NOVEL PRESSURE PROCESSES FOR TREATING WOOD WITH PRESERVATIVES

by

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Summary

There are several novel approaches to treating wood with preservatives. This paper places particular emphasis on those processes which reduce environmental hazards and promote the fixation of the biocide, primarily CCA. The oscillating pressure method (OPM), alternating pressure method (APM), sap-displacement methods, modified full-cell process, and pulsation process are discussed. Particular emphasis is given to the MSU process. The impact of *in situ* or post-treatment fixation schemes is detailed.

Introduction

Traditionally, wood to be treated with waterborne preservatives has been dried before conventional Bethell (full-cell, FC) treatment (Figure 1). In a typical cycle, wood is placed in a treating retort and evacuated at maximum vacuum for 15 minutes to one hour.

The preservative is introduced under vacuum. When the cylinder is completely filled, pressure ranging from 520 to 1380 kPa (75 to 200 psig) is applied to the solution. After a specified time, the pressure is reduced slowly and the preservative is returned to the working tank. This process, patented by Bethell in 1838 (8), provides maximum solution retention and deep penetration of preservative. As a consequence, the treated wood is water-laden, often requiring post-treatment drying to reduce weight and shipping costs, minimize dripping, and fix preservative components. The net absorption with full-cell treatment generally exceeds 400 kg/m^3. The application of a saw-toothed sonic wave has reduced treatment time for southern pine (*Pinus* spp.) poles from six hours to one hour (38).

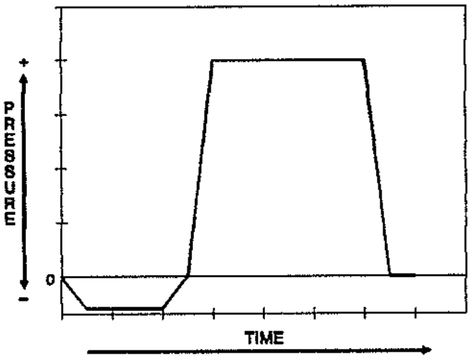


Figure 1. Typical Bethell (full-cell) process.

Modifications to this basic process were patented by Rueping (45) in 1902 and Lowry (31) in 1906. These processes eliminated the initial vacuum period and provided for a post-pressure vacuum period to yield an empty-cell treatment of wood (Figures 2, 3). Net solution absorption is on the order of 140 kg/m^3 for the Rueping process and 200 kg/m^3 for the Lowry process. As discussed later, the use of these processes with CCA preservatives occurred only after further modifications.

With this background, let us detail new or modified treatment technologies being used with waterborne preservative systems, most notably CCA. In such a discussion, the impact of new preservative systems and the advent of new pre- or post-treatment processing procedures should not be overlooked.

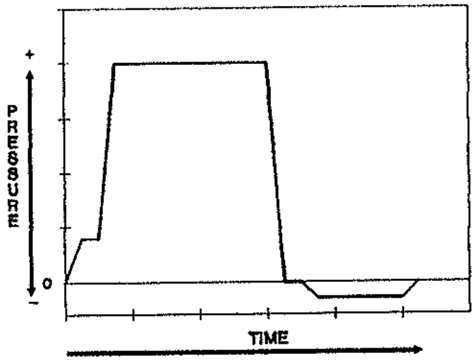


Figure 2. The Rueping empty-cell process.

Treatment Cycles

Treatment of refractory wood

Wet wood is difficult to treat by a conventional full-cell process. Before treatment, wood to be treated with CCA should be dried. Unfortunately, drying may lead to pit aspiration and other complications which reduce treatability, especially in refractory species. The reduction or elimination of this seasoning requirement has the potential for reducing costs significantly.

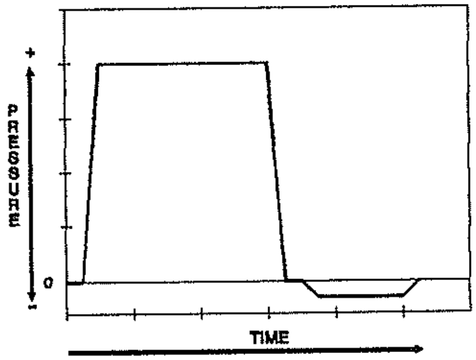


Figure 3. Lowry empty-cell treatment cycle.

