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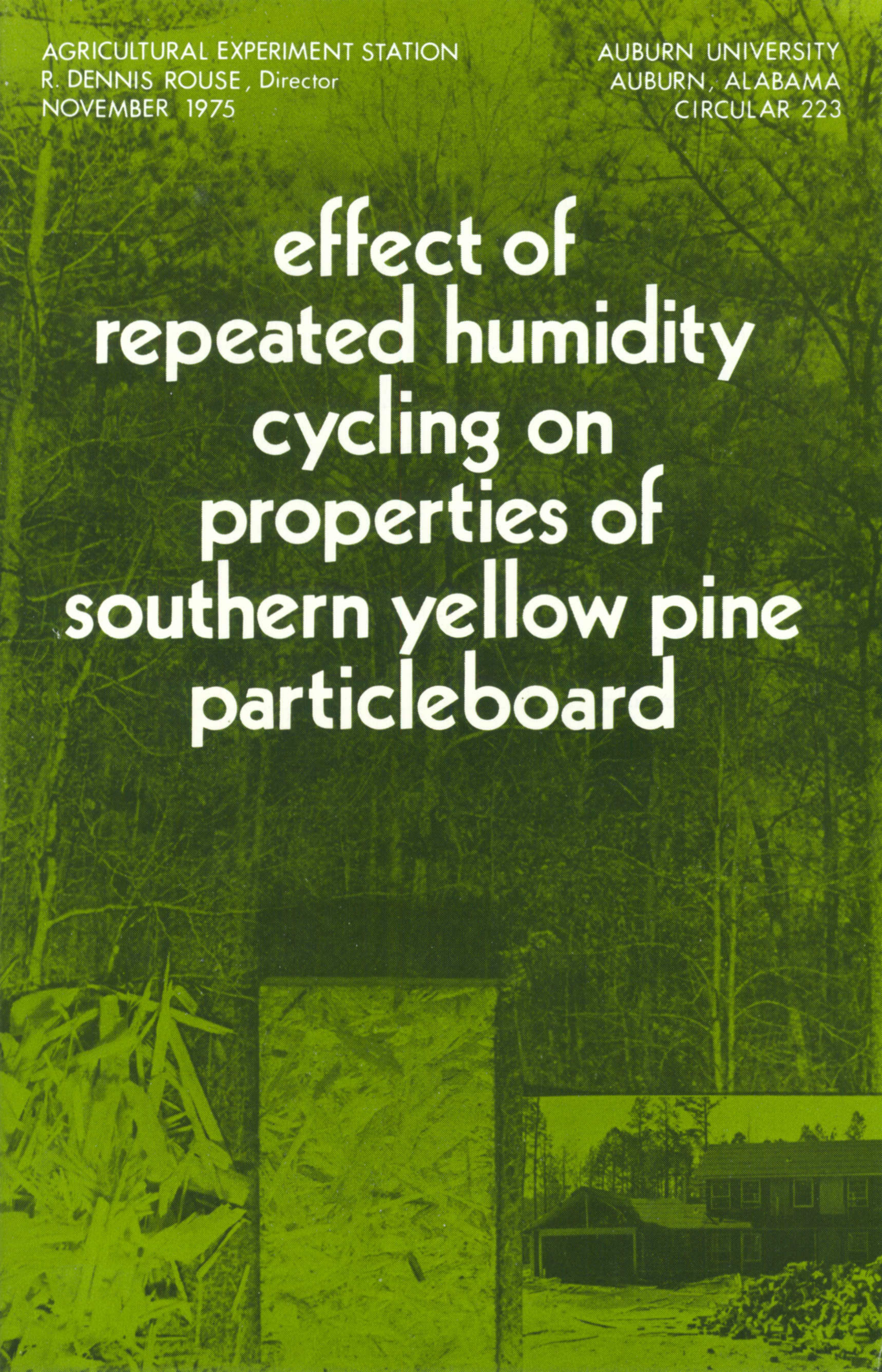

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Effect Of Repeated Humidity Cycling On Properties Of Southern Yellow Pine Particleboard

