the TIE GUIDE

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HANDBOOK FOR COMMERCIAL TIMBERS USED BY THE RAILROAD INDUSTRY

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INTRODUCTION

The wood crosstie has served the American railroad industry since its earliest days when wood ties were used as a foundation for the rail in the track structure. The dependability and service life of this wood component has been exemplary. The information provided in this manual will provide the reader with a description of the identification, treatment and ultimate use of wood in the engineered crosstie system.

WOOD IS THE ONLY STRUCTURAL BUILDING MATERIAL THAT IS RENEWABLE. AS A TIMBER CROP WHICH CAN BE CUT AND HARVESTED ON A ROTATION BASIS, WOOD SAWN FOR CROSSTIES HAS SERVED THE RAILROAD INDUSTRY FOR OVER A CENTURY.

With the use of wood preservatives, the durability and service life of wood is significantly enhanced. This manual brings together wood technology principles with a focus on the practical application for the tie grader in the yard as he performs his duties of classifying oaks, mixed hardwoods and softwoods that will be treated with a preservative solution and subsequently installed in a railroad track.

The task is to develop a common thread illustrating the development and ultimate performance of the treated wood crosstie. Within this manual there are some practical applications given along with certain technical details outlined in the wood crosstie engineering section. The Railway Tie Association Performance Standard found in the engineered wood crosstie section of this manual describes specific strength property characteristics and load traffic environment applications for the various types of wood tie material.

This manual is intended for use in the classroom as well as a practical guide. The Railway Tie Association, as part of its primary mission, sponsors seminars in the practical identification

INTRODUCTION

and grading of wood crossties and on the engineering principals behind tie performance. This manual will also serve as an instructional component in these seminars.

When using this manual, it should be noted that the primary reference for preservative usage is creosote, because it represents the major preservative being used to treat wood crossties. As of this editing in 2016, creosote, its solutions, and the borate systems added to creosote, represent over 90% of preservatives used to treat wood crossties. Thus, consider that within this booklet the term "preservative" will be used; however, because creosote systems are the dominant preservative, there are instances when it is more appropriate to use the term "creosote". To further define use of borates, note that within the past several years the creosote/borate preservative system has been developed. The use of inorganic boron in a water solution was the first type of borate used as a pre-treatment before the follow-up application of creosote. This process is known as the "two-step" method. Recently AWPA approved a new standard, which is termed the "one-step" method in which the borate is incorporated into the creosote as a solution. The use of borates facilitates the movement of this preservative into the center (heartwood) of the wood crosstie. The subsequent treatment with creosote with either "one or two-steps" protects the preservative system against loss of borate from leaching with water.

The other preservatives listed in the AWPA Standards to treat wood crossties include pentachlorophenol, copper naphthenate, and ammonical copper zinc arsenate (ACZA).

WOOD PRODUCTS ACCOUNT FOR 47% OF ALL RAW MATERIALS MANUFACTURED IN THE U.S. BUT USE ONLY 4% OF TOTAL ENERGY CONSUMED BY U.S MANUFACTURERS.*

*Engineered Wood Association, www.apawood.org

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THE TREATMENT OF WOOD CROSSTIES

Wood is a cellulosic material which can be adversely affected by decay fungi, insects, and marine borers. Chemical preservatives (organic and/or inorganic) must be used to protect wood from attack by these organisms.

THE DEGREE OF PROTECTION OBTAINED IS DEPENDENT UPON THE TYPE OF PRESERVATIVE USED AND ACHIEVEMENT OF PROPER PENETRATION AND RETENTION OF THE CHEMICALS.

As will be discussed in later chapters, there is a difference in treatability of wood species. There is also a difference in the treatability of the sapwood and the heartwood portion of many wood species.

With respect to wood crossties, the American Wood Protection Association (AWPA) Use Category System- UC4ABC (previously referred to as Standard C-6) for crossties and switch ties gives the general requirements for preservative treatment by pressure processes. In addition, described within the Standard are the processing, conditioning, treatments, results of treatment (quality control), and storage of treated crosstie materials.

The processing and treatment of wood crossties is somewhat unique. This product, as used by the American railroad industry, has historically been treated with a creosote solution meeting the requirements of AWPA Standard P2. There are also occasions when other timber products, such as bridge material, will be treated using the AWPA Standard P1/P13 meeting the requirements for this creosote.

A heavy petroleum oil that meets AWPA P4 Standard has also been used for blending with creosote. This creosote/petroleum solution has been used extensively for many years to reduce the cost of the preservative solution.

THE TREATMENT OF WOOD CROSSTIES

This creosote blend has been used primarily in the Western and Rocky Mountain States and Canada, which are areas that have climatic conditions less conducive to wood deterioration from fungi and insects. Organisms that attack wood — fungi and termites — are not as active at the lower temperature and humidity levels found in many areas of these geographic regions.

Creosote and its solutions are the preservatives most widely used (see reference in the introduction for other preservative systems). Crossties are typically pressure treated using the empty-cell method (Lowry or Rueping Process). The specified creosote net retention is usually between six and ten pounds per cubic foot (pcf).

Prior to treatment, wood crossties must be properly seasoned or conditioned in order to achieve the desired preservative penetration and retention. The various conditioning methods and processing procedures are described in the AWPA Book of Standards. A current copy of the AWPA Standards is readily available to anyone who is involved in the procurement, treatment, and use of wood crossties and may be obtained from either the AWPA or RTA. (Note that a copy of the AWPA UC4ABC is included in this document, beginning on Page 67.)

The treatment results are described as the retention of preservative and penetration of preservative. The accepted method for retention of preservative is based on the readings of work tank gauges or scales. Penetration of preservative is determined by boring a representative sample number of crossties within a charge of material. Individual railroad customers typically add more specific requirements to the AWPA UC4ABC Use Category, thus creating a railroad "specific use" standard.

For additional reference materials for the treatment of wood crossties, one should consult the specifications for the treatment of crossties as described in AREMA (American Railway Engineering and Maintenance-of-Way Association). These specifications also cover the preservative treatment of crossties, switch ties and bridge ties.

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TECHNICAL ASPECTS AND A LESSON IN WOOD

Wood varies significantly with regard to its structure. The hardwood species differ from the softwoods. In addition, within each of these groups there are also differences between the wood species. To be even more specific, there are differences within the same tree, because the heartwood usually contains substances not found in the sapwood. These differences have an influence on the permeability of liquids, such as wood preservatives, into the structure of wood.

Hardwood (broadleaf) trees such as the hickories, oaks and maples are more efficient sap conductors than softwoods (conifers). Hardwood trees are different from softwoods in that they contain vessels, also known as pores. These cells are positioned end-to-end vertically in the tree and form continuous passages for sap movement within the wood. This makes it fairly easy to penetrate the wood of many hardwood species with preservative chemicals. Mechanical support is provided by the fibers that surround the vessels.

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TECHNICAL ASPECTS AND A LESSON IN WOOD

Softwood timbers (needle-bearing trees) – such as Douglas-fir, pines, hemlocks and true firs – do not have the specialized sap-conducting cells that are found in hardwoods, but instead have elongated cells called tracheids, or fibers which have a closed end. These fibers serve as both mechanical support and to conduct the sap.

THE TERMS HARDWOOD AND SOFTWOOD ARE OFTEN MISLEADING. THERE ARE SOME SOFTWOODS THAT ARE ACTUALLY "HARDER" THAN SOME HARDWOODS FROM A STRUCTURAL STANDPOINT.

Hardness is often a function of density. For example, yellow poplar, although a broadleaf tree and termed a hardwood is a low-density hardwood. It is actually lower in specific gravity, and softer than the coniferous softwood Douglas-fir.

Hardwoods are classified based on pore size and distribution within a growth ring (also known as an annual ring). Hardwoods, such as beech, birch, the gums and maples, in which the pores are somewhat uniform in size and distribution, are called "diffuse-porous" woods. Those wood species which have alternate layers of small and large pores, such as ash, hickory and oak, are termed ring-porous woods. The wood species that exhibit cellular structure in-between diffuse- and ring-porous woods are classified as semi-ring porous (or semi-diffuse). Black walnut and persimmon are semi-ring porous woods.

The primary cause for the difference in penetration of preservatives in both hardwoods and softwoods is the difference in the amount of heartwood and sapwood. Young trees are usually all sapwood. As a tree grows older the heartwood volume increases in the center of the tree as the sapwood layers continue to be formed.

The sapwood is the "living" portion of the wood, which transmits fluids and nutrients (sap) between the roots and leaves of the tree. The heartwood, which often is darker in color than the sapwood, is no longer living. The moisture content of the heartwood and the sapwood are often different.

The heartwood pores in white oak and some other species are "blocked" or partially closed with bubble-like growths called tyloses, and sometimes they are blocked with gum-like materials.

TECHNICAL ASPECTS AND A LESSON IN WOOD

Blockages occur in some softwoods as well, though the mechanism is different.

With most wood species, the change from sapwood to heartwood increases the resistance to preservative penetration. However, there are exceptions. For example, both the sapwood and heartwood of eastern hemlock are resistant to the penetration of liquids. In addition, there are some woods, such as heartwood of red oak, that are relatively easily penetrated by liquids.

The general rule is that the treatability of heartwood is more difficult than sapwood. **Table 1** (Page 10) lists four groups of woods, rating the degree of penetration difficulty for the various wood species.

Tyloses develop in the heartwood of some

hardwoods. With regard to commercial timbers used for crossties, tyloses are most commonly found in black locust and the white oaks. The influence of tyloses on the penetration of preservatives into the heartwood is easily illustrated by comparing penetration in the white oak group and the red oaks.

From the information given in **Table 1**, you might conclude that all white oaks are difficult to penetrate with preservative and that all red oaks can easily be treated. There are exceptions to this rule. For example, chestnut oak (Quercus montana) is a white oak that has few tyloses and thus the heartwood is treatable. There is also an exception among the red oaks: the red oak known as black jack or jack oak (Q. marilandica) has pores that are closed by tyloses impeding the penetration of liquids.

Penetration of liquid preservatives occur in wood in three directions:

- longitudinally, which is the direction along the length of the tree trunk,
- radially, which is in the direction of the radius from the center of tree to the bark,
- tangentially, which is in the direction of the annual rings, perpendicular to a radius.

With few exceptions, practically all species are most easily penetrated longitudinally (or in the vertical direction of the living tree). This can be illustrated by visualizing the wood fibers or vessels as a "bundle of straws." These vessels or "straws"

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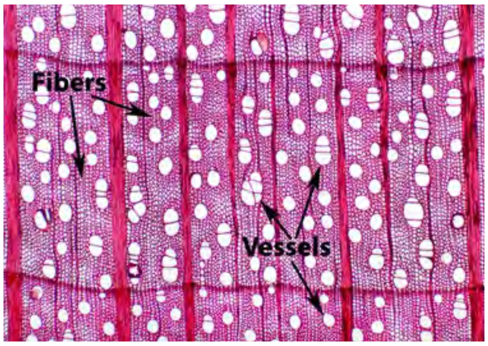
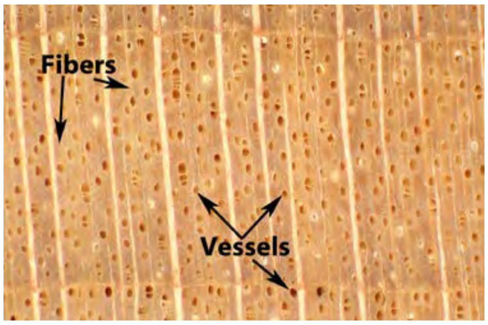
WOOD STRUCTURE

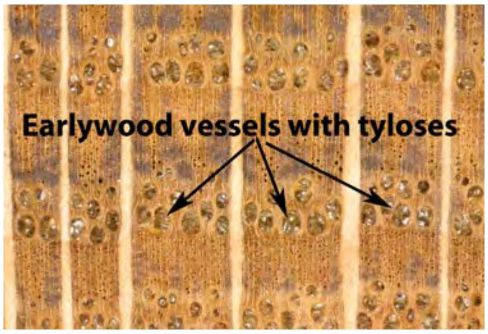
HARDWOOD



FIBER & VESSELS/PORES (BACKLIT)

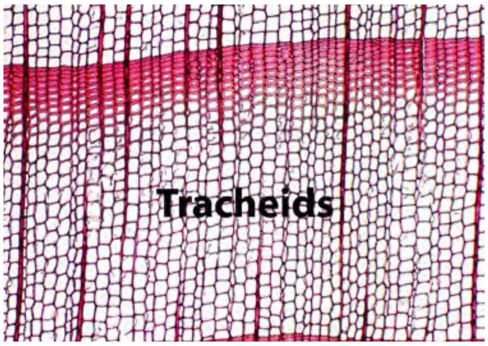


FIBER & VESSELS/PORES (TOPLIT)



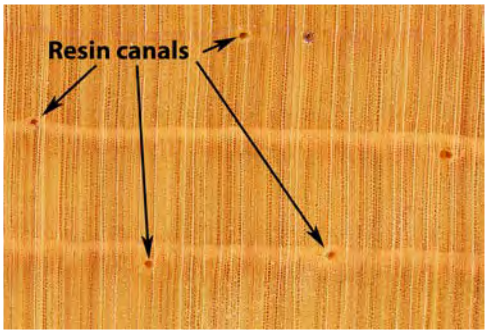
HARDWOOD WITH TYLOSES (VESSEL/PORE OCCLUDED)

SOFTWOOD



TRACHEIDS (BACKLIT)

TRACHEIDS (TOPLIT)



SOFTWOOD WITH RESIN CANAL

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TABLE 1: TREATING WITH CREOSOTE FOR CROSSTIES*

Heartwood least difficult to penetrate - MOST TREATABLE (#1)		31.5 % of ties treated
Softwoods	**Hardwoods**	Interspecies mix
Pondersosa Pine	American basswood Black Tupelo Gum Green ash River birch Slippery elm Water tupelo Red Oaks	Red Oak (75%), Black Gum/ Tupelo Gum (80%), Some Elms Ash (80%)

