionable.

A light reddish brown heartwood color is preferred in cherry. A dark red, variable color, or a greenish cast that can develop at the heartwood-sapwood interface and wide sapwood are objectionable.

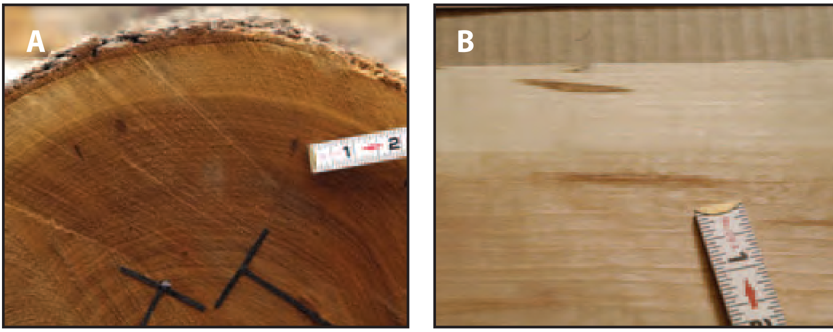

Figure 8-6. Cherry log showing dark spots or "tear drop" (A), which causes a brown streak in the veneer sheet (B).

Walnut

Black walnut was the premier domestic North American species at the beginning of the sliced veneer industry. Due to increased costs, overcutting, and consumer preference, its popularity declined in the 1980s. Now, it is once again in demand, and the availability of logs is also good.

Total color as well as uniformity of color are important in walnut. The best colored walnut is light greenish or mint green when first cut. As the wood is exposed to the air, it turns a gray or mousy brown (Figure 8-2A), which is considered ideal. Unfortunately, the color can vary, or it can lack uniformity. Muddy walnut, which is dark or splotchy, is objectionable. The color of walnut can also be affected by manufacturing variables, such as cooking or vat schedules and processing time before drying.

Bird peck, also called worm by the veneer industry, is an important defect in walnut (Figure 8-7). Yellow-bellied sapsuckers probably cause most of the bird peck. These sapsuckers breed in the upper Great Lakes region during the summer and overwinter farther south or below U.S. Highway 40 in Indiana, Illinois, and Missouri. Walnut veneer log buyers find that there is less peck in the region between the summer breeding and over-wintering grounds. It is generally believed that the bird pecks a hole to cause the flow of sap, which attracts insects. The peck mark penetrates the bark and cambium. It sometimes penetrates the wood—but not deeply. The peck marks are often in horizontal rows going around the tree. A small hole plus stain or flagging in the veneer can result.

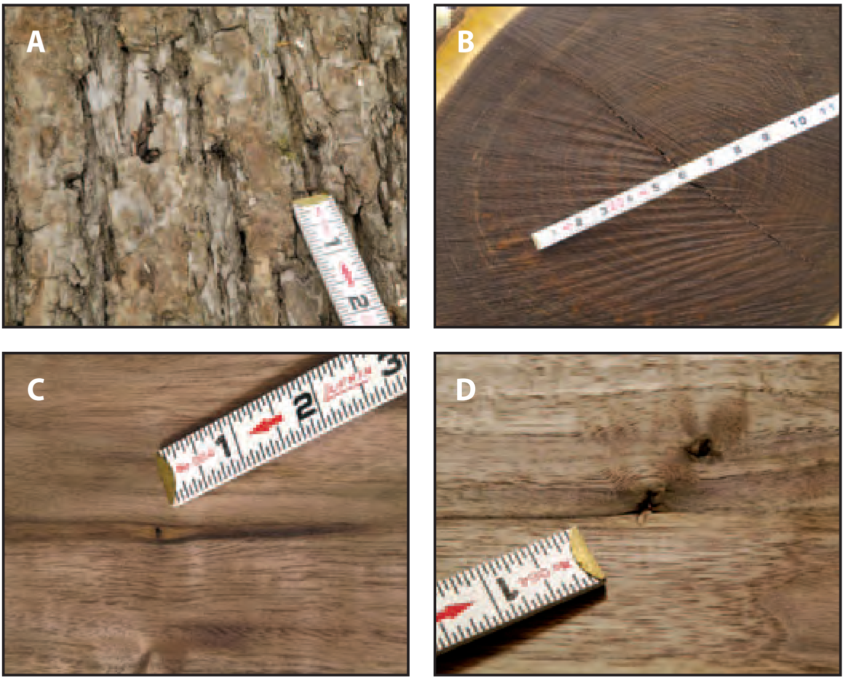

Figure 8-7. Bird peck or worm is a serious problem in walnut. Photo A shows peck marks on the bark. B shows the damage confined to certain rings in the end of a log. C shows a "worm hole" or more likely the slight indentation of the peck mark into the wood and associated discoloration. D shows two peck marks with included bark.

Like bird peck, pin knots (Figure 8-8) can be hard to recognize in standing walnut trees, especially when only a few are present. These defects are the result of suppressed dormant buds that persist for many years as a bud trace or pin knot. As the name implies, the buds may not actually break through the bark, so in some instances they cannot be easily detected. Sometimes, however, due to a stimulus such as thinning and increased light, the bud may sprout. The sprout may develop into a small limb that often dies, but normally the bud trace continues to form. Pin knots are best observed on the ends of the log after the tree is cut or where the bark has peeled loose; they appear as sharp spikes. On flat-sliced veneer, they appear as pin knots, but on quartered surfaces they appear as a streak or "spike" across the sheet of veneer.

Growth rate is important in walnut. The industry uses the word "texture" to define growth rate. Soft texture refers to a slow growth rate, whereas hard texture refers to a fast growth rate. Buyers often find eight to nine rings per inch of diameter the most desirable in walnut.

Figure 8-8. Pin knots in black walnut are another troublesome defect. Photo A shows a pin knot or cluster of knots in the bark. B shows the same type of defect with the bark removed. C shows a pin knot on the end of a log. Finally, D shows a pin knot on a flat slice of veneer and photo E shows the flash or grain deviation for a pin knot on a quartered surface.

Fast-growth trees also tend to have a wide sapwood zone, which is the light-colored wood to the outside of the darker heartwood (Figure 8-9). Sapwood is usually discarded in high quality walnut veneer. Deeply furrowed bark that is not patchy tends to be faster growth and have a wide ring of sapwood. Figure 8-10 shows the bark on slow-growth and moderate-growth trees.

Figure 8-9. Fast growth trees tend to have wide sapwood (left), whereas slow growth trees tend to have narrow sapwood (right).

Figure 8-10. Bark of slow-growth (A) and moderate-growth (B) walnut trees.

White Oak

White oak is another very important veneer species, particularly in the export market. True white oak, especially trees with large patches of flaky bark in the upper portions, or "forked leaf" white oak, are the most desirable in the white oak group. Chinkapin oak sometimes is used, but the resulting veneer has a greenish to brownish cast. Bur oak is also used, but careful selection is required to avoid its more common dark brown color and possible "scalloped" appearance of the growth rings, which can be seen on the ends of the logs. The scallops result in shiny spots on the veneer sheets.

Color in white oak, like in all veneer species, is critical. Current markets prefer a very light, uniform-colored white oak. Contrast in color and dark colors are objectionable (Figure 8-11). Obviously, color cannot be judged in standing trees. Buyers do, however, develop preferences for certain geographical areas and site characteristics because their past cutting experience has taught them that those areas produce the desired color and quality of veneer. Also, very old and slow-growth white oak trees tend to be pink in the center and brown towards the outside. Mineral streaks are also a common defect (Figure 8-12).

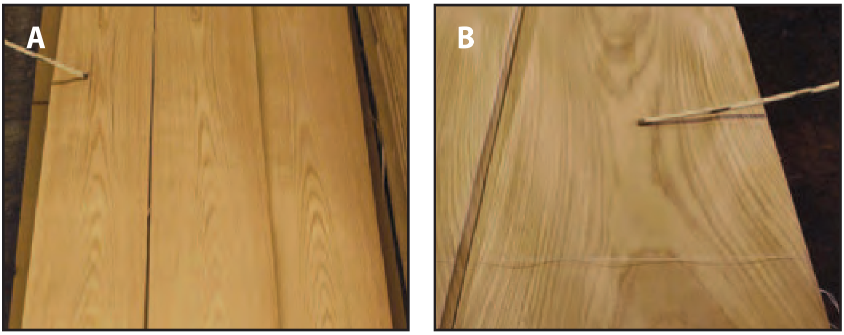

Figure 8-11. Note the perfect light color and centered uniform cathedral of the white oak flitch in (A) compared with the coarse, irregular sheet in B.

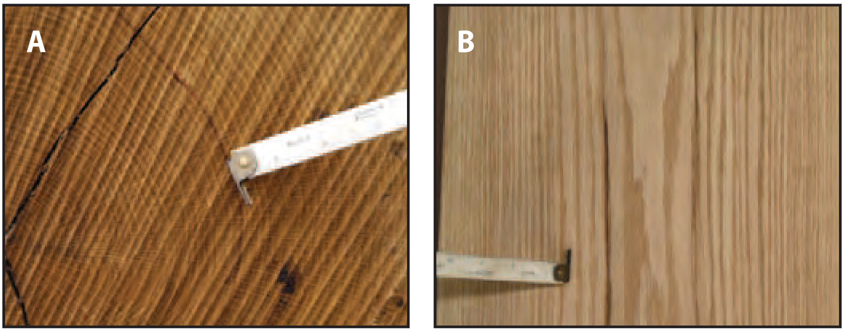

Figure 8-12. Mineral streak following a growth ring on the end of a white oak log (A) and appearance of mineral streak in white oak veneer (B).

Epicormic branching or sprouting from latent buds is a common defect in white oak (Figure 8-13). Several buds may form a cluster. The resulting veneer will have a small pin knot or cluster of pin knots.

Stump worms and the surrounding dark flagging or mineral stain is associated with white oak grown in areas that are poorly drained or have been pasture. This defect is generally concentrated in the bottom 2 feet of the butt log, and it is often impossible to detect until the log is cut (Figure 8-14).

A number of different species of borers can affect white oak. White oak borers attack trees less than about 8 inches in diameter (Figure 8-15). Thus, they are generally not detectable in veneer-sized trees, nor do they damage the outer more valuable portion of the tree. Other borer species also attack white oak, but usually the damage is restricted to declining trees. Borer damage is difficult to see in standing trees. Consequently, when it is found, buyers will assume that more damage is present than what can be seen and will severely degrade the tree.

Some large white oak trees have a "bulge" near their base that resembles an old time soda bottle (Figure 8-16). This is not considered a defect for veneer logs.

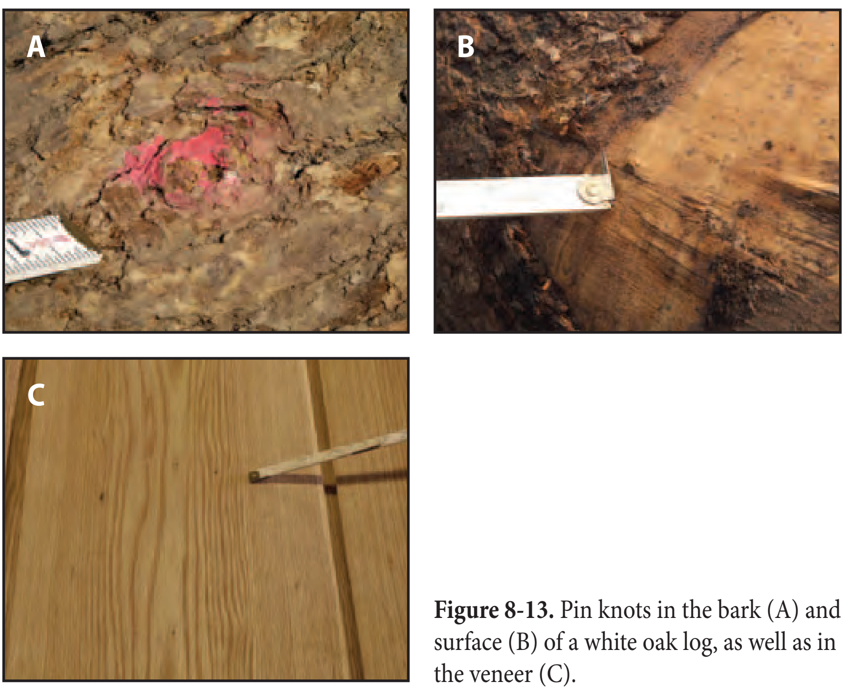

Figure 8-13. Pin knots in the bark (A) and surface (B) of a white oak log, as well as in the veneer (C).

Figure 8-14. Stump worms and associated stain in white oak.

Figure 8-15. Borer damage in the butt of white oak. This log also exhibits slow and fast growth rate, ring shake, and very poor color.

Figure 8-16. Bulges at the base of large white oak, also called "soda bottle effect," are not considered defects.

Red Oak

Red oak is also commonly used for veneer. Color and mineral stain are two of the most common problems associated with red oak veneer, in addition to obvious defects, such as overgrown limbs, borers, and wounds. The premium material demanded by the market is a very light-colored veneer. Mineral stain is common in red oak and may take the form of isolated spots or follow along the annual rings (Figure 8-17). It is objectionable in most finished products. In addition, the wood often tends to split or break apart when mineral stain is present.

Mineral-free, light-colored red oak is more commonly found in certain regions of the country, such as lower New York, Pennsylvania, northern Indiana, and southern Michigan. Therefore, it would seem that site or soil might also be a contributing factor. Regardless of the cause, the presence of mineral in a particular area will result in veneer log buyers offering reduced prices for standing trees of potential veneer quality. In addition to the mineral stain, Figure 8-17A shows the dark red color characteristic of black oak.

Three major types of borers attack red oak. Borer holes can range from 1/100 inch to 1½ inches in diameter. Smaller borer damage is nearly impossible to detect. Larger borer holes that have healed over can be seen by experienced graders, and if the holes are "sap wet" they are easily detected. Carpenter ants often enter trees through large borer holes and keep the hole open and further

Figure 8-17. Examples of mineral stain in the end of two different red oak logs (A and B) and in the veneer (C).

damage the tree. Old trees or stressed trees are more prone to damage (Figure 8-18). Large hole borer damage is usually accompanied by mineral stain. Since most borer damage is hard to detect, buyers will be very cautious if any borer holes are found.

Bars on the bark of a red oak log may indicate a defect that goes all of the way to the heart; however, buyers have indicated that in some regions no defect results.

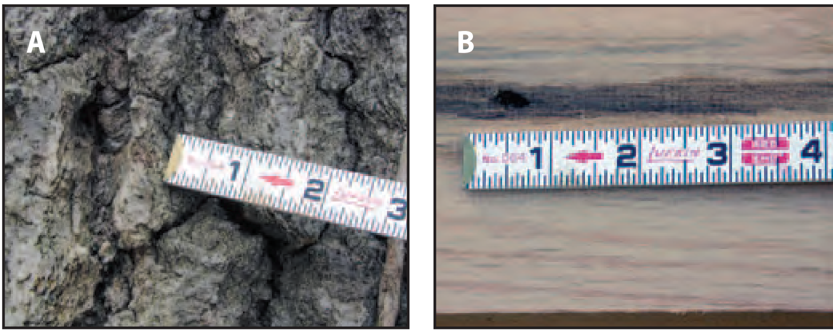

Figure 8-18. Healed-over borer hole in red oak (A) and resulting damage with mineral stain in wood (B).

Sugar Maple

Sugar or hard maple is prized for its white sapwood (Figure 8-19). The whitest maple is reported from Michigan and the Northeast; however, maple from other regions of the country is also used for veneer. The color of maple sapwood is also affected by the season of the year and length of log storage, as well as by processing variables. From a uniform color perspective, it is a very difficult wood to process.

The heartwood in sugar maple is brown, but it is considered “false” heartwood. False heartwood is normally caused by a wound or opening in the bark of the tree, such as a broken or dead limb stub.

The extent and intensity of false heartwood depends on the vigor of the tree, the severity of the wound, and the time that the wound is open. Discoloration continues to advance as long as the wound is open, and false heartwood is often irregularly formed throughout the stem. If the wound heals, the entire cylinder of wood present when the tree was wounded may not become discolored. The cambium continues to form new growth rings that are free of discoloration. Thus, vigorous fast-growing trees with few branch stubs or wounds will produce the widest sapwood.

Mineral streaks ranging from 1 inch to several feet long are a common defect in maple and result from wounds such as broken or dead branches, bird peck, and mechanical damage (Figure 8-20). After a tree is wounded, the living cells in the wood surrounding the injury react by forming materials that inhibit

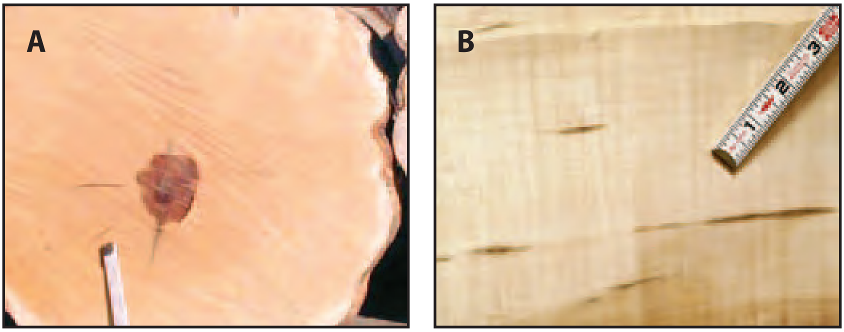

Figure 8-19. The end of a hard maple log shows a very small heartwood, which is desirable. The log end also shows two or more "black lines" or mineral streaks in the lower left quadrant. (B) These black lines result in streaks in the veneer. (C) The veneer from a different log shows the objectionable brown heartwood in contrast to the white sapwood.

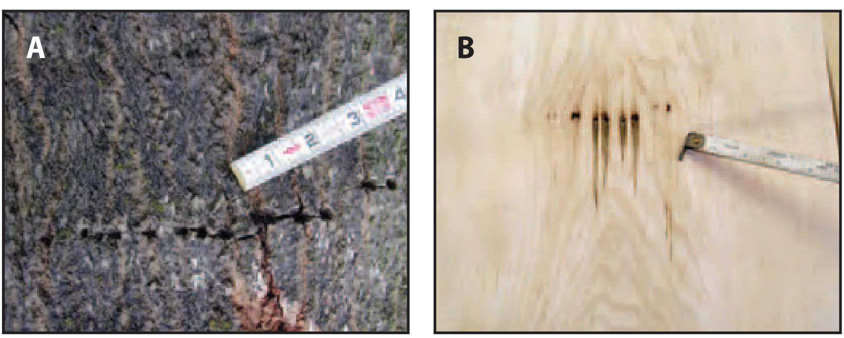

Figure 8-20. Bird peck forms a horizontal row on a hard maple tree (A), resulting in a defect in the veneer (B).

infection. These materials are deposited in the cells and may appear green initially but later turn different shades of brown. High percentages of mineral, especially potassium, are found in the cells. Some of the wood is very hard and difficult to slice, and can damage veneer knives.

Sugar streaks or flecks, narrow brown marks about ¼- to 1-inch long, can also occur in sugar maple (Figure 8-21). The streaks are caused by cambium miners. Cambium miners attack and disrupt the cambium or growth layer of the tree. The tree plugs the gap in response, but the grain pattern has been disrupted. Cambium miners may bore from the soil level all the way to the top of the tree before they exit.

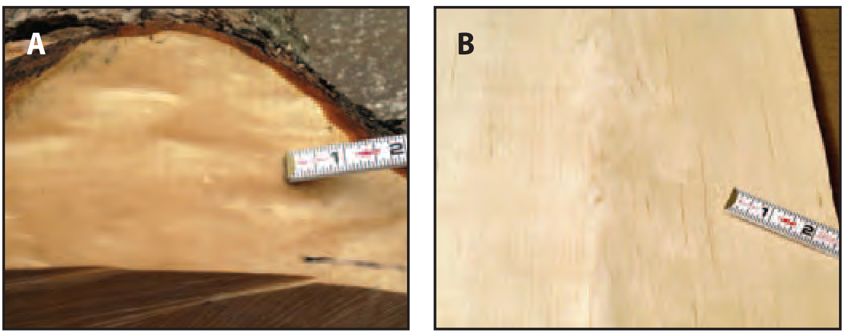

Figure 8-21. This undercut on a sugar maple log shows light brown spots (A) that appear as sugar streaks in the veneer (B).

White Ash

For white ash veneer; the white sapwood is preferred to the heartwood. Like hard maple, white ash has a false brown heartwood. With white ash it is not uncommon for the heartwood to be very small at the butt of the tree but then expand to a significant portion of the tree diameter further up the stem.

Unfortunately, the extent of objectionable heartwood in the top of the butt log is not known until after it is cross cut, often to a shorter length veneer log rather than a longer sawlog.

Glass worms, “turkey tracks” or “worm tracks,” also occur in white ash (Figure 8-22). This zig-zag pattern of light-colored wood is caused by the cambium miner. In some cases the wood associated with the glass worm damage turns nearly black. The characteristic is objectionable because it will not accept stain and finish like normal ash. Turkey tracks are likely caused by a cambium miner and are similar to sugar streaks in hard maple (Figure 8-21B).

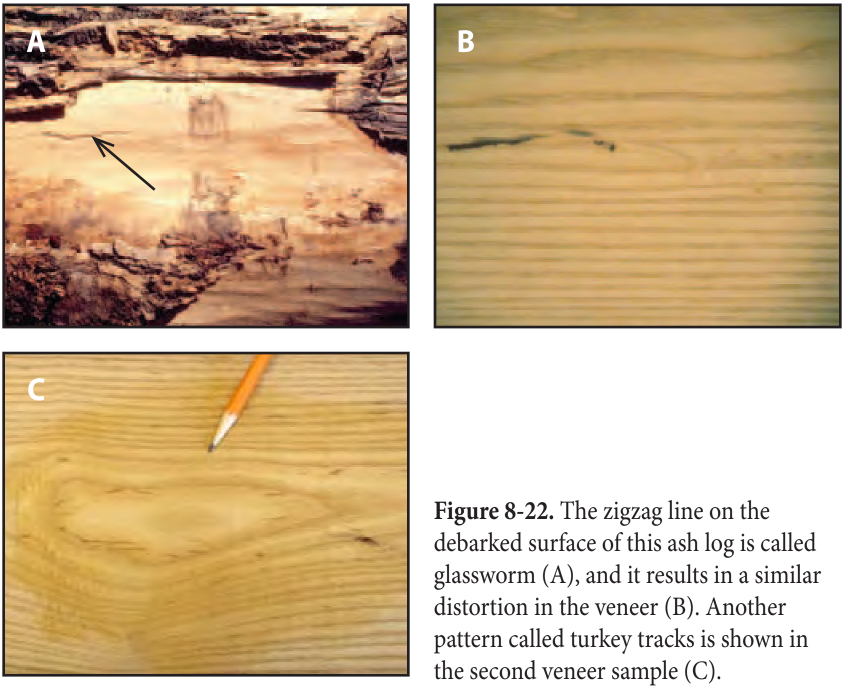

Figure 8-22. The zigzag line on the debarked surface of this ash log is called glassworm (A), and it results in a similar distortion in the veneer (B). Another pattern called turkey tracks is shown in the second veneer sample (C).

Other Species

Several other hardwood species are processed into veneer at various times. In terms of volume and value, they are relatively minor species and thus not included in this limited discussion.

Marketing Veneer Logs

One advantage to marketing logs suitable for veneer is that it returns quick cash. Buying timber can require a substantial capital outlay. Selling the veneer logs can return at least a portion of that outlay within a very short time period. Selling wholesale green lumber will take somewhat longer, while selling wholesale kiln-dried lumber and particularly kiln-dried retail lumber may take at least 2 months.

Veneer log buyers come from at least three different types of companies. First, there are those manufacturers who specialized in veneer alone. These manufacturers maintain a staff of buyers who purchase cut logs and usually standing timber as well. Their buyers may be located throughout the hardwood region in response to species demand. A list of mills and others associated with manufacturing veneer are listed by the Hardwood Plywood and Veneer Association (HPVA). Be sure to look for those who manufacture veneer, not veneer marketers or users of the product.

Second, sawmills in the hardwood region also represent an important source of veneer logs. Since veneer-quality trees are normally scattered, sawmills will accumulate logs from their own purchases or from purchased logs delivered by independent loggers. When a quantity of logs is accumulated, the logs are laid out so each one can be carefully examined. Selected log buyers are invited to examine the logs and to bid on the offering. Depending on the circumstances, some logs may be rejected because they do not meet the quality standards of the buyers. Others may be cut to different lengths and even portions discarded so the log can qualify as veneer.

Third, independent log buyers and loggers may also specialize in veneer logs. These individuals accumulate logs and offer them to buyers.

In a timber sale with a large quantity of veneer trees, sawmill operators and a veneer log buyer may work together. The veneer buyer determines which trees and portions thereof are veneer quality and calculates a bid. The bid is combined with an offer for the remainder of the trees and tops of veneer quality trees to be sold and submitted to the landowner. This procedure can make the two companies more competitive in respect to other bidders on the sale.

Veneer log buyers and sawmills or independent suppliers often develop a mutual sense of trust. Buyers' time and fair prices are important. When buyers are called to a location, they expect to find what they were offered. Likewise, the supplier expects a fair price without too many logs being rejected or cut back. Violation of good business practices and common courtesy will likely terminate a relationship quickly.

When a veneer buyer purchases a parcel of logs, consecutively numbered hard plastic tags are placed on the end of each log. This number stays with the veneer produced from the log until the veneer is priced or sold. At this point, the value of the veneer is compared with the log, manufacturing, and other related costs, to determine if the company made money. It is this recordkeeping process that helps buyers to determine which trees or logs they can use from which locations and how much to pay. The cost to manufacture veneer on a square foot basis can easily exceed the value of the veneer if the buyer is not careful. Therefore, marginal logs are usually rejected before they reach the mill.

Unless your trees or logs are truly exceptional, it can be difficult to market a limited number on an irregular basis, especially to a veneer company. Travel time, inspection time, and transportation are all real costs, and it is much easier to distribute these purchasing costs over a quantity of at least a semi-truck load of logs. Logs cut during cold weather will not deteriorate as rapidly as those cut in summer and are preferred.

Smaller producers are advised to develop a relationship with local sawmills or independent log dealers who already accumulate veneer logs. These individuals can help you identify potential veneer trees or logs and perhaps purchase them from you or help market them to their contacts. Each buyer may want to clip the end of a log, so leave a little extra over length. Removing just a half-inch or so will provide a fresh end surface. When the fresh cut log end is sprayed with water, small defects that affect veneer quality tend to stand out. Check with your district or state forester to locate companies that purchase veneer quality timber and logs.

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For More Information

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Chapter 9.

Bucking, Sawing, Edging, and Trimming Techniques

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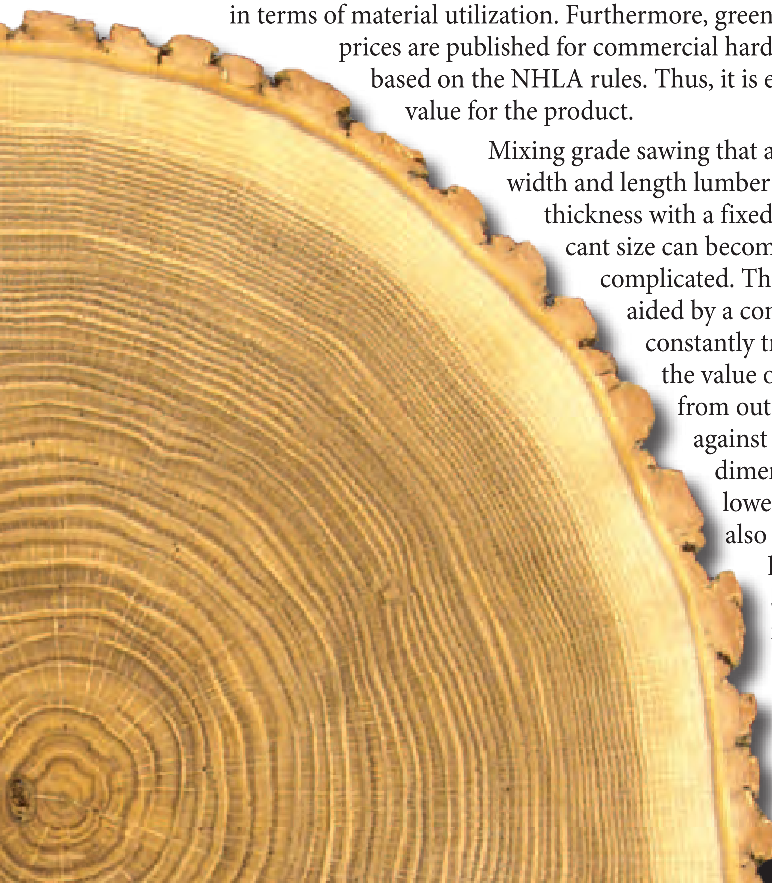
Chapter 9.
Bucking, Sawing, Edging, and Trimming Techniques

When cutting tree length stems into logs, sawing logs into lumber, or edging and trimming boards from the sawmill itself, the end product must be known if utilization and value are to be maximized. The process becomes relatively simple when sawing general construction lumber: only certain length logs and certain cross-sectional dimensions of the lumber product are acceptable. It is up to the log bucker and the sawyer to make certain that they maximize yield and minimize defects.

The process becomes more complicated—especially when sawing hardwoods to maximize grade yield (grade sawing)—because a rigid set of rules applies for each lumber grade. Even if the lumber is not sold based on National Hardwood Lumber Association (NHLA 2011) grades, they are still good rules to follow if the lumber is intended to be processed eventually for furniture, cabinets, millwork, or similar items. The rules just make good sense in terms of material utilization. Furthermore, green and kiln dried prices are published for commercial hardwood species based on the NHLA rules. Thus, it is easy to establish a value for the product.



Mixing grade sawing that allows random width and length lumber of a specified thickness with a fixed heart center or cant size can become very complicated. The sawyer, if not aided by a computer, is constantly trying to balance the value of grade boards from outside the log, against the fixed heart dimension that may be lower in value. It is also important that log producers and sawyers have as many markets as possible to utilize different log lengths, board sizes, and quality. Varied markets help increase utilization and value.

This chapter is written using the NHLA rules as a basis. These grading rules for factory lumber determine how the traditional industry saws, edges, trims, and sells its product. When trees are bucked into logs of different length, the lumber grade yield can be improved by the placement of major defects in the resulting logs. Also, the placement of defects and the amount of wane left on lumber during the manufacturing process will affect the grade. The reader will learn how to maximize lumber grade yield throughout the process. The reader should review the chapter entitled "Hardwood Lumber Pricing and Grading," to better understand the rules.

Bucking Trees into Logs

Bucking Decisions

Bucking trees into logs is perhaps the one process that is the least automated, regardless of the size of the company, and it involves considerable judgment. For many tree-length stems, many of the bucking decisions will be obvious due to the geometry of the stem or presence of major defects.

Begin the process by visually sizing up the entire tree stem. First, any bow needs to be removed. Next, the stem needs to be cut at any major crotches, holes, or other major defects.

The objective at this point is to have straight, sawable sections of the tree stem visualized (Figure 9-1). Now, within each of these sections, logs must be bucked to meet end-use requirements. Grade logs will be 8 through 16 feet plus trim allowance—usually 2 to 3 inches. Railroad tie logs are often 8 feet 6 inches, 8 feet or 9 feet plus trim allowances. Switch ties are another option. Timbers normally have specified lengths. It is important that the length of logs and overlength be carefully measured and bucked. Grade logs cut just short of the next foot must be cut back to the nearest whole foot plus trim allowance.

Veneer logs are an exception, and if they are to be produced substantial experience is needed in what length to cut. Many producers cut the stem long enough for a veneer log of some length, as well as a grade sawlog from further up the stem. An experienced buyer is then allowed to make a decision as to the length of the usable portion for veneer.

Minimum Sizes for F1F and Better, and Selects Lumber

Before proper cutting decisions can be made from bucking through trimming, it is important to understand the minimum requirements for the top grade of lumber to be sold.

When sawing for FAS or FAS One Face (F1F) lumber, the sawyer opens each log face to the minimum 6-inch width required for these grades. Figure 9-2

Figure 9-1. For these tree length stems, consideration must be given before bucking to producing relatively straight logs, with major defects positioned to maximize lumber grade yield.

shows the clear lengths needed or defective "feet to lose" in order for a 6-inch-wide board to grade FAS. For 6-inch wide lumber, these lengths must be contiguous through 14 feet. A 16-foot length will allow two cuts, each at least 5 feet long but totaling 13⅓ feet. As the sawyer cuts deeper, the boards become wider. Wider boards allow more cuttings thus making it easier to grade FAS. As the sawyer cuts deeper, however, the probability of more defects showing up, especially those that were not visible on the surface, greatly increases. Thus, for average timber where only a few high-grade boards are expected from each log face, it is probably best to base log cutting length decisions on a 6-inch wide board.

The production of Selects lumber is becoming more commonplace, especially in the white woods and higher valued species. The minimum size board is only 4 inches by 6 feet or 2 board feet. If selling Selects lumber is possible, operators should study the rules carefully. The increased volume of lumber gained by producing Selects compared with F1F and Better, the cost of handling small pieces, and total lumber value must all be factored together in making a decision.

Clear lengths needed and board length	Feet to lose
6⅔ feet needed Board length 8 feet	1⅓ feet
8⅓ feet needed Board length 10 feet	1⅔ feet
10 feet needed Board length 12 feet	2 feet
11⅔ feet needed Board length 14 feet	2⅓ feet
13⅓ feet needed Board length 16 feet	2⅔ feet

Figure 9-2. When sawing logs for FAS lumber, this figure shows the length of clear cuttings needed or the amount of defective material that can be lost based on the National Hardwood Lumber Association (2011) hardwood grading rules for a 6-inch wide board. An additional cut for boards with 6 to 15 feet of surface measure is not considered. This rule allows two cuttings in the 12- and 14-foot lengths, and three cuttings in the 16-foot length, providing increased yield can be obtained from the board. Thus, in longer logs, defects can be placed in the middle as well as at ends of the logs.

Dollar Value of Lumber Bucking Decisions

Following are three examples of how bucking decisions can affect the value of lumber produced from a tree stem. In order to place dollar values on different bucking options, the resulting logs were graded using the Forest Service hardwood log grading system and lumber grade yields (Hanks and others 1980, Rast and others 1973). The grade yields are given in percentages. Each log was scaled using the Doyle Rule, and 20 percent was added for overrun. The red oak lumber values used are as follows:

Selects and Better	$1,200/MBF
No. 1 Common	$765/MBF
No. 2 Common	$525/MBF
No. 3A Common	$440/MBF
Other	$250/MBF

Example 1. Placing defects at the ends of logs

Figure 9-3 shows one face of a tree stem with two different bucking options analyzed. The difference in lumber value between the two options is about $26 (Table 9-1). How can just two quick cuts with a chainsaw make such a difference?

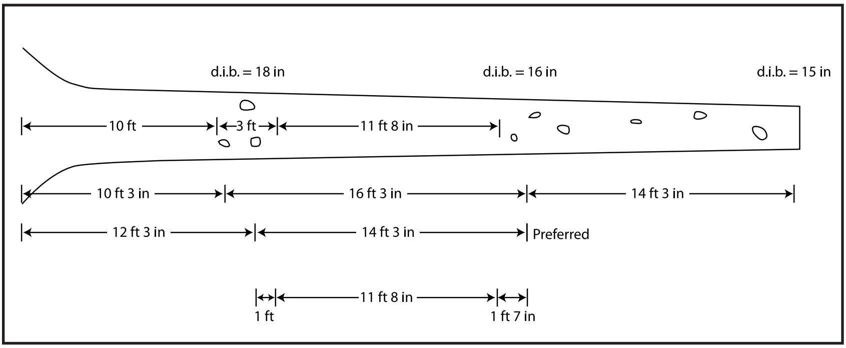


Figure 9-3. Using the preferred solution (option 2) for this tree stem with defects at the end of a 12-foot butt log increased the lumber value from $333 to $360.

Table 9-1. Estimated lumber value in dollars for three logs bucked at different points for the same northern red oak stem illustrated in Figure 9-3

		Option 1	Option 2	
Butt log		$133	$159	
Second log		$129	$129	
Third log		$72	$72	
	Total	$334	$360	
	difference			$26

Figure 9-3, option 1, and Table 9-1 show that an 18-inch-diameter inside bark (d.i.b.), clear or Forest Service grade F1 butt log could be cut at 10 feet with an estimated lumber value of $133. The second log is then likely to be 16 inches d.i.b. and cut at 16 feet or shorter. If cut at an unlikely 14⅔ feet in length (3 feet of defective material plus 11 feet 8 inches of clear length), the log will barely grade a Forest Service grade F1 and yield $129 in lumber value. A short piece (1 foot 7 inches) from the top of the second log ends up in the pallet grade top log. If the second log is cut at 16 feet, it will grade as Forest Service grade F2; because of increased volume, it will again yield $129 in lumber value. For a 16 foot 6 inch wide FAS board, 13⅓ feet are required to be clear. The log will not yield this length. For a 14 foot 6 inch wide FAS board, 11⅔ feet are required to be clear. If the log is cut with 8 inches of over-length and the board properly end-trimmed (an unlikely set of circumstances), the mill might produce the FAS board. It is more likely that the board will need to be cut back, with resulting volume loss, to yield FAS. The third log is pallet grade stock and will yield $72.00 in value.

In Figure 9-3, option 2 shows the second and preferred way to buck the two grade logs. A 12 foot 3 inch butt log could be cut with defects on the top end and produce an estimated lumber value of $159. If the second log is cut 14 feet 3 inches in length leaving limited defects on each end, it will produce lumber valued at $129. There should be no problem in getting an FAS board from the second log produced in this fashion. Both logs will grade as Forest Service grade F1. This combination produces an additional $26 in lumber value and maximizes the volume of grade lumber produced, as compared with the first and probably most common option where a clear butt log is produced.

The increase in lumber value clearly results from placing the knotty material at the ends of the clear wood and increasing the volume in the butt log.

The lumber grades allow for a certain portion of each board to contain nonclear or defective wood. Producing a 12-foot butt log allows the mill the opportunity to produce at least one top grade board that contains as much nonclear wood as possible. If the log face does not cut as expected, the mill still has the opportunity to cut the 12-foot piece back to a 10-foot board.

If the 3 feet of knotty material between the butt log and the second log is to be utilized, it is unlikely that the second log can be made to produce a 6-inch wide FAS board, unless a portion of the defective material is included in the butt log, or is discarded, or more of the second log can be included in the pallet log. The third log is pallet stock, thus its value does not change.

Example 2. Increasing log length

Figure 9-4 shows a second example of how seemingly minor differences in bucking decisions can make important differences in the total value of the lumber produced. This example is for a somewhat smaller stem with numerous and more scattered defects; however, there are a couple of clear areas between the defects. In the first option, the stem is bucked through one of these clear areas resulting in Forest Service grade F3 second and third logs. In the second option, moving the saw cut just 2 feet and placing it through a pair of knots results in a Forest Service grade F2 second log. The value of lumber increases from $199 for the first option to $208 for the second option, or a gain of $9.

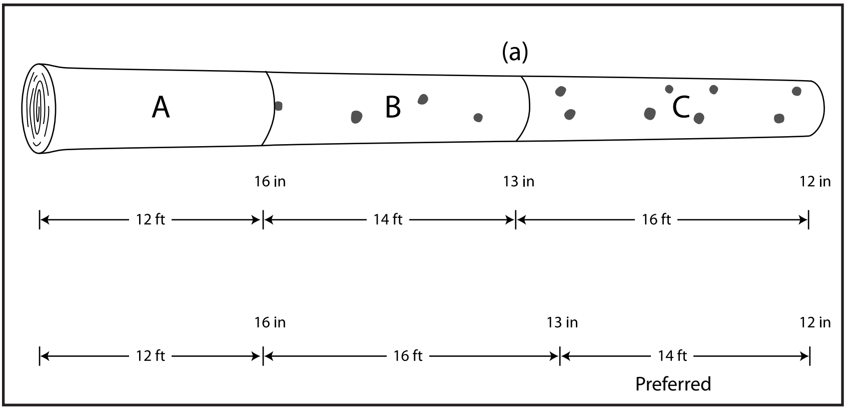


Figure 9-4. Using the preferred solution (option 2) for this tree stem with numerous scattered defects increased the lumber value from $199 to $208.

Example 3. Tree with butt rot

Figure 9-5 is another example of the differences that can result from different bucking decisions. This example may also be a more controversial one. This is a little larger tree with rot in the butt section. Mills often tell loggers to buck off any rot or other defective areas. To avoid all possible rot, an 8-foot section was removed before the remainder of the stem was cut into two Forest Service grade F3 logs with a lumber value of $200.