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MOST PARTICLEBOARD is presently manufactured for interior use. Such boards, in use, are subjected to fluctuations in relative humidity and temperature that affect their performance. Therefore, it is essential to establish the long-term effect of humidity and temperature fluctuations on particleboard durability *(4,5,7)*. Suchsland *(8,9)* reported considerable changes of dimensions and particleboard properties caused by humidity changes. The effect of long term outdoor exposure as well as controlled humidity and temperature on thickness swelling of exterior type particleboards was investigated by Gatchell and others *(3)*. Effect of high and low humidity cycling on certain mechanical properties of Douglas-fir particleboard was investigated by Bryan and Schniewind *(2)*. The effects of one cycle exposure to controlled humidity and temperature on southern pine particleboard properties have been reported by the authors *(6)*. This circular presents the influence of three repeated humidity cycles on dimensional changes and certain mechanical properties of southern pine particleboards.

MATERIALS

One panel (4′ × 8′) of each of the following commercial underlayment particleboard types was used in this study.

Five-eights inch, three-layer southern pine board bonded with phenolic resin (7 percent solids) and 0.7 percent wax.

Five-eights inch, three-layer southern pine board bonded with phenolic resin (7 percent solids) without wax.

Five-eights inch, three-layer southern pine board bonded with urea resin (7 percent solids) and 0.7 percent wax.

Urea board was manufactured from approximately 85 percent southern yellow pine shavings and 15 percent hardwood chips

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while phenolic boards were made from 100 percent southern pine shavings. All boards were fabricated under the same process and had approximately the same density (50 lb./ft.^{3}).

PROCEDURE

The repeated humidity cycling consisted of three identical cycles: 65 percent RH, 72°F; 90 percent RH, 80°F; 65 percent RH, 72°F; 30 percent RH, 80°F; 65 percent RH, 72°F. The boards reached equilibrium moisture contents (E.M.C.) at each condition of all cycles.

Twelve flexural specimens (3″ × 24″) were cut from each type of particleboard. Six of these specimens were conditioned to E.M.C. at 65 percent RH, 72°F and afterwards tested destructively to obtain flexural modulus of elasticity (MOE), fiber stress at proportional limit (FSPL), and modulus of rupture (MOR) as control values. The remaining six specimens were subjected to cycling and tested non-destructively in bending at each condition. At the last condition of the third cycle, specimens were also tested destructively to obtain final MOE, FSPL, and MOR. All flexural tests were made with central loading according to ASTM (American Society for Testing Materials) D 1037.

Four plate shear specimens (18.75″ × 18.75″) were cut from each type of particleboard. Plate specimens were subjected to cycling and tested non-destructively at each condition according to ASTM D 3044 to determine plate shear modulus (G).

Dimensional changes were determined from plate shear specimens at each condition. Moisture contents (M.C.) were calculated from equilibrium weights and oven-dry weights of one-half the flexural specimens.

Ten internal bond specimens (2″ × 2″) obtained from the undamaged portions of the destructively tested bending specimens at initial and final conditions were tested according to ASTM D 1037 to determine internal bond strength.

Edgewise shear strength of particleboards was determined by rail shear test according to ASTM D 1037. Ten control specimens (3.5″ × 10″) of each type of particleboard were conditioned to equilibrium at 65 percent RH, 72°F and tested. Another ten specimens obtained from cycled plate shear specimens were tested to determine changes in rail shear strength caused by cycling.

The time required for cycling and testing was 12 months.

RESULTS AND DISCUSSION

Moisture contents and thickness changes of all particleboards during the long-term humidity exposure are shown in figures 1 and 2, respectively. Thickness changes were expressed as percentages of the original thickness at 65 percent RH, 72°F. The equilibrium moisture content (E.M.C.) of urea board throughout the entire exposure was approximately 1 percent higher than the E.M.C. of phenolic board with wax. Equilibrium moisture contents of each type board were approximately equal at the same conditions of successive cycles. The average E.M.C. at 30 percent RH was 7 percent, while the E.M.C. at 90 percent RH was 14 percent. The average E.M.C. at 65 percent RH ranged from 9 percent to 12 percent depending on absorption or desorption of moisture. An average 2 percent M.C. hysteresis developed during sub-cycling from 65 percent to 90 percent and back to 65 percent RH. Final E.M.C. was approximately 1 percent higher than initial E.M.C.

