Expert Report on

Copper Naphthenate Preservative Treated Wood Poles

for

the U.S. Army Corps of Engineers
Picatinny Arsenal
Dover, New Jersey

by

William B. Smith, Ph.D.
Wood Products Engineering

June 18, 2001

Report on Copper Naphthenate Preservative Treated Wood Poles for the U.S. Army Corps of Engineers, Picatinny Arsenal, Dover, New Jersey by William B. Smith, Ph.D.

Scope of retention:

I was retained on January 19, 2001 by the U.S. Army Corps of Engineers, to provide expert opinion and testimony on the condition and causes of deterioration of copper naphthenate treated poles at the Picatinny Arsenal in the Dover, New Jersey. These poles were supplied to the Army by North Pacific Lumber Co. (Nor-Pac), through local suppliers, from the Cahaba Pressure Treated Forest Products (CPT) treating plant.

Qualifications:

I have over 20 years experience and knowledge in various aspects of wood products processing and manufacturing, including operational experience as plant manager of a southern pine creosote treating plant and both laboratory and field research dealing with wood preservation, deterioration, and pole performance. See attached Curriculum Vitae for further detail.

Information considered:

My opinions in this case regarding the premature deterioration and failure of copper naphthenate poles, including causes and responsibilities for those failures, come from a variety of sources. These include an on-site visit to inspect poles which had failed prematurely, AWPA (American Wood-Preservers' Association) Standards P8, P9, and C4, and ANSI (American National Standards Institute) Standard 05.1, and a number of depositions, expert reports, litigation filings, and relevant experience and correspondence from this and related cases. Several documents of more particular interest among these sources include the following:

- Mooney Chemical copper naphthenate wood preservative brochures.
- Mooney Chemical March 30, 1993 report on premature CuNap pole failures.
- USDA Rural Electrification Administration CuNap treated pole warning letter, by James Huff, January 1993.
- Cahaba Pressure Treated Forest Products v. OMG Americas, Mooney Chemicals and Thomasson Lumber litigation, Alabama, CV-97-N-1917-W.
- Thomasson Lumber v. Cahaba Pressure Treated Forest Products and OMG Americas Mooney Chemicals litigation, Alabama, CV-98-P-0043-W.
- Affidavit of Kermit Stevens, president of Cahaba Pressure Treated Forest Products, in Cahaba v. Mooney and Thomasson litigation, Alabama, CV-97-N-1917-W and CV-98-P-0043-W.
- Evaluation of Copper Naphthenate Wood Supplied by North Pacific Lumber Company to Picatinny Arsenal, Picatinny Arsenal, New Jersey, report by Charles N. Kerr, Southwest Timber Laboratories, on February 13-18 and May 14-19, 2000 evaluations.
- Wood Poles: The Resource. Wood Structure, and Relevant Characteristics. Zak, G.F. and W.B. Smith. 1997. GEI Consultants, Inc., Colchester, CT 25 pp.
- Wood Poles: Preservation Methods and Regulatory Considerations. Mayer, M. and W.B. Smith. 1997. GEI Consultants, Inc., Colchester, CT 22 pp.

Also, information comes broadly from my general professional knowledge of wood science, poles, and preservative treatment practices which have been gained from both experience and general reading of widely published papers and reports in the literature.

Disclaimer:

As discovery in this case is still continuing, this report and my opinions should be considered preliminary in nature. Upon collection and review of additional data, reports, and depositions, the right is reserved to make further analysis and to supplement the report and modify my opinions as appropriate.

Background:

Preservative treated southern pine wood poles have been successfully used by utilities to support electrical conductors and communication lines for over 100 years. When these poles are properly treated with effective preservative chemicals, and inspected and treated with supplemental preservatives when appropriate, it is reasonable to expect an average physical life of over 40, and up to even 80, years service. The procedures, handling requirements, and treatments to achieve this performance are straight forward, simple to accomplish, and clearly described in ANSI 05.1-1987 and AWPA P8, P9, and C4 Standards. When followed, a treated wood pole is readily produced that can be expected to safely and securely perform for many years. With regard to copper naphthenate preservative treatment, specifically, OMG Mooney Chemical Co., which supplied CPT, particularly promoted the use of their M-GARD S520 copper naphthenate wood preservative for poles. Retention level and service life were conservatively based upon over 40 years of USDA Forest Products Laboratory test data with 2 by 4 inch treated stakes in Mississippi and Wisconsin. It was specifically noted that larger treated wood products, such as utility poles, would have longer service life, and that M-GARD equals or exceeds the performance of other preservatives.