Heartwood moderately difficult to penetrate - MODERATELY TREATABLE (#2)		20.5% of ties treated
Softwoods	**Hardwoods**	Interspecies mix
Baldcypress Douglas-fir coastal Eastern white pine Jack pine Longleaf pine Red pine Shortleaf pine Sugar pine Western hemlock Loblolly pine	Chestnut oak Cottonwood Bigtooth aspen Mockernut hickory Silver maple Sugar maple Yellow birch	Red Oak (20%), Black Gum/ Tupelo Gum (20%), Ash (20%), Basswood, Some Maples Hackberry, Some Hickory (5%)

Heartwood difficult to penetrate - DIFFICULT TO TREAT (#3)		8% of ties treated
Softwoods	**Hardwoods**	Interspecies mix
Eastern hemlock Engelmann spruce Grand fir Lodgepole pine Noble fir Redwood Western larch White fir	American sycamore Hackberry Rock elm Yellow poplar Hickories	Red Oak (5%), Hickory/Pecan (80%), Sweet Gum (20%), Persimmon, Sassafras, Osage Orange, Birch, Honey Locust, Some Maples (Large Heart), Sycamore, Butternut, Kentucky Coffeetree, Boxelder

Heartwood very difficult to penetrate - MOST DIFFICULT TO TREAT (#4)		40% of ties treated
Softwoods	**Hardwoods**	Interspecies mix
Douglas-fir (coastal and intermountain) Northern white cedar Tamarack Western red cedar	American beech Black locust Blackjack oak Sweet gum White Oaks	White Oak, Hickory/Pecan (15%) Sweet Gum (80%), Black Locust, Mulberry, Hardy Catalpa, Beech, Poplar (Large Heart)

*Some species are listed in multiple "treatability" categories in roughly the percentages which they occur in the average loads of sawn ties sent to treating plants.

vary in length, with the ends closed. "Holes" or pits occur between the vessels, which allow for passage of liquids from one vessel to another. However, the fact remains that liquids move more easily longitudinally within the vessel rather than radially or tangentially between the vessels.

Even though considerable research was used to develop the process over many decades, in practice the preservative treatment of wood using pressure methods is not necessarily an exact science. This occurs due to the variability of wood itself from within a given species and between the various wood species. Exploring the numerous reference books cited in the **Literature References** (Page 93) will confirm that there is an art and science to wood treatment.

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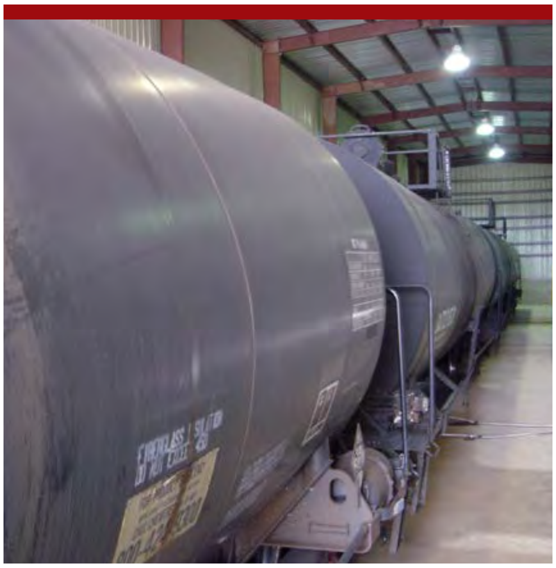
A BRIEF HISTORY OF WOOD PRESERVATION

Wood preservation began in earnest during the second half of the nineteenth century. The first commercial treating plant was built in Lowell, Massachusetts in 1848. The treating process utilized a water-borne solution of the inorganic salt mercuric chloride as the wood preservative. This wood preservative solution was also referred to as the Kyanizing Process. The primary use of this treatment was on wood crossties for installation on several eastern railroads.

IN ADDITION, THERE WERE TWO OTHER INORGANIC CHEMICAL COMPOUNDS — COPPER SULFATE AND ZINC CHLORIDE — USED AS WATERBORNE TREATMENTS TO PRESERVE WOOD.



Subsequently, it was determined that these waterborne mixtures of salt solutions readily leached out of the wood when placed in exterior exposure conditions where there was free running water.

In order to improve the effectiveness of these waterborne inorganic chemical compounds, the wood was first treated with zinc chloride followed by a treatment with creosote. In 1906 J.B. Card patented a one -step impregnation process with a mixture of zinc chloride and creosote. The mixture of zinc chloride/creosote for the treatment of crossties reached a peak in the middle 1920's with the subsequent treatment process being abandoned in 1934.

The first full-cell creosote treating plant was built in 1865 in Somerset, Massachusetts. However, there is more significance attached to the plant that was erected in 1875 in West Pascagoula, Mississippi. This plant was built by the Louisville and Nashville Railroad for the treatment of the various wood materials including crossties to be used within the railroad system. It is generally considered that this marked the initial development of the modern pressure wood treating plants.

The full-cell process was also known as the Bethell Process and was used almost exclusively for all of those early treatments. Because it was not always possible to satisfactorily treat unseasoned timbers ("green" crossties with high moisture), the Boulton Process was patented in

A BRIEF HISTORY OF WOOD PRESERVATION

the United States in 1881. This conditioning method (Boulton Process), or boiling wood timbers under vacuum, removed free water from the wood cells, which then allowed creosote to be impregnated into the wood. The full-cell process placed the maximum amount of preservative into the wood. Thus, for economic reasons, two new empty-cell processes were developed. These empty-cell processes were named for the two individuals who developed and patented them — Max Rueping in 1902 and C.B. Lowry in 1906.

The Rueping and Lowry Processes provide for coating the wood cell with creosote and thus, results in a significantly smaller retention of preservative than that which would have been retained with the Bethell Process. This empty-cell process, with certain modifications is the primary treatment used today for wood crossties.

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A BRIEF HISTORY OF WOOD PRESERVATION

With additional focus on providing an economical treating solution for creosote treated crossties, such materials as coal tar, water-gas tar and petroleum were mixed with creosote. These diluents were added to reduce the overall preservative cost of the mixture without significantly reducing its effectiveness. Water-gas tar is no longer available and the creosote preservative manufacturers have minimized the addition of coal tar. The use of heavy petroleum still continues and is blended with creosote for use by several railroads in arid climates west of the Mississippi. Creosote/petroleum mixtures are exclusively used by the Canadian railroads for treatment of wood crossties.

THE USE OF CREOSOTE AND ITS SOLUTIONS REACHED A PEAK IN 1929 WHEN 203 PLANTS REPORTED TREATMENT OF APPROXIMATELY 360 MILLION CUBIC FEET OF WOOD WHICH INCLUDED 60 MILLION CROSSTIES. CREOSOTE CONTINUED TO BE THE DOMINANT TREATMENT UNTIL SHORTAGES OF THE PRESERVATIVE OCCURRED DURING WORLD WAR II.

During the early 1950s, pentachlorophenol (5-9% concentration) in a carrier-oil began to be used for treatment of utility poles. In the decade of the 1960s, significantly more leach resistant waterborne preservative solutions of copper chrome arsenate (CCA), ammoniacal copper arsenate (ACA) and a formulation revised to include zinc (ACZA), along with several other copper containing preservative formulations were developed. These waterborne preservatives have had a significant impact in the increased volume of pressure treated lumber produced for use in the consumer markets.

The treating industries will continue to look for potential new developments for preserving the wood crosstie. Beside creosote and its solutions (including the borate systems), two oil borne preservatives – pentachlorophenol and copper naphthenate and ACZA, a water-borne preservative, are allowed for use in UC4ABC AWPA Specifications for the treatment of crossties, switch ties, bridge ties and timbers.

Creosote, and its solutions, continues to be the preservative of choice in the treatment of wood that is used by the railroads. The treatment of wood crossties with creosote and its solutions not only protects wood from decay organisms and insects, such as termites, that will attack and destroy the wood, it also provides the wood with a degree of weatherability.

Creosote does not readily mix with water. In fact, when wood is treated with creosote, the water will be repelled. In addition, the service life of the treated wood crosstie is estimated to be well over 30 years. With the creosote treated wood crosstie having been used since the 1880's - over 125 years - it is not difficult to understand the reluctance of railroads to part company with such a reliable partner.

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WHY SHOULD WOOD BE TREATED WITH A PRESERVATIVE?

Wood has been a preeminent material for many types of construction around the world. A significant reason for this is that within North America, as well as other parts of the world, there exists an abundant timber resource. Additionally, wood is a construction material that is renewable.

MANY WOOD PRODUCTS, INCLUDING CROSSTIES, ALONG WITH OTHER WOOD MATERIALS USED BY THE RAILROAD INDUSTRY, ARE MANUFACTURED FROM TREES THAT GROW WITHIN A REASONABLE PERIOD OF TIME.

For economic and durability reasons, it is important to extend the service life of wood products. This is the primary objective for the use of preservative materials in the treatment of wood products. By extending the service life of wood, the ultimate cost of the product is significantly decreased and construction is more permanent.

The crosstie industry is a prime example that demonstrates the benefits of the preservative treatment of wood. During the early part of the 20th century, the average service life of untreated crossties was approximately five and a half years. Subsequently, the treatment with preservatives extended the service life to an estimated average life of more than thirty years.

Some species are naturally more durable. Compare untreated red and white oak crossties.. Red oak and white oak are considered to have similar structural strength properties. Untreated white oak crossties will exhibit an average service life of twelve years. Thus, the service life of this naturally decay-resistant white oak material is more than double that of untreated red oak, but still less than treated wood.

The conclusion should never be drawn that "naturally durable woods" will give acceptable service life as a crosstie or as other components of wood construction. The service life is maximized when creosote is impregnated into either of these two oak wood groups. Wood preservatives increase the life of all timber products by as much as five to eight times.

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WHY SHOULD WOOD BE TREATED WITH A PRESERVATIVE?

To give the maximum durability, wood preservatives must penetrate the wood to enough depth to inhibit attack from various wood destroying organisms that include decay fungi, insects (i.e., termites) and marine borers. With respect to crossties, decay fungi and termites are usually the organisms of concern. When properly treated with a preservative such as creosote, deterioration due to these organisms is essentially eliminated.

It is also important to note that there are physical agents that come under the broad classification of weatherability that have effects on the wood structure. These agents include ultraviolet light, heat, abrasion, and exposure to alternating climatic conditions. These physical agents and their effect on wood can be minimized when the crosstie has been treated with creosote or an oil-type preservative.

Achieving maximum durability and thus increasing the service life of the wood crosstie material requires preservative treatment. Historically, the performance of creosote and its solutions has been exemplary. The use of this preservative makes the wood crosstie a durable and economical timber product produced from a renewable timber resource. This unmatched performance is why wood remains the predominant choice by the railroads for building and maintaining the rail track structure.

As noted in the introduction, inorganic borates are now in use as part of a dual treatment process. Borates facilitate wood preservative treatment throughout the entire cross-section of the wood crosstie (see above left). Any subsequent treatments with oil-borne wood preservatives protects the preservative system against loss of borate from water leaching. This is particularly important in refractory wood species such as the white oak where the heartwood is hard-to-treat. **Table 1** illustrates the significance of this based upon species usage by railroads.

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SUMMARY OF THE COMMERCIAL TIMBERS USED AS CROSSTIE MATERIAL

Many wood species are used for railroad crossties. The most common woods used are the oaks and what are known as the mixed hardwoods, which include the gums, maples, birches, and hickories. Several softwood species such as Douglas-Fir, hemlocks, true firs and several pine species are also utilized as crosstie material. The relative suitability and use of the various wood species for crossties depends on their strength characteristics.

The most important strength properties considered for wood as a crosstie material are:

- bending strength
- end-hardness, which is strength in compression parallel to grain. This indicates the resistance to lateral thrust and spike pull-out
- side hardness, which is compression perpendicular to the grain. This indicates the resistance to plate-cutting

For the purpose of this chapter, all of the wood species recognized by the AREMA and RTA will be grouped into seven categories for Solid Sawn Wood of Crossties. The next chapter on the Engineered Crosstie System gives the material and strength characteristics according to the seven wood species groups listed as follows:

- Oaks
- Northern Mixed Hardwoods
- Southern Mixed Hardwoods
- Southern Yellow Pine
- Eastern Softwoods
- Western Softwoods
- Douglas-Firs

The information given for the various wood species used for crosstie materials may be separated based on treatability, performance and strength characteristics. Typically the density, or specific gravity, indicates the strength characteristics of a wood species (**Table 2**).

SUMMARY OF THE COMMERCIAL TIMBERS USED AS CROSSTIE MATERIAL

THE OAKS

Each of the seven solid sawn wood crosstie groups is made up of numerous wood species. For example, the oaks can be separated into two groups, red and white. There are twelve wood species listed for the red oaks; and ten for the white oaks. Common names and scientific names are given for each species in **Table 3**.

Within North America, crossties from red and white oaks are primarily produced from those states and provinces of the Atlantic coastal region, Southern and Appalachian Mountain regions and the Central Lake State areas (see **Figure 1**, Page 23, which highlights geographic locations for the various wood species). There are two exceptions for the oaks: the California black oak (red oak group) and Oregon oak (white oak group) , both of which grow in the western U.S.

FOR THE MOST PART, THE SEPARATION OF THE RED AND THE WHITE OAK GROUPS INDICATES THEIR RELATIVE TREATABILITY; THE RED OAKS ARE EASILY TREATED; THE WHITE OAKS ARE DIFFICULT TO TREAT DUE TO THE PRESENCE OF TYLOSES. THERE ARE TWO EXCEPTIONS TO THIS: IN THE RED OAK GROUP, BLACKJACK OAK HAS TYLOSES, THUS IS DIFFICULT TO TREAT. CHESTNUT OAK, IN THE WHITE OAK GROUP, DOES NOT HAVE TYLOSES AND IS EASILY TREATED.

