

BIOGRAPHIES & ABSTRACTS

QUALITY DRYING: THE KEY TO PROFITABLE MANUFACTURING

September 23-25, 2002
Crowne Plaza Montréal Centre
Montréal, Quebec, Canada

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The Forest Products Society would like to recognize AMEC Forest Industry Consulting of Vancouver, British Columbia, Canada for supporting the efforts and time expended by conference program Co-Chair Sita Millar in the development of this conference.

CONFERENCE CO-CHAIRS

*Sita Millar
Technical Manager
AMEC Forest Industry Consulting
Vancouver, British Columbia, Canada*



Sita Millar is Technical Manager of AMEC Forest Industry Consulting in Vancouver, British Columbia, Canada. Her responsibilities include evaluating technology in the kiln drying area, developing new technology and new designs for the kiln drying sector, and assessing kiln drying practices for the lumber industry. Previously, she was a Research Scientist at Forintek Canada Corporation.

*Fred M. Lamb
Professor Emeritus
Department of Wood Science
and Forest Products
Virginia Tech
Blacksburg, Virginia, USA*



Fred Lamb is Professor Emeritus in the Department of Wood Science and Forest Products at Virginia Tech, Blacksburg, Virginia. He also is a Wood Technologist, Fred Lamb Consulting, Inc., Christiansburg, Virginia. His expertise is in wood processing and wood products manufacturing with special emphasis on lumber drying, rough mill cut-up operations, wood machining, and furniture manufacturing technology. He received a BS degree in Wood Utilization, an MS degree in Wood Technology, and an EdD in Continuing Education Administration from Pennsylvania State University, University Park, Pennsylvania.

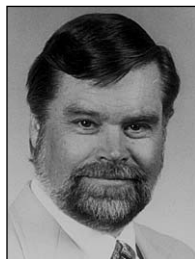
*William B. Smith
Professor
College of Environmental
Science and Forestry
State University of New York
Syracuse, New York, USA*



Dr. William Smith is Professor of Wood Products Engineering at the State University of New York, College of Environmental Science and Forestry in Syracuse, New York. His teaching and research activities include wood drying, preservation, processing, and marketing. Dr. Smith is a member of the Forest Products Society, Society of Wood Science and Technology, New England Kiln Drying Association, and American Wood Preservers' Association.

PLANNING COMMITTEE MEMBERS AND SESSION MODERATORS

*Arthur B. Brauner
Executive Vice President
Forest Products Society
Madison, Wisconsin, USA*



Arthur Brauner received BS and MS degrees in Wood Science and Technology from the University of Michigan. He has been Executive

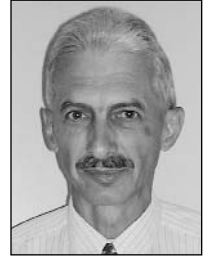
Vice President of the Forest Products Society since 1976. He came to the Society in 1968 as Editor of Publications and Director of the Society's computerized information retrieval system. Previously, he was a Research Assistant and Assistant Professor at West Virginia University's School of Forestry.

*Paul A. Cooper
Associate Professor
Faculty of Forestry
University of Toronto
Toronto, Ontario, Canada*



Dr. Paul Cooper was recently appointed Associate Professor and Chair of value-added wood and composite products in the Faculty of Forestry at the University of Toronto. Prior employment experience includes: Research Scientist and Manager of the University of New Brunswick, Wood Science and Technology Centre in Fredericton; Lecturer and Assistant Professor appointments at the Faculty of Forestry, University of Toronto; Research Chemist with Iroquois Chemicals Ltd.; and Wood Preservation Specialist with the Western Forest Products Laboratory. Dr. Cooper has also worked as a consultant for a number of consulting firms, industry associations, government agencies, and wood preservation companies. His current research focuses on wood deterioration and protection issues, with emphasis on evaluating and reducing environmental impacts of wood preservatives during all stages of the treated wood product life cycle. Other areas of research include studies on preservative treatment technology, utilization of under-utilized species, wood drying and wood quality, value-added wood products and composites, fire retardant treatment of wood, wood modification and diffusion, and reaction of chemicals in wood. He received a BS degree in Wood Science from the University of Toronto, an MS degree in Wood Products from Oregon State University, and a BEd degree in Mathematics and Chemistry and PhD degree in Wood Science from the University of Toronto.

*Yves Fortin
Professor
Department of Wood and
Forest Sciences
Laval University
Sainte-Foy, Quebec, Canada*



Dr. Yves Fortin is a Professor in the Department of Wood and Forest Sciences at Laval University in Sainte-Foy, Quebec, Canada. His responsibilities include teaching (undergraduate and graduate courses) and research in the field of wood drying and preservation. He is also involved in professional activities within IUFRO and various regional and national committees dealing with wood drying. He received BS and MS degrees from Laval University, and a PhD degree from the University of British Columbia.

*John Hector
Science Policy Advisor
Natural Resources Canada,
Ottawa, Ontario, Canada*



John Hector is the Science Policy Advisor for Natural Resources Canada in Ottawa, Ontario, Canada. His responsibilities include performing research on emerging technological challenges, priorities, and needs to enhance competitiveness, market penetration, and productivity on the Canadian forest sector; developing policies and programs that assist in diagnostic assessment of the forest sector; and providing advice and analysis to senior officials of the forest sector as well as senior government officials at various levels. He received a degree in

Biochemical Technology (Biochemistry) from Algonquin College, Ottawa, Ontario, Canada.

Gilles Jeanrie
Director, Quality Control
Department
Quebec Lumber Manufacturers
Association
Sainte-Foy, Quebec, Canada



Gilles Jeanrie has been Director of the Quality Control Department at the Quebec Lumber Manufacturers Association since 1992. He is also the President of the National Lumber Grades Authority Board.

Christopher A. Lenth
Scientist, Wood Material Behavior
New Zealand Forest Research
Institute Ltd.
Rotorua, New Zealand



A native of rural Northeast Iowa, Dr. Christopher Lenth received a BS degree in Forestry from Iowa State University in Ames, Iowa. He went on to Blacksburg, Virginia, to study at Virginia Tech where he obtained MS and PhD degrees in Wood-Based Composites. From June 1999, he has been employed as a Scientist by the New Zealand Forest Research Institute Ltd. in Rotorua, New Zealand. His responsibilities include planning and executing long-term projects for determination of wood material properties pertinent to high temperature drying behavior and stress development; investigating high temperature wood-water relations and associated physio-chemical modification and stabilization; evaluating the influence of fiber alignment on the properties of MDF; and studying the wetting and behavior of wood-fiber networks.

Robert L. Little
Manager, Wood Technology
Armstrong Wood Products
Dallas, Texas, USA



Dr. Robert Little is currently Manager, Wood Technology for Armstrong Wood Products in Dallas, Texas. In this position, he is responsible for the drying and preparation of lumber and veneer for the 12 Armstrong flooring plants. Prior to joining Armstrong, Dr. Little served as Technical Director and Wood Technologist for a hardwood dry kiln manufacturer. Before moving to industry, he was a Professor in the Department of Forestry, Wildlife and Fisheries at the University of Tennessee for 17 years and was an Extension Wood Products Specialist for the Cooperative Extension Service at Auburn University for 7 years. He received BS and MS degrees from Clemson University, and a PhD degree in Wood Science and Technology from North Carolina State University. He is the author of over 60 technical articles and a frequent presenter at wood drying meetings.

Michael R. Milota
Associate Professor
Department of Wood Science
and Engineering
Oregon State University
Corvallis, Oregon, USA



Dr. Michael Milota is Associate Professor in the Department of Wood Science and Engineering at Oregon State University (OSU), Corvallis, Oregon. His responsibilities include research and teaching in wood drying and air emissions. He coordinates OSU's Lumber Drying Workshop for operators and managers held annually in December. He is active in the Forest Products Society as the Chair of the Drying and Storage Technical Interest Group and as the regional board member for the Northwest. He is also active with the Western Dry Kiln Association. Prior to OSU, he was employed by the USDA Forest Products Laboratory and the Masonite Corporation.

