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LINEAR MOVEMENT OF PLYWOOD AND FLAKEBOARDS AS RELATED TO THE LONGITUDINAL MOVEMENT OF WOOD

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LINEAR MOVEMENT OF PLYWOOD AND FLAKEBOARDS AS RELATED TO THE LONGITUDINAL MOVEMENT OF WOOD

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Abstract

Veneer, plywood, and flakeboard specimens were subjected to various humidity conditions. Physical and elastic properties of the veneer were determined and the influence of these properties on the movement of plywood and flakeboards fabricated of like material was evaluated, The linear movement of the plywood and flakeboards was closely related to the longitudinal-to-grain movement of the veneer.

Introduction

In the past, the movement of wood longitudinally (along the grain) has been assigned a negligible value for most purposes. Yet, attempts to predict the linear movement of plywood and more recently of flakeboards without considering the longitudinal movement of the wood have been largely unsuccessful. The question then is--what influence does the longitudinal movement of wood have on the linear stability of plywood and flakeboards?

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

In this study, conducted at the Forest Products Laboratory, one of the primary considerations was to determine the correlation between the longitudinal movement of wood and the linear movement of plywood and flakeboards made from like material. Physical and elastic properties of the raw material were determined and applied in a mathematical relationship to predict the linear movement of plywood.

Purpose

The purpose of this work was to determine accurately the requisite physical and elastic properties of a species, and correlate these data with the linear movement of matched plywood (50-50 grain distribution) and flakeboards made from flakes with a high slenderness ratio. Dimensional change of the veneer, plywood, and flakeboards and modulus of elasticity of the veneer were measured under moisture conditions ranging from ovendry to soaked, These data were applied mathematically to predict the linear movement of plywood,

Preparation of Material

The study was conducted on material cut from flitches of four species: two softwoods, Douglas-fir and redwood; and two hardwoods, yellow birch and aspen. The preferred orientation of growth rings in the flitch was approximately 45° to the faces to facilitate cutting, but this was not always possible, particularly with the Douglas-fir and the aspen. The Douglas-fir veneer and flakes were so cut that edge grain faces resulted. The aspen had random orientation of grain.

The flitches were proportioned equally to flakes and veneer as shown in figure 1. All blocks for flaking and strips of veneer were numbered according to location in the flitch. The blocks for flaking were randomized so that approximately the same amount of flakes came from both ends of the veneer flitch. The veneer and the flakes were cut in the same direction to provide matched material for the fabrication of plywood and flakeboard specimens.

Fabricating Procedures

Plywood

After the veneer was cut and dried, individual strips were randomly selected from the lot and edge glued into 36-inch-square sheets. A further random selection of veneer sheets into two groups of eight sheets provided the material for two pieces of plywood. A balanced construction of 50–50 grain distribution in length and width was attained by placing the grain of the two center veneers parallel.

Two types of plywood were made, one atypical hot–press product made according to Interior grade specifications, and the other pressed at 325° F. for 15 minutes, the veneer being at 12 percent moisture content at the time of pressing. The one pressed at 325° F. was bonded with a gluespread equivalent to 8 percent resin based on the ovendry weight of the veneer. The same uncatalyzed urea resin was also used in bonding the matching flakeboards.

During the course of the study the performance of the two types of plywood was so nearly the same that no further differentiation between them will be made in this report. Specimens for determining the linear movement of the plywood due to changes in moisture content were cut as shown in figure 2.

Flakeboards

Two flakeboards were made, differing only in the percent of resin content. The specifications are as follows:

(1) Size: 1/2 by 24 by 28 inches.

(2) Flakes: 0.010 by 1–1/2 inches cut in the same direction as the plywood veneer.

(3) Density: 40 pounds per cubic foot.

(4) Moisture content of flakes before spraying: 6 percent.

(5) Resin: Liquid urea resin used without catalyst.

(6) Resin content: One board 8 percent, one board 16 percent.

(7) Moisture content of flakes at time of pressing: About 12 percent.

(8) Temperature of the press: 325° F.

(9) Pressed to 1/2–inch stops (down on the stops in about 3 minutes).

(10) Time in the press: 15 minutes.

Determination of Physical Properties

Dimensional change in veneer, plywood, and flakeboards was determined for each of the four species by measuring the change in length of strips of each material moved from equilibrium conditions at 30 percent relative humidity at 80° F. to equilibrium at the following conditions: Ovendry at 220° F.; 12, 30, 65, 80, and 90 percent relative humidity and soaked under water, all at 80° F. Change in thickness was also measured for the plywood and flakeboards. The results of the measurements are expressed in percent change based on ovendry dimensions.

Four slices of veneer, equally spaced across the depth of the flitch, were selected for longitudinal and transverse-to-grain movement measurements. Seven specimens (1/16 by 1/2 by 22 inches) for longitudinal-to-grain measurements and seven specimens (1/16 by 1/2 by 4 inches) for transverse-to-grain measurements were cut from each veneer slice (fig. 2) and measured while at equilibrium in 30 percent relative humidity at 80° F. Four specimens of each type were then moved to each of the seven humidity conditions and allowed to reach approximate equilibrium before being remeasured.

The longitudinal-to-grain movement of the veneer was determined by measuring the distance between two small holes drilled approximately 20 inches apart in each specimen. This distance was measured by a dial micrometer on a slide that contained one fixed point and an adjustable point. The percent change is shown in table 1 and figure 3.

The transverse-to-grain movement of the veneer was measured with a vernier caliper. Length changes were determined and the percent change in the specimens was averaged for each moisture condition. These data are given in table 2 and figure 4.

Change in thickness of the plywood and flakeboards was determined by averaging 10 thickness readings of a dial micrometer taken at random along the specimen.' The percent change is recorded in table 3. Changes in length of the plywood and flakeboard specimens were measured as described for the veneer in the longitudinal-to-grain direction. The percent change is given in table 4 and figures 5 to 8. The accuracy of all measurements was to ±0.001 inch.

Determination of Elastic Properties

The modulus of elasticity in tension, both longitudinal and transverse to grain, was determined for veneer specimens of each of the four species subjected to various moisture conditions. Five representative veneer slices were selected from flitches of each of the four species. Ten specimens were cut from each piece of veneer, five longitudinal to grain and five transverse to grain. One of each was conditioned to constant weight at five different humidity conditions of 12, 30, 65, 90, and soaked under water, all at 80° F. A total of 200 specimens were evaluated.

Preparation of Tension Specimens

The ASTM Standard Method D805-52 for "Testing Veneer, Plywood, and Other Glued Veneer Constructions" was used as a guide in evaluating the specimens. The size of the relative humidity chamber within which the testing took place imposed a length restriction of 8 inches on the specimens. The longitudinal-to-grain specimens (fig. 9) were shaped accordingly with a standard 8-inch template commonly used in the evaluation of plastics to a minimum width of 1/4 inch at the critical section. The transverse-to-grain specimens were left at their original size of 1/16 by 1 by 8 inches (fig. 9) to provide sufficient section for test loads that could be accurately determined with standard equipment.

Method of Evaluation

Specimen deformations were measured with a Martens' mirror type of extensometer (figs. 10 and 11).

The small loads encountered in the transverse-to-grain specimens necessitated the use of a lightweight gage that produced no stress-inducing characteristics on the specimen.

The loads and cross-head movement of the loading machine were automatically recorded. This autographic record of specimen load and head travel was pipped at intervals and observed on a calibrated scale equal to 0.0002 inch per inch. These data were then replotted to a suitable strain scale along the abscissa, yielding load versus strain data from which the modulus of elasticity values could be calculated (fig. 12).

The average modulus of elasticity values of the five specimens of each species at the various moisture conditions are tabulated in table 5.

Maintaining Relative Humidity Conditions

Prior to evaluation, the specimens were maintained at their respective conditions for a minimum period of 48 hours to reach a constant weight. During evaluation, a relative humidity chamber and equipment were used to insure proper conditioning. (The humidity chamber was equipped with a glass door to permit the light source to be reflected properly.) The specimen was exposed to the conditions of the humidity room (50 percent relative humidity, 75° F.) during the short period it was in the loading apparatus and while the gage was applied. To balance any loss or gain of moisture during this brief period, the specimen was left in the humidity chamber for a short period of time before the modulus of elasticity determinations were made.

The humidity chamber had the capacity to handle all the conditions desired except for that at 80° F. and 12 percent relative humidity, For this condition, which yields an equilibrium moisture content of 3.0 percent, an atmosphere of 120° F. and 14 percent relative humidity was used.

Mathematical Treatment

In mathematically relating the physical and elastic properties of the veneer to the linear movement of plywood made from like material, reference was made to C. B. Norris' studies on the warping characteristics of panel constructions (Appendix). He developed a general mathematical treatment for predicting the warpage and linear movement of laminated materials due to changes in moisture content.

This general analysis may be applied to the special case of an eight-ply, 50-50 constructed plywood panel (fig. 13), and the linear movement due to a change in moisture content may be expressed by:

$$\epsilon = \frac{m_w E_w + m_x E_x}{E_w + E_x}$$

where $\underline{\varepsilon}$ represents the linear movement of the panel in inches per inch, $\underline{m_w}$ and $\underline{m_x}$ the coefficients of expansion or strain in inches per inch of the individual plies over the range of moisture change desired in the longitudinal- and transverse-to-grain directions, respectively. The coefficients $\underline{m_w}$ and $\underline{m_x}$ are given in tables 1 and 2. The values of the modulus of elasticity in tension longitudinal and transverse to the grain are represented by $\underline{E_w}$ and $\underline{E_x}$, respectively, and are given in table 5.

The expression for the radius of curvature, $\underline{R}$, was found to be:

$$\frac{1}{R} = 0$$

which is the expected relationship for the 50-50 balanced construction of the plywood panels. The mathematical prediction of movement in plywood of the four species and the observed movement is illustrated in figures 14, 15, 16, and 17.

Discussion of Results

A comparison of the movements of the two hardwood veneers in the longitudinal-to-grain direction (table 1 and fig. 3) with the linear movements of the matching plywood and flakeboards (table 4 and figs. 5 and 6) indicates that movements are very much the same for the veneer, the plywood, and both flakeboards. For the two softwood species (figs. 7 and 8) the linear movement of the plywood is roughly 60 percent more than the longitudinal movement of the veneer. The Douglas-fir flakeboard (fig. 7) with 8 percent resin content also moved approximately the same amount as the plywood, but the flakeboard having 16 percent resin content moved roughly twice as much. In the redwood flakeboards (fig. 8), the movement of the 8 and 16 percent boards was more nearly alike but in both cases somewhat more than the movement of the plywood.

The longitudinal movement of the veneer of the two hardwood species shown in figure 3 is roughly twice as much as the movement of the two softwood species for equivalent relative humidity changes. The shape of the curve for the hardwoods also differed characteristically from that of the softwoods in the range of 70 to

100 percent relative humidity. In this range the slope of the curve increased for the hardwoods, while in the softwoods it decreased and in the case of the Douglas-fir approached zero. This behavior agrees with some earlier exploratory work in which the average longitudinal movement of several hardwood veneers was compared with the average longitudinal movement of several softwood veneers.