With the second option, a portion of the rot was included in the butt log. This resulted in using 4 feet of good clear wood on the outside of the stem. By shifting the saw cuts somewhat into the defective area, Forest Service grade F1, F2, and F3 logs were produced with a lumber value of $299, representing an

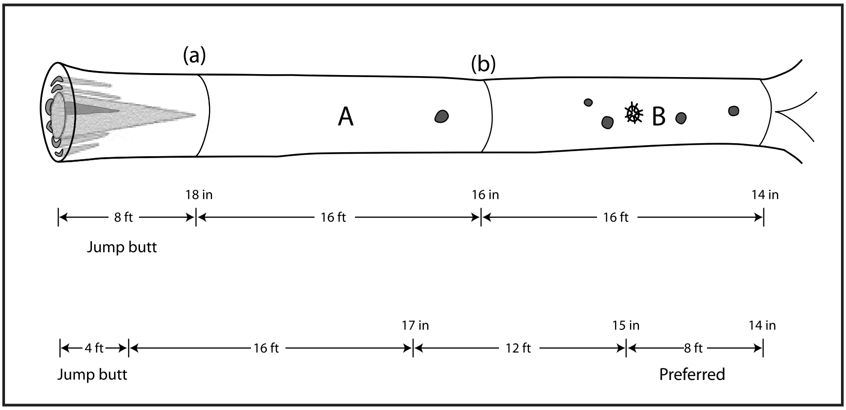


Figure 9-5. Using the preferred solution (option 2) for this tree stem with butt rot increased the lumber value from $200 to $299.

increase of $99. This significant increase results because of the extra clear lumber produced from the outside of the bottom portion of the butt log and from again shifting the saw cut from the center portion of a clear area to bucking through a defect.

If bucking through a defect is effective only a small percentage of the time, log bucking based on NHLA lumber grades could contribute substantial revenue to the mill. This idea can be coupled with other good logging practices, such as leaving low stumps, completely utilizing the stem including upper portions of major forks, limiting jump butting, cutting all available trees, and good bucking, such as eliminating severe sweep and crook, and removing large knots and butt and crotch flare. The combination of practices could result in a substantially higher value received for any given tract or lot of timber. It is important, however, that the mill communicate its ideas to logging crews. Individuals making bucking decisions should know and understand the hardwood lumber grading rules. The individual should see boards beneath the bark and not logs or trees. Production employees can be taught basic lumber grading rules and various rules of thumb in a day or less. Independent crews must be compensated for logs bucked to maximize lumber value yield, and not for the increased volume in short logs or for an irrelevant log grading system.

Michigan Technological University (2006) in Houghton has developed a computer program to provide optimal log bucking solutions.

Sawing Patterns

Several techniques for sawing logs into lumber have been developed over the years. These might be divided into four general categories: (1) sawing around, (2) modified sawing around, (3) live sawing, and (4) quarter or rift sawing. Sawing around might also be called grade sawing whereas modified sawing around or live sawing might be thought of as volume sawing. The available equipment and markets for material other than that which will be sold based on NHLA rules will also greatly affect any particular sawing pattern or combination of sawing patterns.

Sawing Around (Grade Sawing)

Sawing around is probably the most common pattern used in hardwood mills producing grade lumber, pallets, cants, ties, or timbers from the low grade heart of the log. This pattern allows sawyers to work the highest grade boards from the outside of the log (Figure 9-6), while the low grade heart ends up in a large member and helps to reduce saw time and kerf. It helps to keep the grain or cathedral of ring porous woods centered in the board thereby improving appearance and reducing crook. This method is also used in some larger mills to increase production. Once the log is more or less squared up, the center cant can be passed to a resaw, which continues to process the cant for grade lumber and a pallet cant, tie, or timber, if desired.

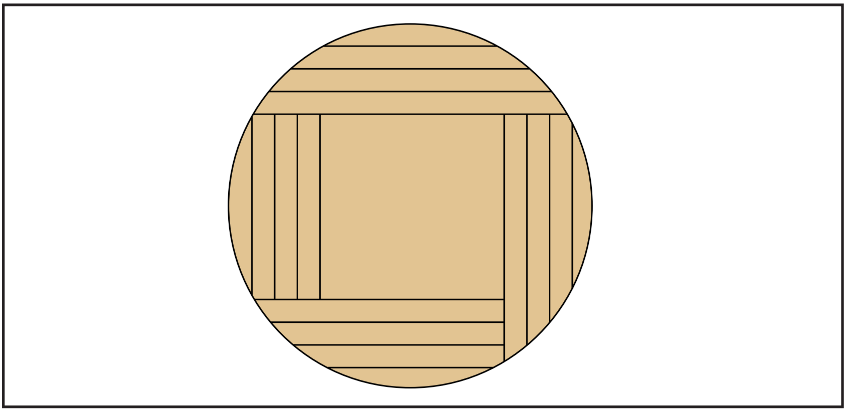


Figure 9-6. Most hardwood grade mills use the traditional sawing around pattern.

Figure 9-6 is a schematic of sawing around showing a scenario where a slab and a number of boards are cut from the face of the log. The log is turned 90°, and more cuts are made. The log is turned and cut again, and turned and cut again. The heart is essentially boxed. Or, sawing can continue until the entire log is processed into boards, and no cant is produced. If the heart is cut to one or more specified dimensions (width or height), it controls where the opening cut is on two of the faces. Or, the opening cuts on two of the faces must be in excess of what the finished heart size is. In this case, shim cuts are made to obtain the correct final dimensions. If the log has grade lumber potential, it is probably best not to open the log face based on the finished dimension of the heart. Computers can easily calculate the cutting sequence for a log, but when a computer is not available, an experienced and skilled sawyer can maximize value yield to the extent possible.

Because sawing around gradually relieves the log stress on each side of the log, less trouble is experienced with thick and thin lumber.

Modified Sawing Around

Figure 9-7 shows a modified sawing around pattern, which is somewhat similar to the traditional sawing around method. In this modified method two faces of a log are slabbed—probably to a specified cant width. Figure 9-7 shows a center cant being produced. The method could also be used to maximize the volume of boards of a specified width, such as 6-inch wide fence boards. In this case no cant would be produced.

On small logs with high internal stress, such as yellow-poplar, this modified sawing around method can result in substantial movement once the sawyer cuts the third face. The center cant is reduced to a relatively small dimension minimizing its stiffness as compared with a larger cant or the original log. Internal stresses are maximized at the log surface. Thus, when the slab and first

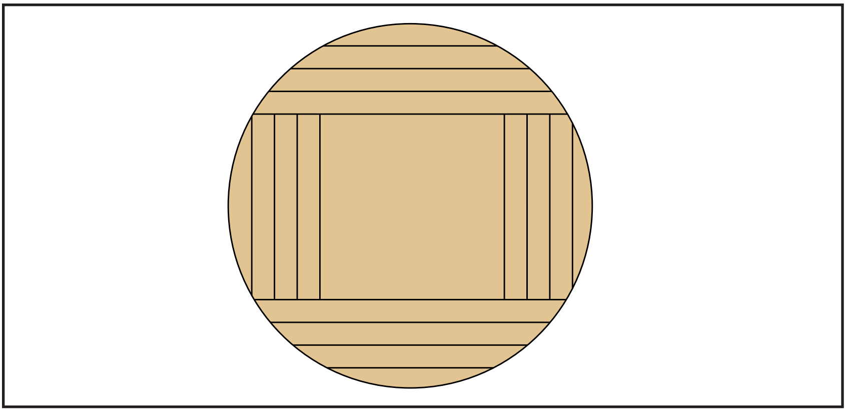


Figure 9-7. Modified sawing around pattern.

board or two are sawed, the stress is greatly unbalanced, and it is relatively easy for the opposite face to distort the cant. If the slab on the third face is removed as the log is turned, distortion is not as bad.

Live Sawing

Live sawing, also called sawing through and through, is another sawing pattern that is often used to maximize volume yield (Figure 9-8). One or two faces of the log may or may not be lightly slabbed. Slabbing one or two faces provides a firm bearing face and prevents all of the boards from needing to be edged. The log is simply sawed from one side to the other. This can be done one board at a time or by use of a gang saw that cuts the entire log into boards in one pass. This method, particularly if a gang saw or series of individual saws is used, produces large volumes, quickly. There is little consideration or opportunity to maximize grade yield. Thus, it is a method commonly used by softwood mills processing small logs. There are also research reports on hardwoods that show the yield of lumber by grade from low grade and very good logs is about the same for live sawing as for sawing around. No timber or cant can be produced. Live sawing also results in a mix of flat sawn, quartered, and rift lumber from the same log. This mix is usually not acceptable to the buyer if the appearance of the finished wood is important, so live sawing is seldom used on high valued species in the hardwood grade industry.

Live sawing one board at a time without turning the log until reaching the pith or sawing close to it will also unbalance growth stress and result in thick and thin lumber.

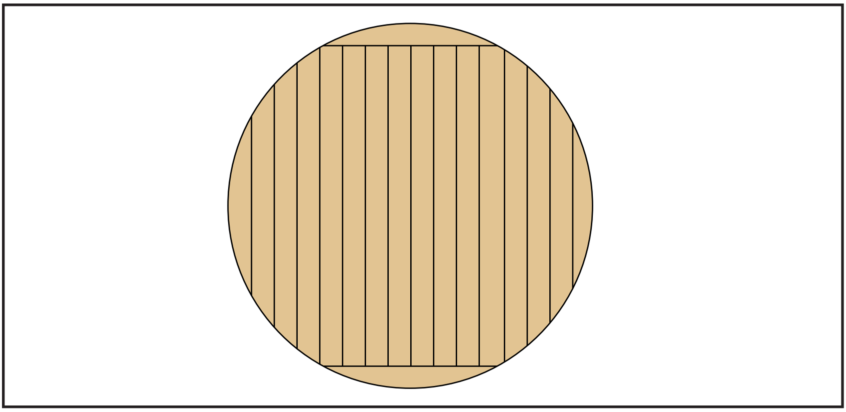


Figure 9-8. Live sawing or sawing through and through.

Quarter and Rift Sawing

Quarter sawing was a method commonly used in the production of white oak in the early 1900s. The lumber was very desirable for use in arts and crafts type houses and for the production of mission furniture. With the disappearance of large old-growth white oak, this sawing method likewise fell into disfavor. More recently, there is renewed interest in quarter sawing because of the demand for quartered lumber in furniture, flooring, and millwork.

In perfectly quartered lumber, the saw line runs parallel with the wood rays (Figure 9-9). In rift cut lumber the saw line intersects the wood rays at about a 45° angle. In flat sawn lumber, the saw line intersects the wood rays at about a 90° angle (see the chapter entitled "Wood Quality and Characteristics," and section "Distinct Surfaces in Wood," for examples of typical quarter, rift, and flat sawn surfaces). In the perfect scenario, boards cut from the same log using these three different techniques appear so different that many consumers might think they were three different species. The quarter and rift grain pattern between and within pieces varies depending on the angle at which rays are intersected. Since some rift lumber is generally produced when quarter sawing, the two are often mixed unless arrangements and price adjustments are made for sorting.

Depending on log size, available equipment, and sawyer preferences, several different methods of quarter sawing can be used. The point to remember is that the angle at which the saw intersects the wood rays will determine the appearance of the board.

Figure 9-9. This quarter sawing method shows several pieces being taken out of the center of the log with a cant at the top and bottom. Note that the center saw line has been placed exactly on the pith. This maximizes figure or the amount of ray fleck and the number of pieces that can be removed before the boards are no longer considered quartered.

Many thin kerf mills do not have the capability to easily hold irregular, somewhat triangular pieces for sawing without the use of a fabricated angle to help keep the piece straight against the stop. So these mills are somewhat limited in quartersawing methods they can use. Nevertheless, these mills are still capable of producing beautifully quartered lumber using the first of the following three methods.

Sawing method for smaller logs

Figures 9-9 and 9-11 show an effective and relatively easy method for quarter sawing on a thin kerf mill. A large log is slabbed on four faces so it will fit through the throat of the saw. Remember, the deeper the slabs are cut, the less quartered lumber will be produced. Next, four to six pieces of well-quartered lumber can be produced from the heart of the log, as well as the top and bottom cants. It is important that the pith of the log be centered along the saw line from end to end. This ensures that the ray fleck will show from one end of the log to the other. Because of taper, particularly in long logs, the fleck can "run out" on some boards, particularly if the pith is not centered.

Because the log is cut through the heart, the center of these pieces will contain numerous small knots, cracks, and other defects associated with the heart center of the log (Figure 9-10). These need to be removed leaving two pieces of high-grade quartered stock, or the wide boards from the center of the log can be kept together for each log. Not removing the center defective area and keeping the center boards together makes it easier to later identify book matches for specialty projects.

Next, one or both of the two cants are returned to the mill, and usually four to six pieces of quartered lumber can be produced from the center portion of each cant. Again, the center of the cant should be centered from end to end. Figure 9-9 (bottom) shows the end of a perfectly quartered log. The end checks indicate the direction of the wood rays. The top of the third board up will be rift cut, as the saw line is intersecting the wood rays at a 45° angle. Quarter sawn lumber is produced from the center of the cants, and rift cut lumber from the top and bottom.

Figure 9-10. A wide board taken from near the center of a white oak log. Note the broad wood rays on the left (quartersawn). In the center of the board is a defective area from the heart of the log, which needs to be removed. The remaining piece on the right side of the board shows some fleck that disappears, resulting in a rift pattern on the far right edge of the piece.

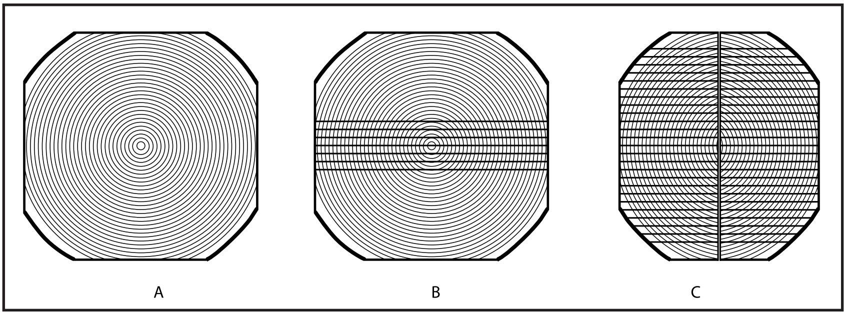


Figure 9-11. Straight forward method to produce quartered and rift lumber
A. Cut four faces on the log, keeping the pith centered from one end to the other.
B. Cut four to six full-width pieces from the center of the log. The defective core can be removed.
C. Turn the top and bottom cants up 90° and saw them. Four to six pieces from the center of each cut will be well quartered lumber, while the rest will be rift cut.

Method to maximize quarter sawn lumber

Figure 9-12 shows a method of quarter sawing similar to the one just described, but in this case the objective is to produce as much quarter sawn lumber as possible. The log is squared up, and the wide center boards are cut as described above. Next, the quarter center boards are removed from the top and bottom cants of the log. Finally, the irregularly shaped four quarters, which would have produced rift lumber in the first method, are returned to the mill and held by a fabricated angle (if needed) and cut into quartered lumber. This method is more involved and time consuming but it does maximize the volume of quarter sawn lumber produced.

Traditional method for large logs

Finally, figure 9-13 shows a method to quarter saw logs about 30 inches in diameter or larger. This is the method traditionally used for large old growth timber in large mills. In this method, four faces are put on the log as before, and then the log is quartered, and each quarter is processed. Large mills are capable of this processing technique. For smaller mills, however, the log may be quartered with a chain saw, and then each quarter processed.

Quarter and rift sawing are more time consuming than traditional sawing methods. In addition, many of the pieces must be edged to provide a square edge. The lumber may also need to be cut slightly thicker, as the thickness of the lumber is in the tangential direction, and wood shrinks more in the tangential direction. Given also that large logs are required, quartered and rift-sawn lumber command a premium.

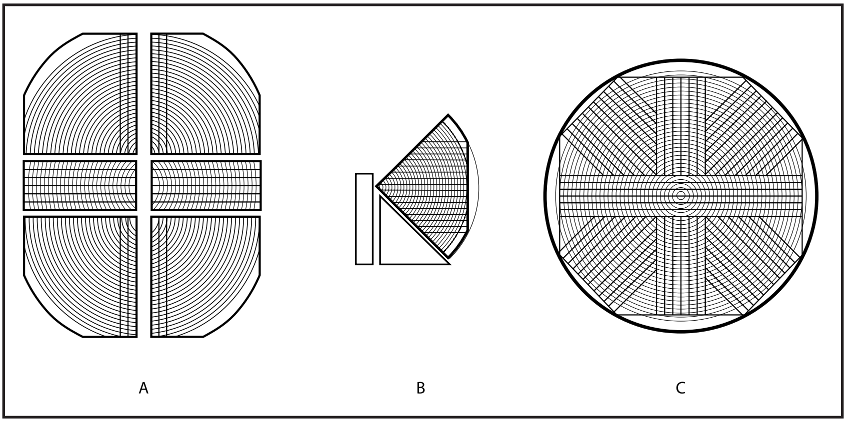


Figure 9-12. Sawing method to maximize the amount of quartered lumber recovered from a log. This method is initially the same as that given in Figure 9-11, but finishes with a different approach.

A. Take four to six well quartered boards from the center of the log and each of the two cants.

B. Turn each log quarter to also produce quartered boards. An angle or stop may be required to hold the piece on some mills.

C. Saw the entire log following the pattern shown.

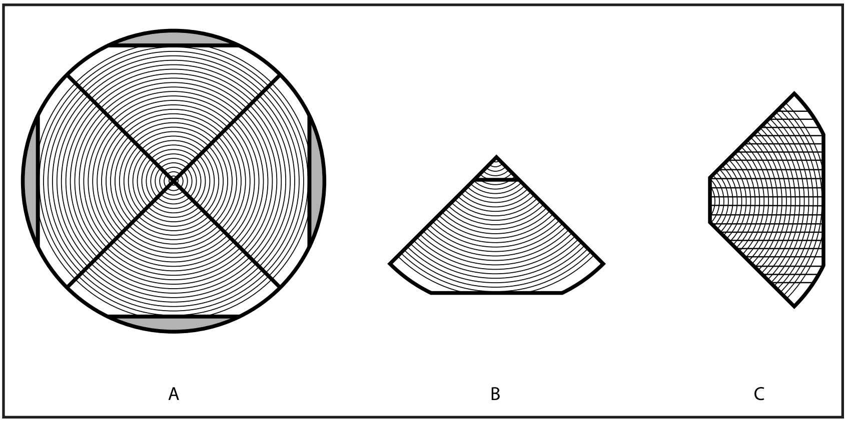


Figure 9-13. Traditional method for sawing large logs into quartered lumber.

A. Cut four faces on the log and cut the logs into quarters, keeping the pith centered from one end to the other.

B. Remove the triangular and defective area from each quarter.

C. Turn the quarter up 90° and process into mostly quartered lumber.

Miscellaneous Sawing Patterns

Traditional mills seldom vary from an established sawing pattern once the best pattern is determined; however, newer thin kerf mills can be much more versatile. As a result, they can be used to obtain particular sized products or grain patterns out of any log. Given the sawing capacity of the mill, they can also be used to saw crotches, burls, and even stumps. In these cases, it is up to the imagination and experience of the sawyer to produce the most desirable product from the material available.

Volume Sawing

Most modern stationary softwood mills perform volume sawing. Generally, the objective is to maximize the volume of sawed product from a given log while minimizing sawing time. This is done by first electronically scanning the log and using a computer to determine the best fit of available sawed product sizes into the known geometry of the log. Prices may also be factored in to favor those items of the most value. The log is then sawed based on the solution given by the computer. For mills without a scanning and computer system, the sawyer must make the judgments on how to maximize the yield from the log. The computer always wins the contest.

Grade Sawing

Grade sawing of hardwoods is a loosely used term that indicates that the objective is to remove the most and highest grade lumber (based on NHLA grades) from a log. With an understanding of the hardwood grading rules and a few sawing principles, grade sawing is relatively easy because the rules admit random width lumber. Producing random width lumber from the log also increases volume yield. In comparison, sawing to fixed dimensions when no computer vision system is available requires the sawyer to estimate the best fit of the boards into the log. Substantial waste can result. In grade sawing, each face of the log is sawed for the highest grade lumber, and the sawyer may even return to a previously sawed face. In order to understand grade sawing, at least a portion of the NHLA hardwood grading rules must also be understood (see the chapter entitled "Hardwood Lumber Pricing and Grading" for the rules). In addition to the NHLA grading rules, there are a few basic grade sawing techniques that help the sawyer produce the most grade lumber.

Width and Length of Opening Face

The width and length of the opening face and all subsequent faces are determined by the markets available and species being sawed. Figure 9-14 shows the minimum width and length for the three top grades of lumber. For FAS lumber the minimum size piece is 6 inches by 8 feet and for selects it is 4 inches by 6 feet. A minimum size selects board is a very small piece of lumber; but if a market is available, producing this size piece will increase the yield of the log. On white woods and small logs such as hard maple, selects boards may find a market. Otherwise, the face should probably be opened up to a minimum 6-inch by 8-foot piece.

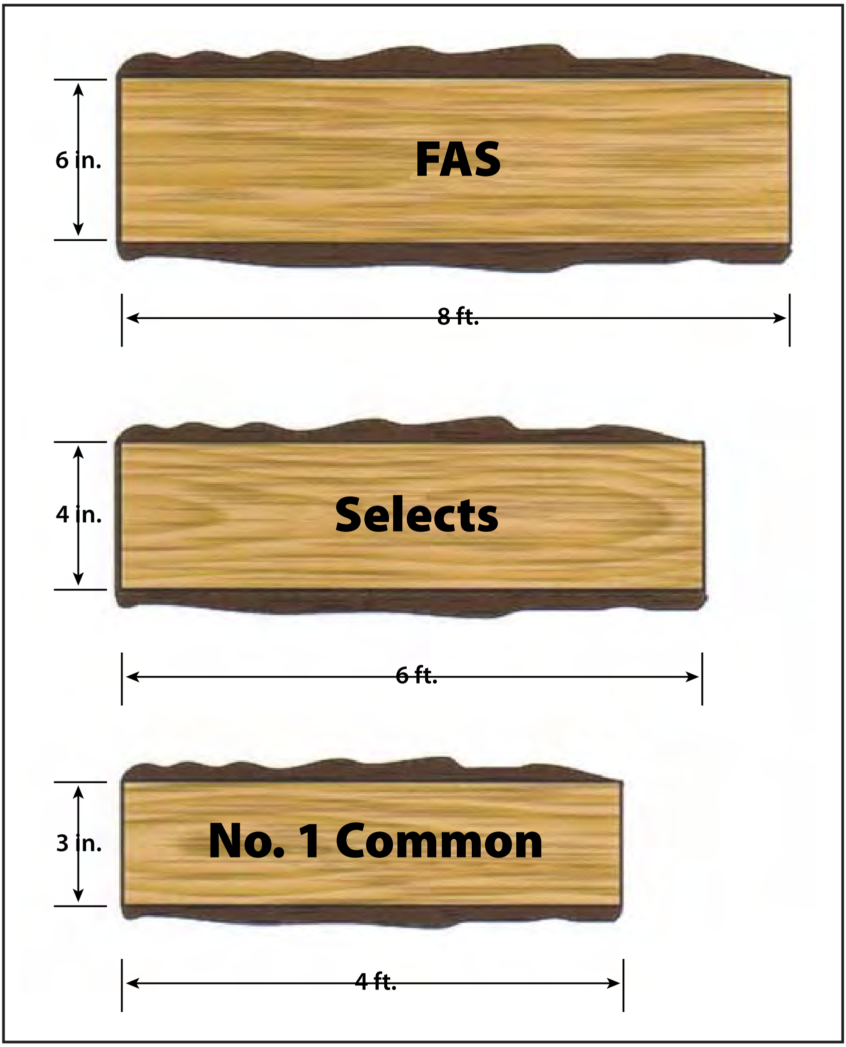


Figure 9-14. Minimum size of boards for the three top lumber grades.

First Opening Face

The first cut on a log determines where the other three faces must fall (Figure 9-15A). At this point, two factors must be considered: (1) the location of other defects or their indicators, and (2) taper. If it is at all possible, major defects should be placed at the edges of the faces to be sawed (Figure 9-15B). With this method, defects are in such a location that they do not tend to disrupt the size of clear face cuttings in determining the hardwood grade of the board. Many of the defects will be removed in the edging process. If the defects are aligned in the center of the face (Figure 9-15C), there is no chance that they can be removed during edging and, in narrow lumber especially, they could stop the length of a clear cutting.

Another factor to consider is the quality of one or two of the faces in respect to the opposite face of the log. An example is a log from a tree that grew at the woods edge. The side to the light retains its branches, and the side to the woods drops its branches and develops clear wood. If one or two faces of a log are particularly poor and will not yield quality lumber compared with the opposite face, it may be best to lightly saw these faces first. Doing this provides a flat face along the length of the entire log for easier handling. More importantly, the log taper is removed and the opposite good face becomes perfectly parallel to the saw, so that a full length board of the desired width can be removed with the first cut.

Better traditional mills have the capability to scan and hold a round log with any face perfectly parallel to the saw. In these cases, the best faces may be sawed first.

Another important factor is the depth to which the first and all subsequent faces are opened. If the objective is to produce FAS or F1F lumber, the final board must be at least 6 inches wide by 8 feet long. So the opening face must be at least this size. On large logs, it is extremely important to exercise care in opening a face. Figure 9-16 shows how quickly the width of a face or board can increase as the depth of cut increases. With a very light cut, a 4-inch face was opened. With just a ¼-inch increase in depth the face opened to 8 inches. The width of the face below the first board is shown at the right. With the time required to grow large quality logs and the effort needed to bring the logs and mill together, it makes good sense not to open the face too deep. It is better to cut shallow and make a second pass to remove a shim if necessary. In Figure 9-16 the face went from a too narrow 4-inch width to a too wide 8-inch width. Assuming the log is 12 feet long, a strip of wood almost 2 inches wide by 12-feet long was left in the 8-inch-wide slab.

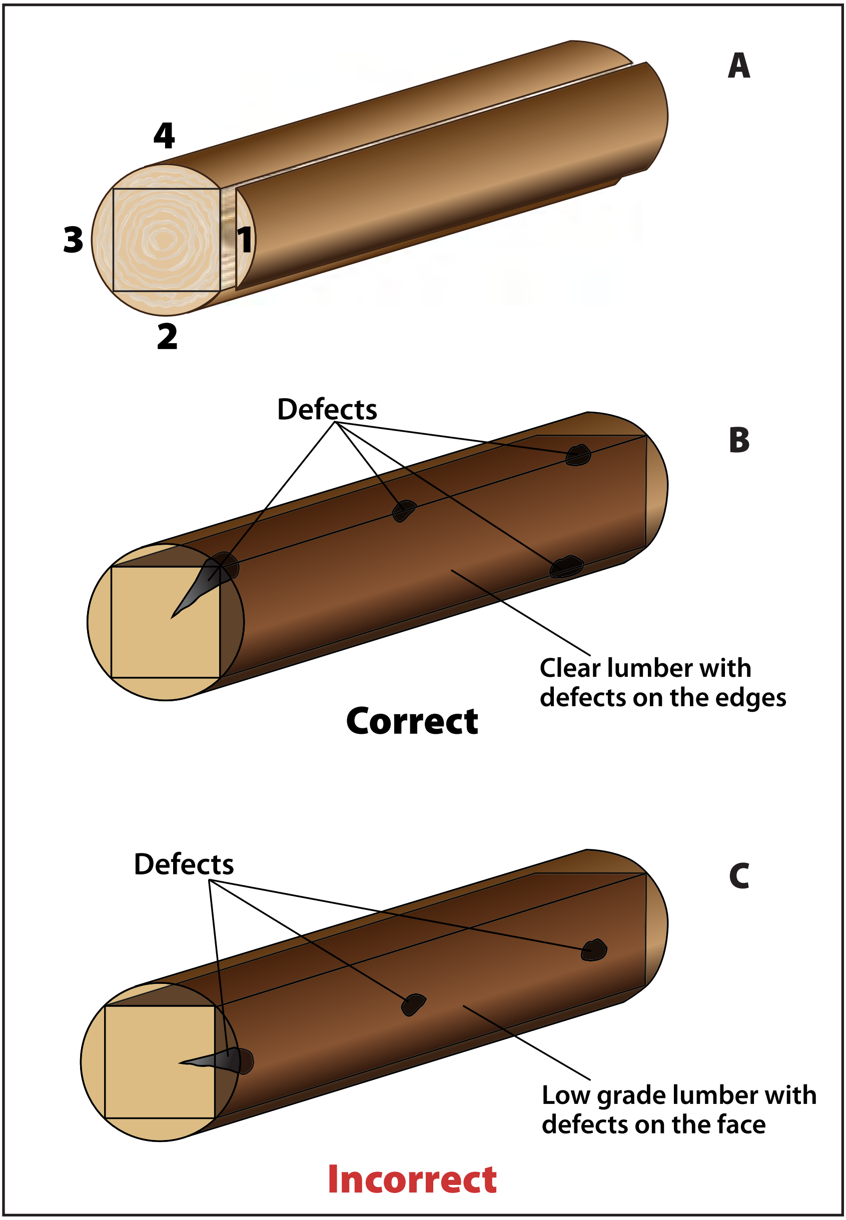


Figure 9-15. Grade sawing

A. The first cut determines the other three log faces.

B. A correct grade sawing procedure is to place the defects at the edges of the faces to be sawed.

C. An incorrect procedure is to center the defects in the faces to be sawed

Figure 9-16. Care should be exercised in opening a log face. For this larger log, the sawyer opened the face to a narrow 4-inch width. The saw was lowered just ¼ inch, in hope of getting a 6-inch wide face. Instead, an 8-inch wide face developed, resulting in wasted clear wood. The piece on the right shows the width that developed after the first board was removed.

Turn When the Grade Drops

Another very important factor is to turn the log as soon as the grade of the face being processed drops below the grade of any adjacent faces. If the lower grade face continues to be sawed, it will likely rob a strip of clear wood the thickness of the board for the full length of the log (Figure 9-17). Thus, on 4/4 lumber and a 1-inch-wide strip and a 12-foot-long log, 1 board foot of lumber is downgraded.

Seams and Cracks

When a relatively straight seam occurs in a log, it should be placed at the corner of two adjacent faces. In many cases, the wood is sound on each side of the seam and, when placed on the edge of a piece, it can simply be ripped off.

Spiral seams create a much more serious problem and should be positioned so that the largest and clearest piece results after the flitch is cut back due to the seam. It is probably best to first lightly saw the two faces with the seam; next, remove the grade lumber from the opposite faces; finally, return to sawing the faces with the seams.

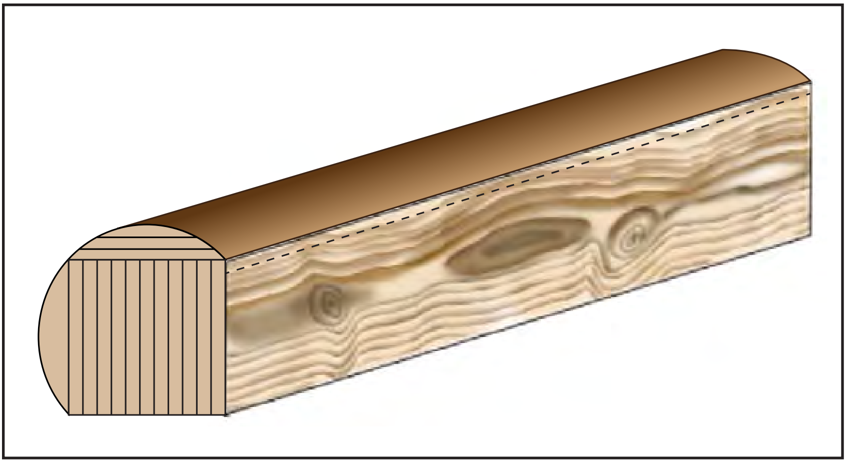


Figure 9-17. The sawyer should turn the log as soon as the grade of the face being sawed drops below that of the adjacent faces.

Taper Sawing

Logs, particularly butt logs, can be thought of as a truncated cone with the most defective material in the center and the clearest wood on the outside of the log. The thickness of the clearest wood decreases from the butt of the log to the top. Thus, the clearest lumber will be produced by sawing parallel to the bark (Figure 9-18A). This is called taper sawing, and it is particularly important when there are opposite good faces on a log. When a log is sawed parallel to the bark on two faces, a tapered cant is produced. If the third and fourth faces are also good faces, they should also be sawed parallel to the bark. The result is a trumeated pyramoid. The boards removed from the third and fourth faces will need to be edged to remove the taper left when sawing the first and second face (Figure 9-18A). The cant must be straightened by sawing short pieces and cutting back the tapered ends (Figure 9-18B). This material should be relatively low grade from the heart. It is more cost effective to discard this low grade wood than clear wood from the outside portion of the butt log, which would be removed as slab wood if taper sawing is not practiced.

Taper sawing requires more time and can be difficult on some smaller mills as the small end of the log must be raised to make the surface of the log parallel to the saw. If the log has three or more good faces, some clear wood can be lost as the taper for two opposite faces is removed. The extra effort in taper sawing must be considered against the value it can produce.

Sawing parallel to the bark can be more beneficial for certain products where a perfectly straight grain pattern is needed. These products would include bending stock, baseball bats, oars, pitman rods, and other highly stressed items.

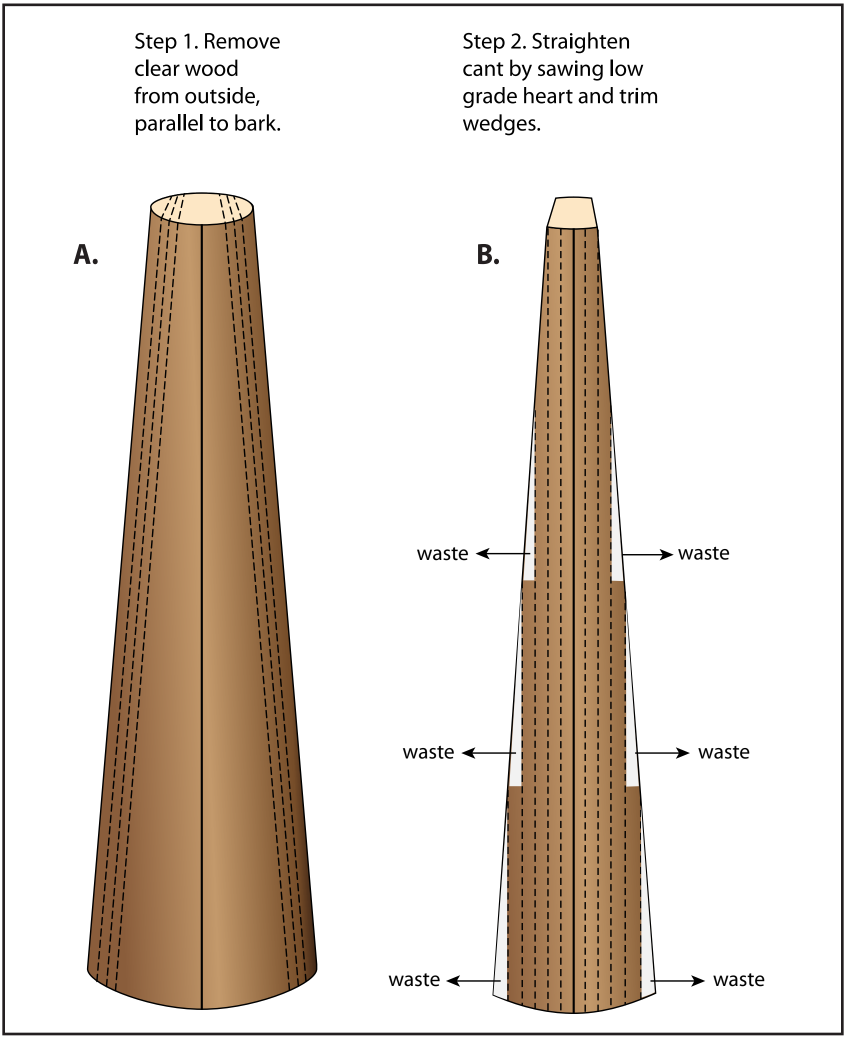


Figure 9-18. Taper sawing. Typical taper is about 2 inches every 12 feet. (A) Step 1 removes clear lumber by sawing parallel to the two opposite good faces on the log. (B) Step 2 straightens the cant by sawing low grade heart and trimming wedges.

Split Taper Sawing

Splitting the taper in large butt logs with all good faces may also help to increase the grade (Figure 9-19). Some species such as oak can have excessive taper. If this taper is all removed from one face it forces the opposite face to be sawed parallel to the bark full length. As a result, the ends of the boards from the small end of the log will begin to show defects from the core of the tree. The sawyer saws into the defective core sooner than if the taper had been split between opposite faces.

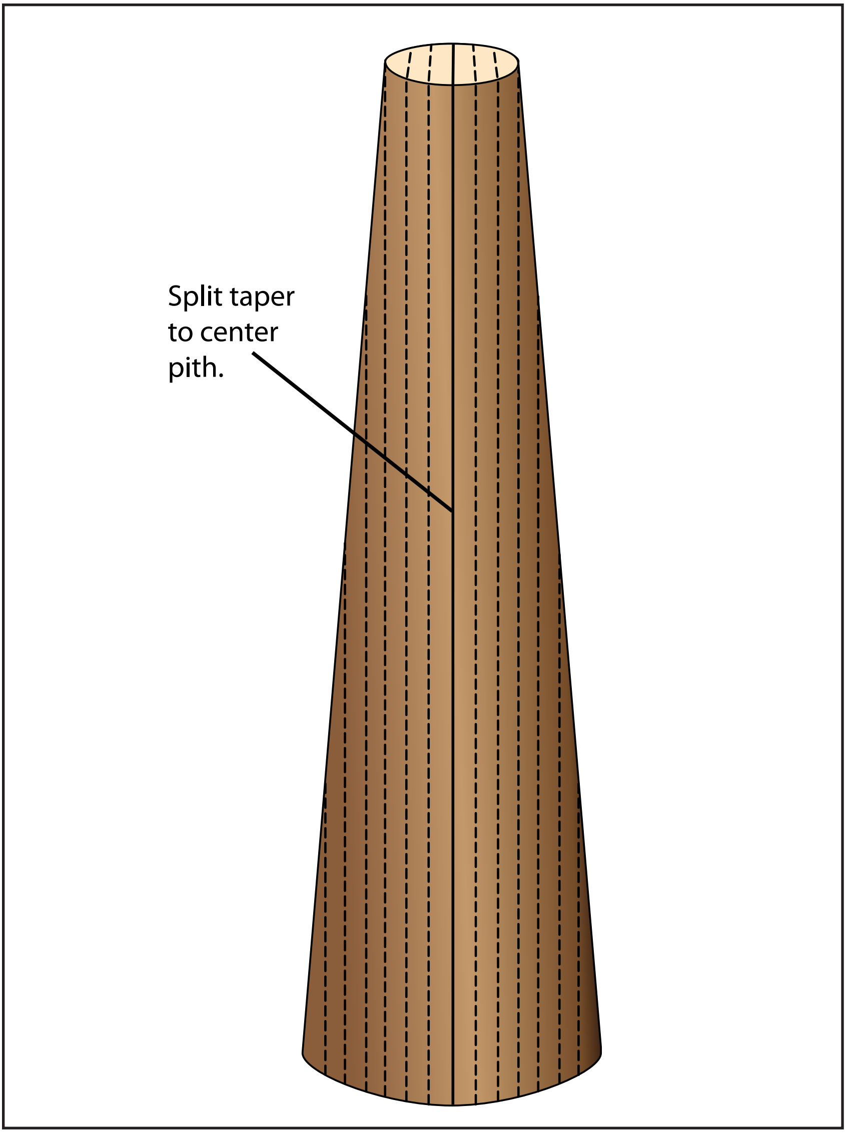


Figure 9-19. In split taper sawing the taper is divided and removed between opposite faces.

Bowed Logs

Bowed logs present a handling challenge on any mill. The best that can be hoped for is to minimize volume loss. If possible, the belly of the log should be removed first. The log is sawed until a full or nearly full length face is achieved. The log is turned 180° to the opposite face and the "horns" removed. The two remaining faces are sawed full length, and some grade lumber may develop.

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Chapter 10.

