

Past, Present, and Future of the Wood Preservation Industry

Wood is a renewable natural resource that typically is preservative treated to ensure structural integrity in many exterior applications.

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Preservative treatment of wood has a long history in the United States and throughout the world. Even the early settlers to the New World in the 17th century used wood preservatives to protect homes and other structures.

The treated wood industry in the United States is evolving as new products emerge, technology advances, and environmental concerns increase. Recently, chromated copper arsenate (CCA) preservative-treated wood has been a frequent subject in the national news. A voluntary phase-out of CCA-treated wood for non-industrial uses has increased the attention on new-generation, arsenic-free preservatives. In a recent feature article in the *Forest Products Journal*, Evans (2003) discussed new preservative systems, including copper- and zinc-based and other metal systems, metal-free systems, treatment technologies, wood modification, and natural protection systems. This article examines the past, present, and future of preservative-treated wood with an emphasis on issues in the marketplace and treated wood use policy.

The Past

The history of humankind is closely intertwined with wood utilization. Some of the earliest uses of wood were for fuel for heating and cooking. Even today, this accounts for the highest demand and use of wood in many developing countries. A period of significant advances in industrial processing occurred during the Industrial Revolution. Among these advances in the United States was the construction of trans-continental railroads, which created the need for crossties and switch ties. As industrial technology advanced, wood was used more frequently in exterior structural applications. Wood species that did not possess inherent decay resistance properties failed in service due to biological attack, creating a need for preservative-treated wood. Several historical treatises on wood preservation can be found in the literature (Hunt and

Garratt 1967, Graham 1973, Wilkinson 1979, Barnes and Murphy 1995).

The earliest U.S. patent for a wood preservative was that issued by the Province of South Carolina to Dr. Wm. Crook in 1716 for “. . . Oyle or Spirit of Tarr . . .” In the 1700s, mercuric chloride and copper sulfate were first recommended, while zinc chloride was recommended as a wood preservative in 1815. A major development in wood preservation history was the use of coal-tar creosote, which was patented in 1836 by Moll, in a pressure impregnation process patented by John Bethell in 1838. Known as the Bethell, or full-cell, process, it was the first major use of pressure for wood treating and remains the basis of most modern wood treating operations. The process utilizes an initial vacuum period followed by filling of the cylinder with preservative and application of a pressure period to inject the preservative. A modern-day modification called the modified full-cell utilizes an initial vacuum of lower intensity and shorter duration along with a final vacuum period. In 1847, a similar pressure system was used with zinc chloride in what would be called the Burnett treatment.

The Boucherie Process developed in 1839 provided the basis for modern-day sap displacement methods such as the SlurrySeal® Process, PresCap®, and Gewecke methods. In 1874, Julius Rütgers of Mannheim, Germany, developed a process for treating wood with zinc chloride and creosote, which was later modified by J.B. Card (Hunt and Garratt 1967) in 1906 in the United States and used until the mid-1920s to treat crossties. Other full-cell treatments developed in the late 1800s to early 1900s, but no longer in use, include the Allardyce treatment, Creoaire treatment, and the Wellhouse method. In 1884, Boulton published his classic work “On the Antiseptic Treatment of Timber,” which provided the basis for the boultonizing process for seasoning wood.

The high price of oil made the creosote process expensive, so an empty-cell process was developed by Max Rüping of Germany, and patented in 1902. This process utilizes an initial application of air pressure (usually 30 to 50 psig) before filling the cylinder and applying a higher pressure (usually 100 psig above the initial air pressure) to inject the preservative. After release of pressure, the excess preservative in the cell lumen is “kicked back,” resulting in a much lower retention than the conventional full-cell treatment. An extended steam flash and vacuum period applied after removal of preservative solution completes the process. This step reduces the amount of entrapped air and hence bleeding of preservative, yielding a much cleaner treatment. A second empty-cell treatment patented by C.B. Lowry



Creosote-treated wood products have been instrumental in the development of the U.S. railroad industry.

in 1906 utilizes atmospheric pressure as the initial air pressure. Both processes provide for impregnation of wood with a relatively large amount of creosote and subsequent withdrawal of part of the oil, giving a smaller final retention of preservative than the Bethell Process. The process is used when deeper penetration but less retention is required.