An examination of figures 14 to 17 illustrates the correlation between the linear movement of the plywood as predicted by mathematical analysis, and the observed linear movement of the panels. While the curves in general do not show a close correlation in percent, it is felt that the tendency toward agreement is present. For three of the species the observed value always fell between the predicted values as determined by considering (1) the longitudinal change of the veneers only, and (2) both the longitudinal- and transverse-to-grain expansion effects of the veneers. The fourth species, redwood, had an observed linear movement considerably greater than that predicted by mathematical analysis. At present, the significance of or reason for this occurrence is not known.

The correlation of the mathematical analysis with measurements of linear movement depends upon the accuracy in determining the properties of the individual veneer layers forming the plywood construction. This may be why a closer correlation was not possible in this study since the modulus of elasticity values used were the average of five different specimens taken from as many sheets, none of which may have been actually used in the plywood construction.

In applying the analysis it is also assumed that the veneers in the plywood attain the same moisture content as those on which dimension changes were measured. A closer examination of moisture content of veneers in the plywood might reveal wetter or drier interior plies, depending upon the mechanism by which moisture travels into the veneers of different wood species. This may account for some of the differences between actual and calculated linear movement.

One of the more significant observations of this study was that the linear movement of the plywood panels could be closely predicted by considering the longitudinal movement of the veneers only. This indicates that the stresses induced in the transverse direction are small, and the corresponding linear change, although relatively large in the veneer, is insignificant in producing linear change in the plywood.

The behavior of the flakeboard (8 percent resin content) showed linear change comparable to that of plywood for equivalent moisture changes. Since linear movement in the plywood was discovered to be similar to the longitudinal movement of veneer, it can be inferred that the flakeboard had enough particles oriented parallel to the direction of the linear movement measurement to render it as stable as plywood.

Summary of Findings

These findings are presented regarding the linear movement of the plywood and flakeboards due to exposure to various conditions of relative humidity:

(1) Dimension change transverse to the grain of wood has little influence on the linear movement of plywood and flakeboards of the types evaluated.

(2) Linear movement of 8-ply balanced plywood corresponds closely to the dimension change of veneers in the direction longitudinal to grain. Calculations including elastic properties resulted in expected changes greater than those predicted by longitudinal movement alone.

(3) The linear stability of the flakeboards bonded with 8 percent urea resin was roughly comparable to that of the plywood.

(4) With all of the species except aspen, the flakeboards bonded with 8 percent urea resin were considerably more stable linearly than those bonded with 16 percent resin. The aspen flakeboard, however, showed little difference in this respect.

APPENDIX

Warpage of Laminated Materials Due to Changes in Moisture Content or Temperature[1]

When panels made of a series of laminations of different materials are changed from one moisture content or temperature to another, they may curve due to the different effects of these changes on each layer. A method of obtaining the change in the radius of curvature due to these changes is developed in this appendix.

The fundamental equation is obtained by equating the strain due to the changes in moisture content and temperature plus the strain due to stress at a point to the strain determined by the geometry of the figure. This equation is:

$$m + \frac{\sigma}{E} = \epsilon + \frac{y}{R} \qquad (1)$$

where m is the strain due to the change in moisture content and temperature, σ is the stress, and E the modulus of elasticity at the point, ϵ is the strain at the face of the panel, R the radius of curvature of the face of the panel, and y the distance of the point from the face of the panel. If R is positive, the face of the panel is concave, as shown in the figure. If it is negative, the face is convex.

The stress at a point is obtained from equation (1):

$$\sigma = \epsilon E - mE + \frac{E}{R} y \qquad (2)$$

The total force on a cross section of the panel must be zero because of equilibrium. Thus:

$$F = \int \sigma dy = \epsilon \int Edy - \int mEdy + \frac{1}{R} \int Eydy = 0 \qquad (3)$$

where the integration is taken over the entire cross section.

[1]This appendix was prepared by Charles B. Norris, Engineer.

Also, because of equilibrium, the bending moment on a cross section must be zero. Thus:

$$M = \int \sigma y \, dy = \epsilon \int Ey \, dy - \int mEy \, dy + \frac{1}{R} \int Ey^2 dy = 0 \qquad (4)$$

Equations (3) and (4) are simultaneous in $\underline{\varepsilon}$ and $\frac{1}{\underline{R}}$. They may be integrated over each layer of material and put in the form of summations.

Let the 2 layers be numbered successively from the facing, so that the facing is numbered 1, the next layer 2, and so on. The thickness of the i th layer is $\underline{t_i}$. The distance from the face through the i th layer is $\underline{S_i}$ so that $S_1 = t_1$, $S_2 = t_1 + t_2$, etc., as shown in the figure. Integrating across the successive layers, equation (3) becomes:

$$\epsilon \sum_1^n E_i t_i - \sum_1^n m_i E_i t_i + \frac{1}{2R} \sum_1^n E_i (S_i^2 - S_{i-1}^2) = 0 \qquad (5)$$

In the same way, equation (4) becomes:

$$\frac{\epsilon}{2} \sum_1^n E_i (S_i^2 - S_{i-1}^2) - \frac{1}{2} \sum_1^n m_i E_i (S_i^2 - S_{i-1}^2) +$$

$$\frac{1}{3R} \sum_1^n E_i (S_i^3 - S_{i-1}^3) = 0 \qquad (6)$$

These two equations may be solved simultaneously to determine values of $\underline{\varepsilon}$ and $\underline{R}$. If the panel is flat before the changes take place, $\underline{R}$ is the radius of curvature the panel assumes. If the panel is not flat to start with but has the radius $\underline{R_o}$, the final radius is given by:

$$\frac{1}{R_F} = \frac{1}{R_o} + \frac{1}{R} \qquad (7)$$

where a positive radius indicates that the facing is concave.

A simple approximate formula between the bow as measured in this report and the radius is:

$$B = \frac{L^2}{\delta R}$$

where <u>B</u> is the bow in the length <u>L</u>, and <u>R</u> is the radius of curvature. This formula is accurate if the bow is very small compared to the radius.

Table 1.--Longitudinal-to-grain movement of veneer as related to change in moisture content from ovendry condition

Conditions	Aspen	Yellow birch	Douglas-fir	Redwood
	Pct.	Pct.	Pct.	Pct.
80° F., 12 pct. RH	0.08	0.07	0.03	0.02
80° F., 30 pct. RH	.12	.14	.07	.06
80° F., 65 pct. RH	.20	.23	.09	.13
80° F., 80 pct. RH	.24	.28	.10	.15
80° F., 90 pct. RH	.27	.35	.10	.17
80° F., soaked	.30	.49	.09	.18

Table 2.--Transverse-to-grain movement of veneer as related to change in moisture content from ovendry condition

Conditions	Aspen	Yellow birch	Douglas-fir	Redwood
	Pct.	Pct.	Pct.	Pct.
80° F., 12 pct. RH	0.40	0.46	0.30	0.23
80° F., 30 pct. RH	.86	1.23	1.05	.64
80° F., 65 pct. RH	1.88	2.88	1.98	1.45
80° F., 80 pct. RH	2.79	3.68	2.66	2.01
80° F., 90 pct. RH	3.91	4.82	3.36	2.76
80° F., soaked	6.17	7.69	5.04	3.27

Table 3.--Change in thickness of plywood and flakeboards as related to change in moisture content from ovendry condition

Conditions	Aspen	Yellow birch	Douglas-fir	Redwood
	Pct.	Pct.	Pct.	Pct.
PLYWOOD				
80° F., 12 pct. RH	0.71	1.71	1.07	1.12
80° F., 30 pct. RH	1.41	3.06	2.03	1.58
80° F., 65 pct. RH	3.16	5.62	6.75	2.45
80° F., 80 pct. RH	5.19	8.49	6.20	3.72
80° F., 90 pct. RH	9.52	12.54	7.68	5.30
80° F., soaked	16.06	21.60	11.36	5.82
FLAKEBOARD--8 PCT. UREA RESIN				
80° F., 12 pct. RH	.82	1.03	.62	.82
80° F., 30 pct. RH	1.64	1.86	1.46	1.23
80° F., 65 pct. RH	4.30	4.73	4.16	2.87
80° F., 80 pct. RH	8.01	8.66	6.46	5.56
80° F., 90 pct. RH	14.17	16.08	12.27	10.70
80° F., soaked	39.09	55.46	21.00	20.37
FLAKEBOARD--16 PCT. UREA RESIN				
80° F., 12 pct. RH	.61	1.23	1.25	1.23
80° F., 30 pct. RH	1.43	2.06	1.88	1.65
80° F., 65 pct. RH	3.89	4.72	4.38	2.89
80° F., 80 pct. RH	6.78	8.02	6.26	5.56
80° F., 90 pct. RH	11.29	13.99	8.35	8.45
80° F., soaked	23.41	41.03	14.82	14.61

Table 4.--Linear Movement of plywood and flakeboards as related to change in moisture content from ovendry condition

Conditions	Aspen	Yellow birch	Douglas-fir	Redwood
	Pct.	Pct.	Pct.	Pct.
		PLYWOOD		
80° F., 12 pct. RH	0.07	0.06	0.04	0.03
80° F., 30 pct. RH	.13	.16	.07	.09
80° F., 65 pct. RH	.22	.27	.14	.23
80° F., 80 pct. RH	.26	.31	.16	.29
80° F., 90 pct. RH	.28	.41	.17	.30
80° F., soaked	.32	.50	.15	.32
		FLAKEBOARD--8 PCT. UREA RESIN		
80° F., 12 pct. RH	.05	.05	.01	.08
80° F., 30 pct. RH	.12	.13	.05	.16
80° F., 65 pct. RH	.22	.23	.13	.31
80° F., 80 pct. RH	.25	.28	.16	.38
80° F., 90 pct. RH	.28	.33	.15	.40
80° F., soaked	.32	.51	.13	.35
		FLAKEBOARD--16 PCT. UREA RESIN		
80° F., 12 pct. RH	.07	.08	.06	.11
80° F., 30 pct. RH	.13	.16	.13	.19
80° F., 65 pct. RH	.24	.27	.23	.35
80° F., 80 pct. RH	.26	.31	.26	.38
80° F., 90 pct. RH	.28	.38	.27	.45
80° F., soaked	.32	.51	.21	.39

Table 5.--Modulus of elasticity values--average from 5 specimens[1]

Conditions	Aspen		Yellow-birch		Douglas-fir		Redwood	
	E_w	E_x	E_w	E_x	E_w	E_x	E_w	E_x
	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.
120° F., 14 pct. RH	1,400	37	2,120	142	2,250	104	728	18.1
80° F., 30 pct. RH	1,790	36	2,050	150	1,960	116	727	21.1
80° F., 65 pct. RH	1,660	34	1,970	129	1,780	92	633	16.5
80° F., 90 pct. RH	1,420	18	1,990	58	2,000	54	524	11.5
80° F., soaked	1,250	11	1,630	36	1,670	40	415	8.5

[1] E_w is in the longitudinal-to-grain direction.
E_x is in the transverse-to-grain direction.

