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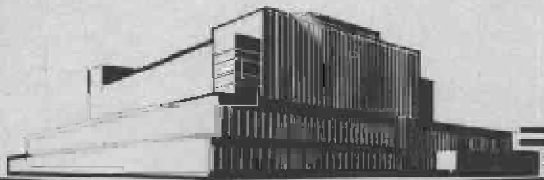

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

HARDBOARD FROM RED ALDER AND FROM A MIXTURE OF SLOW-GROWTH SOUTHERN OAKS[1]

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Introduction

Wet-pressed (screen back) hardboards were prepared from red alder and from a mixture of low-grade southern oaks. The purpose of this study was twofold: (1) to demonstrate the suitability of two widely different hardwoods for the production of hardboard, and (2) to note the influence of the degree of hydrolysis on yield, board strength, and sizing efficiency. In a compact problem design the following factors were covered: the effect of the degree of steam cooking on yield and quality of the board stock, the influence of the amount of alum and the amount of size added to the stock on board quality, and the influence of pressure on oak hardboard.

Material

Wood

Red alder was obtained from a pulp and paper company in the state of Washington.

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[1] This report previously issued as a Pulp and Paper Division report of limited distribution.

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

The oaks used in this study were classified as low grade, unsuitable for lumber. The wood pulped consisted of equal weights of chips (ovendry basis) obtained from 3 red and 3 white oaks. The wood was cut on the Biltmore Estate in Buncombe County, Limestone Township, N. C.

The physical and chemical evaluation data on these woods are given in table 2.

Sizing Chemicals

The following chemicals were used in sizing: (1) paraffin wax size (4); (2) papermakers alum, $Al_2(SO_4)_3 \cdot 18H_2O$; and (3) sulfuric acid. Each was made up in a 10 percent solution before use.

Problem Design

Both the alder and oak chips were fiberized in a stainless steel, laboratory model, Asplund Defibrator (4). The conditions of processing and the yields of pulp are given in table 3. These pulps were further refined, sized, and converted to hardboard in a similar fashion. However, some differences in problem design for each species were made.

Red Alder

The problem design for the alder is given in table 4. A replication of each board was made -- a total of 40 boards each, weighing 128 grams, moisture-free basis. Each Defibrator run produced about 1 pound of pulp, moisture-free basis; hence, 16 to 18 runs per yield were required.

Mixture of Oaks

The design pattern for the oak mixture was different than that of the alder in some phases as shown in table 4. No replications were made other than those dictated by necessity; however, since another variable, molding pressure, was introduced, a total of 40 boards was also required. (For further elaboration see Method of Testing.)

Equipment and Procedure

As previously indicated both woods were fiberized in a laboratory model Defibrator (4).

Pulp Refining

In each case the entire batch of pulp of a given yield was refined in a small disk mill (4). The refining was carried out so as to obtain a stock with a Defibrator freeness of approximately 40 seconds. This was done by frequent sampling of the refined pulp and readjustment of the plate clearances of the mill.

Stock Freeness and Mat Preparation

The determination of the freeness of the stocks and the forming of the pulp mats were accomplished by means of a Defibrator freeness tester and mat former (4). The entire batch of each refined stock was dispersed in softened water in a large tank and thoroughly mixed. In each case, to facilitate freeness determinations, sizing, and mat preparation (4), portions of the slurry were placed in a 30-gallon tank and diluted to a consistency of 2 to 2.5 percent.

Pressing

The hardboards made were nominal 1/8-inch size. The mats were cold pressed at 500 pounds per square inch and the moisture content of the mats approximated 60 percent. All boards were molded at 195° C.

The pressing schedules for these boards are given in table 4. The total pressing time in each case was 10 minutes, including the initial period at maximum pressure, the breathing period at a pressure of 100 pounds per square inch, and the final period at maximum pressure.

Selection of Test Specimens

Test Methods

The hardboard disks were approximately 8-1/2 inches in diameter. This precluded the preparation of standard size specimens for modulus of rupture and water absorption tests. Test specimens cut from each board were as follows:

	Red alder	Oak
Static bending	2 - 5 x 1.4 inches	2 - 5 x 2 inches
Toughness	2 - 4 x 5/8 inches	2 - 4 x 5/8 inches
Linear expansion	1 - 5 x 3/4 inches	1 - 5 x 2 inches

The modulus of rupture specimens, though small, met the length-thickness ratio requirement of 24 to 1 required by ASTM Standard D1037-52T. The modulus of elasticity data for the alder hardboards were calculated from the deflection data obtained in the static bending determinations.

The toughness tests were made according to ASTM Standards No. 805-52 for testing veneer, plywood, and other glued veneer constructions.

The 24-hour immersion water absorption tests were run on the tested modulus of rupture specimens. Previous exploratory investigations have shown that the size of specimen did not materially affect the water absorption values; hence, the findings are more significant and not merely of comparative value.

Chemical Analysis

Both the alder and oak mixtures were analyzed for lignin, total pentosans, and extractives. Ether, 99 percent methyl alcohol, and hot water solubilities were made successively on the same sample. All tests were made according to TAPPI Standards (5), except that 99 percent methyl alcohol was substituted for alcohol-benzene and that extractions were made on the same sample in the succession indicated.

Only total pentosan and 99 percent methyl alcohol solubility were run on the pulps. Unsized boards were also analyzed but this analysis was limited to a 99 percent methyl alcohol solubility determination.