Average thickness swelling from 65 to 90 percent RH for three cycles was 3.2 percent for urea board and 2.5 percent for phenolic boards. A considerable portion of this swelling was irreversible.

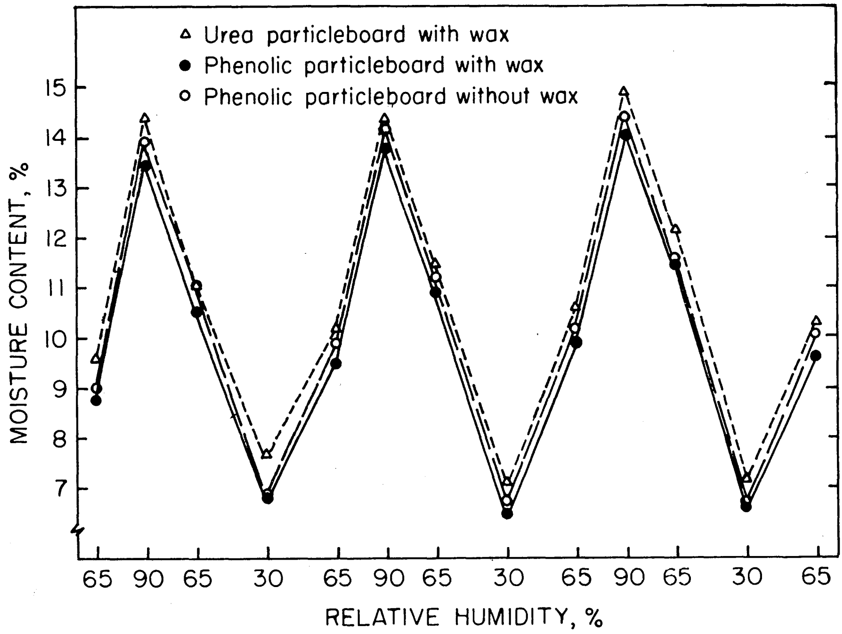

FIG. 1. Moisture content (percent) of particleboards during cycling.

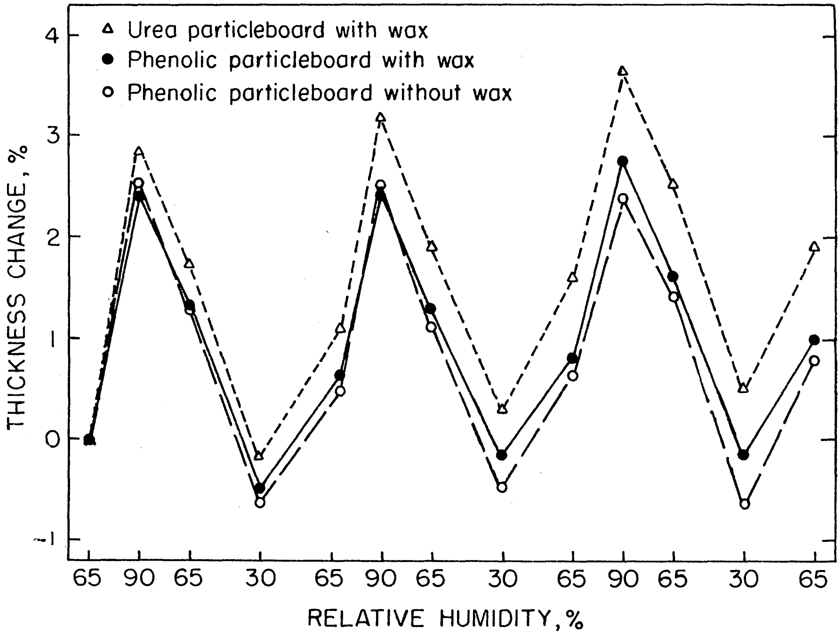

FIG. 2. Thickness changes (percent) of particleboards during cycling.

After three complete cycles, final thicknesses at 65 percent RH of urea and phenolic boards, respectively, were 2 percent and 1 percent higher than initial thicknesses. Urea board exhibited increasing thickness swelling with cycling and simultaneous increase of the irreversible portion. There was no appreciable additional thickness swelling of phenolic boards during the second and third cycles.

