Tru-Core® Protection System for Wood

December 30, 2011

Primary Sponsor: Kop-Coat, Inc.
436 Seventh Avenue
Pittsburgh, PA 15219

Contact Person: Alan S. Ross, Ph.D.
Technical Director
Kop-Coat, Inc.
3020 William Pitt Way
Pittsburgh, PA 15238
412-826-3387
asross@kop-coat.com

Tru-Core® Protection System for Wood

Recent Milestones:

- **U.S. Patent 7,896,960** "*Method of Protecting Wood Through Enhanced Penetration of Wood Preservatives"* issued March 1, 2011.
- **U.S. Patent 7,655,281** "*Method of Protecting Wood through Enhanced penetration of Wood Preservatives and Related Solution"* issued 2/2/10.
- **Tru-Core® Millwork Preservative** approved for registration under FIFRA by the U.S. EPA 8/30/10 (EPA Reg. No. 60061-133).
- **Tru-Core® Millwork Treatment** approved for use by the WDMA (Window and Door Manufacturers Association) under the Hallmark Certification Program (10/27/10).
- **Tru-Core® Type 1 Treated Wood Preservative System** approved for use in the Hawaiian Building Codes for protection of lumber and engineered wood against decay and Formosan termites (8/18/10).
- **Tru-Core® treatment system** used commercially in the treatment of railroad crossties for the Burlington Northern Santa Fe, CSX and other U.S. Railroads (2010).

.

Eligibility: The nominated technology is not eligible for the Small Business Award or the Academic Award. The nomination is by an industry sponsor.

Award Category: Focus Area 3, The Design of Greener Chemicals.

Aspects of the technology occurring within the U.S.: Development of the invention, laboratory feasibility studies, pilot testing, filing for and award of patent, FIFRA registration with U.S. EPA, manufacture of chemical components, and commercialization. The technology has also been commercialized in New Zealand and Australia; however, all major chemical components are manufactured in the U. S.

Abstract:
Wood is the most widely used residential building material in the United States with many environmentally positive characteristics. It is an excellent carbon sink, has low embodied energy and a high degree of sustainability. One of its few shortcomings is its relative lack of durability compared to other building materials due to its susceptibility to decay and insect attack. Durability can be significantly improved through treatment with wood preservatives and insecticides; however, methods for delivering these protectants into wood are still largely based on old technologies which are environmentally deficient. The Tru-Core® Protection System was developed to address the need for treating wood in an environmentally positive manner. It incorporates the principles of green chemistry in several different ways. For example, most conventional treatments for wood windows and doors utilize petroleum-based solvent carriers such as mineral spirits. The Tru-Core® process utilizes water as the carrier, resulting in a significant source reduction of an organic solvent which is an air contaminant and VOC. Because the Tru-Core®

process uses only a small amount of water to carry the preservatives, it also eliminates the energy intensive step of re-drying after treatment.

The Tru-Core® system embodies a unique chemical infusion process that incorporates non-volatile, polar bonding carriers (amine oxides) in water to penetrate the cellular structure of wood and to deposit and bind wood protection chemicals (preservatives and insecticides) within the substrate. The penetration and binding are controlled using buffers such as borates which maintain a basic pH. This basic pH system inhibits the natural acids present in wood, allowing the amine oxides and preservatives to rapidly penetrate.

The Tru-Core® technology was awarded U.S. patents in 2010 and 2011 and was registered as a wood preservative treatment by the U.S. EPA. It has had significant commercial success in the U.S. and other countries due to its ability to effectively, economically and environmentally extend the service life of wood, an environmentally positive building material in its own right.

Tru-Core® Protection System for Wood - Detailed Description of the Technology

The Problem it Addresses:

Unfortunately, in spite of its positive green attributes, wood suffers from a significant shortcoming compared to other major building products. It is susceptible to degradation in service from decay fungi and attack by insects such as termites. This threat to the service life of wood has resulted in a loss of market share of wood products to building materials which are less green but are not prone to decay or insect attack. Some examples of this are the increasing uses of steel framing, cement-based siding and shingles, plastic decking and vinyl windows in residential construction applications once dominated by wood.

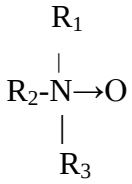
For over 100 years, the forest products industry has utilized chemical treatments to improve wood's resistance to decay organisms and insects in order to extend its service life. Regrettably, some of the historic chemical treatments such as pentachlorophenol and chrome-copper-arsenate (CCA) had significant health and environmental issues of their own. In recent years, chemical treatments have been developed which are more environmentally acceptable in that they do not rely on toxic heavy metals or persistent organic molecules. However, the methods of delivering these preservatives into the wood are still largely based on nineteenth century technology. They often employ long pressure or vacuum treating cycles making these processes cumbersome, time consuming and energy intensive. Moreover, some of these conventional processes utilize volatile petroleum-based solvents, such as mineral spirits, as their carriers. These factors tend to negate many of the green attributes of treated wood as a residential building material.

