A PRELIMINARY STUDY OF THE EFFECT OF INCREASED MOISTURE CONTENT ON RED OAK IN DRAWER CONSTRUCTION AND THE VALUE OF ONE CHEMICAL INHIBITOR

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J.R.B.

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THE NEED FOR RESEARCH IN THE FIELD OF DIMENSIONAL INSTABILITY OF LUMBER

Of the many unsolved problems in the utilization of wood, shrinking and swelling with fluctuation of moisture content is considered as one of the more serious. There are advantages in wood swelling due to an increase in the moisture content, such as in boats and kegs, where the increase in size causes water tight joints, but for the most part, shrinking and swelling are distinct disadvantages as the occurrence of a change of dimension is the reason wood is limited in most uses as a precision material.

There are two main outlooks in solving this problem. One is to eliminate the change by some chemical or mechanical means; the other is to accept dimensional instability and allow for it in manufacture. At present the latter method is being followed by most furniture manufacturers.

Currently tolerances for doors, drawers, and other movable wood parts are large because shrinking and swelling are variable, even within one species. Research is needed, to determine the amount of dimensional change of each species that will take place in a given or expected equilibrium moisture content range, and to apply the results in a practical manner.

This thesis reports tests made at the Wood Utiliza-

tion Laboratory of the School of Forestry and Conservation, University of Michigan, Ann Arbor, Michigan. These tests were conducted to determine the average increase in width, with the addition of moisture, of one species of drawer side material when free to move independently of the drawer ends, and when assembled in normal drawer construction. One commercial chemical preparation intended to reduce shrinking and swelling of wood was tested, and a comparison of results is discussed.

SELECTION OF MATERIALS

The selection of materials for use in the laboratory tests was designed to fit actual furniture manufacturers conditions. The Grand Rapids Chair Company, Grand Rapids, Michigan, donor of the red oak drawer material, expressed great interest in this project, particularly with results concerning red oak. Red oak is one of the more common materials used for drawer side stock in quality furniture now, and it was this, more than any other factor, that led to the selection of the material tested.

The commercial chemical preparation intended to reduce shrinking and swelling of wood is, at this time, the newest material in the field. Non-toxic "Woodlube," a product of the Protection Products Manufacturing Company of Kalamazoo, Michigan, is the substance with which part of the stock was treated, to establish the difference between treated and untreated drawer sides. It is but one of many commercial products designed to retard dimensional change of wood. "Woodlube" was selected because it was developed February 23, 1949, and represented the latest efforts in the field.

Animal glue is the primary bonding material used in drawer assembly today. Peter Cooper "1 Extra Special" hot animal glue was chosen for assembling the drawers to be tested. This glue is the second best grade of animal glue manufactured and sold by the Peter Cooper Corporation, Gowanda, New York, and represents the probable average grade of animal glue used in most quality furniture manufacture.

In an unpublished report dated October 30, 1945, the Furniture Manufacturers Association of Grand Rapids, Michigan, advised the use of the highest grade of animal glue available. The statement was based on results of tests that showed high grade animal glue (1) cost less per pound of prepared glue than lower grades because of greater water absorption, and (2) had more than adequate strength, therefore guaranteeing good joints.

The problem of measuring lumber to a precise degree is one that is not seriously coped with in most wood using industries. The folding wooden carpenters' rule is still much too predominent. In most commercial instances the small measurement needed in these laboratory experiments is not necessary. But because of the small amount of dimensional change anticipated, and the desire to find an accurate average, an Ames gauge, readable to one one-thousandth of an inch, was decided as instrumental.

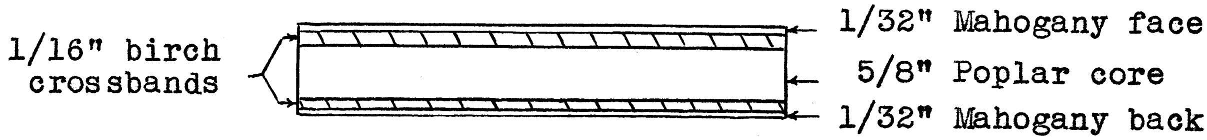
When wood is subjected to a constant humidity and a constant temperature it will attain a moisture content in balance with the surrounding atmospheric conditions, known as the equilibrium moisture content. To gain an accurate control of the equilibrium moisture content of the drawers and drawer stock, constant temperature and humidity rooms were essential. These rooms, when set at a predetermined temperature and humidity, closely maintain conditions desired. Given ample time, wood will assume the equilibrium moisture content governed by the atmosphere in the room.

PREPARATION FOR TESTING

Drawer Stock

Drawer sides of two widths, four inches and eight inches, approximating usual expected commercial sizes, were considered as sufficient to give a fair picture. A length of about fourteen inches is normal in furniture construction and gives ample space for three individual width measurements. The thickness was to be that used by the manufacturer from which the material was obtained. The specifications for the fronts and backs were left to the jurisdiction of the donor.

The donated red oak drawer stock arrived at the laboratory completely machined and ready for assembly into drawer form. This material was scheduled through the furniture plant by the regular procedure, therefore representing similar conditions encountered in actual manufacture. The dove-tailed five-ply construction of the drawer fronts and the surfaced bastard sawn sides and backs, are the same materials that are used in regular production by the Grand Rapids Chair Company. When assembled the inside length and width measured 14 3/8 inches and 6 1/4 inches respectively, and the side thickness 3/8 inches.



Drawer Front Construction
Top View

Figure 1.

<u>Assembly of the Drawers</u>

One hundred grams of Peter Cooper "1 Extra Special" ground animal glue was put to soak in two hundred and fifty grams of water twenty-four hours before the actual assembling was to take place. In preparing for assembly, the glue was heated in a water jacketed electric glue pot, to a temperature of 140 degrees Fahrenheit. This temperature, plus orminus 5 degrees, was maintained throughout the duration of assembly. No additional water was mixed into the glue during this period.

The drawer members were selected to give the best fit in assembly. There were no loose fitting joints as the wood had evidently increased its moisture content since machining and, therefore, had swollen slightly.

Glue was spread on both members to be joined. Ample glue was applied, with a round brush, to insure against dry joints. After firmly pressing the joints into place with minimum open assembly, tapping with a rubber mallet tightly meshed the dove tails and brought the drawer into "square."