In basic terms, poles need to be debarked and dried from initial moisture contents of over 100% to about 25% moisture content. This moisture reduction is required in order to make room within individual wood cells for subsequent impregnation with preservative chemicals. This wood drying, sometimes referred to as seasoning or conditioning, can be via air seasoning, kiln drying, steaming, heating in the preservative, or a combination. If drying is delayed, or if air seasoning is used without adequate control, it is likely that strength reducing decay deterioration will develop before treatment. Treatment of poles with oil-borne preservatives such as pentachlorophenol or copper naphthenate, or creosote, is typically via the empty-cell, or Rueping, process. Air is injected into the wood before pressurization with preservative in order to achieve deep penetration of the preservative compounds into the pine sapwood while controlling preservative retention to desired levels. After treatment, AWPA Standards require that the poles be bored to remove increment core samples for analysis of preservative penetration and retention. Copper naphthenate became an accepted wood pole preservative in AWPA Standards in the late 1980s. While several retention levels are listed, 0.06 pcf (pounds of copper, as metal, per cubic foot) in the 0.5 to 2.0 inch assay zone is a reasonable level for the Dover, NJ climate and decay zone. Preservative penetration requirements are 2.5 inches or 85% of the sapwood [*Sapwood is the outer zone of a tree through which the sap flows. It is typically much more permeable than the interior core region of a tree, which is referred to as the heartwood. The sapwood / heartwood proportion varies between species; for example the sapwood of the southern pines is quite thick, 3 to 5 inches deep, while it is only about 1 inch deep in Douglas-fir*]. Industry standards require that poles and charges which do not meet these standards must be retreated or rejected. As with most products and in most industrial production processes, specific standards and inspection requirements, such as those listed by AWPA, use statistically based sampling techniques that do not analyze the treatment throughout every region and piece of wood. These have proven to work successfully, however, when poles are handled, processed, and treated uniformly and in accordance to standards.

When put into service in the Dover region, poles properly treated in accordance with AWPA Standards should be expected to perform without need for inspection for at least 10 to 20 years. This protocol is based upon the assumption that the quality and treatment of the poles was initially satisfactory and normal, and variability normally distributed. In the service life of a pole treated with oil-borne preservatives, or creosote, naturally occurring deterioration is such that inspections focus on the ground line area, and that is where professional pole inspection firms inspect and apply supplemental treatments, when required, to achieve long, safe, and economical service life.

The copper naphthenate (CuNap) preservative treated poles, supplied to the Army by North Pacific Lumber, from the Cahaba Pressure Treated Forest Products treating plant, have proven to be failing due to fungal decay at a rate considerably greater than normal, and the deterioration is occurring in unique ways in regions of the poles considerably away from the groundline. Typical performance of normal poles is such that utilities should be able to expect only 1 to 2 % rejects due to groundline deterioration after 10 years. While these poles typically fail inspection because they happened to be in the lower tail of the preservative retention values, many can remain in service with application of supplemental groundline treatment. The unique situation with the CuNap poles at Picatinny Arsenal in Dover, New Jersey, identical to that experienced by electric utilities in Stoughton, WI, Cleveland, OH, Greenport, NY, and many other locations, is that decay usually occurs in the middle and upper regions of the poles, beyond the 8 foot height that can be checked with a normal inspection procedure. This abnormal characteristic and performance requires that inspections use bucket trucks to access upper regions of poles and virtually eliminates the normal assuredness with which utilities can put trust in inspection results predicting future safe performance.