The effect of humidity cycling on values of flexural modulus of elasticity is shown in Figure 3. The initial reductions in MOE caused by exposure to 90 percent RH were 22 percent, 23 percent, and 25 percent for urea board with wax, phenolic board with wax, and phenolic board without wax, respectively. Repeated exposure to 90 percent RH by the second and third cycles caused additional reduction in MOE values of all types of boards. The largest additional reduction was observed for urea board, followed by phenolic board with wax and phenolic board without wax. The maximum reductions of MOE values, between the original condition (65 percent RH) and after three complete cycles at 65 percent RH, were 20 percent for urea board, 14 percent for phenolic board with wax, and 15 percent for phenolic board without wax. The calculated reduction of MOE during cycling is not entirely due to reduction of the stiffness of load carrying capacity (P/y) of the material but also to increasing dimensions of material. The change of stiffness (EI) of all boards with cycling is shown in Figure 4. Total reductions of EI after three cycles at 65 percent RH were 15 percent, 11 percent, and 11 percent, respectively, for urea board with wax, and phenolic boards with and without wax.

A comparison of flexural properties of particleboards after three exposure cycles with original properties is presented in Table 1.

TABLE 1. COMPARISON OF FLEXURAL PROPERTIES OF SOUTHERN YELLOW PINE PARTICLEBOARDS AFTER THREE EXPOSURE CYCLES WITH ORIGINAL PROPERTIES[1]

Particleboard type (resin)	MOE (ksi)			FSPL (psi)			MOR (psi)		
	Control	After 3 cycles	Reduction (percent)	Control	After 3 cycles	Reduction (percent)	Control	After 3 cycles	Reduction (percent)
Urea with wax	536	428	20.1	882	578	34.5	2633	2051	22.1
Phenolic with wax	522	448	14.2	827	633	23.5	2589	2201	15.0
Phenolic without wax	547	467	14.6	1065	749	29.7	2979	2377	20.2

[1] Both control specimens and specimens after three cycles were tested at 65 percent RH. Each value is the average of 6 specimens.

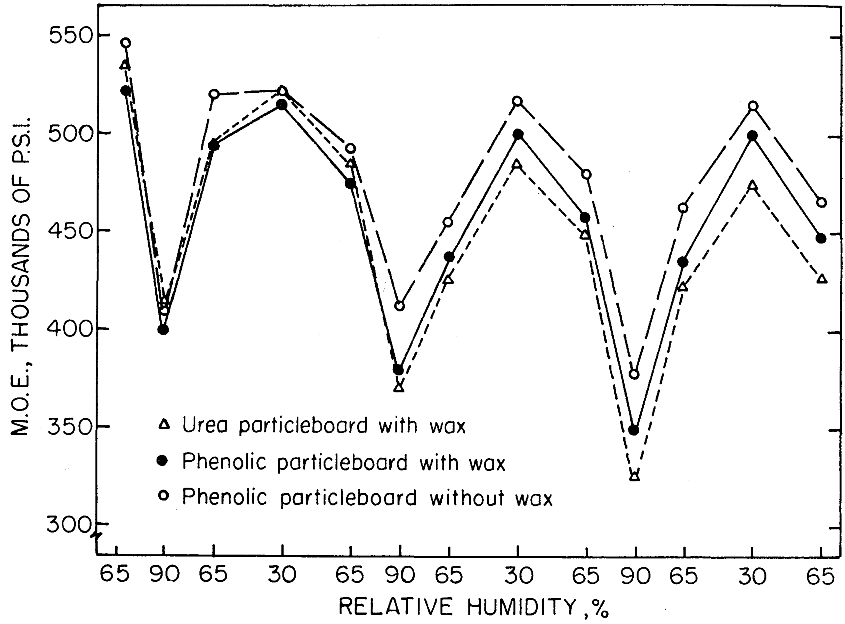

FIG. 3. Modulus of elasticity of particleboards during cycling.

