# Effect of hardboard process variables on fiberbonding

**Otto Suchsland**
**George E. Woodson**
**Charles W. McMillin**


## Abstract

Severely cooked Masonite gun pulp was used in the laboratory to manufacture these four hardboard types: S1S-wet formed, S2S-wet formed, S1S-dry formed (water added after forming), S2S-dry formed. No resins or other additives were used.

S2S boards, both wet and dry formed, had superior mechanical properties. However, these same boards had greater linear expansion. S1S-dry formed boards were very similar to S1S-wet formed boards.

The conclusion was reached that such highly reactive pulp could be used for the manufacture of high quality, dry formed, binderless hardboard.


If a curious observer were to schematically arrange commercial fiberboard processes by their water consumption and type of bonding that occurs between fibers, he would discover a need for clarification of some long standing theories regarding the bonding of fiberboard (Fig. 1).

On the wet side of this process chart are insulation board, S1S hardboard, and S2S hardboard. It is generally agreed that insulation board relies on hydrogen bonding of fibers, brought about by removal from the pulp suspension of water which, owing to its high surface tension, draws fibers into intimate contact with considerable force. This is also the principal bonding mechanism in manufacture of paper.

The S2S-wet[1] board mat goes through the same water evaporation phase and develops the same type of bonding as does the insulation board, although its furnish composition and furnish characteristics may be different. In the hot-press this dried mat is then densified at high pressure and temperature and consolidated "by the activation of the bonding properties of the incrusting substances" (2). The same activation of the incrusting substances (evidently lignin) is believed to be responsible for bond formation in the S1S process (3).

On the other side of the process chart is dry-formed hardboard, which does not benefit from either hydrogen bonding or activation of incrusting substances, but which must rely on added adhesive as binder, like other dry composition boards such as particleboard and plywood.

Figure 1 suggests the following questions:

— What fundamental difference between S2S mats entering the hot-press from both sides of the wet/dry dividing line inhibits the formation of lignin bonding in the dry-formed mat?

— Is the hydrogen bonding associated with wet forming a necessary phase in manufacture of binderless fiberboard?

— To what extent do answers to the above questions depend on raw material and pulping variables?

No clear answers can be found to these questions either in the literature or in discussion with knowledgeable practitioners in the field.

## Design of experiment

To answer the first two questions requires the manufacture and evaluation of all possible hardboard

[1]The attributes wet and dry always refer to the forming process.

The authors are, respectively, Professor of Forestry, Michigan State Univ., East Lansing, MI 48824; Associate Professor of Wood Utilization, Louisiana Tech Univ., Ruston, La.; and Principal Wood Scientist, USDA Forest Serv., Southern Forest Expt. Sta., Pineville, La. This paper was presented at Session 4 (Hardboard and Insulation Board) of the 36th Annual Meeting of the FPRS in New Orleans, La., June 21, 1982. The cooperation of the Masonite Corp. is gratefully acknowledged. The authors further acknowledge the valuable assistance of O.B. Eustis in execution of the experiment. Boards were manufactured at the Forest Prod. Utilization Lab. of the Southern Forest Expt. Sta. in Pineville, La. This paper is Michigan State Agri. Expt. Sta. Journal Article No. 10623, and was received for publication in August 1982.


Forest Prod. J. 33(4):58-64.