The assembled drawers were then immediately placed in bar clamps exerting pressure along all joints. The clamps were allowed to remain in position and maintain pressure for a minimum of fifteen minutes to enable the glue to set properly. After the clamps were removed, the completed drawer was not disturbed for at least twenty-four hours.

Laboratory Stock

In order to determine whether glued joints at the front and back of drawers cause any variation in the swelling of the sides, red oak from the laboratory stock was used for drawer side material, which in testing was free to move independently of the other members.

The lumber was machined, on laboratory equipment, to a size approximately the same as the stock from Grand Rapids. Sixteen specimens 3/8" x 4" x 14 3/8" and sixteen specimens 3/8" x 8" x 14 3/8" were surfaced and cut from the red oak stock, in a manner that yielded clear bastard sawn test pieces.

Treatment with "Woodlube"

One half of the stock to be tested was treated with a solution of "Woodlube." Eight drawers, four 4 inch, and four 8 inch, and sixteen laboratory stock drawer sides, eight 4 inch and eight 8 inch, were subjected to the treatment. This step gives a fair representation of both types of material and establishes equal bases for comparison.

Two gallons of "Woodlube" were poured into a galvanized iron tank large enough to accomodate the largest drawer to be dipped. The drawers were completely submerged in the solution at room temperature, one at a time, for a period of three minutes. The drawer side material was also given a three minute dip treatment at room temperature.

After the dipping operation, the test specimens were placed in a manner such that any excess solution would drain off, and that air circulation would be good. Forty-eight hours passed before any further steps in preparation for testing were performed.

Grouping of Numbers

It was decided that three individual measurements along the edge of each piece of side material would be necessary. This would show the variation of swelling in one piece of wood. Any tendency for the glued joints, at the ends of the drawer sides in the assembled drawers to influence the amount of expansion would be observed in this method. In having more than one measurement per piece also gives a greater number of readings on which to base the final averages.

Test pieces were grouped by virtue of their origin and condition. Treated material was designated by the letter "T", while untreated or plain was given the letter "P." Material from the laboratory was denoted by "L," and the Grand Rapids stock "G." Numbers following the letter designations indicate the size as well as the individual item. All of the four and eight inch stock was numbered in the 40 or 80 groups respectively.

The letters "A" through "F" refer to the individual measurements made on each piece. Dimension observations were taken 2 inches from each end and in the center of the drawer side stock. The assembled drawer sides were measured 2 inches from the end joints and also in the center. This system allowed a clearance of 5 3/16 inches between each end measuring point and the center, in all cases.

Conditioning

To gain information concerning the dimensional change for one percent of moisture content in the normal range encountered in the United States, a spread of 7 percent is needed. A low of 5 and a high of 12 percent, expressed in relation to the oven dry weight of wood, represents furniture moisture content under ordinary seasonal conditions. Measurements were made at four points along this range. The dimensional increase at each of the progressive stages, 7, 9, and 12 percent, was recorded and compared with the original 5 percent dimension.

All test material was placed in a dry location in the laboratory that would yield a 5 percent moisture content. The determination of this figure was made by the oven dry method and calculated by the formula

$$\frac{\text{Original weight of sample} - \text{dry weight of sample}}{\text{Dry weight of sample}} \times 100$$

The remaining test moisture contents were attained by means of constant temperature and humidity rooms. By placing the stock in the room and allowing fourteen days for increasing the amount of moisture, the new percentage was reached.

To determine whether fourteen days was a sufficient period, the oven dry method, shown by the above formula, was again employed at the 7 percent condition. All measurements were made in the same room in which the stock was conditioned, to prevent any minute change in moisture content or dimension.

Method of Measuring

The Ames dial was mounted on one edge of a steel surface plate in such a way that a one-half inch dial piston stroke would absorb any dimension change. A reference surface was bolted to the opposite edge. Two steel key blocks 1/4"x 3/8"x 2" were laid on their 1/4" sides, one between the reference surface and the test piece and the other between the Ames dial and the test piece, so that a small area and a smooth surface could be utilized in measuring. The two inch dimension of each key was along the edge of the test specimen and centered about a line perpendicular to the reference plane passing along the center of the dial piston.

To establish a base measurement, and a zero point for the Ames dial, which would remain constant throughout the testing, gauge blocks were essential. These steel blocks, measured to one one-thousandth of an inch, were inserted between the key blocks, perpendicular to the reference surface, and the dial set to zero before each series of measurements. The gauge block lengths were 4.005 and 7.983 inches. Each drawer side width was then recorded in thousandths of one inch plus or minus the gauge block length.

A steel filler plate was inserted between the reference surface and the key block when measuring the four inch material. This plate, 4 inches wide, prevented the moving of the Ames dial from its original mounting during the entire experimental procedure.