Wood Residues and Potential Markets

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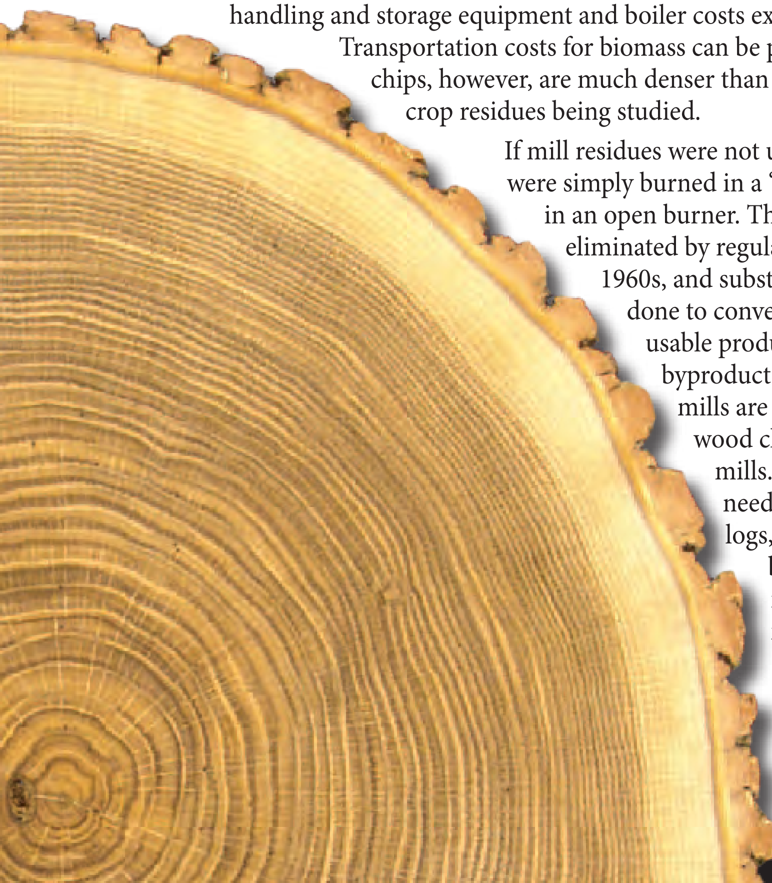
Chapter 10.
Wood Residues and Potential Markets

Many years ago, the wood industry chose the term "residues" to describe all of the "waste" generated when a log was processed into lumber. This waste included sawdust, slabs, edgings, end trims, defective parts of logs, and bark either separated or left on the slabs. These items have been a disposal issue for most small mills. Some of the larger pieces were a source of domestic fuel. With the introduction and common use of steam, large mills normally burned at least a portion of the residue for mill power and even to support the immediate community. The availability of inexpensive fossil fuels after World War II forced mills to abandon this practice. With the increase in costs and development of uncertain fossil fuel supplies in the 1970s, larger mills began reverting back to using wood residue as a source of fuel.

Most economical conversions were completed before the current interest in biofuels. Compared with liquid fuel and coal, wood residues are bulky, making handling and storage equipment and boiler costs expensive. Transportation costs for biomass can be prohibitive. Wood chips, however, are much denser than many agriculture crop residues being studied.



If mill residues were not used as fuel, they were simply burned in a "tepee burner" or in an open burner. This practice was eliminated by regulations in the 1960s, and substantial work was done to convert residues into usable products or so called byproducts. Today, larger mills are able to sell solid wood chips to pulp mills. To do so they need to debark the logs, which created a bark disposal issue; however, most bark is now processed for mulch or other decorative applications. Sawdust has been and remains an issue in most locations. The particles are too small for substantial use in the paper and panel board industry. When possible, sawdust is burned for fuel, often by paper mills.

In addition to sawmilling residue, logging residues—including tree tops, cull and dead trees, landing site debris, and thinnings—generate substantial wood waste. Where collection is economically feasible, many utilization opportunities exist. The future for wood byproducts looks bright because of the increased cost and limited availability of fossil fuels. Boiler fuel and the production of ethanol and fuel pellets are likely areas for future development.

This chapter provides background on how the use of wood residues has changed over time, information on quantifying the amount of residues generated, and current and potential uses for residues.

Quantity Generated

Before looking at potential uses for wood residue, it is important to review the quantities generated by different sources and manufacturing operations.

Logging residues, thinnings, and timber stand improvement (TSI) trees are probably the single largest untapped source of solid wood and bark. Economical collection of wholesale quantities has not been possible to date, but the potential of this resource should not be overlooked. Table 10-1 presents the ovendry weight of whole, small-diameter hardwood trees (Clark and Schroeder 1977, Monteith 1979). These could be trees obtained from plantation thinnings or TSI trees. TSI trees are those that are normally girdled and killed in place to favor the growth of more valuable species or better formed trees.

Table 10-1. Total tree ovendry weights for small diameter hardwoods sampled at several different locations (Clark and Schroeder 1977, Monteith 1979)

Tree d.b.h. (inches)	Hard hardwoods[1]	Soft hardwoods[2]
	Ovendry pounds	
4	80	60
6	210	110
8	440	280
10	770	510
12	1,180	800
14	1,710	1,140
16	2,190	1,520

[1] Includes sugar maple, red maple, beech, yellow birch, red and white oak, white ash, hickory, and black cherry

[2] Data are for yellow-poplar only

Top weight refers to the weight of all wood and bark above the merchantable bole. Table 10-2 presents the ovendry top weights for oak species sampled in southern Indiana. It lists only limbs 4 inches in diameter and larger (Cassens and others 1980). This material is suitable for chips and large enough for firewood. The use of this material for ethanol is another possibility. For average sawlog size trees, it takes only about two trees to generate an ovendry ton of firewood or boiler fuel. On a green-as-cut-in-the-woods basis, this weight is about 1¾ tons. For comparison, Table 10-3 presents the weights for the entire tree top (Cassens and others 1980).

Finally, Table 10-4 is a summary from several research reports that give the ovendry weight for selected species by tree diameter at breast height (d.b.h.) and location (Cassens and others 1980). It is easy to obtain about a ton of ovendry top wood per tree from many sawtimber size trees.

Table 10-2. Predicted ovendry top weight in branches equal to or greater than 4 inches in diameter for white, red, and black oak from Southern Indiana (Cassens and others 1980)

Tree d.b.h. (inches)	Merchantable height (feet)[1]					
	8	16	24	32	40	48
	Ovendry pounds					
10	**425**	372				
11	492	**430**	**375**			
12	569	**497**	**434**	379		
13	657	**574**	**502**	438		
14	760	**664**	**580**	507		
15	879	**767**	**670**	**586**	**512**	
16	1,016	**887**	775	**677**	591	
17		1,026	**896**	**783**	684	
18		**1,186**	**1,036**	**905**	790	
19		1,371	**1,198**	**1,046**	**914**	798
20		**1,585**	**1,385**	**1,209**	**1,056**	923
21		1,832	**1,601**	**1,398**	**1,221**	1,067
22		2,118	1,851	1,616	**1,412**	**1,233**
23		2,449	**2,139**	1,869	1,632	1,426
24			2,473	2,181	1,887	1,649

[1] Bold numbers indicate limits of sample

Table 10-3. Predicted ovendry top weight in *all* branches for white, red, and black oak from Southern Indiana (Cassens and others 1980)

Tree d.b.h. (inches)	Merchantable height (feet)[1]					
	8	16	24	32	40	48
	Ovendry pounds					
10	**675**	588				
11	775	**675**	**588**			
12	889	**775**	**675**	588		
13	1,021	**889**	**775**	675		
14	1,171	**1,021**	**889**	775		
15	1,344	**1,172**	**1,021**	**890**	**775**	
16	1,543	**1,345**	**1,172**	**1,021**	890	
17		1,543	**1,345**	**1,172**	1,021	
18		**1,771**	**1,544**	**1,345**	1,172	
19		2,033	**1,772**	**1,544**	**1,346**	1,173
20		**2,334**	**2,034**	**1,772**	**1,544**	1,346
21		2,679	**2,334**	**2,034**	**1,773**	1,545
22		3,074	2,679	2,335	**2,034**	**1,773**
23		3,529	**3,075**	2,680	2,335	2,035
24			3,529	3,076	2,680	2,336

[1] Bold numbers indicate limits of sample

Table 10-4. Total ovendry top weights for 14-, 18-, and 22-inch d.b.h. trees for selected species and locations (Cassens and others 1980, Clark and Schroeder 1977, King and Schnell 1972, Monteith 1979, Steinhilb and Winsauer 1976, Wartluft 1978, Waint and others 1977)

Species	Location	D.b.h. (inches)		
		14	18	22
Ash	New York	815	940	1,094
Beech	New York	907	1,266	1,724
Oak[1]	Virginia and West Virginia	731	1,170	1,871
Oak (black)	Tennessee Valley Authority	804	1,360	2,071
Oak (white, red, black)	Indiana	980	1,555	2,273
Sugar maple	New York	987	1,214	1,501
Yellow-poplar	North Carolina	289	526	726
Combined hardwoods[2]	New York	894	1,116	1,399
Mixed hardwoods[3]	Virginia and West Virginia	428	662	1,025

[1] Based on 31 red oak, 16 chestnut oak, 6 white oak, 2 hickory, 1 ash, and 1 hard maple.

[2] Based on 14 yellow poplar, 3 blackgum, and 2 cucumber magnolia

[3] Based on 13 sugar maple, 13 red maple, 32 red oak, 32 beech, 32 white ash, 31 aspen, 11 yellow birch, 12 hickory, 11 black cherry, 11 American basswood, 11 white oak, 4 birch, 3 sugar maple, 1 American elm, and 1 yellow-poplar

At most commercial logging operations, the trees are skidded to a central area called a landing. Then the logs are bucked to length. In the process, hollow sections, bow, and other nonmerchantable material is removed and usually shoved to one side. A study of five different landings in West Virginia (Goho 1976) showed that a total of 5,815 cubic feet of material weighing 315,455 pounds was left behind. This is about 31 tons of material per landing, on average.

Compared with logging residues sawmill residues are more important because they accumulate at a central site and must eventually be disposed of. Established traditional mills generally have a good idea of the residues generated per volume of logs processed or per thousand board feet of lumber produced. An example from a traditional band mill operation is 1 ton or somewhat less of chips per 1,000 board feet of lumber produced, and ¾ ton of sawdust and bark for the same unit of lumber. Another study reported 1,534 pounds of bark at 68 percent moisture content or 11 percent of the total log weight generated per 1,000 board feet Doyle Scale or 1.164 pounds per board foot, International Scale (Wartluft 1974). Table 10-5 presents a detailed analysis of residue yields based on the type of mill, as well as the size of logs being sawed (Perry and Gregory 1976). Similar tables do not exist for thin kerf mills. Given the thin kerf of some mills, the volumes of sawdust should be substantially reduced. Wood-Mizer has indicated that a cubic yard of green hogged sawdust, bark, slabs, and edgings weighs about 535 pounds. Table 10-6 shows the moisture content and bark weight of bark generated by species for two common log scales (Wartluft 1974).

Rough kiln-dried lumber is first surfaced in secondary wood processing. The volume or weight generated can be figured by subtracting the thickness of the finished product from the average thickness of rough lumber and applying an appropriate weight figure. So, for each 1/16 inch (0.0052 ft) of thickness removed per thousand board feet, 5.2 cubic feet of solid wood equivalent are removed. For example, if red oak weighs 42.5 pounds per cubic foot, then 221 pounds of planer shavings are removed; and if yellow-poplar weighs 29.2 pounds per cubic foot, then 152 pounds of planer shavings are removed. In most situations multiple sixteenths of an inch are removed.

The yield of solid wood used compared with the volume of lumber processed in dimension plants will vary by grade, size of parts being cut from the lumber, and efficiency of the operation. Yields of usable parts are often in the 50-60 percent range before further machining, such as routing, boring, mortising, tenoning, and sanding. About one-half of the lumber may end up as residue.

Residues from kiln-dried lumber are dry, and thus have an increased fuel value and will not deteriorate in storage like green residues will.

Table 10-5. Conversion factors for estimating green or dry tons of bark, chips, and fines produced per thousand board feet of lumber sawn[1] (Perry and Gregory 1976)

Mill type[2]	Small end diameter (inches)	Hard hardwood[3]						Soft hardwood[4]					
		Bark		Chippable		Fines[5]		Bark		Chippable		Fines	
		G[6]	OD[7]	G	OD	G	OD	G	OD	G	OD	G	OD
A, B, C, and F	5 to 10	0.75	0.53	1.84	1.04	1.26	0.71	0.75	0.53	1.27	0.72	0.86	0.49
	11 to 13	0.64	0.45	1.53	0.87	1.34	0.76	0.64	0.45	1.06	0.60	0.91	0.52
	14 to 16	0.50	0.35	1.17	0.66	1.08	0.61	0.50	0.35	0.81	0.46	0.74	0.42
	17 and over	0.44	0.31	1.03	0.58	1.05	0.60	0.44	0.31	0.72	0.41	0.72	0.41
D and E	5 to 10	0.75	0.53	1.84	1.04	0.92	0.52	0.75	0.53	1.27	0.72	0.63	0.36
	11 to 13	0.64	0.45	1.53	0.87	0.84	0.48	0.64	0.45	1.06	0.60	0.58	0.33
	14 to 16	0.50	0.35	1.17	0.66	0.84	0.48	0.50	0.35	0.81	0.46	0.58	0.33
	17 and over	0.44	0.31	1.03	0.58	0.80	0.45	0.44	0.31	0.72	0.41	0.55	0.31

[1] To use these converting factors first decide the mill type, which is based on equipment; then determine the average scaling diameter of the logs. If the equipment indicates a mill type B and the average scaling diameter is 13 inches, then look in mill type B, line 2. This line shows that for every thousand board feet of hard hardwood sawed 0.64 tons of bark, 1.53 tons of chippable material, and 1.34 tons of fines are produced, green weight. Expressed in ovendry weights, the same thousand board feet yields 0.45 tons of bark, 0.87 tons of chippable material, and 0.76 tons of fines. Equivalent hard hardwood and soft hardwood data are also given.

[2] Mill Type

A. Circle head-saw with or without trim saws

B. Circle head-saw with edger and trim saw

C. Circle head-saw with vertical band resaw, edger, trim saw

D. Band head-saw with horizontal band resaw, edger, trim saw

E. Band head-saw with cant gangsaw, edger, trim saw

F. Scragg Mill

[3] Hard hardwoods include ash, beech, cherry, elm, hickory, hard maple, oak, sycamore, and walnut.

[4] Soft hardwoods include basswood, cottonwood, gum, soft maple, and yellow-poplar.

[5] Fines—sawdust and other similar size material.

[6] G = green weight or initial condition with the moisture content of the wood as processed.

[7] OD = Ovendry. It is the weight at 0 percent moisture content.

Table 10-6. Bark residue weights per log by log volume and species, in pounds. The percent moisture content is given in parentheses under the species (Wartluft 1974)

Log volume (board feet)	Red oak (63%)	Chestnut oak, white oak and hickory (59%)	Maple (55%)	Beech (77%)	Yellow-poplar (96%)	Basswood (114%)
Doyle log rule						
20	70	64	68	35	53	71
40	92	81	89	57	74	87
60	113	99	108	77	94	103
80	135	116	126	96	115	119
100	157	134	142	114	136	134
120	179	151	157	130	157	150
140	201	168	169	146	177	166
160	223	186	181	160	198	182
180	245	203	190	172	219	198
200	266	221	198	184	240	213
220	288	238	204	194	260	229
240	310	255	208	203	281	245
260	332	273	211	210	302	261
280	354	290	212	217	322	277
300	376	308	212	222	343	292
International ¼-inch rule						
20	51	47	45	17	37	60
40	72	64	67	38	55	74
60	92	81	88	57	73	88
80	112	97	107	75	91	102
100	133	114	124	92	109	116
120	153	131	140	109	127	130
140	173	148	154	124	145	144
160	193	165	167	138	163	158
180	214	182	178	151	181	172
200	234	198	188	164	199	186
220	254	215	196	175	217	200
240	274	232	202	186	235	214
260	295	249	207	195	253	228
280	315	266	210	203	271	242
300	335	283	212	211	289	256

Residue Uses

Pulp Chips and Panel Products

The largest current use for sawmill slabs, edgings, and cut-offs is for pulp chips. The chips are required to be bark-free and to have certain physical characteristics, particularly size. These chips are traded in semitrailer loads. The U.S. pulp and paper industry is being challenged by foreign competition, thus the market for pulp chips is beginning to disappear in some locations. The use of forest thinnings and small diameter trees for pulp chips as well as feed stock for structural panels, such as oriented strandboard, is also important in those sections of the country where markets exist.

Sawdust has been used in small proportions in paper as well as panel products, such as insulation board, hardboard, and particleboard. In paper production "coarse" sawdust is required to produce fibers of sufficient length, and it is difficult to pulp small particles along with regular chips. Due to the small particle size of sawdust, using it in panel products can reduce their strength and usually requires additional resin, which increases cost. Given the low value of the typical raw materials used in pulp and reconstituted panel production, and the problems associated with using fine wood particles, sawdust finds little acceptance.

Fuel

Another significant use for wood residues is energy generation or fuel. As mentioned earlier, at operations that have a need for process steam, burning wood in boilers is commonplace. These operations typically include pulp mills, sawmills, and concentration yards with steam-powered dry kilns and secondary manufacturers that dry their own lumber or need plant heat. Since wood biomass is carbon neutral it is receiving increased attention for electrical power generation. In a few other instances, the residues are transported by semitrailer to other locations to be used as boiler fuel. Opportunities for the large-scale use of residues as boiler fuel vary substantially by region and are often related to the cost and availability of fossil fuels and government regulations or subsidies. The demand can also be seasonal.

Chunk wood or firewood

Chunk wood or firewood presents opportunities for smaller scale operations. It can be used for home heating or bundled and sold in urban areas and near campgrounds. Some confined livestock operations also require a source of heat. Firewood is particularly important in rural areas and where the price of fossil fuels is high relative to available income.

The movement of "firewood" is being challenged, however, and is prohibited in some locations. The movement of firewood is thought to be one of the major avenues for the spread of the emerald ash borer, and legitimate concerns exist about other invasive insects and diseases being spread in the same way.

If the wood is to be burned as fuel, the most important issue is the moisture content of the wood. Green wood contains large amounts of moisture, and some species will hardly burn when dead green or freshly cut. Burning green wood requires that a substantial amount of the energy available in the wood be used to heat the water in the wood and convert the water to vapor and exhaust it from the system. When wood is air or kiln dried, its value as fuel greatly increases because most of the water has been removed.

The heat of combustion for ovendry hardwoods is about 7,600 British thermal units (Btu), and for pine is about 8,600 Btu per ovendry pound. Most cellulosic materials are in this range. The resin in pine increases the fuel value.

To better understand the importance of water in wood to be used as fuel, refer to Box 10-1.The information in Box 10-1 is based on the assumption that the sample wood has 100 percent moisture content and that 2 pounds of greenwood are being burned. Thus, there is 1 pound of ovendry wood that will produce 7,600 Btu. There is also 1 pound of water associated with the 2 pounds of greenwood. So, 1,210 Btu are required to heat the water from 65 °F to 212 °F and to raise the steam temperature from 212 °F to a flue temperature of 400 °F. In burning the hydrogen in the dry wood another 0.55 pound of water is formed, and this requires another 660 Btu to exhaust. An additional 690 Btu are lost due to the exhausting of other hot flue gases, such as carbon dioxide, nitrogen, and excess air. Limiting air supply can reduce this loss. Thus, the usable heat from 1 pound of wet fuel is only 2,520 Btu (Koch 1972).

Box 10-1. Net usable heat value for 2 pounds of wood at 100 percent moisture content. Since the sample is only one-half ovendry wood, only 7,600 Btu are available, and about 2,560 Btu are used to remove the water. So the fuel value of the green wood is only 2,520 Btu/pound (5,040 Btu/2 pounds) (Koch 1972).

Heat of combustion of 1 pound of dry wood	7,600	Btu
Less		
Heat loss associated with water content	1,210	
Heat loss associated with hydrogen combustion	660	
Heat loss in other flue gases	690	
Net usable heat	5,040	Btu/2 pounds green wood

The green moisture content for many of the hard hardwoods is in the 60 to 90 percent range (for ash it is only about 45 percent). The soft hardwoods and particularly the sapwood are considerably higher in moisture content. Well air-dried or seasoned wood should be in the 20 percent moisture content range, and the usable heat value will be about 3,600 Btu per pound. The importance of air-drying when using wood for fuel cannot be overemphasized.

Table 10-7 presents comparative figures for the Btu value of wood, fossil fuels, and electricity. A cord (4 feet by 4 feet by 8 feet) of the heaviest air-dried (20 percent) hardwoods will weigh about 4,400 pounds and produce 16 million Btu. This energy is equivalent to 1,890 pounds of coal, 152 gallons of oil, 21 therms of gas, and 4,700 kilowatthour (kWh) of electricity at the given burning efficiencies. The burning efficiencies are probably low for newer energy efficient appliances. Rather it is feasible to use wood as a home heating source, depends on the cost of alternate fuels, which also varies by geographic location. In addition, the use of solid wood as fuel requires substantial effort in terms of gathering, firing, and clean up by the user as compared with the convenience and cleanliness of alternative fuels. Some communities have regulated solid fuel burning appliances due to air pollution concerns.

Table 10-8 presents groupings of numerous hardwood species based on weight. These weight categories correspond to those used in Table 10-7. On the basis of energy generated, wood is a bulky material compared with coal or the other fossil fuels.

Table 10-7. British thermal units (Btu) per air-dried cord of wood and fossil fuel equivalents for heavy, medium, and light weight hardwood classes listed in Table 10-8

Wood class	Cord weight (pounds)	Btu per cord[1] (millions)	Coal[2] (Pounds)	Energy equivalent		
				Oil[3] (gallons)	Gas[4] (therms)	Electricity[5] (kWh)
Heavy	4,400	16	1,890	152	21	4,706
Medium	3,300	12	1,420	114	16	3,529
Light	2,500	9	1,056	86	12	2,647

Burning efficiency:

[1] Based on wood at 50% burning efficiency, 3,600 usable Btu/pound (20% moisture content on ovendry basis)

[2] Based on coal at 65% burning efficiency, 8,450 usable Btu/pound

[3] Based on oil at 75% burning efficiency, 105,000 usable Btu/gallon

[4] Based on gas at 75% burning efficiency, 750,000 usable Btu/therm (1 therm equals 1,000 ft^3)

[5] Based on electricity at 100% efficiency, 3,400 usable Btu/kWh

Table 10-8. Relative weights of different hardwoods

Heavy	Intermediate	Light
Apple	Cherry	Aspen
Ash	Elm	Basswood
Beech	Gum	Box elder
Birch, river	Hackberry	Buckeye
Dogwood	Maple, soft	Butternut
Hickory	Sycamore	Catalpa
Ironwood		Cottonwood
Blue beech		Sassafras
Locust		Yellow-poplar
Maple, hard		Willow
Oak, white		
Oak, red		
Persimmon		
Osage orange		
Walnut		

Green sawdust

Green sawdust has typically been used only by large commercial operations. Other parts of the world have used it for home or shop heating and Wartluft (1975) has reported on a home-made, double-drum sawdust stove.

Wood pellets and logs

Wood residues that have been converted into pellets or fireplace logs have several advantages over solid wood. The pellets or fuel are dry, uniform in size, clean, and are shipped in bags. The process is old technology and similar to that used to pelletize other substances, such as animal feed. Before pelletization, the green residue must be converted to a uniform size and dried. Wax is sometimes added to help hold the particles together. Wood pellets are becoming more commonplace and acceptable due to increased fossil fuel costs. An export market also exists.

Ethanol

Wood residues can also be converted into ethanol and used for fuel. The process of converting woody cellulose to ethanol is more difficult and not as well researched as the conversion of grain to ethanol; however, it is possible. The U.S. Department of Energy (2008) reports that 80 to 100 gallons of ethanol can be produced per ovendry ton of woody biomass, whereas about 124 gallons can be produced from 1 dry ton of corn. Purdue University (2004) research to improve the conversion efficiency of wood cellulose to ethanol is being tested at the pilot plant level.

Mulch and Soil Amendments

Beyond fuel, the use of processed bark residues for mulch and soil amendments is probably the most common and visible use. Mulch is usually bark that has been processed to a uniform size and sometimes artificially colored. When bark or other wood residues are used as soil amendments, the bark is usually mixed with a nitrogen source and decomposed. To supply nitrogen and other nutrients, various sources of manure, sewage sludge, and commercial fertilizer have been used. The bacteria and fungi that cause the decomposition require a source of nitrogen. The cellulose is usually decomposed; the lignin is not. Lignin acts as humus. Thus, the material improves the soil tilth and increases the permeability and water retention, especially of sandy or clay soils. Bark decomposes more slowly than sawdust, so when applied to the surface as mulch, bark lasts longer and consumes nitrogen at a slower rate. Thus, there will be less nitrogen starvation of any crop plants.

Bark residues are usually collected by a specialized company that processes them to a uniform size and then sells the material in bulk or by the bag. Processed bark is used for landscaping or horticultural applications, in orchards, as well as for erosion control on projects ranging from highway construction to strip mines. It is also mixed with other materials and used as a potting medium. As a potting medium, important attributes are the ability to hold moisture, support the plant, and not add excess weight. Most producers have a preferred mix that has performed best for them.

Animal Feed

Some research has been conducted on the use of wood and wood-based residue as a roughage substitute in cattle feed. The work actually started in 1918-19 due to high grain prices during World War I. Efforts resurfaced in the 1970s, but little discussion occurs today. A good summary article was published at that time (Baker and others 1975).

Animal Bedding

Poultry litter

Some poultry operations confine thousands of birds in long narrow buildings. A litter material sometimes about 1 foot deep is placed in the buildings to absorb moisture and to support the birds. Producers have used wood residues ranging from higher valued planer shavings to bark and even ground-up particleboard waste. Low valued round wood may even be processed to fill the demand for litter. Thus, this is a valuable market, but relatively large quantities of dry materials are needed when the litter is replaced. Other applications might be found with some smaller flocks.

Livestock bedding

Planer shavings, bark, and sawdust have all been used as bedding for animals ranging from gerbils to cattle. Important factors for the user to consider are how much moisture the material can absorb compared with other available materials, and if there are any dust issues or other side effects.

The use of dry wood residue for horse bedding is commonplace. There are many small and local horse stables or boarding facilities, which are likely markets for relatively small quantities. Black walnut shavings, however, cannot be mixed into bedding for horses.

Exposure of horses to black walnut shavings used in stalls results in laminitis, which can lead to loss of the animal (Cassens and Hooser 2005). Since the lowest amount of walnut shavings that can cause toxicity has not been established, the safest course is to make certain that no black walnut shavings are used in bedding for horses. Figure 10-1 shows walnut strands mixed with other wood particles. This sample was collected from bedding where the horses had developed laminitis.

Signs of toxicity to horses generally occur within 24 to 48 hours of exposure to the contaminated shavings. The symptoms frequently begin with mild laminitis and swelling of the legs and can progress to extremely severe laminitis, swelling, and edema of all four limbs; and then to pitting edema of the ventral abdomen; and then colic. In extreme severe cases, the laminitis can be severe enough to allow rotation of the coffin bone leading to loss of the animal. When multiple horses are present in a single stable, there can be significant variation in the degree of laminitis and edema among individuals. Call a veterinarian if a problem is detected.

Figure 10-1. Chips and strands of chocolate brown wood are walnut.

Sweeping Compounds

Sawdust has been and continues to be used as a sweeping compound. It is sometimes produced as a sideline business for small companies and sold locally (U.S. Department of Agriculture, Forest Service 1966). The sawdust must be thoroughly air-dried to prevent mold. Paraffin oil is usually added if the compound is to be used on cement, terrazzo, wood, or other floors not affected by oil. The oil can be replaced by a water-wax emulsion so the compound is then suitable for use on linoleum, rubber, asphalt, tile, and similar floors. Sand can be added to improve the cleanability of the compound. Colorants and fragrances can also be added (Harkin 1969).

Miscellaneous Uses

Wood Flour

Wood flour is wood waste that is ground to different consistencies. The fineness of the flour and the uniformity of the raw material are important. Wood flour is used in absorbents, adhesives, cleaning products, plastics, paper, putty and caulk, and rubber. Perhaps the most interesting use is as a filler in the thermo-setting resins, particularly in moldings where it confers impact resistance, shrinkage control, and good electrical insulating characteristics.

Chemical Extractives

Chemical extractives are a large category of materials available mostly from bark (Harkin and Rowe 1971). These materials have been used in various items, such as laundry detergent additives, adhesives, strengthening agents in unfired ceramics, sizing in paper and textiles and as emulsifying agents in paints and foods, stabilizing agents in oil-well drilling muds, printing inks, dyes, binders, artificial vanilla, rayon clothing, photographic film, gun cotton, cordite, cellophane, inner plies of radial tires, conveyor belts, ethyl and methyl alcohol, naval stores, and others. Tannic acid is a common extractive from bark and was used in leather manufacturing. Although substitutes have replaced tannic acid in this application, the product obtained from bark is still used to control viscosity and gel strength in oil-well drilling mud.

Cement-Bonded Wood Panels

Wood materials are now being mixed with mineral binders such as Portland cement and gypsum to produce various building products. Examples include gypsum wallboards, ceiling boards, shingles, and hollow core building blocks that are later filled with concrete. The wood helps to reduce the weight, and larger particle sizes will improve the mechanical properties of the composite.

Summary

Harvesting residues, timber stand improvement residues, saw mill residues, and secondary manufacturing residues represent a huge amount of wood material in North America, only a portion of which is used. The disposal of bulky materials, whether large or small, with little or no value and concentrated at one location presents a serious problem. Various options exist. Where semitrailer load quantities exist, the opportunities are probably improved. On the other hand, smaller operations have the advantage of filling local niches for items such as fuel, bedding, and mulch, at a higher unit price.

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Chapter 11.

Wood Moisture and Drying

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Chapter 11.
Wood Moisture and Drying

The wood tissue in living trees is filled with moisture or "sap." Once the tree is cut into lumber and the lumber is properly stacked, this moisture begins to evaporate. The wood is drying. Tremendous amounts of research and practical experimentation have been conducted in an effort to determine the most efficient conditions for removing the moisture from wood without excessive degradation. The wood drying process is well known; it is a matter of physics.

Wood does not arbitrarily do strange things. There is always a reason for its performance, and quite often it is improper drying or regaining moisture. Many individuals dry and use wood without fully understanding the processes of drying or regaining moisture. If there is one most significant problem with wood, it is moisture and the fact that wood shrinks and swells as it loses or gains moisture.

This chapter first describes many of the problems that occur as wood dries, how it dries, proper air-drying and kiln-drying processes, and how wood regains moisture. Then, proper lumber storage and quality control checks for dried lumber are also discussed.

Problems Associated With Drying Wood

The problems associated with improper wood drying and storage are serious. They are often the cause of dissatisfied customers, or the reason why wood can receive a bad reputation. If wood is not dried to the appropriate moisture content, it will dry after being manufactured into a finished product. Joints open, boards warp, and the product is often unsightly. Conversely, if properly dried wood is installed in a humid environment, it will gain moisture and swell. The stile and rail of a raised panel door can split apart, doors and drawers may stick, and a host of other problems can also develop. If lumber is not properly stored after being dried, it can also regain moisture. After being manufactured into a product it will shrink, and the same type of problems will be experienced as if it had not been properly dried in the first place. Let's look at some of these problems before discussing how wood dries and how the process can be controlled.

Manufacturing Problems

This section describes some of the problems that may occur when wood is not properly dried to its end-use moisture content, when wood regains moisture during storage, or wood is damaged (stressed) during seasoning.

Figure 11-1 shows a raised panel kitchen cabinet door that was stained dark. The wide center panel shrunk during dry winter weather exposing a white line where the stain had not been applied. If the door is exposed to a higher humidity, the center panel will regain moisture, swell, and then the white line will disappear. With center panels that are normally 12 to 20 inches wide, some significant movement can be expected. The groove in the stile of the door is typically oversized to allow the panel to "float." If the center panel is restrained on both edges, it will likely split as it loses moisture.

Figure 11-1. A raised panel kitchen cabinet door shows a white line on the right edge of the center panel due to shrinkage.

The author is familiar with a set of cabinets that were manufactured in the dry winter weather of Minnesota and shipped to the outer banks of North Carolina. In this particular case, the center panel swelled just enough to separate the stile from the top and bottom rail. This relatively large manufacturer had not experienced problems previously, but higher coastal humidity was just enough to cause the separation problem. Raised panel house doors, or other solid raised panel construction, are subject to the same issues of shrinking and swelling. It is important that lumber be dried to the moisture content to which it will equalize in service. This is normally 6 to 8 percent in most of North America, but it can be as low as 4 percent in the dry Southwest and as high as 11 percent in some coastal areas. Consistent interior climate control will obviously affect the end-use moisture content as well.

Figure 11-2 shows a miter joint that has opened up. In this case, the stile and rail shrank, thereby creating an opening on the inside of the joint. If by chance the wood should swell, the joint would open on the outside corner.

Figure 11-3A shows deep checking in white oak, and a similar board with the checks closed is shown in Figure 11-3B. Figure 11-4 shows surface checking in a finished product. Although not open, the checks absorbed stain and are very evident. Surface checking results when the surface of a board dries too fast and shrinks while the core is still swollen.

Figure 11-5 shows the effect of casehardening or drying stress in a cabinet stile. The manufacturer was complaining about the doors not remaining flat. When the rail was cut into sections, the unbalanced stress became evident. A routine test for determining casehardening in lumber is discussed later in this chapter under Tests for Drying Stresses.

Figure 11-6 shows another common problem called planking, which is due to the difference in shrinkage between the radial (quartered) and tangential (flat sawn) directions when two or more pieces of wood are glued together. Tangential shrinkage is about twice that in the radial direction. In this case, the piece on the right is turned so the tangential direction is against the bottom of the square and it shrunk more compared with the piece with the radial direction turned 90°, leaving a gap on the right.

Figure 11-7 shows wide cracks that developed in 130-year-old white pine flooring. Judging by its age, the flooring was probably only air-dried initially. It shrunk slightly. Over the years, dirt accumulated in the cracks. During humid weather, the wood swelled, and the accumulated dirt caused ever so slight compression failures. With each cycle of shrinking and swelling, the cracks widened.

Figure 11-8 shows a buckled hardwood floor. The flooring was carefully conditioned to about 7 percent moisture content and then laid during mid to late winter in a well ventilated attic. Due to the heat accumulation during the summer, the flooring was stable; but by mid-winter of the following year, the flooring had adjusted to outside air-dry conditions, and buckling resulted.

Figure 11-9 shows a white oak trailer deck that was installed dead green. In this case, the shrinkage is of little consequence, but the example does illustrate how much wood can shrink with drying.

Problems can also occur due to impatience during the manufacture of glued panels. Polyvinyl acetate adhesive (PVA or common white glue) is commonly used for assembly, and it may be about half water. The water added through the glue in the immediate vicinity of the glue line causes the wood to swell slightly. If the panels are allowed to set, the water evaporates or disperses itself into the wood and the swelling disappears. On the other hand, if adequate time is not allowed for the panels to set and the swollen joints are surfaced, then the swollen wood is removed, the area later shrinks, and a sunken glue joint results (Figure 11-10).

Figure 11-2. The miter joint has opened up on the inside due to shrinkage.

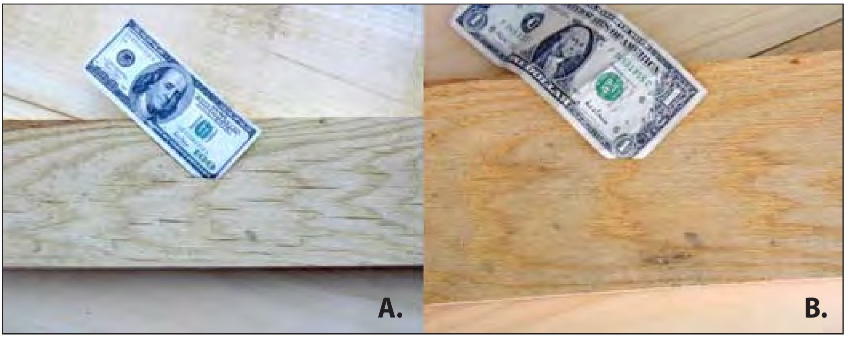


Figure 11-3. Checking. (A) Deep checking in white oak, and (B) a similar board with the checks closed.

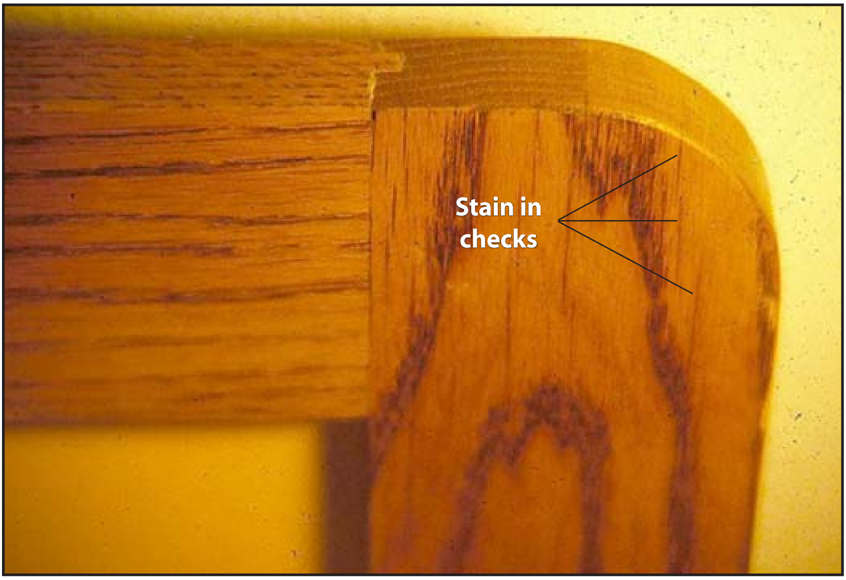


Figure 11-4. Stain has penetrated deep surface checks in a finished product. The checks are currently closed.

Figure 11-5. Casehardening or stress in the cabinet stile caused the entire door to warp. The stile was cut into sections so the amount of stress could be seen.

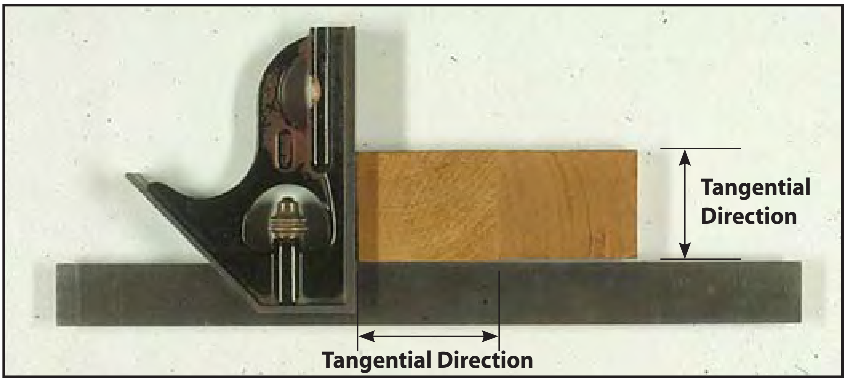


Figure 11-6. Two pieces were glued together to form the block of wood. "Planking" is caused by the difference in the amount of shrinking in the tangential (flat sawn) and radial (quarter sawn) directions by the two pieces. Notice how the right side of the wood does not touch the straight edge.

Figure 11-7. Wide cracks between 130-year-old white pine floor boards.

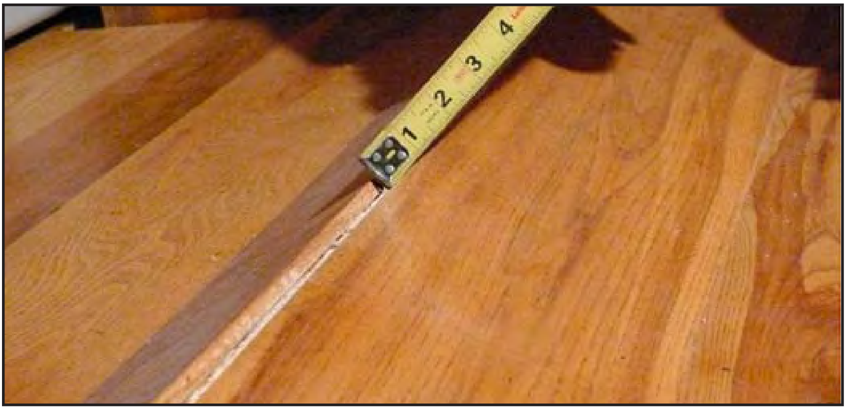


Figure 11-8. The hardwood floor buckled due to moisture regain during winter months.

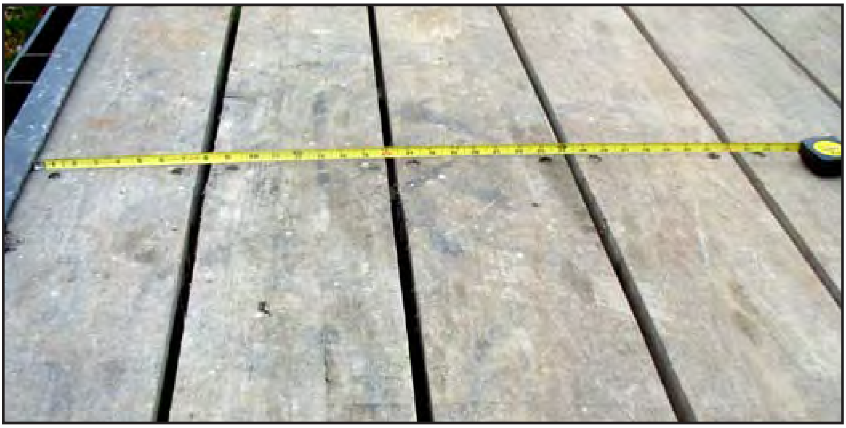


Figure 11-9. Shrinkage in a white oak trailer deck installed green and then allowed to dry.