In the United States, the first Bethell-Process plant was built in 1865 in Somerset, Massachusetts. The first commercial plant for waterborne salt treatments was built in 1848 in Lowell, Massachusetts, for Kyanizing (soaking in mercuric chloride) timbers. The advent of modern timber preservation in the United States is linked to the railroads and the production of crossties by the L & N Railroad at a plant in West Pascagoula, Mississippi, in 1875.

Many modifications to the basic full- and empty-cell processes have been used to treat wood. In Australasia, the Oscillating Pressure Method (OPM), a method employing rapid cyclical oscillation between vacuum and pressure, has been used to treat refractory wood species. A multi-Lowry process, the Alternating Pressure Method (APM), was also developed to treat green or partially seasoned wood with CCA. The High Pressure (HP) method was developed in Australia to treat crossties at pressures as high as 1,000 psig. The Pulsation Process is similar to the APM Process except that the pressure is never fully reduced to atmospheric during the cycle and the pressure is increased during each oscillation. In Scandinavia, the use of an overlaying oil treatment on wood treated with waterborne preservatives constitutes the Royal Process. In the United States, the MSU Process was developed to treat wood with CCA using an empty-cell cycle while providing for *in situ* fixation of the preservative components. The Multiple-Phase Pressure (MPP) Process is very similar to the fixation mode exemplified in the MSU Process (Nasheri

et al. 1999). This system, specifically developed for CCA in New Zealand, requires a minimum of equipment and poses an interesting option for the future of CCA. One problem with this system is the potential for sludging. The MCI Process utilizes a heated expansion bath on the end of a conventional empty-cell process to fix copper in wood treated with copper carboxylate preservatives. Other approaches, notably the Cellon® and Dow Processes, utilized a change in carrier systems to obtain clean, non-oily treatments with pentachlorophenol.

The Vacuum Process is used for some millwork applications, and is also employed to produce very inexpensive fence posts. Many vacuum plants located in Missouri use vacuum only and regularly achieve a minimum of 67 percent of the desired retention and penetration of most woods as specified by the American Wood-Preservers' Association (AWPA). A vacuum-only plant can be built for less than \$100,000, including concrete work. The Double Vacuum Process is used almost exclusively for millwork/joinery. It consists of two vacuum periods in which the treating fluid, usually AWP Type C or LOSP, can be used to successfully penetrate the small dimension pieces. The second vacuum allows the wood to partially equalize in order to be ready to receive more fluid.

Copper naphthenate has been used as a wood preservative since 1889. It was first used in Germany and has been in commercial use since 1911. It was recognized in the AWP standards in 1949, but did not gain wide use for pressure treatments until the late 1980s, when regulatory activities stimulated interest in the product because of its general use classification. Soon thereafter, copper naphthenate began to be used for cross arms, bridges, utility poles, fence posts, and lumber. Copper naphthenate is also used in non-pressure applications such as field-applied preservatives and coatings.

CCA was patented by Kamesam in 1938 and is the major preservative in use today. Three forms were standardized by AWP: type A in 1953, type B in 1964, and type C in 1969, with type C dominating the marketplace today. The three types differ in their ratio of Cu:Cr:As. An additional acidic system, acid copper chromate (Celcure™) was patented in 1928 by Gunn and was standardized in the 1950s.

The other major arsenical preservative, ammoniacal copper arsenate (ACA), was standardized in 1950. Known under the trade name Chemonite™, it was modified by replacing some of the arsenic with zinc in the 1980s; this formulation is known as ACZA. Because ACA and ACZA are alkaline and imbue the wood with vivid color, they have generally been used for industrial products and are used to treat refractory western conifers.



Oriented strandboard mat ready for pressing

During the early 1930s, Dr. Carl Schmittutz of Bad Kissingen, Germany, organized the Osmose Wood Impregnating Company of Leipzig, Germany. The original Osmose patents described a preservative process using sodium fluoride, potassium bichromate, sodium arsenate, and dinitrophenol. This preservative was known in the industry as FCAP. Penetration of preservatives was achieved through the process of diffusion or "osmosis" into green wood or wood of high moisture content. One early commercial use of this preservative in the United States was a timber dipping and stacking process used by coal mines (McNamara 1990, Osmose 2003).