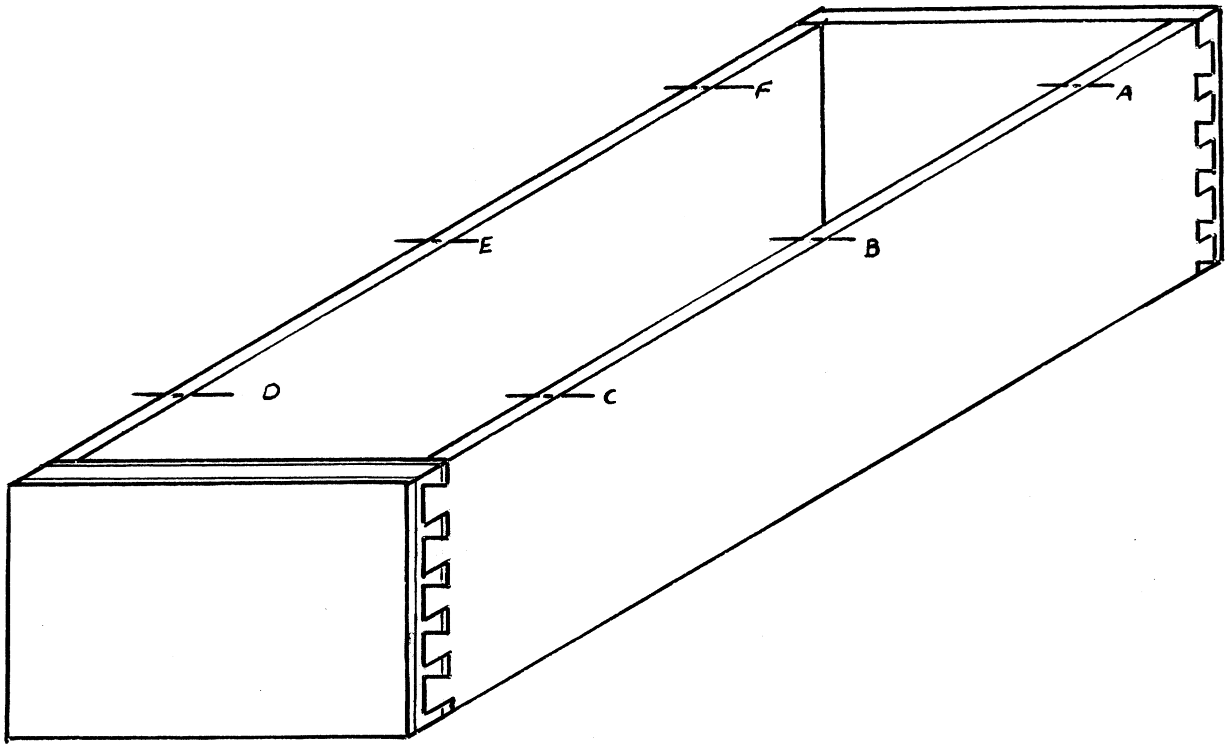


Fig. 2. Sketch of Assembled Drawer.

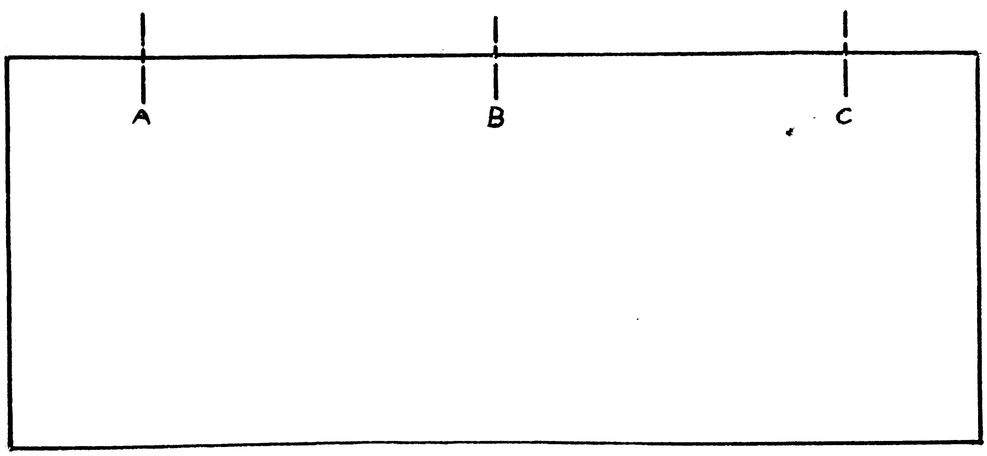


Fig. 3. Sketch of Laboratory Stock Drawer Side.

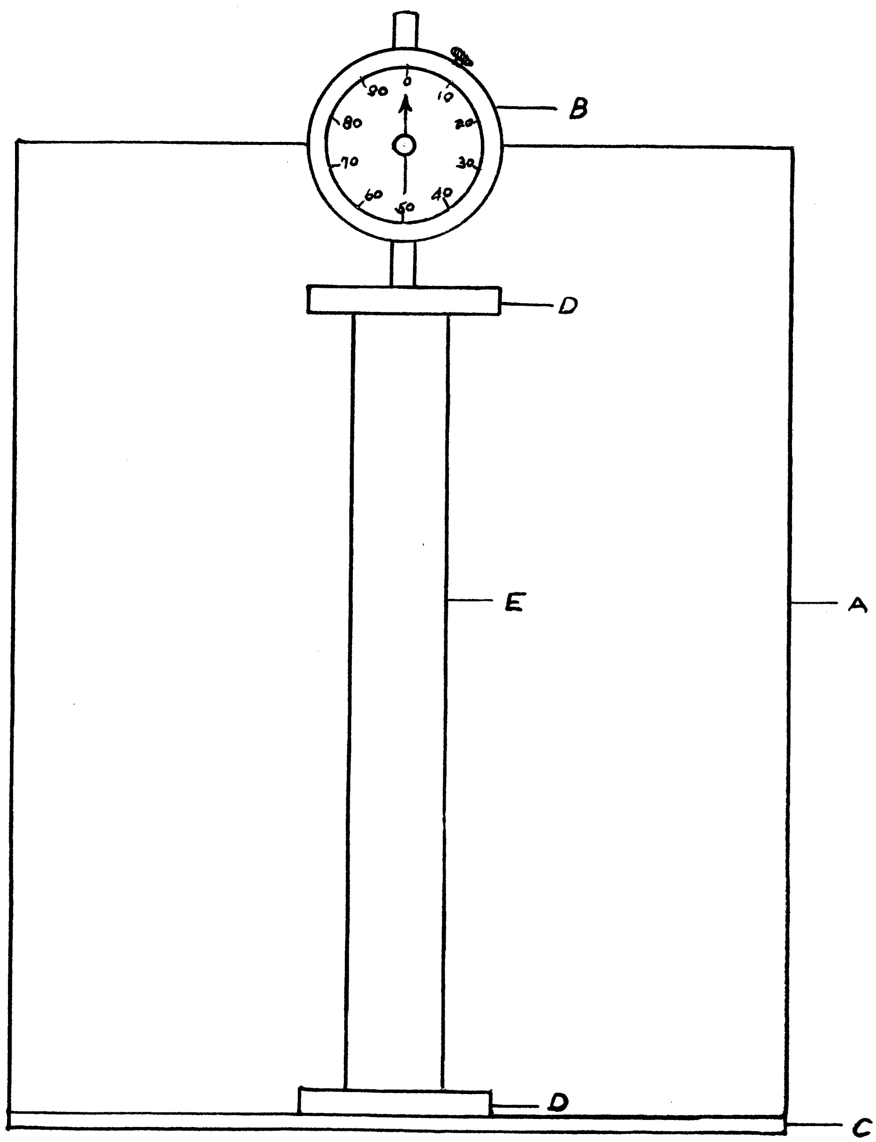


Fig. 4. Sketch of Measuring Device.