Dimensional Stability

The linear and volumetric variations with change in moisture content were made according to ASTM Standards D1037-52T. The specimens were smaller than specified but the comparative data are considered significant.

Discussion of Results

The data collected were in excess of that used for the analysis of results. The data for the entire zero alum content series for both woods were deleted except for the dimensional stability data. This was done because the results indicated that in some instances size was being affixed to the fibers. Furthermore, it was noted that the inclusion of the deleted series would not influence the evaluation of the data.

For both species the data were arranged in a three-yield factorial table. The data tabulated were the averages and range test results for each alum-size combination hardboard. From this arrangement, at each yield level, an estimate, when feasible, of the standard deviation (s) for each property measured was as follows:

Degrees of size content - 4
Degrees of alum content - 4
Total number of average results - 16

$$s = \frac{(\text{Average range})}{\sqrt{16}\ (2.059)}$$

The estimated 95 percent confidence level limits for any particular phase (P) covering three different yields (Y_1, Y_2, Y_3) are:

$$2sP = \frac{2\sqrt{(sY_1)^2 + (sY_2)^2 + (sY_3)^2}}{3}$$

For two comparable phases (P_1P_2) such as oak hardboards molded at 500 pounds per square inch (a) and 1,000 pounds per square inch (b), the estimated 95 percent confidence level limits are:

$$2sP_1P_2 = \frac{2\sqrt{(sY_1P_1)^2 + (sY_2P_1)^2 + (sY_3P_1)^2 + (sY_1P_2)^2 + (sY_2P_2)^2 + (sY_3P_2)^2}}{6}$$

Yields

As previously reported (4) oak wood is sensitive to steam cooking. Thus, to obtain comparable yields of defibrator pulp from the mixture of oak and from the red alder, it was necessary to defibrate the oak at 125 pounds per square inch and the alder at 175 pounds per square inch. Some, but not all, of this difference can be attributed to the high total solubility value for oak shown in table 2.

Relation of Yield to Board Properties

The properties of the hardboards prepared from the alder and the oak mixture are influenced by the yield and the amount of additives--size and alum. It is apparent from the data given in figures 1, 2, 2a, 3, and 4 that:

(a) The flexural strength and toughness of the hardboards reach an optimum at the 83 to 85 percent yield level. This is in agreement with data obtained with pulp sheets obtained from various steam- and water-cooked attrition-milled aspen chips (3).

(b) That water absorption, thickness, and volume change decreases with yield.

(c) That linear dimensional change, though relatively small, increases with a decrease in yield.

Because of the interaction of yield, size, and alum, hardboards that meet specifications for class 1, untreated hardboards (1), are not necessarily in the 83 to 85 percent yield level. All pulp yields, however, above the 85 percent yield level were unsuitable for the production of class 1, untreated hardboard. The data on some indicative hardboards of each yield category are given in table 5.

The Influence of Increasing the Molding Pressure on Oak Hardboards

Increasing the pressure from 500 to 1,000 pounds per square inch in preparing oak hardboard resulted in boards of slightly higher flexural strength but the boards were decidedly denser. No improvement in toughness, water resistance, or thickness change was noted (see figs. 2, 2a, and 3).

The Influence of Alum and Size on Board Properties

Both alum and size are necessary to impart good water resistance to hardboard. In general, increasing the size increases water resistance but decreases all strength properties. This holds for oak as well as alder. Previous contention that a certain amount of size was required to secure oak hardboards of optimum flexural strength is not tenable (3). In general, increasing the alum beyond 1 percent had but little influence on the alder hardboards. On the other hand, increasing the alum beyond 2 percent decreased toughness, water absorption, and thickness change of the oak hardboards. These data are presented on the basis of size or alum to show their relationship to yield of pulp.

The large amount of alum necessary to obtain good sizing with oak Asplund pulps is objectionable. The alum demand has been attributed to tannins or tannin-like compounds in oaks (4). Some means of overcoming this deficiency is in order.

Relationship of Total Pentosans and Methyl Alcohol Solubilities of the Pulps to Some Board Properties

The total pentosans of the alder and oak pulps decreased with yield. As shown in figures 1 and 3, the water absorption and thickness change decreased with a decrease in pulp yield. Hence, it was not surprising to find a direct relationship between total pentosans of the pulps and these properties of the boards (fig. 5). The influence of pentosan content on swelling tendency of softwood pulps was studied extensively. Young and Rowlands (6) experimentally established that this relationship is approximately linear.

The methyl alcohol solubilities of the pulps increased as the yields decreased. This has been attributed to the increase of soluble lignin, a measure of the plasticity or "activation" of lignin (2). Hence, the lower yield pulps produce denser hardboards than the higher yield pulps at comparable molding conditions. Likewise, water absorption and thickness change decreased with an increase in soluble lignin of the pulps (fig. 5); hence, the decrease in water absorption can be attributed to a decrease in pentosan content and an increase in soluble lignin content.

Dimensional Stability

The stability in the thickness dimension and in volume improved as the yield decreased. However, the change in the linear dimension, though relatively small, increases as the yield decreases (fig. 4). These changes can be attributed to the increase in plasticity of the lignin as the yield decreases (2). The increase in linear expansion with a decrease in yield is probably due to an increase in fiber-to-fiber bond, hence less internal slippage.