Treatment of green wood has been accomplished by sap displacement using modifications of the Boucherie process. In the Gewecke modification of the Boucherie process (47,49,55), poles are fitted with suction caps driven into the end of each pole in a treating charge. The caps are attached via flexible tubes to a vacuum manifold inside the pressure cylinder. The manifold is piped through the vessel wall to the vacuum system and the wood is treated by filling the cylinder with preservative under pressure while simultaneously applying a vacuum to the manifold. This process is used extensively in Denmark to treat refractory spruce (*Picea* spp.). The major pole treater in the UK uses a similar process without vacuum to treat green spruce and Scots pine (*P. sylvestris*) poles. In this operation, the pressure differential between the applied and atmospheric pressures is sufficient to drive the preservative into the wood while pushing the sap out of the poles. A modification of this process, the Slurry-Seal method, was patented in the US by Hudson (19,20), but it has not been used commercially. Sap displacement can also be accomplished using a pressurized cap (21,23) or modification of a pressurized cap (48). Because sap displacement methods are restricted to low volume production, these methods are ideally suited to developing nations. Production volume requirements in North American markets have precluded the use of sap displacement.

Boucherie suggested that preservative retention might be improved by repeated cycles of pressure and vacuum. This led to the development of the oscillating pressure method (OPM) in Sweden in 1946 (see Figure 4) (22,53,55).

After an initial pressure period, alternating cycles of vacuum and pressure are applied to the wood. The alternating periods gradually increase in length throughout the cycle. The final cycle consists of about one minute of vacuum followed by a pressure period of about 5.5 minutes. A final vacuum similar to the full-cell cycle completes the method. This method has been used commercially in Germany and Switzerland to treat spruce and fir (*Abies* spp.).

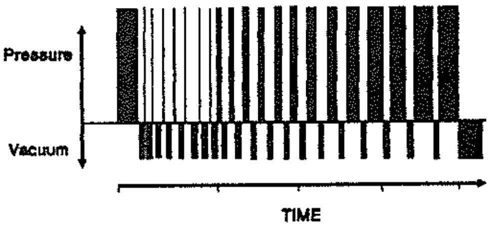


Figure 4. The oscillating pressure method (OPM) for wood treatment.

In New Zealand initial work using the OPM cycle on steam-conditioned radiata pine (*P. radiata*) (34,44) has led to the commercial use of the alternating pressure method (APM). This process (Figure 5) is essentially a multi-Lowry process using three minutes of pressure followed by venting to atmospheric pressure. After holding for one minute, the pressure is again increased. An additional minute of hold time is maintained for each successive pressure/vent cycle. The last pressure period is maintained until refusal retention is reached. Fifteen cycles have been found to be adequate for treating steam-conditioned radiata pine (6,7,52).

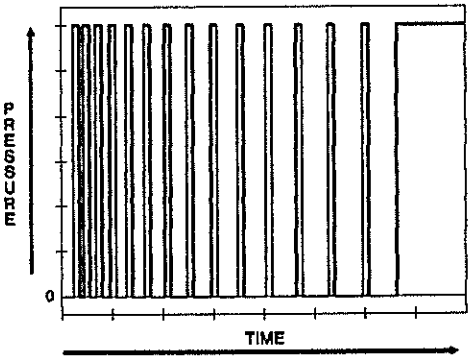


Figure 5. Alternating pressure method (APM) treatment cycle for green pine.

Steam-conditioned southern pine at moisture contents as high as 60% has been successfully treated using this cycle (1). In this work the shape of the moisture gradient, rather than average moisture content, is the controlling variable. Adequate treatment is achieved as long as the moisture gradient is relatively flat. The representative preservative and moisture content gradients shown in Figure 6 are averages for a series of APM charges which have been steam-conditioned and stored for three different periods before treatment. Note that the steepness of the preservative gradient is directly related to the shape of the moisture content gradient. These data indicate the potential for treating southern pine using the APM process. The most serious drawback to the APM process is the potential for sludge formation arising from contamination of working solutions with wood acids and sugars. This problem is minimized in New Zealand by occasionally treating a charge of wood with the full-cell process. Increased production means rapid solution turnover, thus the potential problem is minimized when a full-cell charge is treated during a shift.