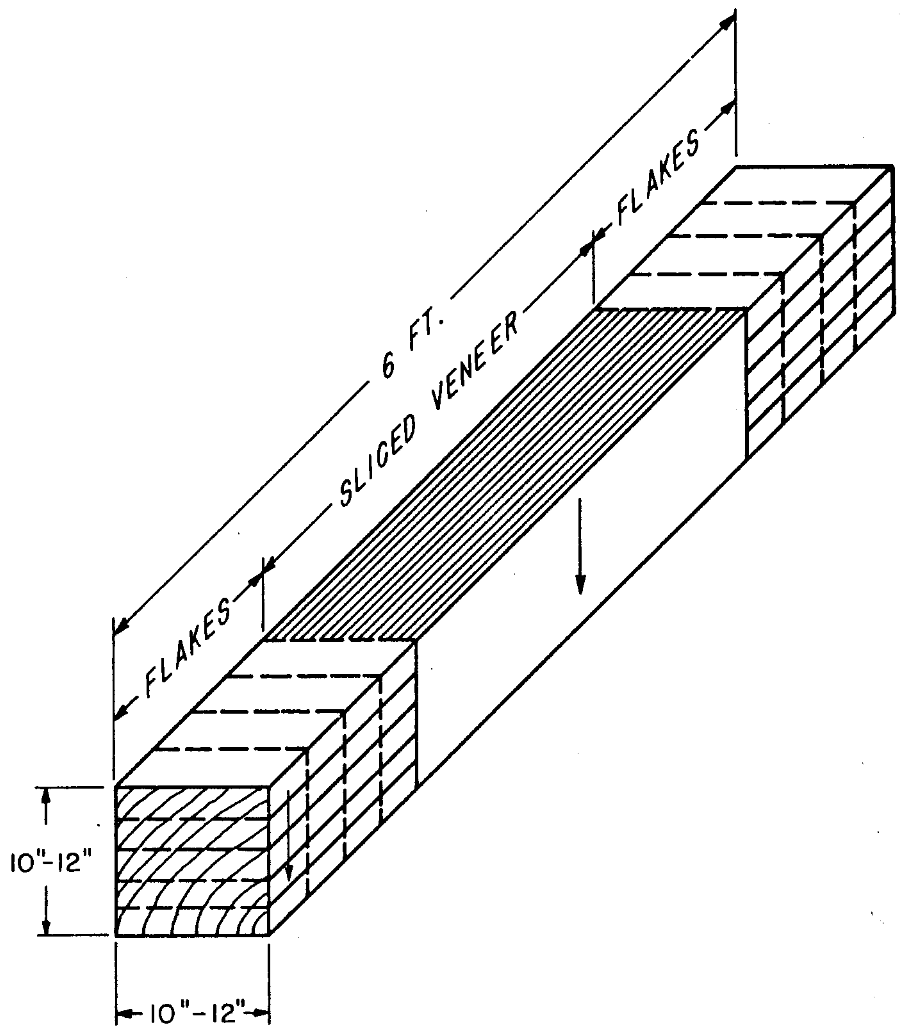

Figure 1.--Cutting diagram of flitch.

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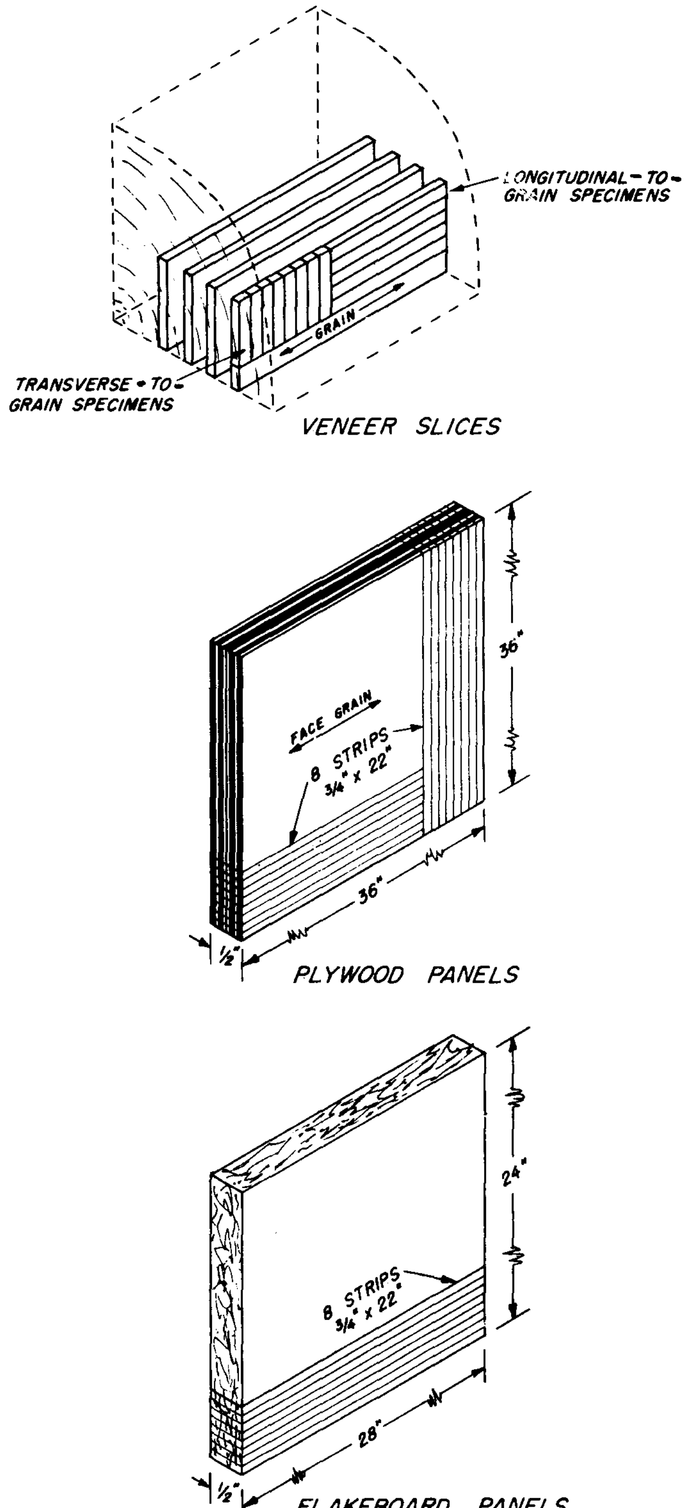


Figure 2.--Specimen cutting diagrams.

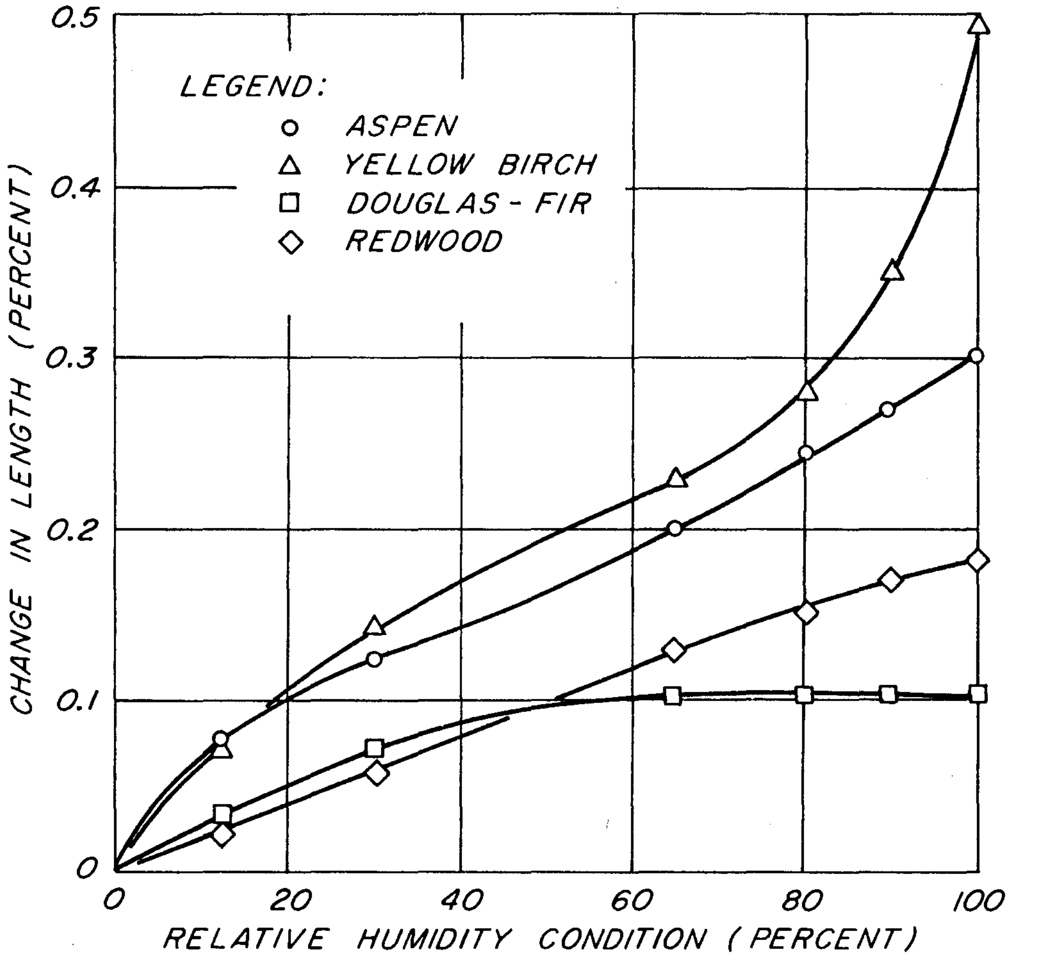


Figure 3.--Longitudinal-to-grain movement of veneer as related to change in moisture content from ovendry condition,