The dimension changes are based on the procedure outlined in ASTM Standards D1037-52T. However, these data do not take into account changes, mainly thickness and volumetric changes, brought about by "springback." In hardboard the fibers are compressed by a force perpendicular to its surface; hence in the thickness change swelling occurs due both to moisture take-up and recovery from compression (springback). Data obtained on a 1-cycle humidity change will not disclose that information. On the basis of a 2-cycle humidity change, we obtain a similar trend of results; however, we have established maximum and minimum dimensional changes for these hardboards (fig. 5). The first cycle of the dimensional stability tests was made on all red alder boards, but the second cycle tests were limited to the 1 percent size and 1 percent alum category of each yield group. The dimensional stability tests on the oak hardboards, however, were limited to the following groups:

Molding pressure.............p.s.i.:	500		1,000	
Alum.......................percent:	0	8	0	8
Size.......................percent:	0	0	0	0
	1	1	1	1

Essentially, the differences between these maximum and minimum values is "springback."

Conclusions

Class 1, untreated hardboards, were prepared from red alder and oak Asplund stocks.

It has been established that for red alder and oak hardboards:

(a) The flexural strength and toughness reach an optimum at the 83 to 85 percent level.

(b) Water absorption, thickness, and volume change decrease with yield.

(c) The linear dimensional change, though relatively small, increases with a decrease in yield.

Literature Cited

1. Interim Federal Specifications (Fiberboard, Hardboard, Fibrous-felted) LLL-F-00311 (GSA-FSS), Dec. 1953.

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3. McGovern, J. N., Brown, K. J., and Kraske, W. A. Tappi, Vol. 32, No. 10, pp. 440-448, Oct. 1949.

4. Schwartz, S. L. Tappi, Vol. 36, No. 10, pp. 445-451, Oct. 1953.

5. TAPPI Standards: T13M-45, T223M-43, T5M-51, T6M-50, and T1M-51.

6. Young, G. H. and Rowland, B. N. Paper Trade Jour., Vol. 97, No. 15, pp. 178-180, Oct. 1933.

Table 1.--Physical characteristics of red alder and several southern white and red oaks

Species	Shipment No.	Data on selected bolts			
		Diameter	Age	Growth rate	Specific gravity (ovendry green volume)
		In.	Yr.	Rings per in.	
Red alder	3265				
(*Alnus rubra*, Bong)		8.3	47	11.2	0.43
Red oaks	4090				
Southern red oak		8.0	131	32.8	.66
(*Quercus falcata*)					
Scarlet oak		7.7	51	13.3	.58
(*Quercus coccinea*)					
Black oak		6.2	49	15.9	.58
(*Quercus velutina*)		7.3	52	15.0	.58
White oaks	4091				
Post oak		9.7	127	26.1	.60
(*Quercus stellata*)					
White oak		8.5	67	15.9	.58
(*Quercus alba*)					
Chestnut oak		8.2	95	23.1	.63
(*Quercus prinus*)		7.4	100	27.2	.65

Table 2.--Chemical analysis of red alder chips and of a mixture of chips of southern white and red oaks

Species	Lignin	Holocellulose[1]	Total pentosans	Solubility data			
				Ether	Methyl alcohol	Hot water	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Red alder	24.1	69.8	18.6	0.5	1.9	3.7	6.1
Mixture of oaks	24.1	64.0	20.1	.8	4.6	6.5	11.9

[1] By difference.

Table 3.--The processing conditions and yields of pulp for red alder and mixture of oak fiberized in a laboratory-model Asplund defibrator

Species	Defibrator run No.	Processing conditions				Pulp			
		Steam pressure	Presteaming period	Milling period	Total time	Number of runs	Yield	Asplund freeness	Selected for use
		P.s.i.	Min.	Min.	Min.		Percent	Sec.	
Red alder	88	175	1	1	2	4	95.2	14	Yes
Do.	93	175	1	3-1/2	4-1/2	4	84.8	16	Yes
Do.	92	175	1	6	7	8	80.0	18	Yes
Mixture of oaks	94	175	1	1	2	1	82.4	....	No
Do.	95	175	1	3-1/2	4-1/2	1	71.4	....	No
Do.	96	175	1	6	7	1	67.4	....	No
Mixture of oaks	97	125	1	1	2	4	91.5	12	Yes
Do.	98	125	1	3-1/2	4-1/2	4	83.2	18	Yes
Do.	99	125	1	6	7	4	78.7	22	Yes

Table 4.--The research design pattern for the production of red alder and oak mixture hardboards

Number of pulp yields	Number of boards	Number of test specimens per board	Size	Alum						Total number of boards
			Percent	Percent	Percent	Percent	Percent	Percent		
					RED ALDER HARDBOARD[1]					
3	2	2	0	0	1	2	4	6		10
			1/4	0	1	2	4	6		10
			1/2	0	1	2	4	6		10
			1	0	1	2	4	6		10
							Grand Total			40
					OAK MIXTURE HARDBOARD[2]					
3	2	2	0	0	2	4	6	8		10
			1/4	0	2	4	6	8		10
			1/2	0	2	4	6	8		10
			1	0	2	4	6	8		10
							Grand total			40

[1]For each pulp yield a total of 160 test specimens were scheduled for the following: (a) modulus of rupture, (b) modulus of elasticity, (c) toughness, (d) water absorption, (e) thickness change, and (f) specific gravity. However, for dimensional stability tests, 1 test specimen per board was scheduled.