A - Steel Surface Plate. B - Ames Dial.

C - Reference Plate. D - Key Blocks.

E - Gauge Block.

Stock No.	Meas-ure-ment	Width at 5%	7%	9%	12%	Total Increase	Increase/"/ 1% m.c. added
PL 41	A	4.046	4.046	4.063	4.079	.048	.0017
	B	4.025	4.036	4.055	4.073	.048	.0017
	C	4.022	4.036	4.055	4.073	.051	.0018
PL 42	A	4.014	4.032	4.052	4.068	.054	.0019
	B	4.017	4.028	4.052	4.067	.050	.0018
	C	4.019	4.034	4.053	4.068	.049	.0017
PL 43	A	4.023	4.037	4.053	4.070	.047	.0017
	B	4.021	4.026	4.044	4.062	.041	.0015
	C	4.016	4.026	4.045	4.063	.047	.0017
PL 44	A	4.018	4.031	4.049	4.066	.048	.0017
	B	4.023	4.032	4.049	4.065	.042	.0015
	C	4.015	4.034	4.047	4.065	.050	.0018
PL 45	A	3.986	4.013	4.028	4.049	.063	.0022
	B	3.989	4.000	4.023	4.045	.056	.0020
	C	3.975	3.990	4.011	4.034	.059	.0021
PL 46	A	3.995	4.011	4.034	4.054	.059	.0021
	B	3.986	3.998	4.027	4.046	.060	.0021
	C	3.984	3.999	4.024	4.044	.060	.0021
PL 47	A	4.016	4.030	4.054	4.069	.053	.0019
	B	4.017	4.023	4.049	4.063	.047	.0017
	C	4.012	4.024	4.048	4.064	.052	.0019
PL	A	3.980	3.999	4.017	4.036	.056	.0020
	B	3.981	3.996	4.017	4.035	.054	.0019
	C	3.981	3.999	4.016	4.036	.055	.0019
Aver-age						.052	.00184

Table of Dimensional Increase of Pl 40 Stock.

Table I

Stock No.	Meas-ure-ment	Width at 5%	Width at 7%	Width at 9%	Width at 12%	Total Increase	Increase/"/ 1% m.c. added
TL 41	A	4.031	4.042	4.061	4.078	.047	.0017
	B	4.031	4.035	4.056	4.073	.042	.0015
	C	4.029	4.038	4.057	4.075	.046	.0017
TL 42	A	4.034	4.043	4.058	4.077	.043	.0015
	B	4.014	4.029	4.047	4.064	.050	.0018
	C	4.027	4.031	4.053	4.068	.041	.0015
TL 43	A	4.016	4.023	4.046	4.062	.046	.0017
	B	4.019	4.023	4.048	4.062	.043	.0015
	C	4.021	4.031	4.048	4.068	.047	.0017
TL 44	A	4.026	4.034	4.050	4.065	.039	.0014
	B	4.029	4.033	4.049	4.061	.032	.0011
	C	4.029	4.034	4.053	4.069	.040	.0015
TL 45	A	4.031	4.039	4.058	4.074	.043	.0015
	B	4.028	4.033	4.049	4.065	.037	.0013
	C	4.021	4.029	4.046	4.064	.043	.0015
TL 46	A	4.020	4.030	4.047	4.064	.044	.0016
	B	4.023	4.028	4.043	4.060	.037	.0013
	C	4.012	4.027	4.046	4.061	.049	.0018
TL 47	A	4.032	4.040	4.060	4.078	.046	.0017
	B	4.031	4.036	4.053	4.075	.044	.0015
	C	4.027	4.035	4.052	4.073	.046	.0017
TL 48	A	4.025	4.034	4.051	4.072	.047	.0017
	B	4.026	4.027	4.044	4.065	.039	.0014
	C	4.028	4.033	4.053	4.072	.044	.0016
Aver-age						.0431	.00155

Table of Dimensional Increase of TL 40 Stock

Table II

Stock No.	Meas-ure-ment	Width at				Total Increase	Increase/"/ 1% m.c. added
		5%	7%	9%	12%		
PL 81	A	7.987	8.019	8.060	8.099	.112	.0020
	B	7.993	8.015	8.058	8.100	.107	.0019
	C	7.992	8.021	8.061	8.102	.110	.0020
PL 82	A	7.982	8.005	8.054	8.091	.109	.0019
	B	7.986	8.004	8.057	8.097	.111	.0020
	C	7.986	8.008	8.059	8.099	.113	.0020
Pl 83	A	7.998	8.017	8.068	8.096	.098	.0016
	B	7.993	8.007	8.062	8.091	.098	.0016
	C	7.991	8.016	8.068	8.099	.108	.0019
PL 84	A	7.983	8.000	8.040	8.073	.090	.0016
	B	7.989	7.994	8.035	8.069	.080	.0014
	C	7.983	7.997	8.038	8.073	.090	.0016
PL 85	A	7.979	8.006	8.045	8.076	.097	.0018
	B	7.989	8.006	8.045	8.078	.089	.0016
	C	7.982	8.001	8.040	8.073	.091	.0016
PL 86	A	8.009	8.026	8.071	8.093	.084	.0015
	B	7.983	8.006	8.049	8.075	.082	.0015
	C	7.979	7.997	8.040	8.067	.088	.0016
PL 87	A	7.995	8.025	8.064	8.015	.110	.0020
	B	7.999	8.013	8.057	8.102	.103	.0018
	C	7.990	8.013	8.060	8.104	.114	.0020
Aver-age						.0992	.00172