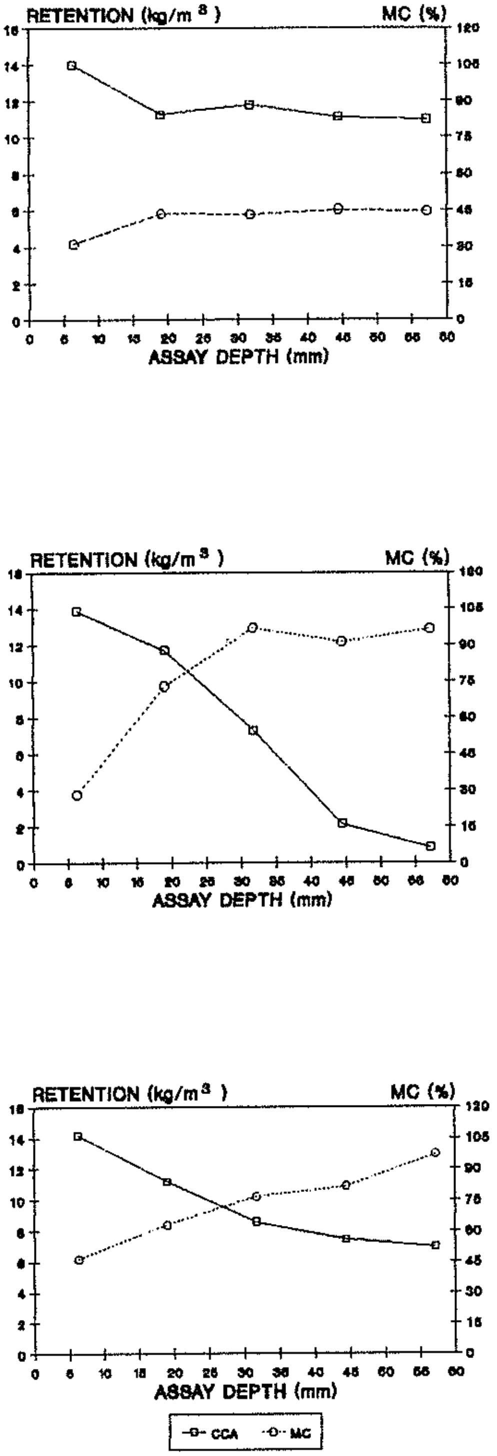


Figure 6. Representative moisture and CCA gradients for APM-treated southern pine (data from Barnes 1987).

Refractory species, such as spruce, pose a challenge to the treater. One approach has been to use pressures of 4-7 MPa, a level up to five times that of conventional processes. The early work in this area was conducted at CSIRO Australia with oilborne systems (12,26). According to Wilkinson (55), one plant in Tasmania uses high pressures to treat pipe staves with CCA.

More recently, Hösli and his coworkers (18) modified the OPM process to treat spruce with CCA using a pulsation technique (Figure 7). Drawing from experience with oilborne systems (15,16,17), the authors rapidly pulsed pressure between initial air and pressures as high as 2.1 MPa. Preservative uptake and penetration in spruce was significantly enhanced, but mechanical damage was considerable.

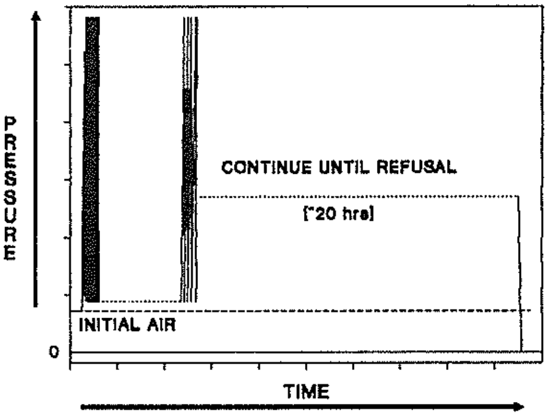


Figure 7. The pulsation cycle for treating refractory wood.