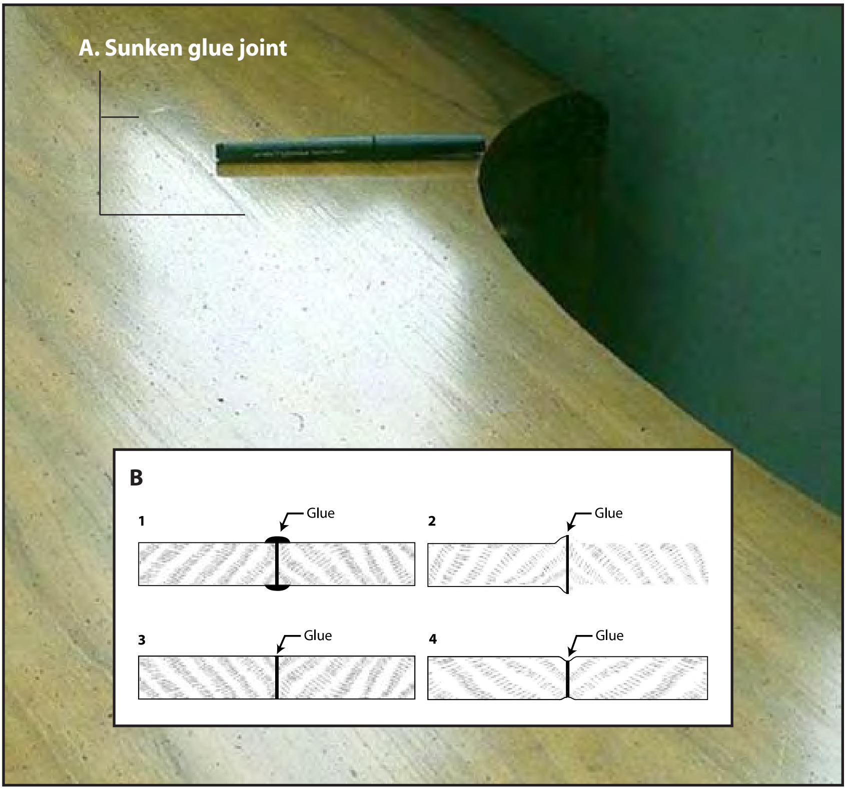


Figure 11-10. Sunken glue joints. (A) A sunken glue joint has telegraphed from the solid lumber core through the veneer surface. (B) Schematic drawing of how sunken glue joints occur. Moisture in the glue swells the wood, which is planed off. Then the remaining wood dries, and a valley or sunken joint results.

Shrinkage

Figure 11-11 and Table 11-1 show the amount of movement that may occur in yellow-poplar over a range of humidity conditions at room temperature. In Figure 11-11 the second piece from the top was dried to about 7 percent moisture content, which is the recommended moisture content for interior wood products in most of the United States. The third piece from the top was conditioned to 65 percent relative humidity, which is not uncommon in many homes during warm weather, and it widened by 1/16-inch. The bottom piece was conditioned at 90 to 100 percent relative humidity and expanded by 7/64-inch. This high humidity condition allows for the most wood expansion, without soaking in water. The piece at the top was ovendried to 0 percent moisture content, and it shrunk in width by ⅛ inch. Zero percent moisture content is a somewhat artificial situation for wood. During cold, dry weather when interior home heating is prevalent; however, the moisture content of wood can drop to 3 percent or a little less.

Figure 11-11. Movement in 6-inch-wide flat sawn (tangential direction) yellow-poplar board over a range of humidity conditions:

Top—ovendried to 0 percent moisture content
Second from top—conditioned at 7 percent moisture content
Third from top—conditioned at 65 percent relative humidity
Bottom—conditioned at 90-100 percent relative humidity

Table 11-1. Effect of relative humidity on yellow-poplar

Sample number	Relative humidity (%)	Equilibrium moisture content (EMC)[1] (%)	Width (inches)	Approximate change[2] fractional equivalent
1	0	0	5.868	-1/8
2	35	6.9	5.993	0
3	65	12.0	6.055	+1/16
4	90	16.0	6.102	+7/64

[1]EMC is the moisture content at which wood will equalize at a constant relative humidity and temperature. In this case, the temperature is room temperature or about 70 °F.

[2]This change is the amount of movement in the wood sample, when it was equalized at a lower or higher relative humidity.

Shrinkage of wood in the tangential, or flat sawn, direction is about twice that in the radial or quarter sawn direction. Shrinkage in the longitudinal direction is insignificant for nearly all applications. Table 11-2 shows total shrinkage from green to ovendry condition by species. Figure 11-12 graphically represents tangential shrinkage for numerous species. Typically, but not always, the heaviest woods shrink the most.

The differential in tangential and radial shrinkage is important because it is responsible for much of the warping that occurs as wood dries without restraint. Flat sawn boards tend to cup toward the bark, thus the bark side is normally turned in for board-and-batten type construction. Some squares can turn to diamonds and rounds turn to ovals (Figure 11-13).

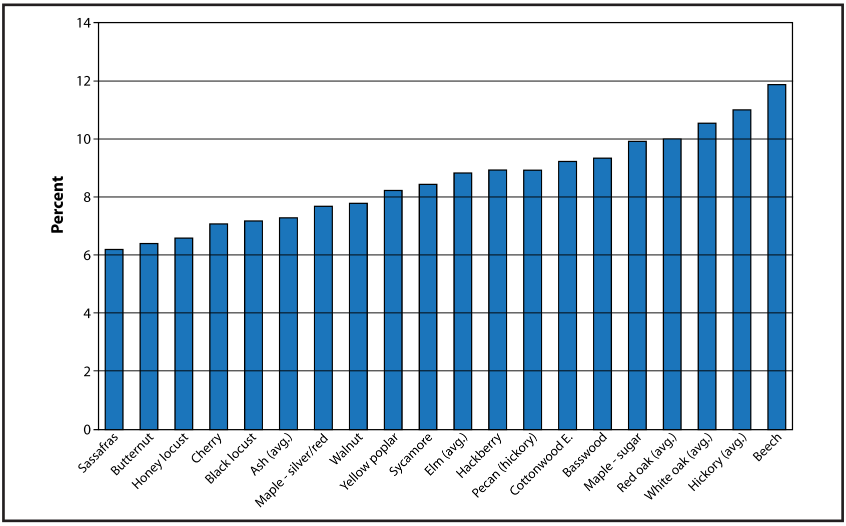


Figure 11-12. Total tangential shrinkage (percent) from green to ovendry moisture content for various species.

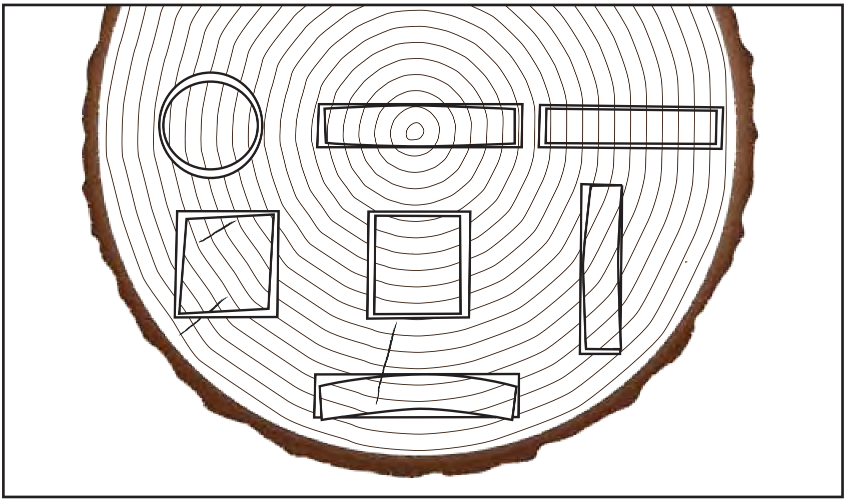


Figure 11-13. Characteristic shrinkage and distortion of flat, square, and round pieces as affected by the difference in tangential and radial shrinkage.

Table 11-2. Shrinkage in percent from green to ovendry moisture content (U.S. Department of Agriculture, Forest Service, 2010, p. 4-6)

Species	Radial (quarter sawn)	Tangential (flat sawn)	Volumetric
Red oak			
Northern red	4.0	8.6	13.7
Black	4.4	11.1	15.1
Pin	4.3	9.5	14.5
Scarlet	4.4	10.8	14.7
Average	4.3	10.0	14.5
White oak			
White	5.6	10.5	16.3
Bur	5.3	10.8	16.4
Chestnut	5.5	9.7	16.7
Swamp white	5.2	10.8	16.4
Average	5.4	10.5	16.5
Ash			
White	4.9	7.8	13.3
Green	4.6	7.1	12.5
Blue	3.9	6.5	11.7
Black	5.0	7.8	15.2
Average	4.6	7.3	13.2
Hickory (true)			
Shagbark	7.0	10.5	16.7
Pignut	7.2	11.5	17.9
Mockernut	7.7	11.0	17.8
Average	7.3	11.0	17.5
Pecan (Hickory)			
Pecan	4.9	8.9	13.6
Elm			
American	4.2	9.5	14.6
Red or slippery	4.9	8.9	13.8
Rock	4.8	8.1	14.9
Average	4.6	8.8	14.4

Continued...

Table 11-2. Shrinkage in percent from green to ovendry moisture content *(continued)*

Species	Radial (quarter sawn)	Tangential (flat sawn)	Volumetric
Hackberry	4.8	8.9	13.8
Walnut	5.5	7.8	12.8
Butternut	3.4	6.4	10.6
Cherry	3.7	7.1	11.5
Yellow-poplar	4.6	8.2	12.7
Maple			
Sugar	4.8	9.9	14.7
Silver	3.0	7.2	12.0
Red	4.0	8.2	12.6
Beech	5.5	11.9	17.2
Basswood	6.6	9.3	15.8
Sycamore	5.0	8.4	14.1
Cottonwood – Eastern	3.9	9.2	13.9
Sassafras	4.0	6.2	10.3
Black locust	4.6	7.2	10.2
Honey locust	4.2	6.6	10.8
Southern yellow pine	4.7	7.5	12.3
Douglas-fir	4.5	7.3	11.6
Spruce – pine fir	3.7	7.1	11.2

How Wood Dries

Wood drying is a physical process that has received much study, and is well understood and documented. These are not trade secrets; the laws of physics apply. Usually a shortage of knowledge is the cause when problems arise or go unexplained. Green wood holds free water, bound water, and water of constitution. In drying, heat and air movement are applied, in order to separate the water from the wood. Commercially, the trick is to apply heat and air movement in such a way that the wood is dried as quickly as possible while avoiding excessive degrade. Wood can also be dried under much milder conditions with less chance of degrade, but it will take longer.

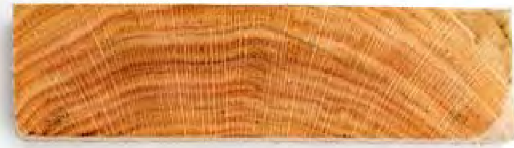
Knowing how a board dries, and related terms, are important to better understanding the drying process. Envision a 2-inch-thick cross-section of flat cut red oak fresh from the saw. Oak is difficult to dry and has large wood rays that can be seen by the unaided eye. Figure 11-14A is a photograph of a perfect piece of fresh cut lumber. It has not begun to dry, and it shows no defects.

Figure 11-14B shows a portion of the sample referred to in Figure 11-14A as it begins to dry. Free water begins to evaporate from the surface. Free water is held in the cell lumens, cavities, or pores. As free water evaporates from the surface, water from deeper within the piece begins to move towards the surface. A moisture gradient is established where water molecules move from a concentrated location (center of the board) to a less concentrated location (surface of the board). Air movement will help to remove the water molecules from the surface, thus increasing the rate of drying and the rate of molecule movement from the interior to the surface.

As drying continues, all of the free water is removed from the surface of the board and the bound water begins to evaporate. Bound water is the water that is held within the cell wall. The point at which all of the free water has evaporated and all of the bound water still remains is called the Fiber Saturation Point (FSP). This is a very critical point, and it is normally considered to be about 28 percent moisture content, but it can vary somewhat by species.

As soon as the bound water begins to evaporate, shrinkage begins, and it continues to 0 percent moisture content. The potential for excessive drying degrade also begins at this point. If the board dries too fast, the surface shrinks but is restrained by the core, which is still above the FSP and has not shrunk. The shell is held in tension by a core, which is in compression. In oak, the wood can literally fail in tension perpendicular to the grain. The weakest spot is at the interface between the side of a wood ray and adjacent longitudinal tissue. Failure is expressed as a check and most likely by many checks. The severity of the checking depends on the moisture gradient and drying stresses that are set up. In some softer woods such as cottonwood, collapse can occur. In this case, the core is crushed by the tensile forces that develop in the face of the board. The shell, because it is in tension, is normally set in a somewhat over-sized dimension.

A.

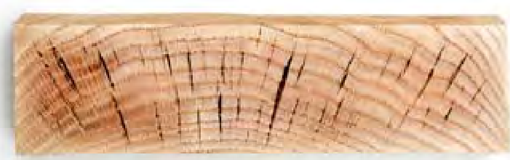


- Wood is uniformly above the fiber saturation point (FSP)
- Wood is free of drying stresses
- No moisture gradient has developed
- Wood is defect free
- Drying begins from the surface

B.

- Moisture gradient develops from low at the surface to high at the core
- Shell drops below the FSP and attempts to shrink
- Shell goes into tension causing the fully swollen core to be in compression
- Shell is set in oversized condition and surface checks may develop In weaker woods such as cottonwood, the core may collapse

C.



- The wood is below FSP throughout
- Core shrinks and pulls away from oversized shell
- Core goes into tension and may develop honeycomb
- Shell goes into compression and surface checks close

Figure 11-14. When wood dries too fast, defects can develop during the three stages of wood drying. (A) Stage 1–No defects in green wood. The wood is dead green or above the fiber saturation point (FSP) throughout. No drying defects or drying stresses have developed. Color differences from the surface to the core indicate that some free water has evaporated from the surface. (B) Stage 2–Surface checks in partially dried wood. The shell of the piece has partially dried to below the FSP and has started to shrink. The core has not dried below the FSP and thus is at its original dimensions. Moisture is migrating from the core to the shell. Because the shell is starting to shrink over the full-sized core, the shell develops tensile stress and forces the core into compression. If drying is too rapid, some surface checks usually develop alongside some wood rays. In some softer woods, like cottonwood, the core may collapse due to compressive forces. Drying will set the shell at an oversized dimension, which will cause the defects in stage 3. (C) Stage 3–Honeycomb or internal checks in wood with a dried core. The core drops below the FSP and attempts to shrink. Because the shell was set in an oversized condition, the core cannot shrink normally. The core is now in tension and pulls the shell into compression. Checks on the shell may close, but internal checking or honeycomb may result in the core. The interior honeycomb checks may be extensions of the now-closed surface checks. The piece may cup and, if drying has been severe, the surface will appear irregular.

As wood dries below the FSP, it becomes stronger. So wood that is above the FSP is weaker than that below the FSP. Whether the wood checks or collapses depends on the tensile strength or compression strength perpendicular to the grain.

The board now continues to dry, and the core finally drops below the FSP. Remember, the shell has dried below the FSP and is stronger than the core and set in a somewhat over-sized dimension. The core cannot shrink enough because of the oversized shell. The core can now pull the shell into compression and close the surface checks. The core goes into tension (Figure 14C). The surface checks simply continue inward along the ray and longitudinal tissues. These checks are sometimes called bottleneck checks. If the condition is severe enough honeycomb develops, and sometimes it is not recognized until the lumber is processed. Because of these drying stresses, nearly all lumber has some degree of casehardening at the end of the drying cycle. Please see the sections titled “Casehardened Lumber” and “Tests for Trying Stresses” for additional explanation.

Surface checks, collapse, and honeycomb cannot be remedied. Casehardening, however, should be relieved at the end of the drying cycle.

When wood is exposed to a particular relative humidity, its moisture content will come into equilibrium with that particular set of environmental conditions. This is called the equilibrium moisture content (EMC). If the relative humidity and moisture content change, the EMC of the wood will eventually change as well. If lumber is kiln-dried to 6-8 percent and then stored in an unheated shop, it will regain moisture to about 12-15 percent. Please see the section on Heated Room Drying under Kiln-Drying for further explanation.

Various types of wood dry quickly and easily, but others such as oak are much more difficult to dry. The knowledge has been developed to dry lumber as quickly as possible with minimal degrade. Table 11-3 presents a list of woods ranked by ease of drying, based on schedules developed for steam-dry kilns. There is substantial variation within each category, but the classification does give a general idea of the difficulty of drying each species, as well as the time required. A more severe drying schedule is used for the easy-to-dry woods.

Table 11-3. Rating of various wood species by the severity of kiln schedules that can be used. A "severe" schedule is used on easy-to-dry woods, and a "mild" schedule is used on difficult-to-dry woods. (U.S. Department of Agriculture, Forest Service, 1991, p. 150-151)

Severe	Moderate	Mild
Aspen	Ash	Beech
Basswood	Birch	Black locust
Yellow-poplar	Buckeye	Hickory
	Cherry	Oak
	Cottonwood	Pecan
	Hackberry	Persimmon
	Heartwood	Rock elm
	Sassafras	Sugar maple
	Soft maples	Sycamore
	Swamp blackgum	
	Sweetgum	
	Walnut	
	Willow	

Air-Drying

Hardwood lumber can go directly from the saw into the dry kiln. This procedure is followed for some species, such as hard maple, in order to better maintain a white color, or to decrease the time required from when the lumber is sawed to when it can be sold. Placing green lumber directly in the dry kiln is also done with easy-to-dry woods such as yellow-poplar. It is important that the kiln has the capacity to vent or otherwise remove the moisture released by the lumber. Otherwise, mold and discoloration will result. Usually, the lumber is air-dried first. Care must be exercised since surface checking and even some honeycomb checking can occur during air-drying. Air-drying reduces energy costs as compared with kiln-drying green hardwood lumber. Air-drying also lessens the likelihood of causing serious degrade in refractory species such as oak.

Air-drying, like kiln-drying, is an extremely important process, and it should be taken seriously with attention given to every detail. Lumber is relatively weak when it is green. Any distortion due to improper stacking will be permanently set when the lumber is dried.

Proper air-drying starts with a perfectly flat foundation that places the bottom lumber course 1 foot or more above soil level (Figure 11-15A). In the past, some air-drying yards were built with their foundations sloped from front to back. Supposedly, this was to help any moisture that entered the pile to drain rapidly. This design is seldom used today. Some foundations are permanent, others temporary. If the foundations are to be reused, a more or less permanent installation is desirable, because it takes considerable time to level a foundation on irregular soil. Also, foundations on soil can move due to the weight of the lumber, and from freezing and thawing. For small quantities of lumber, old but level concrete slabs from demolished buildings are excellent foundations.

A 2-foot spacing for stickers and bolsters has been a standard for many years, but many installations are decreasing the spacing to 18 inches—and even to 1-foot—for species that tend to warp excessively. These species include all gums, sycamore, and elm. Some operations like the spacing to be closer at the ends of the pile, particularly if it contains two lengths of lumber, such as 11- and 12-foot lengths. In this case, a 1-foot spacing provides support for both lengths of lumber.

Stickers are placed between each course of lumber and directly above each other and above the bolster. It is important to keep the stickers perfectly aligned, and as close to the ends of the boards as possible.

A sticker placed right at the end of a board tends to stop deep end splits from developing. Care must be taken, however, if the bundles are later moved to a dry kiln with a forklift over rough terrain; these stickers can work loose, and permanent distortion of unsupported boards will occur in the kiln.

The pile is built to a suitable and manageable height. If a forklift is available, 4 by 4 bolsters are used between the lumber packs (Figure 11-15B). These bolsters must be aligned directly over each column of stickers to assure maximum flatness of the lumber.

Once the pile is built, it should be covered to avoid weathering and subsequent warp and deterioration of the top courses of lumber. A number of different types of covers have been used. These include galvanized roof tin and wood covered with asphalt roofing. The tin, of course, has to be weighted or even held down with springs.

In addition to holding a cover in place, weights are important because they will help keep the top course of lumber flat. For smaller operations, the less valuable stock should be placed on top of the pile. Some operations have begun placing concrete slabs 4 to 6 inches thick on top of the pile. The slab protects the top of the pile from the weather and keeps the boards flat.

Some operations have installed "T sheds" to protect lumber from the weather. A T shed is a long roof supported along its length by posts in the middle (Figure 11-16). It is loaded with stickered lumber from either side. Users have been happy with the results achieved.

Stacking green lumber inside a closed building is not a good idea. Air movement, such as wind, is very important in moving moisture away from the surface of the boards. If this moisture is not moved promptly in warm weather, mold and sticker stain will develop.

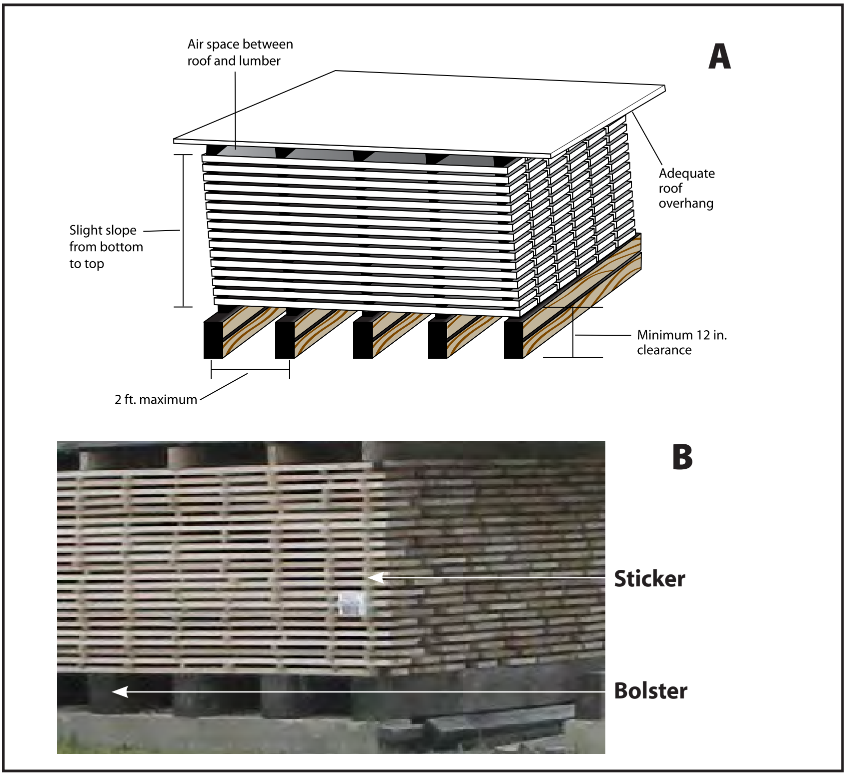


Figure 11-15. Stacking lumber for proper seasoning. (A) Diagram of essential features of stacked lumber. (B) Mostly well constructed temporary lumber pile under commercial conditions. Note the alignment of drying sticks and bolsters. One bolster is misaligned.

Figure 11-16. T sheds are used to protect lumber from the weather during air-drying. Lumber that surface checks easily, such as 8/4 oak, is wrapped in burlap or protected by shade cloth to slow the rate of surface drying during certain times of the year. Slower drying prevents surface checking.

Plastic covers and tarps do not work well as pile covers because they tend to trap moisture. During certain times of the year, moisture may condense on the underside of the plastic cover and then drip back into the pack of lumber.

Stickers are another important issue. Most stickers are ¾-inch thick by 1½- to 2-inches wide. Sticker length is set at the width of the pile plus a few inches. Most piles are 4 to 6 feet wide, but some may be 8 feet wide. Most any species can be used as a sticker, but the dense woods will probably last longer. The stickers should be flat and straight so they can lay in a straight line. Using green wood as a sticker will likely result in sticker stain, especially in the white woods. Unused stickers should be kept dry and not left in the weather. If the stickers are not circulated through a dry kiln that achieves temperatures in excess of 130 °F, they will likely become infected with powder post beetles that can spread to the lumber. These beetles seem to infest wood near any bark that has been left on, so removal of bark from the sticker is probably important as well.

Using lath or plywood strips less than ¾-inch thick will reduce air movement and thus drying rates. During warm weather, or where there is no air movement, stain could develop.

Stickers that are relatively small, as well as other short pieces of wood, can be generated from large logs, such as oak with butt flare, or when cutting 8/4 lumber. When time permits, the author cuts sticker stock to length and incorporates it in the air-drying piles to dry. The pieces are later surfaced to uniform thickness, cut to length, and are then ready for use.

Standard stickers are usually flat surfaced wood; however, there is a patented design that has a diagonal groove cut into the top and bottom flat faces (Figure 11-17). Only the ridges contact the face of the green boards, allowing better air circulation. Users report that less sticker stain occurs in white woods dried with diagonally grooved stickers.

Figure 11-17. Drying stick or sticker with diagonal grooves, which help to prevent sticker stain or shadow on white woods.

Box Piling

It is easiest and most efficient to pile lumber of the same length or maybe of two lengths, such as 8- through 10-foot lengths, all together in one pile. If only small quantities of mixed lengths are available, a technique called box piling can be used. With this method, the longest lengths are placed on the outside edge of the pile and perhaps one or more pieces in the middle (Figure 11-18). The shorter lumber is placed in between the longer lengths. Be certain that each end falls on a sticker. Adjacent pieces in each course and between courses are staggered at their ends. The objective is to have no unsupported stickers for any distance across the width of the pile. The thin narrow sticker can be bent by the weight of the lumber, and any boards in the immediate vicinity will be warped.

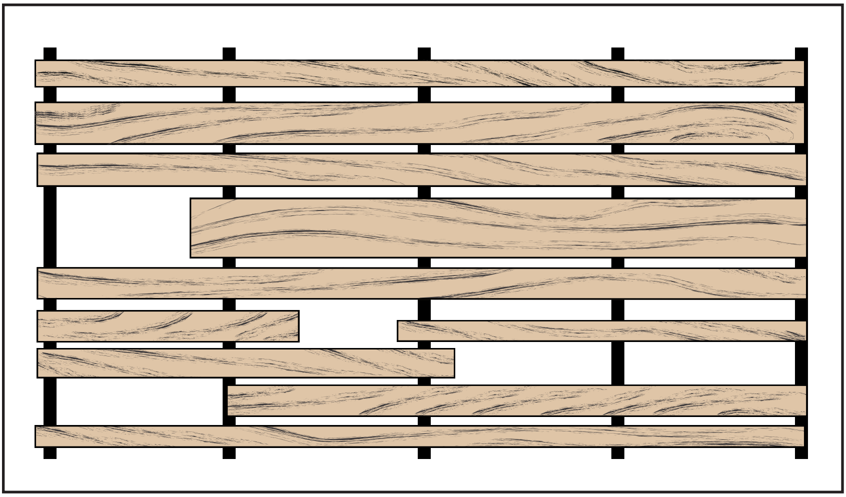


Figure 11-18. Overhead view of a single course of lumber demonstrates box piling, which accommodates different length boards.

Forced Air-Drying

In the South, cottonwood is sometimes forced air-dried in "blow boxes." With this technique, two long rows of stickered lumber are arranged with a space or tunnel between them. One end and top of the tunnel are blocked. Large fans are placed at the opposite end, and air is forced to move between the courses of lumber, causing it to dry faster. Cottonwood is moisture laden but relatively easy to dry. Accelerated air-drying of refractory woods such as oak can result in excessive degrade.

Accelerated drying of small quantities of wood can also be achieved with inexpensive box fans. This approach can be useful if drying time is critical or if stain-prone woods are cut when drying conditions are poor. The idea is to increase the rate of air-drying of the surface of the board and thus prevent discoloration. Care must be exercised with accelerated drying of hard-to-dry woods.

Air-Drying Times

Air-drying times are dependent upon weather conditions. Table 11-4 shows the effective air-drying days by month for the upper Midwest. As one moves from the North to the South, the length of good air-drying conditions increases from 4 months in northern Wisconsin, Michigan, and the Northeast to 12 months in the Deep South. Air-drying time (to 25 percent moisture content) in the Central States and lower Northeast ranges from about 2 months under good weather to 5½ months under less than desirable conditions. In the Deep South, the range (to 20 percent moisture content) is from 1½ months to somewhat over 2 months. Easy-to-dry species, such as yellow-poplar and soft maple, obviously take less time than difficult species, such as oak, which take considerably longer. In general, at least 2 months of warm weather are required to adequately air-dry most species. A week or two of windy, dry fall weather, however, can dry lumber quickly.

The air-drying time for thicker lumber, especially 8/4, is greatly increased to 3 and 4 times that of 4/4 stock.

Air-drying is a cost-effective way of reducing the moisture content of lumber to a point where it can be safely stored without damage from mold, stain, and decay, although air-dried lumber may still be attacked by certain insects. For more information see the chapters titled “Insect Damage to Trees, Lumber, and Finished Products” and “Stain in Logs, Lumber, and Finished Products.” With air-drying, however, some care is required. If the lumber is not thoroughly dry in the core, this moisture will move to the surface in dead-piled lumber, and deterioration is likely. On the other hand, if the lumber is left on the air-drying yard in excess of the time required to be properly air-dry, deterioration will also occur. The edges of the packages will weather. On species such as oak that are subject to surface checking, the checks will be driven deeper into the wood from alternating wet and dry weather as the wood continues to shrink and swell. The objective is to put freshly sawed lumber on stickers as soon as possible to uniformly air-dry it to about 20 percent, or somewhat less, and then move it off the yard and to the next step, which should be kiln-drying or use as air-dried stock. Letting the lumber set longer than necessary is just asking for degrade.

Table 11-4. Effective air-drying days by month for the upper Midwest (Reitz 1972, p. 2)

Month	Effective air-drying days
January	5
February	5
March	10
April	20
May	25
June	30
July	30
August	30
September	25
October	20
November	10
December	5

Kiln-Drying

Kiln-drying is simply the placement of lumber (or other wood items, such as poles and turning squares) in an environment where the temperature, relative humidity, and air circulation are controlled. Equipment for kiln-drying has changed substantially over the years, and many novel methods also exist. The more traditional methods used in large and small operations are discussed next.

Early in the development of drying methods, lumber was stacked as it is today, but with a flue in the center of the pile and a fire built under it. This method certainly delivered hot, dry air that moved upward, but offered little control. Direct fired dry kilns achieving temperatures in the 230 to 250 °F range have more recently been used on southern pine lumber. These installations, of course, had appropriate controls for regulating temperature and safety equipment.

Steam heated dry kilns have been and continue to be the industry standard for many large installations. Each chamber typically holds 50,000 board feet or more. The steam is usually generated from mill waste, thus reducing energy costs. Most of these kilns in the hardwood industry are now package-type kilns, which means they are loaded with a forklift. The lumber is usually three or more courses deep. Track-type kilns also exist. The lumber is stacked on carts and rolled into and out of the kiln on tracks.

Powerful fans, sometimes with variable speed, are located overhead. These fans force the air over fin pipes and raise the temperature. This warm or hot air is forced through the courses of lumber, picking up moisture. A portion of this air is intentionally exhausted through vents in the roof of the kiln. For uniform drying, the spaces between the tops and sides of the lumber packages and the kiln roof and walls are baffled. The lumber packages are staggered to ensure that excess air does not circulate between the ends of the packages. Some operations close the space left by bolsters between the packs of lumber. The fans are periodically reversed.

The dry-bulb and wet-bulb temperatures are closely monitored and controlled depending on a predetermined schedule for each species, lumber thickness, and current moisture content. The dry-bulb temperature is the standard temperature that you and I are familiar with. The wet-bulb temperature is that temperature used to determine the relative humidity. The higher the relative humidity the higher the wet-bulb temperature and the less severe the drying conditions. Low wet-bulb temperatures mean low relative humidities and more severe drying conditions. The classical wet bulb thermometer is a standard thermometer, but it has a wet sock on the bulb. Water will evaporate from the wet sock. The more humid the air, the slower the rate of evaporation, and the higher the wet bulb temperature. Steam kilns are capable of relieving drying stress or conditioning the lumber at the end of the drying cycle by injecting steam.

Equalizing periods are normally used at the end of the kiln cycle to reduce the amount of moisture content variation within and between boards and to better prepare the material for subsequent conditioning. The conditioning step relieves the transverse drying stresses. With the proper conditioning, longitudinal drying stresses can also be relieved.

Proper equalizing and conditioning are the responsibilities of the dry kiln operation and should always be practiced when the lumber is intended for remanufacture. The exact procedures are presented in the Dry Kiln Operator's Manual (U.S. Department of Agriculture, Forest Service, 1991).

Equalizing starts when the driest kiln sample has reached an average moisture content of 2 percent below the desired final average moisture content. Equalizing continues until the wettest sample reaches the desired final average moisture content. When conditioning hardwoods, the EMC is set at 4 percent above the desired final average moisture content. Conditioning time may range from 16 to 48 hours.

Many kilns are now monitored by probes and controlled by computers. The accuracy of electric moisture meters (probes) is not exact but apparently still useful.

Kiln Schedules (Steam)

Although you may never run a steam-powered dry kiln, the concept of the kiln schedule and how it applies to wood drying is worth review. It provides insight as to how wood dries without excessive degrade. Table 11-3 rates the various woods based on the severity of the kiln schedule that can be used. For difficult-to-dry species still at high moisture content, the review will also demonstrate how carefully the conditions must be controlled and the material dried.

Table 11-5 presents the schedule for northern or upland red oak, a difficult-to-dry wood, as well as yellow-poplar, an easy-to-dry species. For red oak lumber above 50 percent moisture content, the initial settings for the kiln are 110 °F for the dry-bulb and 106 °F for the wet-bulb or only a 4 °F depression. This is a relative humidity of 87 percent and a wood EMC of 17.5 percent. These are mild drying conditions. When the moisture content of the lumber drops to 50 percent (based on kiln samples or electric moisture meter probes), the dry-bulb temperature is maintained, and the wet-bulb depression is dropped just 1 °F. When the wood finally reaches about 30 percent moisture content or the fiber saturation point, the dry-bulb temperature is raised and the wet-bulb depression or humidity is dropped substantially in steps until the wood is dry. An equalization period is next, allowing samples that have overdried to regain some moisture and those that are still a little on the wet side to lose some moisture. A conditioning period to relieve stress then follows.

Table 11-5. Kiln schedules for 4/4 northern or upland red oak and yellow-poplar (U.S. Department of Agriculture, Forest Service, 1991, p. 150-151)[1]

Moisture content at start of step (percent)	Dry-bulb temperature (°F)		Wet-bulb depression (°F)		Wet-bulb temperature (°F)	
	Red oak	Yellow-poplar	Red oak	Yellow-poplar	Red oak	Yellow-poplar
Above 50	110	150	4	7	106	143
50	110	150	5	10	105	140
40	110	150	8	15	102	135
35	110	150	14	25	96	125
30	120	160	30	35	90	125
25	130	160	40	40	90	120
20	140	170	45	45	95	125
15	180	180	50	50	130	130
Equalize	173	173	43	43	130	130
Condition	180	180	10	10	170	170

[1] Red oak schedule is T4-D2, and yellow-poplar schedule is T11-D4.

For yellow-poplar, an easy-to-dry wood, the initial dry-bulb temperature starts out at 150 °F with a wet-bulb depression of 7 °F. The schedule is accelerated from that point forward.

Schedules similar to these have been developed and published for each species and for thicker lumber in the Dry Kiln Operator's Manual (U.S. Department of Agriculture, Forest Service 1991). The schedules are thought to be somewhat conservative as some experienced operators are able to accelerate them; however, without justification and experience, the schedules should probably not be accelerated.

For air-dried lumber (15 to 20 percent moisture content) the initial dry-bulb temperatures allowed in a steam kiln are relatively high and probably not achievable in most other methods, such as dehumidification, box, and solar drying. Thus, with air-dried lumber and with low temperature kilns, there should be little concern for causing degrade except for stress.

Steam kilns are designed to dry large quantities of lumber as quickly and precisely as possible without excessive degrade. Improper operation or equipment failure can result in substantial monetary losses. Most dry kiln operators in larger companies are experienced and have attended a 3-day or longer kiln-drying workshop. Detailed dry-kiln schedules are available. Most new kilns are computer controlled with schedules already programmed in. These kilns are typically operated close to the point where the lumber can be damaged.

Dehumidification Drying

Dehumidification drying is probably the next most common method of drying. Large units, as well as units that hold only 1,000 to 3,000 board feet, are available. With this drying method, the lumber is once again placed on drying stickers and put in a box. A commercial grade dehumidification unit is typically placed inside the box. As the moist air passes over the cold coils in the unit, it condenses and gives up heat, which further dries the lumber. The condensate is drained away.

Depending on the unit, dehumidification temperatures range from 120 to 160 °F. Remember, temperatures over 130 °F are required to kill any powderpost beetles or larvae in the wood. Some units come equipped with steam-spray systems or a cold-water mist to relieve stress. Depending on the unit, some lumber can be dried green from the saw, while other smaller capacity units may be best used for air-dried lumber.

Solar Kiln-Drying

Solar kilns are another example of small scale, low-cost drying equipment. Various plans have been proposed, and some suppliers sell a plan along with the parts needed to build your own unit. Again, warm air is circulated through the lumber courses. Solar energy is used to heat the air. The moist air can be vented or allowed to condense on a cold surface in the evening, or both. Some operators indicate that drying stresses are not an issue because of the cyclic nature of the drying process, while others report that a water-spray system is necessary.

Solar kilns received a lot of exposure several years ago, but at this writing interest seems minimal. In the meantime, several suppliers have made electric powered kilns of various designs and sizes available. Some of these kilns have capacities of just 1,000 board feet. Thus, users and producers of small quantities of material now have more choice in how to dry lumber.

Heated Room Drying

With the vast array of commercial equipment available to dry lumber, it is easy to lose sight of the basic principles of how lumber dries. Table 11-6 gives the wood EMC for a given relative humidity and temperature. At 70 °F and 35 percent relative humidity, and given time, the moisture content of wood will stabilize at about 6.9 percent. It is as simple as that! These temperatures and relative humidity conditions are also very comfortable for us human beings and are typical of interior living space. That is why wood is typically kiln-dried to 6-8 percent moisture content. At an average temperature of 60 °F and 70 percent relative humidity, wood will reach a moisture content of 13.3 percent. The typical moisture content of air-dried lumber or lumber stored in unheated sheds is 12 to 15 percent.

Table 11-6. Equilibrium wood moisture content (EMC)[1] for a given relative humidity and temperature (U.S. Department of Agriculture, Forest Service, 2010, p. 4-4)

Temperature (°F)	Relative humidity (percent)															
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
	Wood moisture content (percent)															
30	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.4	13.5	14.9	16.5	18.5	21.0	24.3
40	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.3	13.5	14.9	16.5	18.5	21.0	24.3
50	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3
60	4.6	5.4	6.2	7.0	7.8	8.6	9.4	10.2	11.1	12.1	13.3	14.6	16.2	18.2	20.7	24.1
70	4.5	5.4	6.2	6.9	7.7	8.5	9.2	10.1	11.0	12.0	13.1	14.4	16.0	17.9	20.5	23.9
80	4.4	5.3	6.1	6.8	7.6	8.3	9.1	9.9	10.8	11.7	12.9	14.2	15.7	17.7	20.2	23.6
90	4.3	5.1	5.9	6.7	7.4	8.1	8.9	9.7	10.5	11.5	12.6	13.9	15.4	17.3	19.8	23.3
100	4.2	5.0	5.8	6.5	7.2	7.9	8.7	9.5	10.3	11.2	12.3	13.6	15.1	17.0	19.5	22.9
110	4.0	4.9	5.6	6.3	7.0	7.7	8.4	9.2	10.0	11.0	12.0	13.2	14.7	16.6	19.1	22.4
120	3.9	4.7	5.4	6.1	6.8	7.5	8.2	8.9	9.7	10.6	11.7	12.9	14.4	16.2	18.6	22.0
130	3.7	4.5	5.2	5.9	6.6	7.2	7.9	8.7	9.4	10.3	11.3	12.5	14.0	15.8	18.2	21.5
140	3.6	4.3	5.0	5.7	6.3	7.0	7.7	8.4	9.1	10.0	11.0	12.1	13.6	15.3	17.7	21.0
150	3.4	4.1	4.8	5.5	6.1	6.7	7.4	8.1	8.8	9.7	10.6	11.8	13.1	14.9	17.2	20.4
160	3.2	3.9	4.6	5.2	5.8	6.4	7.1	7.8	8.5	9.3	10.3	11.4	12.7	14.4	16.7	19.9

[1]The equilibrium moisture content (EMC) of wood is that moisture content to which wood will eventually equalize, given a fixed temperature and relative humidity. If the temperature and relative humidity change, the moisture content of the wood will change.

The catch is that it takes time for wood to reach its EMC at room or lower temperatures. Furthermore, the closer the wood comes to its EMC, the more slowly it gives up moisture. Thus, stickered lumber can be put into a room (kiln) with fixed temperatures and humidity conditions, and it will eventually come to the moisture content given in Table 11-6. Add heat and air circulation to the process, and drying will accelerate. Add humidity control, and the room is now a dry kiln. Some operators have successfully made their own dry kiln using inexpensive window fans. Electric heaters can be used to add heat, and household dehumidifiers can be used to lower humidity and also add heat in the process. Electric moisture meters can be used to monitor the moisture content of the lumber as it is being dried. Small, inexpensive sensors that determine relative humidity and temperature are available at building supply stores (Figure 11-19).

When the condensed moisture discharge from the dehumidification unit almost stops (assuming a well-sealed room or box), the lumber is probably dried. Drying stress can be a problem. With this relatively crude system, it is best to use only air-dried lumber. With air-dried lumber, most of the moisture is already removed, mold or deterioration from too moist an atmosphere in the chamber is not an issue, and it is difficult to cause drying degrade in air-dried lumber. Bowe and others (2007) have authored a publication, Dehumidification Drying for Small Woodworking Firms and Hobbyists, which describes a unit they have experimented with.

