

Report of

DIMENSIONAL STABILIZATION SEMINAR

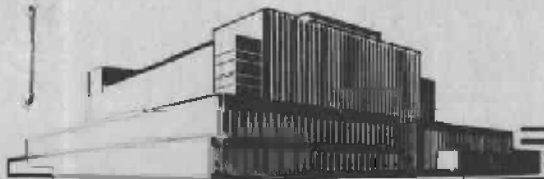
Held at

U. S. Forest Products Laboratory

Madison, Wisconsin

January 21-23, 1959

No. 2145



FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

In Cooperation with the University of Wisconsin

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NEWS
NOTE

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RELEASE

1/28/59

Immediate

Madison, Wis.--The scientific quest for new and better means of stabilizing wood dimensionally got a powerful stimulus here January 21-23, as some 85 scientists, educators, and industrial leaders from all parts of the United States and Canada examined information and ideas with staff members of the U. S. Forest Products Laboratory.

The meeting, first of its kind ever held in the United States, was called by the federal laboratory to encourage and guide fresh research attacks upon what all attending agreed is a problem of fundamental importance to the wood industries: control and reduction of wood's tendency to shrink and swell as it changes moisture content with changes in atmospheric relative humidity. Speakers emphasized that this is one of the most serious problems affecting the use of wood as a construction material.

The seminar was planned and organized by Dr. Alfred J. Stamm, internationally famous chemist at the federal laboratory, who has done much pioneering research on problems of dimensional stabilization. Among his achievements have been broad contributions to fundamental knowledge of wood-liquid relationships and such highly stabilized products as impreg, compreg, heat-stabilized wood, and acetylated wood.

Twenty speakers reviewed past achievements, analyzed existing information and its results, and proposed new avenues of research intended to make wood products more stable whether of lumber, plywood, fiberboards, paper, or

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anything else made of wood fiber. Representatives of these industries, chemical manufacturers, forestry schools, and other laboratories were among those attending the seminar.

The keynote of the meeting was sounded by Dr. J. A. Hall, director of the federal laboratory, at the opening session:

"While by and large wood is still the best structural material we have, if we can come up with some constructive ideas we will have made as great a contribution to the serviceability of wood in our economy as can be made."

A challenge to get away from "traditional thinking" was put squarely before the group by C. D. Dosker, Louisville, Ky., industrialist and chairman of the products and research committee of the National Lumber Manufacturers Association. Dosker called for trebling present research expenditures on wood and its products, which he put currently at about \$60,000,000 a year by all public and private groups in this country.

Six recommendations for future work were drawn up by a committee headed by R. H. Bescher, Koppers Co., Pittsburgh, Pa., and including Dosker; L. T. Sanders, Crossett Co., Crossett, Ark.; J. F. Saeman, assistant director of the Forest Service division of forest products research, Washington, D. C., and J. A. Van den Akker, Institute of Paper Chemistry, Appleton, Wis. The recommendations, unanimously adopted, were:

"1. That substantial additional basic information is necessary on wood-moisture relationships, microstructure of wood, and basic chemistry of wood.

"2. That since the proper use of wood will minimize the limitations caused by lack of stability, the trade associations should be encouraged to publicize the proper engineering principles of use.

"3. That more economical means of mechanically stabilizing wood should be further investigated, particularly with regard to composite structure, press drying to cause mechanical extension, and the use of other mechanical methods of distributing and minimizing the effect of dimensional changes.

"4. That additional work be performed in connection with chemical stabilization of wood. Since bulking and cross linking appear to be the only chemical means of wood stabilization, newly developed chemicals should be screened. Fundamental studies of the extractives of wood should be undertaken to determine why some species are more stable than others.

"5. That in the dimensional stabilization of paper a fundamental investigation of the effect of species should be carried out.

"6. That a bibliography be prepared which would serve as reference material for further research in the dimensional stabilization of wood."

In drawing up its recommendations, the committee pinpointed the wood-moisture relationship "as being basic to the problem and to all approaches to the solution." Its report called for a scientific breakthrough in the basic fields of wood microstructure and chemistry of wood in order to "economically solve the problems."

Sessions of the seminar were devoted to consideration of these aspects of dimensional stabilization: wood and cellulose liquid relationships; minimizing

the effects of swelling and shrinking by proper use; mechanical means of stabilizing wood; chemical means of stabilization; stabilizing paper and fabric; and chemicals for dimensional stabilization.

The chemical nature of wood excited sharpest interest and monopolized discussions as speakers probed deeply into its known relations to dimensional changes. Dr. Harold Tarkow of the federal laboratory described wood's molecular structure as consisting of a backbone of cellulose chains that are linked together at certain points by chemical or physical bonds but only loosely bundled together at other points, where moisture can enter or leave to cause swelling and shrinking. Among chemical problems being attacked, he said, is that of getting stronger bonds between the cellulose chains where these are loosely bundled together, or putting so-called "bulking agents" between the chains to fill up the spaces water otherwise enters and leaves.

One of the roadblocks thus far preventing successful chemical bonding of the cellulose chains, other speakers agreed, is lack of low-cost effective chemicals to do the job. Highly complicating this task, Dr. Tarkow pointed out, is the fact that even the electron microscope can't produce as yet clear pictures of the extremely small elements that make up the structure of wood fiber walls where swelling and shrinking actually occur.

"We don't even know," he said, "how large a molecule we can get into these cellulose bundles to form chemical cross links or bulking compounds that will stop swelling and shrinking. When we find that out, we will be in a better position to tell chemical companies what we need."

In some species, Dr. Tarkow said, extractives act as bulking agents, and these species generally shrink and swell less than others.

Dr. F. F. Wangaard of the Yale University School of Forestry, New Haven, Conn., diagrammed the mechanism of wood swelling and shrinking as understood from existing knowledge. A parallel discussion of the same phenomenon in other fibrous materials, notably cotton and rayon, was presented by Dr. Howard J. White, Jr., Institute for Textile Research, Princeton, N. J.

Much of the harmful effect of swelling and shrinking in wood construction, including furniture, houses, and other buildings, could be avoided, several speakers said, if better use were made of existing knowledge about how to season and handle wood. Fred F. Dickinson, director of the University of California Forest Products Laboratory at Berkeley, emphasized that the construction industry is the biggest market for wood but that other materials are challenging wood more strongly than ever.

That the lumber industry has too long underestimated the importance of moisture content of wood in use was cited by R. P. A. Johnson, former chief of the federal laboratory's division of physics and engineering (now retired), as one reason why wood has lost some of its markets.

Describing himself as a "taxpayer," Johnson delivered a brief but crackling lecture to those elements in the wood industries that still market green or inadequately seasoned products.

"We know what to do," he charged, "but industry doesn't do it, and the consumer doesn't demand it. We've suffered from an attitude of 'good enough,'

but today good enough isn't good enough any more. Manufacturers of other materials are doing a lot of research to make their products equal to or better than wood. As long as we're content with good enough, our markets will continue to vanish."

The air-conditioned home will bring new problems of moisture stabilization in wood-work, furniture, and other wood products used in its construction, warned Raymond C. Rietz, in charge of seasoning research at the federal laboratory.

"We went through this once before," he recalled, "when central heating brought marked changes in the conditions to which wood is exposed in houses. We need a nationwide study of moisture conditions in houses that are air conditioned, in order to get accurate information on the proper degree of seasoning for wood used in such buildings."

Adhesives play an important role as mechanical means of curbing swelling and shrinking in such products as plywood and fiberboard, Dr. George C. Marra, Washington State Institute of Technology, Pullman, Wash., told the group. He described research aimed at developing better bonds in such products as particle board and chipboard.

Progress in curbing swelling and shrinking with paper overlays glued to low-grade lumber was reported on by B. G. Heebink of the federal laboratory staff. He also described the laboratory's process for stabilizing veneer by drying it in a hot press under restraint. Don F. Laughnan, in charge of finishing research, gave a resume of experiments with water-repellent coatings on wood.

Chemical treatments to cross-link the cellulose chains in the cell walls of wood more firmly together or bulk them apart with insoluble chemicals aroused some of the most spirited discussions. Dr. E. C. Jahn of New York State University College of Forestry at Syracuse stressed the need for better knowledge of wood structure and paid tribute to Dr. Stamm's pioneering work, calling him the "Dean of Stability."

His recent work with polyethylene glycol as a stabilizing agent in wood, based on previous results with inorganic salt solutions, was reviewed by Dr. Stamm. He said it has been possible to replace all the water in thin sections of wood with this bulking material and thus stabilize the wood at its green dimensions. The chemical does not affect the toughness of wood, has only a minor effect on gluing and finishes, and at higher levels of treatment virtually eliminates decay, he said.

Experiments with formaldehyde as a cross-linking chemical in wood first treated with an acid salt catalyst were also described by Dr. Stamm. While swelling is reduced as much as 80 percent, the wood is seriously embrittled, he said. Nevertheless, Dr. Stamm declared, the principle of cross linking is a sound one and should prove commercially feasible if the right cross-linking chemical can be developed -- one that will react with wood in the pH range of 4.5 to 8.

The successful use of phenolic resin as a bulking agent, pioneered at the federal laboratory and now commercially applied, was discussed by R. M. Seborg. Costs limit its usefulness, he said, to such high-value items as

forming dies and jigs for metal working, and patterns for steel dies used to stamp auto parts.

The acetylation treatment developed at the federal laboratory was reviewed by Dr. Tarkow. He showed how the reaction imparts stability to the wood by bulking. The main drawback to the process, he said, is the corrosive action of the chemical on processing equipment and the fact that only half of the acetic anhydride molecule used enters into the reaction.

Dr. J. Risi, professor of wood chemistry at Laval University, Quebec, reviewed his experiments on alkylation and acylation of wood and its reactions with various isocyanates and diisocyanates. These, he said, usually caused varying degrees of degradation of the wood due to side reaction products. He suggested possible new chemicals that might avoid these effects on wood.

Dr. Risi also suggested that, instead of gross bulking of the internal structure, research be directed toward obtaining only thin films of water-repellent materials on the internal surfaces to act as barriers to entry of water into the cell-wall structure. Such coatings, he maintained, would require much less material.

Cyanoethylation with acrylonitrile was described by Dr. Irving S. Goldstein, Koppers Co., Verona, Pa., as a bulking treatment that reduces swelling of wood as much as 75 percent and also reduces the equilibrium moisture content of wood. He told of experiments with beta-propiolactone as a bulking agent that does not affect the toughness of wood while giving high resistance to swelling.

Wood fibers are also responsible for swelling and shrinking of paper with changes in relative humidity, Dr. J. A. Van den Akker, Institute of Paper Chemistry, Appleton, Wis., emphasized. More stable fibers would be important, he said, to such products as business forms, map papers, patterns, and template papers.

Moisture stabilization experiments on paper conducted at the National Bureau of Standards, Washington, D. C., in a search for a better military map paper were described by Dr. Gerald L. McLeod. Stability was improved, he said, by blending glass fibers with cellulose fibers and by laminating thin map paper to a more stable film.

A joint investigation on cyanoethylation of paper was described by N. M. Bikales of American Cyanamid Co. in cooperation with John L. Morton of the International Business Machines Corp., New York. Experiments were carried out on wood pulp as well as on paper. Treated pulp imparted substantial dimensional improvement to paper made therefrom, he said.

Considerable success in dimensionally stabilizing paper containing a zinc chloride catalyst was reported by Dr. Stamm, using both heat treatments and a process involving cross-linking with formaldehyde. Formaldehyde cross-linking, he found, had less detrimental effect on the strength properties of paper than did heat treatment.

Paper cross-linked with as little as 0.5 percent of formaldehyde, he pointed out, reduced swelling and shrinking by 60 percent without affecting the tensile strength.

Of the two chemical approaches now being used experimentally to stabilize wood, chemical cross-linking of the cellulose chains looks like the more effective, said Dr. E. G. Locke, chief of the federal laboratory's division of wood chemistry, in opening a panel discussion of new chemicals for wood treatments.

Harold Wakefield, Union Carbide Plastics Co., New York, panel moderator, urged that efforts be made "to stimulate the thinking of chemical manufacturers to look at new chemicals from the standpoint of their application to wood treatments."

He and other speakers mentioned recent experiments with nuclear radiation as a means of stimulating chemical reactions of cellulose. The effects of gamma radiation on ponderosa pine were described by Duane Konaga, Dow Chemical Co., Midland, Mich. He said that, while irradiation doesn't affect the hygroscopicity of wood substantially, it might perhaps stimulate cross-linking of wood cellulose with certain chemicals.

The potentialities of bulking agents for stabilizing wood were discussed by J. W. LeMaistre, in charge of organic research at the central research laboratories of Atlas Powder Co., Wilmington, Del. Saying he had been impressed by Dr. Stamm's work on formaldehyde cross-linking, LeMaistre suggested that perhaps some material with a larger molecule than this chemical might work even more effectively.

The possibilities of a new chemical, polyacrylamide, as a cross-linking agent were explored for the group by N. M. Bikales, American Cyanamid Co., Stamford, Conn.

Another chemical, acrolein, also aroused keen interest. Several speakers referred to it as one of the most reactive potential cross-linking agents.

"If this panel hasn't done anything else than alert chemical companies to the possibilities of finding new uses for their products at this and other laboratories," Wakefield said, "it will have served its purpose."

Dr. Stamm, who is retiring from his post at the laboratory after some 30 years of research, urged that chemical companies keep wood research workers informed of new chemicals so that their possibilities can be investigated.

"I know that this laboratory will continue research in this field," he said, "and I am confident other laboratories will accelerate their research. I think this meeting is a good step toward getting the kind of teamwork we need among laboratories. And let's not poo-poo ideas that may sound a little strange at first. Some of these wild ideas, we may find, aren't so wild after all."

The need for expanded work in many laboratories was also stressed by Director Hall.

"It can't be done in any one or half a dozen institutions," he said. "I'm not worried about duplication of effort. We've had many examples here of men who took the same tools and went through the same motions and came out with diametrically opposite results. This is an extremely complex problem, and we've a long road ahead to achieve a fiber with the properties we want. I hope that the chemical companies will realize that this field of additives to wood represents a tremendous potential market and will keep it in mind in their research."