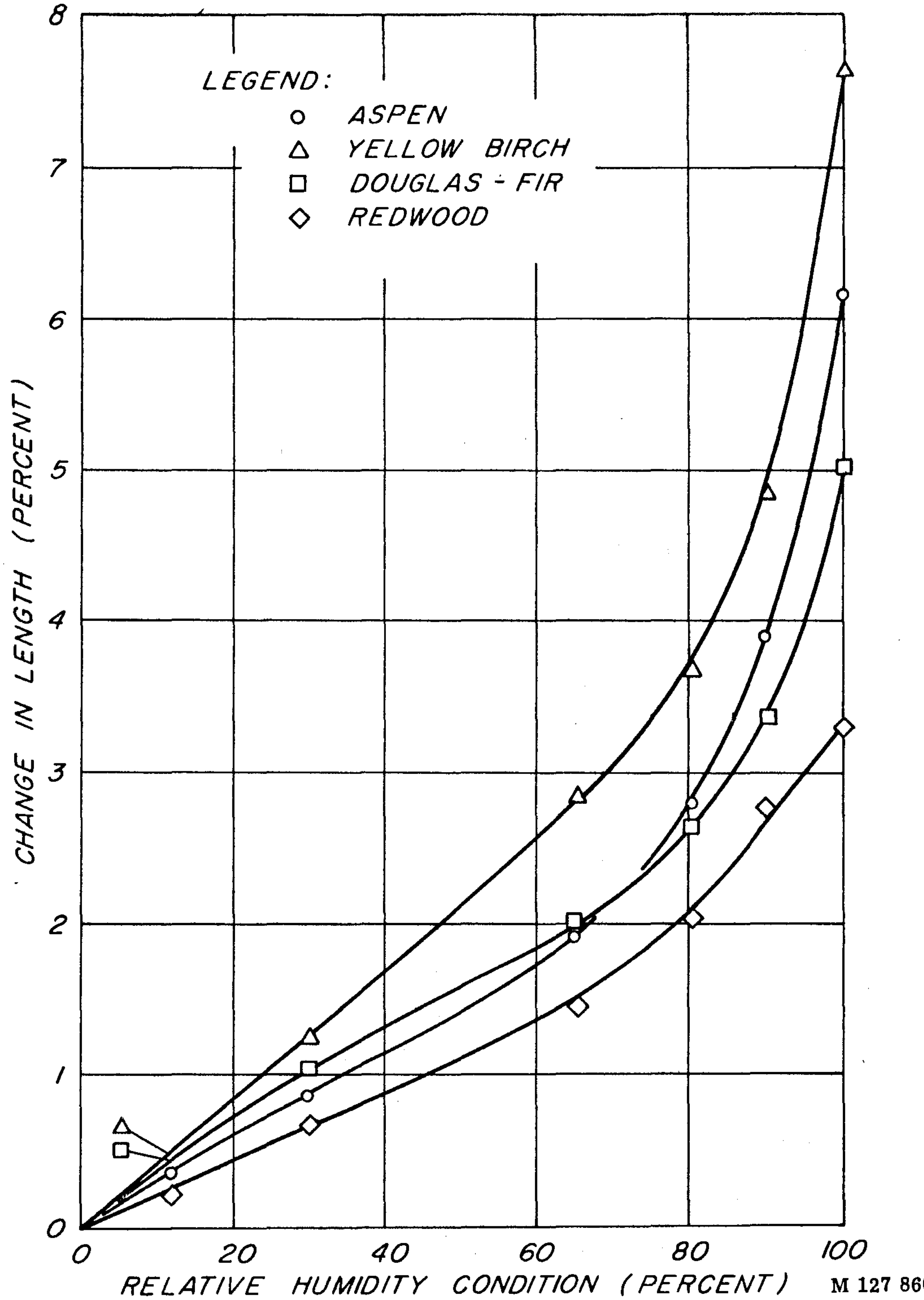


Figure 4.--Transverse-to-grain movement of veneer as related to change in moisture content from ovendry condition.

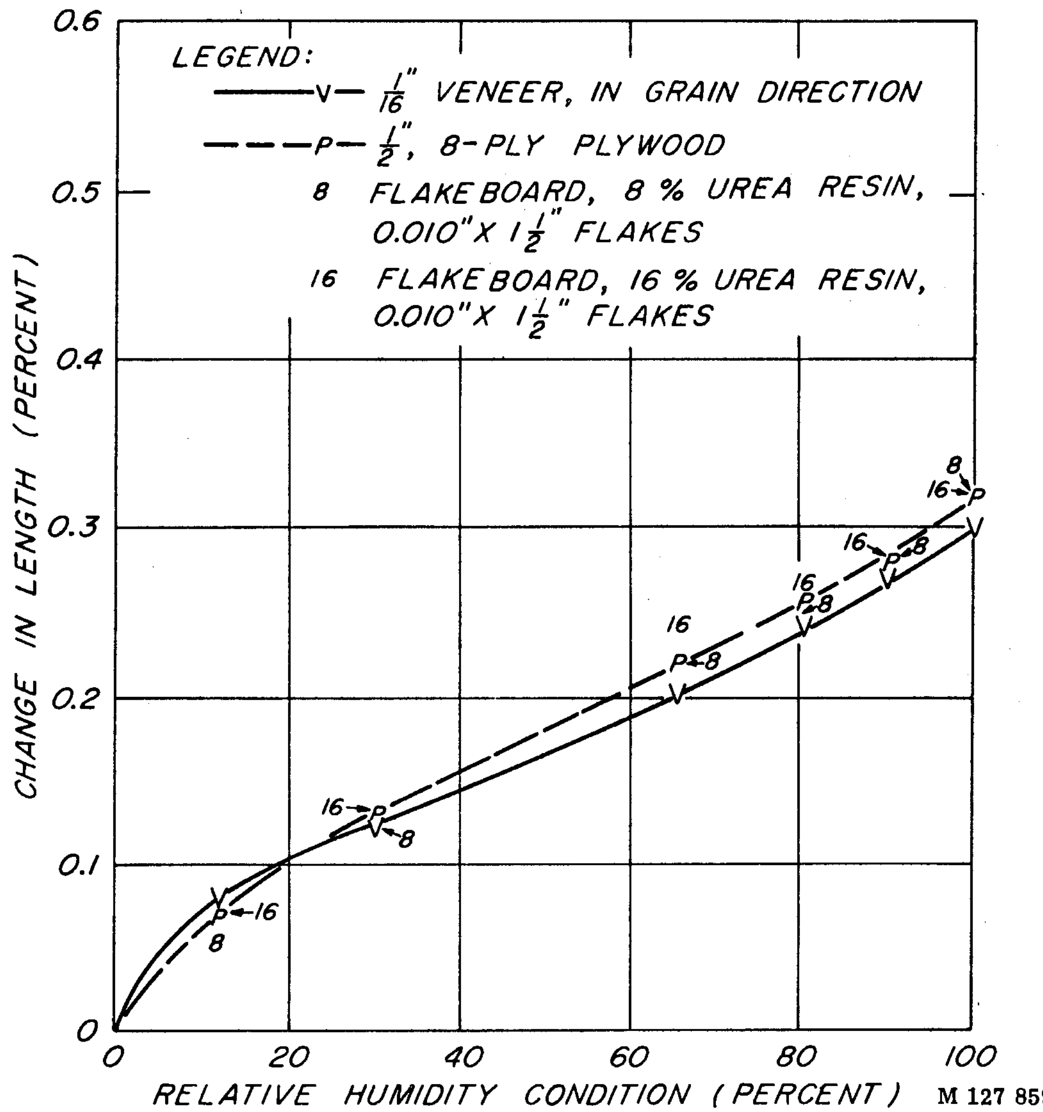


Figure 5.--Aspen: Linear movement of veneer, plywood, and flakeboards as related to change in moisture content from ovendry condition.

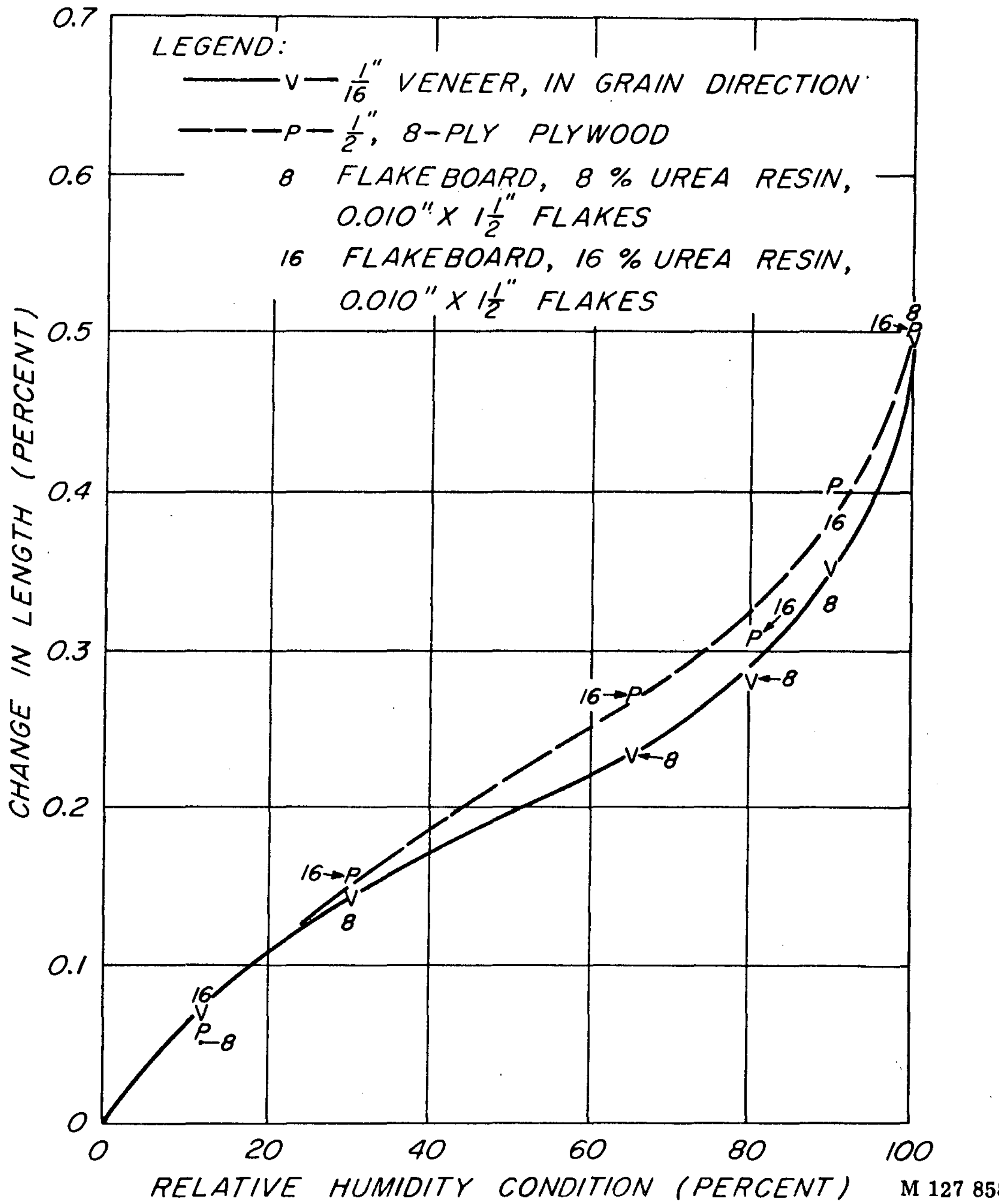


Figure 6.--Yellow birch: Linear movement of veneer, plywood, and flakeboards as related to change in moisture content from ovendry condition.