Findings:

1. Early and unpredictable failures due to fungal decay and rot in numbers and rate considerably greater than normal have occurred with CuNap treated poles at the Picatinny Arsenal, in Dover, NJ. These poles were treated by Cahaba Pressure Treated Forest Products in 1994, and installed during 1994 and 1995. This is consistent with the experiences of other utilities with similar source and treatment poles. The patterns of decay are abnormal and such that a normal industrial pole inspection procedure would not typically detect. As the purpose of a properly treated wood pole is to structurally support electrical conductors and communication lines, with assuredness, for many decades, and many of these poles are failing at an average of less than 5 years (untreated wood will often last longer), it is clear that not only the individual poles which have catastrophically broken, but the entire population must be considered abnormal, and to have been defective when delivered for sale.

2. Some 370 CuNap poles were inspected at Picatinny during 2000 by Southwest Timber Labs professional inspection crews using hammer sounding and bore techniques. According to Ms. Kathleen J. Postal, Army Corps Project Engineer at Picatinny, only some of the poles were full-length inspected, from the groundline to the top. Her basis for this conclusion was personal observation and the fact that the total on-site inspection time was insufficient to fully inspect each pole in the appropriate manner. Results of these inspections found 50 reject danger poles which required immediate removal and replacement. This failure rate of 15% within five years is particularly high, and clear evidence of an abnormal population. Since September 2000, two more of these poles have failed. Similar to the decay deterioration found with these poles at other utilities around the country, the predominate majority of the failures had rotten wood and decay found 9 feet and higher in the pole. This substantiates the requirement that full-length evaluation and bucket trucks are necessary for inspections and that this entire population of poles must be considered abnormal.

3. Inspection procedures have only four possible outcomes; 1. a sound pole which passed inspection, 2. a bad pole which passed inspection, 3. a sound pole which failed inspection, and 4. a bad pole which failed inspection. Obviously, the goal of a satisfactory inspection is to accomplish outcomes 1 and 4, and to avoid outcome 3 for economical reasons and outcome 2 for human safety and property protection reasons. Because the decay patterns in these poles are spotty, randomly distributed, and difficult to assuredly find, the likelihood of occurrences of outcome 2 with these poles into the future is substantially greater than with normal poles. In fact, the Osmose Utilities division, one of the largest and most respected professional pole inspection firms, has not been willing to provide their standard inspection and supplemental treatment service on copper naphthenate treated poles for their utility customers. Their rationale is that with normal poles, when no decay is found in the groundline region it has been proven reasonable to assume that the balance of the pole is in good condition. This is not the case with these poles. Because finding decay and remedially treating the groundline zone cannot assure satisfactory performance of the entire pole, Osmose Utilities division believes these CuNap treated poles to be an abnormal and untrustworthy population. Though recent inspection did not find failures at this time in a number of the Picatinny CuNap poles, much more critical, detailed, and regular inspections will be required in the future of these than a utility should normally expect to need to provide continued service to their customers and safety to the public at large.

4. Inspection of the decay deterioration and pole failures, and knowledge and review of industrial and scientific literature, expert reports, depositions, and litigation filings indicate several reasons for the premature failures which have and are occurring. The depth and extent of decay, and its typical location in the upper regions of the poles are indicative of poles which have pretreatment decay and/or were not satisfactorily dried before treatment. Readily observable evidence of bluestain, a type of fungal deterioration which grows rapidly into wet untreated poles in warm weather, in a number of the failed poles provides additional evidence of likelihood of pretreatment decay in these poles. Another reason for premature failures is likely insufficient treatment penetration and retention, most probably due to insufficient drying before treatment. A number of the poles inspected in other, comparable, cases have retention levels considerably below what anyone could consider a normal distribution. Interestingly, some of those poles which failed from decay deterioration had acceptable or higher than normal retention levels of CuNap. Again, these anomalies point to improper pole processing techniques and quality. Treatment of poles with preexisting decay and excessively high moisture content is contrary to ANSI and AWPA standards and the responsibility of the pole treating company.