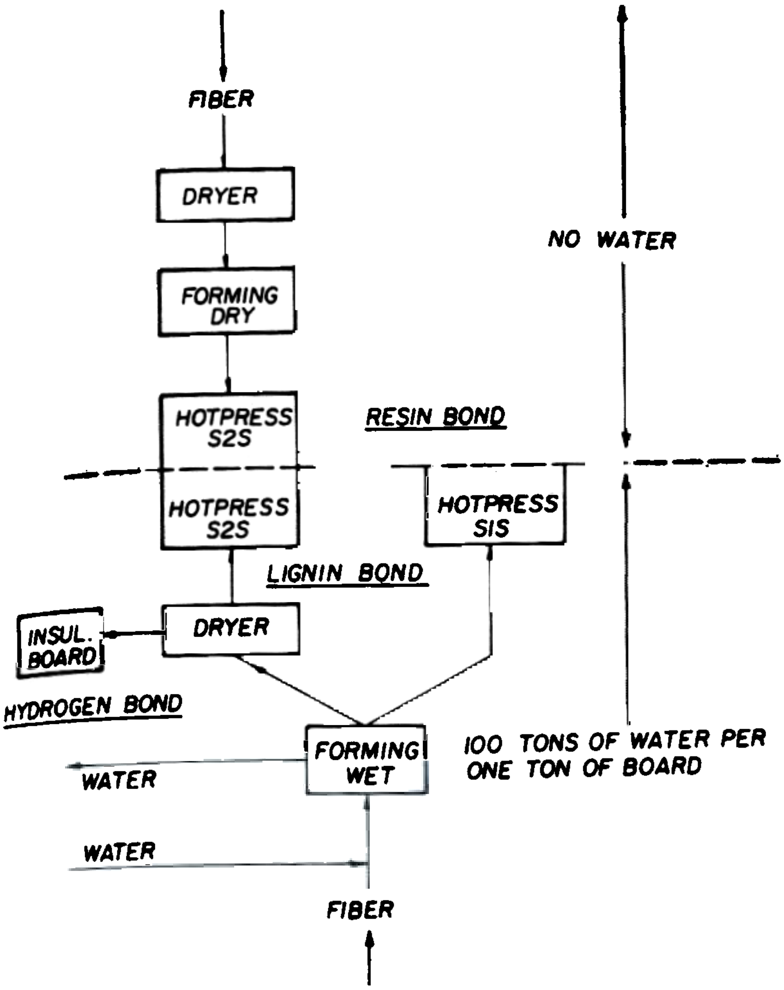



Figure 1. — Schematic overview of commercial fiberboard processes.

types from an identical furnish. The third question requires the repetition of the experiment with different furnishes.

Figure 2 outlines the experiment. It includes four types of hardboard — S1S-wet, S2S-wet, S1S-dry, and S2S-dry. The S1S-dry type attempts to isolate forming variables in the S1S process where mats are normally formed wet. No additives are used in any of the processes with the exception of tap water.

The present study is limited to one pulp furnish, and is the first phase of a larger study including different raw materials and different pulping conditions.

## Procedure

### Pulping

It was decided that the first study would be run with a severely cooked Masonite gun pulp, followed in subsequent studies by refiner pulps, both pressurized and atmospheric. This decision was based on the results of work by Koran (1), suggesting a pulping temperature threshold above which fiber separation occurs primarily in the lignin-rich middle lamellas, leaving the fiber surfaces covered with lignin, and the desire to provide the most favorable conditions for a lignin bonded dry-formed hardboard. Of all commercial pulping devices, the Masonite gun is capable of providing the most severe chip treatment.

The raw material was whole-tree mixed hardwoods chips taken from the production furnish at the Masonite plant in Laurel, Mississippi. A cursory analysis of the chip material is given in Table 1.

The pulp was produced in a commercial Masonite gun under conditions not normally used in manufacture of Masonite hardboard. The gun cycle is illustrated in Figure 3. The resulting pulp was so fine, with the exception of a certain fraction of slivers, that it could not be refined without increasing drainage time to impractical levels. The Tappi drainage time of the raw pulp was 23 seconds.[2] Moisture content averaged 83 percent (55% consistency).

Prior to manufacture of experimental boards in the laboratory, the fraction of slivers was removed by brushing the pulp through 1/4-inch hardware cloth. About 24 percent of the pulp was retained on the screen and discarded. The Bauer-McNett classification of the pulp before and after screening is given in Table 2.[3]

[2]Tappi: T1002 sm-51

[3]Tappi: T-233.