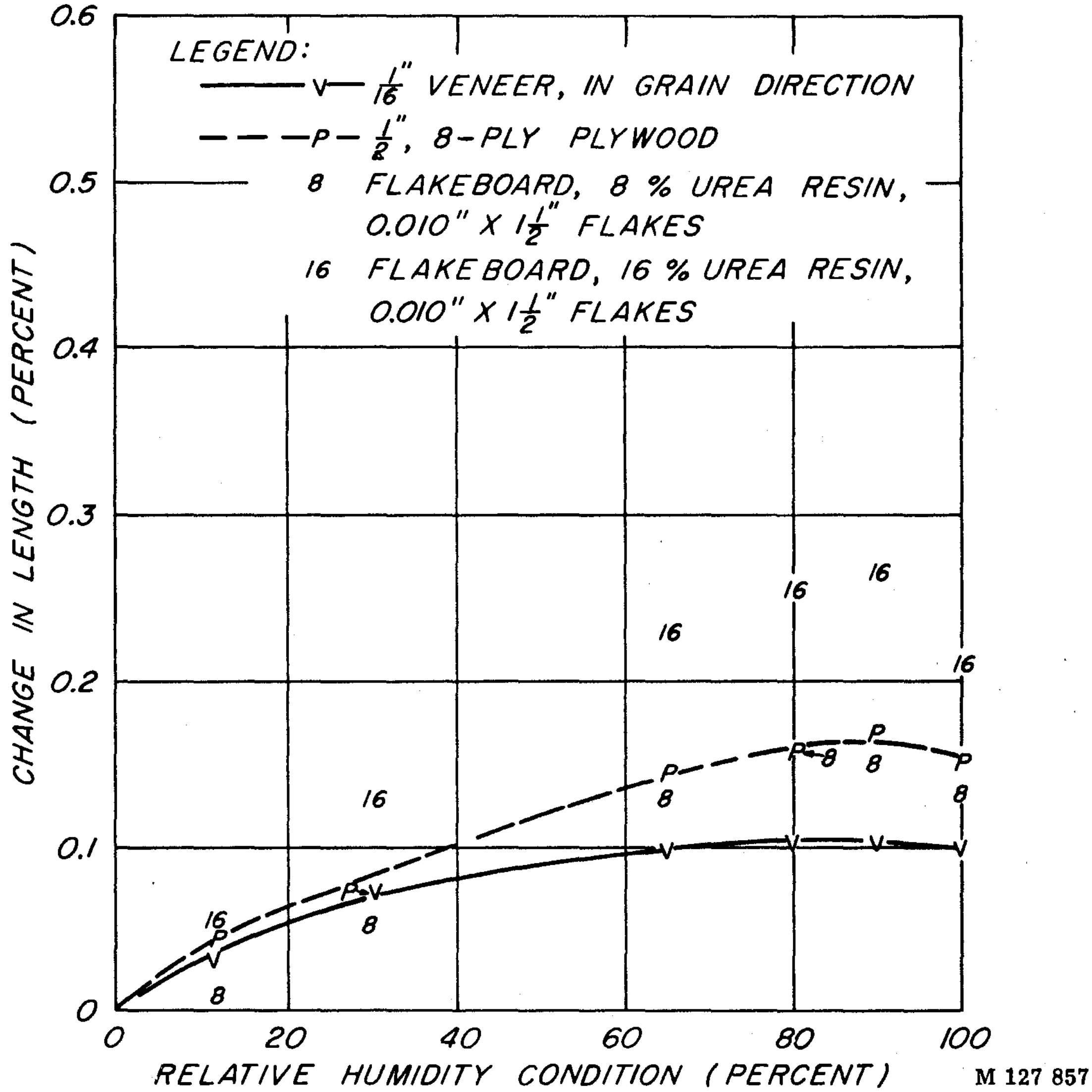


Figure 7.--Douglas-fir: Linear movement of veneer, plywood, and flakeboards as related to change in moisture content from ovendry condition.

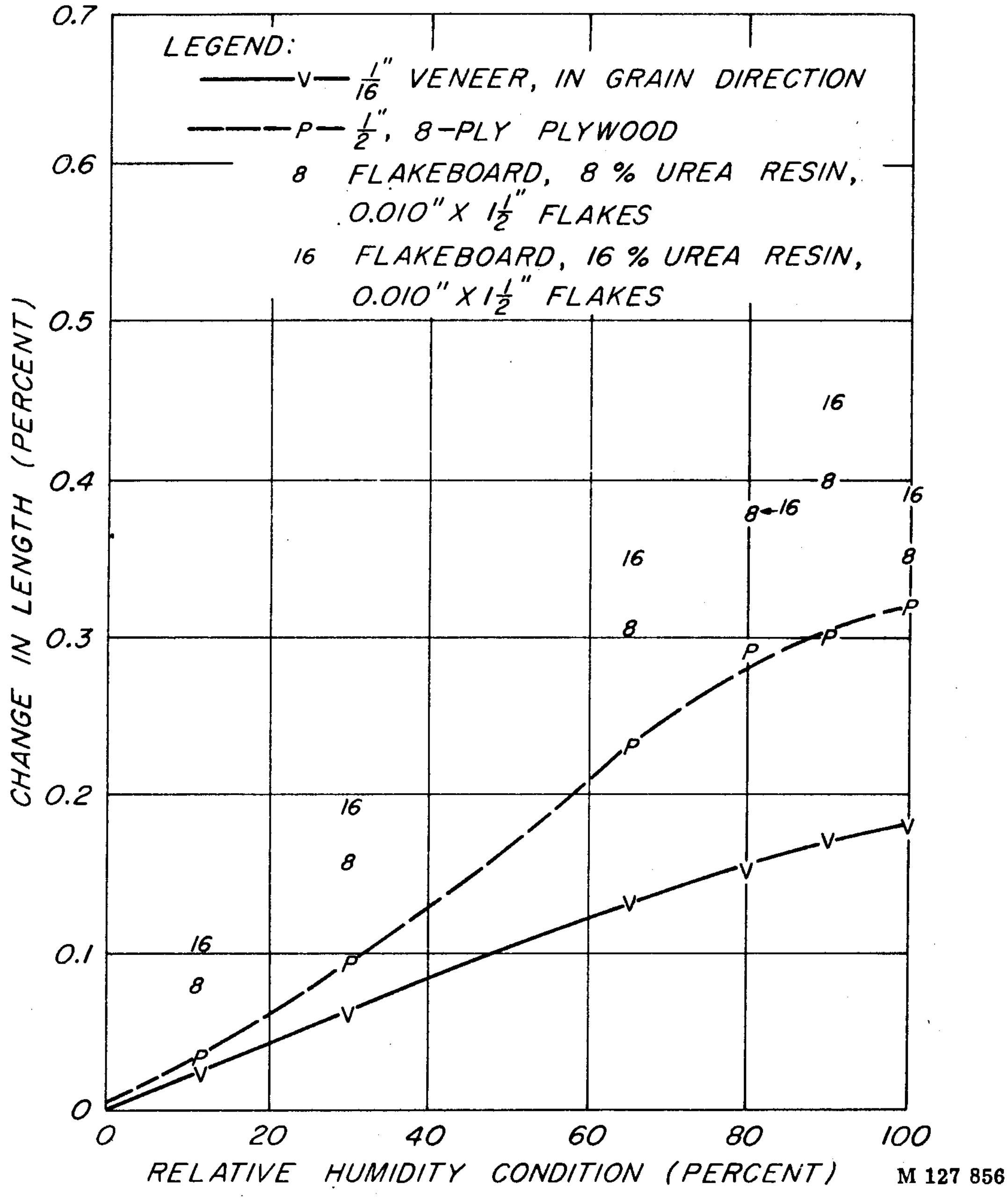


Figure 8.--Redwood: Linear movement of veneer, plywood, and flakeboards as related to change in moisture content from ovendry condition.

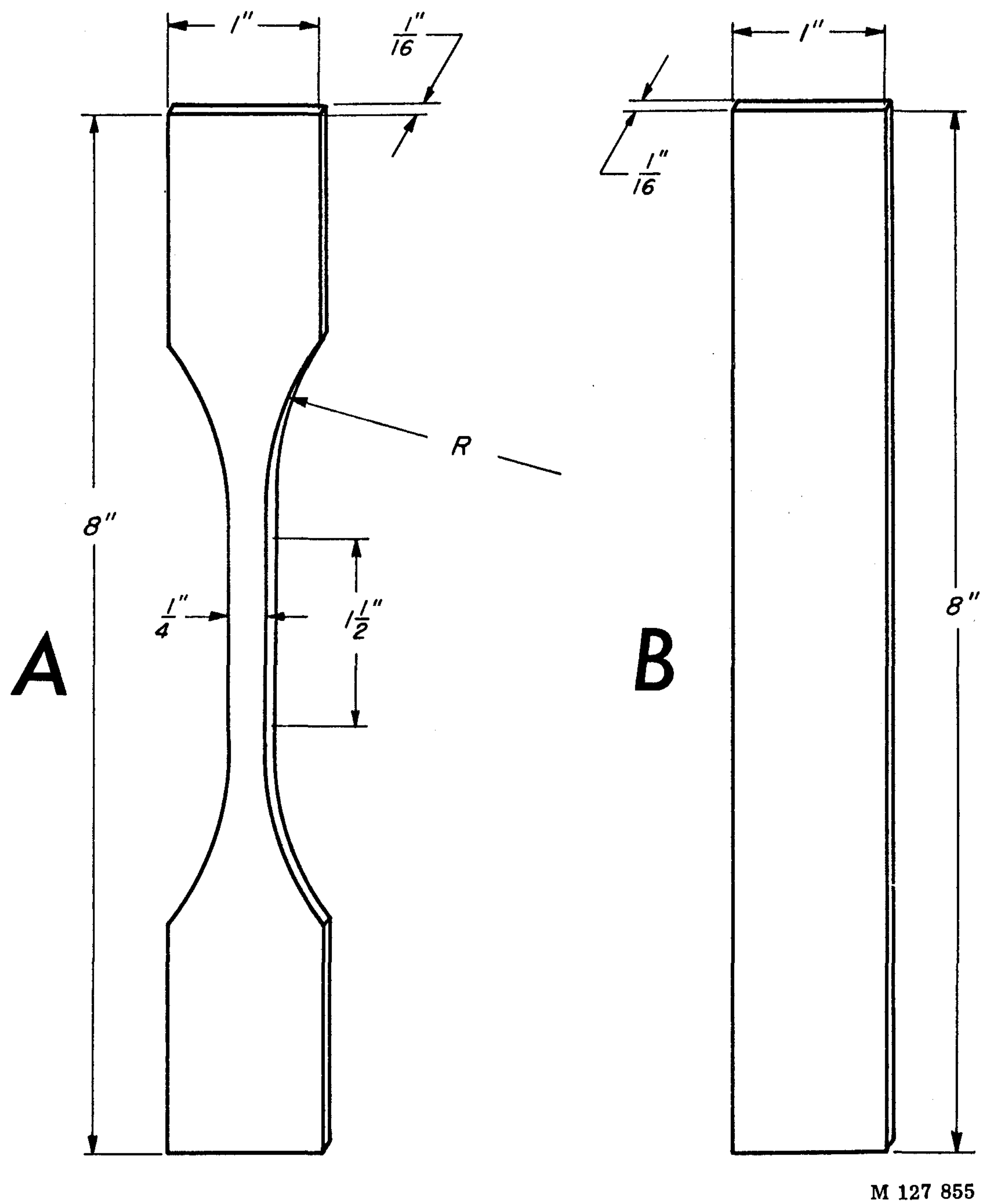


Figure 9.--Tension specimens: A, Longitudinal to grain; B, Transverse to grain.