5. OMG Mooney manufactured copper naphthenate for the wood preservation industry from 1987 to mid 1995. The quality of the OMG Mooney formulation of CuNap used by Cahaba Pressure Treating has been acknowledged to have been inferior to others on the market, in that it had a particular propensity to form emulsions with water in the preservative solution during wood preservative treating operations. These emulsions were typically quite stable and proved difficult for treating plant operators to break (i.e. separate the water phase from the oil phase). It is well known in the industrial and scientific community that treating of wood with oil-borne preservatives in which high water content emulsions have developed will preclude satisfactory treatment, because the preservative compound, in this case copper naphthenate, is only soluble and therefore present in the oil phase. Subsequent treating will result with some regions of a pole improperly treated with mostly water, while other regions of the same pole are properly treated with preservative in oil. The practical consequence of treating with these emulsions is early decay failures and an abnormal population of treated poles. While AWPA specifies maximum water content in P9 type A oil of only 0.5%, actual levels of up to 30, 40, and even 50% were measured on site at the treating plants. This was obviously not a sound treating practice, and the specific consequence of this action of producing early failures and an abnormal population of poles must certainly have been recognized by both Mooney and those persons responsible for pole treatment.

6. It has been reported that OMG Mooney added chemical adulterants, such as propionic acid and ND bottoms, to bring the acid number of their CuNap in line with AWPA specifications. These compounds would increase the water solubility of their copper naphthenate, thus increasing likelihood to form emulsions and subsequent potential for leaching from poles in service. This is contrary to the intent and spirit of the standards and likely an additional contributing cause of early failures and defective poles.

Conclusions:

1. The U.S. Army Picatinny Arsenal CuNap poles in Dover, New Jersey are deteriorating due to fungal decay at a particularly high rate, considerably greater than normal, which has required a substantial number of premature pole replacements.

2. Because the decay deterioration in these poles does not occur in the normal "groundline at most risk" fashion, the middle and upper regions of each pole must also be evaluated, with inspections requiring use of bucket trucks to allow access to regions above 8 feet to the top of poles.

3. Though some of the CuNap poles may appear at this time to be in satisfactory condition, and could in fact perform for many years, the uncertainty inherent in inspection of these poles along with the abnormal characteristics of their population, will require continued thorough inspections at much more frequent intervals than normal poles. Because not every pole was evaluated top to bottom with a bucket truck during the 2000 inspections, each of the poles in this population must still be considered suspect. As such, a complete inspection of the Picatinny CuNap poles still in use should take place as soon as possible. I recommend that inspection be performed by professional commercial pole inspectors using bucket trucks to access all regions, top to bottom, of each pole. It would be prudent to reinspect these poles in at least the next 3 to 5 years. The physical risk to people and property of future pole failures from this abnormal population cannot be underestimated.

4. Responsibility for production and delivery of inferior quality poles to the Army rests with the treater and supplier of those poles. Knowledge of poor wood quality, chemical emulsion formations, and poor treating practices, and the subsequently caused penetration and retention problems, non-uniform and poor treatment quality and in-service risk, must have been known by those parties. With pole and treatment quality problems such as these occurring, it should have been obvious that poles so treated should not have been sold and shipped to utilities for use.

Other litigation:

I am currently working with the firms of Davis & Kuelthau, Madison, WI, representing Stoughton Utilities, Stoughton, WI, and Climaco, Climaco, Lefkowitz & Garofoli, representing

Cleveland Public Power, Cleveland, OH, on similar cases involving copper naphthenate poles. I have also been involved in other litigation with regard to wood poles and crossarms, and other issues of wood products and lumber, quality and performance which do not relate to the specifics of this case.

William B. Smith, Ph.D.

Curriculum Vitae
William Bradford Smith

Business Address:
Wood Products Engineering
SUNY College of Environmental
Science and Forestry
Syracuse, NY 13210
315/470-6832, fax 6879

Home Address:
104 West Franklin St.
Fayetteville, NY 13066

Education:

SUNY College of Environmental Science and Forestry, Syracuse, NY

- Ph.D. Environmental and Resource Engineering - August 1983
- M.S. Environmental and Resource Engineering - May 1978
- B.S. Wood Products Engineering - May 1976

Employment:

1992 - Associate Professor, Wood Products Engineering, SUNY College of Environmental Science and Forestry, Syracuse, NY.

1983 - Technical and management consultant on wood protection, deterioration, preservation, coatings, drying, and processing.

1986-1992 Assistant Professor, Wood Products Engineering, SUNY College of Environmental Science and Forestry, Syracuse, NY.

1983-1986 Assistant Professor, Wood Science and Technology, University of Massachusetts, Amherst, MA.