Using Bryan's work on machining with high-energy water jets (9,10) as a basis, Nearn and Megraw used high pressure jets to treat composite products with fire retardants (37). Recently, treatment of refractory softwoods with waterborne preservatives (ACA) has been accomplished using nozzle pressures as high as 413 MPa to treat western hemlock (*Tsuga heterophylla*) and ponderosa pine (*P. ponderosa*). Douglas-fir (*Pseudotsuga menziesii*) was less well treated, but field trial samples performed adequately after 13 years of ground contact exposure (25). ACA gradients in Douglas-fir stakes after exposure are shown in Figure 8 for two treatment pressures.

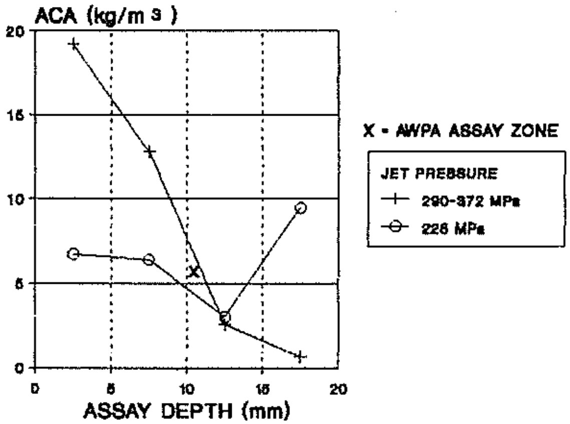


Figure 8. ACA gradients for Douglas-fir treated at two different nozzle pressures by a liquid jet treatment process (data from Jewel *et al.* 1985).

Process modifications and fixation cycles

A major innovation in the US has been the commercial use of the modified full-cell process (MFC, see Figure 9). The cycle employs an initial vacuum of half the duration and intensity, or less, of a conventional Bethell treatment. This lower initial vacuum in combination with a final vacuum period produces wood significantly lower in moisture content than conventional treatment and minimizes post-treatment dripping of preservative, a major environmental concern to treaters. Total cycle time is also reduced. Problems with sludging are minimized by rapid turnover of working solutions and the cooling of working solutions using refrigeration (33) or deep well water.

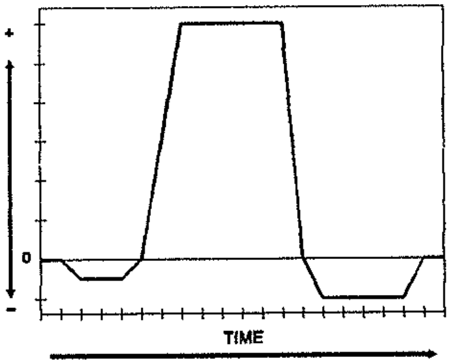


Figure 9. Typical modified full-cell process (MFC).

In Germany, post-treatment steaming is being employed to promote fixation (39-42,56) and reduce dripping. No deleterious effects on strength properties have been reported. Hot air fixation has also been investigated (see Cooper, this Proceedings). Accelerated fixation through kiln-drying after treatment can lead to significant strength reductions depending upon the temperature used (4,5,57). Consequently, the AWPA has instituted a limit of 88° C for redrying of CCA-treated stock. Concerns that potential heat-inactivation may contribute to reduced biocidal activity have been voiced (11,43). To date, these data have not been verified by field tests.

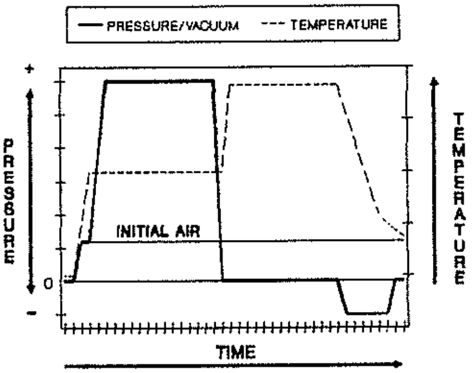


Figure 10. The MCI process for wood treatment.