The sapwood of both red and white oak groups is white in color, between one and two inches in thickness and is easily treated. The heartwood of the red oak group is generally reddish brown; the heartwood of the white oaks is usually grayish brown or olive brown. The widest rays are broad and fairly conspicuous in both species. With the two exceptions previously referred to, the presence of tyloses is a characteristic that distinguishes the red and white oaks.

Even though the heartwood of the white oaks is difficult to penetrate with preservatives, it has moderately satisfactory decay resistance. It is important to properly condition white oak ties with “an envelope” of preservative on their exterior surfaces.

The Oaks as a group are often specified by the railroad industry for crossties because of their hardness, durability and excellent service life.

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TABLE 2

Specific Gravity at 12% MC

Gymnosperms	Sp. Gr.	Angiosperms
	1.0	
	0.95	
	0.85	
	0.75	Persimmon Shagbark Hickory
	0.70	Black Locust Red Oak White Oak
	0.65	Beech Honey Locust Pecan Red Oak
	0.60	Black Gum Sugar Maple Yellow Birch White Ash
Southern Yellow Pine Tamarack	0.55	Black Walnut Red Maple
Douglas-Fir	0.50	American Elm Black Cherry Red (Sweet) Gum
Western Hemlock	0.45	Sassafras Chestnut
Eastern Spruce Redwood	0.40	Catalpa Basswood Yellow Poplar
Eastern Pine Western Red Cedar	0.35	Black Cottonwood Butternut
	0.30	

SUMMARY OF THE COMMERCIAL TIMBERS USED AS CROSSTIE MATERIAL

NORTHERN & SOUTHERN MIXED HARDWOODS

These are the second and third groups of commercial timbers used by the wood treating industry to produce railroad crossties. As previously indicated, it is predominantly the gums, maples, birches and hickories that make up the total mixed hardwood group of woods. With respect to volume treated when combined together, these two groups represent the second largest amount of wood used as crosstie material.

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SUMMARY OF THE COMMERCIAL TIMBERS USED AS CROSSTIE MATERIAL

As indicated by the section following this descriptive summary of the various woods used for crossties, there are thirty-four wood species that make up the northern mixed hardwood group (**Table 4**); there are twenty one different wood species listed in the southern mixed hardwood group (**Table 5**). It should be noted that because of the regions in which the various species grow, there is "overlap" between the mixed hardwood groups. For example both hickories and maples will be found growing in northern and southern localities — for example, red maple grows from New England to Georgia.

THE TREATABILITY OF DIFFERENT MIXED HARDWOOD SPECIES IS GIVEN ALONG WITH THE NORTH AMERICAN REGION FROM WHICH THEY ARE HARVESTED IN **FIGURE 1** AND **TABLES 4** AND **5**. THE TREATABILITY OF THE MIXED HARDWOODS VARIES FROM EASY TO VERY DIFFICULT.

SUMMARY OF THE COMMERCIAL TIMBERS USED AS CROSSTIE MATERIAL

Of the mixed hardwoods, white elm (American elm), ash, black gum, water tupelo, and the gums — with exception of sweetgum — and birches are the most treatable. Both the hickories and maples are considered moderately treatable. Hackberry and sycamore are somewhat more difficult to treat. The most difficult to treat of the mixed hardwood groups are beech, black locust, catalpa, mulberry and sweetgum.

In even the most difficult woods to treat, the "outer" sapwood can be readily treated, thus creating an "envelope" of preservative to provide protection to the crosstie. It should be noted that an asterisk (*) is given for several woods — black cherry, black walnut, honey locust, osage orange, etc. There is no scientific data available on the treatability of the heartwood of these wood species. Generally it has been considered that the "dark colored" heartwood of these woods will not be penetrated by liquid preservatives and if sapwood is present it will be treated.

The wood species that make up the northern and southern mixed hardwood groups have given excellent service performances as railway crosstie material. This is important because the forest resource constantly changes and the utilization of all appropriate wood species allows railroads to improve the overall economics for the wood crosstie. The Canadian railroads, for example, have had excellent service life from hard maple. Several railroads in the United States have had more than satisfactory service from the gums.

SOUTHERN YELLOW PINES

There are five species that make up this group of woods. The wood from the various species is quite similar in appearance. The heartwood begins to form when the tree is about twenty years old. Generally the sapwood, which is easily treated, makes up the greater portion (volume) of the timbers that are produced. The southern yellow pines come from the southern U.S. and all treat similarly (see **Table 6**).

In order to obtain heavy, structurally strong wood from the southern pines, it is necessary to specify "high density" material. The visual characteristics (i.e., growth rings per inch) are cited in the specifications for the structural material. Dense southern pine has been used extensively by many railroads for bridge ties and timbers with very satisfactory service performance. However, consideration must be given to the fact that the southern pines are, for the most part, lower in density than the oaks and mixed hardwoods and thus will not resist "plate-cutting" to the same degree. This is the reason that for higher density "mainline" track the more dense woods are specified.

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FIGURE 1: REGION LOCATOR FOR COMMERCIAL TIMBERS USED AS A CROSSTIE MATERIAL

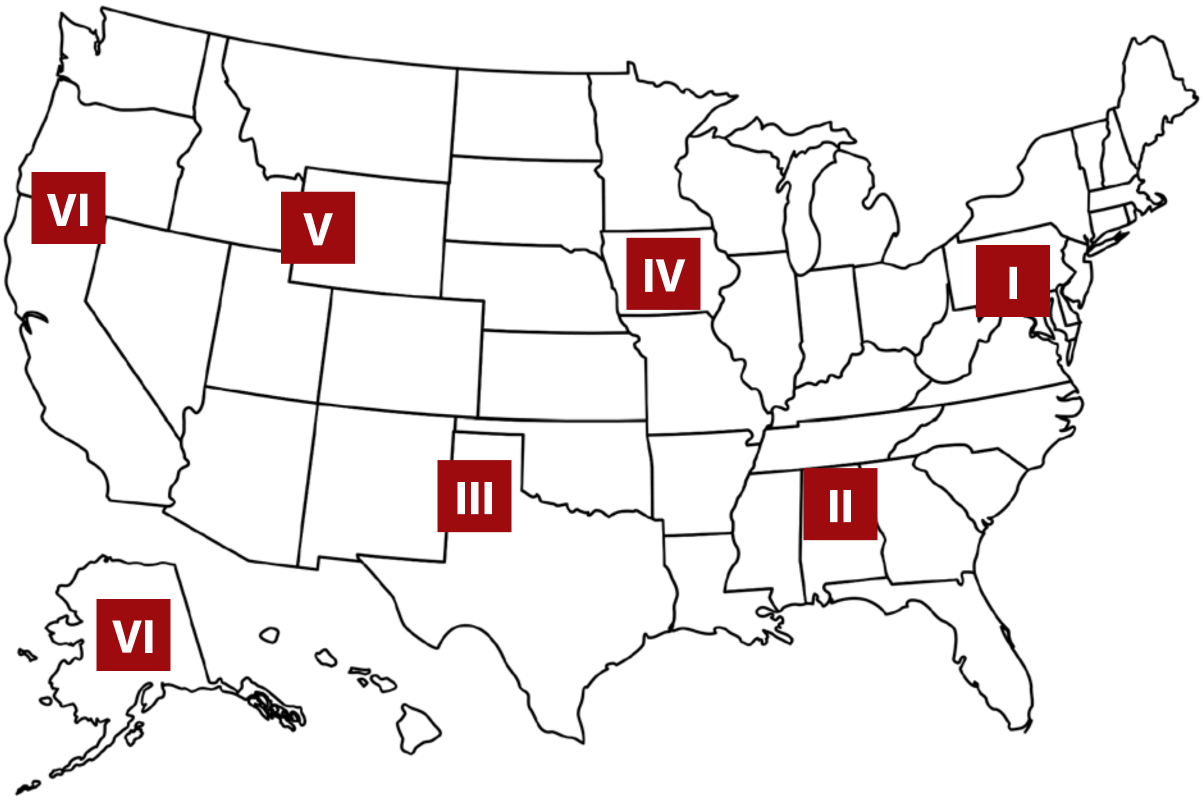

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TABLE 3: OAKS

Commercial Name for Timber (Species)	Location	Treatability
RED OAKS		
Black Oak *(Quercus velutina)*	I,II,IV	1
Blackjack Oak *(Q. marilandica)*	II,III	4
California Black Oak *(Q. kelloggii)*	VI	1
Northern Pin Oak *(Q. ellipsoidalis)*	IV	1
Northern Red Oak *(Q. rubra)*	I,II,IV	1
Pin Oak *(Q. palustis)*	I,IV	1
Scarlet Oak *(Q. coccinea)*	I,II,IV	1
Shingle Oak *(Q. imbricaria)*	I,III,IV	1
Shumard Oak *(Q. shumardii)*	II,III,IV	1
Southern Red Oak *(Q. falcata)*	I,II	1
Water Oak *(Q. nigra)*	II,III	1
Willow Oak *(Q. phellos)*	II,III	1
WHITE OAKS		
Bur Oak *(Q. macrocarpa)*	I,III,IV	4
Chestnut Oak *(Q. montana)*	I,IV	2
Chinquapin Oak *(Q. muehlenbergii)*	I,II,III,IV	4
Live Oak *(Q. virginiana)*	II	4
Oregon Oak *(Q. garryana)*	VI	4
Overcup Oak *(Q. lyrata)*	II	4
White Oak *(Q. alba)*	I,II,IV	4
Post Oak *(Q. stellata)*	I,II,III	4
Swamp Chestnut Oak *(Q. michauxii)*	II	4
Swamp White Oak *(Q. bicolor)*	I,IV	4

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TABLE 4: NORTHERN MIXED HARDWOODS

Commercial Name for Timber (Species)	Location	Treatability
White Elm *(Ulmus americana)*	I,II,III,IV	1
Slippery Elm *(U. rubra)*	I,II,III,IV	1
Hackberry *(Celtis occidentalis)*	I,IV	3
Black Locust *(Robinia pseudoacacia)*	I,II,III	4
Red Mulberry *(Morus rubra)*	I,II,III,IV	4
Hardy Catalpa *(Catalpa speciosa)*	I	4
Honey Locust *(Gleditsia triacanthos)*	II,III,IV	*
White Ash *(Fraxinus americana)*	I,II,III,IV	1
Sassafras *(Sassafras albidum)*	I,II,IV	*
Persimmon *(Diospyros virginiana)*	I,II,IV	2
Hickory		
Shagbark *(Carya ovata)*	I,II,IV	2
Shellbark *(C. laciniosa)*	I,IV	2
Pignut *(C. glabra)*	I,II,IV	2
Mockernut *(C. tomentosa)*	I,II,IV	2
Bitternut *(C. cordiformis)*	I,II,IV	2
Pecan *(C. illinoensis)*	II,III,IV	2
Sycamore *(Platanus occidentalis)*	I,II,III,IV	3
Beech *(Fagus grandifolia)*	I,II,IV	4
Maple		
Sugar *(Acer saccharum)*	I,IV	2
Silver *(A. saccharinum)*	I,II,IV	2
Black *(A. nigrum)*	I,IV	2
Red *(A. rubrum)*	I,II,IV	2
Boxelder *(A. negundo)*	I,II,III,IV,V	2
Black Cherry *(Prunus serotina)*	I,II,III,IV	*
Black Walnut *(Juglans nigra)*	I,II,III,IV	*
Butternut *(Juglans cinerea)*	I,III,IV	*
Yellow Birches *(Betula alleghaniensis)*	I,IV	1
Sweet Birch *(Betula lenta)*	I,II	1
River Birch *(Betula nigra)*	I,II,IV	1
Cottonwood *(Populus deltoides)*	II,III,IV	1
Black Gum *(Nyssa sylvatica)*	I,II,IV	1
Red or Sweet Gum *(Liquidambar styraciflua)*	I,II,III	4
Yellow Poplar *(Liriodendron tulipifera)*	I,II,IV	3
Basswood *(Tilia americana)*	I,IV	1

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TABLE 5: SOUTHERN MIXED HARDWOODS

Commercial Name for Timber (Species)	Location	Treatability
Cork Elm *(Ulmus alata)*	II	3
Osage Orange *(Maclura pomifera)*	III	*
Coffeetree *(Gymnocladus dioicus)*	I,II,IV	*
Persimmon *(Diospyros virginiana)*	I,II,IV	*
Hickory		
Shagbark *(Carya avata)*	I,II,IV	2
Pignut *(C. glavbra)*	I,II,IV	2
Mockernut *(C. tomentosa)*	I,II,IV	2
Bitternut *(C. cordiformis)*	I,II,IV	2
Pecan *(C. illinoensis)*	I,III,IV	2
Nutmeg *(C. myristicaeformis)*	II	*
Water *(C. aquatica)*	I,III	*
Maple		
Silver *(Acer saccharimum)*	I,II,IV	2
Red (A. rubrum)	I,II,IV	2
Boxelder (A. negundo)	I,II,III,IV,V	2
Black Cherry *(Prumus serotina)*	I,II,III,IV	*
Black Walnut *(Juglans nigra)*	I,II,III,IV	*
Butternut *(Juglans cinerea)*	I,III,IV	*
River Birch *(Betula nigra)*	I,II,IV	1
Gums		
Black Gum *(Nyssa sylvatica)*	I,II,IV	1
Red or Sweet Gum (Liquidambar styracifua)	I,II,III	4
Water Tupelo (Nyssa aquatica)	II	1