Keith Parsonage
Director General
Information and Communications
Technologies Branch
Industry Canada
Ottawa, Ontario, Canada



Keith Parsonage is the Director General of the Information and Communications Technologies Branch of Canada's economic development ministry, Industry Canada. In his current capacity, he brings to bear over 30 years of private and public sector service and experience in assisting Canadian firms to improve their international competitive capabilities. Following graduation from Neuchâtel Junior College in Switzerland, Mr. Parsonage attended the University of Toronto gaining a Bachelor's degree in Applied Science with honors majoring in Industrial Engineering. He subsequently attended McMaster University to earn his Master's degree in Business Administration while working full time as an engineer-in-training with domestic and multinational firms in the Hamilton area. Prior to entering government, he served as a senior management consultant with the Research and Productivity Council of New Brunswick where he further honed his many professional skills and expanded his knowledge of international market relations. After joining the Federal Public Service in 1977, he assumed progressively more responsible challenges in the field of industrial development and management in a variety of industry sectors. The last 10 years of his career have been spent working with Canada's high technology community. He is a member of the Board of the Canadian Microelectronics Corporation and of the Telecommunications Executive Management Institute of Canada. He also serves in an ex-officio capacity on the boards of CANARIE, Canada's Advanced Internet Organization and PRECARN, an advanced research network.

Stephen L. Quarles
Wood Durability Advisor
Forest Products Laboratory
University of California
Richmond, California, USA



Dr. Stephen Quarles is a University of California (UC) Cooperative Extension Advisor in Wood Building Durability at the UC Forest Products Laboratory. He is responsible for development and implementation of the outreach and research program on durability issues related to the in-service performance of wood-frame structures and wood and wood-based products. His research is currently focused on the performance of exterior-use building materials and assemblies that are subjected to wildfire exposures, and since wildfire and moisture (rainfall) design features are often conflicting, developing an under-

standing of how to optimize the design of buildings located in the urban wildland interface. Dr. Quarles joined the UCFPL in 1985, and prior to accepting the Wood Durability Advisor position in the fall of 2000, was Head of the Wood Building Research Center and the Service to Industry Program (1992-2000), and was a member of the faculty at Berkeley (1985-1992). He worked at a particleboard plant in Southern Georgia, operated by Weyerhaeuser Company, initially through participation in a cooperative education program while an undergraduate, and then full-time from 1978 to 1980. He received a PhD degree in Wood Science and Forest Products from the University of Minnesota, and an undergraduate degree from Virginia Tech. He has published more than 50 articles in refereed and non-refereed outlets, and numerous technical reports.

Marc Savard
*Eastern Group Leader, Wood Drying
 Forintek Canada Corporation
 Sainte-Foy, Quebec, Canada*

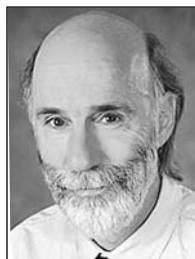


Marc Savard is Eastern Group Leader, Wood Drying at Forintek Canada Corporation in Sainte-Foy, Quebec, Canada. He is responsible for the coordination and supervision of R&D activities and efforts related to wood drying in Eastern Canada. He also conducts research projects and contract works in the laboratory and in the field. He received a BS degree in Wood Science from Laval University.

Robert K. Shaw
*Consultant, Quality Management Systems and Training
 Emmett, Idaho, USA*

Robert Shaw is a Consultant, Quality Management Systems and Training, and has over 30 years of responsibility and practical leadership experience in both staff and line operations. He has both theoretical and practical application of knowledge in all facets of management and manufacturing. He has facilitated process improvement efforts including cost of quality and statistical process control, developed and maintained an intranet web site, and developed and delivered quality and management training. Previous employment includes Total Quality Manager for Boise Cascade Corporation and Cascade Sawmill Superintendent for Boise Cascade Corporation. He received a BA degree in Management and Organizational Leadership from George Fox University. He is a member of the Idaho Quality Award executive board, the Forest Products Society, and the American Society for Quality. He has published articles in the *Forest Products Journal* and is a frequent speaker at quality conferences and industry association meetings.

Bill Wilson
*Director, Industry Trade and
 Economics Research
 Natural Resources Canada
 Canadian Forest Service
 Victoria, British Columbia, Canada*



Dr. Bill Wilson is the Director of a federal government research program focused on global forest product market trends and opportunities, sector competitiveness, forest policy, and on forest sector structure, significance, and performance. Dr. Wilson has worked in both forestry woodlands and in pulp and paper operations. In addition, his research experience has included work on all the major forest product markets and many of the forestry jurisdictions competing with Canada. Dr. Wilson has an extensive record of research publications on a wide range of forestry topics. Recent research interests include both national and international forest policy; BC's policy efforts in sustainable forestry; industrial organization, competitiveness, and structure of the forest sector; secondary manufacturing; international market access; and forest management economics. He received a PhD degree in Natural Resource Economics and Public Finance, a Master's degree in Economics, and a Bachelor's degree in Economics and Biology.

SPEAKERS

Kemal Ahmet
*Sub-Dean and Principal Lecturer
 Department of Design and Architecture
 University of Luton
 Luton, Bedfordshire, United Kingdom*

Dr. Kemal Ahmet is Sub-Dean and Principal Lecturer in the Department of Design and Architecture at the University of Luton, Luton, Bedfordshire, United Kingdom. His current responsibilities include research in moisture sensors, lecturing in materials/physical science, supervising research students, and faculty administration. He received a BS (honors) degree in Physics from the University of Leeds in Leeds, West Yorkshire, United Kingdom, and a MS degree in Astrophysics and PhD degree in Sensor Physics from the University of London.

Frank C. Beall
*Professor and Director
 Forest Products Laboratory
 University of California
 Richmond, California, USA*

Dr. Frank Beall is Director, Forest Products Laboratory, Division of Agriculture and Natural Resources, and Professor of Wood Science in the Department of Environmental Science, Policy and Management, University of California (UC) at Berkeley. He received graduate degrees from the College of Forestry, State University of New York at Syracuse. Prior to his appointment at UC, he worked for Weyerhaeuser Company as a Scientist/Manager, and had previous appointments at Pennsylvania State University and the University of Toronto. One of his specializations is in fire research, particularly effects at the urban-wildland interface; the other is in nondestructive evaluation of wood and wood-based materials using ultrasonic techniques. His professional activities include Past President, Forest Products Society; Past President, Society of Wood Science and Technology; Fellow and Secretary-Treasurer in the International Academy of Wood Science; Fellow and Past Chair of the Acoustic Emission Working Group; and Past Chair of ASTM Committee D07 on Wood. He has over 130 publications, including 12 patents.

Brian H. Bond
*Assistant Professor
 Department of Wood Science and Forest Products
 Virginia Tech
 Blacksburg, Virginia, USA*

Dr. Brian Bond recently joined the faculty in the Department of Wood Science and Forest Products at Virginia Tech, Blacksburg, Virginia. Previously, he was an Assistant Professor at the Tennessee Forest Products Center, University of Tennessee, Knoxville, Tennessee. He received a BS degree in Forest Products from Clemson University, and MS and PhD degrees in Forestry and Forest Products from Virginia Tech.

Frederick C. Burkardt
*Regional Plant Manager
 Armstrong Wood Products
 West Plains, Missouri, USA*

Frederick Burkardt is the Regional Plant Manager of Armstrong Wood Products in West Plains, Missouri. He is responsible for three manufacturing sites and four contract sawmills engaged in the production of 3/4" prefinished and unfinished hardwood floors. Armstrong's process encompasses purchasing raw log and lumber inventory through manufacturing and finishing. Mr. Burkardt received a BS degree in Forest Products from Pennsylvania State University, University Park, Pennsylvania.

Peter A. Drake
Senior Marketing Consultant
AMEC Forest Industry Consulting
Vancouver, British Columbia, Canada

Peter Drake is a Senior Marketing Consultant with AMEC Forest Industry Consulting in Vancouver, British Columbia, Canada. He has an engineering background and comprehensive experience in the wood products industry. He has worked for over 30 years in sales and marketing lumber, plywood and a variety of wood products, both directly and as a consultant. His responsibilities include the development and coordination of corporate and marketing strategies for wood product manufacturers worldwide and the analysis of feasibility studies and business plans for new projects. His product and strategic development work is based on a wide knowledge of consumer needs and preferences for commodity and specialty lumber, engineered wood products and panelboards, and the processing technology available to obtain these products from the resource. He has undertaken field research in many markets in North America, Asia, Europe, and Africa, and in the last few years, has been specializing in the development of value-added lumber products and reconstituted panel products. He received an MA (Engineering) degree from the University of Cambridge.

Réal Frenette
Project Engineer
Autolog Inc.
Laval, Quebec, Canada

Réal Frenette is a Project Engineer at Autolog, Inc. in Laval, Quebec, Canada. He received a Bachelor's degree in Engineering Physics from Laval University, and a Master's degree in Electrical Engineering from the University of British Columbia in Vancouver. Previously, he was a Research Engineer in the Electrical Engineering Department at the University of British Columbia, mainly in the field of robotics applied to forestry equipment; a Research Engineer at the Research and Development Center for Kayaba in Sagamihara, Japan; and a Research Engineer at CRIM in Montreal, in the field of robotics applied to forestry equipment.