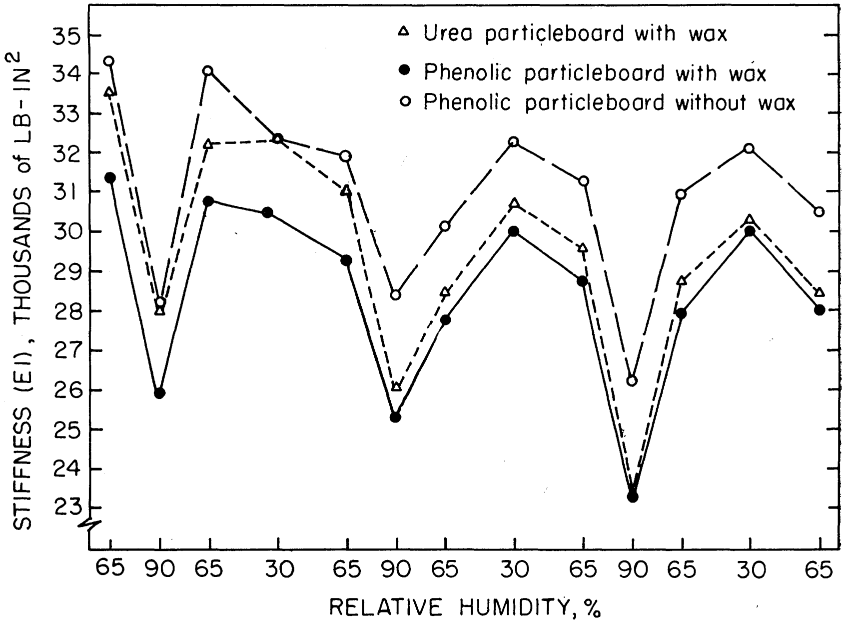

FIG. 4. Stiffness (EI) of particleboards during cycling.

More than one-half of the total reduction of MOE occurred in the first cycle. After three complete cycles at 65 percent RH, values of MOR were reduced by 15 percent, 20 percent, and 22 percent, respectively, for phenolic boards with wax, phenolic without wax and urea board with wax.

Plate shear moduli of particleboards subjected to cycling are

TABLE 2. COMPARISON OF PLATE SHEAR MODULUS, RAIL SHEAR STRENGTH, AND INTERNAL BOND STRENGTH OF SOUTHERN YELLOW PINE PARTICLEBOARDS AFTER THREE EXPOSURE CYCLES WITH ORIGINAL PROPERTIES[1]

Particleboard type (resin)	Plate shear Modulus[2] (ksi)			Rail shear Strength[3] (psi)			Internal bond[3] (psi)		
	Control	After 3 cycles	Reduction (percent)	Control	After 3 cycles	Reduction (percent)	Control	After 3 cycles	Reduction (percent)
Urea with wax	183	157	14.2	1007	872	13.4	127	95	25.2
Phenolic with wax	203	183	9.9	1089	930	14.6	111	101	9.0
Phenolic without wax	212	191	9.9	1120	994	11.3	109	95	12.8

[1] Both control specimens and specimens after three cycles were tested at 65 percent RH.

[2] Each value is the average of 4 specimens.

[3] Each value is the average of 10 specimens.

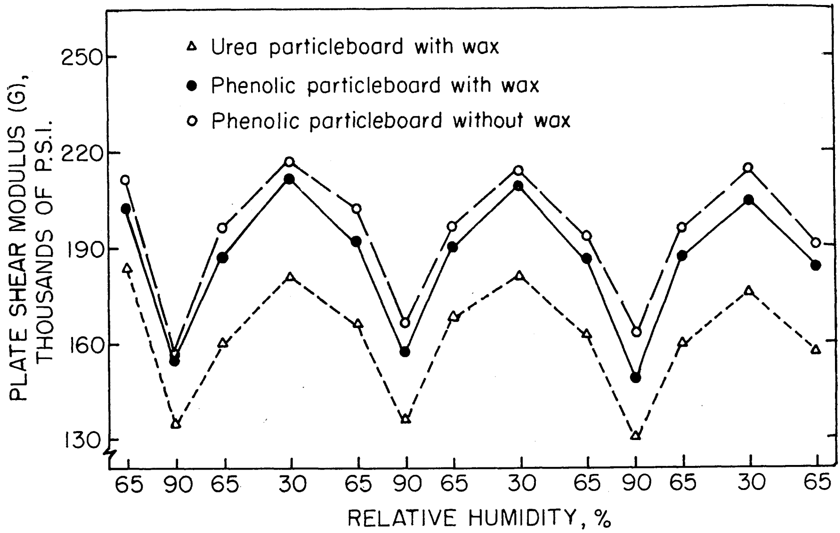

FIG. 5. Plate shear modulus of particleboards during cycling.

shown in Figure 5. Changes of shear moduli in the second and third cycles were similar to those in the first cycle, but more than one-half of the total reduction of G occurred during the first cycle.