Table of Dimensional Increase of PL 80 Stock

Table III

Stock No.	Meas-ure-ment	Width at				Total Increase	Increase/"/ 1% m.c. added
		5%	7%	9%	12%		
TL 81	A	7.990	8.012	8.041	8.075	.085	.0015
	B	7.989	8.003	8.030	8.066	.077	.0014
	C	7.986	8.002	8.033	8.067	.082	.0015
TL 82	A	7.978	7.995	8.028	8.062	.084	.0015
	B	7.984	7.995	8.021	8.057	.075	.0013
	C	7.978	7.994	8.024	8.065	.087	.0016
TL 83	A	7.983	7.994	8.037	8.067	.084	.0015
	B	7.985	7.989	8.031	8.057	.076	.0013
	C	7.982	8.001	8.038	8.068	.084	.0015
TL 84	A	7.983	8.001	8.047	8.075	.092	.0015
	B	7.982	7.988	8.038	8.064	.082	.0015
	C	7.969	7.987	8.032	8.059	.090	.0016
TL 85	A	7.982	7.993	8.038	8.065	.083	.0015
	B	7.988	7.995	8.043	8.071	.083	.0015
	C	7.985	7.999	8.045	8.078	.093	.0017
TL 86	A	8.003	8.017	8.052	8.080	.077	.0014
	B	8.004	8.008	8.044	8.074	.070	.0013
	C	7.995	8.006	8.044	8.075	.080	.0015
TL 87	A	7.983	7.996	8.028	8.006	.083	.0015
	B	7.991	7.994	8.021	8.062	.079	.9914
	C	7.984	7.995	8.027	8.066	.082	.0015
TL 88	A	7.981	8.003	8.036	8.073	.092	.0015
	B	7.987	7.998	8.030	8.071	.084	.0015
	C	7.988	8.004	8.037	8.076	.088	.0016
Aver-age						.0830	.00148

Table of Dimensional Increase of TL 80 Stock

Table IV

Stock No.	Measurement	Width at				Total Increase	Increase/"/ 1% m.c. added
		5%	7%	9%	12%		
PG 41	A	4.010	4.023	4.035	4.050	.040	.0014
	B	4.007	4.017	4.031	4.047	.040	.0014
	C	4.001	4.013	4.027	4.042	.041	.0016
	D	4.015	4.030	4.045	4.068	.043	.0015
	E	4.015	4.030	4.047	4.067	.042	.0015
	F	4.012	4.026	4.041	4.064	.044	.0016
PG 42	A	3.995	4.011	4.029	4.054	.059	.0021
	B	3.990	4.005	4.025	4.048	.058	.0021
	C	3.990	4.004	4.024	4.044	.054	.0019
	D	4.021	4.032	4.046	4.065	.044	.0016
	E	4.021	4.032	4.047	4.067	.046	.0017
	F	4.018	4.031	4.044	4.065	.047	.0017
PG 43	A	4.006	4.021	4.039	4.060	.054	.0019
	B	4.008	4.020	4.037	4.061	.053	.0019
	C	4.003	4.017	4.034	4.054	.051	.0018
	D	4.007	4.025	4.053	4.082	.075	.0027
	E	3.996	4.013	4.042	4.071	.075	.0027
	F	3.993	4.004	4.035	4.063	.070	.0025
PG 44	A	3.996	4.011	4.031	4.048	.052	.0019
	B	4.003	4.017	4.037	4.054	.051	.0018
	C	4.015	4.028	4.045	4.061	.046	.0017
	D	3.992	4.015	4.036	4.063	.071	.0025
	E	3.998	4.013	4.035	4.063	.075	.0027
	F	3.989	4.015	4.038	4.067	.078	.0027
Average						.0545	.00195

Table of Dimensional Increase of PG 40 Drawers

Table V

Stock No.	Measure-ment	Width at				Total Increase	Increase/"/ 1% m.c. added
		5%	7%	9%	12%		
TG 41	A	4.019	4.030	4.053	4.080	.061	.0022
	B	4.011	4.020	4.046	4.071	.060	.0021
	C	4.008	4.019	4.044	4.069	.061	.0022
	D	4.024	4.030	r.049	4.071	.047	.0017
	E	4.017	4.029	4.046	4.066	.049	.0017
	F	4.016	4.027	4.045	4.064	.048	.0017
TG 42	A	4.008	4.015	4.036	4.058	.050	.0018
	B	4.002	4.007	4.028	4.052	.050	.0018
	C	4.003	4.007	4.029	4.051	.048	.0017
	D	4.012	4.023	4.046	4.057	.045	.0016
	E	4.008	4.019	4.041	4.064	.056	.0020
	F	4.011	4.022	4.041	4.061	.050	.0018
TG 43	A	4.017	4.027	4.047	4.065	.048	.0017
	B	4.017	4.027	4.047	4.066	.049	.0017
	C	4.014	4.026	4.042	4.061	.047	.0017
	D	4.000	4.014	4.032	4.034	.034	.0012
	E	4.003	4.016	4.036	4.052	.049	.0017
	F	4.008	4.022	4.042	4.064	.056	.0020
TG 44	A	4.027	4.035	4.051	4.073	.046	.0017
	B	4.025	4.031	4.046	4.064	.039	.0014
	C	4.025	4.032	4.046	4.064	.039	.0014
	D	3.999	4.005	4.019	4.034	.035	.0013
	E	4.014	4.022	4.038	4.052	.038	.0014
	F	4.031	4.037	4.048	4.064	.033	.0012
Average						.0474	.00168

Table of Dimensional Increase of TG 40 Drawers

Table VI

Stock No.	Meas-ure-ment	Width at				Total Increase	Increase/"/ 1% m.c. added
		5%	7%	9%	12%		
PG 81	A	7.885	7.918	7.958	7.992	.107	.0019
	B	7.867	7.905	7.942	7.971	.104	.0019
	C	7.871	7.898	7.934	7.970	.099	.0018
	D	7.891	7.916	7.953	7.980	.089	.0016
	E	7.882	7.909	7.950	7.979	.097	.0018
	F	7.883	7.911	7.955	7.983	.100	.0018
PG 82	A	7.894	7.926	7.964	7.992	.098	.0018
	B	7.895	7.926	7.964	7.992	.097	.0018
	C	7.896	7.925	7.953	7.977	.081	.0015
	D	7.895	7.926	7.964	7.992	.097	.0018
	E	7.880	7.917	7.960	7.993	.110	.0020
	F	7.873	7.909	7.953	7.989	.116	.0021
PG 83	A	7.888	7.923	7.962	7.998	.110	.0020
	B	7.887	7.921	7.960	7.992	.105	.0019
	C	7.885	7.915	7.948	7.975	.090	.0016
	D	7.908	7.937	7.969	7.994	.086	.0016
	E	7.985	7.928	7.964	7.993	.098	.0018
	F	7.890	7.923	7.958	7.993	.103	.0019
PG 84	A	7.881	7.917	7.950	7.981	.100	.0018
	B	7.887	7.921	7.955	7.986	.099	.0018
	C	7.896	7.927	7.953	7.985	.089	.0016
	D	7.892	7.922	7.951	7.982	.090	.0017
	E	7.884	7.917	7.950	7.987	.103	.0019
	F	7.885	7.918	7.953	7.985	.100	.0018
Aver-age						.0987	.00180