Wood, he said, is becoming a true industrial material. While the per capita consumption of lumber has declined over the last 50 years, total use of wood has gone up because it has gone into other products like paper, plywood, particle board, and fiberboards. Strongly stimulating this trend, he pointed out, has been the rising cost of construction labor, which has brought demands for large-size sheet materials that can be quickly and economically put in place.

Summing up the seminar results, Dr. Tarkow emphasized that chemical stabilization is not necessarily a cure-all.

"It occurs to me," he said, "that perhaps we have been shooting too high in our efforts to stabilize wood. Do we have to make it completely stable, or is 30 or 40 percent stabilization useful? Can we use wood that has been somewhat weakened by stabilization treatments?"

He pointed to the possibilities of genetics research in developing strains of trees with "built-in" bulking agents, such as trees with higher amounts of extractives, and in pursuing means of stimulating natural "cross-linking" of cellulose in the growing trees.

"Industry," Dosker declared, "will be very much interested in the work that comes out of this seminar. By sponsoring it, the Forest Products Laboratory has made possible a great forward step in this research."

Complete List of Visitors Attending Dimensional Stabilization Seminar
at U. S. Forest Products Laboratory, January 21-23, 1959

Roland Aubey, Nekoosa-Edwards Paper Company, Port Edwards, Wis.

F. A. Bade, Jr., General Plywood Corp., Louisville, Ky.

E. T. Bailey, International Paper Company, Glens Falls, N. Y.

D. W. Bensend, Iowa State College, Ames, Iowa

R. H. Bescher, Koppers Company, Inc., Pittsburgh, Pa.

N. M. Bikales, American Cyanamid Co., Stamford, Conn.

C. J. Binner, Morgan Company, Oshkosh, Wis.

A. M. Borders, Minnesota Mining and Manufacturing Co., St. Paul, Minn.

T. I. Briggs, Alaska Pine and Cellulose Limited, Vancouver, B.C., Canada

James J. Byrne, Washington Office, Forest Service, Washington, D. C.

R. R. Cahal, Southern Pine Inspection Bureau, New Orleans, La.

Craig C. Campbell, Forest Products Division, Olin Mathieson Chemical Corp., West Monroe, La.

John Campbell, Moore Business Forms, Inc., Niagara Falls, N. Y.

Moss Christian, Chicago Mill and Lumber Co., Tallulah, La.

Robert A. Cockrell, University of California, School of Forestry, Berkeley, Calif.

T. R. Curtner, Townsend Lumber Co., Stutgard, Ark.

F. E. Dickinson, California Forest Products Laboratory, Richmond, Calif.

C. D. Dosker, Gamble Bros., Louisville, Ky.

Nelson R. Eldred, Union Carbide Chemicals Co., New York N. Y.

George C. Flanagan, Elk Lumber Company, Medford, Oreg.

William Frances, Simpson Logging Co., Seattle, Wash.

O. W. Frost, Masonite Corporation, Chicago, Ill.

Peter S. Gamble, Yawkey-Bissell Hardwood Flooring Co., White Lake, Wis.

G. Godin, Johns-Manville Products Corp., Manville, N. J.

I. S. Goldstein, Koppers Company, Verona, Pa.

John B. Grantham, State of Oregon Forest Products Research Center, Corvallis, Oreg.

James Hamilton, Michigan College of Mines and Technology, Houghton, Mich.

Robert Hamre, Forest Products Research Society, Madison, Wis.

Frank J. Hanrahan, American Institute of Timber Construction, Washington, D. C.

Charles B. Hemming, U. S. Plywood Corp., Brewster, N. Y.

R.A.A. Hentschel, Fibers Department, E. I. du Pont de Nemours and Co.,
Wilmington, Del.

S. Hossain, Abitibi Power and Paper Company, Limited, Sault Ste. Marie,
Ontario, Canada

Hank Huber, Dow Chemical Company, Midland, Mich.

E. C. Jahn, New York School of Forestry, Syracuse, N. Y.

J. E. Jayne, Kimberly-Clark Corporation, Neenah, Wis.

Art Johnson, American Bowling Congress, Milwaukee, Wis.

Carl A. Johnson, Federal Housing Administration, Washington, D. C.

Walter Johnson, Kroehler Mfg. Co., Kankakee, Ill.

F. H. Kaufert, University of Minnesota Institute of Agriculture, St. Paul,
Minn.

Duane Konaga, Dow Chemical Company, Midland, Mich.

Leo O. Lake, The KVP Company, Kalamazoo, Mich.

C. Latimer, Nickey Brothers, Inc., Memphis, Tenn.

Mark Lehrbas, Southern Forest Experiment Station, New Orleans, La.

R. I. Leininger, Battelle Memorial Institute, Columbus, Ohio

J. W. LeMaistre, Atlas Powder Company, Wilmington, Del.

Lawrence Leney, University of Missouri, Columbia, Mo.

Bengt Leopold, The Mead Corporation, Chillicothe, Ohio

John R. Lewis, Hercules Powder Company, Wilmington, Del.

Richard K. Madison, American Cyanamid Company, New York, N. Y.

George G. Marra, Washington State Institute of Technology, Pullman, Wash.

T. K. May, West Coast Lumbermen's Assn., Portland, Oreg.

Gerald L. McLeod, National Bureau of Standards, Washington, D. C.

W. H. McPherson, Minnesota and Ontario Paper Co., Minneapolis, Minn.

Lincoln A. Mueller, Rocky Mountain Forest and Range Experiment
Station, Fort Collins, Colo.

Arthur F. Muschler, Edward Hines Lumber Company, Chicago, Ill.

A. C. Nixon, Shell Development Company, Oakland, Calif.

James E. Nolan, National Woodwork Manufacturers Association, Inc.,
Chicago, Ill.

Donald H. Percival, Small Homes Council, University of Illinois,
Urbana, Ill.

J. J. Perot, National Gypsum Company, Buffalo, N. Y.

Gerald F. Prange, National Lumber Manufacturers Association,
Washington, D. C.

Willard E. Pratt, California Redwood Association, San Francisco, Calif.

Stephen Preston, University of Michigan, Ann Arbor, Mich.

Colin N. Ramsay, Durez Plastics Division, Hooker Chemical Corp.,
Chicago, Ill.

Carl A. Rasmussen, Western Pine Assn., Portland, Oreg.

J. Risi, Laval University, Quebec, Canada

John L. Rose, Architectural Woodwork Institute, Chicago, Ill.

George Rosentretter, Crossett Company, Crossett, Ark.

Frank Rovsek, Forest Products Research Society, Madison, Wis.

L. T. Sandborn, Crossett Company, Crossett, Ark.

Robert Schwaner, Quartermaster Research and Development Command,
Natick, Mass.

F. Shafizadeh, Weyerhaeuser Timber Co., Longview, Wash.

C. Skaar, New York State College of Forestry, Syracuse, N. Y.

Alan Sliker, Michigan State University, East Lansing, Mich.

Walton Smith, Southeastern Forest and Range Experiment Station,
Asheville, N. C.

James J. Spadaro, Southern Utilization Research and Development Division,
USDA Agricultural Research Service, New Orleans, La.

J. R. Stillinger, Cascades Plywood Corp., Lebanon, Oreg.

Edwin R. Thomas, Thomas and Proetz Lumber Co., St. Louis, Mo.

H. Dale Turner, Masonite Corporation, Laurel, Miss.

J. A. van den Akker, Institute of Paper Chemistry, Appleton, Wis.

Harold Wakefield, Union Carbide Plastics Co., New York, N. Y.

F. F. Wangaard, Yale School of Forestry, New Haven, Conn.

F. O. Whipple, Crown Zellerbach Corp., Camas, Wash.

Howard White, Institute of Textile Research, Princeton, N. J.

Steve H. Wise, Wood Conversion Co., Cloquet, Minn.

H. L. Wyatt, Ford Motor Co., Dearborn, Mich.

Torbin F. Yates, Kroehler Manufacturing Co., Naperville, Ill.

Karsten A. Zachariasen, The Buckeye Cellulose Corp., Memphis, Tenn.

John I. Zerbe, National Lumber Manufacturers Association,
Washington, D. C.

Program

DIMENSIONAL STABILIZATION SEMINAR

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture
Madison 5, Wisconsin

January 21-23, 1959

Jan. 21 (a.m.)

9:00-9:10	Introductory remarks.....	J. A. Hall, Dir., FPL
WOOD AND CELLULOSE LIQUID RELATIONSHIPS		C. D. Dosker, Gamble Bros., Presiding
9:10-9:20	Opening remarks.....	C. D. Dosker
9:20-9:50	(1) How wood absorbs and swells.....	F. F. Wangaard, Yale University
9:50-10:20	(2) How other fibrous materials absorb and swell....	Howard J. White, Jr., Textile Research Inst.
10:20-10:35	Coffee break	
10:35-11:05	(3) Possible mechanisms for reduction in swelling...	Harold Tarkow, FPL
11:05-12:00	Discussion	
12:00-1:00	Luncheon	

Jan. 21 (p.m.)

MINIMIZING SHRINKING AND SWELLING BY PROPER USE		F. E. Dickinson, Dir., FPL, Univ. of California, Presiding
1:00-1:10	Opening remarks.....	F. E. Dickinson
1:00-1:30	(4) Importance of moisture control in construction..	R.P.A. Johnson, FPL (retired)
1:30-1:50	(5) Proper moisture content for various uses.....	R.C.Rietz, FPL

1:50-2:10	(6) Design of structures to minimize the effects of normal moisture changes.....	O. C. Heyer, FPL
2:10-2:30	(7) Limitations of water repellents and finishes in controlling the dimensions of wood.....	D. F. Laughnan, FPL
2:30-3:10	Discussion	
3:10-3:25	Coffee break	

DIMENSIONAL STABILIZATION OF WOOD BY MECHANICAL MEANS

Walton R. Smith,
SE. For. Exp. Sta.,
Presiding

3:25-3:35	Opening remarks.....	Walton R. Smith
3:35-3:55	(8) Glued wood products.....	George G. Marra, Wash. State Inst. of Technology
3:55-4:25	(9) Overlays and swelling into created checks.....	B. G. Heebink, FPL
4:25-4:45	(10) The Supermicroseal process.....	F. A. Bade, Jr., V.P., General Plywood Corp.
4:45-5:00	Discussion	

Jan. 22 (a.m.)

DIMENSIONAL STABILIZATION OF WOOD BY CHEMICAL MEANS

E. C. Jahn, N.Y.
State Col. of
For., Presiding

8:30-8:40	Opening remarks.....	E. C. Jahn
8:40-9:10	(11) Nonreacting bulking agents.....	A. J. Stamm, FPL
9:10-9:40	(12) Resin treatment.....	R. M. Seborg, FPL
9:40-10:10	(13) Acetylation.....	Harold Tarkow, FPL
10:10-10:25	Coffee break	
10:25-10:55	(14) Other acylation and alkylation treatments.....	R. J. Risi, Laval Univ., Quebec
10:55-11:25	(15) Cyanoethylation and reaction with β -propiolactone	I. S. Goldstein, Koppers Co.
11:25-11:55	(16) Heat treatments and cross-linking with formaldehyde.....	A. J. Stamm, FPL
12:00-1:00	Luncheon	

Jan. 22 (p.m.)

1:00-2:00

Discussion

DIMENSIONAL STABILIZATION OF PAPER AND FABRIC

J. A. van den
Akker, Inst. of
Paper Chemistry,
Presiding

2:00-2:10

Opening remarks.....

J. A. van den
Akker

2:10-2:40

(17) Stabilization of paper by mechanical means.....

Gerald McLeod,
Natl. Bur. Standards

2:40-3:10

(18) Stabilization of paper by cyanoethylation.....

N. M. Bikales,
Am. Cyanamid Co.

3:10-3:25

Coffee break

3:25-3:55

(19) Stabilization of paper by heat and formaldehyde
cross-linking.....

A. J. Stamm,
FPL

3:55-5:00

Discussion

Jan. 23 (a.m.)

POSSIBLE CHEMICALS FOR DIMENSIONAL STABILIZATION

E. G. Locke, FPL
Presiding

9:00-9:10

Opening remarks.....

E. G. Locke

9:10-9:50

(20) Roundtable discussion by representatives of
chemical manufacturing companies.....

Harold Wakefield,
Union Carbide
Plastics Co.,
Moderator.
Duane Konaga, Dow
Chemical Co.
J. W. LeMaistre,
Atlas Powder Co.

9:50-10:20

Discussion from floor

10:20-10:35

Coffee break

REVIEW OF PROCESSES AND RECOMMENDATIONS FOR FUTURE
RESEARCH

J. J. Byrne, Chief,
Div. For. Products
Research, Forest
Service, Presiding

10:35-10:45

Opening remarks.....

J. J. Byrne

10:45-11:15

(21) Correlation and review of meeting papers.....

Harold Tarkow, FPL

11:15-11:30 (22) Report of recommendations committee
for future research.....

Committee:

R. H. Bescher, Koppers Co.,
Chairman;
C. D. Dosker, Gamble Bros.;
L. T. Sanborn, Crossett Co.;
J. F. Saeman, Asst. to Chief,
Div. of For. Prod. Research,
Washington, D. C.;
J. A. van den Akker, Inst.
Paper Chemistry

11:30-12:00 Discussion

The afternoon is left open for those who wish to take a tour
of the Laboratory. Starting time from FPL lobby, 1:30 p.m.

Laboratory members will be available for personal conferences
with visitors all afternoon.

Program Committee:

A. J. Stamm, Chairman, FPL
H. O. Fleischer, FPL
D. J. Fahey, FPL
R. L. Youngs, FPL

HOW WOOD ABSORBS AND SWELLS

By

PROF. FREDERICK F. WANGAARD

School of Forestry
Yale University

Abstract

Like all cellulosic materials wood shrinks and swells upon loss or gain of moisture. The peculiar aspects of the shrinking and swelling of wood are associated with the presence of substances other than cellulose within its cell walls, the layered organization of its fiber walls, and the aggregation of its fibers and other cells into a wide diversity of structural patterns and densities.