[2]For each pulp yield a total of 160 test specimens were scheduled for the following: (a) modulus of rupture, (b) toughness, (c) water absorption, (d) thickness change, and (e) specific gravity. However, for dimensional stability tests, 1 test specimen per board was scheduled. Dimensional stability tests were further limited by confining the tests to 0 and 1 percent size boards containing 0 or 8 percent alum.

Molding Schedules

Species	Pressure		Schedule	Platen temperature
	Maximum	Minimum		
	P.s.i.	P.s.i.	Min.	°C.
Red alder	500	100	2-1-7	195
Oak mixture	500	100	2-1-7	195
Do.......	1,000	100	$1\frac{1}{2}$-$1\frac{1}{2}$-7	195

Table 5.--Some indicative data on hardboards made from red alder and from a mixture of southern oaks

Board No.	Yield	Molding press	Size	Alum	Defibrator freeness	Specific gravity	Modulus of rupture	Toughness	Water absorption	Thickness change
	Percent	P.s.i.	Percent	Percent	Sec.		P.s.i.	In.-lb. per in. of width	Percent	Percent
					RED ALDER					
1758	95.2	500	0	1	40	0.98	7,350	11.0	60.0	36.0
1761	95.2	500	1	1	40	.98	5,100	8.0	28.3	20.6
1778	84.8	500	0	1	43	1.04	8,460	12.8	49.0	29.4
1781	84.8	500	1	1	41	1.03	6,340	9.7	25.5	19.2
1802	80.0	500	0	1	43	1.08	8,330	10.0	42.4	25.6
1805	80.0	500	1	1	42	1.05	[1]5,210	9.4	18.0	14.7
(2)	80.0	500	1	1-6	43	1.06	6,000	10.0	18.5	15.0
					OAK MIXTURE					
1845	91.5	500	0	8	38	.98	6,330	6.6	49.5	26.1
1874	91.5	500	1	8	39	1.01	5,100	5.0	18.9	18.9
1883	83.2	500	0	8	42	1.04	7,480	7.5	40.9	23.4
1913	83.2	500	1	8	44	1.03	5,750	6.3	18.9	15.6
1923	78.7	500	0	8	41	1.06	6,380	4.0	27.8	14.4
1963	78.7	500	1/2	6	43	1.05	5,720	4.4	18.7	12.8
					1/8 HARDBOARD SPECIFICATIONS[3]					
Class 1, Type 1, S-1-S							[4]5,500	....	[5]20.0	[5]16.0

[1] This value is low. The variability of the results obtained is reflected by this value, which is in variance with the overall data.

[2] Average values for boards Nos. 1805, 1809, 1813, and 1817.

[3] Interim Federal Specifications, LLL-F-00311 (GSA-FSS) Dec. 10, 1953.

[4] Minimum value.

[5] Maximum value.