Recently, Hein and Kelso (14) patented the MCI process, essentially a modification of the Rueping process, for use with metal carboxylates (Figure 10). A heating bath is employed at the end of the cycle, prior to removal of the preservative and final vacuum. While not applicable to CCA preservatives, the MCI process may be useful with emulsified copper systems. Research with the process has suggested the fixation of copper from oilborne copper naphthenate systems (3). In a related method, the Royal process used in Sweden (36,55), exterior woodwork is treated full-cell followed by Boultonizing in a pigmented oil, providing a natural finish to the wood.

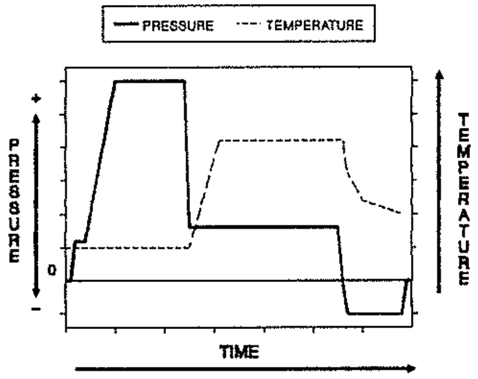


Figure 11. Typical MSU process for treating wood with CCA.

In situ fixation with CCA has been achieved with the patented MSU process developed at Mississippi State University in the 1970s by W. C. Kelso, Jr. (27,32). The MSU process is a modification of the empty-cell processes whereby CCA constituents are precipitated in the wood before kickback occurs. In a typical charge (Figure 11), wood is treated with either a Lowry or Rueping cycle. At the end of the pressure period, excess preservative is removed from the treating cylinder under pressure. The pressure is then reduced to slightly above the initial air pressure before water is introduced into the cylinder and heated. This 'fixation phase' varies in duration depending on the temperature, type of commodity, and wood species being treated. Heat is maintained via steam coils or an external heat exchanger. Either direct or closed steaming can also provide the needed heat. The use of a heated water bath or closed steaming is preferred as this water can be recycled. Following the fixation phase, the heating water is removed from the cylinder and the pressure is reduced to atmospheric pressure allowing kickback to occur. A final vacuum completes the process. This kickback is comprised mostly of water and wood extractives (resin acids, sugars, etc.), with negligible CCA constituents. Treated wood exits the cylinder at a moisture content of less than 40%, representing a 50% reduction compared to a conventional full-cell cycle (2,35,54,58,60). The process does not significantly reduce strength (58,60), and published research has shown that over 95% of the CCA is fixed in the wood (2,54,58,60). Figures 12 and 13 compare full-cell gradients to those for MSU process-treated wood fixed

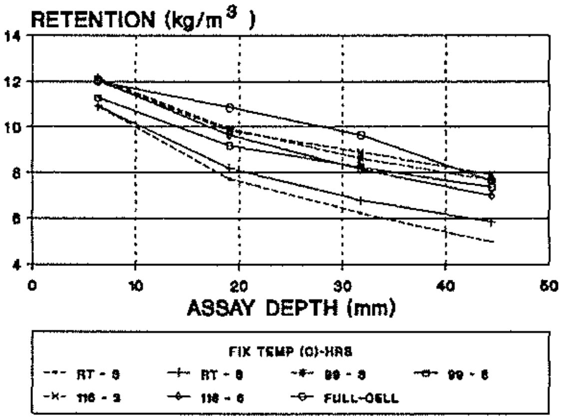


Figure 12. Total CCA gradients as affected heating time and temperature for MSU process-treated southern pine pole (data from Weaver 1981).