***As indicated, no reference could be found for these wood species and the treatability of the heartwood**

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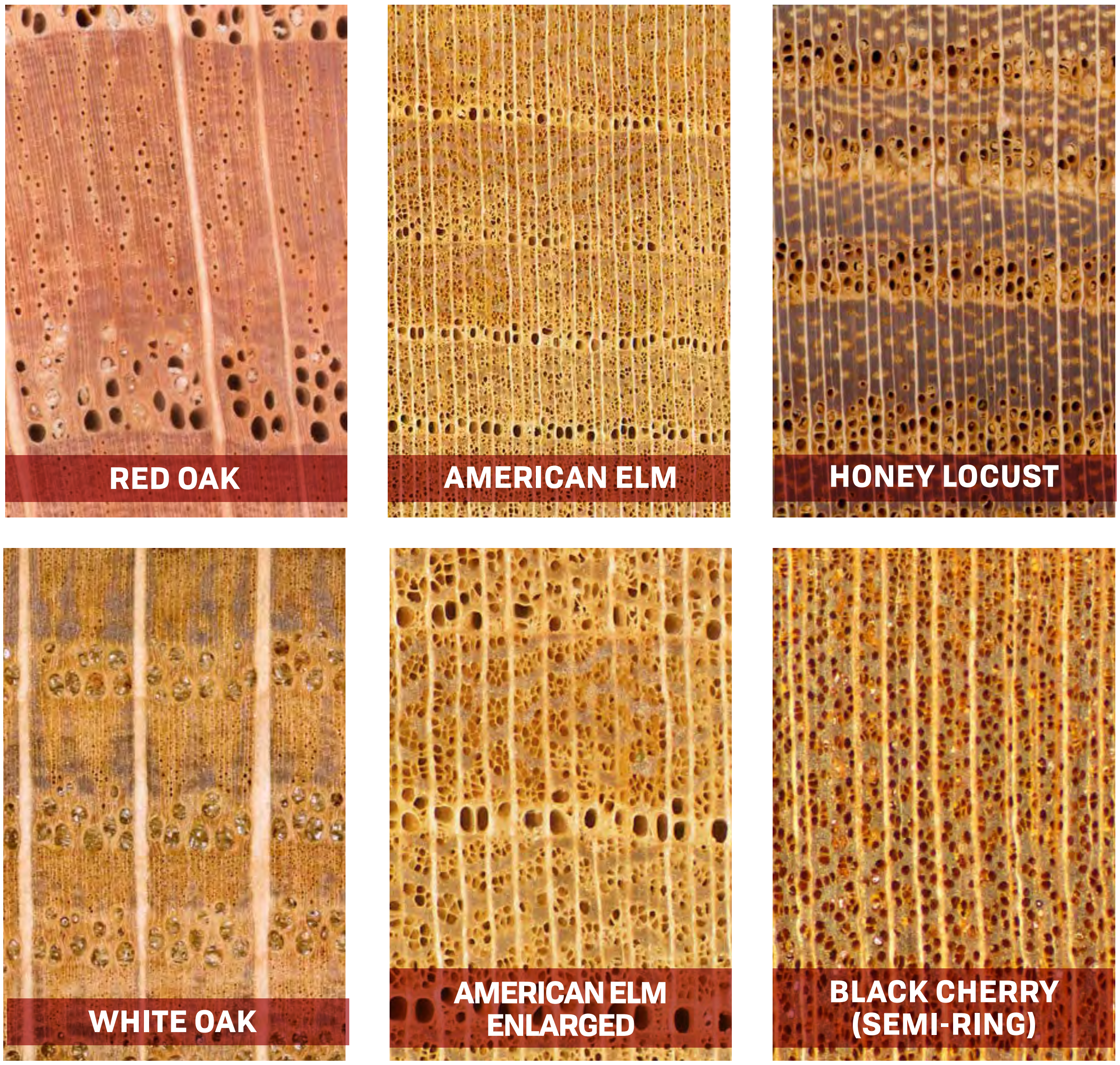
EXAMPLE HARDWOOD SPECIES SECTIONS

RING (& SEMI-RING) POROUS



*Micrographs by **TERRY CONNERS**, University of Kentucky*

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EXAMPLE HARDWOOD SPECIES SECTIONS

DIFFUSE POROUS

*Micrographs by **TERRY CONNERS**, University of Kentucky*

SUMMARY OF THE COMMERCIAL TIMBERS USED AS CROSSTIE MATERIAL

EASTERN AND WESTERN SOFTWOODS

The fifth and sixth groups of woods that are used for crossties are made up of several species from the eastern and western regions of North America. There are six (6) woods from the eastern region and thirteen (13) species from the western area. Location of growth and treatability information are given in **Tables 7 and 8** for the respective two groups of softwoods.

THE USE OF EASTERN SOFTWOODS (WHITE CEDARS, FIR, HEMLOCK, SPRUCES AND TAMARACK) FOR CROSSTIES IN MAINLINE TRACK IS LIMITED. HOWEVER, THERE IS UNDOUBTEDLY SOME USE OF EASTERN SOFTWOODS IN THOSE REGIONS NEAR THE LOCAL HARVEST AREA.

Softwood timbers would be used for the construction of secondary track and bridge timbers. All of the eastern softwoods are considered difficult to treat with preservatives such as creosote. Even the sapwood of eastern hemlock is difficult to treat and with this species incising is necessary, not only to assist in drying the crosstie, but also to improve the penetration of preservatives.

DOUGLAS-FIR

The final timber used for wood crossties is Douglas-fir. It is the only species with the data for growth location and treatability given in **Table 9**. There are, however, two types of Douglas-fir — Coastal and Intermountain. The coastal variety is considered moderately treatable; while the intermountain type is most difficult to treat. Treating Douglas-fir with creosote requires incising ties and timbers for acceptable preservative penetration.

This wood species is one that is referred to as having "thin-sapwood"; usually not more than one-inch in thickness, but in second-growth trees of commercial size the sapwood may be as much as three-inches. The range of Douglas-fir extends from the Rocky Mountains to the Pacific coast and from Mexico to central British Columbia. Considerable quantities of these wood species find their way into railroad crossties for use in track primarily in Canada and the western United States. Douglas-fir timber has also been used extensively for bridge timbers.

TABLE 6: SOUTHERN YELLOW PINES

Commercial Name for Timber (Species)	Location	Treatability
Shortleaf Pine *(Pinus echinata)*	II, III	2
Loblolly Pine *(P. taeda)*	II, III	2
Longleaf Pine *(P. palustris)*	II, III	2
Slash Pine *(P. elliottii)*	II, III	2
Virginia Pine *(P. virginiana)*	II, III	2

TABLE 7: EASTERN SOFTWOODS

Commercial Name for Timber (Species)	Location	Treatability
Eastern Spruces *(Picea spp.)*	I, II, IV	3
Tamarack *(Larix laricina)*	I, II, IV	3
Eastern Hemlock *(Tsuga canadensis)*	I, II, IV	3
Balsam Fir *(Abies balsamea)*	I, II, IV	3
Northern White Cedar *(Thuja occidentalis)*	I, II, IV	3
Atlantic White Cedar *(Chamaecyparis thyoides)*	I, II, IV	3

TABLE 8: WESTERN SOFTWOODS

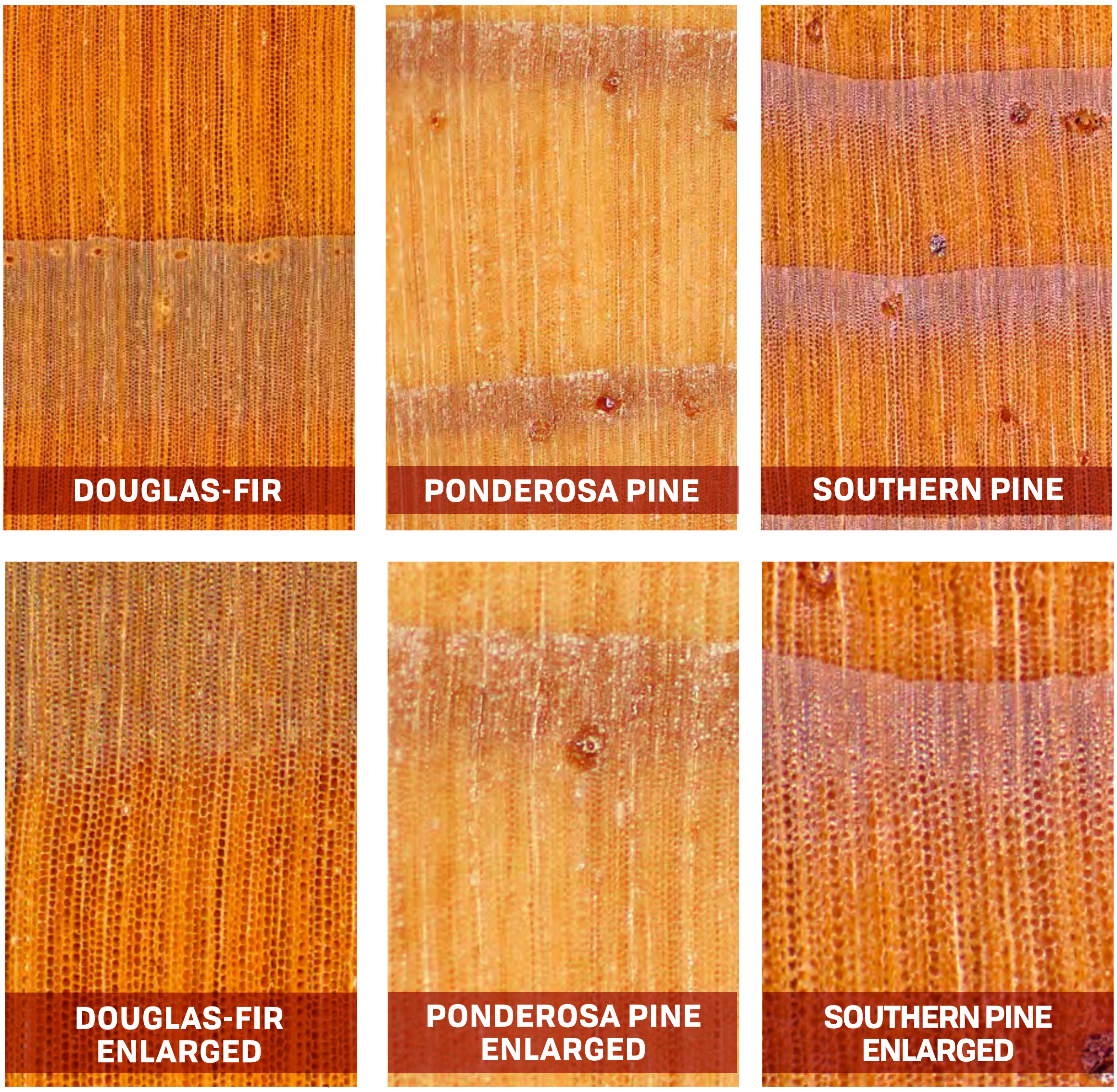
Commercial Name for Timber (Species)	Location	Treatability
Western White Pine *(Pinus monticola)*	III,V,VI,VII	*
Limber Pine *(P. flexilis)*	III,V,VI,VII	*
Jeffery Pine *(P. jeffreyi)*	III,V,VI,VII	*
Lodgepole Pine *(P. contortai)*	III,V,VI,VII	3
Ponderosa Pine *(P. ponderosa)*	III,V,VI,VII	1
Engelmann Spruce *(Picea engelmannii)*	III,V,VI,VII	3
Western Larch *(Larix occidentalis)*	III,V,VI,VII	3
Port Orford Cedar *(Chamaecyparis lawsoniana)*	III,V,VI,VII	*
White Fir *(Abies concolor)*	III,V,VI,VII	3
Grand Fir *(Abies grandis)*	III,V,VI,VII	3
Redwood *(Sequoia sempervirens)*	III,V,VI,VII	1
Western Hemlock *(Tsuga heterophylla)*	III,V,VI,VII	2
Western Redcedar *(Thuja plicata)*	III,V,VI,VII	4

Footnote * - as indicated no reference could be found for these wood species and the treatability of the heartwood

TABLE 9: DOUGLAS-FIR

Commercial Name for Timber (Species)	Location	Treatability
Coastal *(Pseudotsuga menziesii)*	VI	2
Intermountain *(Pseudotsuga menziesii)*	VI	4

EXAMPLE SOFTWOOD SPECIES SECTIONS



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THE ENGINEERED WOOD CROSSTIE

In an earlier section of this guide, the statement was made that wood is the only construction material that is a renewable resource. History books and various literature citations make numerous references to wood as a long standing material of construction. To illustrate a few examples concerning the importance of wood in the development of this country, consider the following:

- The average early frontier log cabins required about 80 logs, as well as smaller timbers. Wood roof shakes and wood pegs were used to hold the structure together.
- During the first part of the 18th century, settlers in the Conestoga Valley of Pennsylvania built a wagon almost completely of wood. The Conestoga wagons transported freight supplies throughout the eastern part of the country.
- Boats, bridges and roads were made of wood. The "wooden plank" road ran between New York and Newark over wet marshland. During the 19th century two thousand miles of wood roads were built in the states of New York, Michigan, Wisconsin and other Midwestern states had extensive systems. In some states, such as Alabama, plank roads delayed the coming of the railroads.
- Wood was the predominant material of construction even into the first part of the 20th century.

THE ENGINEERED WOOD CROSSTIE

Because wood was plentiful and the vast timber resource seemed unending, the production and preservative treatment of crossties for the railroad industry became well established. The hand hewn-tie, and subsequently the sawn-tie, were produced according to standard cross-sectional dimensions (inches) — 6x7, 7x7, 7x8 and 7x9. The length of the wood crosstie depended on the railroad, eventually moving to an acceptable standard length of either eight and a half (8 ½) or nine (9) feet.

The wood crosstie, thus, has specific dimensions. In addition, crossties must meet other specifications (quoted from the AREMA Manual for Railway Engineering, Section 3.1.1.2.1 General Quality):

"Except as hereinafter provided, all ties shall be free from any defects that may impair their strength or durability as crossties, such as decay, large splits, large shakes, slanting grain, or large or numerous holes or knots."