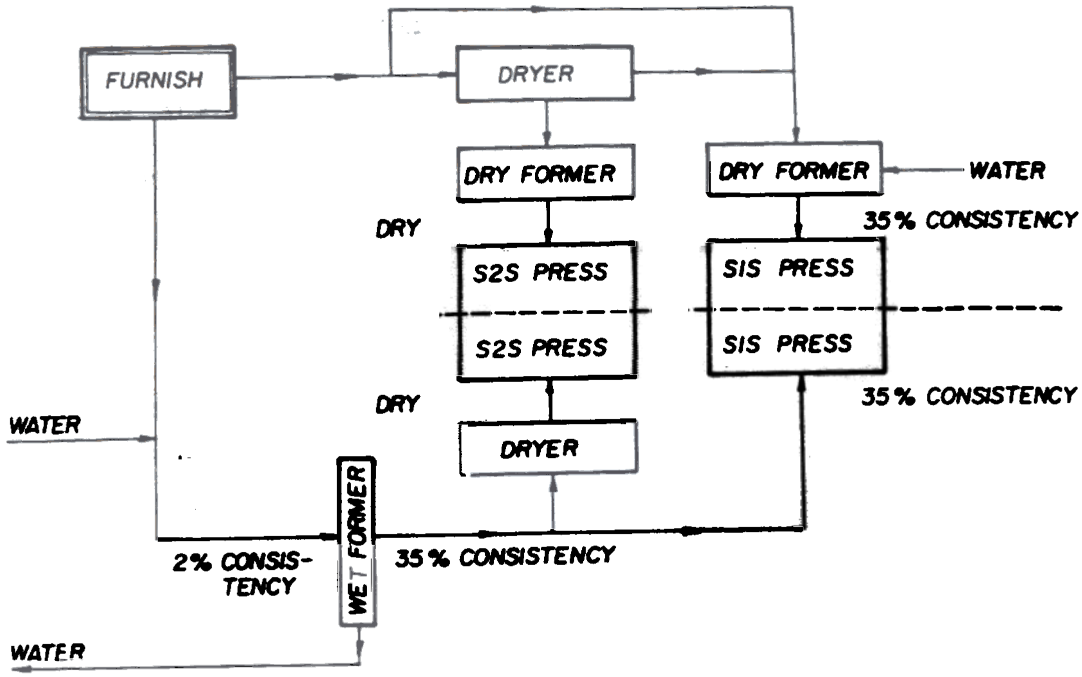



Figure 2. — Flow chart outline of the experiment.

TABLE 1. — *Composition of chip raw material.*

| Material | Percent |
|---|---|
| **Oak** | |
| **Non-oak hardwoods** | |
| **Pine** | |
| **Bark** | |
| **Fines** | |
| **Total** | |

TABLE 2. — *Bauer-McNett classification of 10 g of ovendry Masonite pulp.*

| Fiber type | Mesh classification | | | | |
|---|---|---|---|---|---|
| | **+6** | **-6/+10** | **-10/+20** | **-20/+35** | **-35** |
| | (%) | | | | |
| Unscreened | 14.1 | 17.2 | 10.3 | 11.3 | 47.2 |
| Screened through 1/4-inch hardware cloth | 11.4 | 24.3 | 11.5 | 9.8 | 43.0 |

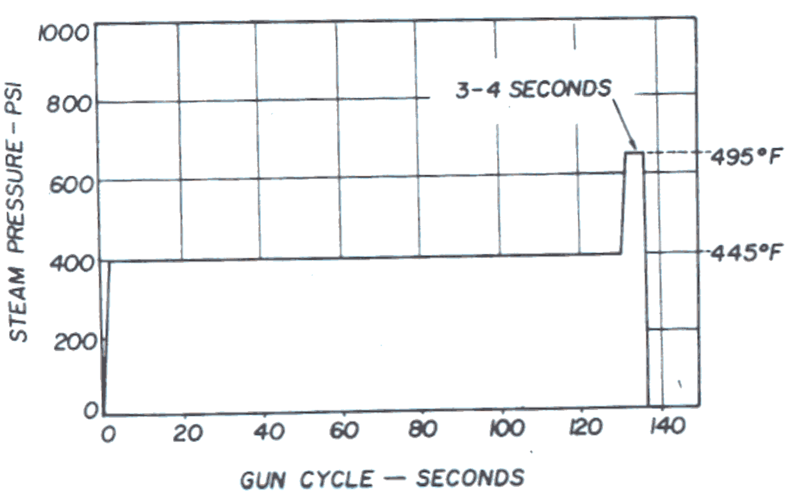



Figure 3. — Masonite gun cycle used for manufacture of study pulp.