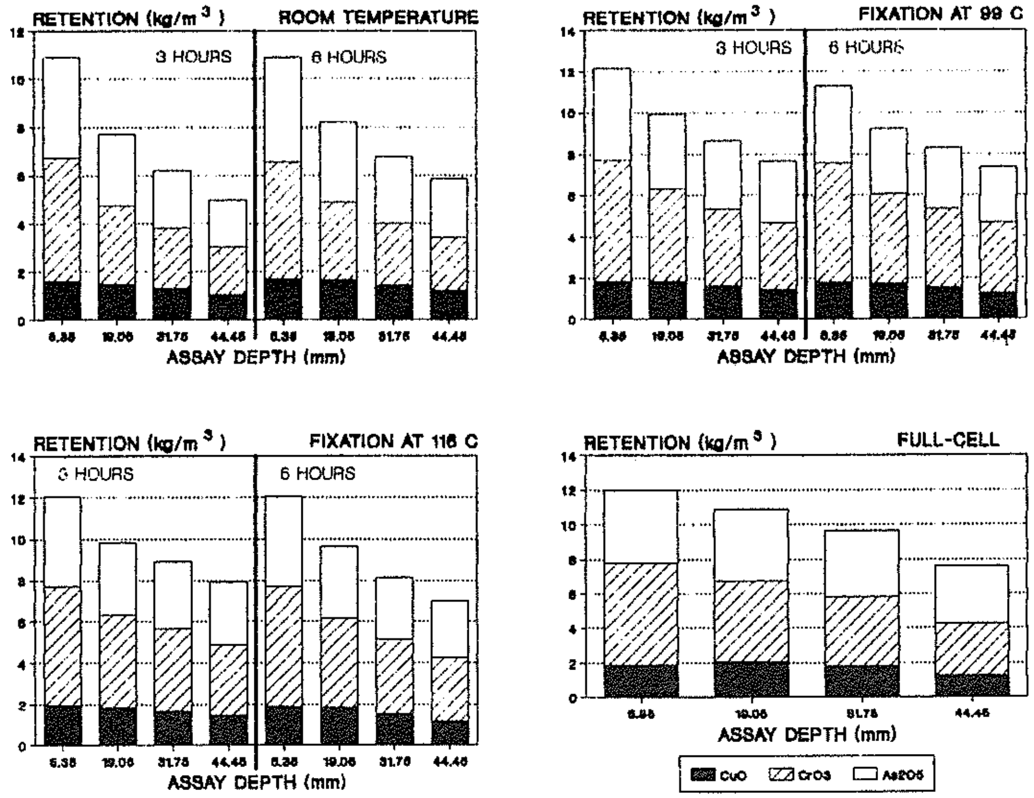
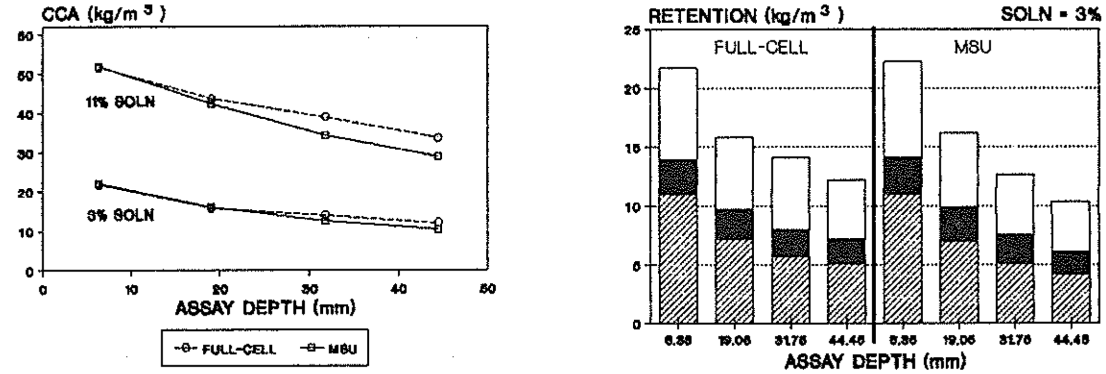


Figure 13. The effect of heating time and temperature on the disproportionation of components in CCA compared to full-cell treatment (data from Weaver 1981).

for two different times at three temperatures (54). These data show similar gradients among treatments and no disproportionation of the CCA components. The effect of solution strength on disproporionation is shown in Figure 14 (58,60). No practical difference in gradient shape is obvious.