To further emphasize the importance placed on characteristics affecting mechanical properties and serviceability, here's a quote from the same AREMA Manual from Section 3.2.1.2.2 Resistance to Wear: "When so ordered, ties from needle leaved trees shall be of compact wood throughout the top fourth of the tie, where any inch of any radius from the pith shall have six or more rings of annual growth."

The point of this dialogue is that wood is a very important structural material, and when used

solely for crossties, historically, the physical characteristics have been the most important consideration.

The wood crosstie is now thought of as the Engineered Wood Crosstie with its own set of specifications based on structural strength test data. Given in **Table 10** are the strength characteristics for the seven types of solid sawn woods that are used in the production of crossties. **Table 10** is based on the species referred to in **Table 11**.

There are now also examples of Composite Wood Materials including glue-laminated lumber and fiber-reinforced laminated products as well as parallel-oriented wood fiber laminated products. These engineered wood products can be made from several different wood species and manufactured to meet specific strength characteristics.

TABLE 10

Material & Strength Properties		SOLID SAWN TIE TYPE 1 Oak	2 North Mixed Hardwoods	3 South Mixed Hardwoods	4 Southern Pine	5 Western Softwoods	6 Eastern Softwoods	7 Douglas-Fir	ENGINEERED HYBRID WOOD 8 Laminated W. Products	9 Parallel Strand Lumber
Based on	Nominal	Southern Red Oak	White Birch	Silver Maple	Shortleaf Pine	Ponderosa Pine	Eastern Hemlock	Coastal Douglas-Fir	(1)	(2)
Dimensions Length (ft) Width (in) Depth (in)	8.5 9 7	8.5 9 7	8.5 9 7	8.5 9 7	8.5 9 7	8.5 9 7	8.5 9 7	8.5 9 7	8.5 9 7	8.5 9 7
Density (pdf)		58.6	55.1	48.1	51.6	41.9	41.9	48.9		
Weight (lbs)		218	205	179	192	156	156	182		
Moment of Inertia (in^4)		257	257	257	257	257	257	257		
Section Modulus (in^3) RS+=RS-=C+=C-		73.5	73.5	73.5	73.5	73.5	73.5	73.5		
Modulus of Elasticity (MOE) 100E + 10^6 psi	-40F +72F +140F	N/A 1.06 1.06	N/A 1.09 1.09	N/A 0.86 0.86	N/A 1.28 1.28	N/A 0.93 0.93	N/A 0.97 0.97	N/A 1.44 1.44		
Modulus of Rupture (MOR) psi	-40F +72F +140F	N/A 6570 6570	N/A 6291 6291	N/A 5499 5499	N/A 7173 7173	N/A 4977 4977	N/A 5985 5985	N/A 7353 7353	(3)	
Rail Seat Compression Test psi		524	273	366	357	279	350	387		
Material Surface Hardness Test Janka Ball		792	536	541	419	301	389	469		
Static Bending Strength (in-Kips) Theoretical (based on MOR and I/c)		483	462	404	527	366	440	540		
Flexibility (deflection in inches) ("Stiffness-Load/Deflection) Theoretical, based on 60" spacing applied load (Kips) of 10		0.165	0.160	0.202	0.136	0.189	0.179	0.122		
Lateral resistance characteristics Single tie lateral push test Load at 0.25" deflection (approx. peak)		1960	1900	1778	1839	1672	1672	1793		

1) Glue-laminated wood, most often Southern Pine or Douglas-Fir, has strength properties that can be "adjusted" by varying the density, wood species and the orientation/ use of wood materials. Laminated products in the future may also contain polymeric fibers and wood in various combinations structurally suitable for use as a crosstie material.
2) Parallel Strand Lumber (psl) begins with rotary-peeled veneer sheets, which are clipped into strands of wood. Wood species more commonly used include Southern Pine, Douglas-Fir, Western Hemlock and Yellow Poplar. The strength properties can be "adjusted" by varying the density and wood species.
3) The engineered hybrid crosstie, in can be assumed, will have strength properties that will equal or exceed solid sawn products while keeping economics under consideration. The user may be able to specify certain strength characteristics within allowable limits.

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MATERIAL PROPERTIES OF SOLID SAWN WOOD CROSSTIE MATERIALS

Wood is an extremely versatile and effective material for use as a railroad track crosstie. However, the key properties of wood will vary with the wood species. To allow for the potential use of a broad range of types, the wood tie properties presented in this section have been divided into seven categories of wood as given in **Table 10**.

For each category a representative wood species was used. The material properties given in **Table 10** represent a minimum value for each category (unless otherwise noted). This is to allow for the use of these material properties in design calculations. The values are based on a collection of material property data, including both handbook sample data and full tie test data.

An explanation for the wood property values given to **Table 10** are as follows:

- Dimensions are based on the AREMA specification that allows a 1/4-inch reduction in width and depth.
- Volume is calculated based on dimensions.
- Density is based on 40% moisture content (as determined from the oven-dry volume). Seven lbs./cu. ft. of creosote was added to the density and the total reduced by 10% to account for variations in values in the material property table and in the treatment process.

MATERIAL PROPERTIES OF SOLID SAWN WOOD CROSSTIE MATERIALS

- Weight is the density multiplied by the volume.
- Moment of inertia is calculated based on the defined dimensions and rectangular cross-section.
- Section modulus was calculated from dimensions and rectangular cross-section.
- Modulus of Elasticity (MOE) is based on green values plus 10% of the difference between the green and the dry values (to account for the fact that the outside of the tie is drier than the interior of the tie). Ninety percent (90%) of the calculated value is taken to determine a minimum value for design purposes.
- Modulus of Rupture (MOR) is based on green values plus 10% of the difference between the green and the dry values (to account for the fact that the outside of the tie is drier than the interior of the tie). Ninety percent (90%) of the calculated value is taken to determine a minimum value for design purposes.
- Rail Seat Compression Test is based on green values plus 10% of the difference between the green and dry values (to account for the fact that the outside of the tie is drier than the interior of the tie) and based on handbook data for Compression Perpendicular to the Grain. Ninety percent (90%) of the calculated value is taken to determine a minimum value for design purposes.
- Material Surface Hardness test is based on green values plus 10% of the difference between the green and the dry values (to account for the fact that the outside of the tie is drier than the interior of the tie) and based on handbook data for Hardness Perpendicular to the Grain. Ninety percent of the calculated value is taken to determine a minimum value for design purposes.
- Static Bending Strength is a theoretical calculation based on the MOR and the section modulus.
- Flexibility (which is a more appropriate term than stiffness-load deflection) is a theoretical calculation based on a applied load of 10,000 lbs. and a sixty (60) inch support spacing.
- Lateral resistance values are based on field tests taken by US Department of Transportation, Volpe Transportation Systems Center, using single tie push tests. Results are based on minimum value for consolidated track. To account for differences in density (weight), 50% lateral resistance was varied linearly as a function of the weight of the ties, using mixed hardwoods as the base reference. To account for the non-weight related component of lateral resistance (due to side and end effects that do not change with weight) only 50% of the lateral resistance was varied with weight, with the remaining 50% held constant.

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TABLE 11

Crosstie Category	Wood Species
Oak	Southern red oak
Northern Mixed Hardwoods	White birch
Southern Mixed Hardwoods	Silver maple
Southern Pine	Shortleaf pine
Western Softwoods	Ponderosa pine
Eastern Softwoods	Eastern hemlock
Douglas-fir	Coastal Douglas-fir

*The above wood species were used to calculate the category values for strength properties in **Table 10**.*

HYBRID ENGINEERED WOOD CROSSTIE MATERIALS

The solid sawn creosote treated wood crosstie has an average service life of well over thirty five (35) years. To this present day, it continues to be the major track component that binds the steel rails together. These solid sawn treated wood crossties will undoubtedly continue as the preferred material of choice by the railroads.

In the early part of the 20th century, the crosstie material used by the railroads progressed from an untreated hand-hewn tie to the creosote treated solid sawn tie. It may be fitting that there is progress in the field of wood technology as the 21st century unfolds.

THE RAILWAY TIE ASSOCIATION, THROUGH ITS RESEARCH AND DEVELOPMENT COMMITTEE, CONTINUES TO TAKE A LEADERSHIP ROLE IN COORDINATING SIGNIFICANT RESEARCH PROJECTS IN THIS AREA. THESE INCLUDE THE EVALUATION OF: UNDER-UTILIZED WOOD SPECIES, DOWEL-LAMINATED WOOD, GLUE-LAMINATED WOOD, PARALLEL-STRAND-ORIENTED LUMBER AND FIBER-REINFORCED LAMINATED WOOD FOR USE AS CROSSTIE MATERIAL.

For lack of a better term, all of these materials should be called composite wood products. They bring together structural adhesives, polymeric fibers, and wood in various combinations to provide an engineered wood structurally suitable for use as crosstie, switch tie and bridge timber materials. These new products may provide advantages over the existing materials for crosstie. It is a fact that some of these hybrid products are already in use by the railroads in widely varying applications.

Given in **Table 10** are structural data for the solid sawn and engineered wood products. It must, however, be recognized that because these are engineered wood products — i.e., glue-laminated timbers, etc. — the strength characteristics can be adjusted by varying the density, wood species and the orientation/use of wood materials. Because of this it is not possible to provide structural test data for all the variations. However, one can assume that the goal is to engineer in strength properties that will be greater than solid sawn products, while keeping economics under consideration.

Wood is a renewable resource but the larger old-growth timber, once abundant, is increasingly less accessible to harvest. Second-growth and third-growth trees that are currently harvested are typically smaller in diameter. While the majority of crossties produced will remain solid sawn material for the foreseeable future, the changes occurring in managing the resource will require increasing utilization of alternative species and engineered hybrid wood products. As the demand for crossties continues, it is realistic to expect that engineered hybrid wood crosstie may have a significant future.

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CONDITIONING AND TREATMENT OF WOOD CROSSTIES

This section aims to provide a general overview of the conditioning and treatment of wood crossties. There are other treated wood materials which are used by the railroad transportation industry including poles, piling, and other lumber products. In generic terminology when there is a discussion concerning wood crossties, there will be some overlap with switch tie and timber product materials.

PREPARATION OF CROSSTIES AND TIMBERS FOR TREATMENT

If there is one process in the treatment of wood products that is more important than any other, it is the preparation and conditioning of wood prior to treatment. It is necessary to remove most of the free water from within the wood cells. This must be accomplished in order to put the wood preservative within those cells. When all the free water has been removed from within the wood cells then it is said that the fiber saturation point has been reached. With most wood species it is thirty percent moisture based on the oven-dry weight of the wood. It is below the fiber saturation point that wood begins to shrink and develops checks and splits. This occurs most notably in large timbers such as crossties.

Water can be removed in four ways:

- Kiln Drying
- Air Seasoning
- Boulton Drying
- Steam Conditioning

KILN DRYING

With respect to practical applications within the crosstie industry, the process of kiln drying is not used to remove water from large timbers (six to eight inch cross-section). To date, it has not been found to be economical to process materials such as crossties and other large timbers in this manner.

AIR SEASONING

This drying process is the preferred method for conditioning wood crossties prior to treatment. It is the general practice to segregate the wood according to species and the size of the timber. For practical purposes, the species separation is into two groups — the oaks and mixed hardwoods (refer to the first section of this book for a more thorough discussion).

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PREPARATION OF CROSSTIES AND TIMBERS FOR TREATMENT

The local climate has a significant impact on air seasoning. In some parts of the Southeast where the temperature and humidity are relatively high during a large part of the year, it can be difficult to air season crossties and timbers. It is imperative in these locations that air seasoning be carefully monitored to avoid incipient decay. Within the treating industry this is often termed "stack-burn". There are certain wood species such as hackberry, because of their high sugar content, that should be pretreated with a preservative chemical to prevent this surface decay/stack-burn potential.

There are both advantages and disadvantages with any of the conditioning/seasoning processes for removal of moisture from wood. The air-seasoning process is the preferred method because it is the most economical. The extra time in the treating cylinder for either Boultonizing or steam-conditioning is considered expensive in contrast. On the other hand, a major shortcoming of the air-seasoning process is the inventory cost of the accumulated, untreated crossties and timbers. Depending on the climate, regional location and the wood species, the required air-seasoning time can range from four to twelve months and in some instances, even longer than twelve months (see RTA Research Compendium, Volume I, Tab 21 available online at www.rta.org>Resources>research).

PREPARATION OF CROSSTIES AND TIMBERS FOR TREATMENT

In addition to air drying, there are two methods used commercially for conditioning unseasoned ties prior to creosote treatment: Boultonizing and steam conditioning. Steam conditioning is mostly used for southern pine timbers and to a lesser extent for other pines. The primary reason for using steam conditioning is that the air-seasoning of pines cannot be effectively performed without some decay occurring in the southern climate areas.

BOULTON CONDITIONING METHOD

In dry or more arid regions of the country, rapid air drying of the timber can cause severe checking and splitting. The conditioning procedure best suited for water removal in these regions is the Boulton process. In addition, a significant advantage for the Boulton drying procedure is that material can be processed rapidly and in a controlled fashion from the green condition.

As currently used in the industry, the Boulton process can be described as follows:

The green/wet wood materials are placed in the treating cylinder which is then filled with hot creosote. It is important to completely cover the timbers with the creosote and that the equipment has sufficient void space for the collection of moisture vapor. The creosote is heated under vacuum to draw the moisture vapor out of the wood cells. It is important **1)** to know the moisture content of the wood prior to treatment and **2)** that all wood within the treating cylinder be uniform in moisture content. By monitoring the amount of water coming from the cylinder the operator can determine when the wood is properly dried.

The treating operator must be able to measure the amount of water that has been removed from the charge of wood material. In addition, there will be a volatile portion of the creosote which will condense along with the water.

These should be separated from the water with the volatile materials returned to the creosote work tank.