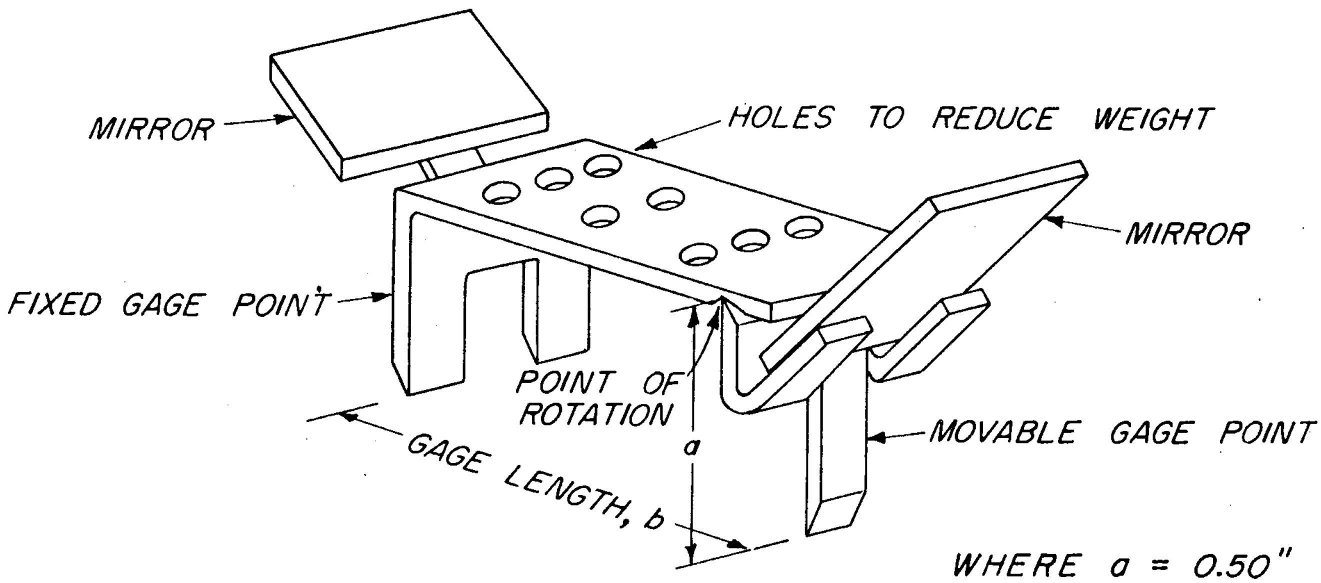


Figure 10.--Gage for measuring extension in tension specimens of veneer.

M 127 864

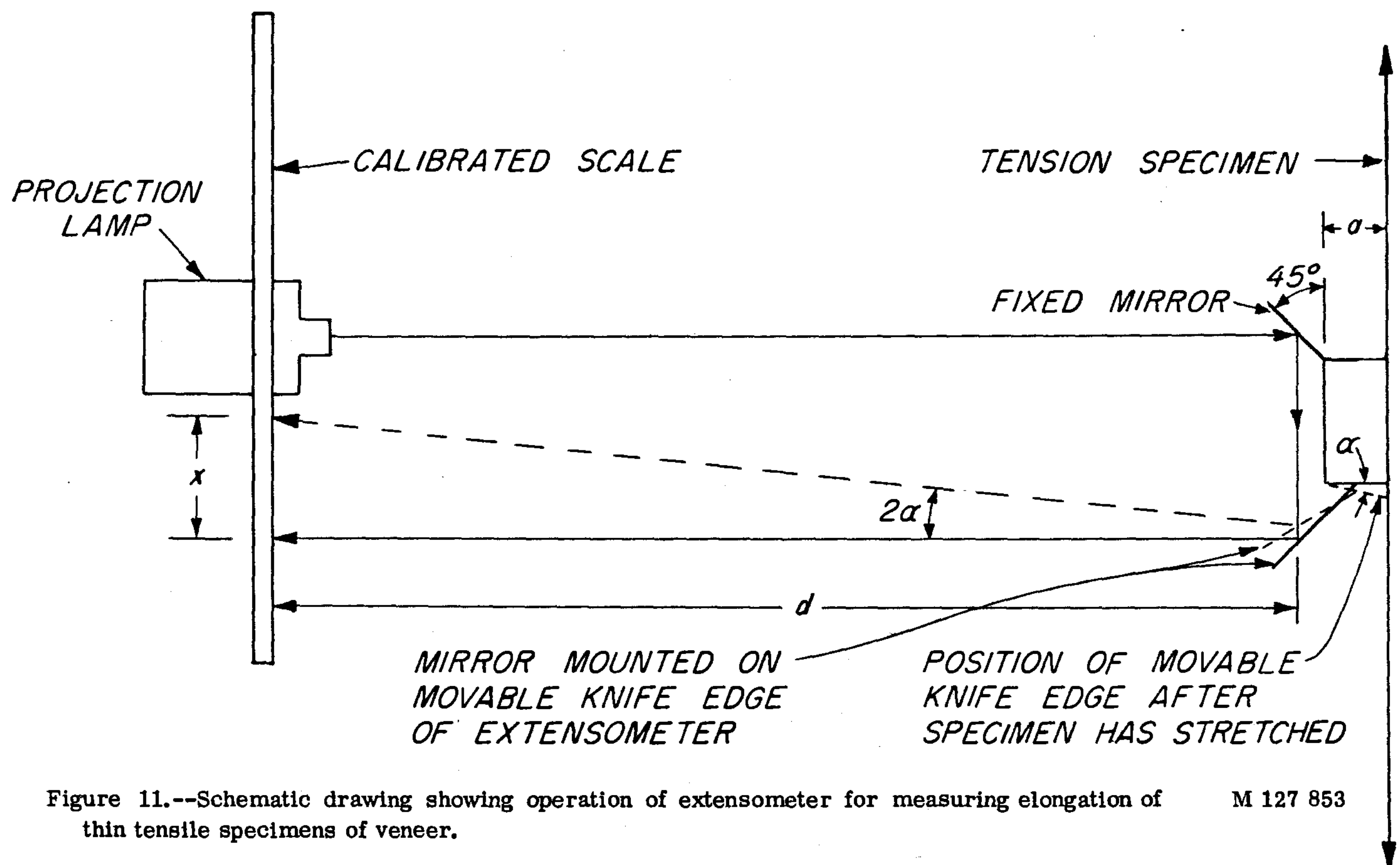


Figure 11.--Schematic drawing showing operation of extensometer for measuring elongation of thin tensile specimens of veneer. M 127 853

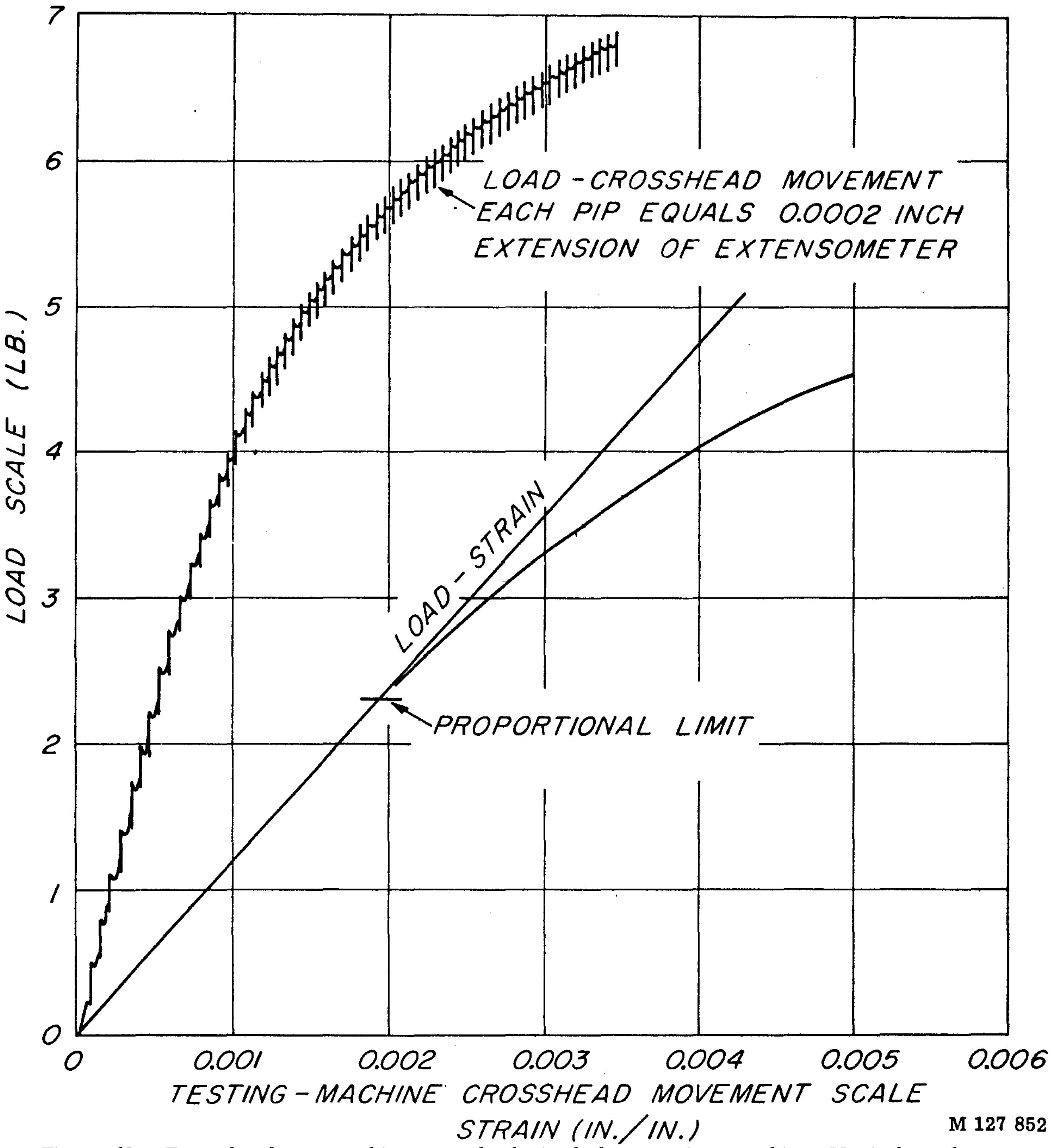


Figure 12.––Example of autographing record obtained from testing machine. Vertical marks or pips were inserted by operator reading extensometer gage.