Boron compounds offer some of the most effective and versatile wood preservative systems available today, combining the properties of broad-spectrum efficacy and low acute mammalian toxicity. Products treated with borates include the following: lumber and plywood, oriented strandboard (OSB), siding, engineered wood, wood-plastic composites, millwork, windows, doors, furniture, telephone poles, railroad ties, and log homes (U.S. Borax 2003). Remedial systems using boron are common in the marketplace.

Another historically important preservative is pentachlorophenol (penta), which is a crystalline chemical compound (C_6Cl_5OH) formed by the reaction of chlorine on phenol. It is a widely used oil-borne preservative. British patent 296,332, issued in 1928 to W. Iwanowski and J. Turski, covers the use of di-, tri-, and polychlorinated phenols for wood-preserving purposes. In 1929 in the United States, L.P. Curtin patented the use of "chlorine derivatives of coal-tar acids of higher molecular weight than the cresols" (U.S. patent 1,722,323) expressing a preference for chlorinated phenols. The production of chlorinated phenols in the United States for wood preserving experiments did not begin until about 1930 (Hunt and Garratt 1967).

The Present

According to Micklewright (1999) and the more recent 2000 Southern Forest Products Association (SFPA) treated wood survey (Wade and Mason 2002) CCA (and small amounts of ACZA in the West and Midwest) are used to protect 80 percent of the lumber that is preservative treated for residential applications. About 7.63 billion board feet (BBF), or 44 percent of the 13 BBF of southern yellow pine (SYP) lumber produced, is pressure treated with some type of preservative system. CCA is inexpensive, highly effective, and poses negligible risk when used for residential and garden construction, outdoor furniture, and playground equipment. Regardless of CCA's excellent performance and environmental record, public perceptions regarding potential arsenic exposure have led to a voluntary withdrawal of CCA-treated wood from the residential market (with the notable exception of wood treated for permanent wood foundations) by 2004 in the United States and in Canada. This represents a potential market share loss of 68 percent for CCA-treated wood. CCA has already been limited in over 26 other countries. Most European countries have already limited CCA use with further restrictions being considered. Japan has changed to preservatives that do not contain either arsenic or chromium. Currently, three commercially available non-arsenical systems appear poised to replace CCA for residential applications: alkaline copper quat (ACQ), amine copper azole (CA), and copper bis-(N-cyclohexyldiazoniumdioxy) (Cu-HDO or copper xyligen). Excellent technical discussions of the newer preservative systems and their properties and applications can be found in the literature (Nicholas and Shultz 1995, Goodell et al. 2003).

One of the most exciting new treating technologies is based on the suggestion by Scheurch (1968)



Southern yellow pine timbers being prepared for treatment.



Treated lumber ready for shipment.

that treatment in the vapor phase could mitigate problems that occur when treating with liquids. All treatments in the liquid phase depend upon the movement of liquid preservative into the wood. Two problems must be overcome in order to get deep, uniform treatment. First, tension forces at the liquid-air and liquid-wood interfaces must be overcome. Secondly, transverse movement is dictated by the permeability of pit membranes. Gas phase treatment would seem to eliminate both of these major problems. The possibility of putting protectants into the cell wall using such an approach would mean that smaller amounts of biocides would be needed, thus further minimizing the impact on the environment. Gas-phase treatments have been used extensively for remedial treatment of wood in service (Morrell and Corden 1986, Morrell et al. 1986), but efforts to modify wood using gaseous reagents have met with only moderate success (McMillin 1963, Barnes et al. 1969). Reaction with alkylene oxides has yielded some decay and termite resistance (Rowell and Gutzmer 1975, Rowell et al. 1979).

Vapor phase boron treatments have been applied as primary treatments for wood and wood-based materials (Murphy et al. 2002). In this treatment, trimethyl borate is heated and introduced into an evacuated cylinder containing dried wood or engineered composites. Diffusion is rapid and penetration is complete. The main advantages of the process are the speed and cleanliness of treatment and the potential for drying, treating, and conditioning in a single vessel. The supercritical CO₂ fluid treatments presented by Evans (2003) and based on ongoing research in Japan and the United States take vapor phase treatments one step further by eliminating any problems caused by the phase of the carrier solvent. Other approaches to improving treatability, especially for refractory species, include mechanical, biological, and microwave pretreatments. A recently patented mechanical stressing process (Amburgey et al. 2000) may have application in the future.