Once the Boulton conditioning process has been completed, the pressure treatment of the wood with creosote can then proceed. This process will be described in a later section of the manual. It is generally considered that the total Boulton processing time will be between six and ten hours. The variability in the time for conditioning is wood species and temperature dependent. For example, there can be a variation between the time required for Douglas-Fir and the oaks. Also, a charge of crossties Boultonized in January in Ontario, Canada will necessarily take longer to a charge of material Boultonized in July in central Texas.

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PREPARATION OF CROSSTIES AND TIMBERS FOR TREATMENT

There are advantages and disadvantages in using the Boulton process in conditioning wood. Major advantages are as follows:

- Crossties and timbers can effectively be conditioned/seasoned in a much shorter time compared to air seasoning. This results in a significantly reduced total time to process and creosote treat the wood products.
- Compared to the steam conditioning method, the Boulton process uses a significantly milder temperature with a minimum effect on wood strength properties.
- Again when compared to the steaming process, a lower moisture content level within the wood can be achieved.

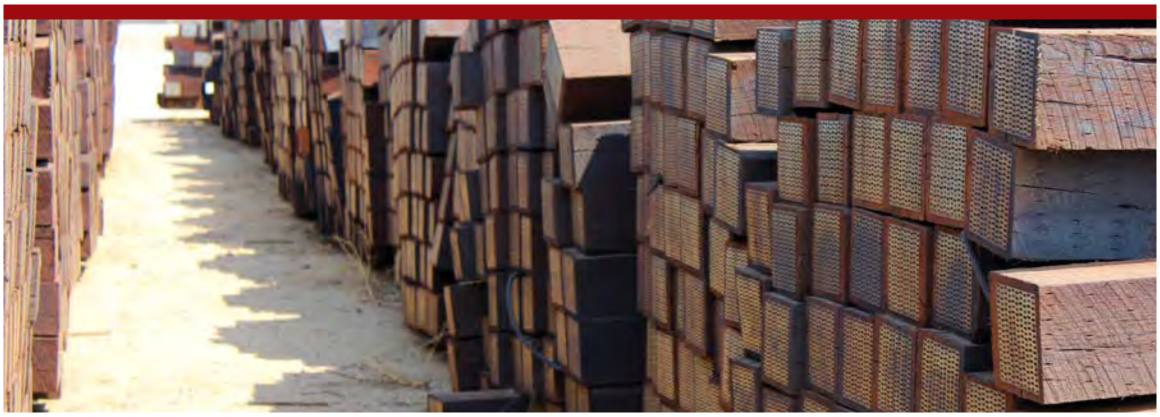
The chief disadvantages of the Boulton process are that it is only suitable for creosote and other oil preservatives; it often costs more than air seasoning; and it heats the wood more slowly than the steaming process.

STEAM CONDITIONING METHOD

Steam conditioning may also be used to remove water from wood prior to treatment. As currently used in the industry, it can be described as follows:

A charge of green pine material is placed in the cylinder and steamed for several hours. The total time for steaming is dependent on the size of the timbers. At the conclusion of the steaming period, a vacuum is applied to remove the moisture vapor from the wood. The steaming time is dependent upon **1)** temperature of the wood, **2)** cross-sectional dimensions of the wood and **3)** wood density.

PREPARATION OF CROSSTIES AND TIMBERS FOR TREATMENT



It is important for the vacuum to be applied as soon as possible after the steaming cycle has been completed. When the temperature of the wood surface is lowered significantly, the average amount of water removed during the vacuum will be lower than if the vacuum had been applied immediately after the steaming cycle.

A COMMON PRACTICE WITHIN THE TREATING INDUSTRY IS TO APPLY THE STEAM IN ONE CYLINDER AND REMOVE THE CHARGE FROM THE CYLINDER, AND THEN CONTINUE WITH THE VACUUM AND CREOSOTE PRESSURE TREATING PROCESS IN A SECOND CYLINDER. THIS PRACTICE IS NOT THE MOST EFFICIENT BECAUSE THE MAXIMUM AMOUNT OF WATER VAPOR CANNOT BE REMOVED.

The common practice of steaming southern pine timbers (assuming twenty pounds gauge pressure) will effectively condition a charge of material in a time period of ten to fourteen hours. This includes both the steaming and vacuum periods of the conditioning cycle. As with the Bouton cycle, these times will vary with **1)** the temperature of the wood and **2)** pine species and its density.

Currently, within the industry, this process is generally used only with southern pine timbers and to a lesser extent for other pines. The primary reason for using steam conditioning is that the air-seasoning process of this wood cannot be effectively performed without some decay occurring in the southern climate areas.

PREPARATION OF CROSSTIES AND TIMBERS FOR TREATMENT

There are advantages and disadvantages to the steaming process. The principal advantages of the steaming process are:

- Steam heats faster than any other heating mediums.
- It is easily applied and usually does not require any special equipment in the treating cylinder.
- The temperature can be easily controlled.

The disadvantages are as follows:

- Only a limited amount of moisture can be removed in the steaming/vacuum cycle
- It is often necessary to use higher temperatures than are used in the Boulton process (note that the AWPA Standards have maximum times and temperatures that can be used in the steaming process).

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PREPARATION OF CROSSTIES AND TIMBERS FOR TREATMENT

MECHANICAL PREPARATION

The first part of this section focused on the methods for removal of moisture from wood cross ties and timbers to condition them prior to creosote treatment. However, it is necessary to take a step back and note several mechanical procedures that need to be implemented before the conditioning processes are initiated.

It is assumed that the crossties and timbers to be conditioned and subsequently treated have been inspected by the customer or a designated person. An inspection "in-the-white" (unseasoned) is important to eliminate those pieces which have defects. There are a number of defects that will cause a crosstie to be culled. These include ring shake, wane, large knots, incipient decay and excessive splits and checks. There are three common mechanical procedures performed on crossties and timbers, as follows:

- Addition of anti-checking devices
- Framing, adzing and boring
- Incising

Historically, anti-checking irons commonly known as S-irons and C-irons were used to reduce severe end-splitting in crossties and switch ties. Today a product known as an end-

plate is the predominant, if not only, product used to arrest splitting. It is generally believed that end-plates are effective in reducing the amount of end-splits. End-plates are usually applied to the ends of crossties that are judged by an inspector to have the potential to split in such a way as to limit the tie's long-term use.

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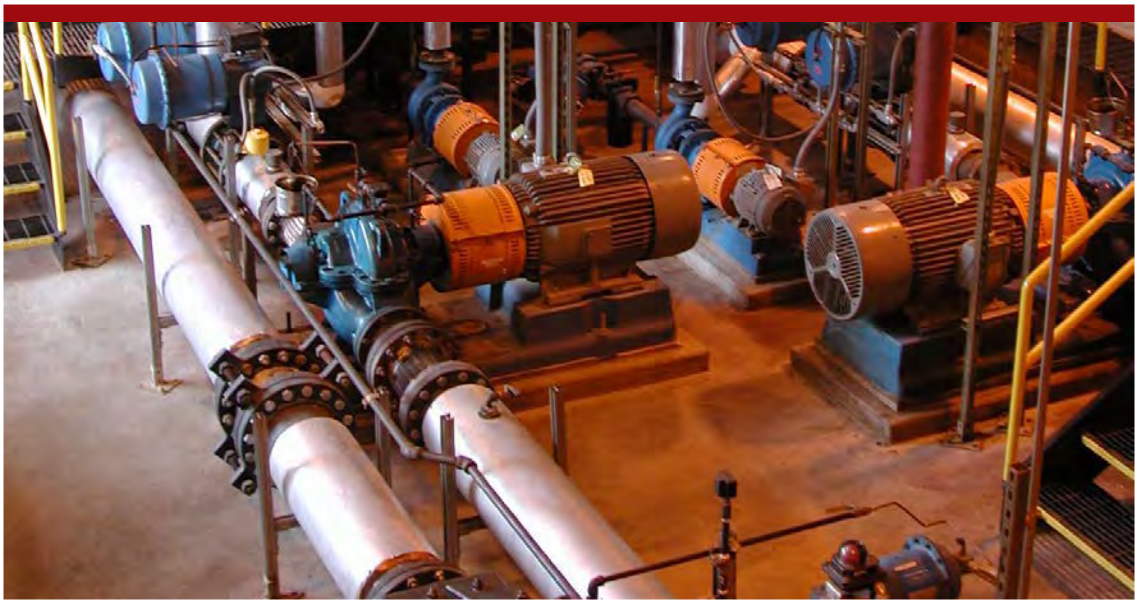
PREPARATION OF CROSSTIES AND TIMBERS FOR TREATMENT



Whenever practical, all framing, adzing and boring of crossties and timbers should be done before the pressure treating process. Cutting into the timber after treatment can expose untreated wood. As a normal practice the standard 7x9 inch crosstie will not be cut or drilled; however, there can often be considerable framing, etc., that will be performed on bridge crossties and timbers. It is important to have all this work done prior to treatment.

Incising of crossties and timbers is a common practice for all wood species. It used to be that only those ties species that are resistant to penetration of liquid preservatives were incised. Now, almost all ties are passed through a machine equipped with cutting teeth projecting from the rollers to not only increase preservative penetration but also mitigate seasoning defects. A properly incised tie can often reduce seasoning checks and splits that occur during air-drying. By incising crossties and large timbers in the original green state, it is possible to achieve a more uniform drying/conditioning of the wood. The use of incising minimizes severe checks and splits that can occur in large timbers. This is why most ties today are incised whether or not they are resistant to liquid preservative penetration.

EFFECT OF WOOD STRUCTURE ON TREATMENT

Wood varies greatly in its structure. The hardwoods differ from the softwoods and within these groups the individual species are different. It is important to note some of the wood structural differences that affect the treatability of various wood species.

Some of the wood characteristics that could possibly influence preservative treatment include:

- Within a specific wood species it is generally accepted that the sapwood is more easily treated than the heartwood. The heartwood may contain gums, resins, extractives and pigment materials. Because of these materials, the heartwood is a darker color.
- Wood density does not significantly influence the treatability of a wood species. There are many other considerations that affect treatability, such as open pores in red oak, tyloses found in white oak, and the presence of resin in the heartwood of various softwoods.
- The longitudinal wood cells in softwoods (termed tracheids or fibers that have closed ends) and hardwoods which have open cells stacked end to end and known as vessels. One could think of the longitudinal wood cells as being a "bundle of straws". The softwood fibers have bordered pits in the cell walls and these allow liquids to pass readily between the cells. Hardwoods do not have this type of cell structure. The penetrability of the liquid preservative depends to a great extent on the open or closed condition of the longitudinal cells.
- The directional structure differences within a cross-section of wood influence the penetration of liquids. Along with the previously mentioned longitudinal fiber direction of wood cells, would be the tangential direction flowing around with the wood growth rings and third the radial direction across the growth rings and parallel to the wood rays. Longitudinal fibers are the most easily penetrated.

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MOISTURE CONTENT AND ITS EFFECT ON TREATMENT

The definition for the fiber saturation point was previously defined as approximately 30% moisture content. This is an important reference point to keep in mind. For example, when trees are freshly cut, the green moisture content for Douglas-Fir sapwood is 115%; the heartwood is 37%. The sapwood of white oak has a moisture content of 78% and the heartwood is 64%.

The water within the cells of the wood completely fills the void space in the cell. This is known as free water. The cell walls remain saturated with water; thus, the term fiber saturation. As this moisture is removed from the wood fibers, shrinkage of the wood will occur. It is important to control this moisture loss in order to minimize the checking and splitting of wood. This fact was illustrated in the previous sections in the discussion of Conditioning Processes and the use of incising in the mechanical preparation of crossties and timbers.

THE PRESENCE OF MOISTURE IN WOOD CAN BE A DETERMINING FACTOR FOR TREATABILITY. IF THE WOOD HAS NOT BEEN CONDITIONED AND THE CELLS ARE FULL OF WATER THERE IS NO PLACE FOR THE PRESERVATIVE TO ENTER THE WOOD.

Large timbers, such as crossties and switch ties, do not have to have their moisture content reduced to fiber saturation point when the treatment will be creosote or an oil-borne preservative.

Satisfactory penetration and retention of preservative can be achieved with a moisture content in the range of 40 to 45%. When treating with the water borne preservative ACZA, the moisture content should be in a range of 23 to 28%.

MOISTURE CONTENT AND ITS EFFECT ON TREATMENT

Consideration needs to be given to the fact that when treating with any of the preservatives, the wood can be too dry for treatment. Quality control procedures exist to minimize issues with improper moisture content at time of treatment. These will be discussed in the section dealing with treatment processes.

THE MOISTURE CONTENT OF THE WOOD PRODUCT NEEDS TO BE KNOWN BY THE TREATING OPERATOR BEFORE THE CHARGE OF MATERIAL IS TO BE TREATED.

The following are examples of information that treating plant operators need to know:

- For green crossties that are to be Boultonized, how much water needs to be removed?
- For air-dried timbers that are to be treated with creosote, has sufficient moisture been removed to allow for proper penetration of the preservative?
- What is the moisture content of pine timbers? Do they need to be steam conditioned? It is important to remember that the process known as treatment to refusal can only be used with refractory wood species such as Douglas-Fir and white oak.

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WOOD PRESERVATIVES AND THE PRESSURE PROCESSES

Wood crossties, switch ties and timbers used by the North American railroad industry have historically been treated with a creosote solution meeting the requirements of AWPA Standard P2. There are also occasions when ties and other timber products such as bridge materials will be treated using the AWPA Standard P1/P13.

Another creosote preservative blend material has been used by the industry to treat crossties and timbers in those regions of North America that have an arid climate or in northern zones where the potential decay and insect attack are less. For these reasons a heavy petroleum oil that meets AWPA P4 Standard has been used with creosote. This creosote/petroleum solution has been used extensively for many years to reduce the cost of the preservation solution. Its use has been primarily in the western United States and Canada.

Creosote and its solutions are the preservatives most widely used to treat crossties. The crossties are pressure treated using the empty cell method (Lowry or Rueping Process). The specified creosote net retention is usually between six and ten pounds per cubic foot (pcf).