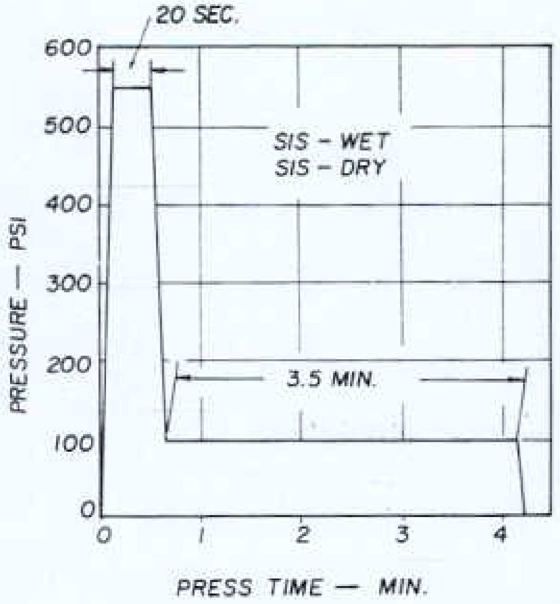



Figure 4. — Press cycle used to manufacture S1S hardboards. Press temperature: 390° F.

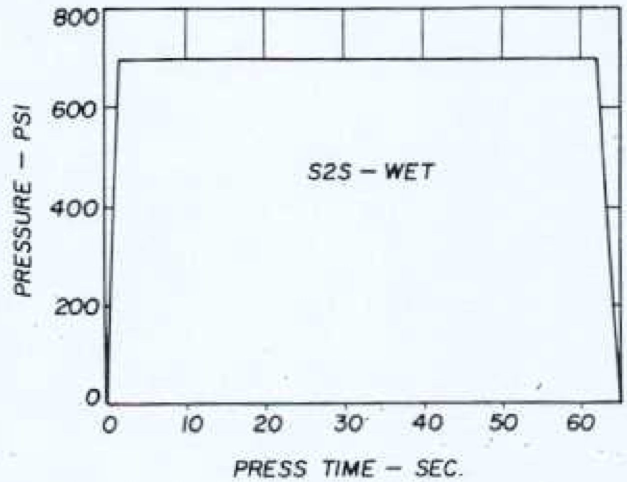



Figure 5. — Press cycle used to manufacture S2S - wet formed hardboard. Press temperature: 430° F.

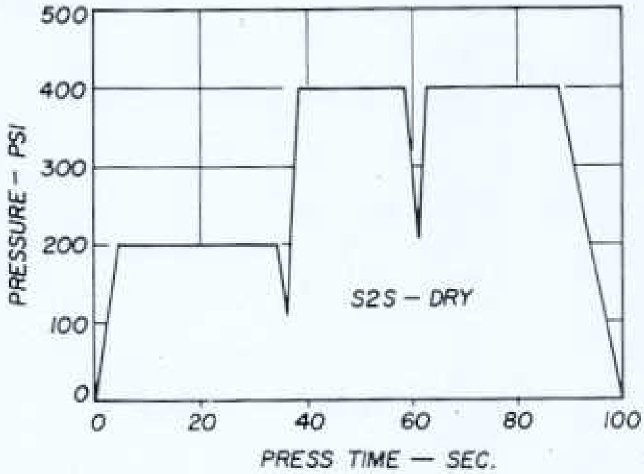



Figure 6. — Press cycle used to manufacture S2S-dry formed hardboard. Careful breathing of the press (no daylight) at about 35 and 60 seconds was necessary to release gases. Press temperature: 430° F.

**Board manufacture**

All boards were made to the following nominal specifications:

| | |
|---|---|
| Board thickness | 1/8 inch |
| Board density | 62.5 pcf |
| Board size | 12 by 12 inches |

Board size was limited by the dimensions of the sheet forming equipment. Ten replications were made for S1S-wet, S1S-dry, and S2S-dry; 15 for S2S-wet.

The four board types were processed as follows:

S1S-wet

- Pulp diluted with tap water to a consistency of 2.5 percent,
- After thorough stirring a small water sample was removed for determination of pH and dissolved solids content,
- Pulp dewatered on sheet former applying 25-inch vacuum first without and then with top caul in place,
- Wet mat pressed in cold press,
- Mat hot-pressed with screen on coarse side of mat.

S2S-wet

- Pulp diluted with tap water to a consistency of 1.5 percent. (The lower consistency was used to raise the pH.),
- After thorough stirring small water sample removed for determination of pH and dissolved solids content,
- Pulp dewatered and pressed as under S1S-wet,
- Mat placed in oven and dried at 220°F until weight remained constant,
- Mat hot-pressed without screen.