Table of Dimensional Increase of PG 80 Drawers

Table VII

Stock No.	Meas-ure-ment	Width at 5%	7%	9%	12%	Total Increase	Increase/"/ 1% m.c. added
TG 81	A	7.894	7.908	7.940	7.972	.078	.0014
	B	7.887	7.900	7.931	7.962	.075	.0014
	C	7.880	7.895	7.922	7.952	.072	.0013
	D	7.893	7.907	7.937	7.966	.073	.0013
	E	7.871	7.889	7.923	7.957	.086	.0016
	F	7.855	7.873	7.910	7.943	.088	.0016
TG 82	A	7.903	7.921	7.953	7.988	.085	.0015
	B	7.888	7.905	4.941	7.973	.085	.0015
	C	7.881	7.897	7.928	7.956	.075	.0014
	D	7.890	7.906	7.943	7.970	.080	.0014
	E	7.875	7.893	7.937	7.973	.098	.0018
	F	7.879	7.897	7.938	7.975	.096	.0017
TG 83	A	7.873	7.889	7.929	7.968	.095	.0017
	B	7.873	7.886	7.924	7.963	.090	.0017
	C	7.886	7.899	7.929	7.964	.078	.0014
	D	7.904	7.921	7.955	7.989	.085	.0015
	E	7.891	7.909	7.948	7.983	.092	.0016
	F	7.887	7.902	7.946	7.982	.095	.0017
TG 84	A	7.894	7.910	7.952	7.990	.096	.0017
	B	7.894	7.906	7.947	7.983	.089	.0016
	C	7.890	7.904	7.940	7.968	.078	.0014
	D	7.898	7.913	7.946	7.973	.075	.0014
	E	7.892	7.905	7.945	7.986	.094	.0017
	F	7.886	7.902	7.942	7.976	.090	.0016
Aver-age						.0853	.00154

Table of Dimensional Increase of TG 80 Drawers

Table VIII

Stock No.	Meas-ure-ment	Increase/"/ 1% m.c. addition based on width at 5, 7, & 9% between		
		5 - 7%	7 - 9%	9 - 12%
PL 41	A	.0019	.0016	.0012
	B	.0014	.0024	.0015
	C	.0017	.0024	.0015
PL 42	A	.0022	.0025	.0013
	B	.0014	.0029	.0013
	C	.0019	.0024	.0013
PL 43	A	.0017	.0020	.0014
	B	.0006	.0022	.0015
	C	.0012	.0024	.0015
PL 44	A	.0016	.0022	.0014
	B	.0011	.0022	.0014
	C	.0024	.0016	.0014
PL 45	A	.0034	.0019	.0017
	B	.0014	.0029	.0018
	C	.0019	.0026	.0019
PL 46	A	.0020	.0030	.0017
	B	.0015	.0037	.0017
	C	.0019	.0031	.0017
PL 47	A	.0017	.0030	.0012
	B	.0007	.0032	.0012
	C	.0015	.0030	.0013
PL 48	A	.0024	.0023	.0016
	B	.0019	.0026	.0015
	C	.0023	.0021	.0017
Aver-age		.00174	.00250	.00148

Table of Dimensional Increase Between Given Moisture Contents of PL 40 Stock

Table IX

Stock No.	Meas-ure-ment	Increase/"/ 1% m.c. addition based on width at 5, 7, & 9% between		
		5 - 7%	7 - 9%	9 - 12%
TL 41	A	.0014	.0024	.0014
	B	.0005	.0026	.0014
	C	.0011	.0024	.0015
TL 42	A	.0011	.0019	.0016
	B	.0005	.0027	.0012
	C	.0019	.0022	.0014
TL 43	A	.0009	.0029	.0013
	B	.0005	.0021	.0018
	C	.0012	.0021	.0017
TL 44	A	.0010	.0020	.0012
	B	.0005	.0020	.0010
	C	.0007	.0022	.0013
TL 45	A	.0010	.0024	.0013
	B	.0006	.0020	.0013
	C	.0010	.0021	.0015
TL 46	A	.0012	.0021	.0014
	B	.0006	.0021	.0018
	C	.0010	.0021	.0017
TL 47	A	.0010	.0025	.0015
	B	.0006	.0021	.0018
	C	.0010	.0021	.0017
TL 48	A	.0011	.0021	.0017
	B	.0001	.0021	.0016
	C	.0006	.0025	.0014
Average		.00092	.00224	.00138

Table of Dimensional Increase Between Given Moisture Contents of TL 40 Stock

Table X

Stock No.	Meas-ure-ment	Increase/"/ 1% m.c. addition based on width at 5, 7, & 9% between		
		5 - 7%	7 - 9%	9 - 12%
PL 81	A	.0020	.0026	.0016
	B	.0014	.0027	.0017
	C	.0018	.0025	.0021
PL 82	A	.0014	.0031	.0015
	B	.0011	.0033	.0017
	C	.0014	.0032	.0017
PL 83	A	.0012	.0032	.0012
	B	.0009	.0034	.0013
	C	.0016	.0032	.0013
PL 84	A	.0011	.0025	.0014
	B	.0003	.0026	.0014
	C	.0009	.0026	.0015
PL 85	A	.0017	.0024	.0013
	B	.0011	.0025	.0013
	C	.0012	.0024	.0016
PL 86	A	.0011	.0028	.0009
	B	.0014	.0027	.0011
	C	.0011	.0027	.0011
PL 87	A	.0019	.0018	.0017
	B	.0009	.0027	.0019
	C	.0014	.0029	.0018
Aver-age		.00128	.00275	.00148