Wood crossties and timbers must be properly conditioned to achieve the desired preservative penetration and retention. The various conditioning methods and processing procedures are described in the AWPA Book

of Standards. A recent copy of the AWPA Standards should be readily available to anyone who is involved in the treatment and use of wood crossties. Before initiating a discussion on the pressure treatment process, it should be noted that many of the railroad customers specify (and many of the treating plants that produce crossties use) a sterilization cycle just prior to pressure treatment to kill wood-destroying organisms. To achieve sterilization, laboratory studies have shown that the heating conditions require both

WOOD PRESERVATIVES AND THE PRESSURE PROCESSES

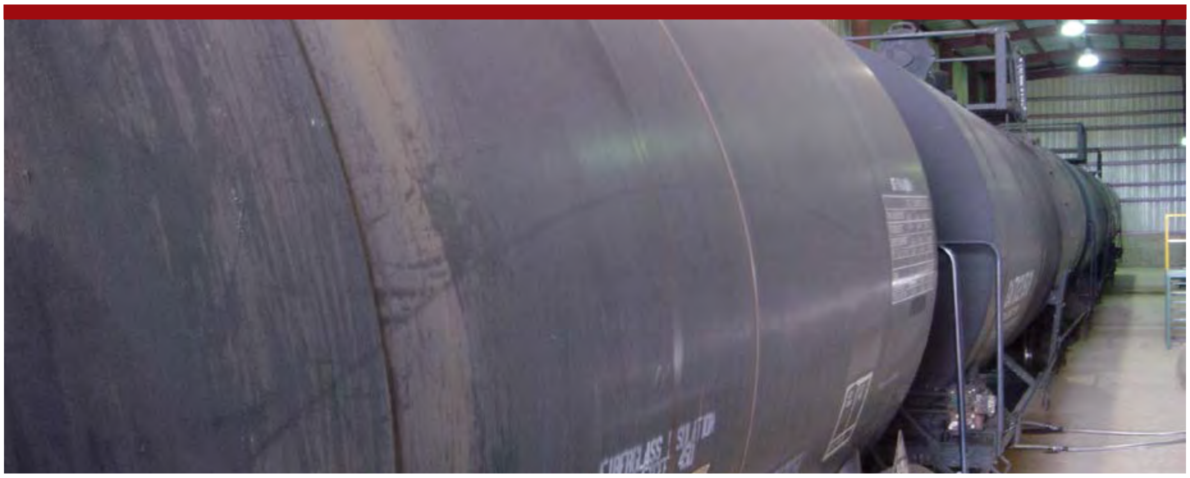
a specific temperature and duration of time. The results also indicate that it is not practical to sterilize wood at temperatures below 150 degrees F. The following shows the temperature/times to attain sterilization in 7" x 9" wood crossties:

Temperature (F)	Time (minutes)
150	75
170	30
180	20
200	10

These temperature specifications are for the center of the wood, not the sterilizing temperature conditions. However, it must be taken into consideration that the temperature required is an internal one, not an external temperature. The center of a 7 x 9 crosstie, or any other large sawn timber, must reach that desired temperature.

At conclusion of the pressure process, initiate post conditioning procedures (i.e., final vacuum and possibly steaming). Next, make the determination if the wood has been properly treated using inspection procedures for penetration and retention of the preservative.

A more detailed description of the pressure treating process will now be given.



THE TREATMENT PROCESSES

Because a vast majority of railroad crossties, switch ties and timbers are treated only with creosote and its solutions, only the procedures used for pressure treating with this preservative will be discussed. As previously indicated, there are two pressure processes that can be used in the treatment of crossties and timbers with creosote. These two principal types are the full cell (Bethell) and the empty cell (Lowry and Rueping) processes. The most commonly used is the empty cell process. For the purposes of this booklet, a somewhat limited description follows. Additional information can be found in reference books and on the RTA website.

The major difference between the full-cell and the empty cell processes is that a preliminary vacuum is applied to the treating cylinder during the initial phase of the full cell process while with the empty cell process, air pressure is applied instead of a vacuum. That initial air pressure can be atmospheric pressure for the Lowry process. The Rueping process is the most commonly used today, and for this treatment regimen, air pressure is forced into the treating cylinder before the preservative is admitted. The air pressure is then maintained while the cylinder is filled with preservative. Thus, the wood cells will contain air under pressure and preservative under pressure as well.

Depending upon the desired preservative retention level and the wood species, the initial air pressure may vary between 20 and 60 psi. The ultimate objective is to control the retention level by varying the amount of the preservative "kick-back" from the wood cells during the final post-conditioning vacuum cycle. Upon release of the pressure, the preservative is forced out of the wood by the expanding air. The amount of recovered preservative will be greater when the initial air pressure is higher.

A good example would be the treatment of southern pine.

- With the full-cell process and the application of a vacuum, 25 pcf creosote will be retained.
- With the Lowry process and atmospheric initial pressure, the retention level could be 20 pcf.
- With the Rueping process and an initial air pressure of 10 psi, the creosote retention could be 16 pcf.
- With an initial air pressure of 30 psi, the creosote retention level could be 12 pcf.
- With the initial air pressure being 60 psi, the creosote retention level could be 8 pcf.

The above is strictly a theoretical example to show the effect the vacuum and initial air pressure can have on the preservative retention level. It is important for any treating plant operator to be aware of these differences and effects of vacuum and the amounts of air pressure.

THE PRESSURE PERIOD

Once the creosote preservative has been admitted into the cylinder and the initial air pressure or vacuum has been maintained during the creosote filling process, the charge of material is then put under pressure. The pressure period may vary depending upon the wood product that is being treated. AWPA UC4

gives recommended maximum and minimum levels of pressure depending upon the wood species. There is a similar recommendation for the maximum and minimum temperature level for the creosote during the pressure period.

The pressure period can also vary depending upon the conditioning cycle used to make the wood ready for treatment. In addition to the wood species, the size of timber can affect the length of the pressure period. For example, kiln dried southern pine 6x6 inch timbers will have a shorter pressure period compared to Boultonized oak switch ties. This assumes that both products have approximately the same creosote retention level. Once again, it is important that the treating operator have knowledge of the products that are being treated and the operation of his own plant facility.

THE TREATMENT PROCESSES

POST CONDITIONING PROCESSES

Once the pressure period is completed, the final post conditioning process is one that focuses on several areas: **1)** preservative recovery and **2)** environmental considerations have become important issues. It is imperative surface deposits and bleeding creosote wood products be minimized. To achieve this, post conditioning processes are as follows:

- Temperature considerations of the preservative as the pressure periods is completed,
- Expansion bath to assist in the recovery of the creosote preservative,
- Vacuum cycles to recover preservative,
- Possible use of steaming improves surface appearance of the treated wood material.

Of the four post conditioning procedures listed above, the temperature and vacuum stops are the most important and must be used in every treating cycle. A brief description of each of the above processes follows:

Temperature considerations — Within two hours of completion of the pressure period, the temperature of the creosote treating solution should reach its peak. That temperature normally should be between 190 and 200 degrees Fahrenheit.

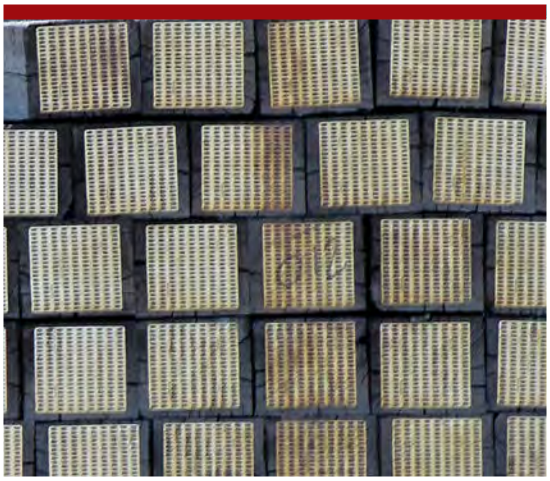
Expansion bath — This is a procedure that is often used with Douglas-Fir timbers. As the pressure within the cylinder is released and the creosote remains in the cylinder with the charge of timber still submerged, the temperature of the preservative is raised approximately 10 degrees Fahrenheit. A vacuum is applied during this period which assists in removing the air and some creosote from the wood.

Vacuum cycles — Once the creosote has been drained from the cylinder, it is imperative that at least one vacuum cycle (minimum 22 inches Hg) be applied to the charge of material. The duration of this vacuum cycle will be dependent upon the species and size of the material that has been treated. For optimum surface cleanliness, it is recommended that following the first vacuum cycle and "breaking" back to atmospheric pressure, a second vacuum cycle be applied. The duration of this second cycle will be based upon the treating operator's experience.

Steaming cycle — The use of steam in the post conditioning part of the treating cycle is definitely optional. Treating plants do not favor the use of steam because it results in the accumulation of waste water that needs to be processed. However, steaming between the two vacuum cycles is an extremely effective way of expanding the air which remains in the treated timber, and this is ultimately removed with the second vacuum cycle. The steam that is applied should not be "live" steam. The steam should originate from water that has been put into the cylinder to cover the coils and thus, generates steam from the boiling of the water (closed steaming operation).

STANDARDS AND SPECIFICATIONS FOR TREATMENT

Standards and specifications are an extremely important segment of any industry. They are the guide by which products are produced. They allow the consumer who purchases and uses the product to have confidence that what has been purchased will perform to expectations that the producer has advertised to the purchaser.



The wood treating and railroad transportation industries are no different. There are essentially three sets of specifications and standards that govern the industry:

- The AREMA specifications for timber crossties, switch ties and industrial grade crossties were jointly developed by the Railway Tie Association (RTA) and the American Railway Engineering and Maintenance-of-Way Association (AREMA). These set of specifications pertain to the untreated (white) wood prior to its treatment with preservative. Within these specifications are given the physical requirements, inspection criteria and the definition of defects.
- The second set of standards which is important to the wood treating industry pertains to the type of creosote that is used in treatment of crossties and timbers. These American Wood Protection Association Standards (AWPA) are listed as follows:
    - P1/P13, Standard for Creosote Preservative
    - P2, Standard for Creosote Solution
    - P3, Standard for Creosote - Petroleum Solution
    - P4, Standard for Petroleum Oil for Blending with Creosote
- The final Standard that is important to the wood treating and railway transportation industries is that which brings together the treatment of "white stock material" and the creosote preservative used in the pressure process for the treatment of crossties and timbers. This is the AWPA UC4ABC, the Standard for Treatment of Crossties and Switch Ties - Preservative Treatment by Pressure Processes. The above stated Standards and Specifications can all be found in a subsequent section of the Tie Guide published in 2016 by the Railway Tie Association.

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ENVIRONMENTAL LIFE CYCLE ASSESSMENT DEMONSTRATES ADVANTAGES OF THE TREATED WOOD CROSSTIE

Railroads, the public, and the wood products industry are concerned about the potential environmental issues related to the production, use, and disposition of treated wood crossties. In response, the Treated Wood Council (TWC), with support from the RTA, completed an environmental Life Cycle Assessment (LCA) of creosote treated hardwood crossties compared to concrete and plastic/composite ties.[1] A copy of this LCA may be downloaded at www.bit.ly/LCAPaper. Results of this LCA and associated environmental issues are summarized in this chapter.

1 — Treated Wood Council (TWC), 2013. Conclusions and Summary Report Environmental Life Cycle Assessment of Railroad Ties. The LCA was also published as an article. See Bolin and Smith, 2013. Life Cycle Assessment of Creosote-Treated Wooden Railroad Crossties in the US with Comparisons to Concrete and Plastic Composite Railroad Crossties. Journal of Transportation Technologies, 2013, 3, pp. 149-161. Website http://www.scirp.org/journal/jtts.

ENVIRONMENTAL LIFE CYCLE ASSESSMENT DEMONSTRATES ADVANTAGES OF THE TREATED WOOD CROSSTIE

LCA PROCESS AND CONCLUSIONS

The LCA study was designed to provide a comprehensive, scientifically-based, fair, and accurate understanding of environmental burdens associated with the manufacture, use, and disposition of railroad ties using accepted LCA methodologies in accordance with the principles and guidance provided by the International Organization for Standardization (ISO) in standards ISO/DIS 14040 and ISO/DIS 14044. The scope of this study included:

- A life cycle inventory of three railroad tie types: preservative-treated wood, concrete, and plastic/composite. Creosote was chosen as a representative preservative for assessment of treated wood railroad ties.
- Calculation and comparison of life cycle impact assessment indicators: anthropogenic greenhouse gas, total greenhouse gas, acid rain, smog, ecotoxicity, and eutrophication of water-body impacts potentially resulting from life cycle air emissions.
- Calculation of energy, fossil fuel, and water use.

The LCA used a functional unit of one mile of railroad track ties for one typical year of use, thus making comparisons meaningful and understandable. Assumptions required for each tie material included the following:

Service life:

- sawn wood product is 35 years
- concrete product is 40 years
- plastic/composite product is 40 years

Tie spacing in Class 1 mainline railroads:

- sawn wood product is 19.5 inches
- concrete product is 24 inches
- plastic/composite product is 19.5 inches

The inventory analysis phase of the LCA involved the collection and analysis of data for the cradle-to-grave life cycle of the railroad ties. For each stage of the product life cycle, inputs of energy and

ENVIRONMENTAL LIFE CYCLE ASSESSMENT DEMONSTRATES ADVANTAGES OF THE TREATED WOOD CROSSTIE

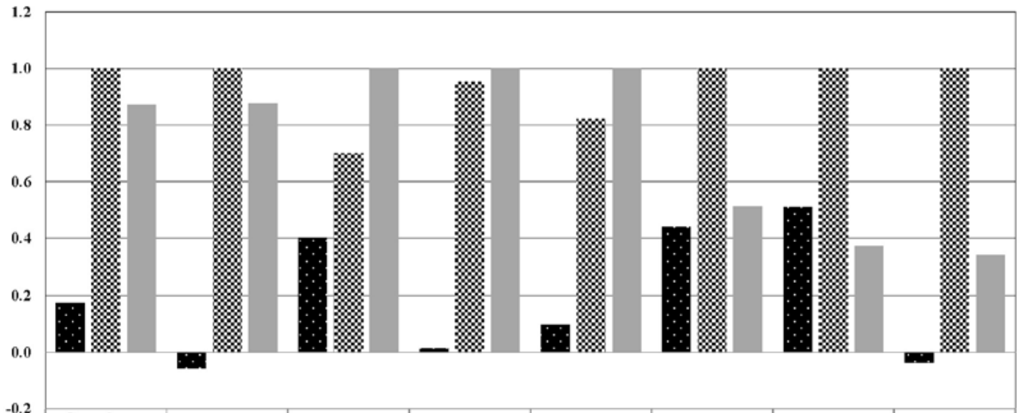
raw materials, outputs of products, co-products and waste, and environmental releases to air, water and soil were determined.