Jim Fuller
President
Fuller Labs - Wood Drying Consultation and Research
Newport, Virginia, USA

Dr. Jim Fuller is the President of Fuller Labs - Wood Drying Consultation and Research in Newport, Virginia. His responsibilities include consultation services to the wood industry and he is currently overseeing the developmental research of a stress-based monitor/control system for dry kilns. Previously, he was a Research Scientist at the USDA Forest Products Laboratory in Madison, Wisconsin. He received a BS degree from Virginia Tech, Blacksburg, Virginia; an MS degree from Oregon State University, Corvallis, Oregon; and a PhD degree from North Carolina State University, Raleigh, North Carolina.

Peter Garrahan
Wood Drying Scientist
Forintek Canada Corporation
Ottawa, Ontario, Canada

Peter Garrahan is a Wood Drying Scientist at Forintek Canada Corporation in Ottawa, Ontario, Canada. His responsibilities include coordinating Forintek's national drying program; research, technical services, and kiln operator training programs; and developing a new kiln manual for drying of Canadian spruce-pine-fir. He received a BS degree in Forestry (specialization in Wood Science and Forest Products) from the University of Toronto.

Eric Hansen
Associate Professor and Extension Marketing Specialist
Department of Wood Science and Engineering
Oregon State University
Corvallis, Oregon, USA

Dr. Eric Hansen is an Associate Professor and Extension Marketing Specialist in the Department of Wood Science and Engineering at Oregon State University, Corvallis, Oregon. His academic background includes a BS degree from the University of Idaho and a PhD degree from Virginia Tech, Blacksburg, Virginia. Much of his recent research and extension work has been on the topics of forest certification and environmental marketing. His other research interests include customer perceptions of softwood lumber quality and use and new product development. He recently coauthored a textbook, *Strategic Marketing in the Global Forest Industries*.

Jeff Hardy
General Manager
Brattleboro Kiln Dry and Milling
Brattleboro, Vermont, USA

Jeff Hardy is General Manager of Brattleboro Kiln Dry and Milling in Brattleboro, Vermont. His responsibilities include managing Brattleboro Kiln Dry and Milling and Hardwick Dry Kiln - two custom drying facilities. He also oversees drying at the Cersosimo Lumber plant.

Kazuo Hayashi
Professor
Faculty of Agriculture
Ehime University
Matsuyama, Japan

Dr. Kazuo Hayashi is a Professor, Faculty of Agriculture, Ehime University, Matsuyama, Japan. His responsibilities include teaching (two Master's courses and three Doctoral courses) and research. He received an MS degree in Fractography and a PhD degree in Cell Collapse from Nagoya University, Nagoya, Japan.

Uli Heimerdinger
President
Lignomat USA
Portland, Oregon, USA

Uli Heimerdinger started his career as an assistant to the top management at Hildebrand Maschinenebau GmbH, a major manufacturer in dry kilns. In 1975, he received an assignment to manage the U.S. subsidiary Hildebrand Machine Company. In 1981, Lignomat USA introduced German technology in moisture measuring and electronic kiln control systems. Mr. Heimerdinger has held the position of President of Lignomat USA since 1981. His education includes Abitur in Germany, followed by a 2 year Military service and studies at the Technische Hochschule (University) of Karlsruhe in Computer Science and Business and Administration. He received a Dipl Ing. (Master's degree) as Wirtschaftsingenieur.

Paul Houghland, Jr.
Executive Manager
National Hardwood Lumber Association
Memphis, Tennessee, USA

Paul Houghland is the Executive Manager of the National Hardwood Lumber Association in Memphis, Tennessee. Previously, he was Executive Director of the Opticians Association of America, Executive Director of the National Association of Dental Associates, and Associate Secretary of Optimists International. He received a BS degree from Oakland City College, Oakland City, Indiana; and an MS degree in Education from Indiana University, Bloomington, Indiana.

Jim Lopez
Executive Vice President, Forest Resource Management
Tembec Inc.
Temiscaming, Quebec, Canada

Jim Lopez received a Bachelor's degree in Economics. He began his career working for Synergetics, an international consulting firm for 5 years, progressing through various levels of management and completing projects for resource based and manufacturing firms throughout Canada and the United States. Subsequent to this, Mr. Lopez was employed as a Plant Manager by the Kellogg Company to start up and manage a new state-of-the-art food processing plant. In 1989, he was hired by his current employer, Tembec Inc., as Manager of Corporate Development. During his 5 years in this position, he was responsible for the strategic planning and worked on a number of internal and expansion projects for the company. He played a major role in the 1991 acquisition of Spruce Falls Inc. with the employees. Mr. Lopez was next assigned as Vice President and General Manager of Tembec Chemical Products Group where he and his management team completed a successful turn around of these operations. In 1996, he was given the responsibility of Vice President, Specialty Products Division of the Forest Products Group. In this position, he was responsible for five hardwood and pine mills in Ontario and Quebec. He currently holds the title of Executive Vice President, Forest Resource Management, reporting to Tembec's President and CEO. Mr. Lopez's Corporate Fibre Supply responsibilities span from New Brunswick to British Columbia. He played a key part in negotiating the conclusion of the Ontario Living Legacy and Ontario Forestry Accord. He is also responsible for the corporation's First Nations community relations. Mr. Lopez is Chairman of the Board of Directors of the Ontario Forest Industries Association, Chairman of *WoodWorks!* Ontario, and holds a seat on the Board of Directors of FERIC (Forest Engineering Research Institute of Canada).

Dan Meyer
Associate Editor
Hardwood Review
Charlotte, North Carolina, USA

Dan Meyer is Associate Editor at Hardwood Publishing Company in Charlotte, North Carolina. His responsibilities include research of hardwood lumber markets and write and edit the *Weekly Hardwood Review* and the *Hardwood Review Export*. Previously, he was the Director of Technical Services at the National Hardwood Lumber Association, and Outreach Specialist, Extension Forestry at the University of Wisconsin-Madison. He received a BS degree in Forestry from the University of Wisconsin-Madison, and an MBA degree from the University of Memphis.

Lech Muszynski
Assistant Scientist
Advanced Engineered Wood Composite Center
University of Maine
Orono, Maine, USA

Dr. Lech Muszynski is native of Poland, where he received an MS degree in Wood Technology and a PhD degree in Forestry and Wood Technology from Agricultural University of Poznan. In 1998, he transferred as a post-doctoral fellow to the University of Maine where he works today as Assistant Scientist in the Advanced Engineered Wood Composites Center, and as a Graduate Faculty in the Department of Forest Management. Most generally, his scientific interest may be described as material-level testing and modeling of mechanical properties of wood and wood composites. In particular, Dr. Muszynski's research field includes hygro-mechanical behavior of wood, durability of advanced wood-plastic and wood-FRP composites, and application of Digital Image Analysis techniques to measurement of deformations in mechanical tests of composite materials. He is a member of the Forest Products Society, SEM, and the Society of Wood Science and Technology.

Luiz C. Oliveira
Research Scientist and Group Leader
Forintek Canada Corporation
Vancouver, British Columbia, Canada

Luiz Oliveira is a Research Scientist, Wood Drying at Forintek Canada Corporation in Vancouver, British Columbia, Canada. He has been with Forintek for 14 years. His activities include research, technology transfer, and training of managers, kiln operators, and quality control personnel. Before joining Forintek, he worked for many years with the softwood and hardwood operations in Brazil. As a Forintek research scientist, he had the opportunity to work extensively with the industry throughout British Columbia, Alberta, and in the United States carrying research projects and training activities. He is currently the Group Leader of Wood Drying Research in the Lumber Manufacturing Department at Forintek.

Konstantin Pougatch
Research Engineer
Department of Mechanical Engineering
University of British Columbia
Vancouver, British Columbia, Canada

Konstantin Pougatch is a Research Engineer in the Department of Mechanical Engineering at the University of British Columbia, Vancouver, British Columbia, Canada. He is a member of the Computational Fluid Dynamics research group where his work involves the development of the numerical models of industrial processes and conducting the computational analysis. Previously, he was a Research Engineer at Gasmaster Industries in Surrey, British Columbia, Canada, and a Research Engineer at the Research Institute of Hypersonic Technologies in St. Petersburg, Russia. He received an MS degree in Engineering from the Technical University in St. Petersburg, Russia.