Figure 11-19. Inexpensive sensors can monitor temperature and relative humidity.

Vacuum Drying

The concept of vacuum drying has existed since the early 1900s. Commercial equipment became available in the 1970s, but little current interest exists. Vacuum drying results in faster drying with fewer defects, particularly in thick refractory stock; however, convective heat does not exist in a partial vacuum. The choices are to use alternative cycles of vacuum and atmospheric pressure, heat blankets, or high frequency electrical energy.

Storing Lumber

Once lumber is kiln-dried to the specified moisture content, it must be properly stored, or it will continue to gain or lose moisture in response to the relative humidity of the surrounding air. Wood is always attempting to come to equilibrium with the moisture in the surrounding air. The moisture content to which lumber is kiln-dried should be the same as the average moisture content to which it will equalize in service. For woods used indoors, in most parts of the United States, this is 6 to 8 percent. In the dry desert regions of the Southwest the figure is somewhat lower, while in the damp coastal areas it is higher. Table 11-7 presents the range of suggested moisture content for both interior and exterior applications in the United States.

Table 11-7. Recommended moisture content for various wood items at time of installation (U.S. Department of Agriculture, Forest Service, 2010, p. 13-2)

Wood use	Moisture content (percent)					
	Most areas of United States		Dry southwestern areas		Damp, warm coastal areas	
	Average	Individual pieces	Average	Individual pieces	Average	Individual pieces
Interior: Woodwork, flooring, furniture, wood trim, laminated timbers, plywood	8	6-10	6	4-9	11	8-13
Exterior: Siding, wood trim, framing, sheathing, laminated timbers	12	9-14	9	7-12	12	9-14

If lumber is kiln-dried to the standard 6 to 8 percent moisture content suitable for interior applications and then exposed to the outdoor atmosphere, it will gain excessive moisture and swell in most regions and seasons in the United States. If manufactured into a product and exposed to conditions inside a plant or house, for example, it will again lose moisture and shrink. Split ends, open glue joints, and warping will likely result. These problems are particularly severe during the heating season, because indoor relative humidities are reduced.

To further complicate the situation, lumber is normally stored in bundles. In this case, the outside boards, and especially the ends, will be the first to pick up or lose moisture, while the interior of the bundle will be slow to change. The moisture content between and within boards will no longer be uniform, and end-use problems are nearly certain.

The efficiency of a closed shed or chamber in maintaining a low-moisture content in lumber is enhanced if the air can be heated as required to maintain the desired EMC. Only a small amount of heat is needed to raise the temperature enough above the average outdoor temperature to lower the relative humidity and to keep the EMC in an acceptable range. Table 11-8 shows typical temperature increases required.

Table 11-8. Amount by which temperature of storage area must be increased above outside temperature to maintain equilibrium moisture content at different relative humidities (U.S. Department of Agriculture, Forest Service, 2010, p. 13-15)

Outside relative humidity (%)	Temperature differential in °F for desired equilibrium moisture content			
	6%	7%	8%	9%
90	33	29	23	18
80	30	25	19	14
70	25	20	15	10
60	20	15	9	6
50	15	10	5	1

For small storage areas, a dehumidifier can also be used on an as-needed basis. The unit removes any excess humidity and raises the temperature of the storage area. The desired condition can be determined from Table 11-7 and by using a temperature and humidity sensor as shown in Figure 11-19.

Quality Control for Kiln-Dried Lumber

Many problems can arise during the lumber drying process. These range from a lack of knowledge on the part of the operator, poor design of monitoring and kiln-drying equipment or their malfunction, wood variation issues, weather conditions, and so on. If poorly dried lumber is to be used in demanding applications, and particularly in fine finished products such as furniture, cabinets, millwork, and flooring, problems are almost certain to develop. Therefore, it is important that both the producer and seller of the lumber conduct routine tests to assure that the material is suitable for the end use intended.

Measuring Moisture Content

The first test is for moisture content, and nearly everyone with any understanding of wood is concerned about it. Before considering what the moisture content of wood should be, the end use of the lumber and its average moisture content must be considered. As an example, I once answered a phone call concerning hardwood flooring. Having explained the importance of careful and consistent drying to the 6 to 8 percent moisture content range, I learned the flooring was intended for a recreational cabin that would be heated only occasionally and for short periods on weekends. This is an application for wood dried for an outdoors but protected environment. Had lumber that was kiln-dried to 6 to 8 percent been used, it would have gained moisture to about the 12 to 15 percent range and swelled by about 2 percent. This could very likely result in pressure being applied against the walls or buckling of the floor.

The most accurate and accepted way of determining moisture content is the ovendry test, so called because it is based on the ovendry weight of the wood. A small sample of wood is cut from near the center of the length of the board in question and placed in a laboratory grade drying oven set at 212 °F (Figure 11-23A). The sample is periodically weighed until it achieves a constant weight. It is reweighed, and the moisture content is calculated by using the following formula:

$$\frac{\text{green weight} - \text{ovendry weight}}{\text{ovendry weight}} \times 100 = \text{percent moisture content}$$

The test is easily repeatable. If the sample regains water it can be redried, and it will return to the sample's original ovendry weight. Commercial kiln-drying operations are equipped with drying ovens, and they are constantly checking moisture contents by the ovendry method.

Another method for checking moisture content is with an electric resistance type moisture meter (Figure 11-20). This instrument has two needle-like probes that are inserted along the grain of the wood. Correction factors for temperature and species are built into the newer meters. The meters are used to estimate the wood moisture content in the 6 to 28 percent range. Some variation does occur, and the accuracy of the meters varies. Although time consuming, the ovendry method is the most accurate method for determining moisture content.

Dielectric power loss moisture meters are also available. The surface-contact electrodes do not penetrate the wood. The meter is used primarily on rough lumber. The electric field penetrates the wood by about three-quarters of an inch. The surface layers of the specimen have a predominate effect on the meter readings.

It is appropriate to sample several pieces within a quantity of lumber. The variation of moisture content from the shell to the core of the piece is also important. The standard method for determining the variation of moisture content by depth is to crosscut from a board, a piece of wood that is an inch or so long (Figures 11-21 and 11-23B). This moisture distribution section is then turned on end. The thickness of the shell portion of the sample is about one-quarter the total thickness of the sample. The shell and core sections should be weighed immediately upon cutting. A uniform moisture content throughout the piece is ideal. If the moisture content is not uniform, the stress test could be misleading.

Figure 11-20. Electric resistance type moisture meter for estimating wood moisture content. The short prongs on the meter are for 4/4 stock, while the long needles can be hammered into thick stock.

Figure 11-21. Crosscut samples for determining the moisture content of the shell and core of lumber. See Figure 11-23B for method of cutting samples.

Figure 11-22. Stress or casehardening test in kiln-dried lumber. Prong tests in the top row show no stress. The two samples on the bottom left show casehardened lumber, while the two on the right show reverse casehardening.

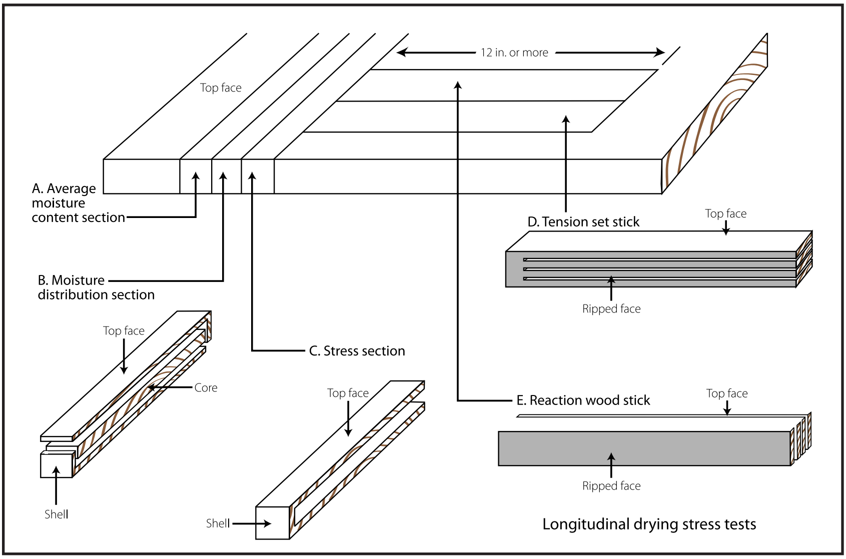


Figure 11-23. Method of cutting sections for final moisture content and drying stress tests. (U.S. Department of Agriculture, Forest Service, 1991, p. 128).

Box 11-1. Key to casehardening and moisture gradient problems based on prong movement. (Provided by Jim Steen of Pike Lumber Company, Akron, IN)

1. **Immediate observation:** No movement.
   a. **Delayed observation:** No movement. (No stress or moisture gradient problems).
   b. **Delayed observation:** Movement occurs.
      i. Casehardening movement. (Indicates that the core moisture content is higher than shell moisture content, which could indicate that the piece was stress relieved before the core reached the target moisture content, and the subsequent movement is a result of the inside surface of the prong test shrinking.) This type of movement also occurs early in the drying cycle when the shell has started to set but the core has not.
      ii. Reverse casehardening movement. (Indicates that the shell moisture content was higher than that of the core, and that it was offsetting the effect of reverse casehardening.) This type of situation would be rare; but, in theory, it is possible.

2. **Immediate observation:** Casehardened movement.
   a. **Delayed observation:** No further movement. (Indicates that casehardening exists, and there is no moisture gradient). This is caused by not conditioning or not fully conditioning a kiln charge of lumber.
   b. **Delayed observation:** Further movement occurs.
      i. Further casehardening occurs. (Indicates that in addition to case hardening that the core was of higher moisture content than the shell.) This can occur when the final target moisture content was not reached in the core of the piece, and then it was either improperly or not at all conditioned.
      ii. Casehardening eases. (Indicates that although there is some failure to properly condition the piece, part of the initial movement is the result of the shell being of higher moisture content than the core.) This is common and is usually caused by improper storage somewhere, in combination with inadequate conditioning.
      iii. Casehardening disappears. (Indicates that the shell is of higher moisture content than the core.) More than likely, this is the result of poor storage conditions.

3. **Immediate observation:** Reverse casehardening movement.
   a. **Delayed observation:** No further movement. (Indicates that reverse casehardening has occurred and that there is no problem with the moisture gradient.) This usually results from overconditioning of the piece.
   b. **Delayed observation:** Further movement occurs.
      i. Further reverse casehardening occurs. (Indicates that shell moisture content was greater than core moisture content.) A scenario would be that overconditioned lumber was stored for an undetermined period in a higher than 6-8 percent moisture content area.
      ii. Reverse casehardening eases. (Indicates that core moisture content was higher in the core than in the shell and at the same time overconditioned.) This could occur if lumber that was overconditioned was moved to an area drier than 6-8 percent moisture content for an undetermined amount of time before testing.
      iii. Reverse casehardening disappears. (Indicates that the moisture content of the core was higher than the shell for some reason.) A scenario might be that correctly conditioned lumber was stored for an undetermined period in a place drier than 6-8 percent moisture content.

Casehardened Lumber

Lumber dried to moisture content of 6 to 8 percent, and thus suitable for the manufacture of products used indoors, develops stress. It is said to be "casehardened." Drying stresses are a normal result of the drying process. They can develop in the air-drying yard, in the predryer, during dehumidification drying, or particularly during steam kiln-drying. Drying stresses may be either transverse or longitudinal. The transverse type generally creates the most problems. How drying stresses develop was explained earlier in the section on How Wood Dries.

The severity of the drying stresses varies with the drying method and the drying conditions. As the lumber is machined, and particularly during the ripping operation, the stresses are relieved, and unacceptable distortion often results (Figure 11-5). Thus, these stresses should be relieved during the drying of lumber that is to be cut up and used in manufacturing products.

If casehardened lumber has not had the stress relieved, several problems can develop when the wood is machined. These include warp such as cup and crook, excessive planer splits, and end checking. The defects normally develop at the time of machining or immediately afterwards.

Warping is probably one of the most noticeable defects that can result from casehardened lumber. During the resawing of thick stock into thinner material, stresses in the boards become unbalanced, and cup or bow with the concave edge toward the saw will result. The curvature or distortion develops because the core of the board is normally in tension, and it is pulling the surface or shell inward. Ripsawing may relieve longitudinal stress. When the board is ripped, crook may develop with the concave edges toward the saw. This obviously results in manufacturing problems or discarding of the material.

End checking can occur in the core of freshly crosscut casehardened boards. One case has been reported where excessive end splits developed in panels immediately after high frequency gluing. The splits were all in the wood and not the glue line. The problem was thought, at first, to be due to high moisture content in the wood, but an ovendry test showed it all to be about 6 percent. The kiln operator had been relieving transverse stress; however, longitudinal stress was still present, as indicated by the test for drying stresses, which is described in the next section. Special kiln settings were used to relieve the longitudinal stress, and the problem ended.

During planing, if the cut is not uniform on both sides, the board will cup, with the concave face being the one most heavily machined. The lips on edge-grooved material may turn inward and break as the tongue or spline is inserted. Where unequal cuts are necessary, especially in producing moulding and trim, or during routing and carving, cupping will likely result.

Planer splits can occur in relatively flat lumber that is casehardened. The splits result from the internal drying stresses and the action of the knives.

Boring is difficult in casehardened lumber. The bit is pinched by the board.

Squares can also be casehardened. Splits along the length and at the ends may develop even though the moisture content is 6 to 8 percent.

Tests for Drying Stresses

The stress test is used to determine the presence of casehardening in the board. The core of the section is simply removed with a band saw (Figure 11-22 and 11-23C). If the two outer prongs pinch in, the section is casehardened or has residual drying stress. The prongs turn in because the tension stress in the core is released by the saw cut, and the inner faces of the prong shorten because of the release of the stress. Figure 11-22 shows sections with different degrees of stress and for different thicknesses of lumber. If the stress is severe, the prongs will snap together. In this case, the stress section can be turned down and band sawed in such a way as to allow diagonally opposite prongs to bypass each other.

Moisture gradients across the thickness of the board can also result in prong movement, but not immediately as with casehardening. Moisture gradients result from improper drying or improper storage. Residual drying stresses and moisture gradients can also interact. When a moisture gradient exists, the core of a stress section is not at the same equilibrium moisture content with the air conditions where it is cut. With time, the moisture content of the core will change, and the inner face will shrink or swell. Most commonly, the core is at a high enough moisture content that with time it shrinks when cut, the prongs move in, and it appears to be casehardened. Box 11-1 is a key to identifying casehardening and moisture gradient problems based on prong movement shown in Figure 11-22.

The time required for prong movement is a good indication of whether residual drying stresses or moisture gradients, or a combination of these two, caused prong movement. Residual drying stresses cause prong movement immediately, whereas moisture content requires up to 12 hours to complete a change. The delayed observations should be made in an environment that is at 6 to 8 percent EMC (75 °F and 30 to 40 percent relative humidity, for example). If immediate prong movement is observed, followed by additional prong movement, then both factors are the cause. In either case, prong movement points to a condition that should be corrected to avoid warp upon resawing or machining. Either additional stress relief, equalization, or both procedures are required.

In addition to the more common transverse drying stresses that occur in lumber, longitudinal drying stresses can also develop and should be monitored for the same reasons discussed for transverse stress. There are several causes for longitudinal drying stresses thus making analysis more difficult. The first reason is similar to transverse drying stress where the shell is uniformly set in tension and the core is set in compression. Additional reasons for longitudinal stress are related to how the tree grew. These reasons include natural growth stress in the tree, the presence of reaction wood (tension wood in hardwoods or compression wood in softwoods) or even juvenile wood (Wengert 1990, 1992; Denig and others 2000.) See the chapter titled "Wood Quality and Characteristics" for more information about these stresses in wood.

Normal wood shrinks only about 0.2 percent in the longitudinal direction as compared to about 4 to 8 percent in the transverse direction. Thus longitudinal drying stresses in normal wood are generally not as significant as the transverse ones, but they can still cause distortions in parts when lumber is remanufactured.

Longitudinal shrinkage from reaction wood and juvenile wood is often more than the 0.2 percent typical of normal wood thus resulting in problematic longitudinal stress. In this case, the stress is likely to be more random in occurrence.

A method to prepare longitudinal stress or tension set sticks is shown in Figure 11-23. Each stick should be 1-inch wide and at least 12 inches along the grain and the full thickness of the board. Saw kerfs shown as thin void areas in Figure 11-23D should be placed along the length and parallel to the original surface (face) of the board. If both of the outer prongs bow inward and pinch the saw, the sample probably has longitudinal stress from the drying process. If only one outer prong pinches the saw, the sample probably has longitudinal stress from reaction wood, juvenile wood, or growth stress.

A second test sample is prepared as shown in Figure 11-23E. In this case, the saw kerfs are placed parallel to the ripped face of the sample or perpendicular to the face of the board. If only one prong bows in, the sample probably has longitudinal stress from tree growth, reaction wood, or juvenile wood. Neither growth stresses, reaction wood, nor juvenile wood are the results of poor drying practices, and-neither is considered a grading defect in hardwood lumber. Another test (Wengert 2009) for longitudinal stress from these three possible causes is shown in Figure 11-24. This is the same tension set test used to identify drying stress, but in this case a center prong moves at 90° to the face of the board.

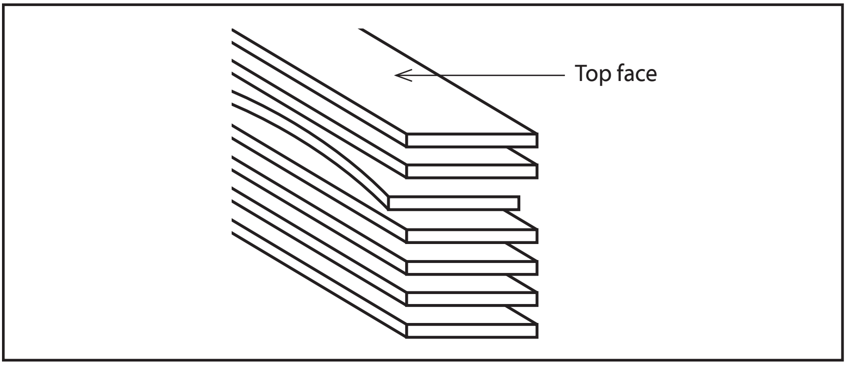


Figure 11-24. The center prong moved due to growth stress, reaction wood, or juvenile wood (Wengert 2009).

To check for longitudinal stress in turning squares, their thick sections were cut along the grain (Clay 1990). These sections were then broken along the grain, and the pieces were fitted back together. When the pieces fit perfectly, no defects developed in the turning stock. When stress was present, a small gap between the pieces could be seen indicating longitudinal stress. This test does not indicate the source of the stress such as "normal wood" shrinkage, reaction wood, juvenile wood or growth stress.

Surface and End Checking

Surface or season checking, end checking, and internal checking or honeycomb are sometimes costly and troublesome defects when hardwood lumber is processed into furniture, cabinets, millwork, and other products where surface appearance and finish are critical.

Surface and end checks often extend deeper than casual observation of the rough lumber would indicate. Furthermore, in hardwoods many surface checks close in the later stages of drying and may not be particularly evident. The lumber is still damaged, however, and the checks are likely to open as the moisture content of the wood changes at some time in the future. Sometimes the final product is returned from the field, or excess rejecting of parts occurs during manufacturing. Honeycomb may not be detected until the lumber is cut up. For these reasons, the lumber should be carefully examined at the time of receipt.

Surface checks

Surface checks are actual failures that generally occur in the wood rays or at the junction of the wood ray and other adjacent wood tissue on the surface of flat-sawn boards (Figure 11-3A). They occur because the drying stresses exceed the tensile strength of the wood perpendicular to the grain, when the surface of the material dries much faster than the interior. As a result, the surface is trying to shrink. In so doing, it is forced into tension, and the wood literally tears itself apart. As the wood dries, the interior will start to shrink, and sometimes the surface checks can become invisible to casual observation (Figure 11-3B).

Surface checks rarely appear on the edges of flat-sawn boards less than 1½ inches thick but can occur on the edges of thicker flat- or quarter-sawn stock. Surface checks are also likely to develop in mineral streaks and resin ducts.

Surface checks develop because the wood is drying too rapidly. Rapid drying occurs during hot, dry weather and is further aggravated by strong winds. Checking of green lumber can also be aggravated during transport if the lumber is left uncovered and exposed to the sun and wind. Difficult-to-dry species such as oak can check in as little as an hour when exposed to the hot sun. Two-inch-thick wood of any species can check. Surface checking can also occur in the dry kiln.

End checks

End checks are likewise a serious problem. In thick stock, end checks that are not even hairline cracks on air-dried material can extend a foot or more from the end of the piece. It is easy to overlook the significance of end checks, but the effect on yield can be significant. For example, losing 3 inches of trim from each end of an 8-foot-long board represents over 6 percent yield loss.

End checks are similar to surface checks in that they occur in or along a wood ray but on the ends of boards. End checks associated with wood rays appear as lines on the radius between the pith (center) of the tree and the bark. End checks occur because wood dries much faster from the end grain than from the surface. This difference results in shrinkage and stress at the end of the boards, and the checks develop. Depending on the severity, checks develop into splits to relieve the stress.

Controlling surface and end checks

With proper precautions, surface checks or end splits can be eliminated or at least controlled to acceptable limits. Surface checks can be prevented or reduced by protecting freshly sawn lumber from the sun and wind during sorting and accumulation at the sawmill and during transport. The use of pile covers in the air-drying yard will protect the top courses from weathering and checking. As the surface of lumber is wetted from the weather and then redries, surface checks are driven deeper into the wood. This is particularly true of oak. Therefore, lumber should not be left on the air-drying yard any longer than necessary. Air-drying sheds or covered yards are becoming somewhat more common. Pre-driers, if properly run, will also help reduce checking and keep the lumber bright. Species prone to checking, such as oak, are sometimes wrapped in burlap or otherwise protected with shade cloth to reduce air movement over the surface (Figure 11-16). Placing the stickered lumber packs in a protected place on the air-drying yard may be of minimal help. Lumber cut during the winter months is also less likely to be exposed to severe drying conditions and, thus, less likely to check.

Coating log ends or spraying the logs with water will reduce or eliminate end checking during storage. Checks that begin at this time continue to develop once the log is processed into lumber and dried. End coatings applied to lumber within a few hours of sawing have been shown to reduce end checking significantly.

Tests for surface and end checks

The presence of both surface and end checks is relatively easy to determine. To see if surface checks are present, cut 1-inch strips across the width of the board and away from the ends and other obvious defects or grain distortions. Now, turn the strip down and band saw ⅛-inch-thick pieces from each face. If these pieces separate when sawed loose or when lightly flexed, surface checking is present (Figure 11-25). If they do not separate, the section is free of checks. Successive cuts will help determine how deep the checks penetrate the piece.

For end checking, simply begin by cutting the ends of the piece back about 1 inch or less at a time. If checks are present, the cut-off piece will either fall apart by itself or break easily if lightly flexed. Continue cutting off sections until the wood becomes usable.

It is difficult to estimate the number of samples that should be examined. Refractory species such as oak and beech tend to check more than other species. Also, if the green wood is exposed to hot, dry weather and sun when it is first manufactured, the probability of checking increases. Thicker and wider stock also checks more than thin stock or narrow boards. Loads that contain a mix of thicknesses and species should be more carefully examined since air and kiln-drying times and conditions were probably different. As the amount of exposure of the lumber at the air-drying yard increases, so does the probability of checking, especially on species such as oak. Alternate wetting and drying of the wood drives the checks in deeper. The wood will also be grayer or discolored and not bright.

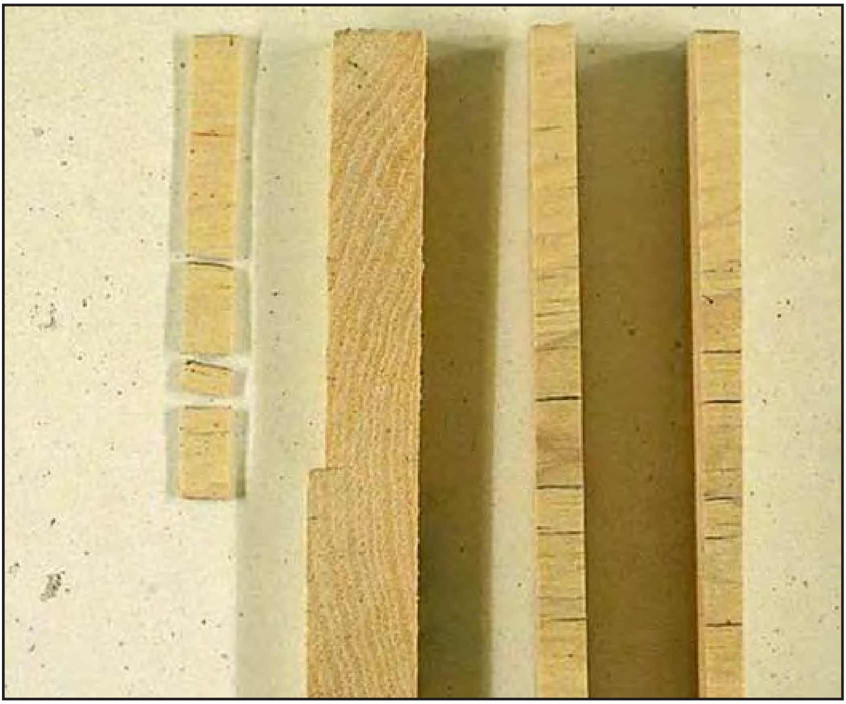


Figure 11-25. Surface checking is not always evident. To see if surface checking is present, cut a thin strip from the surface of a board. In badly checked lumber the thin strip simply falls apart as in this figure.

NHLA rules on surface and end checks

Before January 1, 1990, the National Hardwood Lumber Association (NHLA 1990) grading rules permitted ordinary surface or season checks in clear-face cuttings. Season checks that did not impair the strength were admitted in sound cuttings and construction grades. Unfortunately, it was not always clear between buyer and seller as to what constituted "ordinary season checks."

The rule now indicates that "ordinary season checks are admitted in clear-face cuttings if they will dress out at standard surface thickness" (NHLA 2011, p.8). Thus, for example, season checks should not appear in the required clear face cuttings for the given grade when 1-inch rough lumber is surfaced to 13/16 inch. Other standard surfaced thicknesses are as follows:

Lumber dimension (inches)	Surfaced thickness (inches)
5/4	1 1/16
6/4	1 5/16
8/4	1 3/4

Splits

All trees develop a certain amount of stress as they grow. Usually the outside portion of a log is in tension, and the core is in compression. Thus, as a flat-grain board is sawed from the face of a log, it tends to curve away from the headsaw. No particular problems develop.

Sometimes, however, if the log is sawed deep or if a more or less full-width board is cut from around the heart area, it will develop deep splits in the ends. These splits are from growth stresses. They occur on a sporadic basis, and are not the result of mishandling the lumber during drying. Splits can also develop from tension wood. Tension wood forms in the upper side of leaning hardwood trees. See the chapter entitled "Wood Quality and Characteristics" and the section "Reaction Wood" for more information about tension wood.

Internal checks or honeycomb

Internal checking or honeycomb (Figure 11-26) is one of the most troublesome defects to lumber suppliers and users. "Bottleneck checks" is a term that is sometimes applied when deep surface and end checks have closed tightly on the surface of the lumber but remain open below the surface.

Honeycomb is an internal defect, and when damage is light or scattered, it often goes undetected until the lumber is machined. Severely honeycombed lumber, however, frequently has a corrugated appearance on the surface.

Honeycomb, like surface or end checks, is caused by a tension failure across the grain of the wood, and it usually occurs in the wood rays. It is often an extension of a surface check. The wood is literally tearing itself apart. It occurs

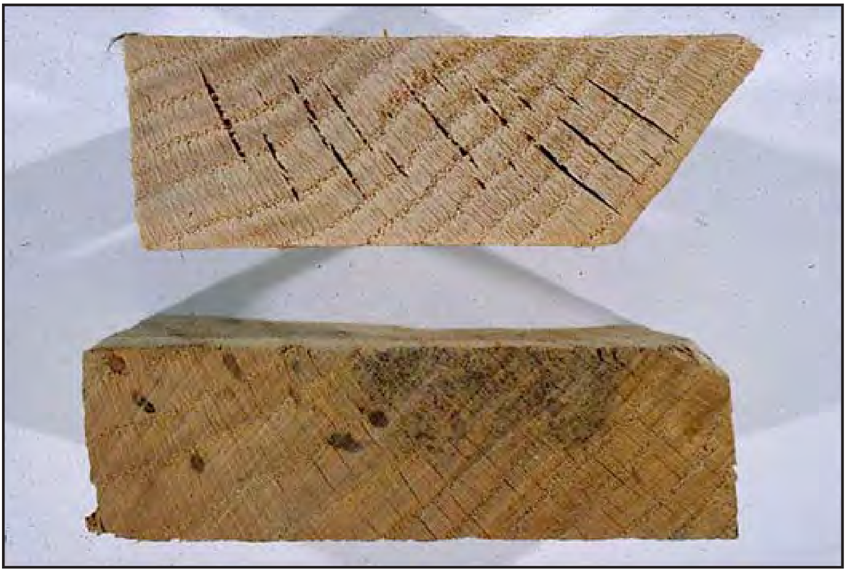


Figure 11-26. Internal checking or honeycomb in red oak. The checking was discovered after the top sample was cut from the board shown below.

when the core is still at a relatively high-moisture content and drying temperatures are too high.

Thus, to control internal checks during the drying process, the moisture content of the core must be below the fiber saturation point or about 30 percent, before kiln temperatures are raised. It is the responsibility of the dry kiln operator to determine when the core is dry enough so the temperature can be safely raised. The operator should also check the lumber before kiln-drying, to determine if surface checking or honeycomb occurred during air-drying. Surface checks that occurred during air-drying usually have small specs of dirt in them, especially those checks located on the upper side of the boards.

The presence of honeycomb is determined by cross cutting several boards. Mixed loads that appear variable with regards to surface discoloration and thickness should be closely scrutinized.

Lumber Weight and Moisture Content

Knowing the weight of lumber is important for shipping and handling purposes, but it is also difficult to predict due to numerous factors. In general, the weight of green wood can vary due to natural variation within and among trees—position in the tree, tree age, dominance, rate of growth, geographic location, moisture content, amount of drying at the time of sampling, percent of sapwood or heartwood, and others. As a result, any available number should be considered as only an estimate.

Table 11-9 gives the weight in pounds per actual thousand board feet at kiln-dried (6 percent), air-dried (15 percent), and 80 percent moisture content, by species. These weights are calculated weights, based on specific gravity and moisture content. Adjustment factors for other moisture contents are also given. These data are provided to enable the reader to calculate weights at moisture contents other than those given in the table if needed. For example, to determine the weight of basswood at 85 percent moisture content, multiply the factor of 16.6 by 5 and add the result to 3,004 pounds. These weights are for exactly 1,000 board feet, when a board foot is a piece 1 inch thick and 12 inches square. Since most green 4/4 hardwood lumber is cut slightly thicker than an inch, this extra thickness must be taken into account.

The available average moisture content for green heartwood, sapwood, and mixed heartwood and sapwood is given in Table 11-10. Complete data is not available.

Table 11-9. Calculated weights of wood per thousand board feet actual measure (U.S. Department of Agriculture, Forest Service, 1991, p. 31-33).

Species	Approximate correction factor per 1,000 board feet for each 1 percent moisture content change		Weight (lb) per 1,000 actual board feet of various moisture content levels		
	Below 30 percent moisture content	Above 30 percent moisture content	6%	15%	80%
Ash					
Black	9.3	23.4	2,824	2,908	4,218
Green	14.3	27.6	3,246	3,375	4,970
White	13.9	28.6	3,392	3,517	5,156
Aspen					
Bigtooth	10.3	18.7	2,191	2,284	3,374
Quaking	10.3	18.2	2,125	2,217	3,283
Basswood, American	6.2	16.6	2,019	2,081	3,004
Beech, American	8.9	29.1	3,579	3,659	5,248
Birch					
Paper	8.8	25.0	3,049	3,128	4,510
Sweet	11.9	31.2	3,779	3,886	5,625
Yellow	9.2	28.6	3,502	3,585	5,153
Buckeye, yellow	8.9	17.2	2,021	2,101	3,095
Butternut	11.3	18.7	2,168	2,270	3,375
Cherry, black	13.8	24.4	2,853	2,977	4,404
Cottonwood, black	8.5	16.1	1,897	1,974	2,907
Elm					
American	10.2	23.9	2,871	2,963	4,311
Red	11.5	25.0	2,974	3,078	4,501
Rock	12.2	29.6	3,567	3,677	5,340
Hackberry	11.8	25.5	3,036	3,142	4,594
Hickory, pecan					
Bitternut	14.7	31.2	3,711	3,843	5,624
Hickory, true					
Mockernut	9.1	33.3	4,113	4,195	5,997
Pignut	9.3	34.3	4,246	4,330	6,177
Shagbark	10.9	33.3	4,071	4,169	5,998
Shellbark	6.6	32.2	4,037	4,096	5,805
Locust, black	21.2	34.3	3,961	4,152	6,185
Maple					
Soft					
Red	13.1	25.5	3,004	3,122	4,593
Silver	12.4	22.9	2,683	2,795	4,126
Hard					
Black	12.3	27.0	3,228	3,338	4,873
Sugar	12.3	29.1	3,498	3,609	5,248

Continued...

Table 11-9. Calculated weights of wood per thousand board feet actual measure *(continued)*

Species	Approximate correction factor per 1,000 board feet for each 1 percent moisture content change		Weight (lb) per 1,000 actual board feet of various moisture content levels		
	Below 30 percent moisture content	Above 30 percent moisture content	6%	15%	80%
Oak, red					
Black	11.7	29.1	3,511	3,616	5,247
Laurel	6.3	29.1	3,640	3,697	5,246
Northern red	13.6	29.1	3,467	3,589	5,248
Pin	13.0	30.2	3,616	3,733	5,438
Scarlet	13.2	31.2	3,748	3,867	5,625
Southern red	9.6	27.0	3,290	3,376	4,870
Water	10.4	29.1	3,543	3,637	5,248
Willow	6.4	29.1	3,636	3,694	5,245
Oak, white					
Bur	15.4	30.2	3,558	3,697	5,438
Chestnut	10.1	29.6	3,616	3,707	5,338
Live	17.5	41.6	4,997	5,155	7,497
Overcup	10.7	29.6	3,603	3,699	5,340
Post	11.0	31.2	3,799	3,898	5,623
Swamp chestnut	10.7	31.2	3,806	3,902	5,623
White	10.8	31.2	3,803	3,900	5,622
Persimmon, common	7.0	33.3	4,164	4,227	5,997
Sweetgum	8.9	23.9	2,902	2,982	4,311
Sycamore, American	10.7	23.9	2,858	2,954	4,310
Tupelo					
Black	10.4	23.9	2,866	2,960	4,311
Water	12.4	23.9	2,817	2,929	4,310
Walnut, black	13.4	26.5	3,132	3,253	4,779
Willow, black	8.6	18.7	2,232	2,309	3,373
Yellow-poplar	10.6	20.8	2,454	2,549	3,748

Table 11-10. Average moisture content of green wood (U.S. Department of Agriculture, Forest Service, 1991, p. 22)

Species	Moisture content (percent)		
	Heartwood	Sapwood	Mixed heartwood and sapwood
Ash			
Black	95	—	—
Green	—	58	—
White	46	44	—
Aspen	95	113	—
Basswood, American	81	133	—
Beech, American	55	72	—
Birch			
Paper	89	72	—
Sweet	75	70	—
Yellow	74	72	—
Buckeye, yellow	—	—	141
Butternut	—	—	104
Cherry, black	58	—	—
Cottonwood, black	162	146	—
Elm			
American	95	92	—
Cedar	66	61	—
Rock	44	57	—
Hackberry	61	65	—
Hickory			
Bitternut	80	54	—
Mockernut	70	52	—
Pignut	71	49	—
Red	69	52	—
Sand	68	50	—
Water	97	62	—
Locust, black	—	—	40
Magnolia	80	104	—
Maple			
Silver (soft)	58	97	—
Sugar (hard)	65	72	—
Oak			
Live	—	—	50
Northern red	80	69	—
Southern red	83	75	—
Southern swamp	79	66	—
Water	81	81	—
White	64	78	—
Willow	82	74	—
Osage--orange	—	—	31
Persimmon, common	—	—	58
Sweetgum	79	137	—
Sycamore, American	114	130	—
Tanoak	—	—	89
Tupelo			
Black	87	115	—
Swamp	101	108	—
Water	150	116	—
Walnut, black	90	73	—
Willow, black	—	—	139
Yellow--poplar	83	106	—

Summary

Drying lumber or working with lumber that has regained moisture can be a frustrating experience. Fortunately, lumber can be dried with a minimal amount of degrade if correct procedures are followed. After drying, lumber must be properly stored to prevent degrade. This chapter has outlined appropriate procedures. Additional information is available in the Dry Kiln Operator's Manual (U.S. Department of Agriculture, Forest Service, 1991), and by joining one of several dry kiln clubs located throughout the United States and attending a dry kiln operator short course. These short courses are offered by the dry kiln clubs, usually in conjunction with a state university.

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Chapter 12.

Insect Damage to Trees, Lumber, and Finished Products

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Figure 12-3 This severely infested drying stick shows damage ranging from bore holes through the surface of the wood to frass accumulation Note: Drying sticks should be heated to at least 130 °F to destroy infestations and prevent insects from spreading to valuable lumber 283

Figure 12-4 Powderpost beetle damage can also occur after a product is manufactured from infested wood and installed, as in this cabinet rail At this point, the wood product has to be removed or treated in place Once the wood is finished, the insects are not able to penetrate the smooth surface and reinfest it 283

Figure 12-5 Southern lyctus beetle (*Lyctus planicollis* LeConte) is found throughout the United States and is particularly common in the South The adults are black to reddish brown and from 0 2 to 0 24 inch long Note the eggs, which are usually laid in the large pores or vessels of species such as oak, ash, and walnut 284

Figure 12-6 Anobiid beetles (*Xyletinus peltatus* Harris) are 0 06 to 0 32 inch long and range in color from bright reddish-brown with orange patches on the wing tips to shiny ebony black Some appear yellowish or grayish from the dense pubescence covering their bodies The damage from this group is similar to the Lyctidae, except the emergence holes are a little larger and the frass coarser 286

Figure 12-7 The bostrichid beetles differ from the lyctids and anobiids in that bostrichids bore into the wood to lay eggs rather than deposit them at the surface Adults of native species are reddish brown to black and 0 12 to 0 24 inch long Most of the damage is done to partially seasoned wood with bark The beetle shown here is *Amphicerus cornutus* Pallas 286

Figure 12-8 Damage from wood borers (A) Long-horned beetle (*Neoclytus*) and associated damage in freshly sawed white pine board from old log Blue stain damage is also evident (B) Long-horned beetle damage in sapwood of walnut (C) Damage from the long horned beetle in stickered lumber 289

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Chapter 12.

Insect Damage to Trees, Lumber, and Finished Products

Numerous types of insects can infest logs and wood during air drying, after kiln drying, in storage, and even in use. Many of these insects are particularly troublesome, because it seems that wood should be "safe" and trouble-free after sawing and drying. Worse yet, in some cases the product is machined, finished, and installed before the eggs or larvae mature, and the insects emerge leaving unsightly holes and dust.

This chapter describes the different groups of insects that infest wood and discusses prevention and control measures. Table 12-1 summarizes the unique characteristics of the prominent wood pests, as well as other less serious pests that may be mistaken for them. Additional information can be found at the Bugwood Network of the University of Georgia.

Insects that Attack Lumber in Storage or Use

Powderpost Beetles

Powderpost beetles may be the most damaging group of insects to stored lumber. The term "powderpost beetle" is used to refer to the insects that convert the inner portion of infested wood to a characteristic powdery or pelleted mass. They are normally detected due to either the exit holes or the powder that collects around or under their exit holes (Figures 12-1 through 12-4). Damage is probably heaviest in warm, humid climates, but it can occur throughout the world.

Figure 12-1. Powderpost beetle damage showing tiny insect exit holes (shot holes) in the sapwood of walnut. The sapwood of all species is susceptible to attack, although the heartwood of naturally durable species such as walnut and white oak is resistant.

Figure 12-2. Wood boring beetle damage is usually detected when piles of frass or powder accumulate under the insect exit holes. The powder may also stream down the side of the infested lumber, such as on these old hard maple boards stored in a barn.

Figure 12-3. This severely infested drying stick also shows damage ranging from bore holes through the surface of the wood to frass accumulation. Note: Drying sticks should be heated to at least 130°F to destroy infestations and prevent insects from spreading to valuable lumber.

Figure 12-4. Powderpost beetle damage can also occur after a product is manufactured from infested wood and installed, as in this cabinet rail. At this point, the wood product has to be removed or treated in place. Once the wood is finished, the insects are not likely to penetrate the smooth surface and reinfest it.