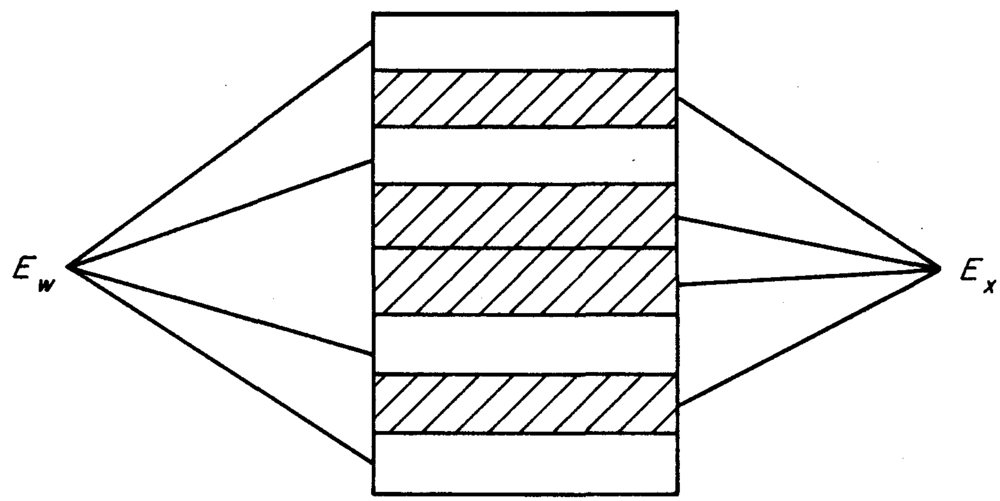
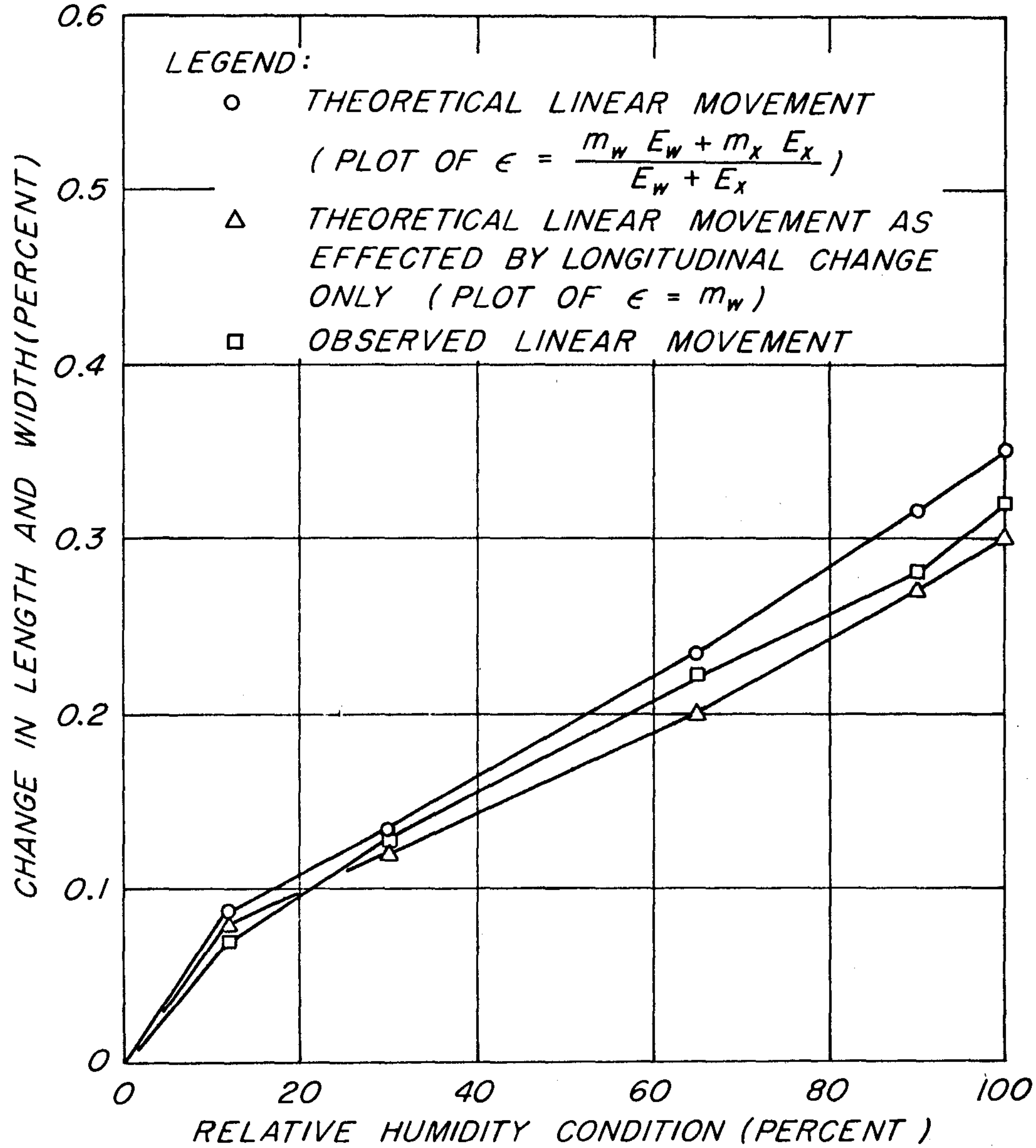


Figure 13.--Section of 8-ply 50-50 construction plywood. M 127 851



M 127 850

Figure 14.--Aspen: Linear movement of plywood as related to change in moisture content from ovendry condition.

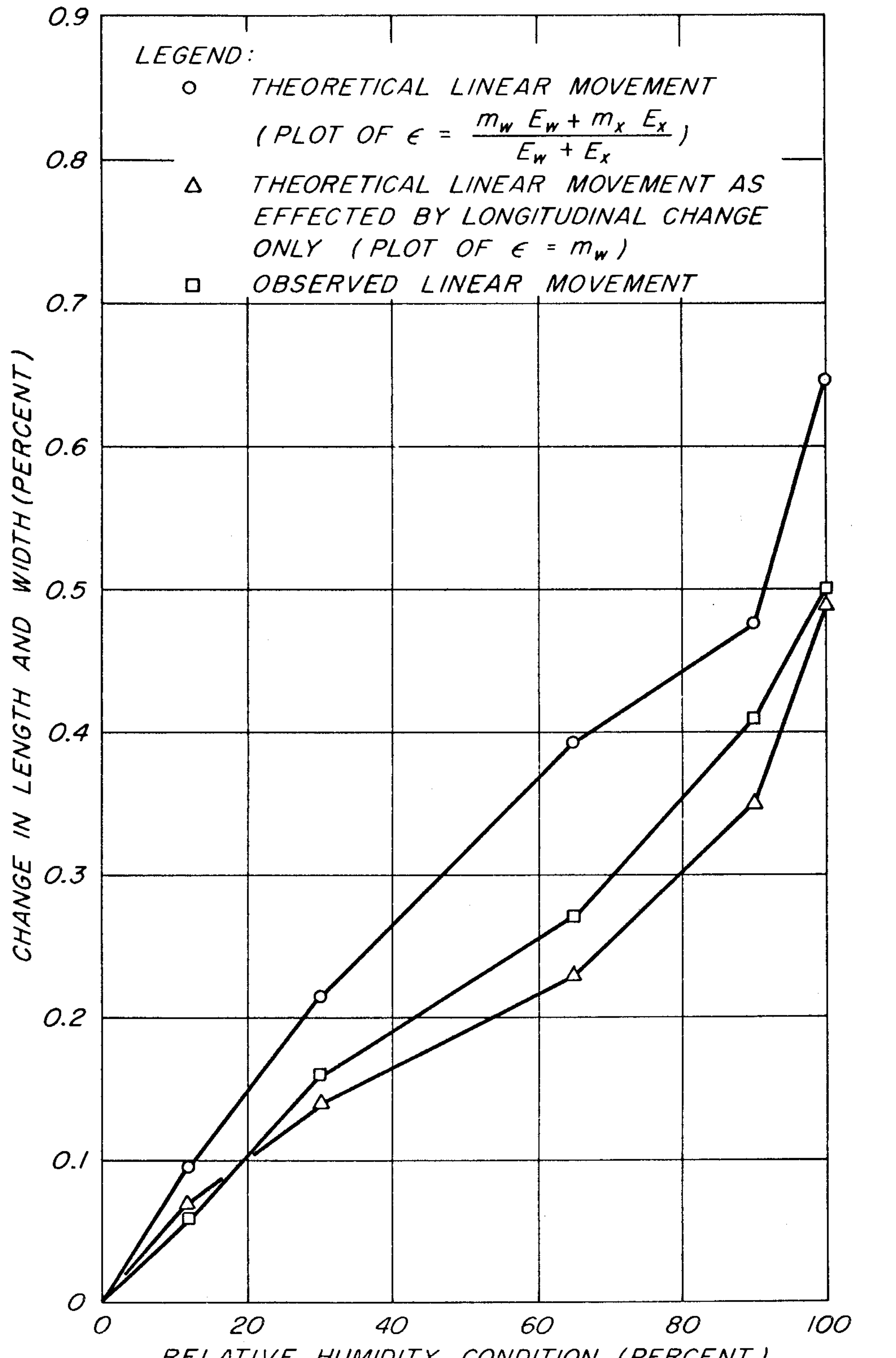


Figure 15.--Yellow birch: Linear movement of plywood as related to change in moisture content from ovendry condition.