Steve Riley
Scientist, Wood Processing
New Zealand Forest Research Institute Ltd.
Rotorua, New Zealand

Steve Riley is a Wood Processing Scientist at the New Zealand Forest Research Institute Ltd. in Rotorua, New Zealand. His responsibilities include research within the Wood Drying Group - kiln control systems, moisture sensing, fundamental wood processing, and drying technology transfer to industry. He is also the Manager of a wood drying multi-client industry research cooperative. He received a BS degree in Physics and Mathematics from the University of Sydney, Sydney, Australia.

Rubin Shmulsky
Assistant Professor
Department of Wood and Paper Science
University of Minnesota
St. Paul, Minnesota, USA

Dr. Rubin Shmulsky is an Assistant Professor in the Department of Wood and Paper Science at the University of Minnesota, St. Paul Minnesota. His responsibilities include research, teaching, and consulting related to wood and wood products. Previously, he was an Instructor and Research Assistant for wood drying and processing at Mississippi State University's Forest Products Laboratory. He received a BS degree in Building Materials and Wood Technology from the University of Massachusetts, and MS and PhD degrees in Forest Products from Mississippi State University.

Mike Sprague
President and CEO
M. Sprague, Inc. - Thermal Products and Consulting
Portland, Oregon, USA

With an engineering degree and 30+ years of experience in the wood products industry, Mike Sprague, President and CEO of M. Sprague Inc. - Thermal Products and Consulting, is a highly qualified kiln systems expert. He led the kiln departments of two of the nations largest kiln manufacturers during a period of nearly 20 years prior to moving on to his own business ventures. Mr. Sprague is a highly sought-after consultant to kiln operators and his company produces the patented "UltraVent Plus" heat/energy recovery and vent optimization systems and has received state and federal honors for exceptional energy recovery results when their equipment is value-added to new or existing kiln facilities. On an international scale throughout the Western Hemisphere, his expertise is unsurpassed in the management of large kiln installation and boiler projects.

Dieter E. Steinmann
Senior Lecturer
Department of Wood Science
University of Stellenbosch
Stellenbosch, Republic of South Africa

Dr. Dieter Steinmann is a Senior Lecturer in the Department of Wood Science at the University of Stellenbosch, Stellenbosch, Republic of South Africa. His responsibilities include lectures in wood physics and drying, research on wood drying and methods of moisture measurement, training kiln operators and mill management, and consulting and extension. Previously, he was a Statistician at African Explosives and Chemical Industries, a High School Teacher in Physics and Mathematics, and a Nuclear Reactor Physicist for the Atomic Energy Board. He received a BS degree, a Senior Teachers Diploma, and a PhD degree from the University of Stellenbosch. He also received an MS degree in Nuclear Reactor Technology from the University of Aston, Birmingham, England.

Carl Tremblay
Research Scientist
Forintek Canada Corporation
Sainte-Foy, Quebec, Canada

Dr. Carl Tremblay is a Research Scientist at Forintek Canada Corporation in Sainte-Foy, Quebec, Canada. As a Research Scientist and Project Leader, he works on drying projects such as wood drying modeling, air drying of balsam fir, and impact of curve sawing on kiln drying as well as other projects regarding new drying technologies. Previously, he was a Project Engineer in the Department of Wood Science at Laval University. He received a Bachelor's degree in Mechanical Engineering, and MS and PhD degrees in Wood Science from Laval University.

Robert L. Zwick
Vice President, Technology
HeatWave Technologies, Inc.
Crescent Valley, British Columbia, Canada

Robert Zwick is Vice President of Technology at HeatWave Technologies, Inc. in Crescent Valley, British Columbia, Canada. He is responsible for overseeing the development and protection of the Company's technology and intellectual property. Mr. Zwick's work experience includes being a Research Scientist in lumber drying at Forintek, Business Analyst for International Forest Products, and Director of Technical Services at the Council of Forest Industries. He is a founder of HeatWave, the Company's first President, and was instrumental in the development of much of HeatWave's current technology. Mr. Zwick is a Professional Engineer and his background includes a Master's degree in Thermodynamics and PhD studies at the University of British Columbia.

SESSION ABSTRACTS

MONDAY, SEPTEMBER 23

SESSION I: OVERVIEW OF THE RESOURCE AND THE TECHNOLOGIES

Keynote Address

Jim Lopez, Executive Vice President, Forest Resource Management, Tembec Inc., Temiscaming, Quebec, Canada

The keynote will open with a review of the current competition for forest products, including competing products and competing Hemispheres. Mr. Lopez will then move on to an analysis on "the New Green Wave", including a description of the contemporary ENGO, whether strategic alignment is possible and whether certification is a real opportunity or just an additional cost of doing business. He will also present an overview of current green building trends. He will then discuss the impact of value-added products and processes and close with comments on future opportunities and challenges for the North American forest products industry.

Drying Systems Design and Considerations

Mike Sprague, President and CEO, M. Sprague, Inc. - Thermal Products and Consulting, Portland, Oregon, USA

Timely and cost-effective production of a quality product is the goal of many companies. This presentation challenges participants with a discussion of the basics of drying system design and how initial investment in value-added technological advances in these systems can reap long-term rewards. As technology endeavors to find ways to improve productivity, it becomes extremely important to keep sight of the basic parameters involved in drying wood products. Technological advances can reduce energy and operating costs, add value to product lines, and enhance the flexibility of corporate operations. General aspects and specific examples of kiln structure, functional charge design practices, air flow dynamics (fan size, design and use; baffles and their placement; entire system venting and humidity control); heating systems (including condensate tank placement and system corrosion issues); and effective cost recovery methods (i.e., preventive maintenance schedules, energy recovery tax credits and equipment, increased grade recovery, reduced drying times, etc.) will be presented. Customer satisfaction and corporate profitability form the basis for business success. The insights gained from this presentation will be immediately useful in fulfilling those goals and values.

Current Drying System Alternatives

Fred M. Lamb, Professor Emeritus, Department of Wood Science and Forest Products, Virginia Tech, Blacksburg, Virginia, USA

There is a heightened awareness of the importance of proper lumber drying and moisture control during manufacturing in today's more complex, automated, multi-plant, and even multi-national manufacturing operations. Quality drying starts with the understanding that lumber drying is a process and that the individual drying methods are pieces of equipment. Once the drying process is understood in this context, then a drying system can be constructed that truly fits the objectives of the individual operation. Using this concept, the question is not "what kind of a dry kiln do I buy?" The question should be "What type of drying system do I assemble, and how should it be arranged and operated so that the drying process produces the level of production and quality that is required?" Viewed in this manner, drying systems can be divided into two major classes: pre-drying systems and final drying systems. For most industrial operations, pre-drying systems would include air-drying yards, drying sheds, fan-shed dryers, and steam-heated predryers. Final drying systems would include conventional dry kilns, dehumidification dryers, and vacuum dryers. This paper will compare the major advantages and disadvantages of these various drying methods and their relevant technologies. The grouping of these drying methods into drying systems to meet varying drying objectives will also be presented.

Process Control Technologies

Uli Heimerdinger, President, Lignomat USA, Portland, Oregon, USA

When drying hardwoods, the most common process control involves creating drying schedules based on changes in climate conditions in (normally) a convection-type dry kiln. The climate conditions, controlled by adjustments in temperature and relative humidity, are changed depending on the decreasing level of moisture content of the lumber in the kiln. Use of this type of process control requires continuous measurement of the temperature and, relative humidity, and of the moisture content of the wood in the kiln. Temperature, relative humidity, and the moisture content of the wood below the fiber saturation point are relatively easy to measure; the challenge comes into place when it is desired to measure the moisture content of the wood at values above the fiber saturation point. This presentation will outline several methods available today to measure with sufficient accuracy the moisture content of wood above the fiber saturation point while lumber is being dried, with the objective of developing schedules that can be run automatically from the beginning to the end of the drying process, thereby allowing the lumber to be dried with shorter drying times and producing better quality.

SESSION II: MARKETS AND CONSUMER NEEDS

Changing Hardwood Markets: Impacts on Production and Marketing

Dan Meyer, Associate Editor, *George Barrett*, Editor, and *Andy Johnson*, Associate Editor, *Hardwood Review*, Charlotte, North Carolina, USA

Domestic and international market forces are driving continued changes in the production and marketing of hardwood lumber. The rapid emergence of substitute materials and timber sources; the wholesale migration of entire manufacturing sectors; and a general lack of profitability have forced many North American producers out of business. Many others are still teetering on the edge. As a result, hardwood lumber production in North America has dropped by as much as 35% since the beginning of 2000, the sharpest decline in recent history. The very recent return to profitability for the remaining producers suggests that a heavy investment in technology, innovative marketing and production strategies, and a concentrated focus on product quality can allow North American producers to compete in the new global hardwood marketplace.