1983 Postdoctoral Research Associate, SUNY College of Environmental Science and Forestry, Syracuse, NY.

1979-1983 Graduate Research Fellow, SUNY College of Environmental Science and Forestry, Syracuse, NY.

1978-1979 Operational Manager, Creosote pressure treated wood products plant, Atlantic Wood Industries, Inc., Hainesport, NJ.

1976-1978 Graduate Research Assistant, SUNY College of Environmental Science and Forestry, Syracuse, NY.

Courses taught at SUNY College of Environmental Science and Forestry and the University of Massachusetts:

- Fluid Treatments
- Forest Products Marketing
- Wood Coatings Technology
- Wood Preservation
- Chemical Modification of Wood
- Mechanical Processing
- Wood-Water Relationships
- Wood Seasoning
- Chemical Processing of Wood

Distinguished Teacher Award, presented by SUNY College of Environmental Science and Forestry Undergraduate Student Association, April 8, 2000.

Research Projects:

- Characteristics of Recycled Plastic Lumber
- Prevention of Sticker Stain in Hard Maple
- Differential Copper Adsorption Phenomena in Wood
- Wood Decay Comparison of Red Maple Sapwood and Heartwood
- Strength Properties of Preservative Treated Wood
- Comparison of Wood Pole Strength Evaluation Procedures
- Analysis of Residual Creosote in Southern Pine Poles
- Utilization of Radio-Frequency Energy to Dry Lumber
- Radio-Frequency/Vacuum Lumber Drying - Demonstration Project
- Evaluation of Lumber Drying Technologies
- Preservative Treatability of Red Maple
- Western New York Forest Industry Initiative
- Utilization of Jamestown, NY District Heating System to Heat Lumber Dry Kilns
- Effect of Drying Method on Preservative Treatability
- High Temperature Drying of Red Pine
- Interactions of Polymer Systems and the Wood Cell Wall

Memberships in Professional Organizations:

- Forest Products Society
- Society of Wood Science and Technology
- American Wood-Preservers' Association
- New England Kiln Drying Association
- International Research Group on Wood Preservation
- National Hardwood Lumber Association, Research Member
- Sigma Xi, The Scientific Research Society
- Lake Erie and Ontario Sawyers & Filers Association

Other Professional Activities:

Executive Secretary, New England Kiln Drying Association

American Wood-Preservers' Association Technical Committee Membership

- P-3, Organic and Organometallic Preservative Systems
- P-4, Inorganic Preservative Systems
- P-7, Fire Retardant Systems
- T-2, Lumber and Timbers
- T-4, Poles
- T-9, Commodities Treated with Fire Retardants
- Special Committee on Wood Preservation Research

NY State Pesticide Applicator, Category 7D certification

Technical Reviewer,

- Forest Products Journal
- United States Department of Agriculture
- American Wood-Preservers' Association
- National Institute of Standards & Technology
- Wood and Fiber Science
- Wood Science and Technology
- Small Business Innovation Research

Professional Presentations:

Numerous invited technical and research presentations, related to wood characteristics and properties, drying, processing, performance, and deterioration, have been made at scientific conferences, and for industrial associations and organizations.

Refereed Publications:

Anagnost, S.E. and W.B. Smith. 1997. Hygroscopicity of Decayed Wood - Implications for Weight Loss Determinations. Wood and Fiber Science 29(3)299-305.

Smith, W.B. and C. Tascioglu. 1997. Differential Adsorption and Absorption of Copper-Based Wood Preservatives in Southern Pine. Proceedings, American Wood-Preservers' Association 93:464-482.

Anagnost, S.E. and W.B. Smith. 1997. Comparative Decay of Red Maple Sapwood and Heartwood. Wood and Fiber Science 29(2)189-194.

Smith, W.B., P.F. Schneider and H. Resch. 1996. Rapid Fixation of CCA Wood Preservative with Electromagnetic Energy. Forest Products Journal 46(7/8)47-51.

Smith, W.B., N. Abdullah, D. Herdman and R.C. DeGroot. 1996. Preservative Treatment of Red Maple. Forest Products Journal 46(3)35-41.