TABLE 3. — *Pulp consistencies and white water characteristics.*

| Properties | Board type S1S-wet | S2S-wet | S1S-dry | S2S-dry |
|---|---|---|---|---|
| Consistency (%): | | | | |
| Screened pulp | 55 | 55 | 55 | 100 |
| Before forming | 2.5 | 1.5 | 55 | 100 |
| After forming | 29 | 29 | 28 | 100 |
| After cold-press | 47 | 45 | 45 | — |
| White water | | | | |
| pH | 3.8 | 4.0 | — | — |
| Dissolved solids content (%) | .42 | .24 | — | — |
| Dissolved solids losses (%) | 16.2 | 15.5 | — | — |

S1S-dry

- Mat formed on vacuum dry-former from pulp of about 83 percent moisture content,
- Mat soaked in tap water until saturated,
- Wet mat dewatered and prepressed as under S1S-wet,
- Mat hot-pressed with screen on coarse side of mat.

S2S-dry

- Pulp dried to constant weight at 220°F,
- Mat formed on vacuum dry-former,
- Mat hot-pressed without screen.

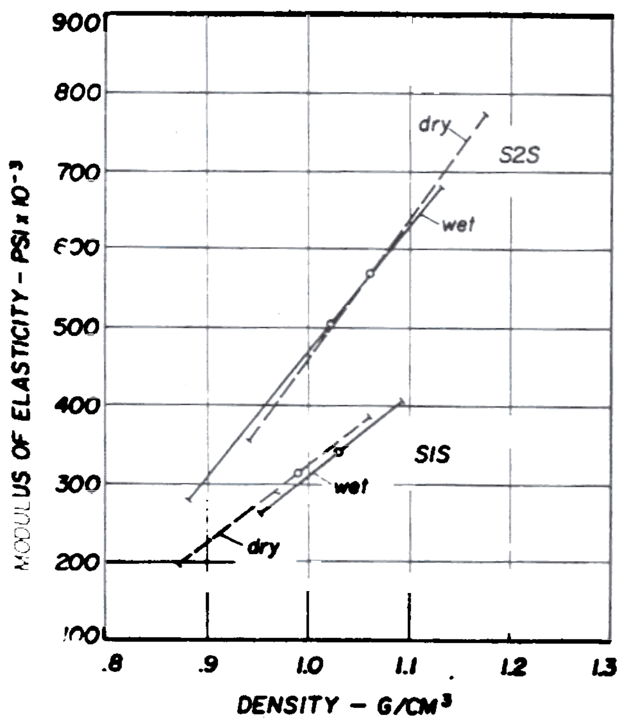
Achieving the proper press cycle that would result in the desired board density and thickness without developing surface water spots, blisters, or sticking to screen or cauls required considerable experimentation. The press cycles shown in Figures 4, 5, and 6 consistently produced satisfactory results. Pulp consistencies and white water characteristics are listed in Table 3.

## Results

The interpretation of the experiment is based on results obtained from a number of standard tests. This limited evaluation does not approach a satisfactory characterization of these hardboard types with regard to their performance in specific applications such as paneling and siding. Neither can these results be meaningfully compared with any commercial products. They do, however, allow some comparisons within the framework of this experiment and some conclusions with regard to fiberbonding and the role of water in bond formation.

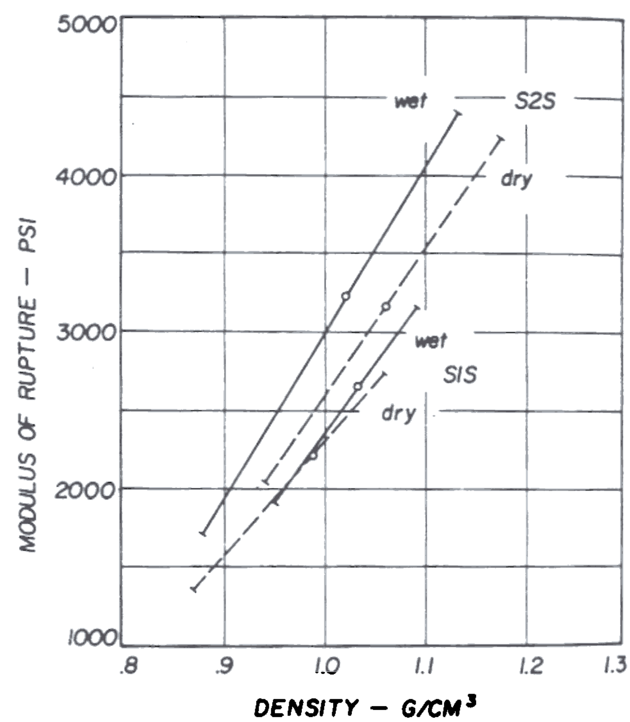
### Modulus of elasticity (MOE) and bending strength (MOR)