The external shrinkage of wood, expressed as the change from green to oven-dry dimension, ranges from 4-14 percent of the green dimension along the tangential axis, from 2-8 percent radially, and usually from 0.1-0.2 percent longitudinally. Volumetric shrinkage, the aggregate of shrinkage in all three directions, ranges from 7-21 percent. Shrinkage to intermediate levels of moisture content is proportional to the amount of moisture removed from wood below its fiber saturation point, which is commonly 25-30 percent moisture content but may range as low as 18 percent and as high as 33 percent. Swelling, associated with moisture absorption, is related to moisture-content change in an identical manner.

Basically, the swelling of wood arises from its hygroscopic character and is a consequence of the submicroscopic micellar nature of the cell wall. The secondary cell wall consists largely of cellulose with a large internal surface capable of adsorbing water molecules from the atmosphere. At low relative humidities most of the adsorbed water molecules are strongly bound to the cellulose surface by free OH groups in the less ordered portions of the micellar network. Some authorities describe the phenomenon as a case of solid solution. Swelling is actually the spreading apart of the structure as water enters between the micelles and, as swelling proceeds, new active sorption centers are created by the breaking of bonds between adjacent cellulose chains. The crystalline portions of the cellulose network are not invaded but act as cross-links restricting the formation of additional sorption sites. At relative humidities above 50-60 percent, water is adsorbed chiefly in multilayers with diminishing forces of attraction and continues to add its volume to that of the cellulose itself until the distended network is saturated.

Swelling may be expressed quantitatively as the volume of water adsorbed by the cell wall. This swelling is in turn transmitted to the external dimensions of solid wood. It is perhaps more convenient to express the relationship as shrinkage:

$$S = gf, \text{ in which}$$

S = volumetric shrinkage, green to oven-dry

g = specific gravity (oven-dry weight, green volume)

f = apparent volume of adsorbed water (cc) per 100 grams of dry wood. (Because of sorption-compression effects, f is a few percent less than the usual gravimetric fiber saturation point.)

This relationship assumes that the cell cavities remain unchanged in volume. The degree to which an individual wood conforms to this assumption depends upon restraints imposed on swelling by the cross-oriented inner and outer layers of the secondary cell wall.

Data on volumetric shrinkage, specific gravity, and fiber saturation point are presented to illustrate the application of this relationship to woods representing a wide range in density and fiber saturation point. Several factors including expansion or contraction of cell cavities, shrinking stresses, and error in expressing specific gravity due to the weight of extractives in the cell cavities contribute to the deviation of individual species from the general relationship. Water-soluble extractive substances occurring in the cell walls reduce shrinkage and swelling by their bulking action and are a major factor influencing the level of fiber saturation point.

HOW OTHER FIBERS ABSORB AND SWELL

By

HOWARD J. WHITE, JR.

Textile Research Institute
Princeton, New Jersey

Abstract

The study of cellulosic fibers other than wood fibers provides information on experiments which are impractical for wood fibers because of their small size. In addition a wide range of states of physical order can be examined.

A survey is given of existing experimental information on the effects of changes in relative humidity, temperature, fiber structure and mechanical conditions on the absorption and swelling of cellulose fibers. An attempt is made to correlate the observed behavior with the molecular properties of cellulose in a qualitative way. Some observations are also made on possible quantitative correlations.

POSSIBLE MECHANISMS FOR REDUCTION IN SWELLING

By

DR. HAROLD TARKOW, Chemist

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

Abstract

Some of the implications of considering wood substance to be a cross-linked polymer are discussed. The advantages of such a model are (1) it permits a ready understanding of currently proposed dimension-stabilizing procedures, and (2) it clearly suggests or sets up directions in which future work should go. Methods by which permanent stabilization has been attained, namely, by reducing the hygroscopicity, bulking the fiber, and cross-linking the structural units are discussed.

IMPORTANCE OF MOISTURE CONTROL IN CONSTRUCTION

By

R. P. A. JOHNSON, Engineer

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture, retired

Abstract

Moisture content has an important bearing on the service wood renders in a structure because of its influence on the development of decay and defects, its effects on strength and stiffness, and its control of the changes in size and shape that occur in drying. The importance of these factors with respect to the service wood renders is discussed separately for heavy and light construction, because the lumber and construction practices in seasoning and construction are quite different in these two types of construction. The limitations imposed by present practices are examined and needs for improvement discussed.

MOISTURE CONTENT OF WOOD FOR VARIOUS USES

By

RAYMOND C. RIETZ, Engineer

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

Abstract

Perhaps one of the earliest publications issued by the Forest Products Laboratory on the subject of moisture content in use appeared in 1932. This report summarized data gathered in about 8 city houses in different regions of the United States. A relation between the moisture content of interior woodwork and outdoor climatic conditions was clearly demonstrated. The recommended moisture content values of wood used in dwellings published at that time have not been modified, and they seem to have found general usefulness by the wood fabricating industries. The known relationship of wood moisture content to temperature and relative humidity has been extensively used by wood technologists to determine the best moisture levels at the time of machining and assembly to minimize dimensional changes of the product in use. This basic relation is used world-wide to determine seasoning practices and the moisture content standards for production when the "in-use" equilibrium conditions are known or can be reasonably well estimated.

"In-use" conditions in the United States, however, are changing.

Outdoor weather is not changing, but we are modifying the climate of occupancy in our homes, offices, schools, factories, auditoriums, churches, and the many other places where people live, work, worship, or seek entertainment. We condition the atmosphere in these places for increased comfort. Conditioning means cooling and dehumidification in the warmer season of the year, and humidification with heating during the cold winter months. The influence that these changes have and are making on the climate of occupancy and the extent to which wood moisture content requirements need to be modified to assure satisfactory performance of the many wood products being made and used has not been extensively investigated. Two Forest Service Experiment Stations, in cooperation with the dry kiln clubs in their regions, are now conducting research on moisture content of wood in use. Whether the changes in our indoor living and working conditions are really affecting wood equilibrium moisture-content conditions should be indicated by these studies. More extensive studies of present day "in-use" wood equilibrium conditions will be needed if we are to bring our moisture content recommendations up to date.

DESIGN OF WOOD STRUCTURES TO MINIMIZE
THE EFFECT OF NORMAL MOISTURE CHANGES

By

OTTO C. HEYER, Engineer

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

Abstract

Americans have built houses with wood frames for so long that so-called light frame construction has become tradition; yet poorly framed houses are not uncommon. There are several methods of framing dwelling houses. The two most commonly used are the platform and the balloon frame. Of these, the platform frame seems better adapted to present-day methods of construction. In addition to load factors, the choice of framing systems is influenced by architectural design. The one-story so-called ranch-type house so popular since World War II, appears to be giving way to hybrid combination of one- and two-story structure known as the "split level." The framing of this type of house may result in unbalanced construction, which can complicate lumber shrinkage problems. Other types of framing methods also appearing on the horizon may likewise present shrinkage problems.

LIMITATIONS OF WATER REPELLENTS AND FINISHES

IN CONTROLLING THE DIMENSIONS OF WOOD

By

DON F. LAUGHNAN, Paint Chemist

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

Abstract

No moisture-proof coating has yet been developed. It is not possible, therefore, to keep wood at a given moisture content by applying a finish, whether of the surface-coating or penetrating type. Finishes simply retard the rate of exchange of moisture between wood and the atmosphere in which it is exposed. Therefore, wood kept indefinitely under conditions of dampness or dryness will come ultimately to the moisture content at which it is naturally in equilibrium, finished or not.

The ability of a finish to retard the exchange of moisture between wood and air is called its moisture-excluding effectiveness. The Forest Products Laboratory has long used a method for determining such effectiveness based on average amounts of moisture absorbed per unit surface area by newly coated and by uncoated wood panels subjected to a relative humidity of 95 to 100 percent for 14 days. By this method, perfect protection would be represented by 100 percent effectiveness; complete lack of protection,

as would be the case with unprotected wood, by zero. Since effectiveness values vary greatly with the conditions of the test, with the kind of wood on which the tests are made, and according to the thickness of the coating, they must be considered relative rather than absolute.

Moisture-excluding effectiveness values, as determined by the Forest Products Laboratory method, range from as low as 3 percent for a single application of raw linseed oil to as high as 95 percent for three coats of aluminum flake in a phenol-formaldehyde resin varnish of high quality. For high moisture-excluding effectiveness, a finish must form a substantial, continuous coating on the surface of wood. Mere filling of the wood pores is not sufficient since this leaves the cell walls at the surface of the wood exposed. This explains the low effectiveness values of penetrating finishes like stains, fillers, sealers, and water-repellent preservatives, and the greater effectiveness of lacquers, varnishes, paints, and enamels in that order.

The moisture-excluding effectiveness of finishes is greatest, of course, against fluctuating humidity conditions in which the period of extreme dampness or dryness is short and is followed by conditions permitting return to the average moisture content. Against day-to-day changes, even the penetrating finishes retard changes in the moisture content of wood appreciably, but for seasonal changes, involving a 6-month trend in one direction followed by 6 months in the other, even the

most effective finishes permit considerable change in moisture content.

For many of its uses, wood need not be dimensionally stable. We have learned how to use it successfully even under conditions that cause it to change its dimensions almost constantly. Against such changes, finishes can be used to advantage.

However, even the finishes of high moisture-excluding effectiveness cannot prevent the extensive changes in the dimensions of wood that occur from season to season. To hold such changes to a minimum, wood must be seasoned to a moisture content close to the midpoint between the high and low values it will attain in service. If this rule is followed, properly selected finishes can and will provide all the stabilizing we need demand of them for most uses.

GLUED WOOD PRODUCTS

By

GEORGE G. MARRA

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Division of Industrial Research
Washington State Institute of Technology

Abstract

The dimensional stabilization of wood products by mechanical means refers basically to the substitution of internal stress for changes in external dimensions of a member subjected to changes in moisture content. In some cases, the internal stresses are minimized by providing opportunities for internal change, such as in tenderizing treatments for veneers.

Virtually all of the applications of mechanical stabilization involve the use of at least one chemical, the adhesive, to bring about a system of mutual restraint of the movement of adjacent components when bonded together. This basic principle of mutual restraint calls for a bond of superior integrity in order to withstand the repeated stresses to which it is subjected during changes of moisture content.

The restraint mechanisms are set up by virtue of the differential shrinkage and swelling properties in the three recognized grain directions of wood. The most potent of these is the longitudinal vs. transverse combination, while the radial vs. tangential is less potent. Radial vs.

radial, or any other like combination, of course, would develop no restraint and would therefore be ineffective in improving stabilities.

Unfortunately, glued lumber products can take little advantage of these mechanical restraints to improve dimensional stability. If permitted to develop stresses, these thick members are capable of accumulating forces sufficient to rupture the bond or the wood adjacent to the bond.

Plywood, on the other hand, being made up of thin veneers, can take maximum advantage of these restraints and can make effective use of the 90° orientation of adjacent plies. It is notable that the shrinking and swelling of plywood is not the average of the longitudinal and transverse components, but rather is very near the longitudinal component.

Flakeboards, at first glance, appear to embody an extension of the plywood philosophy. However, they are much more complex, involving such factors as orientation of flakes, varying resin contents and densities, and flake geometry. Dimensional stability in these products draws attention to the thickness direction as well as to the plane directions. Available data leads to uncertainty regarding the relationship of internal restraint to external change. Internal restraint requires good bonding between flakes, but in flakeboard there is some experimental evidence to indicate that this bonding also contributes to dimensional instability. A further source of confusion is the operation of a factor best described as an "internal Poisson's ratio effect." Cases have been observed, for example, in which

negative values were recorded for linear expansion after 24-hour soaking. In these cases, thickness swell was observed to be excessive.

Particle boards introduce still further departures from the classical plywood example. Because of the geometry of these particles, the number of potential orientations with respect to other particles is increased. Very little data exists on which speculation as to cause and effect may be based. Most of the available data are of little value since they were obtained by water immersion rather than by exposure to high humidities. Water immersion produces extraneous effects due to water films and capillary forces. In addition, almost all data involve the effect of wax in varying amounts.

The final step in this analogy progresses naturally to fiberboards wherein individual fibers or fiber bundles exercise multi-directional influences similar to the particles in particle board, but to a higher degree.

STABILIZATION WITH OVERLAYS AND BY
SWELLING INTO OPENINGS

By

BRUCE G. HEEBINK, Engineer

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

Abstract

Restraining dimensional movement of lumber by means of overlaying is quite effective with the proper selection of base and overlay materials. It is, however, a means of stabilizing only the surfaces, and therefore stresses are set up that must be balanced to prevent warping. These stresses can be severe, hence the overlay (or restraining material) must have sufficient strength to resist without rupturing. Resin-impregnated kraft sheets (0.018 inch thick) glued to each side of a 3/4-inch pine board reduce the dimensional changes across the grain by about 35 percent. If one overlay sheet is omitted, severe warping results. On oak, the paper overlays rupture under severe exposure. Overlay materials that exert a high degree of restraint may cause more cupping than those imposing less restraint, depending largely on the grain orientation of the board.

For centuries it has been common practice to provide cracks or open joints in certain constructions made of wood to take care of swelling across the grain. Common examples are narrow flooring strips instead of wide

boards, parquet floors, and even the recommendation of using roof and subfloor boards not more than 6 inches wide. The theory is that a wide expanse across the grain is thus broken up into many narrow pieces, so there can be no continuous tensile stress across the grain of the construction, and compression or swelling stresses develop only after the cracks are completely filled.

If a continuous sheet of veneer is broken across the grain into many individual pieces by flexing, splitting, or machining, somewhat similar results are obtained. Likewise, if a continuous sheet of veneer is held uniformly over its entire area to prevent normal shrinking across the grain while it is dried, numerous small checks or cracks, scarcely visible to the eye, are produced. This process, commonly called "press drying" or "drying under restraint," produces a marked effect on the behavior of the veneer in subsequent exposure to high and low relative humidity. The initial swelling is greatly reduced but the initial shrinkage is reduced only slightly, resulting in indeterminate antishrink effectiveness which gradually becomes less with additional cycling. In part this behavior is due to the induced checks, but undoubtedly other factors, such as enforced additional shrinking in thickness that results in collapsed or distorted pores, have an effect on flatness of veneer and an increase in flexibility.