Smith, W.B., H.O. Canham, J. Harris, E.F. Neuhauser, and A. Smith. 1996. Economic Production Analysis of Radio-Frequency Vacuum Dried Red Oak Dimension Squares. Forest Products Journal 46(3)30-34.

Park, J.H., G.H. Kyanka, W.B. Smith. 1995. Computation of Drying Stresses in Red Oak using Equilibrium and Non-Equilibrium Creep Models. ASME AMD-Vol.209/MD-Vol.60, Mechanics of Cellulosic Materials pp.135-152.

Wright, M.E. and W.B. Smith. 1995. Performance of Utility Pole Strength Prediction Techniques. Proceedings, American Wood-Preservers' Association 91:34-54.

Gallacher, A.C., C.R. McIntyre, M.H. Freeman, D.K. Stokes and W.B. Smith. 1995. Standard and New Analytical Techniques for CDDC Preserved Wood Analysis. Proceedings, American Wood-Preservers' Association 91:194-207.

Jung, Hee-Suk and W.B. Smith. 1994. Comparison of Equilibrium Moisture Contents for Conventional Kiln Dried- and High Temperature Dried Softwood Lumber by Moisture Content Determination. The Journal of Korean Wood Science and Technology 22(4)37-42.

Smith, W.B. 1992. Determining moisture content in eastern red cedar. Forest Products Journal 42(7/8):67-69.

Smith, W.B. 1986. Treatability of several northeastern species with chromated copper arsenate wood preservative. Forest Products Journal 36(7/8):63-69.

Smith, W.B., W.A. Cote, J.F. Siau, and R.C. Vasishth. 1985. Interactions between waterborne polymer systems and the wood cell wall. Journal of Coatings Technology 57(729):27-35.

Smith, W.B., W.A. Cote, J.F. Siau, and R.C. Vasishth. 1985. Study of interactions between wood and water-soluble organic cosolvents. Journal of Coatings Technology 57(727):83-90.

Smith, W.B. and J.F. Siau. 1979. High-temperature drying of red pine. Journal of the Institute of Wood Science 8(3):129-133.

Siau, J.F., W.B. Smith, and J.A. Meyer. 1978. Wood-polymer composites from southern hardwoods. Wood Science 10(3):158-164.

Patent Application:

Resch, H., W.B. Smith and P.F. Schneider. 1992 Process for Accelerated Fixing of Water-Borne Chromium-Containing Wood Preservatives. Invention assigned to SUNY and submitted to U.S. Patent and Trademark Office.

Other Publications (selected):

Smith, W.B. 2000. Plastic Lumber: What is it, and Where is it Going? American Wood-Preservers' Association Newsline Jan./Feb. 9-10.

Smith, W.B. 1998. Crossarms: Current and Future Options. Proceedings of the 1998 Northeast Utility Pole Conference, pp.106-109. October 13-14, 1998, Binghamton, NY.

Smith, W.B. and D.J. Herdman. 1998. Effects of Kiln Schedules and Sticker Variables on Board Color and Sticker Stain in Hard Maple. Proceedings of the Twenty-Sixth Annual Hardwood Symposium, Technology and Market Information for the Next Millennium, pp.121-133, National Hardwood Lumber Association, Memphis, TN.

Zak, G.F., M.M. Mayer and W.B. Smith. Wood Pole Compendium Series. Proceedings of the Treated Wood Handling, Use, and Recycling Issues Workshop, May 15, 1998, Scottsdale, AZ.

Mayer, M. and W.B. Smith. 1997. Wood Poles: Preservation Methods and Regulatory Considerations. GEI Consultants, Inc., Colchester, CT 22 pp.

Zak, G.F. and W.B. Smith. 1997. Wood Poles: The Resource. Wood Structure, and Relevant Characteristics. GEI Consultants, Inc., Colchester, CT 25 pp.

Smith, W.B., D. J. Herdman. 1996. An Investigation of Board Color and Sticker Stain in Hard Maple. pp. 325-334 in Proceedings of the 5th IUFRO International Wood Drying Conference, Quebec City, Canada.

Anagnost, S.E. and W.B. Smith. 1996. Hygroscopicity of Decayed Wood - Implications for Weight Loss Determinations. IRG/WP 96-20085. International Research Group on Wood Preservation, Stockholm, Sweden.