Future Challenges

Mold

Mold growth in homes has not necessarily increased in recent years, but new court cases involving mold, sensationalistic media coverage, and publication of questionable scientific research have increased public awareness of the issue (Robbins and Morrell 2003). Much of the recent concern about mold was aroused after several articles on the subject appeared in scientific journals. One of the most widely publicized articles was written by researchers from the U.S. Centers for Disease Control (CDC). They reported that in 1993 there were 10 cases of acute pulmonary hemorrhage/hemosiderosis in infants, some of whom died, that was thought to be linked to the mold *Stachybotrys chartarum* (also known as *Stachybotrys atra*) (Robbins and Morrell 2003). It was later determined there was no evidence or scientific proof that *Stachybotrys* caused the health problems in these infants (CDC 2000a). In fact, the CDC notes: "At present there is no test that proves an association between *Stachybotrys chartarum* (*Stachybotrys atra*) and particular health symptoms." (CDC 2000b) It appears as if good moisture control could solve most mold problems. The mold issue has only become a problem because the public now perceives it as a severe health threat, and attorneys are bringing the issue before juries to seek large judgments.



Mold and decay are the result of moisture that accumulated in this wall.

Photo by T.L. Amburgey, Mississippi State University

Formosan Subterranean Termites

The Formosan subterranean termite (FST) has done tremendous damage to cellulose-based products. The majority of the damage has occurred in the U.S. South and Hawaii. It is estimated that the FST causes some \$300 million in damage per year in the Greater New Orleans Metropolitan Area (McClain 1999). In 1993, the Wood Protection Council of the National Institute of Building Sciences (NIBS) estimated the annual cost of replacing wood damaged by the FST to be \$2 billion, up from \$750 million in 1988 (Ring 1999). These tremendous losses caused by the FST have renewed interest and attention in the research area of wood durability. The public is now demanding preservatives that have a high degree of efficacy against the FST and other wood-destroying organisms, while also requiring that the preservatives are safe.

Engineered Wood Composites

Most prognosticators agree that engineered wood composites (EWC) will be the wave of the future. These products pose special problems if we are to increase their durability. The successful marriage of a biocide and EWC must consider the effect of the biocide on the chemical interaction with the resin used, the physical properties of the composite, the distribution of biocide within the product, the efficacy of the treated composite, and the effect of manufacture on EWC properties. Newer treatment technologies will need to be developed and refined and the workplace environment will need to be considered.



Wood damaged by the Formosan subterranean termite is surrounded by carton material produced by the termites.

Photo by T.L. Amburgey, Mississippi State University

Other Considerations

It has been suggested that companies that are considering developing and marketing environmental technologies such as ACQ, CA, and Cu-HDO can't simply tout environmental advantages. They must show that the new alternative does the job just as well for the same cost or less. The companies also have to convince suppliers and distributors to make changes to transition to this alternative. Further, they must also work with wood treaters to install new equipment for new generation systems and they must convince wholesale and retail distributors to carry the new product line.

There is a threat that wood will lose market share to substitutes. Areas that have been greatly impacted by the FST are often very vulnerable to this threat. For example, the area in and around New Orleans, Louisiana, has been targeted by the North American Steel Alliance, Inc. for a new marketing campaign. Some homeowners who have had serious structural damage to their houses have vowed not to rebuild with wood. The North American Steel Alliance, Inc., is offering a guarantee against insects and fungi, as well as emphasizing that there is no arsenic exposure with their product.

The Need for Public Education

In 2002, the Environmental Protection Agency (EPA) transition away from CCA-treated wood for non-industrial uses had been announced but not yet implemented. At that time, homebuilders were surveyed to elicit perceptions regarding treated wood (Vlosky and Shupe, in review). Respondents were asked if they were aware of the (at that time) pending EPA change. Fifty-eight percent of respondents fell on the "not aware" side of the midpoint of the 5-point awareness scale used in this question, with 43 percent not being aware at all. Only 5 percent of respondents were "very aware." As a follow-up question, respondents were asked what effect they expected from a switch to "new generation" preservatives for both them and their customers. Forty-nine percent did not know what the effect might be. But 53 percent of respondents said that they had concerns about using treated wood in homes they build. The greatest concern is the perceived health risk followed by a closely related concern: long-term exposure to treated wood. One-third of the respondents were not familiar with treated wood consumer information sheets. Nearly a third of respondents believed that some types of treated wood are safer than others and over half were unsure.