Three insect families, namely Lyctidae, Anobiidae, and Bostrichidae, make up the group commonly called powderpost beetles. Each of these families is described below; however, it is difficult for lay persons to distinguish between the three groups. Control procedures are the same regardless of the family.

Lyctidae—true powderpost beetles

Lyctid or true powderpost beetles attack the sapwood of hardwoods (Figure 12-5). They probably cause more damage to U.S. hardwoods than any other group of beetles and also are an important pest of imported hardwood products. Ring porous hardwoods such as oak, pecan, hickory, and ash are the most susceptible, but semi-ring and diffuse porous woods such as cherry, elm, persimmon, sycamore, walnut and others (U.S. Department of Agriculture, Forest Service, 1985) are also susceptible. The greatest beetle activity occurs when the wood moisture content is between 10 and 20 percent, but beetle activity can occur when the moisture content ranges from 6 to 30 percent. (Air-dried lumber and lumber stored under cover but without climate control, such as heat and dehumidification, will be in the 10 to 20 percent moisture content range.) Lyctids rarely infest wood over 5 years old (Price 2008).

The female deposits eggs in the pores of the wood or in cracks and crevices. When the larvae hatch, they first bore along the vessel, thus enlarging the tunnel as they grow. The tunnels are straight and initially along the grain, but later become more irregular and often intersect other tunnels. Mature grub-like larvae are usually less than ¼ inch long, curved, wrinkled, and enlarged at the thorax, and have six legs. The larvae form a pupal chamber just under the wood surface. The emerging adult beetle then cuts its way to the surface forming a circular exit hole. The entire life cycle usually requires 9 to 12 months but may be shorter if conditions are favorable. One species can complete a life cycle in 4 months. **The beetles will reinfest the same wood source**.

Figure 12-5. Southern lyctus beetle (*Lyctus planicollis* LeConte) is found throughout the United States and is particularly common in the South. The adults are black to reddish brown and from 0.2 to 0.24 inch long. Note the eggs, which are usually laid in the large pores or vessels of species such as oak, ash, and walnut. (U.S. Department of Agriculture, Forest Service Archive 2007)

Credit—USDA Forest Service Archive, USDA Forest Service, Bugwood.org

Infested wood does not show any external evidence of attack until the first generation of adult beetles emerges. The circular emergence holes and longitudinal galleries are 1/32 to 1/16 inch in diameter (Table 12-1). Small piles of fine flour-like wood or frass can be found on or under the wood. The frass is loosely packed and a slight jarring of the wood will cause the frass to sift from the holes. With severe infestations, the sapwood may be completely converted to frass held in by a very thin veneer of surface wood riddled with beetle exit holes.

Anobiidae—death watch or furniture beetles

Anobiids, sometimes referred to as death watch beetles or furniture beetles, are found on recently seasoned and older hardwoods as well as softwoods, throughout the United States (Figure 12-6). Sapwood, particularly close to the bark, is preferred because it contains the highest percentage of starches, sugars, and proteins. Unheated buildings or houses built with crawl spaces over damp ground, such as often occurs in the southeastern United States, are particularly susceptible; but houses are usually 10 or more years old before damage becomes obvious. Wood moisture content of 13 to 20 percent is preferred, which is typical of wood used in protected but unheated areas.

It is very difficult to detect an anobiid infestation during the initial stages. During and after emergence, however, a light-colored powder and tiny pellets may be found streaming from the exit holes or accumulating underneath infested wood. The frass in the galleries is loosely packed and does not tend to fall freely from the wood unless the wood has dried out considerably since the attack occurred. The exit holes are round and vary in diameter from 1/16 to 1/8 inch (Table 12-1). The anobiid pellets are smaller than those excreted by drywood termites and taper towards each end. Some pellets are bun shaped.

The beetles can reinfest the wood. When anobiid infestations die out naturally, the frass is yellowed and partially caked on the surface.

In old, heavily infested wood, very tiny round exit holes, about 1/32 inch in diameter, may be scattered over the infested surface. These are emergence holes of parasitic wasps, which feed on powderpost beetle larvae.

Bostrichids—false or large powderpost beetles

Bostrichids are called false powderpost beetles or large powderpost beetles, to distinguish them from the lyctids (Figure 12-7). Because they naturally infest dead or dying branches, bostrichids are also called branch and twig borers. These beetles are of less importance in wood products than are lyctids or anobiids. Bostrichid powderpost beetles normally do not reinfest wood, but one generation can do substantial damage in some cases.

Figure 12-6. Anobiid beetles (*Xyletinus peltatus* Harris) are 0.06 to 0.32 inch long and range in color from bright reddish-brown with orange patches on the wing tips to shiny ebony black. Some appear yellowish or grayish from the dense pubescence covering their bodies. The damage from this group is similar to the Lyctidae, except the emergence holes are a little larger and the frass coarser. (U.S. Department of Agriculture, Forest Service Archive 2007)
Credit—USDA Forest Service Archive, USDA Forest Service, Bugwood.org

Figure 12-7. The bostrichid beetles differ from the lyctids and anobiids in that bostrichids bore into the wood to lay eggs rather than deposit them at the surface. Adults of native species are reddish brown to black and 0.12 to 0.24 inch long. Most of the damage is done to partially seasoned wood with bark. The beetle shown here is *Amphicerus cornutus* Pallas.
Credit—Forest and Kim Starr, U.S. Geological Survey, Bugwood.org

Table 12-1. Characteristics of wood infestation by native wood boring beetles, borers, and carpenter bees. To use the table, match the size and shape of the exit or entry holes in the infested wood to those shown. (Levi 1975, U.S. Department of Agriculture, Forest Service, 1985).

Actual shape and size (inch) of exit/entry hole	Wood type	Condition of wood attacked	Appearance of frass in tunnels	Insect type	Reinfest
Round 1/50–1/8 inch	Softwood and hardwood	Unseasoned logs and lumber	None present	Ambrosia beetles	No
Round 1/32–1/16 inch	Hardwood	Newly seasoned	Fine, flour-like, loosely packed	Lyctid beetles or true powderpost beetles	Yes
Round or elongate 1/16–1/12 inch	Softwood and hardwood	Slightly damp, decayed	Very fine powder and tiny pellets, tightly packed	Curculionids, snout beetles, or wood boring beetles	Yes
Round 1/16–3/32 inch	Bark/sapwood interface, softwood and hardwood	Unseasoned under bark only	Fine to coarse, bark colored, tightly packed	Bark or engraver beetles	No
Round 1/16–1/8 inch	Softwood and hardwood	Seasoned	Fine powder and pellets, loosely packed (pellets may be absent and frass tightly packed in some hardwoods)	Anobiid beetles or furniture beetles (powderpost beetles)	Yes
Round 3/32–9/32 inch	Softwood and hardwood (bamboo)	Seasoning and newly seasoned	Fine to coarse powder, tightly packed	Bostrichid beetles or false or large powderpost beetles	Rarely
Round-oval 1/8–3/8 inch	Softwood and hardwood	Unseasoned logs and lumber	Coarse to fibrous, mostly absent	Cerambycids Long-horned borers or round-headed borers	No
Oval 1/4–3/8 inch	Softwood	Seasoning to seasoned	Very fine powder and tiny pellets, tightly packed	Cerambycids a round-headed borer also called old house borers	Yes
Oval 1/8–1/2 inch	Softwood and hardwood	Seasoning	Sawdust-like, tightly packed	Buprestids or flat-headed borers	No
Round 1/2 inch	Softwood	Seasoned	None present	Carpenter bee	Yes
Flat oval 1/2 inch or more or irregular surface groove 1/8–1/2 inch	Softwood and hardwood	Unseasoned logs and lumber or seasoning	Absent or sawdust-like, coarse to fibrous; tightly packed	Round or flat-headed borers, wood machined after attack	No

Most species prefer the sapwood of hardwoods, but a few attack conifers. The wood may be freshly cut, partially seasoned, or relatively dry, and have the bark on. The beetles feed primarily on starch, thus their activity is predominately in the outer sapwood. The beetles bore into the wood to lay eggs, unlike the lyctids and anobiids, which lay their eggs in the pores or cracks on the surface of the wood.

The species that attack freshly sawn softwoods usually reach maturity in 1 year, but may require up to 5 years if the wood dries rapidly. They are found primarily when bark edges have been left on the lumber.

The first signs of infestation are the 3/32- to 9/32-inch entry holes. The exit holes, which are similar to the entry holes, are often filled with frass. The frass is meal-like, tightly packed in the galleries, and contains no pellets like those of the anobiid. Consequently, the frass does not sift out of the wood easily.

The interior of the sapwood may be filled with round tunnels ranging from 1/16 to ⅜ inch in diameter, depending on species (Table 12-1). In intensive infestations, the sapwood may be completely destroyed. Bostrichid damage can occur more rapidly than with the anobiids; however, only the outer part of the sapwood is destroyed, and damage will not extend more than 1 or 2 inches into a board.

Wood Borers

Wood borers are one of the largest and most important families of wood infesting insects, and they are found throughout the United States. Two families of insects within this group will be discussed. They are the long-horned woodborers, round-headed wood borers (Cerambycidae), and flat-headed wood borers (Buprestidae) (Figures 12-8 and 12-9).

Cerambycids—Long-horned wood borers or round-headed wood borers

Long-horned borers derive their name from the mature beetle having antennae longer than half their body length. The larvae are described as round-headed wood borers, presumably due to their circular emergence holes (Table 12-1). The round to oval exit holes are ⅛ to ⅜ inch. This group is important because these insects may emerge after the wood is put into service, or the damage may be mistaken as evidence of an active infestation of powderpost beetles.

Damage from long-horned borers usually occurs in fire-damaged, disease-infested, or insect-killed timber that is being salvaged. The borers are attracted to the wood and damage it before it is processed. Attraction ceases when the wood is dried. Many species feed just under the bark before moving into the sapwood, and sometimes the heartwood. Some species may survive a year or more. Most of the beetles emerge within 1½ years. If infested wood is used in construction, the borers may tunnel through adjacent materials (such as plasterboard, hardboard, hardwood flooring, insulation, roofing felt, shingles,

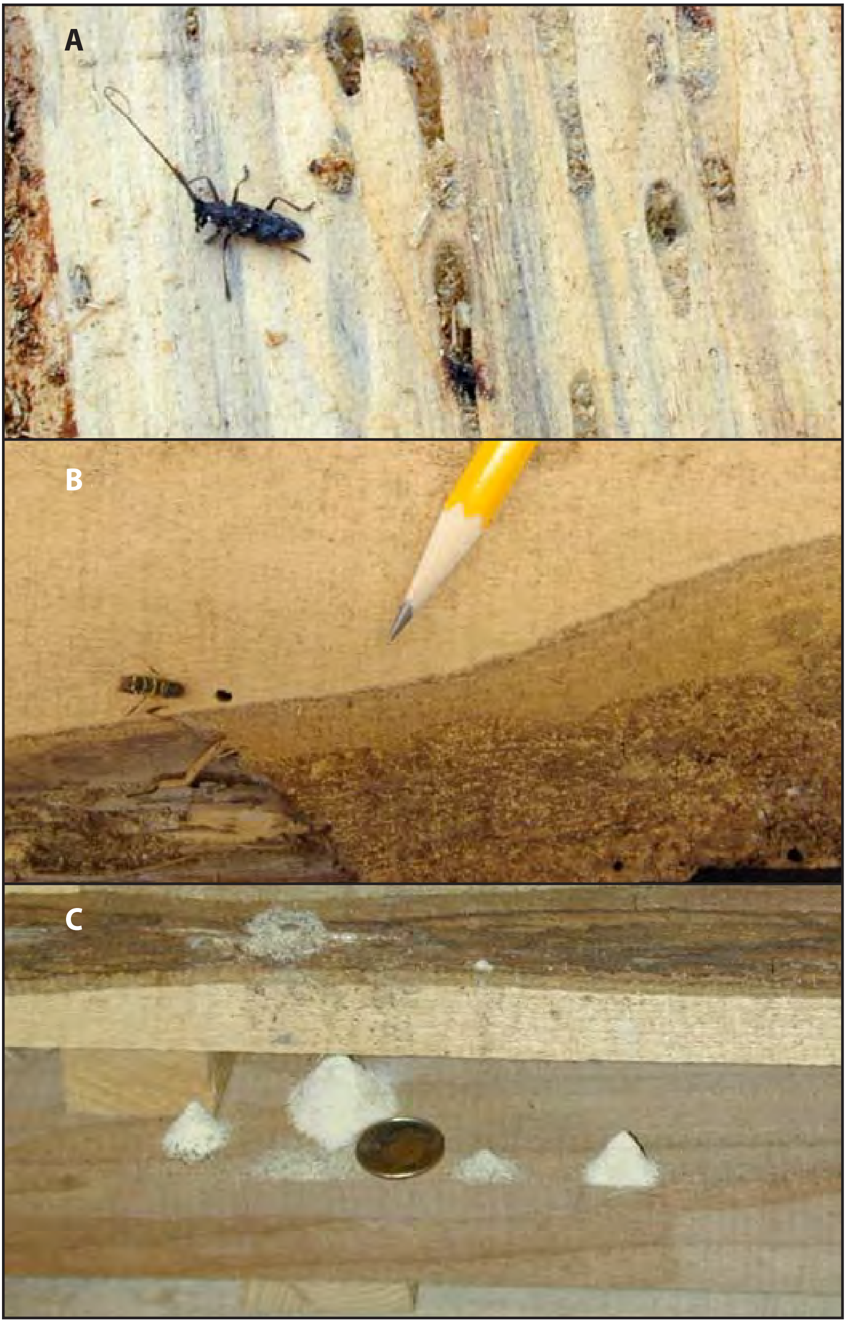

Figure 12-8. Damage from wood borers. (A) Long-horned beetle (Neoclytus) and associated damage in freshly sawed white pine board from old log. Blue stain damage is also evident. (B) Long-horned beetle damage in sapwood of walnut. (C) Damage in stickered lumber from the long horned beetle.

Figure 12-9. Flat-headed wood borer (Buprestid) damage in persimmon. Note the flattened oval shaped holes. Note also the cut tunnel (lower left) evidencing that the tunnels were in place before the wood was sawed.

plywood) in order to emerge. Since the beetles are in the wood only a limited time, serious structural damage usually does not result and they do not re-infest the wood.

As beetles emerge, they make slightly oval to nearly round exit holes ranging from ⅛ to ⅜ inch or more in diameter. The species that are more flattened in cross-section make more oval holes about twice as wide as high, the widest dimension being about ¼ inch. In some cases, coarse, even stringy, frass is present inside or around the exit holes.

If the damage occurred in the log, the galleries in the sawed lumber may appear oval to elongate, depending on how the saw intersected the galleries. Cut or sawed galleries are evidence that infestations occurred before sawmill operations. Gallery diameter in true cross-section varies with the age of the larvae that made the gallery and with the species. Tightly packed, rather coarse frass may be present in the exposed galleries (Table 12-1). At other times, the galleries are free of frass because it was loosely packed and has fallen from the wood. If the bark edges have been left on the lumber, there often is much frass in evidence underneath. The texture of the frass varies from rather fine and meal-like in some species to very coarse and almost excelsior-like in other species.

Cerambycids—Round-headed or old house borer

The most damaging round-headed wood borer (also called the old house borer), unlike most of the others in this family, is capable of reinfesting wood in use. It probably ranks next to the termites as a structural pest of buildings in the eastern United States. The heaviest infestations occur along the Atlantic seaboard, particularly the mid-Atlantic states. It is found in old and new construction, and seasoned and relatively unseasoned softwood lumber, but not hardwoods.

The adult beetle is ⅝ to 1 inch long, slightly flattened, and brownish with many gray hairs on its head and the forepart of the body. The hairs are easily rubbed off. The pronotum has a shiny ridge down the middle and a shiny raised knob on each side. This gives the appearance of a face with a pair of eyes. The adult lays its eggs in cracks and crevices in the wood. The larvae hatch in about 2 weeks, appear as typical round-headed borers, and grow to 1¼ inches long. There are three black eyespots in a row on each side of the small head. The larvae crawl over the surface of the wood and eventually bore their way into the sapwood. The larvae generally take 2 to 5 years to develop and, in particularly dry wood, development may take 12 to 15 years. A moisture content range of 15 to 25 percent encourages rapid development.

Early infestations are almost impossible to detect since there are no external signs. The larvae, when boring in the wood, make a rhythmic ticking or rasping sound much like that of a mouse gnawing. The borers tunnel very closely to the surface but seldom break through. The surface may bulge out due to packed frass. These bulged or blistered areas are best discovered by shining a light parallel to the wood surface.

After the adults have emerged, there may be small piles of frass beneath or on top of the infested wood. The frass, which is loosely packed in the tunnels, is composed of very fine powder and tiny, elongate, blunt-ended pellets that often split lengthwise when dry. The exit holes are oval and ¼ to ⅜ inch in diameter (Table 12-1). Probing the wood surface sometimes exposes the damage. The sapwood may be completely destroyed leaving only a paper thin surface of wood. The galleries have a rippled pattern like sand over which water has washed. In centrally heated houses without moisture problems, the borers seldom do excessive damage. Serious damage occurs where enough humidity or moisture exists for reinfestations to occur.

Buprestids—Flat-headed wood borers

Flat-headed borers, or metallic wood borers, commonly attack weakened, injured, dead, or dying trees and freshly cut logs of both hardwoods and softwoods. They seldom attack dry wood. The larvae have a characteristic flattened area behind the head, and the adult beetles usually bear beautiful markings and metallic colors. They are found throughout the contiguous United States and the tropics. This borer rarely emerges from within a building, and there is no danger of serious damage to structural timbers. The flat-headed borer should be recognized, however, for the type of damage it can do before the wood is put into service.

Wood damaged by flat-headed borers has winding serpentine tunnels that are extremely flat (3 to 4 or more times as wide as high). Since the wood is usually sawed after the damage has occurred, the tunnels are often cut at an oblique angle and their cross-sections are distorted (Figure 12-9). The tunnels are very tightly packed with layers of sawdust-like borings and pellets, and their walls are scarred with fine transverse lines. The frass is somewhat like that of some round-headed borers, but the galleries are much more flattened.

The galleries under the bark edges left on structural timbers are serpentine and wander over the surface of the outer sapwood. Sometimes larvae can be heard chewing under the bark. The galleries are packed with a mixture of light wood-colored frass and brown bark-colored frass.

Exit holes made by the adults are sometimes present in the surface of the wood. If the wood has not been machined, the holes are elliptic to flat, and, ⅛ to ½ inch in diameter (Table 12-1). Flat-headed wood borer exit holes may appear much like the exit holes made by some of the flattened long-horned beetles, such as the old-house borer. Once the wood is machined or sawed, the holes can be intersected at an angle and now appear as flat ovals ½ inch or more in size.

Snout Weevils

Curculionidae is a family of beetles known as the snout beetle or wood boring weevil. These beetles are not common, do not cause significant damage, but could be confused with anobiid beetles (Table 12-1).

Some curculionid beetles attack hardwoods and softwoods. When damage is heavy, the interior of the wood, including sapwood and heartwood, is honeycombed. They may be distinguished from the other beetles by the characteristic prolongation of the head into a snout. The larvae are always legless and somewhat “c-shaped” in appearance.

Bark Beetles

Bark beetles or engraver beetles are in the family Scolytidae and range throughout the country. They are serious pests of living trees but do not cause any serious structural damage to lumber (Figure 12-10). They can be present in both hardwood and softwood products with some bark on. The beetles may survive in sawed lumber for a year or more, or until the wood is dry.

The female lays eggs in a gallery constructed in the cambium. The larvae tunnel away from the egg gallery. The galleries increase in size and can become very elaborate in design; and the frass can be tightly packed. Only the surface of the wood is slightly etched by these tunnels (Table 12-1). Bark beetles pupate at the ends of the tunnels. The adults emerge from the pupal stage and tunnel straight out through the bark. The surface of the bark is sometimes riddled with round exit holes 1/16 to 3/32 inch in diameter. The beetles are brown,

Figure 12-10. Bark beetle damage in ash. The galleries are just beneath the bark.

reddish-brown, or black, no more than ⅛ inch long, cylindrical, and robust. The head is partially or completely concealed from above. Bark beetles cannot live in seasoned wood, so there is no reinfestation.

One species called ambrosia beetles, attack wood above the fiber saturation point or about 30 percent moisture content. This includes storm damaged timber, cut logs, and some living trees as well. Their damage can be seen as small tunnels, surrounded by stained wood in both hardwood and softwood lumber (Figure 12-11). The damage usually does not affect the strength of the wood.

The adult ambrosia beetles bore 1/50- to ⅛-inch-diameter (Table 12-1) tunnels straight for several inches into the wood of trees or green logs and throw out all of the frass. Once inside the sapwood, the tunnel may branch and follow the curvature of one or more annual rings, or it may be unbranched and relatively straight. There also may be short side tunnels of the same diameter that follow the grain where larvae feed and later pupate.

As the tunnels are constructed, the walls are inoculated with a fungus by the adult beetles. The fungus stains the gallery walls black, blue, or brown. The staining often spreads through the surrounding wood and is particularly obvious in lighter-colored wood species. The beetles will continue to infest the wood as long as it remains moist, but attack ceases when the wood dries out. Upon drying, the wood can be used without further deterioration.

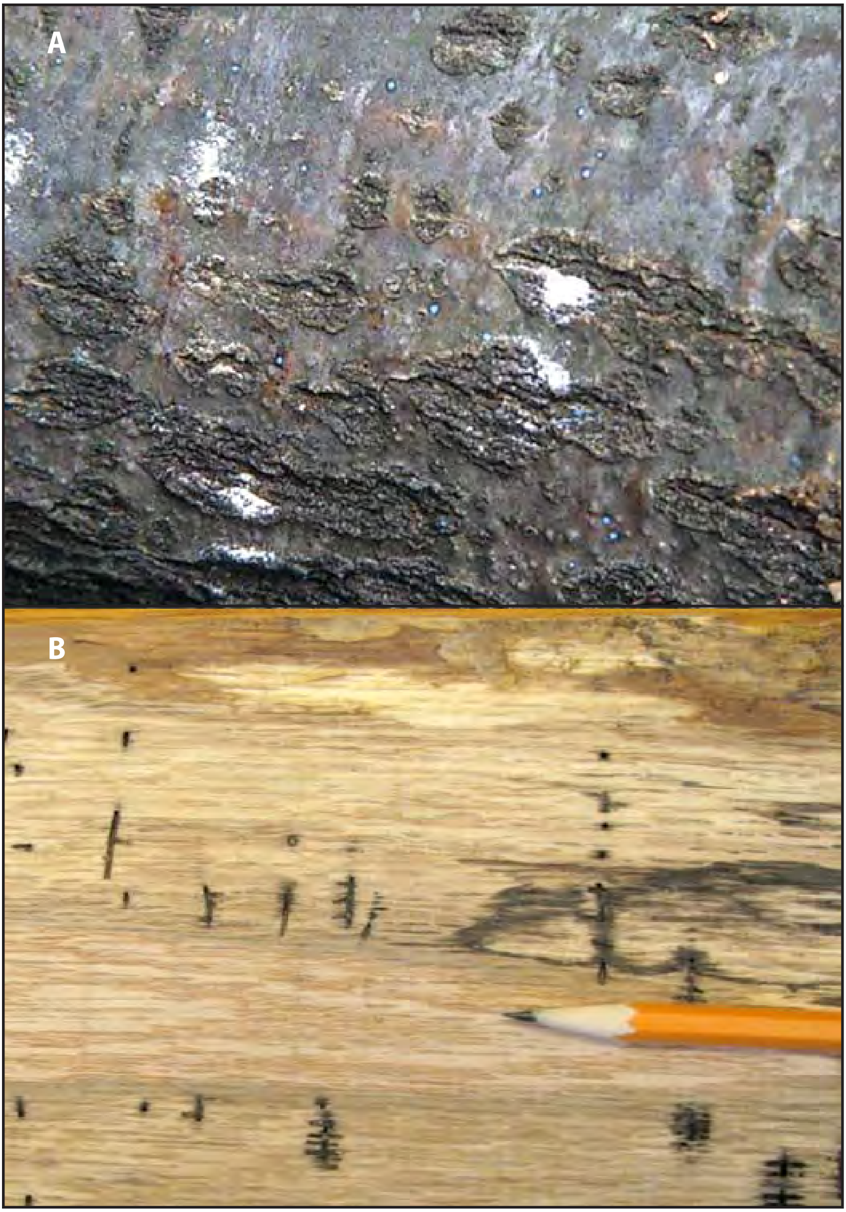

Figure 12-11. Ambrosia beetle damage in oak logs and lumber. (A) Frass at the entrance holes on a small log. (B) Damage in the sapwood of red oak lumber. The sapwood is also badly decayed.

Carpenter Bees

Carpenter bees are found throughout the United States and are similar to bumblebees in appearance, may appear aggressive, but seldom sting. Carpenter bees usually choose wood that is soft and easy to tunnel. They are most commonly found in redwood, cypress, cedar, white pine, yellow-poplar, and southern yellow pine. Bare unpainted wood is preferred; lightly painted or stained wood is also subject to attack. They also may tunnel into wood that has been lightly pressure-treated for above ground use with water-borne preservatives.

The only external evidence of attack is the entry holes made by the females. The original entry hole is perfectly round and approximately ½-inch in diameter (Table 12-1). After penetrating approximately 1 inch, the tunnel turns at a right angle and then follows the grain of the wood for 4 to 6 inches. Tunnels are always smooth walled (Figure 12-12). Frass accumulates on surfaces below the site of activity. Frass is usually the color of freshly sawed wood, but varies with the species of wood under attack. There are no fragments of insects mixed with this frass as with carpenter ants.

In subsequent seasons, an old gallery may be extended or used without further burrowing. When an old gallery is repeatedly used by succeeding generations, it may ultimately reach 6 to 10 feet in length.

Damage from carpenter bees can be prevented by keeping wood surfaces well painted. Interior unpainted surfaces should be protected by keeping windows and doors closed or screened during the spring and early summer when the bees are looking for a nesting site. Where limited numbers are present, the bees may be killed by swatting or with the use of insecticides labeled for homeowner use.

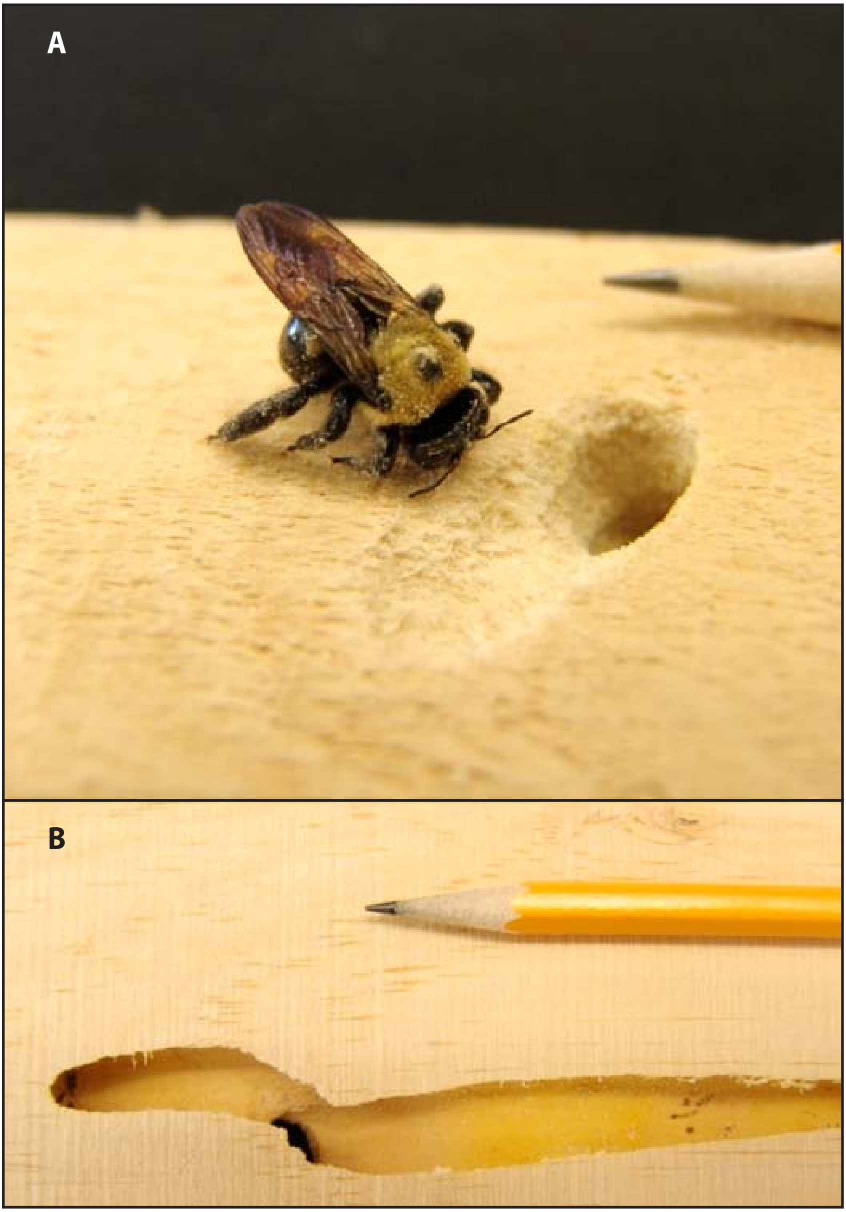

Figure 12-12. Carpenter bee and damage in white pine showing (A) a single entry hole leading to (B) a longitudinal gallery inside the board.

Invasive Pests

Trees and other woody vegetation in North America have been and continue to be seriously affected by several insects and diseases native to other continents. Once these insects and diseases become established, they often do substantial damage because there are no natural predators, and native plant species may have no resistance. In the early part of the 19th century, chestnut blight essentially eliminated the American chestnut species. White pine blister rust affected that species as well but did not eliminate it. Gypsy moth has and continues to be a threat to many native hardwood species.

More recently, Asian longhorned beetles have caused serious concern due to the damage they can cause in hardwood trees. Now the emerald ash borer threatens to kill all ash species in North America. The emerald ash borer and resulting damage are shown in Figure 12-13. Many areas in the central Midwest, Pennsylvania, New Jersey, and Canada have been quarantined in an effort to slow the spread of this pest. Quarantined areas and other information about emerald ash borer can change. For the most current information check the emerald ash borer Web site—a collaborative effort of the U.S. Department of Agriculture, Michigan Department of Agriculture, and Michigan State University.

Legitimate concern exists over introducing exotic pests and other potentially destructive invasive insects. It is important to call your local county agent or state authorities to report any insect that appears destructive.

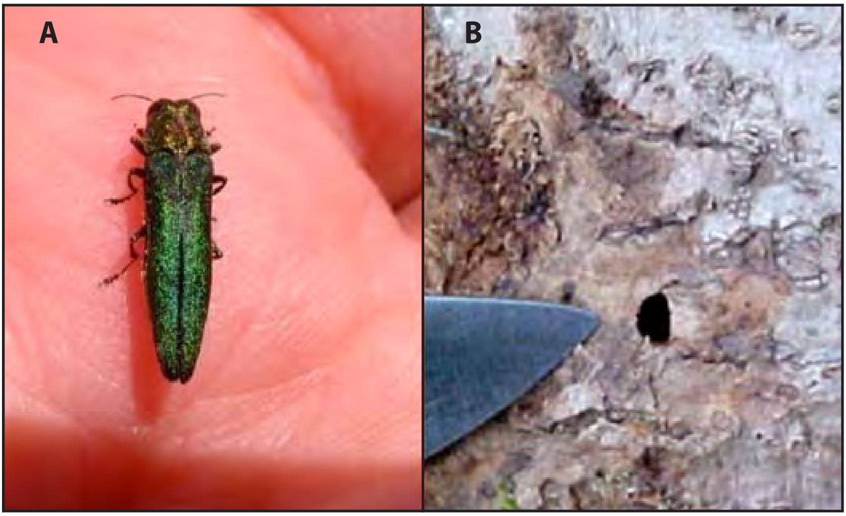

Figure 12-13. Emerald ash borer (A) adult and (B) D-shaped hole in bark.
Figure 12-13A—Jodie Ellis, Purdue University.
Figure 12-13B—David R. McKay, USDA Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Bugwood.org.

Prevention and Control

General recommendations for control are difficult because there are so many different insects that affect wood--from live trees, to logs, to green lumber, to air-dried and kiln-dried lumber, to finished products. Furthermore, thin kerf mill operators can deal with wood products over the entire range, but they are probably mostly concerned about infestations that occur in sawed, drying, and stored lumber. In the author's experience, there is no escaping the problem. Sooner or later the tell-tale signs of "powder" will be seen on some boards.

The first step in prevention is sanitation. Many wood boring insects are attracted to and can develop in homes provided by old, unsawed logs; slabs, edging strips and cut offs; firewood; and drying sticks or other wood products. All unused materials should be properly disposed of. In the author's experience, sawing dead and dying trees or letting cut logs sit for extended periods seems to attract insects. It is important to minimize storage of lumber. Lumber that is allowed to sit for extended periods in unheated facilities seems particularly vulnerable.

If an infestation does occur, it is important to have the insect correctly identified to determine if it is one that will do serious damage or will reinfest wood (including anobiids and lyctids).

The traditional approach to treat any powderpost beetle infestation is to put the lumber on sticks and place it in a dry kiln capable of achieving elevated temperatures. The wood is essentially heat sterilized. The schedules are presented in Table 12-2. Air-drying sticks and bolsters should periodically be sterilized by heat treatment to prevent a build-up of insects.

Table 12-2. Schedule for killing *Lyctus* (powderpost) beetles and their eggs (U.S. Department of Agriculture, Forest Service, 1991, p. 176)

Temperature (°F)		Relative humidity (percent)	Equilibrium moisture content (percent)	Thickness of lumber (inches)	Kiln reaches set conditions (hours)
Dry-bulb temperature	Wet-bulb depression				
				1	3
140	7	82	13.8	2	5
				3	7
				1	10
130	16	60	9.4	2	12
				3	14
				1	46
125	15	61	9.7	3	48
					50

In the past, most lumber was dried in large steam kilns, and the interior temperature of the wood easily exceeded the minimum 130 °F. Thus, any insect infestation was killed. Reinfestation could occur at a later date, but at least the lumber was initially sterilized. With the development of low-temperature kilns or even lumber being air-dried and subsequently further conditioned inside heated facilities without achieving elevated temperatures, existing infestations are not killed and problems develop later in the processing cycle.

Another approach is to fumigate the lumber. Fumigation is quick, and may completely control the infestation but provides no residual protection. Pest control operators specifically licensed to use fumigants must perform the work. The material to be fumigated is normally tightly tarped and the fumigant injected and kept under pressure for a specified period of time, after which it is released. Be certain to check the costs of the procedure to determine if it is economically feasible. Some operators are capable of fumigating entire houses. Price (2008) reports that fumigants do not penetrate “wet” logs very well and often fail to control cerambycids and buprestids in log homes.

The treatment of wood by dipping, brushing, or spraying with a residual insecticide has been used to control beetles. Dipping, brushing, and spraying are surface treatments only. They can help to prevent initial infestations and reinfestations, but they will not kill the larvae that already exist in the wood. These larvae will continue to tunnel and will eventually exit. Some traditional mills dip susceptible species in an approved insecticide as soon as the lumber is sawed. Boric acid and diatomaceous earth have also been found to be effective in protecting wood and preventing reinfestations.

Diffusion treatment of green wood with boron can also prevent beetle attack. The wood is usually dipped or sprayed, and the boron diffuses into the wet wood over time.

When using insecticides, be certain to check with local regulators about available chemicals, follow label directions, and be aware of how the lumber product will subsequently be used or processed. If the lumber is to be further machined, how are the treated residues disposed of, and is there any danger to equipment operators?

Once a product is installed and an infestation becomes evident, the problem becomes even more serious. Fumigation of the article of concern or the entire structure is effective, but also expensive. Beetles are not capable of infesting finished wood. Thus, if some damage can be tolerated, reinfestation at least from the finished surface is not likely. Unfinished wood can be treated as discussed above. If only a few pieces of wood are infested, prompt replacement may be an option.

For beetles that begin their attack under the bark, the removal of any bark edges is a good preventive measure. Many of the round-headed and flat-headed borers must feed under the bark for extended periods before they enter the wood. The bark beetles confine their attack to the inner bark, and are thus eliminated by bark removal.

The use of good building design helps control beetles. Proper ventilation in crawl spaces and attics, adequate drainage, and proper clearance between wood and soil helps to reduce the equilibrium moisture content of wood in buildings, and thus create conditions less favorable to beetle development.

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For More Information on Insects

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NOTICE!

Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers--out of reach of children and pets--and away from foodstuffs.

Apply pesticides selectively and carefully. Do not apply a pesticide when there is danger of drift to other areas. Avoid prolonged inhalation of a pesticide spray or dust. When applying a pesticide it is advisable that you be fully clothed.

After handling a pesticide, do not eat, drink, or smoke until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If the pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Dispose of empty pesticide containers by wrapping them in several layers of newspaper and placing them in your trash can.

NOTE: Registrations of pesticides are under constant review by the Federal Environmental Protection Agency. Use only pesticides that bear the EPA registration number and carry directions for home and garden use.

Chapter 13.

Stain in Logs, Lumber, and Finished Products

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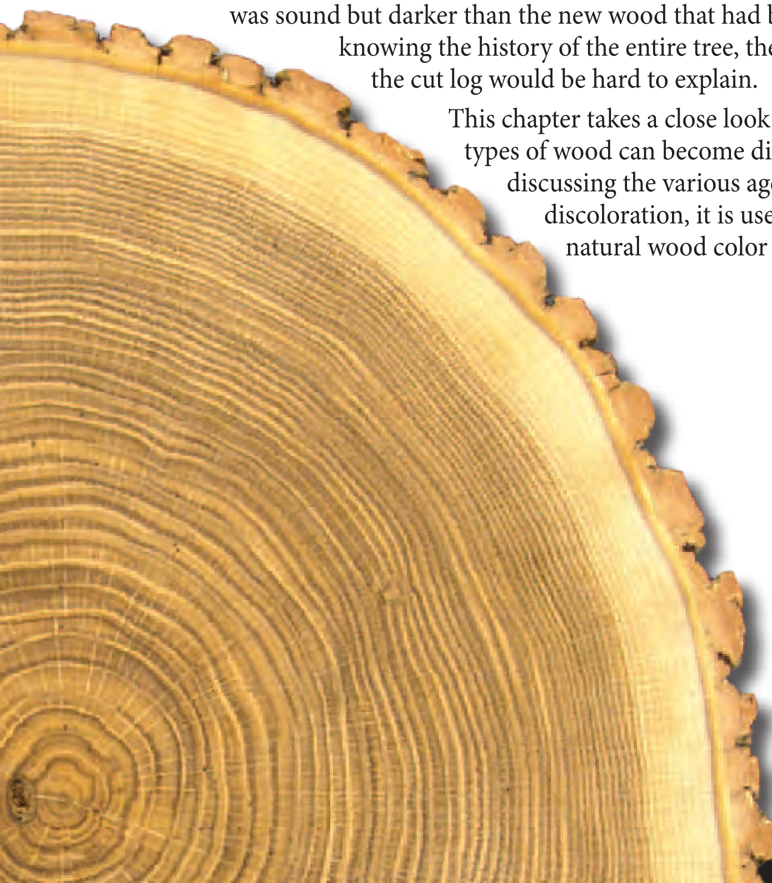
Chapter 13.

Stain in Logs, Lumber, and Finished Products

Color in wood, particularly the decorative hardwoods, is extremely important. Natural color varies between and within trees, however, and it can be altered in standing trees by wounding, the development of mineral stain, or from adjacent decay. In cut logs and lumber, mold, fungal, and enzymatic stain can also cause color change. As soon as a tree is harvested, the natural degradation process begins. Warm weather accelerates the agents of discoloration.

Color can also be altered by excessive and prolonged heat during kiln drying, and at the extreme, wood will just rot with adequate moisture and warm temperatures. Most manufacturers are just concerned about stain in general and try to follow procedures to eliminate or control it. Several years ago I sawed a large red oak tree that had the top broken out 14 to 15 years prior. A short distance from the damaged area, which had developed decay, the wood was sound but darker than the new wood that had been formed. Not knowing the history of the entire tree, the discoloration in the cut log would be hard to explain.

This chapter takes a close look at how different types of wood can become discolored. Before discussing the various agents of discoloration, it is useful to look at natural wood color variation.



Color in Wood

Color Variation

Wood color varies between trees, as well as within the same tree. Just how white is “white hard maple” is difficult to define. How uniform the color is across the width of a glued-up panel or across a paneled wall is equally important. Figure 13-1 shows both issues. The four samples on the right are all considered white sapwood with no stain. The wide board on the left has a brown heartwood flanked by white sapwood on each side. The second and fifth pieces from the left are the whitish samples, and are certainly acceptable. The third and fourth pieces are also white sapwood but somewhat darker in color. The mixing of the four samples could create an issue for some customers. If the second and fifth pieces are “sorted” from the third and fourth pieces, however, there will likely be no issue. Obviously, this is a very difficult and perception driven issue. Figure 13-2 is another example showing the heartwood and sapwood of yellow-poplar. The third piece from the left shows an “average” sapwood color for yellow-poplar. The fourth piece shows a very common gray or enzymatic stain. Depending on conditions, this stain can be lighter or much darker.