Background and Outlook for Certified Wood Products

Peter A. Drake, Senior Marketing Consultant, AMEC Forest Industry Consulting, Vancouver, British Columbia, Canada

The growth in the area of forest certified under the various third party certification schemes has been dramatic over the last few years. The Forest Stewardship Council (FSC) now has close to 30 million hectares and the new Pan European Forest Certification Scheme (PEFC) has already certified 43 million hectares. In addition to these International schemes there are a number of National certification schemes, such as the Sustainable Forest Initiative (SFI), which now has certified 34 million hectares in the US and Canada, and the Canadian Standards Association (CSA) which has 8.8 million hectares certified. There are also regions, including Canada, where other approaches such as ISO 14001 have been adopted. The Confederation of Paper Industries (CEPI) has taken a strong initiative to develop some mutual recognition between the schemes but the arguments and decisions between the proponents of each scheme are contentious and deep. Once there is availability of certified timber the next step is to obtain Chain of Custody (CoC) certification for the production operation so that the wood product itself can be labeled as being from certified timber. Each of the main schemes has provision from CoC certification, FSC now has certified over 2,000 operations, and PEFC has issued close to 150 but has over 3,500 logo users. The growth in demand for certified wood products (CWP) has been steady but has not matched the growth in forest certification. The initial drive to create demand came from the environmental movement. Strong support developed from a group of retailers in the UK and about 25% of lumber used in the UK is now certified. Significant but much lower percentages are apparent in parts of Northern Europe. So far, the share of CWP's in North America is very low but well publicized commitments from some big box stores such as Home Depot and Lowes could lead to significant increases.

Impact of Certification on Markets for Manufactured Wood Products

Eric Hansen, Associate Professor and Extension Marketing Specialist, Department of Wood Science and Engineering, Oregon State University, Corvallis, Oregon, USA

Environmental certification of forests and ecolabeling of wood products has been an important issue in the forest industry during the past decade. Although certified and labeled forest products are still a minor part of the overall marketplace, certification has had a significant marketplace impact. Along with other factors, such as the growing power of big box retailers, certification has led to structural changes in the marketplace and in certain cases has totally shifted the way products go to market. This presentation will provide examples of the changes in the marketplace resulting from forest certification as well as treatment of certification as a component of product quality. Certification often has few direct impacts on the drying of wood products. However, indirect impacts via development of new products and exploration of new markets can be important. Certification and product labeling will continue to grow in the short term. The future is difficult to predict, but additional changes in the marketplace can be expected.

An Examination of Market Trends and Opportunities in Secondary Manufacturing

Bill Wilson, Director, Industry Trade and Economics Research, Natural Resources Canada, Canadian Forest Service, Victoria, British Columbia, Canada

The decade of the 1990's witnessed a shocking pace of fundamental change in timberlands management, processing technologies, markets, products, and corporate structure in forestry. Public sector institutions and private sector capital struggle to position the sector in order to sustain a stream of economic contributions historically generated by forestry. Secondary manufacturing in wood products has emerged in response to and because of these changes. Incremental processing is seen as a vehicle to provide additional employment and more efficient utilization of timber supporting resource sustainability objectives. This paper discusses the drivers promoting secondary manufacturing including timber supply, employment goals, product performance and pricing, and industry concentration. Trade and production trends are examined for the major engineered wood products, furniture, mill-work, and profiled wood. The economic and market outlook in North America, Europe, and Japan for secondary manufactured products will be presented. In conclusion, a number of macro-level market conditions in the sector will be presented. Recognition and incorporation of these conditions within the business plan will influence future financial success in secondary manufacturing.

Meeting Market Needs: The Perspective of a Custom Kiln Dryer

Jeff Hardy, General Manager, Brattleboro Kiln Dry and Milling, Brattleboro, Vermont, USA

By kiln drying lumber we cannot improve grade or appearance. We can only minimize degrade and damage to color. Knowing this, we can take green lumber, with a limited number of uses and markets and by proper drying provide a product with unlimited uses and markets, provided that the beginning product is of sufficient quality to match a particular use. Advances in technology have been related to drying equipment, drying schedules, and drying procedures. To help our customers and us compete, we continually need to keep up with proven advances in technology. Markets used to offer a premium for lumber that is of good color, correct moisture content, and packaged well without drying defects. This has now become industry standard. As a custom kiln dryer, we have an unique vantage point as we see lumber from a large number of mills that ship to a wide variety of market places and also quite often to the same market. We can usually understand why or why not a particular load will work out, and learn quickly what we can do within our own control systems to enable our customers compete with changing demands.

Demands of the Export Market: Standards for Sterilization

Paul Houghland, Jr., Executive Manager, National Hardwood Lumber Association, Memphis, Tennessee, USA

Standards recently enacted by the European Union and the International Plant Protection Convention pose a major challenge to the forest products industry. Wood packing materials (pallets, boxes, crates, dunnage, etc.) must be sterilized either by heat treating or by fumigation. The purpose of the standards is to reduce the risk of intro-

duction and/or spread of quarantined pests associated with wood packing materials, both coniferous and non-coniferous. National plant protection organizations are establishing procedures to verify that an approved measure, including the application of a globally recognized mark, is in place. Wood packaging material which fails to meet the recognized standard may be disposed of, properly treated, or returned to the country of origin.

TUESDAY, SEPTEMBER 24

SESSION III: ADVANCES IN DRYING TECHNOLOGIES

Energy Management in Kiln Drying Control Systems

Steve Riley, Scientist, Wood Processing, and *Richard Dandoroff*, Process Control Engineer, New Zealand Forest Research Institute Ltd., Rotorua, New Zealand

This presentation provides a general discussion about the factors that need to be addressed when designing an energy management system for banks of dry kilns, with emphasis on plantation-grown softwood drying. Within the limits of known drying schedules, savings achieved by optimizing for energy costs are usually exceeded by the subsequent losses due to reduced throughput. Thus, energy management system design often focuses on the need to optimize production when demand exceeds supply. Practical ideas developed to achieve this are briefly presented, drawn from the authors' experience in developing the Dryspec™ kiln control system. Factors influencing the decision on prioritizing strategies are presented. Energy managing strategies, including flow-based systems and heat medium temperature/pressure-based systems, are discussed. Ways of combining strategies, future flow prediction, heat plant-dry plant information sharing, and ideas for reducing installation and instrumentation costs are presented. Future developments, including maximizing production when supply exceeds current demand, and schedule optimizing are discussed.

Drying Emissions and Environmental Regulations

Michael R. Milota, Associate Professor, Department of Wood Science and Engineering, Oregon State University, Corvallis, Oregon, USA

Understanding and complying with environmental regulations is very complex, and failure to comply can and has resulted in large monetary fines to companies in the forest products industry. A summary of the VOC (volatile organic compound) and HAP (hazardous air pollutant) studies in the published literature will be presented. Factors that affect emissions will also be discussed as is the relevance to air quality. VOC emission factors will be presented for 22 species and HAP emission factors for five species. Several of the major environmental regulations affecting the lumber industry will also be discussed, such as new source review, the boiler and panel MACTs, and the regional haze rule with the caveat that mill location and proximity to other company operations can influence how regulations are applied.

Stress-Based Kiln Monitor/Control: Concept and Industrial Trial

Jim Fuller, President, Fuller Labs - Wood Drying Consultation and Research, Newport, Virginia, USA

The production goal of drying appearance grade lumber is to dry the lumber as quickly as possible with zero defects. Drying the lumber quickly is the best way to avoid defects, with one exception. To avoid drying checks, the kiln operator needs to reduce drying speed which reduces the drying stresses that cause the drying checks. After the risk of checking has past, the drying rate can be increased. But how this risk can be detected or predicted has been the question of a tremendous amount of research performed over the past half century. Because there has not been an effective way to measure drying stresses, lumber has been dried excessively slowly, and the cost and degrade associated with drying lumber has been unnecessarily high. Presented here is the theory behind a method of monitoring drying stresses and an associated control of the drying process to avoid drying checks. The presentation then goes on to describe an actual industrial application of the process in a commercial setting. In a commercial trial, this method reduced the total drying time by at least 30% while, at the same time improving the quality of the lumber. With reduced drying time and increased quality, significant increases in profits can be realized.