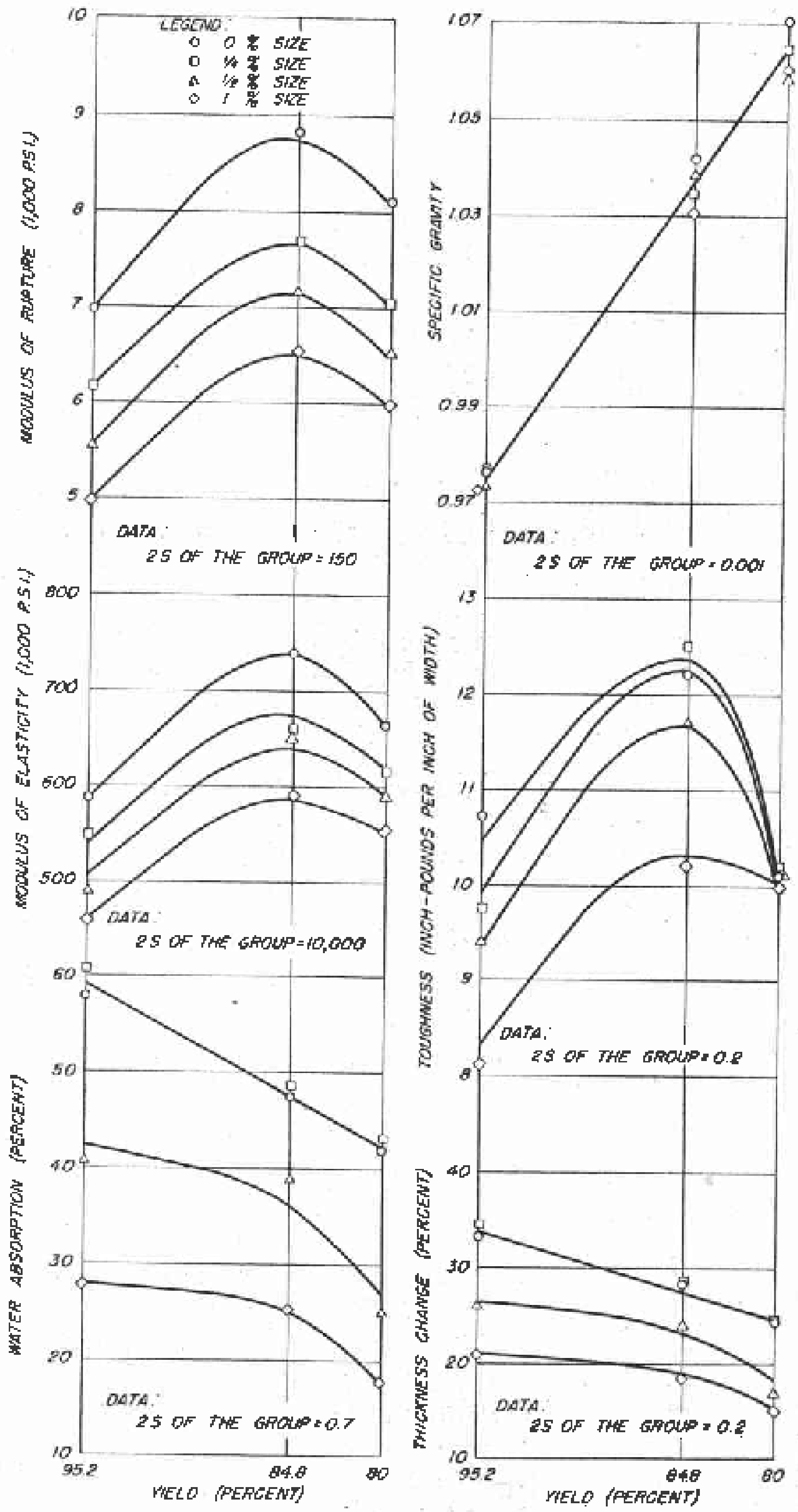

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Figure 1.--The relationship of pulp yield to some physical properties of red alder hardboard.

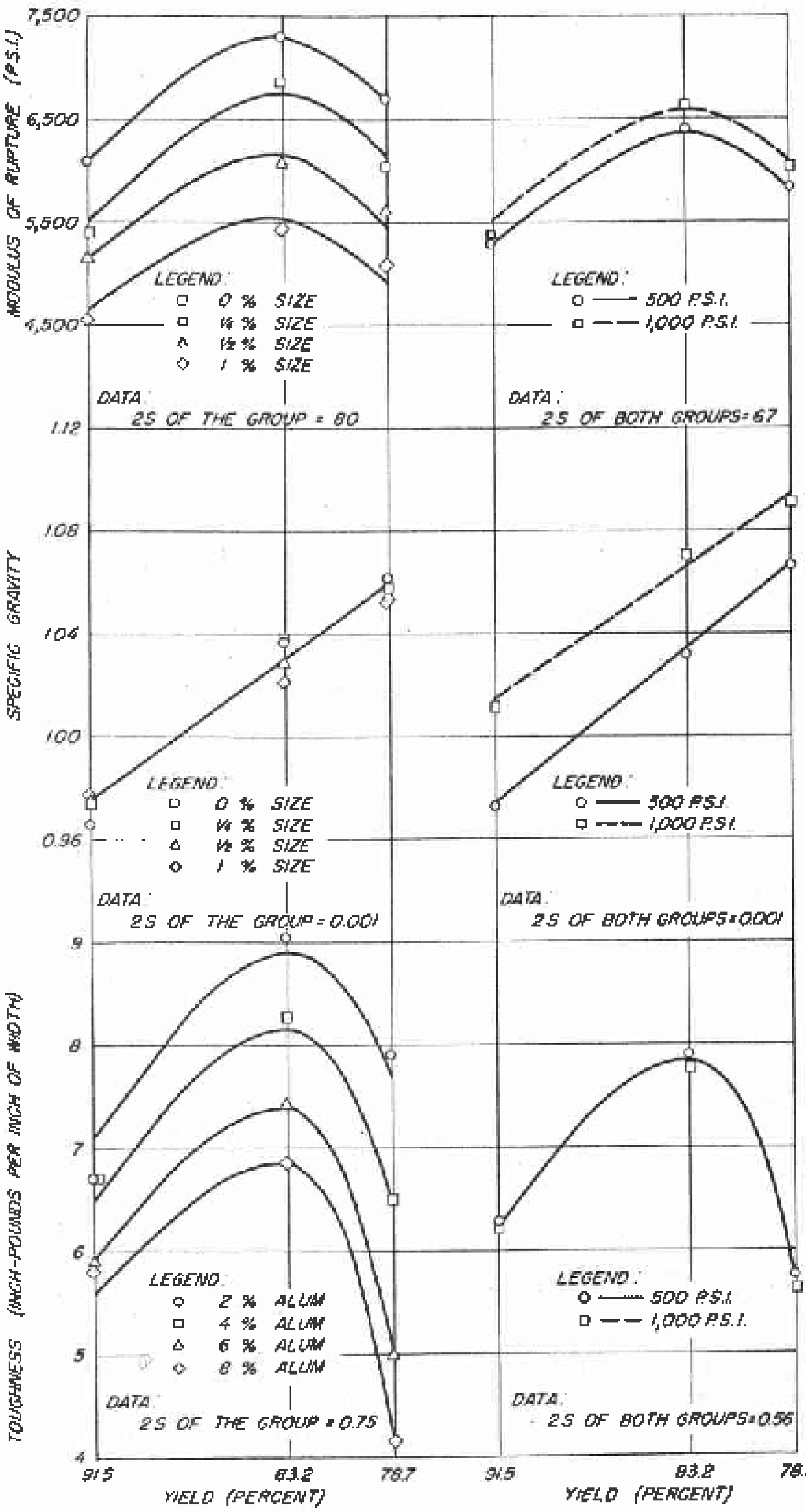

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Figure 2.--The relationship of pulp yield to some of the physical properties of oak hardboards.