Tru-Core® Technology:

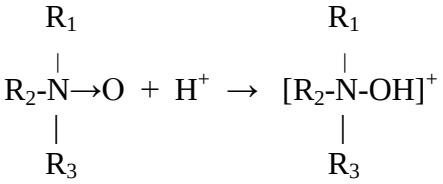
The Tru-Core® Protection System is one of the few unique treating processes introduced commercially in the past 50 years. It was the subject of two U.S. patents granted in 2010 and 2011 as "an improved method of effecting enhanced penetration of wood

preservatives into wood". Other patents are pending. The patents recognize that buffered amine oxides are a completely novel invention for enhancing the penetration of protectant ingredients into wood. This technology offers many advantages over conventional methods of wood treatment, as will be detailed in a later section. Wood is a very complex material, in both its chemical and physical structure. It has both crystalline and amorphous regions and contains a number of constituents including cellulose, hemicellulose, lignin and extractive oils. Typically, it is very difficult to achieve penetration of organic molecules beyond the surface of wood without the use of mechanical-physical means such as pressure or vacuum treatments. The Tru-Core® system, however, utilizes chemistry to drive the penetration of desirable compounds deep into the substrate.

There are four components to the Tru-Core® Protection System. The first component consists of an amine oxide, preferably a tertiary amine oxide. These compounds are formed as reaction products of tertiary amines and hydrogen peroxide and are widely used for their excellent surfactant properties. They are somewhat unique in that the nitrogen-oxygen bond is a coordinate-covalent bond in which both electrons come from the same atom. This bond is usually represented by an arrow, as in the structure below, where R_1, R_2 and R_3 are alkyl groups.

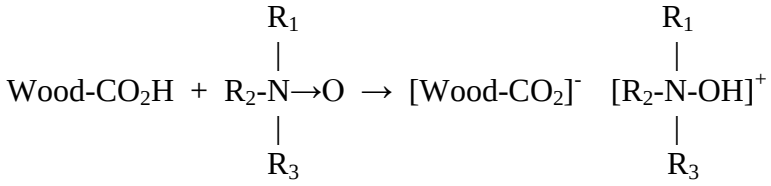


Amine oxides are highly polar molecules, having a polarity close to that of quaternary ammonium salts. Lower molecular weight amine oxides are very hydrophilic and have excellent water solubility. Amine oxides are weak bases and are protonated in acid solution according to the following equation:



The rate and completeness of this reaction will depend on the strength of the acid. The knowledge of this chemistry can be used advantageously in wood treating systems. Wood contains mildly acidic sites such as the carboxyl groups present in both the cellulose and lignin. Therefore, one can treat with the nonionic version of the amine

oxide and expect that conversion to the cationic form will occur in the wood resulting in chemical fixation of the amine oxide as expressed in the schematic equation below:



Fixation studies carried out using sawdust indicate that the amount of amine oxide found in wood exposed to a neutral or alkaline solution of amine oxide in water is less than for an acidified solution. Penetration of the amine oxide into the wood is inversely related to the fixation rate. Therefore the use of an amine oxide in a neutral or slightly alkaline formula will maximize penetration. Conversion to the protonated form in the slightly acidic pH environment of the wood will subsequently result in fixation.

In the Tru-Core® system, the slightly alkaline pH is provided by the second major component, a buffer. While a number of different buffering systems can be used, it has been found that a mixture of boric acid and sodium borate pentahydrate provides a pH of 7 to 8, which allows the amine oxides to rapidly penetrate the surface of the wood.

The third major group of constituents of the Tru-Core® system consists of the wood preservatives and insecticides which ultimately provide the main protection to the wood against decay fungi and insect attack. These are organic (carbon-based) molecules which are typically introduced in the form of water-dilutable emulsifyable concentrates. Examples of wood preservatives used with this system include 3-Iodo-2-propynyl butlycarbamate (IPBC), propiconazole and tebuconazole. Examples of insecticides used with this system include permethrin and imidacloprid. The amine oxides, due to their high polarity and excellent surfactant properties tend to help disperse these organic components in the treating solution and may partially solubolize them. Importantly, the amine oxides act as carriers for these ingredients in the Tru-Core® system resulting in many cases, in their complete penetration. However, use of amine oxides without the buffering system does not result in enhanced penetration demonstrating that the technology is more than a simple surfactant system.