THE SUPERMICROSEAL PROCESS

By

F. A. BADE, JR., Vice President
General Plywood Corporation

Abstract

Expensive on-the-job finishing costs pointed up the need for a stabilized wood surface that would reduce the need for most of the finishing steps now employed.

The Supermicroseal process is a practical, high-speed operation that produces a slightly densified, glossy wood surface that is stabilized in depth. It is not a film or overlay, but a basic change in the wood structure near its surface. Apparently, a slight flow of lignin in situ caused by the simultaneous action of pressure and frictional heat is at least partially responsible for this phenomena.

A Supermicrosealed wood surface normally requires the addition of only one coat of finishing material, such as wax or varnish. Sanding is never required because the surface fibers are permanently set.

Savings of 75 percent or more in on-the-job finishing costs on wood so treated are now common throughout the industry.

NONREACTING BULKING AGENTS

By

ALFRED J. STAMM, Chemist

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

Abstract

The phenomenon of bulking was first observed when wood was treated with concentrated inorganic salt solutions. It was shown that salts diffuse into the cell wall structure of water-swollen wood to attain a concentration virtually equal to the bulk concentration. When salt-impregnated wood is slowly dried, water is first lost from the coarse capillary structure, thus building up the salt concentration and permitting its further diffusion into the cell walls. This diffusion continues until the solubility limit of the salt is reached. When the wood is completely dried, the shrinkage is reduced by an amount dependent on the partial specific volume of the salt in solution in the cell walls when inward diffusion of salt ceases. This reduction in shrinkage persists over repeated cycles of swelling and shrinking when the swelling occurs without accompanying leaching.

Data showing the effectiveness of salt and sugar bulking agents are presented. A means is described for depositing bulking agents not soluble in water within the cell walls by a replacement process in which the water is

replaced by a wax solvent and this in turn is replaced by a wax. Neither this nor the salt and the sugar bulking agents have proved commercially practical. Knowledge thus gained has been helpful, however, in the development of the more successful bulking treatments with phenolic resins and by acetylation.

Recently a more promising nonreacting bulking agent has been investigated; namely, polyethylene glycol-1000. This wax-like solid is soluble in water in all proportions at only slightly elevated temperatures. In spite of its molecular size it diffuses quite readily into the cell walls of swollen wood. Under carefully controlled conditions, it has been possible to replace completely the water in thin cross sections of wood with non-volatile polyethylene glycol and thus virtually to retain green dimensions even after all of the water is removed. This material can act as a combined seasoning aid and dimensional stabilizing agent, can be used to prevent pie checks in log cross sections, and is now used commercially to make wood carvings. Data show that, unlike a number of other treating agents, polyethylene glycol does not reduce the toughness of wood, has only a minor effect upon gluing and finishes, and at the higher levels of treatment virtually eliminates decay. Possible future uses for the treatment are given.

RESIN TREATMENT

By

RAY M. SEBORG, Chemist

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

Abstract

The treatment of wood with phenolic resin as a means of dimensionally stabilizing wood is reviewed. The methods of manufacture and the properties of resin-treated wood are given. Included are the current commercial applications for which the material is produced and the suitability of the material for other applications.

ACETYLATION

By

DR. HAROLD TARKOW, Chemist

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

Abstract

A brief comparison is made between the acetylation of cellulose to produce cellulose acetate and the acetylation of wood to obtain dimension-stabilization. Comparison will include objectives, procedures, physical changes and properties. The mechanism of this stabilization is discussed and related to those involved in other treatments.

OTHER ACYLATION AND ALKYLATION TREATMENTS

By

J. RISI

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Laval University, Quebec

Abstract

Hygroexpansivity of wood might be reduced by a chemical modification of one or several of the wood components, including the substitution of the hydroxyl groups of cellulose and lignin with less polar groups. Although several ethers and esters of isolated or regenerated cellulose are nowadays important industrial products, none of the common etherification or esterification reagents are yet commercially used to increase the dimensional stability of lignocellulosic materials. In spite of many attempts in this direction, it seems that an ideal alkylation or acylation treatment of wood still has to be found.

A short account is given of the results obtained by various authors through alkylation by means of methylation, ethylation, allylation, crotylation, n- and t-butylation, vinylation, arylation, and through acylation by means of crotonylation, phthaloylation, and some other treatments. Unpublished results obtained in more recent work by treating wood with various isocyanates and diisocyanates are also briefly discussed.

The conclusion arises from past experience that alkylated and acylated wood usually show a varying degree of degradation caused by side reaction products. The ideal approach to chemical stabilization therefore would be to employ reactants that do not yield harmful byproducts. A few newer chemicals of potential interest for such work are suggested.

The great need of more information dealing with the economics of chemical wood stabilization processes, as well as with the mechanical properties, glueability, paintability and corrosiveness of chemically stabilized wood is emphasized.

CYANOETHYLATION AND TREATMENT
WITH BETA-PROPIOLACTONE

By

DR. IRVING S. GOLDSTEIN

Koppers Company

Abstract

The chemical modification of wood by cyanoethylation or treatment with beta-propiolactone provides a high degree of dimensional stability by a bulking mechanism. The wood is permanently swollen by the treatment and stabilized in proportion to the permanent swelling and weight gain.

Wood and beta-propiolactone react readily without the need for a catalyst to give products which probably contain polyester side chains made up of carboxyethyl groups grafted to the cellulose backbone. Reductions in swelling of 60 to 70 percent in both high humidity and liquid water are obtainable.

In the presence of suitable catalysts wood may be successfully cyanoethylated by reacting with acrylonitrile to give products having weight gains as high as 34 percent and nitrogen contents of 8.2 percent. Reductions in swelling as high as 75 percent have been achieved with an increase in weight of about 35 percent.

The equilibrium moisture content of wood modified by these treatments is also reduced. Under conditions where untreated wood will

contain 13 percent water, wood treated with beta-propiolactone to a weight increase of 30 percent will contain only 8 percent water. Under these same conditions the less polar cyanoethylated wood will contain only 4.5 percent moisture.

Unlike resin-treated wood the toughness of wood treated with beta-propiolactone is not affected, and there is only a small but not serious loss in the impact strength of cyanoethylated wood.

HEAT TREATMENTS AND CROSS-LINKING
WITH FORMALDEHYDE

By

ALFRED J. STAMM, Chemist

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

Abstract

Heat treatments more severe than those normally used in kiln drying impart permanent dimensional stabilization to wood. Dry wood has been stabilized 40 percent when heated for 1 hour at 260° C., 1 day at 210° C., 1 week at 180° C., and 1 year at 130° C. Wood containing 2.5 percent of zinc chloride catalyst develops dimensional stabilization about 17 times as fast as when no catalyst is present. A weight loss always accompanies heat stabilization, the square of the dimensional stabilization being proportional to the weight loss. A weight loss of 12 percent accompanies a 40 percent dimensional stabilization.

Heat stabilization was formerly believed to be due to the loss of water of constitution and resultant formation of ether cross-links. Data show that it is more probably due to destruction of hygroscopic hemi-celluloses and the formation of sugar and sugar-furfural polymers.

Heat stabilization, unfortunately, is accompanied by excessive embrittlement of wood and lowered abrasion resistance. Wood heat stabilized

to a given degree sustains the same strength losses irrespective of whether a salt catalyst is present. Heat stabilization thus does not look promising as a commercial means of dimensionally stabilizing wood.

When wood containing an acid salt catalyst is heated in the presence of formaldehyde vapor, dimensional stability develops much faster than in the absence of formaldehyde as a result of cross linking by the formaldehyde. Reductions in swelling of 70 percent have been accomplished by heating small wood specimens containing 2.5 percent of zinc chloride catalyst at 120° C. for 8 hours while they are exposed to formaldehyde vapors generated from paraformaldehyde. About 4 percent of the dry wood on a weight basis becomes bound in the process, which is far less than the 25 to 30 percent of phenolic resin or of acetyl groups required to attain this degree of stabilization. Other chloride and sulfate catalysts have been tried to catalyze the reaction. The effectiveness of various cations was shown to decrease in the order H^+ , Fe^{+++} , Zn^{++} , NH_4^+ , Na^+ , with the chlorides being slightly more effective than the sulfates.

Unfortunately, formaldehyde cross-linked wood is considerably more brittle and much less abrasion resistant than normal wood. Data show that the loss in strength properties is due almost entirely to the heat and the catalyst. Milder catalysts give less embrittlement but they also give less stabilization. This process is not commercially practical in its present form. The principle of cross-linking is, however, sound. Cross-linking agents should hence be sought that will react under more neutral conditions and at lower temperatures.

STABILIZATION OF PAPER BY MECHANICAL MEANS

By

GERALD L. McLEOD
National Bureau of Standards
U. S. Department of Commerce

Abstract

A study of methods for developing paper with good dimensional stability to moisture was made at the National Bureau of Standards in connection with the need for a more stable military map paper. Two of the physical methods investigated were the lamination of thin map paper to a more dimensionally stable film and the use of synthetic fiber-cellulose fiber blends. Reductions in expansivity up to 30 percent in the machine direction and 70 percent in the cross direction were obtained by lamination. Strength properties, in general, were improved. Polyester, polyacrylic and polyamide fibers used in admixture with cellulose fibers resulted in generally improved strength properties (especially wet strength) as compared to pure cellulosic paper. The polyester-cellulose paper had the best moisture stability, the polyacrylic-cellulose paper was not quite as good while the polyamide-cellulose had less moisture stability than cellulosic map paper.

The use of glass fiber blends with cellulose and the alteration of strains in machine-made paper to reduce expansivity are briefly mentioned.

CYANOETHYLATION AS A MEANS OF IMPROVING
THE DIMENSIONAL STABILITY OF PAPER

By

JOHN L. MORTON, Staff Paper Technologist
International Business Machines Corporation

and

NORBERT M. BIKALES, Chemist
American Cyanamid Company

Abstract

A joint investigation between I. B. M. and Cyanamid was made of the properties of cyanoethylated paper, particularly with respect to dimensional stability. It was found that a substantial improvement in dimensional stability results when cyanoethylation is carried out on the pulp, rather than on preformed sheets. The improvement is proportional to the degree of cyanoethylation when substitution is carried out in the range where morphology of the pulp is unaffected. The expansivity in blends of untreated pulp with cyanoethylated pulp is in direct proportion to the ratio of pulps in the blend. The improvement in dimensional stability is the result solely of etherification with acrylonitrile, as indicated by the fact that a control treated with alkali only showed no decrease in expansivity.

A promising new process of cyanoethylation is described, involving the use of minimal quantities of both sodium hydroxide solution and acrylonitrile.

STABILIZATION OF PAPER BY HEAT AND
BY FORMALDEHYDE CROSS-LINKING

By

ALFRED J. STAMM, Chemist

Forest Products Laboratory, Forest Service
U. S. Department of Agriculture

Abstract

Paper, like wood, is dimensionally stabilized by heat and by catalyzed cross-linking with formaldehyde. The situation is, however, considerably better from the standpoint of loss of strength properties. The reason for this is discussed, together with differences in the way paper swells in comparison with wood.

Higher degrees of heat stabilization can be obtained with paper than with wood. In paper treated with 1.25 percent of zinc chloride catalyst, 40 percent dimensional stabilization can be attained by heating it for 1 minute at 190° C., 1 hour at 140° C., or 1 day at 100° C. As with wood, the square of the fractional reduction in swelling is proportional to the weight loss, but the weight lost in attaining 40 percent dimensional stabilization is only 1.0 percent in contrast to 12 percent for wood.

Heat stabilization has no really serious effect upon the strength properties of dry paper less than 40 percent stabilized. Tensile and ring compression strength of wet paper increase rapidly with increased

dimensional stabilization; when a dimensional stabilization of 40 percent is exceeded, however, tensile strength decreases while ring compression strength continues to increase. Strength values for heat stabilized paper when wet are about equal to those attained with 6 percent of phenolic resin.

Dimensional stabilization is more rapidly attained by catalyzed cross-linking with formaldehyde than by heat stabilization. Paper containing 1.25 percent of zinc chloride catalyst attains a 60 percent dimensional stabilization when heated at 120° C. for 1.5 hours over paraformaldehyde. Under these conditions, only 0.5 percent of formaldehyde is bound.

Formaldehyde cross-linking has a less detrimental effect upon the strength properties of paper than does heat stabilization. Losses in tensile strength do not occur until a dimensional stabilization of 60 percent is attained. Strength values of the wet paper are somewhat higher, equal to those attained with 8 to 10 percent of phenolic resin, when treated by formaldehyde cross-linking than when treated by heat stabilization.

Heat stabilization of paper shows commercial promise only in cases where some embrittlement can be tolerated. Formaldehyde cross-linking is more generally promising for commercial use, as significant losses in strength properties do not occur except when the stabilization exceeds 60 percent.

FLOOR DISCUSSION

(January 23, 1959)

Wood and Cellulose Liquid Relationships (C. D. Dosker, Presiding)

E. C. Jahn: The session this morning was extremely interesting and stimulating in reviewing the basic conceptions relating to liquid relationships of wood, however, in discussing the cell wall I heard very little, if anything, about any hemicelluloses or lignin, and yet the weight of the tissue is roughly 50 percent of these materials. To be sure, they undoubtedly contribute very much less to the problem than the cellulose, but I don't believe they should be ignored, particularly the hemicelluloses, which are highly hygroscopic materials and somewhat related in structure to the cellulose; yet they are not crystalline, neither are they soluble in water. I would like to ask if any consideration has been given to the role that they play in this problem. For example, compare certain conifers with certain hardwoods. There are very large differences in the percentages of these materials. Does this influence the dimension change relationships?