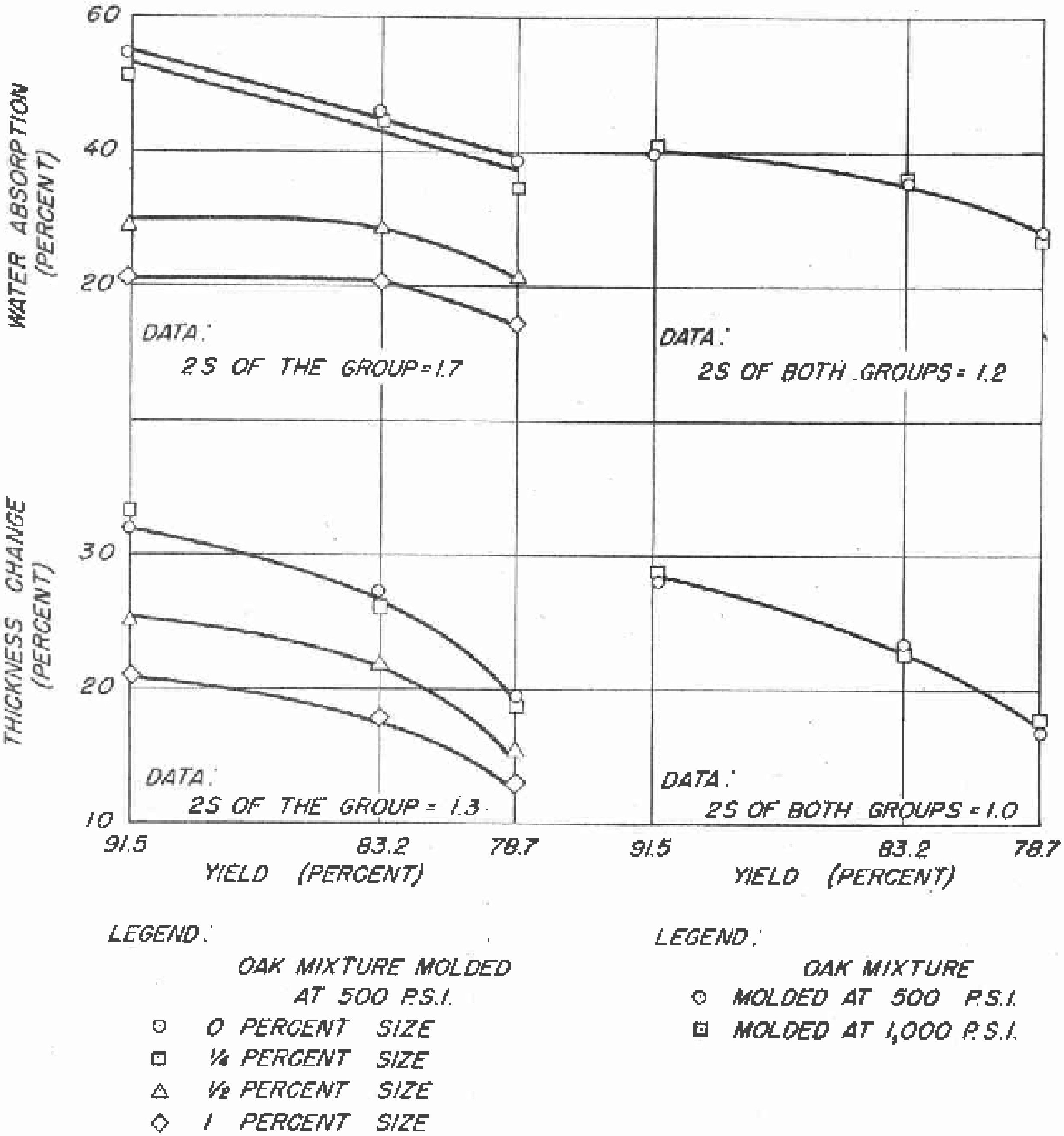

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Figure 2a. --The relationship of pulp yield to some of the physical properties of oak hardboard.