Table of Dimensional Increase Between Given Moisture Contents of PL 80 Stock

Table XI

Stock No.	Meas-ure-ment	Increase/"/ 1% m.c. addition based on width at 5, 7, 9% between		
		5 - 7%	7 - 9%	9 - 12%
TL 81	A	.0014	.0018	.0014
	B	.0009	.0017	.0015
	C	.0010	.0019	.0014
TL 82	A	.0011	.0021	.0014
	B	.0007	.0016	.0015
	C	.0010	.0018	.0017
TL 83	A	.0007	.0027	.0012
	B	.0003	.0026	.0011
	C	.0012	.0024	.0012
TL 84	A	.0011	.0030	.0012
	B	.0004	.0031	.0011
	C	.0011	.0028	.0011
TL 85	A	.0007	.0028	.0011
	B	.0004	.0030	.0012
	C	.0009	.0029	.0014
TL 86	A	.0009	.0021	.0012
	B	.0002	.0022	.0012
	C	.0007	.0024	.0013
TL 87	A	.0008	.0020	.0016
	B	.0002	.0017	.0017
	C	.0007	.0020	.0016
TL 88	A	.0014	.0021	.0015
	B	.0007	.0020	.0017
	C	.0010	.0021	.0016
Aver-age		.00081	.00228	.00136

Table of Dimensional Increase Between Given Moisture Contents of TL 80 Stock

Table XII

Stock No.	Measurement	Increase/"/ 1% m.c. addition based on width at 5, 7, & 9% between 5 - 7%	7 - 9%	9 - 12%
PG 41	A	.0016	.0015	.0012
	B	.0012	.0017	.0013
	C	.0015	.0017	.0012
	D	.0019	.0021	.0017
	E	.0019	.0019	.0019
	F	.0017	.0019	.0012
PG 42	A	.0020	.0021	.0021
	B	.0019	.0025	.0019
	C	.0018	.0025	.0017
	D	.0014	.0017	.0016
	E	.0014	.0019	.0017
	F	.0016	.0016	.0017
PG 43	A	.0019	.0022	.0017
	B	.0015	.0021	.0020
	C	.0017	.0021	.0017
	D	.0022	.0035	.0023
	E	.0021	.0035	.0024
	F	.0014	.0039	.0022
PG44	A	.0019	.0025	.0014
	B	.0017	.0025	.0014
	C	.0016	.0021	.0013
	D	.0029	.0026	.0021
	E	.0031	.0027	.0022
	F	.0033	.0029	.0024
Average		.00188	.00230	.00178

Table of Dimensional Increase Between Given Moisture Contents of PG 40 Drawers

Table XIII

Stock No.	Measure-ment	Increase/"/ 1% m.c. addition based on width at 5, 7, & 9% between		
		5 - 7%	7 - 9%	9 - 12%
TG 41	A	.0014	.0029	.0022
	B	.0011	.0032	.0020
	C	.0014	.0031	.0021
	D	.0007	.0022	.0019
	E	.0015	.0021	.0017
	F	.0014	.0022	.0016
TG 42	A	.0009	.0026	.0018
	B	.0006	.0026	.0020
	C	.0005	.0026	.0018
	D	.0014	.0028	.0009
	E	.0014	.0027	.0019
	F	.0014	.0024	.0017
TG 43	A	.0012	.0025	.0015
	B	.0012	.0025	.0016
	C	.0015	.0020	.0016
	D	.0018	.0022	.0002
	E	.0016	.0025	.0013
	F	.0017	.0025	.0018
TG 44	A	.0010	.0020	.0018
	B	.0007	.0019	.0015
	C	.0009	.0017	.0015
	D	.0008	.0018	.0012
	E	.0010	.0020	.0012
	F	.0007	.0014	.0013
Aver-age		.00116	.00245	.00159

Table of Dimensional Increase Between Given Moisture Contents of TG 40 Drawers

Table XIV

Stock No.	Meas-ure-ment	Increase/"/ 1% m.c. addition based on width at 5, 7, & 9% between		
		5 - 7%	7 - 9%	9 - 12%
PG 81	A	.0021	.0025	.0014
	B	.0024	.0023	.0015
	C	.0017	.0023	.0012
	D	.0016	.0023	.0011
	E	.0017	.0026	.0012
	F	.0018	.0028	.0012
PG 82	A	.0020	.0024	.0012
	B	.0020	.0024	.0012
	C	.0018	.0018	.0010
	D	.0020	.0024	.0012
	E	.0023	.0027	.0014
	F	.0023	.0027	.0015
PG 83	A	.0022	.0024	.0012
	B	.0022	.0025	.0013
	C	.0019	.0021	.0011
	D	.0018	.0020	.0011
	E	.0021	.0023	.0012
	F	.0021	.0022	.0015
PG 84	A	.0023	.0021	.0013
	B	.0022	.0021	.0013
	C	.0020	.0016	.0013
	D	.0014	.0025	.0013
	E	.0021	.0027	.0015
	F	.0021	.0022	.0013
Aver-age		.00203	.00233	.00128

Table of Dimensional Increase Between Given Moisture Contents of PG 80 Drawers

Table XV

Stock No.	Measurement	Increase/"/ 1% m.c. addition based on width at 5, 7, & 9% between		
		5 - 7%	7 - 9%	9 - 12%
TG 81	A	.0009	.0020	.0013
	B	.0008	.0020	.0013
	C	.0010	.0017	.0013
	D	.0009	.0019	.0012
	E	.0011	.0022	.0014
	F	.0011	.0023	.0014
TG 82	A	.0011	.0020	.0015
	B	.0011	.0023	.0013
	C	.0010	.0020	.0012
	D	.0010	.0023	.0011
	E	.0011	.0028	.0015
	F	.0011	.0026	.0015
TG 83	A	.0011	.0025	.0016
	B	.0008	.0024	.0016
	C	.0008	.0019	.0015
	D	.0011	.0025	.0015
	E	.0011	.0025	.0015
	F	.0010	.0028	.0015
TG 84	A	.0010	.0027	.0016
	B	.0008	.0026	.0015
	C	.0009	.0023	.0012
	D	.0009	.0021	.0011
	E	.0008	.0025	.0017
	F	.0010	.0025	.0014
Average		.00098	.00229	.00140

Table of Dimensional Increase Between Given Moisture Contents of TG 80 Drawers

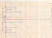
Table XVI

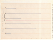
Group of Stock	Dimensional increase in inches per 1% moisture addition, between 5-7, 7-9, and 9-12 % based on dimension at			Average total increase in inches	Total average dimensional increase in "/1% m.c. addition based on 5% width
	5%	7%	9%		
PL 40	.00174	.00250	.00148	.0520	.00184
TL 40	.00092	.00224	.00138	.0431	.00155
PL 80	.00128	.00275	.00148	.0992	.00172
TL 80	.00081	.00228	.00136	.0830	.00148
PG 40	.00188	.00230	.00178	.0545	.00195
TG 40	.00116	.00245	.00159	.0474	.00168
PG 80	.00203	.00233	.00128	.0987	.00180
TG 80	.00980	.00229	.00140	.00853	.00154