Harold Tarkow: I didn't want to give the impression that I was ignoring the hemicellulose or the lignin. What I wanted to do, first of all, was to point out the similarity between various cellulosic materials -- be it cotton, wood, or pulp. We note that qualitatively the response to moisture is the same. Quantitatively, of course, there is a difference. For example, the EMC (equilibrium moisture content) of wood is a good deal higher than that of cotton. Quite likely one reason for this is the presence of the components that you mentioned. It is conceivable, for example, that as nature lays down these materials, the presence of lignin and hemicellulose interferes with the tendency of the cellulose to crystallize. Probably the presence of lignin and hemicellulose can distort the long cellulose chains sufficiently, so that the crystalline order is nowhere near as good as it is in say cotton. Secondly, the hemicellulose and lignin are hygroscopic. They will take on moisture and, of course, exert a swelling pressure on the structural network.

S. Hossain: We have found that if we use raw fibers versus cooked fibers, we get much greater hydroexpansivity in boards from the cooked fiber. Can you tell me some mechanism by which this could be explained?

Harold Tarkow: The difference in the nature of the fiber-to-fiber bonding and the rigidity of the single fibers may influence the extent of internal swelling transmitted to the external dimensions. I would be interested in knowing whether the EMC at some relative humidity is also different. If it is, it would suggest that, what we called the internal swelling, has also been altered.

I would like to ask Dr. White a question. It is in connection with the effect of moisture on the extensibility of different fibers. If I recall your slide correctly, cotton extensibility increased with increased water take-up. This was just the opposite with rayon. Could you comment on that.

Howard White: Yes, that is a well known effect -- sort of second order effect. Cotton gets stronger and shows greater extensibility when it has a little bit of water in it. The theory is that when the fiber is not plasticized at all you get build up of stresses when you start to break the fiber at points within the fiber, and essentially you break it piece by piece instead of all in one piece. When you do allow it to have just a little bit of internal mobility and allow it to move around a bit, the various segments within the fiber reinforce one another and finally break all together. You can prove this, for example, when you measure the breaking properties at increasing gage lengths, starting from very small ones and getting bigger and bigger gage lengths. As you do this your breaking loads and breaking elongations will drop. The reason they drop is presumably because as you get a bigger and bigger part of the fiber under tension the chances of having a weak zone in the part of the fiber under test increases greatly. Your ultimate properties are sort of specific in the sense that they depend on some kind of a weakness within the fiber. Apparently, with cotton you can do a little bit of repair work with just a little bit of plasticizing.

_____ : I'd like to ask Dr. White whether he knows of any difference between the skin and the core type of rayon with respect to their shrinking characteristics?

Howard White: Well, indirectly, yes. You can now make rayons that for lack of better designation you might say are all skin or all core. The core is less organized; the skin is the more highly organized, and so the skin absorbs a little bit less water and swells a little bit less, at least if left to its own devices. If you have the two of them attached together in one fiber, they interact with one another -- each has its tendency to force its natural dimension changes on the other.

N. M. Bikales: I'd like to ask Dr. Tarkow about the natural cross links in dry cellulose, wood, textiles, or paper. These crystalline regions that you have drawn on the blackboard are a type of crosslinking -- at least the cellulose molecules are held together, and in any dried cellulose, I am sure,

there are also hydrogen bonds that form probably in noncrystalline regions. Are there any other types of natural crosslinking known in dried cellulose?

Harold Tarkow: There has been a fair amount of thought given to bonds, between say carboxyl groups and hydroxyl groups. Some sort of inter-ester has been proposed, but I don't know how prominent they are. In connection with hydrogen bonding, there must be a wide gradation in the intensity of hydrogen bonding, depending upon how closely the chains could come to each other. In one extreme, when they came together very nicely over long distances, they form these crystalline areas indicated on the blackboard. At the other extreme, they come together at points, and they form what some people call simply "junction points" in contrast to these crystalline areas. In between these two cases there is a spectrum of hydrogen bonding of varying intensity. Steric factors are very important.

G. C. Marra: I'd like to address this question to Dr. Tarkow. I gather from Nearn's data that the phenolic resin impregnated wood had no more effect on the wood as far as equilibrium moisture content is concerned than did the extractives in the high extractives containing woods. How do you explain this?

Harold Tarkow: I wondered about that myself. I don't know how Nearn treated his wood. It's simply listed as resin-treated wood. When I read the paper I wondered, too, about the smallness of the effect. Perhaps there wasn't as much resin introduced as we normally put into phenolic resin-treated wood, or the resin he used was not the type that we normally recommend, or perhaps instead of treating relatively thin pieces of wood to assure good penetration he used thick pieces.

C. D. Dosker: Gentlemen, here endth the first session.

Minimizing Shrinking and Swelling by Proper Use
(F. E. Dickinson, Presiding)

Stephen Preston: I would like to address this question to Don Laughnan. The curves that you showed for moisture-excluding effectiveness of the various types of sealers, etc., indicated that untreated wood reached a higher equilibrium than did wood that was treated with a water repellent. Do you feel that there is a change in hygroscopicity of the wood as a result of the application of the repellent?

D. F. Laughnan: No, I think it was simply a case, Steve, of moving the curve up a little bit to fit the words "water repellent" in between them. The

specimens came to about 25 percent moisture content with a few tenths variation, and that is experimental error. I failed to point out one thing, though. Moisture vapor and liquid water are two different breeds of cats. Against liquid water, our water-repellent preservative gives us first-class protection. Against moisture vapor, you might as well dispense with using it.

G. C. Flanagan: I have a comment in connection with R. P. A. Johnson's talk and Ray Rietz's talk. One thing that we have found out is that you can't dry certain kinds of lumber as dry as it's going to end up in service. Under the planer knives at 3,500 revolutions per minute with about anywhere from 10 to 16 knives, you've got a terrific knot breakage. We have found that you don't dare, if you want any panelling left, dry your knotty panels under 12 percent. It should be surfaced at 12 to 14 percent. The rest of the shrinkage can occur in the building; it won't hurt you. But if you try to surface at 10 percent, you're going to have a bunch of cracked knots and knotholes. The same thing is true to a less degree in connection with framing and sheathing lumber to be surfaced at less than 14 percent. We found there was just too much degrade and too much breakage of the knots -- even sound knots would shatter like glass. For this reason 14 to 18 percent is what we aim for, or say an average of 16 percent. In sheathing we aim for about an average of 13 percent. In knotty panelling we aim for about an average of 12 percent.

R. P. A. Johnson: I'd like to comment on the shattering of knots in the framing material. As far as the serviceability of the structure is concerned, we are not concerned with shattered knots. A knot is no good in there anyway. It doesn't add anything to the strength and only adds something to the appearance. You have, I know, a problem in connection with grade. Construction grades are more or less fictitious because a cracked or broken knot or knot-hole with no knot in it has no more effect upon the strength than one that's sound and intact.

G. C. Flanagan: Yes, but try and sell it.

G. Godin: I'd like to address this question to Mr. Rietz. In view of the inverse relationship shown between the moisture content and the dry bulb temperature of the absorption curves, would you comment on the industrial practice of increasing the dry bulb temperature as a means of accelerating the humidification of reconstituted wood?

R. C. Rietz: You are using higher dry bulb temperature at a given wood moisture equilibrium. The moisture content equilibrium -- temperature -- relative humidity curve would then indicate that the equilibrium at the same relative humidity but at a higher temperature would be lower. You can maintain the desired equilibrium condition at the higher temperature by adjusting the relative humidity.

G. Godin: Do you mean the higher temperatures?

R. C. Rietz: High dry-bulb temperatures -- yes.

G. Godin: To accomplish what now?

R. C. Rietz: To accomplish the humidification at a faster rate. The diffusion of moisture in wood is directly related to temperatures -- the diffusion constants are higher with increasing temperatures. Not only as far as drying is concerned, but I think that Dr. Stamm will agree with me that the sorption rates would also be higher at the higher temperatures. We use that technique in conditioning wood to relieve case hardening all the time. In other words, our conditioning time for so called stress release is much shorter at temperatures at 180° or higher than it is at 140° or 160° in maintaining the same equilibrium moisture content condition in the drier.

R. H. Bescher: I want to address this question to Otto Heyer. In building mill-type construction, is it common practice in your design to compensate for the shrinkage that you're anticipating; in other words, in the illustration that you gave you showed the beam was going to shrink, or the combination of cross lumber with it was going to shrink as much as an inch. Is there any thought ever given to making that structure an inch higher so that when you end up you're right?

O. C. Heyer: I don't think there is any serious consideration given to trying to compensate for shrinkage, because we use the standard members. If this was done, it would require special detailing.

_____: Actually, those floor joists usually go from the outer wall clear across; so they're no problem, because you're going to get the same shrinkage on the outer walls as you get in the center, and lots of times those joists are dry anyway. And then the other thing I wanted to comment on was that if you put in steel posts with steel girders, you're going to have your house going up and down with changes in temperature, which you don't have with the wood.

O. C. Heyer: If I understand your question correctly, you said the joist usually has a clear span. I think you will find that the joist will bear on the foundation wall on the outside and on a girder at the center. Now, the difference in shrinkage could be appreciable from the outside wall to the inside wall, and it probably would be just enough to cause plaster cracks. I think you answer the question by saying, if the moisture content of the lumber is within the 5 percent range, which it will reach in service, there will be little or no damage due to shrinkage.

C. C. Campbell: I'd like to address this to Mr. Rietz. These tighter buildings, as you stated, with air conditioning and with central heating, do make quite a difference in wood equilibrium. I would like to ask if there has been any official contact with the air conditioning and heating people to ask them to include in their literature, information on humidification equipment. Many people, of course, have trouble with a nasal closure. They boil water to increase the humidity. They feel a higher humidity is a healthier condition.

R. C. Rietz: I think actually that we could maintain the higher relative humidity in our homes during winter heating season that the medical people recommend for comfort and a reduction in respiratory problems. Our overall dimension change would be considerably less. In recent years we have been telling people, particularly if they're having a lot of trouble with outside paint coating, that perhaps one of the things they should do is set their humidifiers down to a lower level. Don Laughnan knows a lot more about that particular aspect than I do, but I think that with the better use and proper installation of vapor barriers, troubles with paint blistering because of the migration of vapor through the walls can be minimized. This means that we could maintain higher humidities in our homes during the winter, and our structure literally would not dry out as much. Now, in the summertime we, in addition to cooling our homes, are doing more dehumidifying. This means that as far as comfort is concerned in our homes, the relative humidity is lower than it would be if we had our windows wide open. As a result, the equilibrium moisture content conditions are lower. The more we move into air conditioning in our homes and offices, the dimension changes from season to season very likely might be less than we previously experienced in homes that were heated without humidification in the winter and opened up in the summer to be exposed to existing outdoor relative humidity conditions.

D. F. Laughnan: I'd like to add one thing to that. In those instances where we can positively stop cold weather condensation as contributing to the blistering of the exterior paint, we actually tell people to shut off their humidifiers. Those things have the habit of getting out of control, and we run into house owners that say "Oh, I get 35 percent relative humidity in here," and then find that it's about 50. There's an instance in Madison last year where the man was actually heating a water reservoir. He had water all through his walls. Now, until we learn how to install effective vapor barriers and to use them properly, we can't get away with that excessive humidification inside of the house. Not with the water-sensitive paints we're using.

Dimensional Stabilization of Wood by Mechanical Means
(Walton R. Smith, Presiding)

E. T. Bailey: I have a question about the supermicroseal process. I wonder what application the process could have in synthetic boards, like hardboards?

F. A. Bade: We have gotten fairly good results on composition boards, specifically on your product; in fact a Canadian licensee is interested in the use of some of your board as a relatively inexpensive wall panelling.

C. D. Dosker: I would like to direct a question to Mr. Heebink. In drying your veneer in expanded form, is the copper screen preheated or is it placed cold in the press?

B. G. Heebink: It was not preheated.

C. D. Dosker: In other words, we do have some expansion of that copper screen to counteract the contraction of the veneer?

B. G. Heebink: I suppose it's possible. I doubt if there is much effect. I said it wasn't preheated -- it isn't on the first cycle, after that it's probably warm from the previous load.

We've wondered about characteristics of the screen -- whether it made any difference if the weave of the screen was one way or another in relation to the grain direction. We haven't looked into this.

D. W. Benseid: I would like to direct this question to Bruce Heebink. Bruce, in that press-dried veneer, you showed us some sections that had been cut on a microtome. Is it possible that the preparation of those sections may have removed some of the distortion?

B. G. Heebink: I doubt it. Mr. Marts prepared them, and he was very careful in preparing the specimens and pointed out to me that some of the material that you saw in the pores was shavings or crumbs from his preparation and wasn't produced in our processing. I presume you meant the distortion of the cells.

D. W. Benseid: Well, usually you either boil them in water or some other preparation.

B. G. Heebink: Oh yes, I see what you mean. No, he didn't do that. These were cut dry. That's why he was explaining that there were some shavings

in the pores that shouldn't be there, but he couldn't avoid it because they have to be cut dry.

J. B. Grantham: I'd like to direct this to Bruce Heebink. In some of your overlay work, Bruce, you continually run into a problem of balanced construction. Now if you're overlaying with a material that has a cost of 20, 40, 50 dollars a thousand square feet, it's expensive to have to put the same material on the back in order to get balanced construction. What's been your experience with saw cuts or the like to relieve and balance the material on the back side at lower cost?

B. G. Heebink: We haven't tried that in our work, but I know it has been tried by others. One thing we have done, when we wanted only a surface coating on one side and didn't need it on the other, was to search for some paper or sheet that had the same dimensional characteristics as the board. We found that vulcanized fiber is such a material, and we measured the dimensional properties of vulcanized fiber and found that it shrunk and swelled across the machine direction just about as much as a flat-grained pine board, so we argued that we could glue it on one side only. We've done that, and it's been fairly satisfactory in making beveled siding from southern pine, for instance. You get no dimensional restraint whatsoever. We do get a slight amount of cupping from that combination by virtue of the fact that we more or less unbalance it with a glue line, which provides more of a vapor barrier on one side, so if you take a piece of wood that is overlayed on one side with vulcanized fiber and put it in one of our high humidity rooms and look at it the next day, it would be quite cupped. Leave it there for a month, it would be flat again.