MOE and MOR show great sensitivity to and close correlation with board density (Figs. 7 and 8). This is particularly true of the S2S-dry boards. If these results reflect the quality and the extent of the bonding between fibers, the contribution of hydrogen bonding in wet formed boards must be discounted. It is clearly the bonding developed under the dry conditions of the S2S press that is responsible for the superior properties of the S2S boards. Whether the S2S board is approached from the wet or the dry side, or whether the water in the S1S mat is added before or after forming seems to be of little consequence.



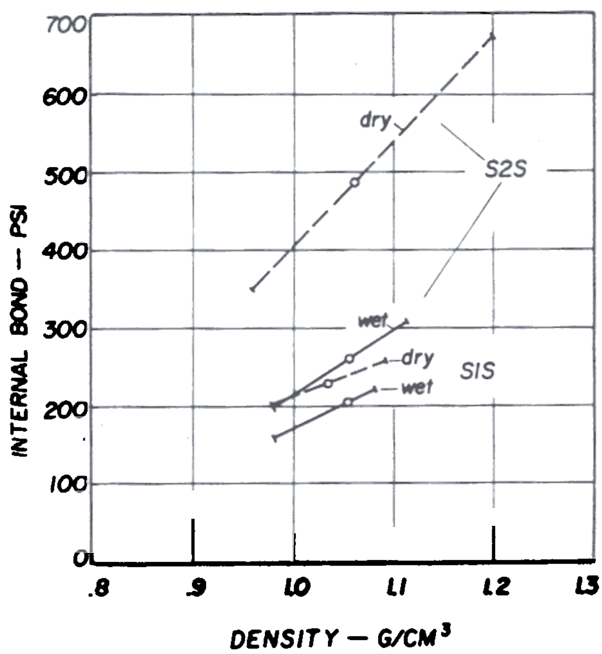

| Type board | No. observations | Correlation coefficient |
| --- | --- | --- |
| | 29 | |
| | 30 | |
| | 43 | |
| | 30 | |

Figure 7. — Modulus of elasticity in bending as function of board density of four hardboard types.




| Type board | No. observations | Correlation coefficient |
| --- | --- | --- |
| | 29 | |
| | 30 | |
| | 43 | |
| | 30 | |

Figure 8. — Modulus of rupture in bending as function of board density of four hardboard types.




| Type board | No. observations | Correlation coefficient |
|---|---|---|
| | 10 | |
| | 8 | |
| | 8 | |
| | 10 | |

Figure 9. — Internal bond as function of board density of four hardboard types.

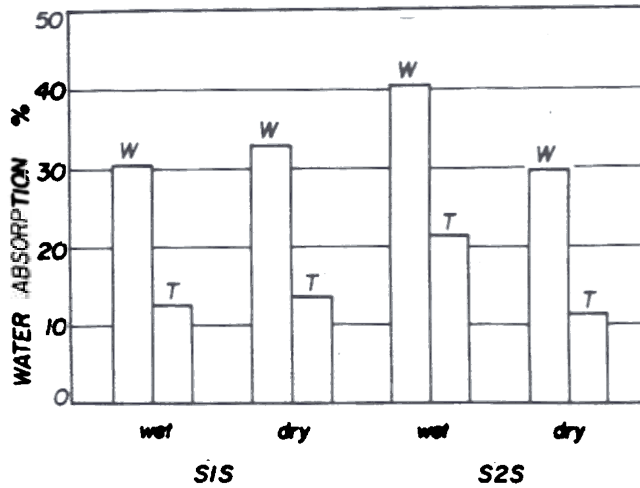



Figure 10. — Water absorption by weight change and thickness change of four hardboard types (24-hour soak).