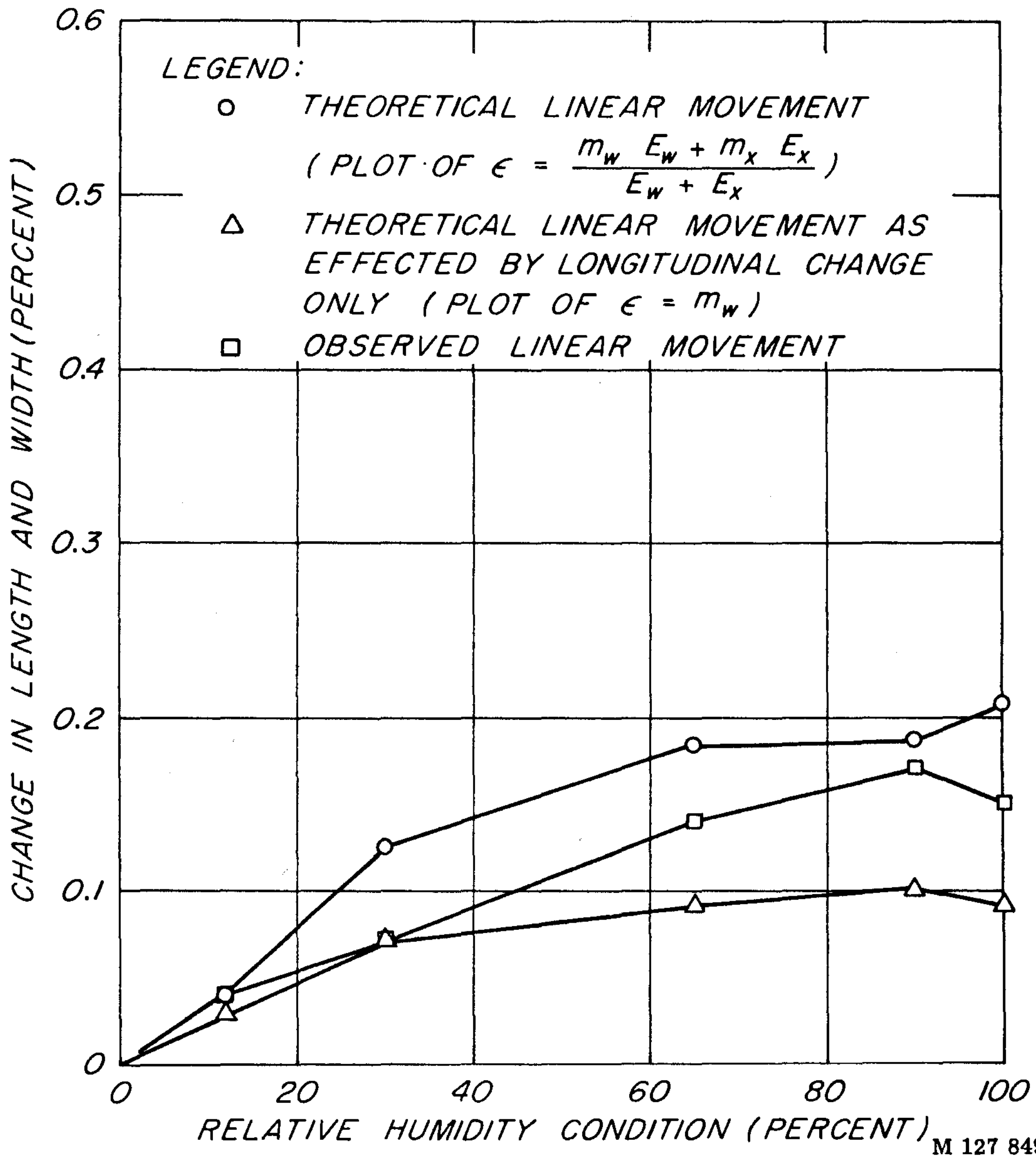


Figure 16.--Douglas-fir: Linear movement of plywood as related to change in moisture content from ovendry condition.

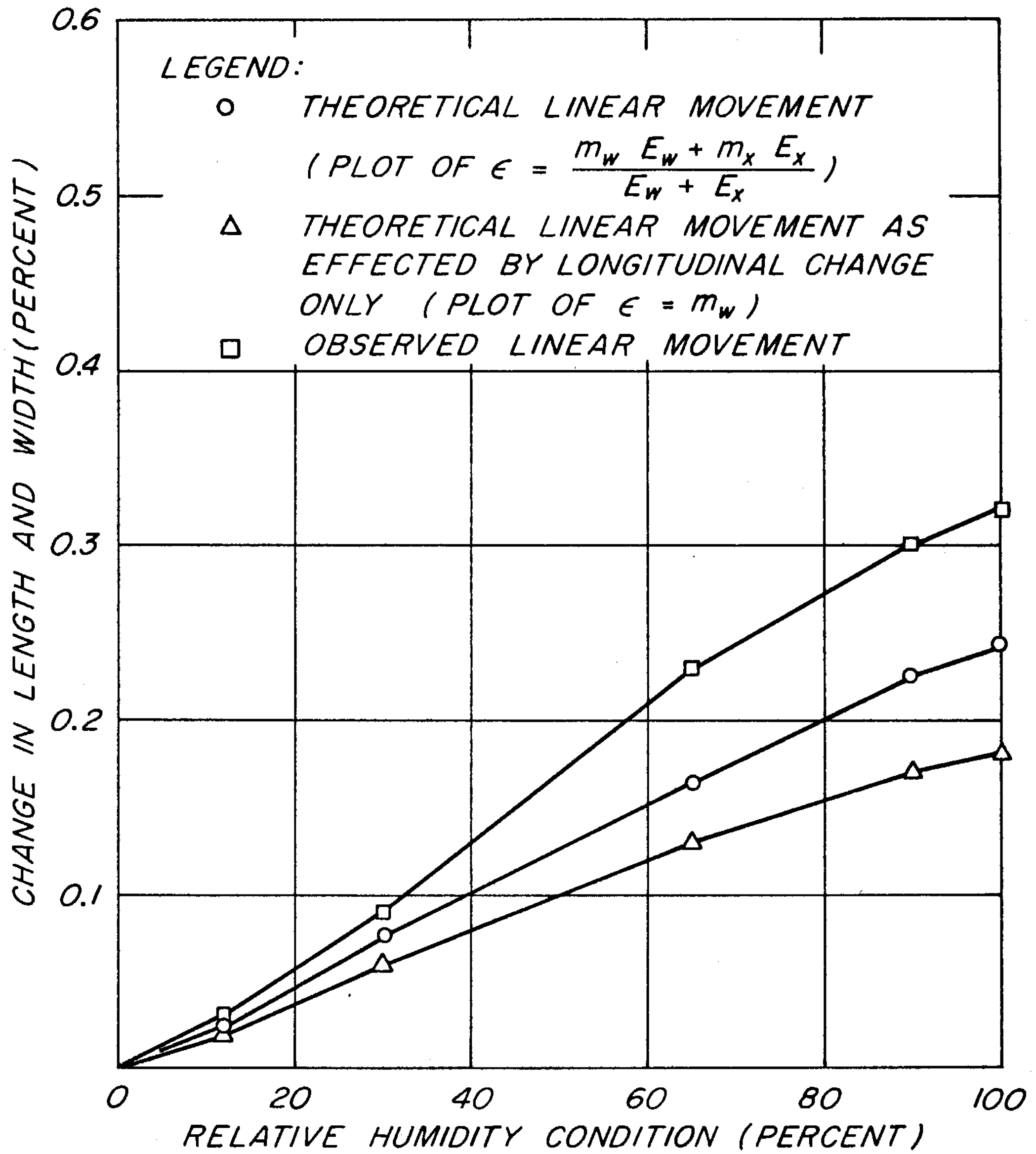


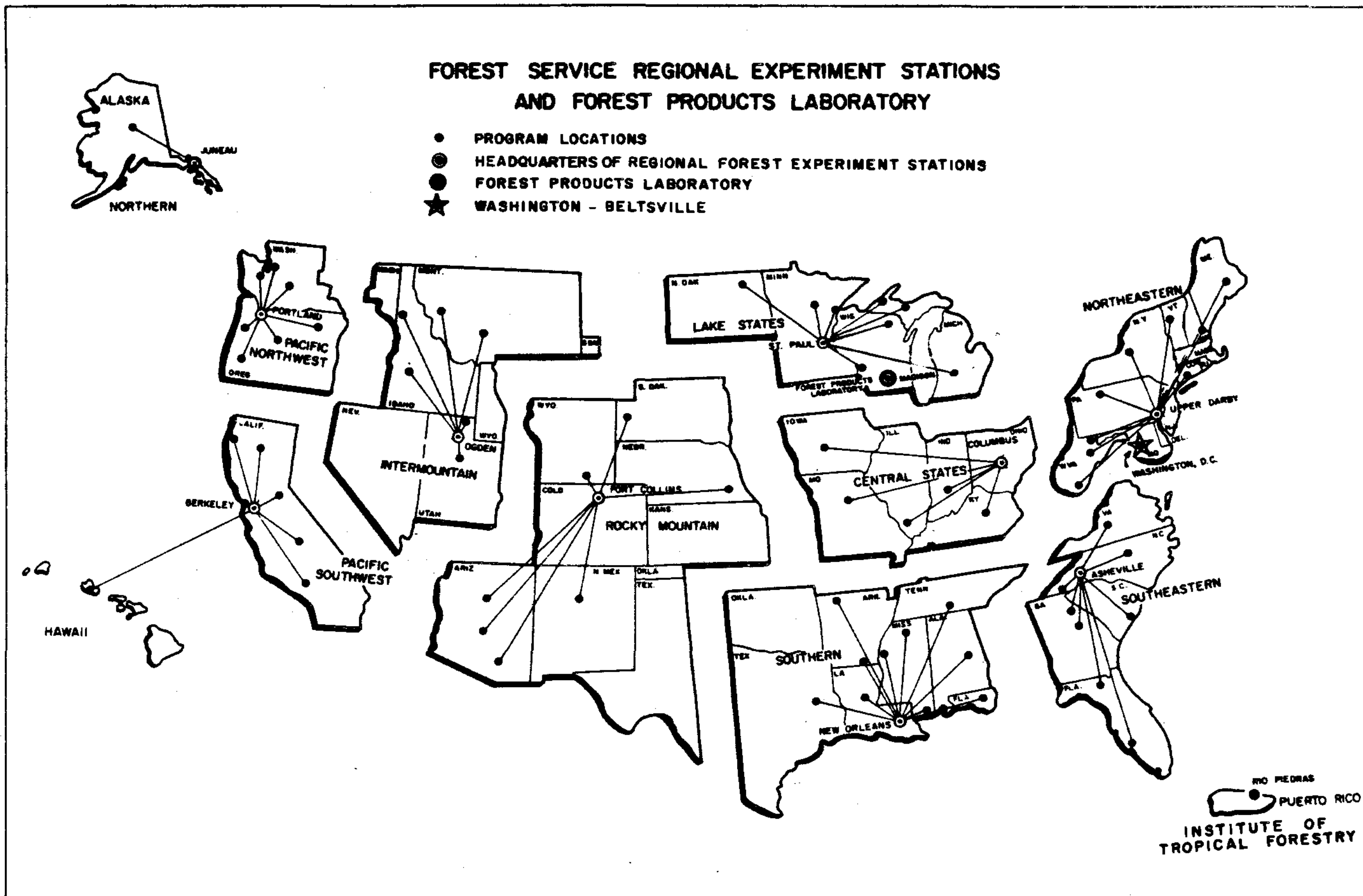
Figure 17.--Redwood: Linear movement of plywood as related to change in moisture content from ovendry condition.

PUBLICATION LISTS ISSUED BY THE FOREST PRODUCTS LABORATORY

The following lists of publications deal with investigative projects of the Forest Products Laboratory or relate to special interest groups and are available upon request:

- Box, Crate, and Packaging Data
- Chemistry of Wood
- Drying of Wood
- Fire Protection
- Fungus and Insect Defects in Forest Products
- Glue and Plywood
- Growth, Structure, and Identification of Wood
- Furniture Manufacturers, Woodworkers, and Teachers of Woodshop Practice
- Logging, Milling, and Utilization of Timber Products
- Mechanical Properties of Timber
- Pulp and Paper
- Structural Sandwich, Plastic Laminates, and Wood-Base Components
- Thermal Properties of Wood
- Wood Finishing Subjects
- Wood Preservation
- Architects, Builders, Engineers, and Retail Lumbermen

Note: Since Forest Products Laboratory publications are so varied in subject matter, no single catalog of titles is issued. Instead, a listing is made for each area of Laboratory research. Twice a year, December 31 and June 30, a list is compiled showing new reports for the previous 6 months. This is the only item sent regularly to the Laboratory's mailing roster, and it serves to keep current the various subject matter listings. Names may be added to the mailing roster upon request.



Forest Service regional experiment station and Forest Products Laboratory