Walton Smith: Most of you are familiar with the vapor drying process developed by Monie Hudson of Spartanburg, S. C. In that process you get a number of minor checks on the interior of cross ties, and the question was discussed around here the other day as to whether that afforded any stabilization. It reduces serious end splits on cross ties, and it does offer a means of drying oak cross ties. Oak's pretty difficult wood to dry rapidly, a matter of few hours from grass green to fully air seasoned conditioned without creating serious splits or checks in the cross ties, which are visible from the outside. If the tie is partly dried at the time you put it through this process, you get a very serious split. In other words, if there is a check started in the end and you put it through the process, that check grows, but if you have no checks started and put it through the process, you do not get a check and you get very fine results. Along the same line, Jake Hoffman down at the University of Florida, has kiln dried cross ties, particularly gum cross ties, at very high temperatures -- 230° to 240° F. He gets the same kind of a result, in other words, you get some honeycombing in the inside, but practically no seasoned checks or splits on the outside of the ties.

So there appears to be a possibility of conditioning wood at quite elevated temperatures at a very rapid rate, and you get a lot less damage than you would if you kiln dried it at a much lower temperature and much longer time. As to whether you get dimensional stability in the ties after they're processed, I don't know.

 : I have a question for Dr. Marra. Yesterday in your discussion you were talking about the relative stability of the particle boards in the plane of a board and also in the thickness of a board. In your opinion, for the most of the uses of particle board, which dimensional stability is the more important, or are both of them equally important?

G. G. Marra: I think for coreboards that are to be used with overlays of either veneer or plastic, that the thickness dimension is perhaps the most critical. For wall panelling I think the linear expansion is the more important.

James Hamilton: I have a question for Mr. Bade. First, is there a specific hardness developed in the microseal process, and second, I was wondering if this process has any potentiality for hardening of the surface of such things as flooring and other types of products that could be conceivably treated under a process of this type with more than a superficial type of treatment?

F. A. Bade: To answer your first question, there is a definite hardening of the surface. Now, we have not made tests such as Brinell tests or abrasive tests, to say that it's twice as hard as raw wood or sanded wood. The hardness is sufficient though to protect the work very well from the time it is processed to the time it is installed in a home. The surface is much more resistant to dirt and scratches and drag marks. In answer to your second question, it's difficult with this process to get any depth of surface, as the resin does not tend to penetrate. Build-up of resin on the surface is not desirable either as the belt then does not act on the wood. The process is thus not suitable for building up a complete finish.

James Hamilton: Can possibly some extension of the principal of hardening on a continuous basis for more than a superficial treatment conceivably be made? Has your research department explored the possibility of getting more than the superficial treatment, like for example, a hardened floor surface?

F. A. Bade: Yes, our work is continually in the direction of getting more plasticizing of the surface. I remember I didn't go into the question of smoothing action. I usually stay away from the term smoothing, because we use non-abrasive belts. Everytime you talk about smoothing, people think it's sanding or you're removing stock and smoothing. There is, however, a definite smoothing of the wood surface. Dr. Elmendorf showed this in a FPRS paper describing his smoothness tester last July.

Dimensional Stabilization of Wood by Chemical Means

(E. C. Jahn, Presiding)

F. E. Dickenson: Going back to the presentation on polyethylene glycol, I wonder what the possibility is of applying this treatment to a product such as flooring. I realize that for the treatment to be real effective it has to be applied in the green state. How about using hardwood lumber that is partly air dried?

A. J. Stamm: Well, I'm afraid you'd run into trouble as soon as you start with partially dry wood. This morning I showed panels of Douglas-fir plywood made with polyethylene glycol treated faces. We had no green veneer available at the time, so I had to treat the dry material. I had to apply 200 pounds per square over night in order to get enough chemical into the structure. Treating of dry or partially dry oak I imagine might be equally if not more difficult. One of the advantages of the polyethylene glycol over any of these other treatments is that it serves as a seasoning aid as well as a dimensional stabilizer.

G. Godin: I did some experiments with Quilon, which is made by the Dupont Company. I thought this chemical might react with fiberboards and modify the water absorption characteristics. The strength of the finished board was, however, poor.

A. J. Stamm: The particular chemical you're speaking of is one that I now have under test. I do not as yet know its effect on the strength of wood. Your loss in strength can be accounted for on the basis of the chromium in the compound catalyzing the thermal degradation on drying. For example, I have shown that 1 percent of zinc chloride in wood increases the thermal degradation 17 fold.

G. Godin: Do you feel that hydrogen bonding has anything to do with hardboard formation? Like in paper?

A. J. Stamm: Oh yes, I think that hydrogen bonding is involved in hardboard formation as in paper formation, but that it is complicated by other effects.

R. K. Madison: I'd like to ask Dr. Stamm whether it would be possible to insolublize some of the salts that you have used inside of the wood?

A. J. Stamm: We have been doing just that. Not from the standpoint of dimensional stabilization, but the standpoint of preservation. We call it the double diffusion process. One of the combinations receiving major attention

is copper sulfate and sodium arsenate, forming copper arsenate precipitate. We have increased the life of treated fence posts in areas in the South where the rainfall is great and an ordinary chemical, like the copper sulfate alone might leach out in a matter of say 6 months, to over 18 years.

_____: I made some experiments with Aquapel, which is a water repellent agent. It does a tremendous job as far as sizing is concerned, but when I tried to use it in making a synthetic board, actually the water absorption properties became worse -- something I cannot understand. Do you have any comments on that?

A. J. Stamm: I happened to have tried that same material, and I find that as a water repellent it is excellent, as an antishrink material it has no value at all. Incorporating it with the stock, I can well imagine, would give a poor board, as it would cut down on the effectiveness of surface tension forces pulling the fibers together and on subsequent hydrogen bonding.

G. G. Marra: I want to offer several comments with respect to resin treatments of wood products. I heard recently that in England they are making considerable quantities of compreg for use as protection against atomic radiation. I wondered if that has been done yet in this country. Anyway it does indicate another large potential use for compreg. Another comment I might offer is that in many of these applications we've been thinking of, the problem seems to be how to get the resin into solid wood. We find ourselves continually forced in the direction of using veneers. I wondered if it wouldn't be possible to go one step further and utilize flakes rather than veneer, as they can be handled mechanically and the impregnation is rather simple. I was thinking of the compreg type of material that we have been making from flakes. The impregnation step is very simple and very fast -- it changes the order of cost of the material considerably.

Harold Tarkow: I would like to answer your first question about how compreg is being used in England. I think the effect could have been predicted. You simply have doubled or tripled the amount of wood substance per unit of volume by making compreg, so it's simply the fact that you've increased the concentration of mass. Relative to your question regarding making compreg from flakes, I am sure you can do it.

C. D. Dosker: I want to direct this question to Dr. Stamm. I want to go back to this double diffusion thing. Have you checked it as an instrument of stabilization? Suppose you don't get complete penetration. Suppose you get partial protection. Isn't it a pretty cheap way to get partial protection?

A. J. Stamm: If you remember, I think it was the first slide that I showed this morning, the salts that do the best job of bulking are the most soluble

and are the least likely to form a precipitate. If barium chloride and the sodium sulfate were used, they would probably form a precipitate in the fiber, but not more than 10 percent antishrink efficiency would be obtained.

_____: There was no mention made this morning of staypak. We've been told that heat treatments reduce the toughness and also resin treatments. I've been led to understand that staypak retains its toughness. Why is this, as it involves a heat treatment?

A. J. Stamm: The staypak has had a very mild heat treatment, not enough to cause loss of water of constitution, so you don't get heat stabilization at all. Staypak, further, is not dimensionally stabilized. Because of its high density, its rate of water take-up and swelling are considerably reduced but not the equilibrium amounts.

_____: I'd like to ask Dr. Goldstein whether he has tested any of the propiolactone treated materials and the cyanoethylated materials for termite resistance? We have done some work along that line, and I was wondering whether you had also.

I. S. Goldstein: We have made both decay resistance and accelerated service tests on 3/4-inch stakes on both these materials. The stereochemistry, which enables the enzyme system of micro-organisms to attack the cellulose, has been changed so that these modified woods are resistant to microbiological attack. However, the termite does not know in the absence of the toxic material whether or not he is going to be able to digest this material or not, so he will explore it. Depending upon how many termites you have and how hungry they are, you will get more or less exploration before they find out they are not getting subsistence. So I would have to say in theory these materials are resistant to attack by termites as far as offering the termites subsistence is concerned. The termites will go through all kinds of things to get to food. Since these materials are not hard, they have roughly the same hardness as untreated wood, they would certainly be subject to a good deal of deterioration if they got in the way of termites.

_____: Dr. Stamm, you say that water is lost from wood when it is heated to high temperatures. Are there other changes taking place?

A. J. Stamm: I can't remember the exact proportions but it's something like this, 10 moles of water to 1 of carbon dioxide and a small amount of organic compounds like methane.

_____: How is that water present in the wood originally?

A. J. Stamm: It is not adsorbed water but water formed from a chemical degradation of the wood. When wood is heated in air, part of the oxygen in those reactions comes from the air. Water and carbon dioxide are, however, formed, but perhaps to a lesser degree in the absence of oxygen.

J. A. Hall: Don't you have an approximate analysis of the heat-treated wood as opposed to the normal wood? What is the relationship between cellulose and hemicellulose content for example?

A. J. Stamm: We have data to indicate that hemicelluloses decompose first, then cellulose and then lignin.

_____: Dr. Stamm, have you tried any other aldehydes besides formaldehyde?

A. J. Stamm: Yes we have, we've tried acetaldehyde, benzaldehyde, and furfural. We find that we need practically the same acidity to get the reaction with all of them. Our results indicate, however, that the resulting acetals are not so stable as that obtained with formaldehyde.

E. C. Jahn: I might just make a comment. Dr. Stamm pointed out this afternoon in his last paper that a very small amount of formaldehyde was needed to give a considerable reduction in dimensional change. This is brought out by some quite different experiments that we did in the laboratory. We used some isolated purified hemicellulose from birch. This material was readily soluble in very dilute alkali solution. However, when it was reacted with formaldehyde only to the extent of a few tenths of a percent in the presence of ammonium nitrate catalyst, the hemicellulose was no longer soluble.

_____: How expensive is propiolactone?

I. S. Goldstein: The present cost of propiolactone is approximately 90 cents a pound. A producer states that, if the volume used increases considerably, they might be able to cut the price in half. We would be very happy to have any of the members of this seminar come up with uses of dimensionally stabilized wood that would enable us to take advantage of this price reduction.

R. H. Bescher: I have been quite interested in all this cost discussion. If you take wood at 100 dollars a thousand, it's worth about 5 cents a pound. The chemicals we're talking about even the most inexpensive ones are maybe 30 cents a pound, and it takes one third of a pound, so we're talking about 10 cents worth of chemicals and 5 cents worth of wood. Now how many applications can we find that will stand this three fold increase in cost even if the processing were free?

J. A. Hall: Let us consider, for example, the basic cost of a dresser. This will not contain more than about 25 board feet of lumber, at a cost of about 200 dollars a thousand. That means we do not use more than \$5 worth of wood. The rest of the cost is labor. Tripling the cost of the wood, hence, should increase the cost of a \$100 dresser by only \$10. This, of course, is not the full answer. In the manufacture of television cabinets, where the competition is very high, hardboard with the grain of mahogany photographed on the surface has replaced wood as the cost is \$1.50 or \$2 less. Confound it, that's enough, that's the kind of margin that we're operating on. You made a very important point, Ralph, we have got to have methods of stabilization that use far cheaper materials than anything we have so far used and lots cheaper too.

Dimensional Stabilization of Paper and Fabric
(J. A. van den Akker, Presiding)

G. G. Maŕra: Just before I left home, Dr. Stamm, we were starting to use zinc chloride and paraformaldehyde to try to achieve stabilization in flake board. We were treating the flakes prior to adding resin. I don't have any data for the final board, but at the end of about 3 days at 90 percent relative humidity the flakes seemed to show about 30 percent less swelling in thickness than the controls.

A. J. Stamm: I would have expected at least that good of results. I had been thinking of trying it here at the Laboratory. Although the wood flakes will lose in toughness and abrasion resistance, the damage done can in a way be repaired by the resin.

_____ : I wonder, Dr. Stamm, if you've ever tried using dialdehydes for dimensional stability? Some of them might cause a little less degradation of the paper. Perhaps they could be applied as a liquid or solution.

A. J. Stamm: We have tried glyoxal. It showed no advantages over formaldehyde. I see no advantage of using a liquid. Aqueous formaldehyde gave dimensional stabilization only upon drying the paper. Cross linking seems to take place only after shrinkage has brought the structural units of the paper close together.

I have a question that I would like to ask Mr. Bikales. I rather felt that the large losses in strength that you got with your paper made from precyano-ethylated pulp were largely due to changes in physical structure. You intimated that the porosity of the paper had gone up considerably; that's a pretty

good indication that the density of the sheet is down. If the density of the sheet is down, the amount of fiber-fiber bonding in the sheet is down, so your strength might be low merely because you had less fiber-fiber bonding, not because of the presence of the cyanoethylation medium. I, hence, do not think it's fair to blame the cyanoethylation chemical for those losses -- it seems to me to be due to the effect of the treatment on formation.

N. M. Bikales: I believe you have just answered the question yourself. I mean that if cyanoethylation is a whole process that you have to take it as it is, you can make improvements to make it more economical, but you still need to have alkali and you still have to have a acrylonitrile and, consequently, if the treatment affects formation as you have just described, then you just have to live with it.

A. J. Stamm: Could you densify the sheet further so as to bring it back to a normal density? Then the strength would be better.

N. M. Bikales: We haven't done any work along that line. I believe that dry-strength resins could be added and bring back the strength. I do feel, however, that the presence of the cyanoethyl groups contribute certainly to some extent in the loss of strength. Perhaps it is not the complete answer.

H. D. Turner: I would like to ask a question of Al Stamm. Most of your work has been in connection with either whole wood sections or paper, and the question that I would like to ask is, have you done anything on, say, a single fiber to determine whether this loss in tensile strength is really the loss between fiber-fiber bond, or is it in the fiber structure itself? For example, the formaldehyde stabilization of a single strand of cotton.

A. J. Stamm: No, we have not done that. It would be a very enlightening experiment, Dale.

I would like to ask Mr. Bikales if he has tried going down in alkali content to see how far down you can go and still get a reaction.