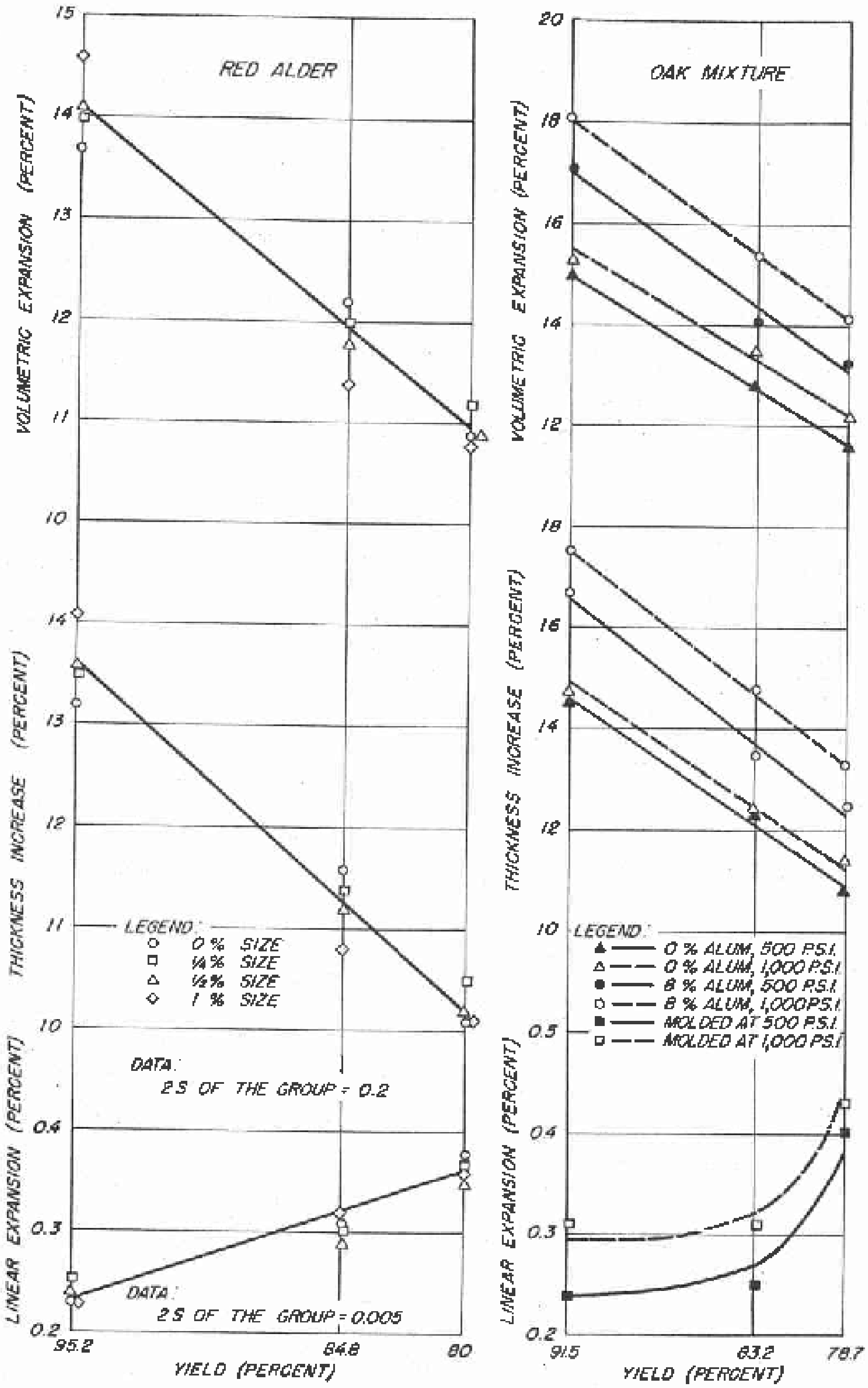

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Figure 3.--The relationship of pulp yield to dimensional changes of red alder and oak hardboards (1st cycle).