The assessment phase of the LCA used the inventory results to calculate total energy use, impact indicators of interest, and resource use. For environmental indicators, US EPA's Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) was used to assess anthropogenic and total greenhouse gas, acid rain, smog potential, ecotoxicity, and eutrophication impacts potentially resulting from air emissions.

THE CATEGORIES ENERGY USE, RESOURCE USE, AND IMPACT INDICATORS PROVIDE GENERAL, BUT QUANTIFIABLE, INDICATIONS OF ENVIRONMENTAL PERFORMANCE. THE RESULTS OF THIS IMPACT ASSESSMENT ARE USED FOR COMPARISON OF RAILROAD TIE PRODUCTS.

The numeric results of the calculated impacts are included in the cited reports, but are difficult to understand. To help with the interpretation of the results, impact indicator values were normalized to the product (creosote-treated tie, concrete tie, or P/C tie) having the highest cradle-to-grave value, allowing the relative comparison of indicators between products (Figure 1). The product with the highest value at final disposition receives a value of one, and the other products are lesser fractions.

ENVIRONMENTAL LIFE CYCLE ASSESSMENT DEMONSTRATES ADVANTAGES OF THE TREATED WOOD CROSSTIE



	Greenhouse Gases	Net GHG	Fossil Fuel Use	Acid Rain	Water Use	Smog	Eutrophication	Ecotoxicity
Creosote-treated tie	0.17	-0.06	0.40	0.01	0.10	0.44	0.51	-0.037
Concrete tie	1.0	1.0	0.70	1.0	0.82	1.0	1.0	1.0
Plastic/composite tie	0.87	0.87	1.0	1.00	1.0	0.51	0.37	0.34

FIGURE 2: Creosote-treated wood, concrete, and P/C ties normalized impact comparisons (normalized to maximum impact = 1)

In **Figure 2**, note that creosote-treated ties have lower environmental impacts than concrete ties in all categories and have lower impacts than plastic/composite ties in seven of eight categories. The distinctions are quite significant.

Greenhouse Gases

The first data column of **Figure 2** illustrates that greenhouse gases, mainly carbon dioxide, are emitted in much greater amounts for concrete ties (about six times more) and for plastic/composite ties (about five times more) than for creosote-treated wood ties.

Net Greenhouse Gases

The contrast is even greater when the uptake of carbon dioxide during wood growth is considered in the second column, Net GHG, where wood ties actually result in a reduction, rather than an increase, of atmospheric greenhouse gases. This impact category includes carbon dioxide removed from the

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ENVIRONMENTAL LIFE CYCLE ASSESSMENT DEMONSTRATES ADVANTAGES OF THE TREATED WOOD CROSSTIE

air as trees grow using photosynthesis to produce wood mass. Dry wood is approximately fifty percent carbon.

Fossil Fuel Use

Used wood ties have useful energy value as fuel that can be used in place of fossil fuel, further reducing net emissions. Thus, the result is a net negative value for carbon emissions related to treated wood ties. While a given length of track with treated wood ties would result in recovery of nineteen pounds of GHG per year from the atmosphere, the same length of track would add one hundred pounds of GHG per year if concrete ties were used instead. Wood is a unique building material because it alone begins its life cycle removing carbon dioxide from the atmosphere.

The amounts of fossil fuel used to produce each type of tie are reflected in other indicators, since such use contributes to these, but is also relevant to consumption of natural resources. Plastic/composite tie production uses the most fossil fuel.

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ENVIRONMENTAL LIFE CYCLE ASSESSMENT DEMONSTRATES ADVANTAGES OF THE TREATED WOOD CROSSTIE

FOREST SUSTAINABILITY

Ties are sustainable forest products. Most are manufactured from hardwoods, although softwoods are also used for bridge timbers and some ties. Both hardwood and softwood forest wood volume and land coverage are increasing even as harvesting continues.[2] Co-production of ties and lumber from logs maximizes wood utilization. Market value of wood ties and timbers enables profitable management of land as forest, thus supporting forest land use rather than subdivisions or other crops. Further note that as service life of wood ties is increased in the southeastern U.S. due to borate dual treatment, fewer ties will be required each year, thus improving sustainability.

GREENHOUSE GASES

In **Figure 2**, the first comparison is for "Greenhouse Gases," which evaluates only anthropogenic, or human caused, releases. This value is important and shows that treated wood ties result in lower emissions than either concrete (the highest with a normalized value of 1) or plastic/composite ties. Production of preservative treated wooden railway ties requires less fossil fuel and energy and result in less environmental impact than ties made of alternative materials such as concrete or plastic-composite.

The second comparison for "Net GHG" shows the importance of considering both anthropogenic plus natural processes. This impact category includes carbon dioxide removed from the air as trees grow using photosynthesis to produce wood mass. Dry wood is approximately 50% carbon.[3] Additionally, used wood ties have useful energy value as fuel that can be used instead of fossil fuel, further reducing net emissions. Thus, the result is a net negative value for carbon emissions related to treated wood ties. While a given length of track with treated wood ties would result in recovery of 19 pounds of GHG per year from the atmosphere, the same length of track would add 100 pounds of GHG per year if concrete ties were used instead. This difference between wood and products of other materials is clear in **Figure 2**.

Concrete ties use 70% and creosote-treated wood 40% as much fossil fuel as plastic/composite ties.

2 — USDA Forest Service, August 2014. U.S. Forest Resource Facts and Historical Trends. http://www.fia.fs.fed.us/library/brochures/docs/2012/ForestFacts_1952-2012_English.pdf.
3 — Treated Wood Council (TWC), 2013. Conclusions and Summary Report Environmental Life Cycle Assessment of Railroad Ties.

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ACID RAIN

Both concrete and plastic/composite ties result in acid rain causing emissions, such as hydrochloric acid, that are about 100 times higher than for creosote-treated wood ties.

WATER USE

Creosote-treated ties require about one-tenth as much water as plastic/composite ties and one-eighth as much as concrete. (Washing plastic as part of the recycling effort requires substantial water.)

SMOG

Emissions that may cause smog are highest for concrete; plastic/composite tie production creates about half the emissions of concrete ties, and creosote-treated wood production creates the fewest emissions (44% of the concrete tie production process).

EUTROPHICATION

Emissions that cause eutrophication (growth of algae) in water bodies are highest for concrete and lowest for plastic/composites, with creosoted wood tie production in the middle. This is the only category in which plastic/composite ties are better for the environment than creosoted wood ties. Emissions that may be toxic within the environment are also highest for concrete, due to combustion for process heat and electricity, while emissions related to plastic/composite ties are about 34% of the concrete ties.

ECOTOXICITY

While wood ties are treated with creosote and/or other pesticides, such use does not correspond to a greater environmental impact than for concrete or plastic/composite ties. The last column of **Figure 2**, Ecotoxicity, shows a measure of environmental impact resulting from the life cycle toxic emissions of the products. Toxic air emissions result from combustion of fossil fuel to make electricity and cement, as well as from processes to make creosote, plastic, or transportation fuel. Because many creosote-treated wood ties are recycled for energy production after use in ways that offset combustion of

2 — USDA Forest Service, August 2014. U.S. Forest Resource Facts and Historical Trends. http://www.fia.fs.fed.us/library/brochures/docs/2012/ForestFacts_1952-2012_English.pdf.
3 — Treated Wood Council (TWC), 2013. Conclusions and Summary Report Environmental Life Cycle Assessment of Railroad Ties.

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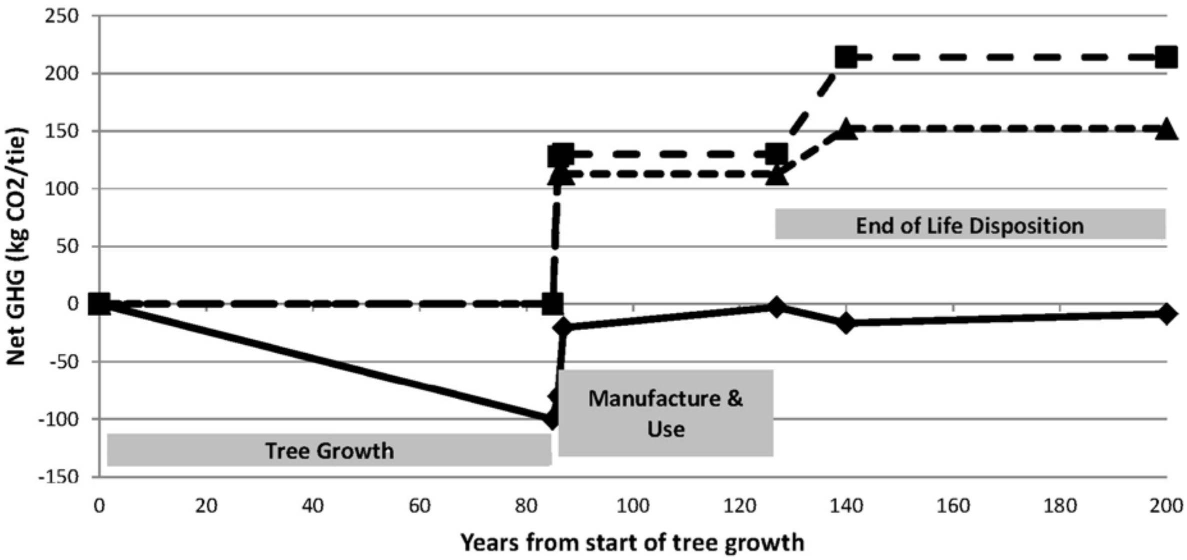

Figure 3 - GHG uptake and release by manufacture, use, and disposition of ties over time

fossil fuels and the associated toxic emissions, the use of creosote-treated wood ties results in a small decrease in toxic emissions.

The environmental advantages of creosote-treated wood ties in comparison to either concrete or plastic/composite ties are clear and substantial. These advantages are also part of the story for the issues discussed below.

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SERVICE LIFE

Environmental impacts are inversely related to service life. Sensitivity analyses in the LCA report showed that increased environmental impacts due to the use of borate for dual treatment with creosote would be less significant than the environmental impact reductions resulting from the extended service life. Borate-creosote dual treated ties will therefore have lower impacts than creosote-only ties and will have lesser environmental impacts than either concrete or plastic/composite ties.

DISPOSITION

Railroads are rightly concerned about future options for and the associated costs of final disposition of ties after removal from use in tracks. Currently, approximately eighty-one percent of used wood ties are recycled for energy while less than one percent are landfilled.[4] While future options may be affected by legislation or regulations, recycling for energy will likely remain the preferred and most used choice. Concrete ties may be recycled by grinding the ties to produce gravel for use or sale and the steel can be recycled. Recycling plastic/composite ties into plastic feedstock is possible, but to date the economic feasibility has not been demonstrated. These ties will most likely be disposed of in landfills. Thus, disposition options and costs seem to favor the continued use of treated wood ties.

CONCLUSION

The Life Cycle Assessment of preservative-treated wood railroad crossties demonstrated that these ties have lower environmental impacts than alternative ties made of concrete or plastic/composite materials. The supply of wood for ties is sustainable in that forest growth continues to exceed harvests. Use of treated-wood ties lowers atmospheric greenhouse gas levels while use of concrete or plastic composite ties would increase green house gas levels. Toxic air emissions are lower with treated-wood ties than with either concrete or plastic/composite ties. Final disposition of treated-wood ties following removal from service further reduces impacts, as such fuel offsets fossil fuel combustion. Use of treated-wood crossties by railroads results in lower environmental impacts than use of concrete or plastic/composite tie alternatives.

4 — Smith, 2015. Railroad Tie Disposal Practices Updated RTA, AAR & ASLRRA Survey Provides New Railroad Tie Disposal Practices Updated. Crossties. May/June 2015, pp. 8-11. Also available online at https://rtax.memberclicks.net/assets/docs/RTASponsoredResearch/Environmental/ties%20survey%20report%2012aug20151.pdf.

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AWPA Standards for Railway Ties

The printed edition of The Tie Guide contains a 17-page section which is designed to assist the reader in understanding the American Wood Protection Association Standards that are pertinent to railroad crossties. In that section, excerpts from the following AWPA Standards as published in the 2015 edition of the AWPA Book of Standards are found:

- *U1-15: Use Category System - User Specification for Treated Wood*
- *T1-15: Use Category System – Processing and Treatment Standard*
- *P1/P13-13: Standard for Creosote Preservative*
- *P2-13: Standard for Creosote Solution*
- *P3-14: Standard for Creosote-Petroleum Solution*
- *P22-14: Standard for Ammoniacal Copper Zinc Arsenate (ACZA)*
- *P25-14: Standard for Inorganic Boron (SBX)*
- *P35-10: Standard for Pentachlorophenol (PCP)*
- *P36-11: Standard for Copper Naphthenate (CuN)*
- *P60-14: Standard for Inorganic Boron, Oilborne (SBX-O)*

To purchase copies of these AWPA Standards, the reader is encouraged to contact AWPA:

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