N. M. Bikales: I think that the lowest sodium hydroxide concentrations that we used were about 3/10 of a percent. In the experiments that I described we used 1 to 2 percent. Even with the lowest sodium hydroxide concentrations you still had the problem of sheets actually disintegrating.

A. J. Stamm: One of the difficulties of the 2 percent sodium hydroxide is that you are opening up the crystalites and making the fiber more accessible. Hence, you have to put more chemical into the fibers to do what you want to do. I would like to find a less alkaline catalyst for this reaction.

N. M. Bikales: I don't believe that the crystalites have been effected too much, because of the X-ray work that has been done.

R. A. A. Hentschel: I have a couple of comments I'd like to make. In the first place, regarding the effect of cross linking on the tensile strength of fibers. I don't have any very direct evidence, but in the textile field this has been looked at quite a bit, and I think as a generalization that cross linking generally does lead to a reduction of tensile strength for most of the work that I have seen any records of. This may have some bearing on what we have heard here today. The other comment has to do with the meaning of the dimensional stability tests that we have heard here today. I believe someone earlier made the comment that many of these sheets have strains in them, and that the presence of these strains can affect the behavior of the sheet and the hygroexpansivity. In our laboratory we have felt that this is very decidedly the case and I've found that in order to get reproducible results, and results that we felt were reliable, we have had to go through quite a number of cycles of humidification and dehumidification before the materials have reproducible results. In our case this usually amounted to as many as 5 or 6 cycles. I wonder whether the tests that we have heard described here today have been run under those circumstances so that we are talking about the same changes in stabilization of dimension, or whether the measurements have been made on the first cycle or two, where we have noticed that the dimensional changes are frequently considerably greater than they are after a number of cycles.

A. J. Stamm: In the case of measurements made here at the Forest Products Laboratory, we never depend on the first cycle. Sometimes we don't even record it because it isn't worth too much. If the dimension change -- measurements are being made between water soaked and a low relative humidity, you don't have to go through as many cycles as you would if you were working between 30 and 90. When water soaking is involved, there isn't too much difference between the second and third cycle.

N. M. Bikales: Not having made the measurements myself, I can't say for sure how many cycles were employed. I can say this, however, that my co-author, John Morton of I. B. M., felt very sure about the reproducibility of his measurements.

G. M. McLeod: Most of our expansivity results are on the first cycle. We were fundamentally interested in comparative results. I don't know how much they would vary, if you took, say, two or three different types of papers and carried them through several cycles whether the expansivities would get closer together or whether this variation between different types of paper continues through the five or six cycles.

J. A. van den Akker: The Chairman would like to comment on this. We agree with you in your observation. In the case of machine-made papers the loops usually not only close, but show reduction in dimension. Once in a while, however, presumably depending upon the tension under which the sheet was dried, the loop will not close by quite a good deal. In this case, the hydroexpansivity determined on the first desorption is apt to be considerably less than that of the subsequent desorption. Although the results might be reproducible, if carried out according to a certain procedure, they might be quite different if the loop doesn't close; however, if the loop does close, it was our observation that the first cycle had almost the same slope whether it was absorption or desorption as, I'd say, the fourth or fifth cycle.

I'd like to ask if anyone has any information on the effect of sodium hydroxide on the strength of paper?

A. J. Stamm: Dr. W. E. Cohen of the Australia Forest Products Laboratory, has been working on the effect of very small amounts of sodium hydroxide on the strength of paper. In the tenths of a percent range, some of the strength properties increase. When the concentration increases all strength properties drop. He's preparing this material for publication now. I think it will be of interest to many of the pulp and paper people.

_____: One of the tests that we run on the stability of our insulation board is the cycling type of things that Dr. Hentschel spoke about. We run 12 cycles of drying and a soaking. Water soaked for some 20 hours, and a drying cycle. We notice that our length keeps getting progressively less. Now the first question I have for Dr. Hentschel is: Did you notice a progressive shrinkage in your paper also?

R. A. A. Hentschel: Yes.

_____: Now then let me ask, do you have any observations as to what might explain this progressive shrinkage? Is this a morphological thing -- I mean, is it a mechanical thing or is it a chemical process? Have you any observations on that?

A. J. Stamm: I'm afraid I can't give the reason for this progressive shrinkage, but it is something that we have observed for years with wood.

J. A. van den Akker: I don't have any good theories either, except that it may be related to stress relaxation. Our thinking has been chiefly along that line. Each fiber, of course, is constrained by all the other fibers in the sheet to have a shape different from what it would have if left to itself, and, of course, no fiber can return to that shape, but there will always be a tendency toward that condition. Chances are that it will be toward minimization of the dimensions of the paper.

R. I. Leininger: What effect do the treatments that we have been talking about have on the electrical properties of paper?

A. J. Stamm: We have made D. C. electrical resistance tests on several treated materials that we've worked with, and invariably, when we decrease the hygroscopicity of a material, be it wood or paper, we improve its electrical resistance. There is good evidence to the effect that electrical conductivity of wood or paper is due to adsorbed water. If you cut down on the hygroscopicity, you improve its insulating properties greatly by removing the source of conduction.

Possible Chemicals for Dimensional Stabilization
(E. G. Locke, Presiding)

A. C. Nixon: I would like to comment very briefly on the toxic hazards of acrolein. We don't want to discourage anybody from working with the acrolein. Perhaps one-tenth of a part per million is toxic, but I suspect that was given to a rat in a closed box and he had to stick around and take it. Now I don't think there is anybody here that would have to stick around and take one-tenth of a part of acrolein or even one-thousandth of that much very long. Acrolein has a very effective warning. The effect upon one's eyes and nose at far below toxic levels will drive one to safety.

R. K. Madison: A worker in our laboratory has recently come up with a process of grafting on to cellulosic materials using a ceric salt as the catalyst. We have been able to graft onto various types of celluloses a number of monomers. The amount that we can put on can be varied considerably to give a range of properties from that of practically pure cellulose up to the properties of the polymer made from the pure monomer. We haven't investigated the use of this technique on wood, but it certainly seems like it might be of some value. There is some work being done at the United States Department of Agriculture Laboratories in Peoria in which starch has been partially oxidized with periodates to give a polyaldehydic starch. One other comment is that diepoxides are extremely good cross-linking agents for cellulose, but they require rather drastic catalysis. Peroxides are preferred catalysis. Zinc chloride, aluminum chloride, magnesium chloride are as good catalysts, but you get rather extensive acid damage when you use these materials. Whether such a system could be used on wood, I don't know, but it could be considered.

_____: I would like to ask Dr. Nixon whether acrolein is available in a dimer or trimer stage that might perhaps have the desired reactivity. This would get away to some extent from the toxic properties.

A. C. Nixon: Yes. We are looking at the various derivatives and, of course, you cannot only make a dimer but you can make a polymer, which is a linear branched polymer of molecular weight, perhaps as much as 100,000, and there are various derivatives of this, such as the sodium bisulfite derivatives that are quite interesting materials -- but we really haven't done enough with them yet to know how applicable they are. It seems to me, however, that where you want penetration without too much disturbance of the wood structure you want to use small molecules that will diffuse rather readily through the structure, where as for surface treatments the polymers would be the first things you would try.

N. M. Bikales: We have been talking about acrylonitrile, which has the structure $\text{CH}_2 = \text{CHCN}$. We have also been hearing about acrolein, which

has this structure $\text{CH}_2 = \underset{\text{H}}{\text{CH}} = \text{O}$. You can readily see that they are very

closely related. The addition that was indicated to take place at the double bond of acrolein is similar to that which takes place in acrylonitrile. They are just different cases of the same general reaction. We have another material available in commercial quantities that is also closely related called acrylamide, wherein the nitrile group has been converted to the amide group, thus $\text{CH}_2 = \underset{\text{NH}_2}{\text{CH}} = \text{O}$. This material, however, has quite different properties.

For one thing it is a solid material and because of that it has lower toxicity problems, because of lower vapor pressure. Acrylamide can be polymerized to water soluble polyacrylamide polymers. It should hence be suitable for impregnation into wood. Acrylamide can also be reacted with formaldehyde to form methylol acrylamide. One part of the formaldehyde molecule reacts with the acrylamide and the other part is available for reaction, let's say with cellulose. You can do the same thing with a polymer and you can get polymethylol acrylamide. Now the interesting feature of this is that it is also water soluble, but on heating it will crosslink, the methylol groups being reactive enough to crosslink either with itself or with cellulose, and form an insoluble material. Here you would have a way of introducing a water soluble material into cellulose and by mere application of heat you can insolublize it within the structure. I believe that in the presence of a sufficient number of hydroxyl groups, which you have in cellulose it would anchor on to the cellulose backbone. Since it is like formaldehyde, and as little as half a percent of formaldehyde is needed for effective crosslinking, perhaps not very much of this sort of material would be needed. It would have the advantage over formaldehyde in that it would have more carbon atoms in between the crosslinks. For example, you do not have to treat it in such a way that all the amide groups in polyacrylamide are methylated. You could take polyacrylamide and just add a few methylol groups and therefore you would have only a few sites of attachment, which would give a greater flexibility. I have made some very brief experiments and incorporating this material into paper

for possible dimensional stability. I certainly have not done enough to report on it to say that it is a promising approach. I did find that as little as 5 percent gave the paper a very stiff appearance. It seemed to me that this was much more than was needed.

I. S. Goldstein: I think we should not lose sight of what has been said in the past few days about what has been going on in the interior of the fiber where the wood and water are interacting. Right behind you, Norbert, we have an excellent illustration of the environment in which these reactions have to take place (sketch of the crystalline and amorphous regions of cellulose). We should remember that anything that we use has to get into where it is going to do the most good; in other words, the cellulose has to be accessible to these materials. We have broad experience in the resin treating field. If we try to impregnate wood with phenolic resins which have passed their water solubility stage, you need an organic solvent to get them into the fiber. Without the organic solvent, you no longer get the high degree of dimensional stability because we haven't gotten the resin into the excessible parts of the cellulose structure. I am afraid that in this case of the polyacrylamide, you are going to end up with a surface treatment. We may not be able to find reagents as small as formaldehyde to go into fine cell wall structure -- we should concentrate on chemicals that are not too much larger than formaldehyde.

A. J. Stamm: During the last 6 months we have had visitors at the Forest Products Laboratory from two of the big chemical companies. They came to tell us about all of their new chemicals. They met with representatives of the Lab who were interested in glues and additives, members of our Pulp and Paper Division, who were interested in fillers and sizings, and those interested in preservatives and dimension stabilizing chemicals. We all took notes on what was told us and each of us picked out one or two chemicals that we would like to try in our research. As a result of these meetings, I have four different chemicals under test as dimension stabilizing agents. I am not far enough along to give a report at the present time on their suitability. The point that I would like to make is that other chemical companies might profitably send representatives to the Forest Products Laboratory to acquaint us with their new chemicals. Perhaps we'll find an application for some of these chemicals that you folks haven't thought of in the past, as being useful in modifying the properties of wood and wood products.

E. G. Locke: I want to thank the members of the panel, Wakefield, Konaga, and LeMaistre, for their remarks and effective stimulation of the audience to participate in the discussion. It is very gratifying that so many of you have made comments.

Review of Symposium
(J. J. Byrne, Presiding)

Harold Tarkow: I am supposed to review and correlate the 20 papers presented at this seminar. However, rather than review the papers, I would like to see if there are some threads of unity running through the 2-1/2 days of discussion. One point that was emphasized pertained to the disuse to which wood is put. We have had several papers presented about the improper seasoning of wood, the improper control of the moisture content of wood, the improper use of wood during construction on the job, and there was much concern about the subsequent economic losses. Now I am personally not familiar with the history of these arts or how they were carried out years ago. Perhaps to a degree these various practices were better performed years ago, and perhaps some of the bad practices we have heard the past few days have sociological origin. For example, it may be that the pride that the earlier operators took in their finished products is no longer a factor in the present day work world. I think, however, it would be wishful thinking to assume we can reestablish this trait. Perhaps the hot breath of competition, the presence of competitive materials, and perhaps strong emphasis on education will force the guilty operators to change their practices. Another concept that was present throughout the meeting was the fact that we have now recognized principles for stabilizing wood. One principle was concerned with reducing the shrinking and swelling of the wood substance. We had a number of papers in that regard, describing chemical treatments and resin treatments; all of these were aimed at modifying the wood substance by one of two methods -- the crosslinking or the bulking method. We had discussions about the problems involved -- problems of cost, problems of penetration. The problem of penetration came up in the last session in connection with our discussion of what is required to get chemicals into the wood substance. Another principle for stabilization was concerned with the other factor we spoke about Wednesday morning, that is, doing something to change the amount of internal swelling that is transmitted to the external dimensions. This second principle is concerned with changing the degree of communication and the transmission of internal swelling to the external dimension. We had discussions pertaining to the use of paper overlay on wood and to the incorporation of noncellulose fibers in papers and fabrics. We had discussions pertaining to the creation of what you might call swelling sinks; that is by creating cracks and crevices in wood, swelling is simply absorbed in these sinks. And so on. Throughout the 2-1/2 days of sessions I got the impression that finally some degree of maturity is settling into this field, defining maturity as a state of mind where you are willing to accept certain facts of life. In the past we have tried very hard to get the ultimate in dimensional stabilization and without loss in mechanical properties. We lost sight of the fact that there may be