Comparisons of original values of plate shear modulus, rail shear strength, and internal bond strength with values after exposure to three cycles are shown in Table 2. The effect of humidity cycling on the internal bond strength of urea board was much larger than that of phenolic boards. Urea board lost 25 percent of internal bond strength after exposure to three cycles, while phenolic boards with and without wax lost only 9 percent and 13 percent, respectively.

SUMMARY

Equilibrium moisture contents of particleboards exposed to low humidity (30 percent RH) and high humidity (90 percent RH) were 7 percent and 14 percent, respectively. The E.M.C. of urea board was always higher than the E.M.C. of phenolic board at the same RH condition. A moisture hysteresis developed during sub-cycling from 65 percent to 90 percent and back to 65 percent RH. Thickness changes of particleboards during cyclic exposure ranged from –0.6 percent to +3.6 percent based on the original thickness at 65 percent RH. A significant amount of irreversible swelling developed during sub-cycling from 65 percent to 90 percent and back to 65 percent RH. Urea board exhibited additional thickness swelling during the second and third cycles, while phenolic boards did not.

Flexural properties (MOE, FSPL, and MOR) of particleboards after exposure to three cycles were reduced between 14 percent and 34 percent of their original values. More than one-half of the total reduction in MOE occurred in the first cycle.

Reductions of plate shear modulus and rail shear strength after three cycles ranged from 10 percent to 15 percent. Internal bond strength of urea board was reduced 25 percent after cycling, while phenolic board with wax decreased only 9 percent. Among three types of boards, phenolic board with wax exhibited the highest retention of flexural properties and internal bond strength after cycling. Both phenolic boards exhibited smaller thickness changes and lower E.M.C. than urea board during cycling.

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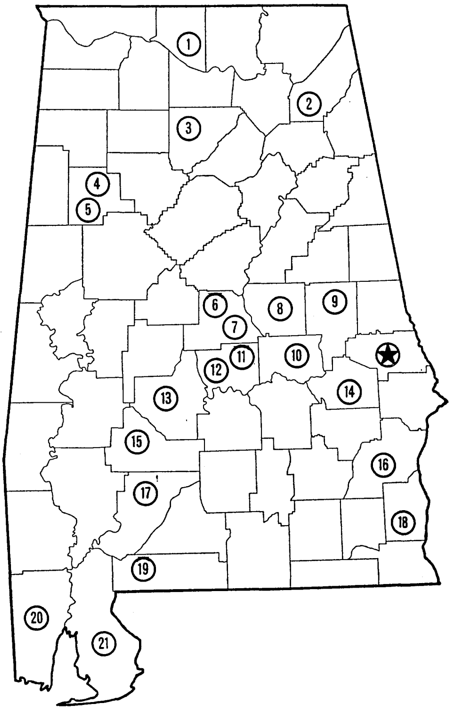
With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the State has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.



Research Unit Identification

★ Main Agricultural Experiment Station, Auburn

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Thorsby Foundation Seed Stocks Farm, Thorsby.
7. Chilton Area Horticulture Substation, Clanton.
8. Forestry Unit, Coosa County.
9. Piedmont Substation, Camp Hill.
10. Plant Breeding Unit, Tallassee.
11. Forestry Unit, Autauga County.
12. Prattville Experiment Field, Prattville.
13. Black Belt Substation, Marion Junction.
14. Tuskegee Experiment Field, Tuskegee.
15. Lower Coastal Plain Substation, Camden.
16. Forestry Unit, Barbour County.
17. Monroeville Experiment Field, Monroeville.
18. Wiregrass Substation, Headland.
19. Brewton Experiment Field, Brewton.
20. Ornamental Horticulture Field Station, Spring Hill.
21. Gulf Coast Substation, Fairhope.