## Internal bond (IB)

Figure 9 shows the relationship of IB to board density. S2S-dry boards had remarkably high IB values, consistently higher than those of all other processes. If a strong vertical fiber orientation component was responsible for the high values of the S2S-dry boards, then the modification of this component in the S1S-dry boards, which were formed in exactly the same way, must be attributed to the force of the water being squeezed out of the mat during pressing.

## Water absorption and linear expansion (LE)

Water absorption, both by weight and thickness change, does not show great variation between board types (Fig. 10). LE shows significant differences between S1S and S2S boards (Fig. 11). Part of this difference is due to higher equilibrium moisture contents at 93 percent relative humidity of the S2S boards (Table 4).

## Conclusions

1. The important bonding process in the manufacture of hardboard occurs in the press, not on the forming machine or in the dryer. Hydrogen bonding, therefore, contributes little or nothing to final board strength in both dry and wet formed and pressed boards.

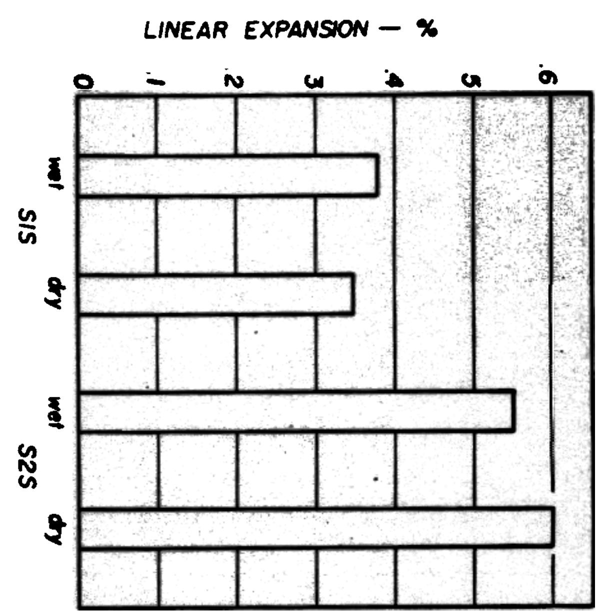



Figure 11. — Linear expansion (50% to 93% relative humidity) of four hardboard types.

TABLE 4. — *Summary of linear expansion test of four hardboard types.*

| Property | Board type | | | |
|---|---|---|---|---|
| | S1S-wet | S1S-dry | S2S-wet | S2S-dry |
| | (%) | | | |
| LE (50% to 93% RH) | .377 | .347 | .549 | .599 |
| MC (50% RH) | 4.26 | 4.06 | 4.64 | 4.08 |
| MC (93% RH) | 8.05 | 7.89 | 8.76 | 9.05 |
| MC change | 3.79 | 3.84 | 4.12 | 4.97 |

2. Bonds formed in the press are of the lignin type and, at the temperatures used in this study, appear to be greatly independent of mat moisture content during pressing. Superior bonds formed between dry fibers may reflect the effects of higher press temperatures used.
3. The wet-dry process dividing line is no real barrier to the manufacture of binderless hardboard.

These conclusions apply only to the particular pulp used. It is probable that different pulps will produce different results. For this particular pulp, however, and for similar pulps these practical consequences are envisioned:

- Highly reactive pulps can be formed dry and pressed dry without resin into a hardboard of superior properties.
- Dry-formed fiber mats can be processed into an S1S hardboard with minimal amounts of process water with practically 100 percent yield and with essentially the characteristics of a wet-formed S1S hardboard.
- Highly reactive pulps could be formed dry and combined with slush overlays, or could be applied as resin-free surface layers to dry fiber or particle mats in the manufacture of medium density sheet materials.

## Literature cited


1. Koran, Z. 1970. Surface structure of thermomechanical pulp fibers studied by electron microscopy. Wood and Fiber 2(3):247-258.
2. Mason, W. H. 1932. Process of making ligno-cellulose fiber products. U.S. Patent No. 2,120,137. U.S. Patent Office, Washington, D.C.
3. Spalt, H. A. 1977. Chemical changes in wood associated with wood fiberboard manufacture. *In* Wood technology: chemical aspects. (I.S. Goldstein, ed.) Am. Chem. Soc.