many instances where we can use wood, stabilized not by 70 percent but perhaps by 40 percent or 50 percent or maybe even 30 percent. There are also places where we can use stabilized wood, which has lost somewhat in mechanical properties. Now having said all these things I don't want to give the impression that all that need be done is to continue along the lines we discussed during the past 2-1/2 days. As I listened to these papers, I became curious about a number of things, and if I may, I would like to mention some of them. For example, this morning when we were speaking about the use of these new chemicals, it occurred to me that we still do not know how large a molecule can penetrate the wood substance. We've always said in the past that the material, if it is a resin, should be of a low degree of polymerization, water soluble and, of course, we implied that beyond a certain molecular size, there were problems of penetration. Actually we do not know the maximum size of molecule that can penetrate the wood substance. We have had indications that it can be larger than that of a small molecule. For example, Dr. Stamm reported yesterday on the use of carbowaxes. Now you will recall that some of the carbowaxes, which he designated by numbers, 100, 200, up to several thousand, represent average molecular weights. You will recall that he was getting nice stabilization with some of these bigger molecules. Does that mean that we can use bigger molecules than we normally thought could be used? I am very curious to know how large a molecule can readily penetrate the wood substance. I think it could be very useful information. Another thing that I became very curious about was the matter of fiber-to-fiber bonding, not so much as it occurs in wood because nature got there first and we can't do much about that, but fiber-to-fiber bonding in connection with paper and in connection with fiberboards. These materials are manmade, and perhaps we have some control over their development. I am very curious about their role in this matter of dimensional stability because very likely, depending on the nature of these bonds, we have varying amounts of internal swelling transmitted to the external dimensions. I am very curious about the rigidity of these fibers, again not so much in the case of wood but in the case of these reconstituted materials, because depending upon the rigidity of the fibers, which would be influenced by prior processing treatments, varying amounts of internal swelling are transmitted to the external dimension. You will recall that Dr. White mentioned the fact that the hygroscopicity, that is, the moisture content at a fixed humidity varies with the temperature. The fiber-saturation point, too, is also an EMC. It is the EMC of wood substance at virtually 100 percent relative humidity. It, too, would be expected to vary with temperature. Normally we lose sight of the fact that the usually quoted value is a room temperature value. During the course of its growth, a tree is exposed to extremes in temperature; at one extreme the temperature might be as high as 100° F., at the other extreme it might get down to many degrees below zero. The wood substance in the living tree is subjected to this wide range in temperature, and during this time the fiber-saturation point is varying; it is therefore swelling and shrinking. With the seasons there is a "working" of the

cell walls. I am very curious to know what effect this working with the seasons has upon the development of a submicroscopic structure within the green tissues of the cell walls. Either a submicroscopic structure develops, that is the submicroscopic structure which we find later when we study dry wood, or the submicroscopic structure, which we finally see in dry wood develops only during the seasoning process. I would like to see a renewal of interest in the structure of this native green tissue. During the course of the discussion I became very curious about why certain species contain extractives. We learned that these species, including the many which Prof. Wangaard told us about, have relatively low swelling and shrinking capacities. It was pointed out during the discussion that this is largely due to the presence of the extractives within the wood substance itself. I am very curious to know whether we could learn how to stimulate artificially the deposition of such extractives in the wood -- just think how convenient it would be if we could have built-in bulking agents. I have always been impressed and have become more so recently with the work in genetics. Recently we have learned that geneticists have found strains of corn in which there are wide variations in the content of the two normally occurring starches. Since these strains propagate themselves, there can now be some control over the starch composition. The Forest Service and schools of forestry are becoming more concerned about the use of genetics in tree improvement. I would be curious to know whether in the course of such work we could find a strain of Douglas-fir or yellow pine that shows, for its density, an unusually low shrinking and swelling. Is that a true genetic characteristic that can be propagated? I am very much interested and would be curious to know about the condition of the moisture present in cell walls. Dr. White was telling us about the use of certain new tools; he mentioned the work done at the Western regional laboratory in studying the nature of the moisture present in wool fibers by means of nuclear magnetic resonance. They are able to study the characteristics of the moisture present and divide it into various classes. I think all of us here are curious about the condition of the moisture in the cell walls. I am curious why surface finishes, when applied by nature, are so effective in reducing moisture transmission. Insects living in dry desert areas have a "surface finish" which prevents loss of bodily fluids. Wouldn't an understanding of this be useful in our synthetic finish work.

These curiosities can be satisfied only by long research programs; none of them are weekend jobs. They would all require almost a lifetime of activity, perhaps similar to the extensive research that Dr. Stamm has put into this field. I am sure that all of you have your own questions, as what needs be done. I have simply listed some of the things that occurred to me as I listened to these papers. But I wouldn't want to close these remarks without again paying tribute to Dr. Stamm, not only for organizing this seminar but primarily for the 30 years of real pioneering and painstaking work that he has put into this field of wood-water relationships.

J. J. Byrne: Now we come to the committee report on recommendations for future research. Ralph will you come up here and present your report.

R. H. Bescher: The Committee has met to discuss the problems of future research in the dimensional stabilization of wood. The Committee recognizes the wood moisture relationship as being basic to the problem and to all approaches to the solution. Associated with this is the microstructure of wood and the chemistry of wood and it is felt that a breakthrough is needed in order to economically solve the problems.

They therefore recommend the following: (1) That substantial additional basic information is necessary on wood moisture relationship, microstructure of wood, and basic chemistry of wood.

(2) That since the proper use of wood will minimize the limitations caused by lack of stability the Trade Associations should be encouraged to publicize the proper engineering principles to use.

(3) That more economical means of mechanically stabilizing wood should be further investigated, particularly with regard to composite structure, press drying to cause mechanical extension, and the use of other mechanical methods of distributing and minimizing the effect of dimensional changes.

(4) That additional work be performed in connection with chemical stabilization of wood. Since bulking and cross linking appear to be the only chemical means of wood stabilization newly developed chemicals should be screened. Fundamental studies of the extractives of wood should be undertaken to determine why some species are more stable than others.

(5) That in the dimensional stabilization of paper a fundamental investigation of the effect of species should be carried out.

(6) That a bibliography be prepared which would serve as reference material for further research in the dimensional stabilization of wood and paper.

Committee: R. H. Bescher, Koppers Co., Chairman

C. D. Dosker, Gamble Bros.

L. T. Sanborn, Crossett Co.

J. F. Saeman, Asst. to Chief, Div. of For. Prod. Res.
Washington, D. C.

J. A. van den Akker, Inst. of Paper Chemistry

J. J. Byrne: The meeting is now open for a discussion of the Committee's report. Does anybody have any further suggestions.

F. J. Hanrahan: One thing, I don't know whether it was brought out or not, but I am sure everybody would like to see some sort of a record of this meeting, which they could examine at their leisure later. It would be a shame to have all this fine information presented without making a permanent record of it.

J. A. Hall: Only a few of the papers are available in the text form in which they were presented, because most of the boys didn't want to write them. The ones that were not written are available in abstract form. Whether you knew it or not, all of the discussion has been tape recorded. Lord help you if you said something you didn't mean. We'll do the best we can to edit the discussion and put it in reasonably understandable English. Then we will put together the abstracts, and the discussion, and distribute it to the members of the conference.

J. J. Byrne: I was interested to see that the Committee recommended more research on microstructure of wood and other basic research. When Bob Dosker was promoting the idea of holding this meeting, he mentioned the possibility of some of these things that Harold Tarkow brought up on the genetics and selection of trees that might have potentially greater dimensional stability and other desirable properties. Bob, I notice that you are a member of this Committee -- do you have anything further to say on the subject?

C. D. Dosker: Jim, one thing I consider to be very important, when the bibliography of what has been done in the field of stabilization has been prepared, I think it is extremely important that copies of it be made available to the research sections of the various companies in the country, particularly the petro chemical industry and others working in this field. With regard to what Al Stamm said, there are many new chemicals becoming available -- no one individual working in this field can find time to dig up information on all new chemicals. If we could point out in that bibliography some of the things that we are looking for, I think it would be of great assistance in bringing about a breakthrough, because you don't know when some deviationist is going to come up with some crazy idea with some new chemical that may prove an answer to our problem. I hope that we are going to be able to have enough copies of that bibliography so that they can have more or less general distribution. One of the troubles that we run into all the time is that we have too much duplication of effort. Often an investigator doesn't know that an idea has been proven false so he goes ahead and spends many man-hours of effort to come to the same conclusion.

J. J. Bryne: Thank you Bob, I think one of the important things that has been brought out here is Al Stamm's suggestion that the Laboratory has an open door to ideas and wishes to be kept informed on the new chemicals that

have possibilities in wood chemistry as well as in dimensional stabilization. I notice, Ralph, that wasn't put in a form of a recommendation. Don't you think that it might be put in the recommendations?

R. H. Bescher: We did put in a statement that chemicals should be screened. Our Committee's instruction was that we write the recommendations for the benefit of everybody not necessarily the Forest Products Laboratory.

J. J. Byrne: That's right Ralph, any further discussion?

S. Hossain: I was particularly interested in Dr. Tarkow's mention of some investigations of manmade fiber-to-fiber bonds. I am interested in this from the point of view of chipboards, particle boards, and hardboards. We know something about the bond that takes place in paper formation, but my impression is that we know very little if anything at all about the bond that takes place during the formation of hardboard or chipboard. I was wondering if some investigation could be undertaken on making hardboards with wood materials where the hydroxyl groups have been replaced by acetyl groups. This should lead to some understanding as to whether hydrogen bonding really occurs.

J. J. Byrne: Al, do you want to make a comment on that?

A. J. Stamm: Mr. Hossain is suggesting a nice field of research. I think however, that before we can do this we are going to have to study fiber-to-fiber bonding in the simpler system, paper. We don't know enough about it in paper. I would rather learn about bonding in paper first and then try and project it into the other fields. I have a project that I started before I went to Australia along that line. It has unfortunately been sidetracked because of other research. I hope that sometime in the near future that I will be able to work on it again.

Harold Tarkow: A number of years ago Harrison at the Institute of Paper Chemistry carried out such work in which he acetylated pulp fibers and attempted to make a sheet therefrom. I recall, using water as a vehicle he had great difficulty in making a sheet, but, interestingly enough, when he used acetone, instead of water as the vehicle he got a very coherent sheet with very nice properties. It certainly suggests that acetylation of the pulp fiber has done something to interfere with the bonding from a water medium. Perhaps Dr. van den Akker can amplify on this.

J. A. van den Akker: I might add that the paper made from acetylated fiber in acetone is not only stronger than the paper formed from water, but, as one might expect, had much reduced hygroexpansivity. With regard to fiber-fiber bonding I would like to say, that at the Institute we have a rather large

project on pulp evaluation sponsored by a number of companies throughout the United States. Although we admit to colossal ignorance in this field, we are trying to learn something about fiber-fiber bonding beyond the supposition that the bonds are essentially hydrogen bonds, are trying to learn something about energy sites, and we hope ultimately to learn something about the contribution of the micro fibrils on the surface of fibers, and how they become involved in bonding. I would like to add just another point here, the evidence obtained in England and elsewhere some years ago on the effect of temperature while drying is very interesting in regard to fiber-fiber bonding in that it shows that this is not simply a chemical phenomenon but also a phenomena having to do with micro structure as influenced by a very slight movement caused by tension during drying.

H. D. Turner: I appreciate the interest that Mr. Hossain has placed on hardboards. However, from some rather close experience in the last few years in hardboard operations I think that strategy should be more directed, at least with the limited manpower that we have on fundamental problems, to simpler and rather classical systems rather than something as crude and complex as hardboard. We have found to our dismay, I might add, the extremely critical effect of species between the deciduous hardwoods in the South and the redwood in the West. We have also found for example that it sometimes takes surprisingly small amounts of polymeric materials to interfere with the bond, instead of enhancing the bond we have had it actually degrade the bond between fibers. A great deal depends upon the particular process that you are employing. I think what we are dealing with in the hardboard industry is a rather complex combination of effects. If we attempt to do our initial research on fiber-fiber bonding in such systems it will lead to many years of floundering rather than understanding.

C. E. Jahn: I agree that the question of fiber-fiber bonding is still one that needs much more information in order to get the complete answer. In the case of lignocellulosic materials like hardboards and chipboard and so forth, I would like to suggest that probably other mechanisms enter into the picture than simple hydrogen bonding. For example, it is possible to make quite strong materials out of wood flour or sawdust by simple compression, heat, and pressure. One good example of this is the so called Prestologs, which are made by compressing wood waste under fairly high heat and temperature, just as Dale Turner pointed out we have observed that the presence of resin in pine, for example, definitely inhibits bonding. If you remove the resin by ether or benzene extraction one obtains very much better bonding and this bonding is done in the completely dry condition.

J. J. Byrne: I think it is proper that we should have some closing remarks from the Chairman of the program committee, Al Stamm who has headed up making arrangements for this meeting.

A. J. Stamm: I have been tickled pink with the way the meeting has run. Everyone has been interested. I was a little skeptical at first in trying to bring together chemists, lumbermen, and folks representing all different fields, but it seems to have worked. The way folks have been talking things over, back and forth, I think is a good step toward the future teamwork that we desire. I know the Lab is going to keep pressing this problem of dimensional stabilization even after I leave. I hope that the forestry schools will all jump onto the bandwagon. If we are just going to screen the new chemicals as they come out, we are going to need a lot of chemists to do so. Lets get together in bull sessions ever once in awhile and try to imagine new wild approaches and try them out. Some of these things that sound wild aren't as wild as we may think they are. I learned from sad experience in my early days that you can't pooh pooh something just because it sounds off hand as though it won't work. My first job after I got my bachelor's degree, was as a chemist for a petroleum company in California. We were pestered at that time by people who had the crackpot idea of putting a little pill or something in gasolene and getting a lot more power out of their cars. The chief at the Lab and I both said "those little pills, they won't do anything, you can't expect a pill to increase the B. t. u. of the gasolene it's silly, the mass is too small." Well, the impossible was finally solved by Tom Midgley who knew some chemistry but was primarily a mechanical engineer. He realized that it wasn't a matter of putting something into gasolene to get more B. t. u. out of it. The problem was making gasolene burn different to give a different thrust. He was looking at it from the mechanical standpoint. Now we as chemists were right in saying that it would be silly to try and increase the B. t. u., but that isn't what Midgley did, he did something different. We must watch ourselves and not pooh pooh ideas that sound a little strange. From our analytical standpoint, we may be right in saying that the man is wrong but from some other angle he may be perfectly right.

J. J. Byrne: Thank you Al. Well Al Hall I guess we are coming to the close of the session, do you want to say something?

J. A. Hall: I could reminisce a little with Al Stamm too if I wanted to. I guess Al that it will be soon 30 years ago that you and I used to sit down and shoot the breeze about this particular thing. In those days I was supposed to be a biological chemist up on the 4th floor and I had a kind of embrionic acquaintance with surface phenomenon.