The major advantages claimed for the process include: (1) weight gains of 160 kg/m^3, one-third that of products treated by the full-cell process; (2) *in situ* insolubilization of toxic components which leaves the wood safe to handle immediately following treatment, and elimination of contamination by dripping; (3) plant efficiency is improved by reducing mechanical handling, reducing inventory, and shortening the time between receipt of orders and shipment; (4) a full-cell gradient is achievable using an empty-cell process; (5) uniform and permanent color can be imparted depending



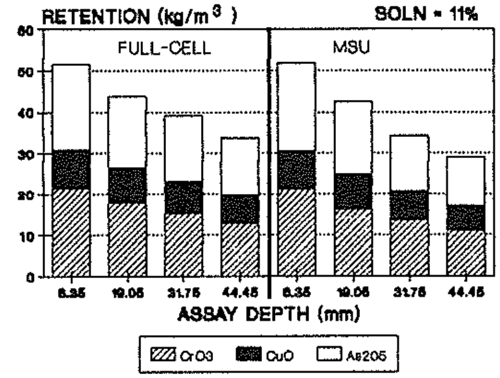


Figure 14. Effect of solution strength on gradient shape and disproportionation in southern pine poles (data from Wood 1980).

upon the choice of heating medium; and (6) the basic process makes possible the use of preservative-carrier systems and dual treatments currently unused by the industry. Finally, extension of the basic process to other preservatives and preservative systems offers possibilities for future treatments, including: (1) precipitation of organic biocides in wood from their water-soluble salts; (2) dual treatments; (3) treatments to increase permeability; (4) treatments to recover wood sugars and other extractives; (5) segregation of the kickback for removal of insolubles and/or entrained water in oily preservative systems; and (6) treatments with newly developed preservative systems that have less environmental hazard.

The use of heat in the MSU process and the low final moisture content of the treated product would seem to offer advantages to treaters in the northern US and Canada. Treaters in cold climates face problems with the treatment of frozen wood, with reduced fixation rates, and with freeze-bursting after treatment. Excellent results have been obtained with lodgepole pine (*P. contorta*) from Canada (2). In this study, water at 93° C was used as the heating medium. Results were comparable to MFC and FC treatment, with over 95% of the CCA components being fixed in the wood. Representative CCA gradients from this work are shown in Figure 15. The author has suggested that for thin sapwood species, shorter heating periods should produce adequate results. Final weight was reduced an average of 18% compared to FC treatment when the MSU process was used to treat thin-sapwood lodgepole pine in this study.

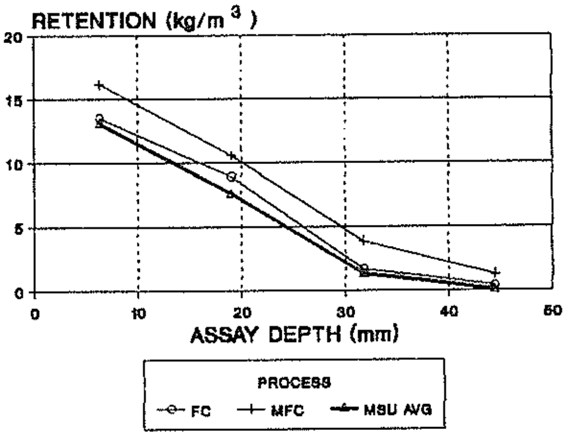


Figure 15. CCA gradients for lodgepole pine treated using the MSU, modified full-cell (MFC), and full-cell (FC) processes (data from Barnes 1988).

The capitalization and operating cost of the MSU process have been proposed in an earlier presentation (see Anderson, this Proceedings). Besides the obvious savings in shipping costs for treated material, other economic advantages would include savings on water costs and reduced pollution control costs (59). On the negative side, engineering and operating costs would increase due to longer cycle times and the need for a heating source.

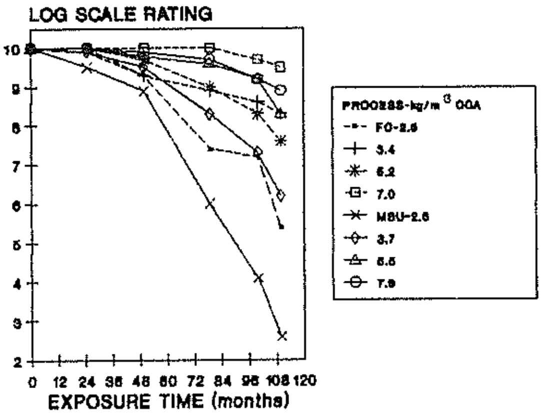


Figure 16. Performance in north Mississippi of 19-mm stakes treated with CCA by the MSU and full-cell processes (10 = no attack).