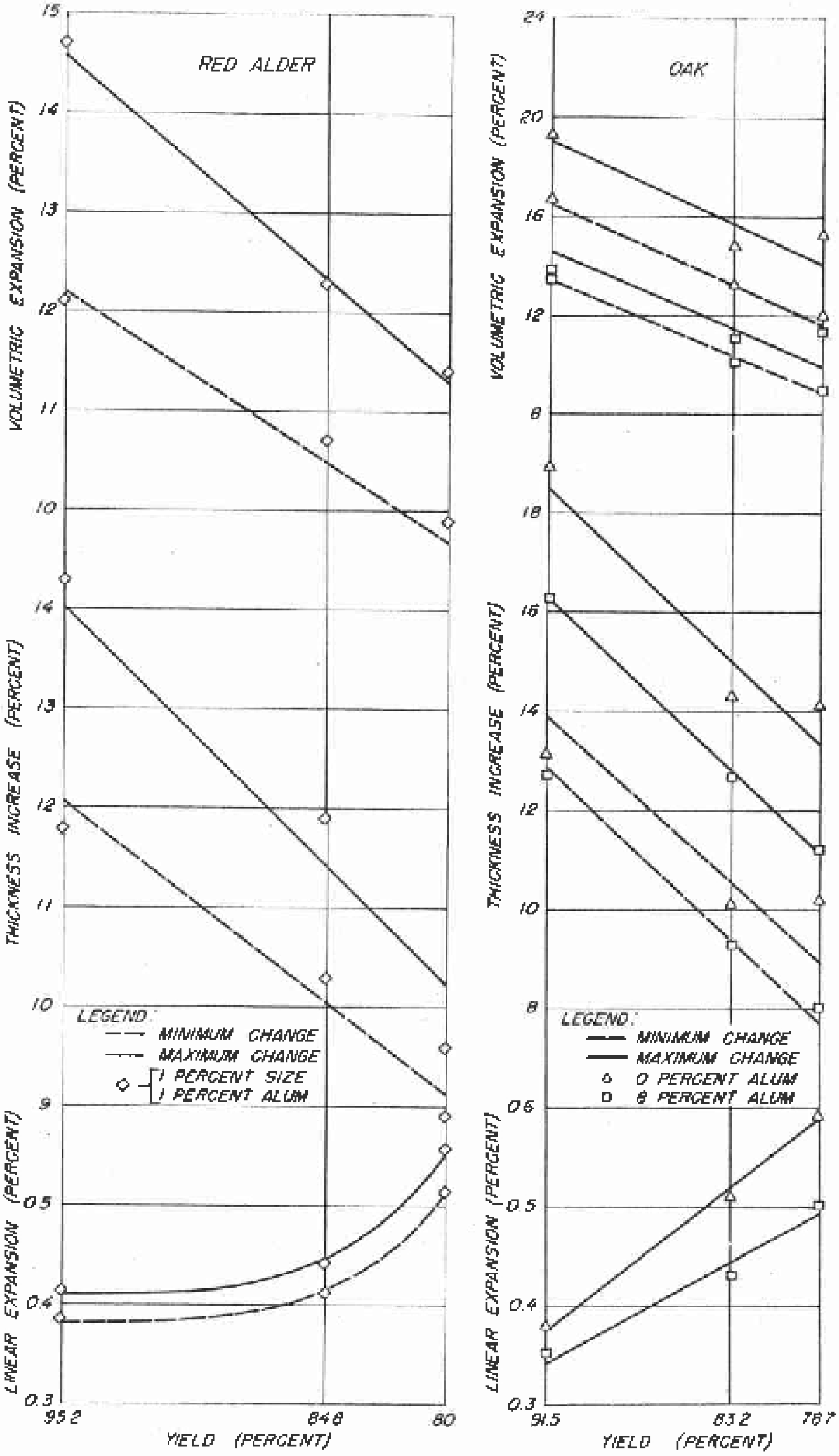

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Figure 4. --The relationship of pulp yield to dimensional changes of red alder and oak hardboard (2nd cycle).

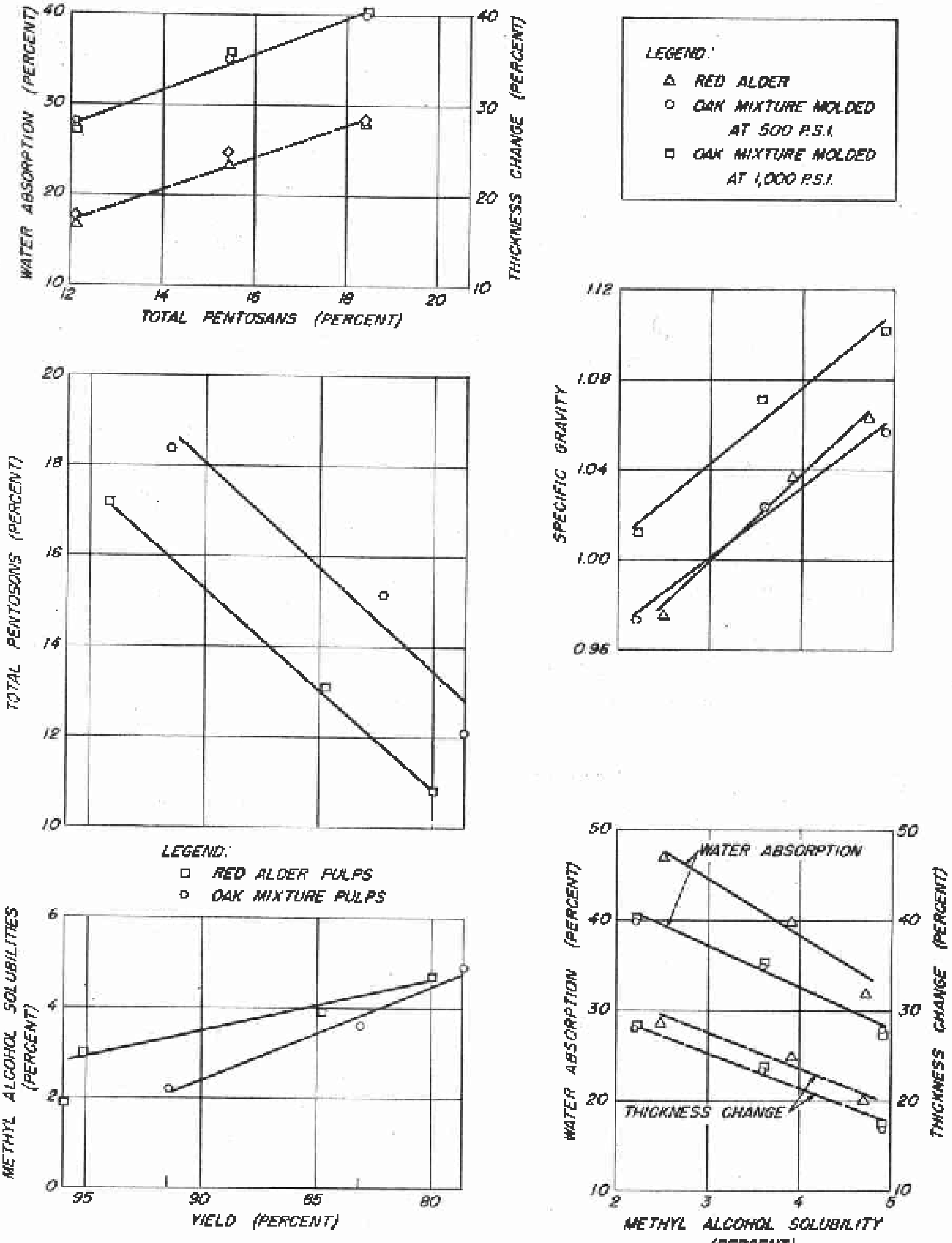

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Figure 5.--The relationship of total pentosans and methyl alcohol solubilities to pulp yields and water resistance of red alder and oak hardboards.

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