Hardwood Drying Control Using Acoustic Emission Technology

Frank C. Beall, Professor and Director, University of California Forest Products Lab, Richmond, California, USA

This patented method uses metal stickers to monitor acoustic emission (AE) during drying, and provides means of measuring ultrasonic transmission to determine the drying endpoint. The nominal behavior of AE during drying is a high rate very early, possibly from initial surface checking, followed by a quiescent period with minimal AE. A major AE peak coincides with the range of moisture content near the fiber saturation point, where stresses also tend to peak. As a strategy to minimize degrade from stresses and maximize the drying rate, the drying rate can be accelerated during the quiescent period until the major AE peak is reached. At that point, the drying rate can be reduced until the peak has passed, and then increased through the remainder of drying. With experience, the AE peak could be correlated with moisture content to assist in the prediction of the desired endpoint. The approach in this invention is to use a substitute sticker ("special sticker"), preferably of metal, that is inserted into the load of lumber to be dried, acting as an accumulator of acoustic emission during the drying process. Because of the multiple board contact, the AE would be much greater in numbers and more reflective of the response of the load. There would also be a very stable attachment configuration with no effect on airflow through the slot. As an example of a typical means of use, with a 1.2-m wide package of 25 by 150 mm boards, the sticker would have contact with the 16 boards across the course. The special sticker(s) would be located at lower levels of stack, which would provide sufficient coupling pressure during the drying process. The special sticker could be inserted during stacking or in the kiln, using a manual "lifting bar," which was developed for inserting wood stickers into loads where the sticker is missing. The initial application is directed to hardwoods to minimize temperature effects on active electronic elements, but can be used with any species operating below 100°C, and with electronic cooling of elements, at any temperatures used in drying.

Radio Frequency Vacuum (RFV) Drying and Radio Frequency (RF) Heat Treating

Robert L. Zwick, Vice President, Technology, HeatWave Technologies, Inc., Crescent Valley, British Columbia, Canada

HeatWave Technologies has developed patented E-field heating and RF Vacuum drying technology. The advantage of E-field heating over microwave is that the heating is uniform and volumetric throughout the entire product cross-section (including solid packages of lumber products). This is especially advantageous for heat-treating lumber packages. HeatWave generates, controls, shapes and applies an E-field that is completely different than how RF heating has been approached before. Under vacuum, this unique industrial drying technology can be leveraged towards several applications in the wood industry, including: the processing of trim ends (as well as frozen blocks), hardwoods, large-dimension wood products, re-drying of conventional kiln "wets" (Q-Sift), heat treating, and veneer drying. Case examples are discussed for several of these commercial applications.

Wood Color and Stain Control

William B. Smith, Professor, and *Hwanmyeong Yeo*, *Patrick Rappold*, *Douglas Herdman*, and *Daniel Montoney*, former Graduate Research Assistants, Wood Products Engineering, State University of New York, College of Environmental Science and Forestry, Syracuse, New York, USA. The authors wish to acknowledge the New York Center for Forestry Research and Development for funding this work.

Customers were once relatively satisfied with lumber that was the proper moisture content, flat, and check and stress free. Recently, however, requirements have also demanded that manufacturers provide lumber which is attractive, and of a specified, uniform, and replicable color. Detrimental color changes in lumber can be biological, such as blue stain from fungal growth, or chemical, such as enzymatic or oxidative staining, which would include darkening in maple, pinking in hickory, sticker stain and brown stain in the pines and hemlock. Biological stains are typically controlled with reasonable success by rapid processing and drying of lumber, or with the appropriate use of sapstain control chemicals. Industrial experience and research has shown that lumber color changes are very often effected by the temperature and relative humidity conditions the wood is exposed to during drying. For example, published drying schedules for specifically white hickory and maple use reduced dry bulb temperatures and relative humidity values. With higher temperature and %RH pinkish, orange, and brown shades and darker color lumber is produced.

Another method of modifying color is presteaming, typical with black walnut and also being done with red oak and cherry, to cause darkening of bright sapwood so that it is less distinct from heartwood. Vacuum drying, as with a radio-frequency/vacuum kiln, will produce lighter and brighter color lumber because of the low temperatures and lack of oxygen in the reduced pressure environment. There are several additional issues felt by many to affect lumber color, of which practical control can be complicated. These include harvesting and processing season, log age, yard storage and delay time from saw to kiln, source of supply, geography, and climate. Also, sometimes surface and interior color differs, with varying acceptability. Further difficulty to lumber manufacturers and marketers, beyond these natural and processing variables, is caused by the fact that individual people perceive color differently. Acceptable lumber color can become unacceptable for reasons which are hard to understand. A solution to these problems of processing and perception involves use of spectrophotometers, which measure color precisely by analysis of multiple data points of light reflected back from an object across the entire visible spectrum and describe color as numerical values, typically in terms of $L^*a^*b^*$ (L^* , lightness; a^* , red/green; b^* , yellow/blue). They thus accommodate the phenomena of color difference due to illumination source, and perception difference between human observers. Data, in terms of $L^*a^*b^*$, will be presented on wood color change and control with several processing variables and wood species.

SESSION IV: MANAGING THE DRYING PROCESS

Modeling the Conventional Kiln Drying Process and Comparison With Experimental Results

Carl Tremblay, Research Scientist, Forintek Canada Corporation, Sainte-Foy, Quebec, Canada, and *Yves Fortin*, Professor, Department of Wood and Forest Sciences, Laval University, Sainte-Foy, Quebec, Canada

The kiln drying process involves heat and mass transfer phenomena within the lumber and at the boundary layer between the wood surface and the incoming air flow. Mass transfer in wood can be explained by a combination of capillary, diffusion, and convection mechanisms, while heat transfer is a combination of conduction, phase change, and advection mechanisms. Heat and mass transfer phenomena at the boundary layer call upon convection and phase change mechanisms. A two-dimensional wood drying model was developed in order to predict the evolution of wood moisture content and temperature during conventional kiln drying. Heat and mass transfer during wood drying are then described by mass conservation and energy balance equations and the corresponding boundary conditions equations. The use of this model requires the determination of some basic parameters such as the convective heat and mass transfer coefficients, the moisture content - water potential relationship, the effective water conductivity, and the ratio of vapor diffusion to total mass flow. The 2-D model was adapted to stack drying by considering the effect of the stack geometry and air flow characteristics on the drying process. In order to validate the model, drying tests were conducted in an experimental kiln on black spruce, balsam fir, and jack pine lumber in conditions pertaining to conventional kiln drying. Work is ongoing at Laval University and Forintek Canada Corp. to develop a 3-D wood drying model that will predict both drying kinetics and wood mechanical behavior (drying strains and stresses, and check formation).

Modeling Wood Drying Linked With Airflow in the Kiln

Konstantin Pougatch, Research Engineer, *Martha Salcudean*, Professor and Weyerhaeuser Chair Emerita, and *Ian Gartshore*, Professor Emeritus, Department of Mechanical Engineering, University of British Columbia, Vancouver, British Columbia, Canada

A dry kiln is a complex system, where different mechanisms are involved in the process to reduce the wood moisture content. To adequately represent the full drying process inside the kiln, a numerical model has to account for airflow. Two sub-models describing airflow and wood drying are integrated into one comprehensive model. A detailed review of both the airflow and wood drying models will be presented together with a description of the coupling procedure between the models. The performance of the coupled model is validated by comparison of the computational results with the experimental data in the small test kiln. Some examples will be discussed that indicate possible benefits of using the model for the improvement of the drying quality. The model may be utilized in the design of new kilns, as well as in the optimization of existing kilns. Different drying condi-

tions, various schedules, and lumber arrangements can be studied in depth without costly experimentation.

Analysis of Drying Data

Luiz C. Oliveira, Research Scientist and Group Leader, Forintek Canada Corporation, Vancouver, British Columbia, Canada

Although in the past, kiln drying of softwood dimension lumber was primarily motivated by the reduction of transportation costs, it is certain that today it is one of most important phases in lumber manufacturing. Markets demand quality and competitive prices. Thus, an increased level of sophistication in kiln drying is expected to ensure that lumber products will exhibit the characteristics that are compatible with current requirements. Today, the concept of successful kiln drying implies more than high productivity. It invariably means low operational costs coupled with high-grade recovery. Unquestionable competition from other building materials and the highly desirable characteristics exhibited by wood engineered products are clear signs that the kiln drying of lumber products must ensure consistency in final moisture content uniformity to perform according to specifications. To achieve consistency and uniformity of final moisture content, kiln supervisors must rely on high performance equipment and a comprehensive quality control system. Very often, it is necessary to carry out detailed drying data analysis to determine the main sources of problems so that proper adjustments can be implemented. This discussion will illustrate concepts and approaches to the analysis of kiln drying data and therefore provide kiln supervisors with tools and ideas that will be useful for interpreting drying results and thereby optimizing the kiln drying operation. Some of the concepts illustrated have been used in actual industrial situations to evaluate and compare kiln drying runs.