Figure 13-1. Range of color in hard maple. The board on the left shows both the dark heartwood and the preferred white sapwood. The four sapwood pieces on the right show a range of “white” in white hard maple lumber.

Figure 13-2. Range of color in yellow-poplar. The third piece from the left is about average for color in sapwood, while the fourth piece shows a very common gray or enzymatic stain.

For larger companies, there are now color matching systems that help prevent a somewhat dark piece being placed beside a very light piece. The objective is an esthetically pleasing result, and this is usually accomplished by avoiding large contrasts between adjacent pieces of wood.

Wood also tends to change color with time and exposure to the sun. Most woods become darker with exposure, whereas walnut tends to lighten. Woods exposed to the weather often gray.

Grain Pattern

Grain pattern, particularly in the coarse-grained woods such as oak, also needs to be considered. A flat-sawn piece laid beside a rift cut piece in the center of the panel could be objectionable, but if the flat grain is placed in the center of the panel and the rift to the edges, a much more esthetically pleasing panel results. Many companies hand sort pieces for color and grain pattern that are to be glued up into panels.

Mineral Stain

Mineral stain or streaks occur in the living tree and thus there is very little if anything that can be done about this type of stain. Entire sections of a tree can be discolored, as is the case with the purplish blue and black discoloration that develops in yellow-poplar (Figure 13-3). Discoloration can also be dispersed in or along annual rings or in streaks and spots throughout, such as the dark color in red oak (Figure 13-4), or olive to greenish black streaks in sugar maple and basswood.

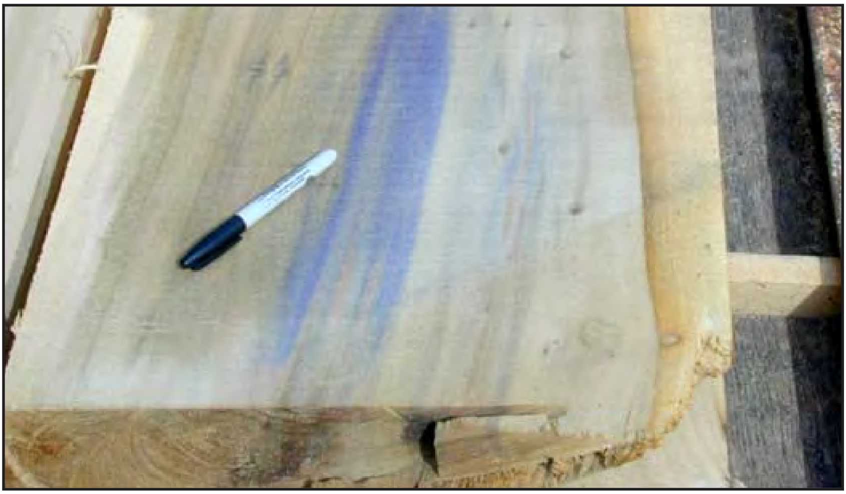


Figure 13-3. Purplish to bluish mineral stain in yellow-poplar. The stain is probably the result of wounding.

Figure 13-4. Dark mineral stain caused this cabinet door to be rejected.

The origins of mineral stain are not well understood. Documentation links the discoloration in yellow-poplar to wounding. Mineral is also found in conjunction with large borer damage in red oak, and with bird peck in maple and hickory. Some timber buyers indicate that mineral is more troublesome in timber stands that have been grazed, perhaps linking it to root damage. Others indicate that red oak growing in bottom lands or adjacent to natural springs is more likely to exhibit mineral stain. Veneer log buyers indicate that certain geographic regions are less prone to mineral stain than others.

The term "mineral" probably originates from the fact that sandy grit-like particles are often found in the discolored wood. Furthermore, experience has indicated that discolored wood is very hard and difficult to cut and shape, and that cutting tools can be damaged. Research has shown that discolored areas in wood contain abnormally high concentrations of mineral, especially potassium in hard maple.

The National Hardwood Lumbermen's Association (NHLA 2011) lumber grading rules do not consider mineral stain a defect, but they do limit the amount that can be present. Regardless of the rules, buyers who must eventually apply a light-colored finish will object and select against it. Drying problems such as checking or honeycomb are sometimes related to mineral stain.

Enzymatic, Oxidation, Gray, or Chemical Stain

Description

Enzymatic, oxidation, gray, or chemical stain all refer to the same type of discoloration. Stain can occur in the sapwood of any hardwood species in both the North and South. It is perhaps the most difficult stain or discoloration issue that the lumber industry has to deal with. It is particularly troublesome on those woods where the wide, white sapwood is preferred, such as hard maple, hackberry, and ash. Since southern oak can have a wide sapwood, it can also be an issue for that species as well. The stain develops because of a chemical or oxidation reaction in the living parenchyma cells of the white sapwood. When those cells die slowly their contents oxidize, resulting in a gray color. If the cells die fast or are rapidly killed, the wood remains white.

Gray stain can take several different forms depending on weather conditions. First, the entire board surface can turn a dirty, dull gray as compared with the bright white sapwood usually preferred (Figures 13-5 and 13-6). In other cases the surface of the board can be a normal white color and the lumber looks fine, but after surfacing and machining the discoloration begins to show (Figure 13-7). This form of interior graying can be a particularly difficult situation, since the shipper may not have known the lumber was stained, and the buyer already has the lumber scheduled to run and perhaps has no alternative in stock.

Figure 13-5. This wide yellow-poplar board was ripped in half, and the right side was surfaced. The dark oxidation stain seems to have originated near where the drying sticker had been placed.

Figure 13-6. This yellow-poplar board from the same stack of lumber as that shown in Figure 13-5 is still stained, but it is actually white under the drying sticker.

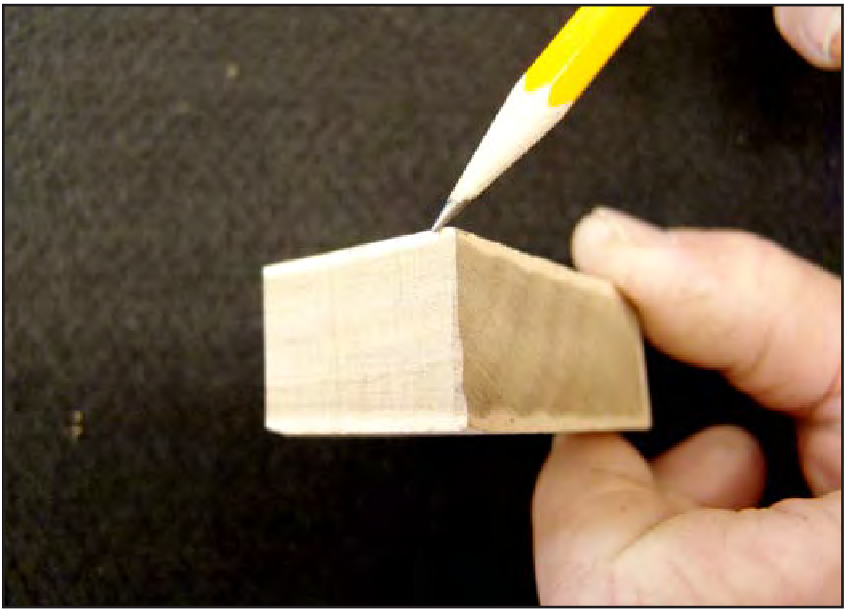


Figure 13-7. This small sample was cut from the sapwood of a persimmon board. The surface is white, but the interior has grayed. Enzymatic stain in persimmon is so common that the white sapwood is nearly always discolored.

Sticker stain or burn is also commonly caused by the oxidation process. It can likewise take two different forms. A gray area can form where the stick has had contact with the board and may also be present even after surfacing (Figures 13-5 and 13-8). In this case, the wood dried too slowly under the stick and stained. In another scenario, but less common, the wood immediately under the stick and after surfacing is white but adjacent wood is discolored (Figure 13-6). The moisture from the board in contact with the dry stick probably moved toward the stick before stain could develop, while the rest of the board did not dry quickly enough due to poor weather conditions.

Control

Control of enzymatic, oxidation, gray, or chemical stain is particularly difficult and uncertain. First, chemical treatment with fungicides designed to control fungal stain is ineffective. Just because lumber has been dip treated to prevent stain does not mean that oxidation stain will not be present. Storing logs under water spray is another time-honored approach that prevents fungal stain, insect attack, and end checking. There is no research documentation, but the author has been told by experienced lumber producers that holding logs under water spray during warm weather seems to predispose the lumber cut from them to oxidation staining. That is, the lumber seems to easily develop oxidation stain once the watered logs are processed.

Figure 13-8. Sticker shadow in white hard maple.

Graying is also reported to be worse under poor drying conditions. These include damp, moderately cool weather such as in the spring or late fall. Again, the cells are dying a slow death, and there is time for the oxidation process to take place.

Experienced lumber producers agree that rapid processing is the best procedure to prevent oxidation and thus gray stain. Logs should be moved from the woods as soon as possible and promptly sawed into lumber. The lumber should go on stickers immediately, and many operators will place high valued lumber in a dry kiln where they have control over the drying conditions. Schedules at this point are normally proprietary, but drying should be as rapid as possible without causing degrade or discoloration from heat. Any excess moisture in the kiln needs to be vented promptly.

Winter cut logs and lumber in the North are the least prone to oxidation or gray stain. Since oxidation stain is a chemical reaction, the temperatures may not be warm enough for damage to occur.

For small quantities of freshly cut lumber exposed to poor drying conditions, it may help to place fans near the pile. Forcing more air to move over the board surfaces accelerates drying. Care must be exercised not to dry refractory species such as oak and beech too fast, as surface checking will result.

Mold, Fungal Stain (Sapstain), and Decay

Mold, fungal stain, and decay are caused by fungi. Fungi are microscopic nonphotosynthesizing, flowerless, single cell to thread-like organisms that use wood and other plant materials as a food source. Fungi are composed of millions of microscopic thread-like structures called hyphae that spread throughout the wood. The hyphae secrete enzymes that dissolve certain portions of the wood substance stored in the cells or on the surface and use it as a food source. Fungi have four basic requirements: a food source (wood), oxygen from the air, a preferred temperature of 75 to 90 °F (but they can be active in a much broader range), and finally, moisture. If the moisture content of wood is below about 20 percent, fungi—even if present in the wood—are not active. Eliminate any one of these four factors, and fungi cannot damage wood. The word "sapstain" is commonly used in the industry to refer to discolored sapwood. The discoloration may have been caused by the oxidation process or by fungi.

Mold

Molds discolor the surface of both hardwoods and softwoods (Figure 13-9). Molds are predominately different shades of green, black, and occasionally orange or other light shades. Although the fungal hyphae does penetrate into the wood, the surface discoloration can generally be planed or even brushed off. On hardwoods, some shallow staining may result, and on certain woods it will be objectionable. Strength other than toughness is not seriously affected by molds, but the permeability of the wood may be greatly increased.

Figure 13-9. Dark mold on the surface of yellow-poplar lumber.

Fungal stain

Stain caused by fungi (Figures 13-10 and 13-11) is the blue to black, gray or brown darkening of the sapwood of both hardwoods and softwoods. The dark color is due to the deep penetration of large masses of fungal hyphae and is sometimes called blue stain. Some fungal stains may produce relatively bright colors, such as red, purple, and yellow. Logs, as well as green lumber, are susceptible. In warm weather, the sapwood of some species can discolor in less than a week.

Fungal stains do not seriously reduce wood strength, except for toughness. Therefore, the wood should not be used where it will receive significant repeated jars, jolts, or blows. It should be recognized, however, that decay could easily accompany intense fungal stain and thus affect other strength properties. Like the molds, fungal stains increase the permeability of wood.

Figure 13-10. Blue stain or fungal stain in the sapwood of a white pine log.

Figure 13-11. Fungal stain or blue stain in buckeye. The stain was present when the log was cut. Note that the stain does not extend to the end of the log. The spores that cause the stain actually entered through the end of the log, but due to end drying, they were able to discolor only the moist wood from the inside of the log.

Decay

In standing trees, large wounds or even small ones that do not heal promptly expose the tree to decay. Pockets of decay then develop, and within time an entire tree can become hollow. Some trees seem to develop diseases that destroy or decay the wood, but the tree continues to live until it is weakened and eventually destroyed. Large beech trees are often hollow due to decay. Other examples include white pocket rot in pine and Douglas-fir, and brown pocket rot in cypress and western red cedar.

If the conditions that favor mold or fungal stain continue, cut wood will decay. Sapwood is always subject to decay, and it will be the first part of any board to stain or decay.

Logs are subject to mold, stain, and decay as soon as they are cut. In some cases, mold can be seen in less than a week. The bark on many tree species is resistant to fungal attack. As a result, the ends of the logs, particularly the sapwood and any areas on the log where the bark has been removed, are attacked first. Damage occurs during warm weather. “Winter cut” logs in the North are not subject to damage until warm weather returns.

Control of Mold, Fungal Stain, and Decay

Again, logs should be processed as quickly as possible after being cut. This is not always possible, however, and large quantities of logs are often yarded in fall to be processed during winter and spring.

Wax end coatings can help prevent end checking of logs as well as fungal penetration. For maximum effectiveness, these coatings must be applied as soon as the logs are cut.

Another procedure to control fungal and insect damage is to place the logs under a water spray system (Figure 13-12). The logs must be kept consistently wet, so the system needs to be designed with ample capacity. Strong winds on dry days that can cause some of the logs to dry will result in stain. The idea of using water spray systems originated from early times when logs were stored in ponds. Those logs—or at least the submerged portions—were not stained or damaged by insects. Figure 13-13 is a relatively unusual water spray system. Most systems are fully exposed but this one is under cover. The cover helps slow evaporation and the shade created also keeps log temperatures lower, thus helping to preserve the logs.

Figure 13-12. Water spray system for preventing log deterioration. Note the sprinkler heads in the background.

Figure 13-13. These high-valued logs are being protected by a water spray system. The shade from the roof slows the water evaporation rate and prevents the sun from heating the logs.

Fungal stain and mold in lumber in the northern states is usually not a problem except during warm summer months. In the Deep South, it can be a problem nearly year round due to warm temperatures. To control or minimize fungal damage, logs should be processed as soon as possible, and the fresh cut lumber should be placed on sticks as soon as it is cut. This allows the air drying process to begin. Once the surfaces and ends of the boards are dry, the fungi cannot penetrate the wood and discolor it. When lumber is bulk piled, the interior surfaces cannot dry. During warm summer weather, molds and fungal stains can begin to develop within just a few days. For particularly stain-prone and valuable species, some mills will put the green lumber directly into a dry kiln. In the South, cottonwood is sometimes initially dried in blow boxes. See the chapter entitled "Wood Moisture and Drying" and the section "Forced Air Drying," for a discussion of blow boxes.

For small quantities of lumber, inexpensive household fans can be used to start the drying process and prevent surface infection by fungi. Be sure not to dry refractory species too quickly, as surface checks can develop.

Finally, fungicides and insecticides can be used to control fungi and insects in freshly cut lumber. This practice is most common in the South where warm weather persists most of the year, but it is also used in the North. Two primary methods are employed. At larger mills with green chains the lumber passes through a dip tank located somewhere between the trim saw and where the lumber is stacked. With this method, every board must pass through the tank. The second method is to stack and strap the lumber and then dip it into a tank located away from the production area. With this method, only the lumber for which stain or insects could be an issue is dipped. Other lumber is processed without treatment. Some mills believe it is important to dip the lumber bundles at a slight angle so air can escape from the higher end. This insures that all of the surfaces are treated.

Less common methods include pressure spray systems where the employees stacking the lumber spray each course. The bottom of the next course of lumber laid cannot be sprayed, but it seems to get some protection from the top surface of the sprayed lumber below it. Some portable mill operators have employed sprinkler cans, or even put the fungicide in the fluid container used to clean the blade.

When using fungicides and insecticides, be sure to check state regulations and follow the label directions. Consider how the lumber and any byproducts will later be processed downstream.

NOTICE!

Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers--out of reach of children and pets--and away from foodstuffs.

Apply pesticides selectively and carefully. Do not apply a pesticide when there is danger of drift to other areas. Avoid prolonged inhalation of a pesticide spray or dust. When applying a pesticide it is advisable that you be fully clothed.

After handling a pesticide, do not eat, drink, or smoke until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If the pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Dispose of empty pesticide containers by wrapping them in several layers of newspaper and placing them in your trash can.

NOTE: Registrations of pesticides are under constant review by the Federal Environmental Protection Agency. Use only pesticides that bear the EPA registration number and carry directions for home and garden use.

Reference

National Hardwood Lumber Association. 2011. Rules for the measurement and inspection of hardwood and cypress. Memphis, TN. 101 p.

Chapter 14.

Structure of the Hardwood Lumber Industry

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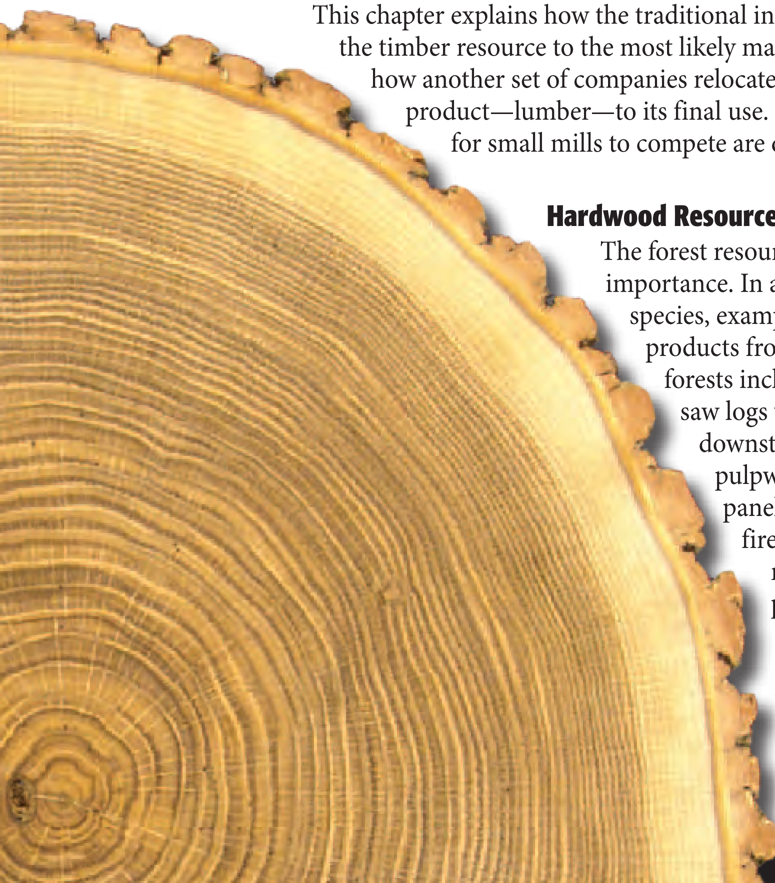
Chapter 14.
Structure of the Hardwood Lumber Industry

Marketing hardwood forest products is a complicated process. On the supply side, in a typical wooded property, there are many species, sizes, and quality levels of trees available. On the consumer side, there is a vast array of potential markets varying in size from a few boards to a train car or container load of product. To maximize value through the entire process, various companies with an assortment of product specialties may become involved. In addition, the types of markets may vary depending on region of the country or even part of the world. Much of the domestic business conducted in the hardwood industry is done based on trust, which is contrary to the world of contracts and litigation. There is a relatively close-knit group of companies or individuals who operate in a highly efficient way. In order to identify their own potential markets and opportunities, it is helpful for new companies to understand traditional companies and their marketing process.

This chapter explains how the traditional industry allocates the timber resource to the most likely manufacturer, and how another set of companies relocates the primary product—lumber—to its final use. Opportunities for small mills to compete are discussed.



Hardwood Resource

The forest resource is of primary importance. In addition to species, examples of raw products from hardwood forests include veneer logs, saw logs with multiple downstream uses, pulpwood, furnish for panel products, poles, firewood, and other miscellaneous products.

Species is the most important factor to consider. Depending on the region, oak followed by hard maple are two of the most common species groups. These are followed closely by yellow-poplar, ash, silver or red maple, aspen, or hickory/pecan, basswood, beech, and birch. High-valued, low-volume species such as cherry and walnut are more restricted in their range of high-quality trees. Cottonwood, gum, sycamore, and willow are found over a wide range, but are typically produced as grade lumber only in the South. There are nearly 20 species or species groups that the industry must deal with. Some sites have half of these species on relatively small acreages.

Many sites may have different age classes and diameters of trees. Often the most valuable species have been cut, leaving the rest to dominate the site. At this point in U.S. forest history, hardwood stands likely have been cut numerous times. Each time, different species may have been preferred.

Tree quality has been affected by past cutting practices. Lack of stand management may have resulted in the best quality trees being removed, leaving only the poorest quality, least valuable trees. In other managed stands, the quality is often good, and many valuable species will be present.

Within any of the above potential products, there may be different grades of material and only some species may be acceptable. For example, in grade hardwood lumber a sawmill typically produces three to four different grades and two or three (sometimes four) lumber thicknesses. Sorting for lumber widths and lengths is becoming more important.

The biggest challenge in starting with standing timber and producing lumber as the primary end product is to divert each log to its highest economic value. This is not an easy task even for the traditional industry that deals with semitrailer size loads. To better understand how a smaller producer might best fit into the above scenario, it is useful to review how the existing traditional industry has developed and succeeded.

Veneer Industry

The veneer industry is described in the chapter titled "Hardwood Logs and Trees for Fine Face Veneer." There are a limited number of veneer manufacturers in North America. These manufacturers generally have log buyers throughout the hardwood region who are in search of the very best logs for each major species. They pay a premium price for logs or standing timber. In most cases, the sawmill industry sends the highest quality logs to the veneer industry.

Hardwood Lumber Manufacturing

The hardwood lumber manufacturing segment of the industry has the capability to utilize any material large enough to be classified as a sawlog. The industry may purchase standing timber by using its own buyers. They may also purchase logs cut by others and delivered to the mill (these are commonly called gate logs). They purchase certain select logs from other mills because of the unique marketing or processing abilities of the purchaser or combinations of the above possibilities. In general, the hardwood lumber industry does not own large amounts of timberland. They depend on private landowners for a timber supply.

Mills, loggers, or others usually make every attempt to sort logs at the woods landing and divert them to their highest value at the time they harvest standing timber. The best logs are diverted to veneer mills and receive top priority. Lower grade logs or less valuable species are usually diverted to mills that produce pallet stock or railroad ties. Further sorts are made if other markets are competitive with grade sawlogs. An example might be logs for tool handle stock or turning squares. The remainder of the logs are considered grade sawlogs and are transported to the sawmill, usually in semi-load quantities. A semiload of logs contains about 3,500 board feet Doyle scale, depending on species and log size.

Traditional sawmills vary greatly in their size and capabilities. Mills cutting pallet stock or railroad ties represent some of the simplest plant layouts, but equipment can be sophisticated. Pallet mills are interested in maximizing the volume of sound wood produced from a given log. These mills are often captive to a pallet or box manufacturing plant. If the end use of the lumber product is known at the time of harvesting and sawing, it can sometimes help improve utilization.

Mills producing railroad ties are also producing a specific end product. Crosstie specifications call for 8-foot, 8-foot 6-inch, and 9-foot lengths. Side lumber or the boards produced in sawing to the specific dimension of the finished tie or cant are also produced by both tie and pallet mills. Only certain log lengths, quality levels, and species are acceptable.

Kiln-drying is normally not required in either pallet or tie operations; however, pallets are often heat treated to control the spread of insects. The demand for crossties is variable; and, as a result, mills enter and leave the crosstie production business depending on market opportunities.

Grade Hardwood Sawmills

Grade hardwood sawmills typically cutting 5 to 20 million board feet per year are the norm or standard for the sawmill industry. Next to veneer or specialized products, grade lumber produces the most value. Therefore, all logs with an adequate potential for grade lumber production are directed to these operations. Given the species, grades, thicknesses, and lengths of hardwood lumber already discussed, these mills must decide whether to dry lumber and how to dispose of secondary products such as pallet cants, chips, bark, and sawdust.

Traditional small sawmills have permanent locations, use large diameter circular saws, and usually sell green lumber. “Small” sawmills, or those typically cutting less than about 5 million board feet per year, have always been an important segment of the hardwood lumber industry. These mills are located close to the resource. As members of the local community, they have access to timber. Some local use lumber may be marketed by the mill. Primary sorting and breakdown of logs near their source helps reduce trucking costs. Some mills may operate only when lumber demand warrants it.

Most traditional small mills have made arrangements with large sawmills, concentration yards, or perhaps end users who kiln-dry their own lumber. The important factor to the producing mill is that within trucking distance there are usually limited numbers of buyers that can take the smaller quantities, various species, and upper grades of lumber that are produced from the available logs. Again, this segment of the industry is dealing with semitrailer loads of lumber. A semi load of green lumber normally contains about 9,000 to 10,000 board feet, while a load of kiln-dried lumber contains about 12,000 to 16,000 board feet depending on the species. Kiln-dried lumber weighs less, due to the loss of moisture. Concentration yards, large sawmills, and wholesalers continue to be the primary consumers of lumber from traditional small mills. The number of these traditional small sawmills has declined only to be replaced by the newer thin kerf band mills.

Large traditional grade hardwood sawmills producing in excess of 5 million board feet per year normally have dry kilns and, because of their size, will also have many market opportunities. With larger mill sizes, semitrailer load quantities of one species, one thickness, and one grade are available to buyers. Mixed loads can also be produced. The larger the mill, the greater the opportunity for the mill to constantly sell large quantities of lumber of the same species, grade, and thickness to the end user. These mills have one or more full-time individuals devoted to lumber sales.

Table 14-1 lists the advantages and disadvantages of large and small hardwood sawmills. Small mills include traditional mills plus newer thin kerf band saw operations. Large sawmills are permanently located and appear more like a traditional business with a full-time office and staff. They carry substantial inventories; they can kiln-dry lumber; and they often provide other services such as surfacing, straight line ripping, and perhaps sorting. They are well known in the industry. Many larger sawmills purchase lumber from smaller mills, and thus the uniformity of the boards can vary somewhat.

At first review, larger mills appear to have substantial advantages; however, the hardwood industry is diverse and smaller mills, especially efficient thin kerf band mills, have their own set of advantages. First, many of these mills are set up to be mobile. This eliminates the cost of and need for heavy equipment to load and transport logs. These mills can provide custom sawing on site, which generates quick income. Smaller, portable mills can harvest just a few trees on small land areas. These small areas can have some of the better timber because they may not have been harvested for some time. Also, forest land is being constantly divided into smaller parcels, particularly near urban areas.

Large operations require good-sized tracts of timber to make the harvest economical. Small mills are also able to produce specialty items almost upon demand. Price can be negotiated up or down depending on daily circumstances, and quality is mostly known since the same operator is always in charge.

It may also appear that large and small sawmills are in competition. In some situations this may be the case; however, I firmly believe that well-run small mills, particularly thin kerf portable operations, fill a different niche. Small and larger operations need to know and understand each other and make referrals. Business for both parties is likely to improve with cooperation.

Because of the wide range of potential products and different buyer's needs, the hardwood lumber industry is composed of many other players in addition to the hardwood sawmills. These players include concentration and distribution yards, wholesalers and brokers, and even retail outlets. Various types of companies commonly work together in order to find the most profitable market for the numerous products produced. Mills may market wood products through other companies, even before it gets to an end user, as described in the next section.

Table 14-1. General capabilities of large and small hardwood sawmills, by marketing factors

Factor	Large sawmills	Small sawmills
Business atmosphere	Good	Limited
Inventory	Good	Limited
Services	Good	Limited
Industry contacts	Good	Limited
Specialty items	Limited	Good
Quality	Mostly known	Known
Price	Competitive	Negotiable
Timber base required	Large	Small (portable mills)
Custom sawing	No	Yes
Mobility	No	Usually (portable mills)
Small quantity sales	No	Yes

Wholesalers and Brokers

Mills producing a consistent volume of lumber in semi-load quantities may work with wholesalers or brokers to move all of the lumber or just certain items. Wholesalers and brokers commonly work as marketers or as sales persons for smaller to midsize sawmills. These mills often do not have the resources or volume to justify a full-time salesperson, and thus the wholesaler or broker serves as their part-time marketer. Wholesalers and brokers have been important assets to the hardwood industry ever since lumber began to move from remote production areas, at or somewhat before the beginning of the 20th century. These individuals are in constant contact with many producers and purchasers of lumber. They are specialists in knowing large numbers of sellers and buyers. Their job is to move lumber that a producer has or can produce, to a buyer, again mostly in semi-load quantities.

Most wholesalers will move large volumes of lumber with a low markup; however, wholesalers may not be able to deliver the least expensive lumber. In other cases, they can act as a clearinghouse by helping mills reduce inventories of certain items and offer them as specials to potential buyers. Wholesalers typically purchase the lumber from the producer and are thus the legal owners of it. They can make quick payment to the mills and assume accounts receivable. They can also make advance payments to the mill in return for having a product to sell. They will arrange for freight and other services and manage any claims. In many cases, they never actually see or handle the lumber—they are simply facilitating its sale and movement while operating out of an office. Some wholesalers, however, will have their own yard with dry kilns or arrangements with a yard that can take physical possession of the lumber and dry it before selling to an end user.

Brokers typically perform the same services as wholesalers but work on a commission basis and never own the lumber. The distinction between wholesalers and brokers on commission is not always clear within the industry.

Concentration Yards

Concentration yards typically purchase and inventory green lumber of mixed grades and species from a large number of smaller producers. Purchases are normally in semitrailer load quantities, but smaller quantities—particularly of scarce items—are sometimes accepted. These yards are potential buyers for green lumber produced by smaller thin kerf band sawmills, as long as quantities and qualities consistently meet the yard's specifications. During warm weather, stain-prone species must be shipped and handled promptly. The lumber is graded, sorted, air-dried, and kiln-dried. Additional services, such as surfacing, straight line ripping, and sorting, are usually available. Large quantities of lumber are accumulated and held in inventory. As a result, these yards are in a position to supply nearly any species, thickness, and length used by domestic and overseas buyers. Like wholesalers, concentration yards serve as the marketing arm for many smaller mills. Some wholesale firms will have their own concentration yards or contract with other yards to perform this service.

Distribution Yards

Distribution yards usually purchase semi-load quantities of kiln-dried lumber from a few selected sellers. The yards then resell it in quantities ranging from just a few boards to a few thousand board feet, to local end users such as cabinet shops, architectural woodwork shops, and others. Some yards may advance credit to the buyer. Because of the small quantities handled and services provided, markup can be significant. The lumber is mostly top grade, sometimes sorted by width and length, with surfacing and straight line ripping services available. Many companies also perform molding services. The traditional distribution yards are normally located in metropolitan areas where smaller wood manufacturers and custom woodworkers are common. The yards are often set up to make deliveries; one truck may be loaded with numerous orders of just a few hundred board feet each and travel the same route on a weekly basis. Some of these yards may also focus on retail sales of lumber as well as panel products and supplies. Because yards sell small quantities of lumber to individual customers, opportunities for thin kerf band mills with dry kilns and consistent inventory of the more common lumber items exist in this market.

Retail Outlets

Within the last couple of decades, marketing hardwood lumber through retail outlets has become more popular. A vast array of scaled-down and affordable planers, jointers, routers, sanders, and other woodworking equipment has made it possible for hobbyists and small businesses to process hardwood lumber into useful consumer products. As a result, many retailers stock some hardwood lumber and panels. A few sawmills and other traditionally "wholesale" type operations conduct retail sales, much like distribution yards have done for years. The markup compared with wholesale lumber is substantial, because significant time, expense for inventory, and a place to conduct business is usually needed. Newer thin kerf mills with dry kilns seem well positioned to capture a portion of the local market, as long as prices are competitive.

Summary

The hardwood industry has been and continues to be composed of many different types of companies that supply an equally complex set of buyers. On the supply side, many companies perform more than one of the traditional functions outlined. Overlapping is common. Large and small companies have always coexisted. Small companies can help supply large companies with additional lumber. Small companies are capable of utilizing a portion of the resource that large companies cannot economically utilize, or they can fill other niches for small quantities or specialty items. Successful companies efficiently convert a portion of the resource utilizing their equipment, and monetary and human capital to produce a needed product. Regardless of company size, the objectives of efficient conversion, marketing, and profitable sales are the same.

Chapter 15.

Trends in Marketing Wood Products

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Table 15-1 Hardwood lumber consumption in billions of board feet, by market sector from 1999 to 2009 — 335

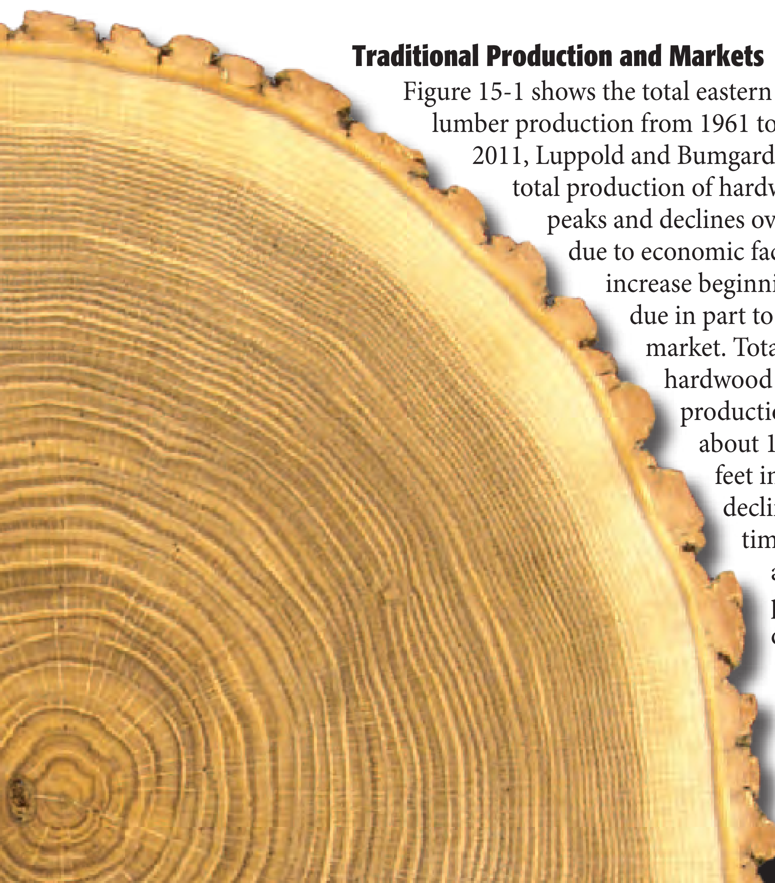
Figure

Figure 15-1 Eastern hardwood lumber production, 1961 to 2009 — 334

Chapter 15.
Trends in Marketing Wood Products

This chapter discusses factors affecting the marketability of lumber, different types of markets, and how to locate lumber buyers. It is not intended to be a generic presentation on marketing.

Marketing and selling hardwood lumber by traditional mills and others is the topic of the chapter titled "Structure of the Hardwood Lumber Industry." This chapter, however, presents information on hardwood lumber production and major markets for the last several years. The focus here is on factors, such as seasoning, that determine what a hardwood product can be used for, and on broad market categories, such as grade or industrial lumber. Resources to develop markets and locate buyers are also presented. Many of these markets are currently serviced by traditional mills and others. Depending on production capabilities, however, the new generation of thin kerf band mills may be able to fill certain needs.



Traditional Production and Markets

Figure 15-1 shows the total eastern hardwood lumber production from 1961 to 2009 (Luppold 2011, Luppold and Bumgardner, 2008). The total production of hardwood lumber peaks and declines over time, mostly due to economic factors. The general increase beginning about 1986 is due in part to the export market. Total reported hardwood lumber production peaked at about 12.6 billion board feet in 1999 but has declined since that time. Between 1999 and 2009 production declined by about 6 billion board feet to 6.7 billion board

Figure 15-1. Eastern hardwood lumber production, 1961 to 2009 (Luppold 2011)

feet (Luppold 2011). By February 2010, the estimated yearly demand had declined to 5 billion board feet. (Hardwood Market Report 2010a).

Many factors, such as general economic conditions, housing starts, imports, exports, exchange rate, weather—and more recently—fundamental changes in the structure of the marketplace have affected lumber production and prices; however, some of these changes may be regional. As an example, in 1999, the furniture industry consumed 2.6 billion board feet of lumber, and by 2004 the consumption had declined by one-half. This industry was centered in North Carolina and Virginia. In spite of the increase in national demand for wood furniture during this time, production continued to decrease in North Carolina and Virginia. Lumber production in West Virginia also declined because their timber was used by the Virginia and North Carolina furniture industry. On the other hand, lumber production increased by 5 percent in Ohio (Luppold 2007).

New producers should be aware of the ups and downs of the market and even regional developments. Entering the traditional marketplace when it is not expanding will be difficult for new producers unless they are offering very competitive specialized products or services.

Estimates of lumber consumption by major market segments from 1999 to 2009 were published in the Hardwood Market Report (2009b and Johnson 2011). Table 15-1 gives the market segment and average consumption over those 6 years.

Pallets and railroad ties consumed about 40 percent of the total hardwood production in 1999 but increased to 60% in 2009. These are also the only major markets for green or unseasoned products. The balance of the lumber is used for finished products and requires kiln-dried lumber.

Table 15-1. Hardwood lumber consumption in billions of board feet, by market sector from 1999 to 2009 (Hardwood Market Report 2009b, p.10), Johnson 2011)

	1999	2005	2006	2007	2008	2009
Furniture	2.6	1.2	1.1	1	0.7	0.3
Building products	3.9	4.4	4.1	3.6	2.7	1.6
Pallets	4.5	3.8	3.7	3.6	3.5	3.0
Ties and mats	0.7	0.9	1.0	0.9	1.2	1.0
Exports	1.2	1.3	1.3	1.2	0.9	.08
Total	12.9	11.6	11.2	10.3	9.0	6.7

Much of the lumber produced by thin kerf band sawmills is probably not included in these numbers.

The decline of the residential furniture industry in North Carolina and Virginia and other factors have resulted in a fundamental shift in the marketplace. Table 15-1 shows the decreased demand for kiln dried hardwood lumber by the furniture, building products and export sectors. From 1999 to 2009 the furniture sector dropped by 88 percent, the building materials sector by 59 percent and exports by 33 percent. As a result, the hardwood industry is more dependent on home construction and remodeling, which includes custom kitchen cabinets and flooring. These items increasingly are being manufactured by smaller local firms.

It is interesting and useful to look at national and regional trends in hardwood lumber production and consumption; however, these historical data have very little to do with a small local producer. In fact, what many small local mills produce is not included in the "mega" numbers. Examples are custom sawing and salvage of trees from land clearing activities, urban trees and other salvage trees, or timber stand improvement trees.

The opportunities for local producers are determined by local supply and demand. If local timber is readily available, there are likely to be several local suppliers, which in turn forces down prices and cost of services, such as custom sawing. Also, heavily timbered areas tend to be less populated, thus limiting potential buyers, particularly ones who can afford custom hardwood products. Small producers in these areas should probably focus on concentrating small quantities of lumber into larger lots and having it moved to distant markets where the demand is higher.

Small producers in areas where available timber is scarce and where populations are concentrated may do better by developing local markets for rough lumber or custom finished products, such as dimension, cabinets, flooring, and molding. National trends do not necessarily reflect local conditions.

Regardless of where your marketing focus will be directed, it is still important to recognize the major market categories for hardwood lumber as well as how the level of seasoning and other processing affects the marketability and value of your product.

Most state universities and other county or regional economic development groups offer generic marketing workshops. Individuals not familiar with these programs should definitely search them out and plan to attend or ask for individualized assistance. Because the programs and the exact name of the group offering the programs and assistance varies between states and even within a state, it may be best to start by contacting the county cooperative extension service office. These offices are located in nearly every county of the nation and are part of the state land-grant university system. Many of these programs appear to deal with food or the more common agricultural commodities, but the principles are the same as for wood marketing. The information presented here can be used to help carry out ideas obtained in these sessions.

SCORE (www.score.org) is a nonprofit group that can provide free, confidential business assistance to starting or existing small businesses, either in person or on line. The providers are business owners, executives, and corporate leaders willing to share their wisdom and lessons learned in business.

Market Categories for Hardwoods

Grade Lumber

There are only about three general categories in which hardwoods are marketed, plus a category for miscellaneous. I have also added a category for producing environmentally acceptable "green" lumber. The first and generally most valuable is grade lumber. For end use applications, this is generally kiln-dried material that meets specific grade requirements as specified in the Rules for Measurement and Inspection of Hardwood and Cypress (National Hardwood Lumber Association 2011). The upper grades at least represent the clearest material available and also command the most value. This lumber normally moves in semi-load quantities to larger manufacturing firms, or in smaller quantities of a few hundred to a few thousand board feet from distribution yards to smaller manufacturers and custom woodworkers. Naturally, the smaller the quantities the higher the price. Grade hardwood lumber is also sold at the retail level by distribution yards, retail stores, and more recently by some smaller producers who have dry kilns. Opportunities for smaller mill operators exist in this area.