A companion study surveyed owners of newly built homes regarding their attitudes toward treated wood (Vlosky and Shupe 2002). In that study, it was found that only 5 percent of respondents had a negative perception of treated wood and 75 percent were willing to use treated wood in their homes. Of those who were unwilling to use treated wood in their homes, health concerns were the major reason. There was a general misunderstanding among respondents regarding treated wood: 49 percent of respondents reported no understanding of the concept of wood treating; 45 percent didn't believe that using treated wood could reduce deforestation; 79 percent reported that they did not have knowledge of treated wood consumer information sheets; 60 percent desired additional information on treated wood. Only 27 percent of respondents trusted claims made by treated wood manufacturers, indicating that there is work to be done in this arena.

From these two studies, it is evident that U.S. homebuilders and homeowners currently use and have plans to continue to use treated wood. However, there is a general misunderstanding of the properties of treated wood, which may be the cause of consumer safety concerns and their lack of trust of information coming from the wood treating industry. The treated wood industry is currently not providing enough education and promotion to homebuilders and homeowners. If these studies and the previous issues mentioned tell us anything, they should indicate the clear need for good information based on science and not innuendo or perception.

What Does the Future Hold?

The future for wood preservation looks very bright indeed! We are already seeing many new wood substitutes for solid treated wood, including engineered wood composites like wood-plastic composites and products such as preserved oriented strandboard (OSB), laminated veneer lumber (LVL), and parallel strand lumber (PSL.) All of these products will need to use both new and existing preserving technologies to prevent the colonization by decay organisms, and infestation by wood-destroying insects. Even wood-plastic composites, which are still 40 to 60 percent wood fiber, will need to incorporate active biocides to insure that they will be long-term useful building materials. Evaluation of wood-plastic composites already in service has found that those without biocide incorporation have exhibited both mold and fruiting bodies after exterior exposure.

Many new methods of wood preservation will include innovative processes. We have just begun the possibility of modifying wood properties to perform such needed tasks as dimensional stability to minimize the effects of moisture and moisture-temperature changes. Dimensional stability has long been the holy grail of wood treatments and will likely continue to be so into the future. A few of the new processes (e.g., supercritical fluid treatment) will allow us to broach the physical and mechanical limitations of treating with conventional liquid treatments by exploring the nearly limitless possibilities of treating with a liquid that penetrates a substrate like a gas, or using vapor phase technology to impregnate wood with a diffusible product, like boron, without significantly altering the dimensional properties of the wood.

The public perception of potential arsenic exposure is having an effect, but as long as arsenical chemistry is allowed for wood preservation, we will continue to see research that focuses on possible methods of minimizing leaching of arsenic into the environment. Recently, we have also begun to see environmental pressure on benign elements, like copper. Copper-based pesticides have begun to experience some environmental pressure in certain areas of the world due to aquatic toxicity, although copper continues to be the most widely used fungicide in the world for protection of both wood and agricultural crops. Professionals in the field of wood preservation feel that copper-based preservation technology will continue to be dominant for water-based treatment for at least another decade, but the development and use of all-organic biocides continue to be of interest to all those in wood preservation research.

Summary and Conclusions

Modern wood preservation is barely two centuries old. Wood, being the most versatile building material that has ever been utilized, will continue to need protection from degrading factors, like decay, insects, and fire. Significant growth in this industry has been seen in every single decade since Bethell originally impregnated timber with creosote in the 1830s.

The use of newer process technologies holds promise for new wood preservatives, and breaks ground for modern advances in commercial production plants, and innovation in research opportunities. There is an increasing need to educate the consumer regarding new wood-treating chemistries and new products.

By December 31, 2003, the voluntary cancellation of arsenically treated wood for residential and consumer use in the United States and Canada will take effect. These products will likely be replaced by more expensive preservative systems. Therefore, while the actual volume of wood being treated may decrease due to product substitution (e.g., plastics), total market dollar volume will increase because the new alternatives are more expensive.

A recent survey showed that most of the southern pine lumber produced in the United States is pressure-treated with wood preservative compounds. The widespread use of wood preservatives greatly extends the life of wood products and allows us to reduce the environmental impact of cutting more forestland. The old forest products saying of "conserve the forests by preserving the wood" can sometimes best summarize it.

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