Moisture Measurement in Wood With a 1 GHz Transmission Line Probe

Francois S. Malan, Researcher, and *Kemal Ahmet*, Sub-Dean and Principal Lecturer, Department of Design and Architecture, University of Luton, Luton, Bedfordshire, United Kingdom

Measurement of moisture is essential for process control in lumber drying processes. Currently, employed hand-held moisture meters use resistance or capacitance as the basis for measurement. Transmission line sensors that have recently been developed are cost effective and highly sensitive to changes in moisture content. The advantage of a very high frequency moisture measurement system is that it eliminates errors introduced by ionic conduction and the relative permittivity of free ions. For continuous monitoring, the transmission line described can be embedded into a wood dowel plug, and then inserted into a drilled hole in representative timber samples. For spot-checks, the sensor can alternatively be utilized as a strip-line which can be used by making contact against the surface of the material under test. The electrical or apparent length of the transmission line sensor is a function of the relative permittivity of the surrounding medium, where the latter is strongly affected by the moisture content. The transmission line is used as the tuning element for a radio-frequency oscillator. The frequency of the oscillator is thus a function of the relative permittivity and therefore the moisture content. The frequency is converted into a voltage via a frequency to a voltage converter, the output of which can be monitored on a voltage datalogger. Results from trials show excellent correlation between moisture content and the relevant measurement parameters.

Evaluating the Cost of Drying Degradate

Peter Garrahan, Wood Drying Scientist, Forintek Canada Corporation, Ottawa, Ontario, Canada

Most mill and kiln operators now realize that drying degrade is an inevitable part of drying and that it is also a cost consideration just as real as energy and labor. Unfortunately, degrade is not as easy to quantify as energy and labor or any of the other drying costs. There are no on-line gauges or automatic sampling devices that can tell you what your degrade level is today. This presentation is intended to cover some of the techniques that can be employed in a mill to develop estimates of drying degrade. Fortunately, the levels of drying degrade in industrial kilns are relatively low, however, this contributes to the problem of assessment. It means we need to sample large volumes of lumber in order to get any meaningful results or to identify trends. In a study on drying degrade conducted a number of years ago, we estimated that spruce-pine-fir mills in Eastern Canada were losing from 2 to 9% of the potential value of their product in the dry kilns. Recently, we visited a number of mills across the country in order to see how

they evaluate drying degrade. We also conducted a test on an in-line grading system to study its potential as a drying degrade evaluation tool. There are useful techniques which mills can employ. Most mills need good information on drying degrade in order to justify new investments in equipment or changes in drying procedures.

WEDNESDAY, SEPTEMBER 25

SESSION V: IMPROVING PROFITABILITY

Spruce and Fir Drying Optimizer: System Description and Performance Study

Réal Frenette, Project Engineer, Autolog Inc, Laval, Quebec, Canada, and *Marc Savard*, Eastern Group Leader, Wood Drying, Forintek Canada Corporation, Sainte-Foy, Quebec, Canada

Currently, used methods of sorting spruce and fir lumber for drying purposes necessitate the presence of an operator to identify, as best as they can, and in a limited amount of time, the species of lumber. This requirement is very demanding on an operator and is prone to error. But knowing the species is only one of the variables affecting drying behavior of lumber. Another very important aspect is the moisture content of the lumber. The SAPTEK Drying Optimizer provides a completely automatic method of sorting spruce and fir lumber which takes into account both the species and the moisture content of the lumber. A relatively dry piece of fir will end up inside a package that contains mainly spruce lumber; similarly a piece of spruce having a large proportion of sapwood will end up in a package that contains mainly fir lumber. The overall results mean more uniform packages in terms of drying characteristic. Therefore, kilns will be easier to operate and moisture content after drying will be more uniform. The SAPTEK Drying Optimizer utilizes an alcohol-based chemical reagent that is sprayed on the end of the lumber. A vision system analyzes the color of the chemical reaction to determine whether the piece of lumber belongs to the group requiring longer drying time or the group requiring shorter drying time. This presentation will describe the SAPTEK Drying Optimizer, its components, and a typical installation of the system in a sawmill, and the results of a study on the economics of the system will be presented.

Increasing Yield of Hardwood Lumber Through Precision End Trimming

Brian H. Bond, Assistant Professor, Tennessee Forest Products Center, University of Tennessee, Knoxville, Tennessee, USA

Whether over-length is a benefit or disadvantage in drying and processing operations has long been questioned. It is believed that eliminating over-length and using precision end-trimmed lumber (PET) would allow straighter lumber piles with stickers placed close to the ends, promoting good airflow, reducing warp, increasing kiln capacity, and increasing rough mill yields. However, many drying operations use stacking practices where boards contain over-length and are aligned even on one end and uneven and poorly supported at the other. This study was conducted to determine differences in lumber degrade volume and value between lumber stacked with over-length versus PET stacked lumber, to determine if differences in kiln volumes exist between lumber stacked with over-length versus PET stacked lumber, and to determine if rough mill yield differences exist for lumber stacked with over-length versus PET stacked lumber. The study has currently been completed at three manufacturing facilities. The results indicate that using PET lumber leads to a 4 to 12% increase in kiln capacity with an average increase of 9%. When pre-dryers are used prior to kiln drying, no significant difference in lumber degrade between stacking methods exists. For the companies participating the study lumber containing over-length provided a 1 to 2% higher rough mill yield. The results of this study are based on red oak.

Accelerated Drying of Hardwoods

Rubin Shmulsky, Assistant Professor, Department of Wood and Paper Science, University of Minnesota, St. Paul, Minnesota, USA

Acceleration of dry kiln schedules was investigated as a means of increasing the drying rate of hackberry, red oak, and sweetgum lumber. Accelerated schedules for ash and yellow poplar were developed but not tested. Results indicated that accelerated schedules can increase drying rates without increasing defect incidence.

Methods of Managing Variations in the Drying Process

Sita Millar, Technical Manager, AMEC Forest Industry Consulting, Vancouver, British Columbia, Canada, and *Brad Hunt*, General Manager, West Fraser Mill, Williams Lake, British Columbia, Canada

Managing variation in the lumber drying process presents our industry with challenges and opportunities. The most important challenge is to balance production with quality and still make a profit. In the drying process the first challenge is to identify where variability exists in the process and try to control it. This is accomplished by the following techniques: 1) Standard quality assurance methods; 2) modeling the drying process; and 3) development and implementation of new technologies to control the drying process. This paper presents the results of technical and economic evaluation of two technologies that have been developed and demonstrated at a dimension mill handling SPF mixture. The first technology demonstrated the use of a non-contact infra-red moisture sensor for initial MC sorting. The sensor was installed and integrated into the existing lumber sorting system. The impact on drying degrade, drying time, and energy savings was quantified. The first study evaluated the economic benefits of sorting lumber into moisture content classes before kiln drying in terms of grade outturn and energy savings resulting from shortened drying times. The tighter final moisture distribution resulting from moisture sorting eliminated over-drying or under-drying. Based on grade outturn and energy savings, the benefits averaged \$10.94/mbd ft. for 2x4, 2x6, and 2x8 lumber 16 feet in length. The second technology was an infrared imager developed specifically to visualize and measure the kiln charge average moisture content and moisture content distribution. This system was shown to be effective in meeting the design objectives and it was found to provide a real-time measure of the lumber drying rate. These measurements allowed the development of a family of drying curves that were then used to accurately predict the time remaining to the target final moisture content. It was demonstrated that this tool provided better control of the final moisture content of the lumber than the conventional drying cycle, reducing losses from over-drying. The economic value of this improved drying quality was estimated to be \$145,000 per kiln annually.

Weight-Based Drying - "Just the Facts"

Frederick C. Burkardt, Regional Plant Manager, Armstrong Wood Products, West Plains, Missouri, USA

With the advent of computerized, resistance-based control of moisture loss in the kiln drying of 4/4 oak lumber into our process, we were expecting to see improvements in efficiency in our drying process compared to the traditional weight-based drying methods. This has not been the case at our operation. At moisture contents above 30%, using only the resistance-based information, our process yielded very inaccurate results, and produced inefficiencies in the production of dry lumber. We continued to monitor our kilns using traditional weight-based drying methods, but continued our search for a more modern approach to this type of drying. We are satisfied that the type of weight-based drying we now employ is accurate over the entire span of MC%'s that we encounter. This presentation will describe the data and circumstances surrounding our decision to convert wholly to weight-based drying, incorporating the newest technology available to control the drying process, and can be customized for different species and conditions. The resulting gains in efficiencies have far exceeded our expectations.