Table of Averages of Red Oak

Dimensional Increase

Table XVII





Group of stock	Increase /"/1% m.c. addition based on width at 5, 7, and 9% between		
	5%-7%	7%-9%	9%-12%
PL 40	.00174	.00250	.00148
PG 40	.00188	.00230	.00178
PL 80	.00128	.00275	.00148
PG 80	.00203	.00233	.00128
Average	.00178	.00247	.00151

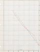
Table of Average Dimensional Increase Between Given Moisture Contents of Untreated Material

Table XVIII

Group of stock	Increase /"/1% m.c. addition based on width at 5, 7, and 9% between		
	5%-7%	7%-9%	9%-12%
TL 40	.00092	.00224	.00138
TG 40	.00116	.00245	.00159
TL 80	.00081	.00228	.00136
TG 80	.00098	.00229	.00140
Average	.00097	.00231	.00143

Table of Average Dimensional Increase Between Given Moisture Contents of Treated Material

Table XIX



EFFECT OF THE ADDITION OF MOISTURE

Each group of red oak tested showed a tendency to swell, with the addition of moisture, within a wide range. The spread of this range may be caused by one or more factors in each instance.

Bastard sawn lumber, when ripped to widths, will yield pieces that vary between pure flat sawn and pure quarter sawn. This means that swelling in width may be tangential to the growth rings in flat sawn and radial to the growth rings in quarter sawn, with a combination of both in most pieces. If all swelling is not measured in the same constant relation to the annual growth rings a large spread of values will occur. Tangential shrinkage is two times that of radial, consequently swelling should be approximately in the same proportion.

Light wood has less tendency to shrink and swell with a change of moisture content than heavy wood. This will be true within one species, and, although longitudinal reaction is greater in this condition, radial and tangential will not be as large as normal. If the wood is heavy for its species, the shrinking and swelling will be greater due to the densness of structure and the increased amount of cell material in a given space.

The amount of springwood in proportion to the amount of summerwood influences the density. Porous springwood has fewer cells in an equal volume than does summerwood. The fewer wood cells present a smaller number of crystallites around which moisture can gather to cause swelling. In the specimens tested a small variation in the amount of springwood was observed.

VARIANCE OF SWELLING

It may be noted in the graph, Fig. 5, that, in both the treated and untreated material, the eight inch stock showed less increase in dimension than did the four inch stock. It is possible that the greater width afforded more space for expansion within the material itself, and evidences of swelling did not entirely reach the surface.

The wider pieces also present a better opportunity for cupping or other form of warping that would absorb the swelling so that it was not evident in a width measurement.

EFFECT OF THE CHEMICAL INHIBITOR

The graph in Fig. 5 shows that the material treated with the wolution of "Woodlube" did not swell as much as did the material without the treatment. The average reduction of almost three thousandths of an inch for every inch of lumber with a change of one percent moisture content cannot be considered too carefully. Two weeks were allowed for the stock to reach a new moisture content. No record of the rate of change was made during the two weeks. Also, the duration of the effects of the reduction has not been checked at this time.

Although an apparent reduction in swelling, which may be only temporary at a sustained moisture content, resulted in these tests, further testing, with respect to drawers, must be done. Cost is a prime factor as are machining tolerances in utilizing the advantage gained by an inhibitor.

CONTROL OF SWELLING

Because of the great variation in the amount of swelling, even within one species, it is difficult to manufacture drawers for furniture that give a satisfactory fit in the case at all times. Drawers that fit snugly during the humid summer months will be loose in the winter, while snug fits in the winter will bind because of swelling in the summer. The variation of swelling in untreated stock can be seen in Fig's. 6, 8, 10, and 12. The graphs in Fig's 7, 9, 11, and 13 show how identical stock, treated against swelling, has a tendency for the variation to conform more closely with the average. Possibly with the proper selection of lumber, with respect to factors mentioned on pages 40-41, and the use of a chemical inhibitor, better drawers could be manufactured.

EFFECT OF GLUE JOINTS

No definite evidence of major consequence was noted, in the swelling of assembled drawers, by measuring the drawer side at a distance of two inches from the glue joint. Difficulty in making a possible comparison with the unassembled drawer side stock arose when the swelling of all measurements of assembled drawer sides exceeded that of the material free to move at the ends. Considering the variance in the swelling encountered within one piece and the range in which the measurements of the glued joints exceeded the plain material, no conclusion as to the effect can be drawn.

With a greater number of specimens, all from the same source, selected for density and grain structure, a smaller degree of swelling could conceivably occur. This would not necessarily be due to the glue joint but to the construction of drawer front where a light weight wood, which would swell less with the same moisture increase, could retard or prevent complete drawer side expansion at the point of contact.

IRREGULARITY OF SWELLING

Below the fiber saturation point, wood will shrink in direct proportion to the loss of moisture. In the experiments with red oak, swelling did not increase in a direct proportion to the increase in moisture. See graphs Fig's. 14 and 15.

Owing to mechanical difficulties in the operation of the constant temperature and humidity rooms, the correct equilibrium moisture content, at the time of measuring the specimens, may have been slightly above or below the desired point. The two week period also may not have been sufficient to allow the equilibrium moisture content to be reached and therefore disrupt the basis by which swelling was measured. Measurements taken at two moisture contents, to determine tha mount of swelling between them, would accumulate any error. The amount of swelling would then be plotted against too large or too small a moisture increase and deviation from a straight line would result.

THE NEED FOR ADDITIONAL RESEARCH

Because no significant conclusion can be drawn as a direct result of this work, and the many individual problems involved, additional testing in the field is instrumental. Swelling of one species of wood requires a multitude of tests before an accurate trend can be determined. With the introduction of other materials, such as in drawer construction, a change in the trend may occur, which could not be observed in these tests.

The division of this problem into smaller units, all of which could be studied extensively, is necessary in order to reach conclusions that may be applied to industry. The work performed here is merely a preliminary investigation of a problem that furniture manufacturers have attempted to overcome in a satisfactory manner for years.