Smith, W.B. 1995. Controlling the Kiln-Drying Process. pp. 107-111 in Proceedings: Drying Pacific Northwest Species for Quality Markets, October 30 - November 1, Bellevue, WA. Forest Products Society, Madison, WI.

Gallacher, A.C., C.R. McIntyre, M.H. Freeman, D.K. Stokes and W.B. Smith. 1995. A Comparison of Analytical Techniques. Doc. No. IRG/WP 95-20061. International Research Group on Wood Preservation, Stockholm, Sweden.

Milota, M.R. and W.B. Smith. 1994. Contrasting Drying Practices for Hardwoods and Softwoods. Proceedings of DRYCON Wood Technology's Drying Management Conference, Vancouver, BC.

Smith, W.B. 1994. Handling and Drying Short Pieces and Parts. Proceedings of DRYCON Wood Technology's Drying Management Conference, Vancouver, BC.

Smith, W.B., A. Smith and E.F. Neuhauser. 1994. Radio-Frequency/Vacuum Drying of Red Oak: Energy, Quality, Value. Proceedings of the 4th IUFRO International Wood Drying Conference, Rotorua, New Zealand: 263-270.

Smith, W.B., A. Smith and E.F. Neuhauser. 1994. Radio-Frequency Vacuum Drying of Red Oak. pp. 101-108 in Proceedings: Profitable Solutions for Quality Drying of Softwoods and Hardwoods, May 25-27, Charlotte, NC. Forest Products Society, Madison, WI.

Smith, W.B. and R.C. DeGroot. 1994. Preservative treatment of red maple. Proc., American Wood-Preservers' Assoc. 90:112.

Smith, W.B. 1994. Strength and corrosion properties of CDDC treated wood and solutions. Proc., American Wood-Preservers' Assoc. 90:113.

Canham, H.O. and W.B. Smith. Western New York Forest Industry Initiative, Final Project Report. February 1994. Cornell Cooperative Extension, Ellicottville, NY.

Smith, W.B. and H.S. Jung. 1993. Effect of High Temperature Drying on Moisture Content Determination with Electronic Meters. Proceedings of the Western Dry Kiln Association. p.31-38, May 12-14, Reno, NV

Canham, H.O., W.B. Smith and S.L. Brooks. Market Opportunities for Strengthening the Forest-Based Industries of Southwestern New York. Report prepared for Western New York Forest Industry Initiative. January 1993.

Canham, H.O., and W.B. Smith. Primary Wood Using Industry of Southwestern New York. Report prepared for Western New York Forest Industry Initiative. April 1992.

Canham, H.O., and W.B. Smith. Secondary Wood Manufacturing in Western New York. Report prepared for Western New York Forest Industry Initiative. April 1992.

Burnett, Fred, edited by Bill Smith. Dehumidification Drying from an Owner's Point of View. May 1991. FPRS Wood Drying News Digest G-5.3.

Chenard, Mark, edited by Bill Smith. The Basics of Steam: Making, Trapping, and Heat Exchange. June 1991. FPRS Wood Drying News Digest F-8.5.

Smith, W.B. 1991. Kiln-Drying Schedule Should be Based on Wood Dynamics. Woodshop News March 1991.

Smith, W.B. and R. Harrington. 1989. Technical Editor and Reviewer. Northeastern Retail Lumber Association's Retail Lumber Dealers Foundation's Product Training Manual.

Smith, W.B. 1988. The History of New York's Lumber Industry. The Lumber Co-Operator 72(7)26-27.

Smith, W.B. 1988. Setting a Standard in Wood Products Engineering. The Lumber Co-Operator 72(7)49-50.

Smith, W.B. Book Review of Finishing Eastern Hardwoods for Fine WoodWorking Magazine Jan./Feb. 1985.

Smith, W.B. and J.F. Siau. 1983. Comparison of thickness and width shrinkage in red pine studs. FPRS Wood Drying News Digest G-2.12.

Smith, W.B. and J.F. Siau. 1983. The effects of subsequent treatments on twist in red pine studs. FPRS Wood Drying News Digest G-2.11.