Certifying the Operator and His Dry Kiln on the Basis of Drying Results

Dieter E. Steinmann, Senior Lecturer, Department of Wood Science, University of Stellenbosch, Stellenbosch, Republic of South Africa, and South African Lumber Millers Association, Isando, Republic of South Africa

A system for specifying and guaranteeing the dry quality of the wood supplied by a sawmill is described. The system defines dry quality, and based on these definitions, describes the procedures and methods to measure dry quality. These methods and procedures are used by the kiln operator to evaluate himself and his drying system's ability to achieve the specified target dry quality. If a mill achieves the target dry quality in a load specially dried for this purpose, the mill can be licensed to use a registered Dry Quality Mark for advertising its product. To the customer this mark specifies the highest dry quality he can expect the mill to produce. In practice the required dry quality depends on what the customer wants to do with the wood. The dry quality (and the corresponding price) must therefore be clearly specified in writing between the customer and the mill. This allows the customer to obtain the exact dry quality for his purpose and insures that the mill carrying the Dry Quality Mark will consistently produce what is required. In case of claims regarding the dry quality supplied, the Dry Quality Mark Authority can be called upon to inspect and arbitrate. The Dry Quality Mark must be maintained by the mill by producing at least one kiln load of wood annually which must be subjected to inspection by the Dry Quality Mark Authority and must meet the target dry quality. The benefits of this system are discussed.

POSTER PRESENTATION ABSTRACTS

BOOTH 1

Possibility of Moisture Condition Monitoring Under RF/Vacuum Drying

Kazuo Hayashi, Professor, and *Yingchun Cai*, Faculty of Agriculture, Ehime University, Matsuyama, Japan

There is little information available regarding systems for monitoring the drying process during radio frequency/vacuum drying. This poster presentation discusses the development of a convenient sensor complex to measure temperature and pressure during RF/vacuum drying.

BOOTH 2

Wood Drying Simulation Model for Eastern Softwood Commercial Species

Carl Tremblay, Research Scientist, Forintek Canada Corporation, Sainte-Foy, Quebec, Canada, *Yves Fortin*, Professor, Department of Wood and Forest Sciences, Laval University, Sainte-Foy, Quebec, Canada, and *Daniel Verret*, Mathematician, and *Eric Dumais*, Computer Scientist, Forintek Canada Corporation, Sainte-Foy, Quebec, Canada

A 2-D heat and mass transfer finite element model based on the water potential concept was developed to simulate the evolution of moisture content (MC) and temperature in the cross section of a piece of lumber during drying. In order to be able to use the model in an industrial environment, an user interface was developed and the experimental parameters required for the model were determined for three eastern softwood commercial species. The user interface was developed using the MatLab development environment. It generates the mean drying and wood temperature curves, and computes the maximum effective MC gradient and 2-D moisture content and temperature profiles at various drying times. The pressure membrane technique and equilibration over saturated salt solutions were used to determine the moisture content-water potential relationship at 30, 60 and 90°C for balsam fir sapwood and heartwood, black spruce heartwood, and jack pine heartwood, in desorption from green to dry conditions. The instantaneous profile method was used to determine the effective water conductivity of the same species from 20 to 90°C in the three main directions: radial, tangential and longitudinal. The development of the drying model continues in close collaboration between Laval University and Forintek Canada Corp. in order to generate a 3-D model of drying kinetics and lumber warping including splits and checks formation.

BOOTH 3

A Three-Dimensional Mathematical Model of the Hygro-Thermo-Mechanical Behavior of Wood During Drying

Mohssine Moutee, Ph.D. Student, and *Aziz Laghdir*, Post-Doctoral Fellow, Department of Wood and Forest Sciences, *Mario Fafard*, Professor, Department of Civil Engineering, and *Yves Fortin*, Professor, Department of Wood and Forest Sciences, Laval University, Sainte-Foy, Quebec, Canada

The purpose of this study is to develop a 3-D mathematical model to predict the evolution of the hygro-thermo-mechanical behavior of wood during drying. The total strain is seen as the summation of free shrinkage, thermal expansion or contraction, and mechanical strain. The latter is composed of the elastic strain, viscoelastic creep, and mechano-sorptive creep. The main characteristics of this model are that it takes into account the coupling effect between the directional creep strains (i.e., axial and transverse strains), and the effect of external load, and it introduces the concept of a threshold plastic (permanent) strain which is dependent on stress level and time. The constitutive law for viscoelastic strain is based on a modified Burger model while the mechano-sorptive behavior is described through the Ranta-Maunus' approach. Model parameters to be determined experimentally are the components of the elastic, viscoelastic, and mechano-sorptive tensors with respect to moisture content, temperature, load level and wood species. A cantilever-type wood specimen is proposed for the determination of the viscoelastic and mechano-sorptive parameters of the model, by measuring the surface and strain both in tension and in compression. A series of preliminary tests are being conducted to validate the experimental setup and identify the proper range of load levels and load application times. Once validated, the mathematical model will be solved numerically through a finite element technique and combined with the 3-D heat and mass transfer model under devel-

opment to predict the overall wood drying process (drying rate, warp, drying stresses) for conventional and high-temperature conditions.

BOOTH 4

Requirements for Experimental Methods for Quantification of the Mechano-Sorptive Behavior of Wood

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When wood is subjected simultaneously to stress and moisture content changes below the fiber saturation point, the mechano-sorptive effect may be observed as an additional deformation which cannot be attributed to simple superposition of elastic deformation, free shrinkage or swelling, or creep in steady climate conditions. In wood drying, the mechano-sorptive deformation is responsible for mitigation of drying stresses, which otherwise manifest themselves in surface checking. This phenomenon has been subject to research for more than half a century. First reported in early 1950's as the effect of MC changes on creep behavior of wood beams, in the 1970's it was recognized as a separate phenomenon. The state-of-the-art knowledge on the mechano-sorptive effect in wood was summarized by Morlier in 1994. Although numerous mathematical models and detailed qualitative descriptions have been proposed over time, the basic mechanism of mechano-sorption remains unclear, the experimental data are scattered and lack logical classification, and the experimental determination of its basic parameters on a material level remains a serious challenge. In this paper, basic requirements for adequate experimental methods for quantification of the mechano-sorptive behavior of wood are proposed and briefly discussed. The principal requirements are that the experimental research on mechano-sorption is focused on the material level properties and elementary loading modes (tension and compression), that proper attention is paid to the effect of changing distribution of moisture content within the tested volume, and that the tests are designed so that a comprehensive separation of strain components is enhanced.

BOOTH 5

Cause and Control of Interior Darkening in Hard Maple

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Consumer demand for bright colored "white" hard maple lumber has led many wood processing and dry kiln operations to utilize schedules which use lower temperatures and relative humidities. Some have found, however, that while surface color is satisfactory the interior of boards is sometimes relatively dark. This phenomena of dark interior color becomes a major concern during processing operations such as surfacing, resawing, and molding where asymmetrical machining exposes contrasting bright and dark colorations. For this reason, appropriate kiln schedules should be selected and properly used to control not only surface, but entire board color. In this research study occurrence of interior darkening of hard maple was observed at various drying temperature and moisture content conditions. Experimental results and processing recommendations are presented.

BOOTH 6

An Investigation of the Relationship Between Harvest Season, Log Age, and Drying Schedule on the Coloration of Hard Maple Lumber

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The preferred color of kiln-dried hard maple is bright white. Within the industry harvest season, log age, and kiln drying schedule are thought to play important roles in determining wood color. In this study the relationships between harvest season, log age and kiln drying schedule on the coloration of hard maple lumber were examined. Trees were harvested in the winter, spring, and summer. For each harvest season one-inch boards were sawn from freshly felled trees, logs stored four weeks, and logs stored eight weeks. Logs not freshly sawn were end coated with a commercial wax emulsion sealer. Drying

schedules that produce "normal orange-yellow" (T8-C3) and "white" (T3-C5) colored hard maple were used to dry the boards. A small number of boards were also air-dried. Determination of lumber color, for comparisons between harvest season, log age, and drying schedule, was done with a spectrophotometer. Results illustrated that drying schedule was a much more important factor in determining wood color than log age or harvest season. Desired color became most noticeable and uniform after the top 1/32" was surfaced from the boards. Results also showed that industry acceptable white hard maple can be produced from logs stored up to eight weeks during any season by using a low temperature and humidity drying schedule.



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