The question of heat-inactivation of the biocide would also be a consideration with MSU process-treated material. Performance data for nine years of exposure in Mississippi (Figure 16), while not conclusive, tend to show a heat-inactivation effect at low retentions. Generally, performance at or above threshold was equivalent for FC or MSU process-treated material.

New or Modified Preservative Systems

Environmental and other concerns have led to modified CCA systems. Australian researchers have combined CCA with creosote to produce pigmented micro-emulsion systems (13). Hickson Corporation has developed an emulsified oil/CCA system (patent pending) for treatment of pole stock (see McIntyre, this Proceedings). The inclusion of oil reduces hardness and improves the climbability of poles. Polyethylene glycol has also been used as an additive to reduce hardness (50). Changes to emulsified systems dictate different treating techniques to maintain emulsion stability. Other commercial additives include pigments to improve color, water repellents, and fungicides (*eg.*, substituted isothiazolones, see Lightley, this Proceedings) to retard mold growth. The addition of boric acid to CCA has improved the penetration of CCA into refractory western conifers (28,30) and has been used to eliminate afterglow in treated southern pine pole sections (29). Boron also may improve the biocidal efficacy of CCA (Figure 17).

Strong pressure from the US EPA and environmental groups is being placed on major components in CCA systems, notably arsenic and chromium. This is also true in European markets, especially Germany. Current research has been directed at replacement of one or both of these components in copper systems. Copper carboxylates are an example of a possible replacement. Current research at the Mississippi Forest Products Lab with metal salts, polymer systems, and water repellents are encouraging, and may lead to new metal salt preservative systems. Additionally, unpublished data indicate that polymer/water repellent systems may be effective in increasing the service life and reducing the depletion in CCB and other boron-based preservative systems. Chapman Chemical Company has developed an alternative waterborne system (patent pending) composed of an initial empty-cell treatment with an alkaline water-soluble dimethyl dithiocarbamate. This is followed by a full-cell treatment with an alkaline water-soluble copper compound. The components are complexed in the wood and are extremely leach resistant. Such new systems as have been described will require changes in treatment technology.

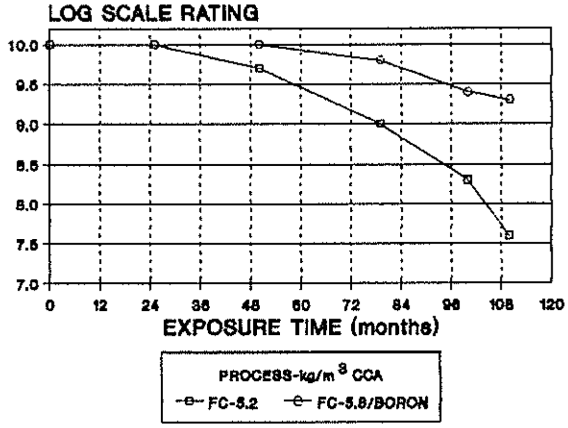


Figure 17. Effect of the addition of boric acid on the performance of CCA-treated stakes in north Mississippi.

Future Considerations

Computerization of future treating plants and processes will lead to better process and inventory control, reduced treatment time, and better environmental protection. To keep pace, treating technologies will have to change. For example, consider the potential of micro-emulsion-based systems with which formulators can tailor a system to a given end-use. Treatment with new biocides in the gas phase, a possibility advocated by Scheurch (46), has become a reality in the laboratory (51) and is scheduled for pilot plant trials. Another interesting concept is treatment at or above the critical point (24). Fluids, such as CO_2, become super-solvents at critical temperature and pressure. A critical point of 31.1° C and 7.4 MPa for CO_2 makes this technology a realistic possibility.

This paper has focused primarily on CCA treatment of solid wood commodities. The development and use of new generation structural laminates and composites are a significant challenge to the wood treating industry. The partnership among research laboratories, preservative suppliers, commodity suppliers, and wood treatment companies should provide the foundation for improved treated wood products for the 21st century.

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