The fourth constituent of the Tru-Core® system is water which is the carrier. Water is commonly used as the carrier for preservatives in pressure-treating systems, as well, but the difference here is in the amount of water taken up by the wood. In conventional pressure treatment, it is not uncommon for wood to pick up 100-150% of its weight in water. Before the wood can be used, most of the water must be removed by air drying or kiln drying. Air drying can take several weeks and is very uneconomical due to the extra handling and time required. Kiln drying is also costly because it is energy intensive. In either case, once the wood has been pressurized with that large amount of water, it is often physically damaged. Checking, splitting, grain raising and warping often occur resulting in losses due to material of unacceptable appearance or properties. In contrast, the Tru-Core® process introduces only 2-3% of additional moisture into the wood

because it is chemically driven rather than physically driven. This low level of added moisture has little effect on appearance or physical properties of the treated wood resulting in little or no loss. Moreover the treated wood can be used or subjected to further processing or painting without the need for additional drying.

Unlike conventional pressure or vacuum treatment of wood, where the treating cycle can take many hours and the drying cycle many days, Tru-Core® treatment of wood or wood-based composites is accomplished in seconds through rapid dip, flood coat or spray application of the treating solution. Treatment can take place at ambient temperatures. However, the treating solution can also be mildly heated (55-65° C) to effect more rapid penetration of the active ingredients into the wood. Once treated, the wood is usually stacked and covered with a plastic tarp for 12-24 hours. This "activation" period allows the penetration and fixation processes described above to be completed. As noted previously, after the brief activation period, the wood is ready for use or for further processing or painting.

Comparison to existing technologies:

- **Termite Resistance – Results of 2-year efficacy results in Hawaiian exposure study -** Boards of lodgepole pine lumber (50mm x 100mm x 450mm) were treated as follows: 1)no treatment; 2)pressure treatment with ACQ (a standard commercial treatment); 3)pressure treatment with borates (a standard commercial treatment); 4)Tru-Core® treatment (30 second dip + conditioning). Replicate samples were installed at the University of Hawaii Formosan termite exposure site near Honolulu. Samples were monitored at 12 and 24 months exposure and rated by University of Hawaii researchers on a scale of **0** – (complete failure) to **10** – (no attack). Results after 24 months exposure are as follows: 1) no treatment - **1.80**; 2) ACQ pressure treatment – **9.15**; 3)borate pressure treatment – **8.00**; 4)Tru-Core® treatment – **10.0**. These results demonstrate the superior performance of the Tru-Core® treatment system against Formosan termites compared to standard pressure treatment systems. Similar results have been obtained in fungal decay resistance testing.
- **Speed and Cost –** Wood can be treated with the Tru-Core® system in seconds with full activation (penetration) occurring in 12-24 hours. This contrasts with conventional pressure treatment and vacuum treatment, where the treating cycles can take many hours and drying can take days to weeks. Dip diffusion is mainly used for treating products such as log home logs and can take 6-12 weeks. Due to the efficiency of the process and greatly reduced handling requirements, **Tru-Core® treatment is less than one quarter the cost of the closest competing treatment technology**.
- **Penetration –** Tru-Core® treatment can penetrate most wood species to the core whether or not the wood consists of heartwood, sapwood or is green or kiln-dried before treatment. Pressure and vacuum treatments must generally be used on wood which is pre-dried and they do not typically penetrate the heartwood portion of many species. Tru-Core® has been shown to fully penetrate a number of wood species that are considered difficult to penetrate (refractory) using conventional treatment methods. These include Douglas fir and spruce. Finally, Tru-Core®

treatment has been demonstrated to penetrate resins and glue lines in wood composites such as laminated veneer lumber (LVL) and oriented strand board (OSB). These engineered wood products cannot be easily treated using alternative methods.

Experimental Results - In a typical experiment to demonstrate the superior penetration of Tru-Core® components into wood, boards of Radiata pine (30mm x 100mm x 6 ft) were dipped for one second in a water-based Tru-Core® treating solution containing borates, amine oxides and the fungicide IPBC. Control boards were dipped for one second in a mineral spirits-based treating solution containing the same concentration of IPBC. Boards were covered with plastic for 24 hours then allowed to air dry for 48 hours. A cross sectional slice of 10mm thickness was cut from the center section of each board. A center core sample of 20mm x 20mm was then cut out of each slice. These center core samples represent the area at the center of each board. Analysis of IPBC concentration in each center core was conducted by the Ecole Polytechnique in Montreal using neutron activation analysis. Ten replicate samples were measured for each treatment. The core samples from the Tru-Core® treated boards had an average IPBC concentration of 24 ppm, which is a biocidally effective level. The core samples from boards treated with IPBC in mineral spirits had no detectable levels of IPBC in any of the samples tested.