Dimension Parts

In the hardwood industry, dimension refers to parts of a specific size that are later machined and assembled into a final product. Examples might be kitchen cabinet door fronts where stiles, rails, and glued-up panels are used. Normally, the lumber is surfaced to the required thickness, ripped to a specified width, and cross cut to length. Dimension plants may also provide some machining and sanding. The traditional dimension business is highly competitive. The manufacturer spends a high percentage of the finished product's value on purchasing grade lumber and adding minimal value. Lumber costs constitute most of the product cost. Therefore, it is important for dimension manufacturers to have markets for a wide variety of part sizes. That enables the plant to maximize yield for the lumber.

Smaller lumber producers, particularly those who have quality planing, sawing, gluing, and sanding equipment, might consider producing custom dimension parts. Quality parts need to be perfectly cut to size and done so without chipped grain. Selling finished parts allows you to select the boards to complete the job and also adds extra value to your product. If you do not fill the order, you will not sell any lumber to this customer either. Since you are producing a custom product with minimal value to others, a substantial down payment or total payment up front is appropriate.

Industrial Lumber

Another major market segment is industrial lumber. This material is usually shipped green from the mill in semi-load quantities. Examples include pallet cants and crating lumber, blocking, timbers, railroad ties, truck and trailer flooring, lumber for board roads, and drag line mats. Larger mills usually separate the high-grade lumber from the outside of the log and then convert the lower grade core into industrial lumber, depending on market demands. Like dimension parts for furniture or cabinets, opportunities also exist for certain cut-to-size or even machined parts in this segment. Grade and survey stakes might be an example.

General Construction Lumber

General construction lumber is another broad market category. Examples might include framing lumber and boards, general farm lumber for fences, post and beam timbers and other applications. Softwoods are typically used in construction, and this lumber is often produced by extremely efficient mills that produce in excess of 100 million board feet per year. As a result, it may be difficult for smaller hardwood mills to compete in this market, but it does provide an outlet for sound, lower grade material, especially if it can be easily nailed. Also, the density and strength of hardwoods may be desirable in some applications, such as horse stalls.

Some care must be exercised in the production of construction lumber. Where building codes are enforced, construction lumber must be graded and stamped by a certified grader before it can be used. This requirement can be a difficult and confusing situation for smaller producers or others wanting to use their own lumber. First, the code is not always enforced, particularly in rural areas. Second, the inspector may not be concerned about the grade stamp given good construction practice. This author was contacted in regards to a horse barn that was about to be dismantled because the lumber was not grade stamped; so, beware. You may want to review the chapter titled “Softwood Lumber Grading” if you are planning a construction project.

Miscellaneous

Lastly, a miscellaneous category needs to be considered. This category might include items such as bending stock, sofa frame stock, boat building materials, and other items that range in value from low to high. These items are often specifically selected in order to produce a desired effect or appearance and can command a premium price. The author once filled a request for persimmon lumber that a company manufactures into dowels. The dowels were subsequently shipped to another company for conversion into drum sticks. There was more demand, but no trees. Miscellaneous markets need to be carefully considered. Because of the uniqueness or sorting and small volumes of lumber involved, large producers may not want this business. Purchasers may have a hard time finding a source. The wood item may represent a small part of the end cost of the product, thus allowing the buyer to pay a premium. Some items in this category could be considered niche markets. For a detailed discussion of niche markets, consult Hacker (2006).

“Green” (Environmentally Acceptable) Lumber

Our society, particularly the more affluent portions, and some governmental agencies are becoming more and more environmentally conscious in regards to building construction. Wood is a renewable resource, and Forest Service statistics indicate that the United States is producing far more wood volume than it is using. That obviously is a good thing, but the issue is much more complicated. Responding to the environmental concerns could be a marketing opportunity. Some background information is appropriate.

The Forest Stewardship Council (FSC) was formed to promote responsible stewardship of the world’s forests and, among other things, to accredit independent third party organizations that can certify forest managers and forest products producers to FSC standards.

A second entity, the Sustainable Forestry Initiative (SFI) was formed based on the premise that responsible environmental behavior and sound business decisions can coexist. Products from SFI-certified companies are recognized under both the Green Building Initiative's (GBI) Green Globes and the National Association of Home Builders (NAHB) Green Building Systems.

A third entity, PEFC, or programme for the Endorsement of Forest Certification Schemes follows internationally accepted procedures for third party certification. The American Tree Farm System is now working with PEFC. This is an important development because many small forest landowners are members of the American Tree Farm System. These small forest landowners could not economically justify individual certification, so group certification is now an option.

In sourcing certified, sustainable wood products, either FSC, SFI, or PEFC, may be involved. All are relatively well known. The emphasis is on the product being certified as having been produced in a sustainable fashion. A paper trail documenting the origins and processing steps must accompany the product.

More recently, Leadership in Energy and Environmental Design (LEED) is promoting a nationally accepted benchmark for the design, construction, and operation of high performance green buildings. Architects design and construct a building using various materials and then receive points, based on how environmentally acceptable the materials are. At this time, LEED will only accept FSC-certified materials.

Small individual operators or forest landowners are not likely to be certified by FSC, SFI, or PEFC or supply materials to an architect for a LEED-certified building. Nevertheless, the proliferation of various groups and individuals concerned about forest sustainability and environmentally conscious construction continues. As more individuals become concerned about these issues, at least a few may want to complete construction projects using some green materials. These individuals may not have the ability or resources to follow the "certification" protocol, but still desire to do whatever is locally possible. This could offer new marketing opportunities. For example, the use of urban trees for green building could be a possibility. The use of this material reduces landfill use, transportation costs, and carbon emissions, and promotes good stewardship of urban resources. Urban trees are not certified, but their use as a construction material has environmental benefits. Traditional retailers cannot respond to this market, and the product could carry a premium due to the "customization" involved.

Substantial controversy exists over the various certification groups and the processes they have adopted. Readers are encouraged to consult each group's Web sites and other sources for more details.

Amount of Seasoning

Another way to look at potential markets is by the amount of seasoning the wood has undergone. Generally, as the wood goes from green (unseasoned) to air-dried to kiln-dried conditions, the value and number of potential markets increases.

Green (unseasoned) lumber

Many smaller mills sell only green lumber because they lack the technical expertise required for drying. Also substantial capital expenditures are required for dry kiln equipment and inventory. Arrangements for the sale of the green lumber should be made before sawing, and the lumber or other products shipped within a few days of being processed.

Marketing of green lumber has several disadvantages including these:

- The presence of water and sap make the wood heavy and subject to checking, shrinking, and warping, if exposed to drying conditions. These changes usually occur to the pieces on top of a pile that are fully exposed to the weather. Degrade can also occur in the leading edge of bundles during truck transportation in hot, dry weather.

- The interior boards of a stack of dead or tightly piled lumber can mold, stain, and even decay if allowed to sit long enough. Depending on species, objectionable discoloration can occur within just days during hot summer weather.

- Green lumber is generally more susceptible to insect attack. Kiln-drying at temperatures over 135 °F kills any existing infestations, but it does not preclude lumber from being reinfested by certain insects.

- Green lumber is lower in strength than dried lumber.

- If green structural members are put in place and deflection occurs due to loading, the wood will be permanently set as it dried.

- Mills that kiln-dry lumber expect a volume loss of 6 to 7 percent from the green condition due to shrinkage. The grade of the lumber will also decline somewhat during drying due to problems such as warping, end checks, and splits.

- The types of markets for green stock are limited, and many utilize relatively low grade material. Thus, the value of the product is also relatively low. Selling upper grades of green lumber to larger sawmills or distribution yards is an exception.

On the positive side, about 40 percent of the total hardwood lumber produced is consumed as green lumber in the form of pallet cants and railroad ties.

Some common outlets for green lumber are as follows:

- Sell to other mills or yards
- Custom dry
- Pallets and crates
- Dunnage
- Railroad ties
- Timbers and cabin logs
- Farm or local use lumber
- Fence posts and corner posts
- Fence boards
- Truck and trailer flooring
- Small bridge decking
- Board roads
- Drag line matts
- Tobacco stakes
- Stakes in general

Air-dried lumber

Air-dried lumber is just one step up from green lumber. The lumber is simply put up on stickers and allowed to dry. It is a simple process, but care must be exercised if a quality product is to be produced. Air-dried lumber is lighter because most of the water has been removed, is stronger, and will not mold, stain, or decay—unless it is rewetted. It can be bulked down if moved inside, thus reducing storage space. Some--but not all--shrinking, warping, and checking has occurred. The lumber is vulnerable to insects. Depending on species and weather conditions, air drying may take one to several months. Again, markets are limited, and value is increased only slightly. If markets are poor, some mills will attempt to hold stock on the air drying yard, but prolonged storage will result in degrade. Air dried lumber has many of the same applications as green lumber, but there are some notable exceptions.

Air-dried lumber is essentially at the same moisture content that green lumber would come to in an unheated but protected (covered) environment. As a result, the lumber will not continue to significantly change moisture content and shrink, and checking should not be a problem so long as the lumber is used in similar applications. Applications include unheated buildings such as garages, recreational structures, farm buildings, and truck and trailer decking. In fact, if more expensive kiln-dried lumber is used in these applications, it will gain moisture, swell, and problems could result. As an example, the use of kiln-dried hardwood flooring in a mostly unheated recreational structure can result in buckled flooring.

Bending stock for furniture plants and other bending applications is typically air-dried. This stock is specifically selected for several factors and thus commands a premium price. It will represent only a small proportion of what is produced from the log. Boat builders also use air-dried stock because the end use is exposed to relatively high moisture conditions.

Finally, many sofa frame manufacturers have used air-dried hardwood stock. This material is covered by the upholstery, so strength is more important than appearance. The Hardwood Market Report (2010a) lists prices for "frame stock." The prices are somewhat more than pallet cants. Markets for frame stock have declined in recent years due to the substitution of plywood and strandboard.

Kiln-dried lumber

Kiln-dried lumber is material that has had most of the moisture removed by careful manipulation of the temperature and relative humidity by forcing air over the surface of the lumber while it is restrained. Hardwood lumber is typically dried to 6 to 8 percent moisture content for use in North America. For humid coastal areas, higher moisture content may be desirable, and for the dry Southwest even lower moisture content can be used. For comparison, softwood construction lumber is often dried to a 15 to 18 percent moisture content.

Compared with green or air-dried lumber, properly kiln-dried lumber is lighter, stronger, and will not shrink, warp, or check, in interior use. It has a higher monetary value, and many applications as compared with green or partially seasoned lumber. The ability to provide kiln-dried lumber simply opens up a vast array of lumber markets. Drying does increase costs and seasoning time. The wood is still subject to certain wood boring insects, and it can regain moisture, so proper storage is required.

Applications for kiln-dried lumber are numerous:

- Furniture
- Cabinets
- Millwork
- Molding
- Caskets
- Toys
- Musical instruments
- Athletic equipment
- Manufactured products
- Export
- Tool handles
- Plaques and trophies
- Signs

Locating Commercial Buyers

Depending on the hardwood items and quantities available, potential buyers need to be located. In small communities and on a very local basis, sellers may already know the buyers. If the buyer is not local, the seller needs to tap other resources. It is important that sellers, for the most part, understand that the burden is upon them to locate buyers or to provide information so buyers can easily find them.

Local Resources

When searching for potential customers, it makes good sense to start by using local resources. First, check your own list of contacts and those of your friends. Yellow pages in your town and adjacent towns are useful. Always be on the watch for dust collectors and stored lumber in industrial areas. Many industrial users of wood products may not be listed or known as wood manufacturers. These are manufacturers who use wood for pallets, blocking, packing, and a host of other uses, or, as one small part (and cost) of the product they manufacture. A wood threshold on a metal door and frame might be an example of a low-cost part compared with the door, and an example of a nonwood manufacturer requiring at least some wood to produce a "metal door and frame."

The State forestry organization known as the Department of Natural Resources (DNR), or Forestry Commission in some states, often maintains a list of both primary and secondary wood manufacturers. This is a specialized list, and when available it can be valuable in locating potential contacts. Many lists may even indicate species, grades, quantities, etc. that are produced or used. In addition to the DNR and Forestry Commission, some States also have Conservation District foresters, Rural Community Development (RCD) districts, and—of course—the Cooperative Extension Service with agents in each county. Arrangements vary greatly, and it is up to sellers or sawyers to contact all appropriate groups and let them know what services they can provide.

Internet Search

The Internet is used in part to bring buyers and sellers together. For the most part it is used by sellers trying to promote their product to potential customers. It is up to the customer to search out the supplier and make the contact. Simple lists of potential buyers are not to be found. Some trading sites allow posting of both for-sale and wanted items. Thus, it is possible to find items that you can supply. For small quantities or unique items of just about anything, eBay.com is a common Web site. Other sites are more specific to lumber and forestry, for example, www.woodweb.com, www.forestryforum.com, www.woodfinder.com/, www.smallwoodnews.com/Forum/phpBB2/, www.timberbuysell.com, and www.sticktrade.com.

The Internet can be used to search for associations that may provide a link to their membership. Very few will provide a simple listing of their members. Searching directly for wood manufacturers is another possibility. For a small local supplier, most of these companies will be located at some distance and probably purchase large quantities of lumber at one time.

Manufacturing Directories

Commercially prepared and for-sale directories of all manufacturers working within a state are usually available in hard or electronic copy. Harris Industrial Directory (www.harrisinfo.com) is one example. It lists manufacturers by geographic location, by standard industrial classification or SIC code, alphabetically, and by product. Most importantly, it gives the size of company, type of product manufactured, key personnel, and contact information. This is adequate information to make an initial determination about whether the company could be a potential buyer.

Thomas Register (www.thomasnet.com) is another industrial directory that would be useful in locating manufacturers as potential customers. It is available in many libraries.

Association Directories

Most manufacturers choose to join one or more trade associations. The associations are commonly divided into state- and national-level groups. These trade associations often represent their members in the political arena, provide opportunities for members to meet and discuss common opportunities and problems, and publish directories of their membership. In some cases these directories are available on line or for purchase. In other cases, distribution is limited to members only. Following are lists of key associations that represent the primary and secondary wood industries.

Associations representing primary manufacturers and the forestry community

Alabama Forestry Assn., Inc.
555 Alabama Street
Montgomery, AL 36104
www.alaforestry.org

American Forest and Paper Assn.
1111 19th Street NW, Suite 800
Washington, DC 20036
www.afandpa.org

American Forests (formerly American Forestry Assn.)
734 15th Street NW, Suite 800
Washington, DC 20005
www.americanforests.org/

American Hardwood Export Council
1111 19th Street NW
Washington, DC 20036
www.ahec.org/

Appalachian Hardwood Manufacturers, Inc.
P. O. Box 427
High Point, NC 27262
www.appalachianwood.org/

Arkansas Forestry Assn.
410 South Cross Street, C
Little Rock, AR 72201-3014
www.arkforests.org/

Assn. of Consulting Foresters of America
312 Montgomery, Suite 208
Alexandria, VA 22314
www.acf-foresters.org

Associated Cooperage Industries of America, Inc.
8923 Stone Green Way, Second Floor
Louisville, KY 40220-4073
www.acia.net/

Canadian Lumbermen's Assn.
30 Concourse Gate, Suite 200
Ottawa, ON K2E 7V7
Canada
www.canadianlumbermen.com/

Canadian Wood Pallet and Container Assn.
P.O. Box 128
Fenelon Falls, ON K0M 1N0
Canada
www.canadianpallets.com/cwpca_home.asp

Empire State Forest Products Assn.
828 Washington Avenue
Albany, NY 12203
www.esfpa.org/home.asp

American Walnut Manufacturers Assn.
P. O. Box 5046
Zionsville, IN 46077-5046
www.walnutassociation.org/

Florida Forestry Assn.
P.O. Box 1696
Tallahassee, FL 32302
www.floridaforest.org/

Georgia Forestry Assn., Inc.
P.O. Box 1217
Forsyth, GA 31029-1217
www.gfagrow.org/

Hardwood Manufacturers Assn.
400 Penn Center Boulevard, Suite 530
Pittsburgh, PA 15235
www.HMAmembers.org

Hardwood Plywood and Veneer Assn.
P.O. Box 2789
Reston, VA 20195
www.hpva.org

Illinois Wood Products Assn.
Southern Illinois University, Mail code 4411
Department of Forestry
Carbondale, IL 62901-4411
www.siu.edu/~iwpa/index.html

Indiana Division of Forestry
402 W. Washington Street, Room W296
Indianapolis, IN 46204
www.state.in.us/dnr/forestry/

Kentucky Forest Industries Assn.
106 Progress Drive
Frankfort, KY 40601
www.kfia.org/

Louisiana Forestry Assn.
2316 South MacArther Drive
Alexandria, LA 71301
www.laforestry.com/

Lumberman's Assn. of Texas
816 Congress Avenue, Suite 1250
Austin, TX 78701
www.lat.org/

Maine Forest Products Council
535 Civic Center Drive
Augusta, ME 04330
www.maineforest.com/

Maine Wood Products Assn.
P. O. Box 401
Belfast, ME 04915
www.mwpa.org/

Michigan Assn. of Timbermen
7350 M-123
Newberry, MI 49868
www.timbermen.org/

Mississippi Forestry Assn.
620 N. State Street, Suite 201
Jackson, MS 39202
www.msforestry.net/

Mississippi Lumber Manufacturers Assn.
P. O. Box 5241
Jackson, MS 39296-5241
www.mslumbermfg.org/

Missouri Forest Assn.
611 E Capital Avenue
Jefferson City, MO 65101
www.moforest.org/

National Hardwood Lumber Assn.
6830 Raleigh LaGrange Road
Memphis, TN 38134
www.natlhardwood.org/

National Assn. of State Foresters
444 N. Capital St. NW, Suite 540
Washington, DC 20001
www.stateforesters.org/

National Wooden Pallet and Container Assn.
1421 Prince St., Suite 340
Alexandria, VA 22314-2805
www.nwpca.com/

Northeastern Lumber Manufacturers Assn.
P.O. Box 87
272 Tuttle Road
Cumberland Center, ME 04021
www.nelma.org/

Ohio Forestry Assn.
4080 S High Street
Columbus, OH 43207
www.ohioforest.org/

Southeastern Lumber Manufacturers Assn., Inc.
671 Forest Parkway
Forest Park, GA 30297
www.slma.org/

Southern Cypress Manufacturers Assn.
400 Penn Center Blvd, Suite 530
Pittsburg, PA 15235
www.cypressinfo.org/

Southern Forest Products Assn.
2900 Indiana Avenue
Kenner, LA 70065-4464
www.sfpa.org/

Texas Forestry Assn.
P.O. Box 1488
Lufkin, TX 75902-1488
www.texasforestry.org/

Virginia Forest Products Assn.
220 E. Williamsburg Rd.
P.O. Box 160
Sandston, VA 23150
www.vfpa.net/

Wood Products Manufacturers Assn.
175 State Road East
P.O. Box 761
Westminster, MA 01473
www.wpma.org/

Associations representing secondary manufacturers

American Home Furnishings Alliance
317 W. High Avenue 10th Floor
High Point, NC 27260
www.ahfa.us

Architectural Woodwork Institute
46179 Westlake Drive, Suite 120
Potomac Falls, VA 20165
www.awinet.org/

Business and Institutional Furniture Assn.
2680 Horizon Drive SE, Suite A1
Grand Rapids, MI 49546
www.bifma.org/

California Furniture Manufacturers Assn.
1240 N. Jefferson Street, Suite G
Anaheim, CA 92807
www.cfma.com/

Florida Assn. of Furniture Manufacturers
P. O. Box 545946
Surfside, FL 33154-5946
www.fafm.org/

Hardwood Distributor's Assn., Inc.
2559 South Damen
Chicago, IL 60608
www.hardwooddistributors.net/

Juvenile Products Manufacturers Assn.
15000 Commerce Parkway, Suite C
Mt. Laurel, NJ 08054
www.jpma.org/

Kitchen Cabinet Manufacturers Assn.
1899 Preston White Drive
Reston, VA 20191
www.kcma.org/

Maple Flooring Manufacturers Assn., Inc.
111 Deer lake Road, Suite 100
Deerfield, IL 60015
www.maplefloor.org/

Assn. for Retail Environments
(formerly National Assn. of Store Fixture Manufacturers)
4651 Sheridan Street, Suite 470
Hollywood, FL 33021
www.nasfm.org/

NOFMA: The Wood Flooring Manufacturers Assn.
22 N. Front St., Suite 660
Memphis, TN 38103
www.nofma.org/

National Wood Flooring Assn.
111 Chesterfield Industrial Boulevard
Chesterfield, MO 63005
www.NWFA.org/

National Kitchen and Bath Assn.
687 Willow Grove Street
Hackettstown, NJ 07840
www.nkba.org/

Window and Door Manufacturers Assn.
1400 E. Touhy Avenue, Suite 470
Des Plaines, IL 60018
www.wdma.com/

Canadian Home Furnishings Alliance
(formerly Furniture Manufacturers Assn.)
6900 Airport Road, Suite 200 Box 85
Mississauga, ON L4V1E8
Canada
www.chfaweb.ca/

Quebec Furniture Manufacturers Assn.
101-1111 Saint-Urban St.
Montreal, PQ H2Z 1Y6
Canada
www.afmq.com

Stairway Manufacturers Association
385 Garrisonville Rd., Suite 116
Stafford, VA 22554
www.stairways.org/index.htm

Summer and Casual Furniture Manufacturers Assn.
P. O. Box HP-7
High Point, NC 27261
www.ahfa.us/divisions/scfma.asp

Timber Framers Guild of North America
P. O. Box 60
Beckert, MA 01223
www.tfguild.org/

Unfinished Furniture Assn.
15000 Commerce Parkway, Suite C
Mt. Laurel, NJ 08054
www.unfinishedfurniture.org/

Wood Component Manufacturers Assn.
741 Butlers Gate, Suite 100
Marietta, GA 30068
www.woodcomponents.org/

Moulding and Millwork Producers Assn.
507 First Street
Woodland, CA 95695-4025
www.wmmpa.com/

Woodwork Institute (Formerly Woodwork Institute of California)
P. O. Box 980247
West Sacramento, CA 95798-0247
www.wicnet.org/

Trade Journals

Trade journals are yet another means of communication for industry members. Some of the trade journals are rather broad and represent the primary or secondary wood manufacturing industry. Others are specific and represent only a small segment of an industry. Many trade journals provide free subscriptions and rely on paid advertisement as a source of income. Most advertisers are larger companies that operate on a national or international basis, but smaller companies also find it beneficial to participate in some state or regional publications. Many trade journals also publish directories.

Trade journals of interest to primary manufacturers

American Lumber and Pallet
416 Main Avenue South
Fayetteville, TN 37334
www.amlumber.com/

National Hardwood Magazine
1235 Sycamore View Road
Memphis, TN 38184
www.millerpublishing.com/NationalHardwoodMag.asp

Northern Logger
Northeastern Loggers Assn.
3311 State Route 28, Box 69
Old Forge, NY 13420-0069
www.northernlogger.com/

Pallet Enterprise
10244 Timber Ridge Dr.
Ashland, VA 23005
www.palletenterprise.com/

Panel World
225 Hamrick Street
Montgomery, AL 36104-3317
www.panelworldmag.com/

Sawmill and Woodlot Magazine
P.O. Box 1149
Bangor, ME 04402-1149
www.sawmillmag.com/

Timber Processing
225 Hanrick St.
Montgomery, AL 36102
www.timberprocessing.com/

TPA (Timber Producers Assn.) Magazine
Great Lakes Timber Professionals Assn.
P. O. Box 1278
Rhinelander, WI 54051
www.timberpa.com/

Trade journals of interest to secondary manufacturers

Cabinet Maker, Furniture Design and Manufacturing
303 N. Main St. Suite 500
Rockford, IL 61101
www.cabinetmakerfdm.com/

Custom Woodworking Business
Vance Publishing Corp.
400 Knightsbridge Parkway
Lincolnshire, IL 60069
www.woodworkingnetwork.com/

Fine Woodworking
The Taunton Press
63 South Main Street
P.O. Box 5506
Newton, CT 06470-5506
https://store.taunton.com/onlinestore/link/finewoodworking-magazine-subscription

Furniture Today
Cahners Publishing
Box 2754
High Point, NC 27261
www.furnituretoday.com/

Modern Woodworking
3200 Rice Mine Road NE
Tuscaloosa, AL 35406
www.modernwoodworking.com/

Woodworkers Journal
P.O. Box 8572
Red Oak, IA 51591-1572
www.woodworkersjournal.com/

Wood and Wood Products
Vance Publishing Corp.
400 Knightsbridge Parkway
Lincolnshire, IL 60069
http://woodworkingnetwork.com/

Woodshop News
10 Bokum Road
Essex, CT 06426
www.woodshopnews.com/

Locating Private Buyers

Hardwood distribution yards and retail outlets handling hardwoods exist to supply retail buyers as well as others with small quantities of lumber. These companies usually have high name recognition, are easy for a customer to locate, and stock a consistent supply of desirable items. Thin kerf band mill operators with dry kilns could supply at least a portion of this market. In the initial development phase, sellers must get their names and products before the buyer, probably by using mass advertising. The cost of advertising should be viewed as a long-term investment for building a customer base and not as just the cost of making an immediate sale.

In this case, having a well-maintained Web site might be the first priority. Small users looking to make contact are very likely to use the computer. Make certain you provide a list of current and future items available and a point of contact. Listing a return e-mail address or providing a cell phone number gives the buyer the opportunity to make immediate contact and not go on to another seller.

Newspaper advertising, either in the traditional want ads or display ads can sometimes be effective. Want ads are effective, but in the author's experience, the effectiveness seems to have diminished. Less specific want ads can also be useful for attracting customers. For example, rather than list two or three lumber items for sale, one might say "stack of cherry boards" and list a relatively low price. This type of ad is likely to attract "bargain hunters" who may be interested in low quality lumber. Sometimes the person may be willing to pay more for a better quality item, which you should have in stock. Internet want ads are also popular and offer an alternative to traditional advertising, often at very competitive rates or sometimes for free.

Yellow Pages are yet another alternative. Lumber is a common category, so finding companies that sell it within the Yellow Pages is not an issue for potential buyers. Many Yellow Page providers also provide an Internet listing. Be prepared for some strange inquiries. My personal ad lists only kiln-dried hardwood lumber, but it has generated several inquiries for finished parts and construction type hardwoods.

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Luppold, William. 2011. Personal communication. U.S. Department of Agriculture Forest Service, Northeastern Area State and Private Forestry, Wood Education and Resource Center, Princeton, WV.

National Hardwood Lumber Association. 2011. Rules for the measurement and inspection of hardwood and cypress. Memphis, TN. 101 p.

For More Information

"Green" (Environmentally Acceptable) Lumber

Forest Stewardship Council (FSC) www.fsc.org/about-fsc.html.

Sustainable Forestry Initiative (SFI) www.sfiprogram.org.

Marketing and Business

A Marketing Guide for Manufacturers and Entrepreneurs of Secondary-Processed Wood Products in the Northeastern United States.

Ed Cesa. 1992. USDA Forest Service, Northeastern Area State and Private Forestry, Morgantown, WV. NA-TP-09-92. http://na.fs.fed.us/pubs/misc/guide_wood_products/marketing_guide_wood_products_ls.pdf

A Planning Guide for Small and Medium Size Wood Products Companies; 2d ed.

Jeff Howe and Steve Bratkovich. 2005. USDA Forest Service, Northeastern Area State and Private Forestry, Newtown Square, PA. NA-TP-03-05. 66 p. + appendixes. http://www.fpl.fs.fed.us/documnts/misc/natp0995.pdf

A Record Keeping System for Small Sawmills.

George Niskala. 1985. USDA Forest Service, Northeastern Area State and Private Forestry.. Market Bull. 74.

Forest Products Marketing.

Steven Sinclair. 1992. McGraw-Hill, Inc., New York, NY. 403 p.

Income Opportunities in Special Forest Products

Margaret Thomas and David Schumann. 1993. USDA Forest Service, Washington, DC. Agric. Info. Bull. 666. 203 p. http://www.fpl.fs.fed.us/documnts/usda/agib666/agib666.htm

Value-Added Wood Products Marketing Guide for Manufacturers and Entrepreneurs.

Timothy Holmes, Carl Golas, Duane Gould, Terry Martino, and Ed Cesa. 2010. USDA Forest Service, Northeastern Area State and Private Forestry, Newtown Square, PA. NA-UP-01-10.

Wood From Municipal Trees

Recycling Municipal Trees: A Guide for Marketing Sawlogs from Street Tree Removals in Municipalities

Edward T. Cesa and Edward A. Lempicki. 1994. USDA Forest Service, Northeastern Area State and Private Forestry. NA-TP-02-94. 60 p. http://www.fs.fed.us/na/morgantown/frm/cesa/rmt/rmt_index.html

Utilizing Municipal Trees: Ideas From Across the Country

Stephen M. Bratkovich. 2001. USDA Forest Service, Northeastern Area State and Private Forestry. NA-TP-06-01. 91 p. http://na.fs.fed.us/spfo/pubs/misc/utilizingmunitrees/index.htm

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Chapter 16.

Sales Techniques

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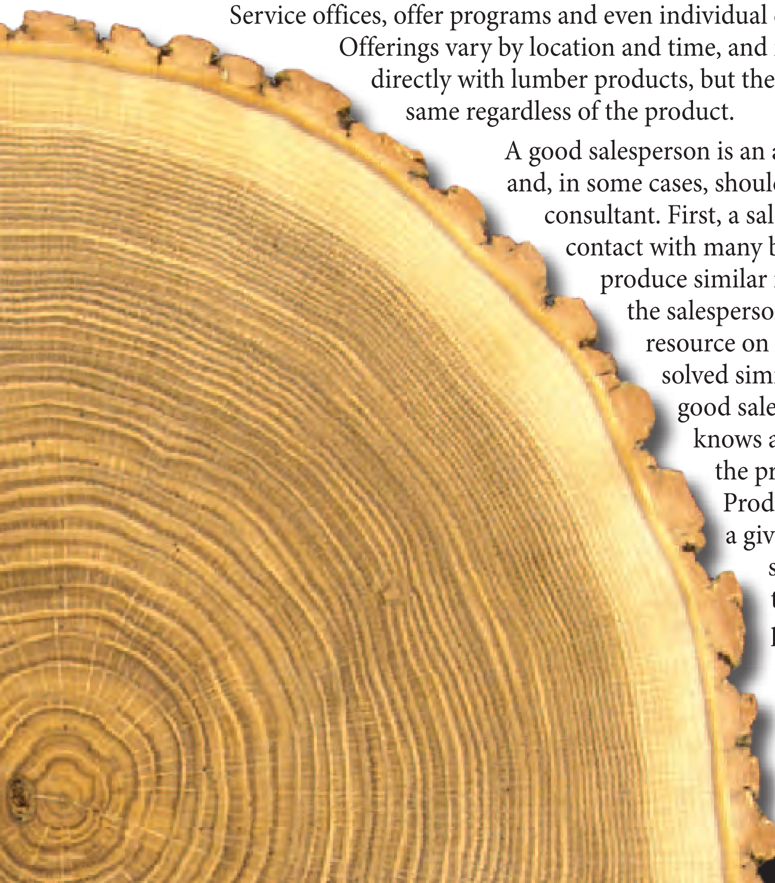
Chapter 16.
Sales Techniques

If your lumber products or other wood items are not used within the company, you will need to find a way to sell them. In a single proprietorship or small company, the owner will be the salesperson. Many small wood manufacturers are afraid of the word “sales” because of previous unpleasant experiences, or just the connotations the word carries. Yet, these same individuals have no problem explaining what they do, especially when talking to other individuals or small groups. That is “selling,” but it is usually not thought of in that manner.

Much like marketing, there are numerous generic educational programs offered on sales. Registration fees are often substantial, but the programs can be very useful. For example, the American Management Association offers a wide variety of programs in most major U.S. cities. County or regional economic development organizations, as well as state and County Extension Service offices, offer programs and even individual counseling. Offerings vary by location and time, and may not deal directly with lumber products, but the concepts are the same regardless of the product.



A good salesperson is an asset to the buyer and, in some cases, should act as a consultant. First, a salesperson is in contact with many buyers who may produce similar items. As such, the salesperson can be a resource on how others have solved similar problems. A good salesperson also knows and understands the product being sold. Product knowledge is a given. A good salesperson needs to know the purchaser’s business. Just asking reasonable questions can help a buyer think about their routine and find a better solution. A good salesperson listens when the client talks.

A poor salesperson is just an order taker who knows little about the product and cares little about the customer. This unfortunately is the stereotype some individuals have of sales people. Fast-talking, high pressure sales people will not do well in the wood business.

Making the sale is a learned skill. Assuming there is a beneficial match, a good salesperson will lead the buyer step-by-step to the close or order. The salesperson must evaluate each buyer's statement and determine if more information and understanding is needed, or if the buyer can move to the next step. A "natural salesperson" does not exist. Selling may appear easier for the salesperson with an outgoing personality or a natural quickness to understand the buyer and the ability to respond. The salesperson must still understand the steps to a sale and work hard to communicate with the buyer.

The objective of this chapter is to provide some insight into the sales process. There are set procedures and steps in selling lumber. Following them will help improve the chance for success.

Steps to a Sale

Seven steps can be outlined in the process of making a sale:

1. Greeting the potential buyer
2. Probing for information
3. Giving the presentation
4. Obtaining agreement or intent to buy
5. Responding to objections
6. Negotiating the terms
7. Closing the deal.

Depending on the circumstances, some steps will be more involved than others. The steps may not follow in order, but each and every step needs to occur before a sale is completed. It does not matter if lumber or a car is being sold. In fact, it might be helpful for the untrained or inexperienced sales person or seller to recall a recent significant purchase, such as of a car, truck, sawmill, or appliance. Recall the process and steps which occurred from the beginning to end of the sale. The steps should be very much like the seven given above.

Greeting the Potential Buyer

Greeting is an easy and simple step once a potential buyer and seller are in contact. It can be as simple as exchanging name and contact information, but it should not be taken for granted. The two parties need to know and trust each other. Eye contact is important. The salesperson needs to show confidence, gain trust, and say something of interest to start the conversation.

Probing for Information

Probing helps the salesperson understand the buyer's needs and the products being produced. The salesperson needs to engage the buyer. The salesperson should learn as much about the potential buyer and company as possible, before making contact.

Probing can be divided into closed probes and open probes. An example of an open probe might be asking which species the buyer uses. The answer could be any number of species. A closed probe might be asking if the buyer uses red oak or white oak, or if the buyer uses ash for the same purpose or as a substitute. Knowing what the buyer manufactures can provide an indication of what the needs are, but the salesperson must confirm each need. It is also important to reconfirm each need so the buyer does not deny the need at a later time.

A salesperson should make a list beforehand of everything the buyer might need. For lumber, this list will likely include species, volume, grade, moisture content, special attributes of width and length sorts or other factors, color issues, delivery date, payment schedule, current supplier, and others. If lumber is in short supply, issues such as volume, grade, special attributes, and color, may not be as important as simply getting lumber to keep the plant running.

For my small lumber business, most initial contacts are made by the buyer using the phone or Internet. The contact is usually from a referral, advertisement, or Internet search. The buyer usually wants to confirm that I have kiln-dried lumber for sale. I usually want to know what the buyer plans to use the lumber for and what quantity is needed. With this knowledge I can determine if I have the material to fill the need. I usually give a price range at this point, since it will be considerably less than retail or yard outlets that are likely alternatives for the buyer.

Giving the Presentation

The presentation provides an opportunity for the sellers to present themselves and their companies. Some of the presentation information may have been given in the greeting. The presentation should not be segmented if at all possible. The buyer needs to hear how the seller and the product could be beneficial. Any salesperson should be good at telling the buyer what a great job they and their company are doing. For example, the presentation could include that the company produces uniform kiln-dried lumber from the best hardwoods grown. These include cherry, maple, walnut, oak, ash, and others. The company saws logs promptly to prevent stain, air-dries the lumber before putting it in a kiln, and stores kiln-dried lumber in a temperature- and humidity-controlled building to prevent moisture regain.

Depending on the buyer, the presentation may need to be adjusted. For example, for an environmentally sensitive buyer or company, the seller could mention how many trees are saved by the use of thin kerf sawmill technology. Or, perhaps the company processes urban trees that would otherwise be sent to the landfill or used for firewood at best.

The presentation needs to get the buyer's attention to the extent that they want to do business.

Obtaining Agreement or Intent to Buy

Agreement or the intent to buy can come from a potential buyer at any time during the discussion. The buyer has to agree with the technical details of the product being offered. For example, ash is a grainy hardwood, it looks very much like oak when finished properly, and it could be used as a substitute for oak. The buyer must agree that a relationship with the seller is better than any other existing possibilities. Emphasizing the shortcomings of the competition, if they are known, is a good idea. Maybe it is price, delivery time, sawing variation, incorrect moisture content, or lack of service.

If the salesperson offers a good price, and the buyer acknowledges it, then the salesperson should be sure to summarize that he or she has agreed that ash could be used as a substitute species and that it costs less than oak. When the buyer mentions price, it is a very strong sign of intent to buy, and the seller should ask for the sale. If the buyer objects to placing the order, then the salesperson did not uncover, discuss, and resolve all of the buyer's concerns. The salesperson must determine what the issue is and address it, in an effort to get the buyer to agree to the sale.

Responding to Objections

Objections are not necessarily bad, if they are legitimate. They are strong signs of intent to buy. The buyer is expressing interest but has concerns. The objections may be real or perceived. A real objection might be that the buyer likes the idea of using cheaper ash lumber, but all of the company's promotional literature emphasize the beauty and strength of oak. A price for oak might then be quoted, but appears high to the buyer. This is a perceived objection. The buyer needs to be told that the price includes free delivery and a money-back guarantee. Other objections could include these: satisfaction with another supplier, delivery arrangements, terms of the sale, an unknown reputation, quality, quantity, widths and lengths, grade, no need, timing (just bought a load), past history with the company (grudge), waiting on orders, payment terms, wants to test it, needs references, wants to check with boss, or any number of other objections. Regardless of the objection, each one must be addressed until the buyer agrees that it is resolved. A quiet buyer who does not express concerns is much harder to deal with. Perceived objections can be diminished by reviewing the facts.

A real objection can be diminished by reviewing the other benefits that make the product desirable to the buyer. A salesperson should never say “but” or “however” when dealing with an objection, which will appear confrontational. Asking the buyer to repeat the objection can diminish its significance. Recognizing common objections is important. Responses to common objections can be prepared as company policy. Objections can be softened by saying “I am not surprised that you brought that up. We often have people ask about that.” This makes the item a concern, not an objection.

Negotiating the Terms

Negotiations are usually the sixth step but can occur at any time. They generally involve routine items, such as delivery time, delivery method, quantities purchased, packaging (steel or plastic straps), length and width sorts, or other services. If a buyer is demanding a particular in-demand item, the seller frequently asks the buyer to take other grades or species that could be used as well. Sellers cannot liquidate all of the “in demand” items and not move others.

Price can be negotiated as well. Everyone has a set price but, depending on the producer, log supply, and inventory, price negotiations are possible and may be tied to the items listed above. For example, I recently accumulated a sizable number of walnut shorts, 4 to 7 feet long. Due to a shortage of suitable storage conditions, they were offered at the same price as upper grade ash and red oak. The first two buyers took all of the available material.

Payment terms constitute another important item that is related to price and is often negotiated. Small sales are usually cash at the time of closing, or some small shops may ask for credit. Some companies offer a half percent discount if the invoice is paid within 10 days. Many options are available, but the important thing is that both buyer and seller have a clear understanding of when the buyer will receive the material, and when and how the seller will be paid.

Closing the Deal

The close summarizes all of the above discussions and represents the sale. It should be a logical solution to a need, a painless improvement, the beginning of a partnership, an exchange of assets, a look into the future, and a wise investment. The close should not be the result of combat. It should not represent a chance or risk of assets, and neither party should be giving up control. Both buyer and seller should benefit, or the relationship will be short-lived. If a sale cannot be made it is important for the seller to tastefully and persistently determine at what time in the future additional discussions might be useful and when a contact can be made. Examples of reasons for reinitiating the contact might be major shifts in markets or pricing.

Conclusions

The above steps may seem to describe a seller and buyer or purchasing agent from large corporations attempting to reach agreement over a major transaction. That is correct; however, the same process is followed whenever a salesperson makes a new contact or a potential buyer calls or visits. The seller may be probing, giving their "presentation," and looking for agreements or signs of intent to buy, answering objections, and negotiating price while the customer is looking at the lumber, or logs and processing equipment, or showing a portfolio of completed projects.

In the wood industry, being genuine goes a long way towards being successful. Many customers may not understand wood as a material, or everything involved in its production. Sales experience and the information provided in this text can remedy that, and increase success with more repeat buyers. People buy from people. The seller must appear as a knowledgeable, forthright person who can fill the buyer's needs the first time and gain the trust and respect to win their repeat orders in the future.

Acknowledgment

This chapter on Sales Techniques is a brief summary of what I think Walt Clarke would tell us about "making a sale" if he were here today. Walt Clarke was a professional salesperson and market development specialist for several major firms in the Chicago, IL, area, beginning at about the end of World War II. He eventually became a successful independent consultant and also worked for the American Management Association, where I first met him. Walt and I offered several well received product knowledge and sales seminars for the National Hardwood Lumber Association, Indiana Hardwood Lumbermen's Association, Michigan Timbermen's Association, and private companies. The information in this chapter is based on those seminars.