- **No Adverse Effects on Wood –** Unlike waterborne pressure or vacuum treatments, the Tru-Core® process does not introduce large amounts of water into the substrate (2-3% versus up to100-150% for pressure treatments). As a consequence, Tru-Core® treatment has no adverse effects on wood properties and appearance such as checking, warping, cracking, grain raising or strength loss as is often the case with the alternative treatment methods.

In addition to theses practical advantages over conventional treatments (which have indirect green consequences)**,** Tru-Core® offers a number of specifically green advantages over the conventional treatments. These are as follows:

- **No Use of Petroleum-Based Solvents –** Unlike other treating systems**,** Tru-Core® contains no petroleum-based organic solvents. The chemicals used in the Tru-Core® process have no VOC's and are not flammable. The Tru-Core® system also improves the use of natural resources by substituting water for the petroleum-based solvents used in solvent-based treatments.

  Potential Environmental Benefits – Taking just one example of potential environmental benefits for the Tru-Core® system, the preservative treatment of wood windows and doors: Approximate annual use of petroleum-based solvents by this industry is 700,000 gallons (4.5 million pounds). Assuming half of this amount is not recaptured or scrubbed before being emitted, the result is over 2.25 million pounds of VOCs emitted annually. Use of Tru-Core® would be practical for about 90% of this application resulting in a source reduction of over 2 million pounds of VOCs annually. This example is for a single industry.
- **Globally Recognized Ingredients –** All of the active ingredients utilized in the Tru-Core® protection system are recognized and registered by major global regulatory agencies such as the U.S. EPA. The FIFRA- registered fungicides

include IPBC, propiconazole and tebuconazole. These fungicides have low acute mammalian toxicity levels, are not carcinogens, mutagens, teratogens or sensitizers and they biodegrade rapidly in bioactive soil or water. The FIFRA-registered insecticides used with the Tru-Core® protection system, Permethrin and Imidacloprid also have relatively low acute mammalian toxicity levels, no major adverse long-term health effects and are readily biodegradable. The major non-pesticide ingredients in the Tru-Core® protection system are the borates and the amine oxide. Borates have very low mammalian toxicity levels, exhibit no adverse chronic effects and are considered environmentally benign. Amine oxides have a similarly positive health, safety and environmental profile. While all chemicals and certainly all pesticides carry some level of risk if improperly used, the components of the Tru-Core® protection system were specifically chosen to provide the least amount of potential risk to human health or the environment. It should be noted that many pressure treating systems rely on copper as their main fungicide. While copper has relatively low human toxicity, it is still a persistent heavy metal with some consequences to water quality at higher levels.

Recent Commercial Success:

In 2011, the Tru-Core® technology was used in the dual treatment process for approximately 2 million railroad crossties. Its use is being expanded into 5 of the largest tie treating plants in the U.S. Using this process, ties can be fully treated with a borate core and a creosote shell in about 8 hours. This replaces a dip/diffusion treatment which required 6-8 weeks of diffusion and 4 weeks of air drying. In Hawaii, Tru-Core® treatment with borates and Permethrin is rapidly replacing LOSP pressure treatment to protect LVL beams and I-joists from termite attack. Tru-Core® Type 1 has been accepted into the Hawaiian Building codes and is currently undergoing evaluation by ICC-ES for acceptance into the 2012 International Building Code.

Conclusions:

- The nominated technology (Tru-Core® Protection System for Wood) is based on a chemical technology which is original and scientifically valid as evidenced by its being recently granted two U.S. patents (with others pending) and its being adopted by organizations such as the WDMA and the Hawaiian Building Codes.
- The nominated technology improves upon the properties of wood, one of the greenest building materials available, by rendering it resistant to attack by decay fungi and insects, thus lengthening its service life.
- The nominated technology involves design and implementation of a treating process driven by this unique chemistry. As such it is less toxic than competing technologies (no petroleum solvents or heavy metals), inherently safer than these competing technologies (no flammable solvents), safer for the atmosphere (no VOC's or Air Toxics) and involves components which are all biodegradable. The treated wood itself is also biodegradable or recyclable after use.
- The nominated technology is more cost-effective than most competing wood treating technologies. This is evidenced by its rapid, high level of commercial success in a variety of treating applications.