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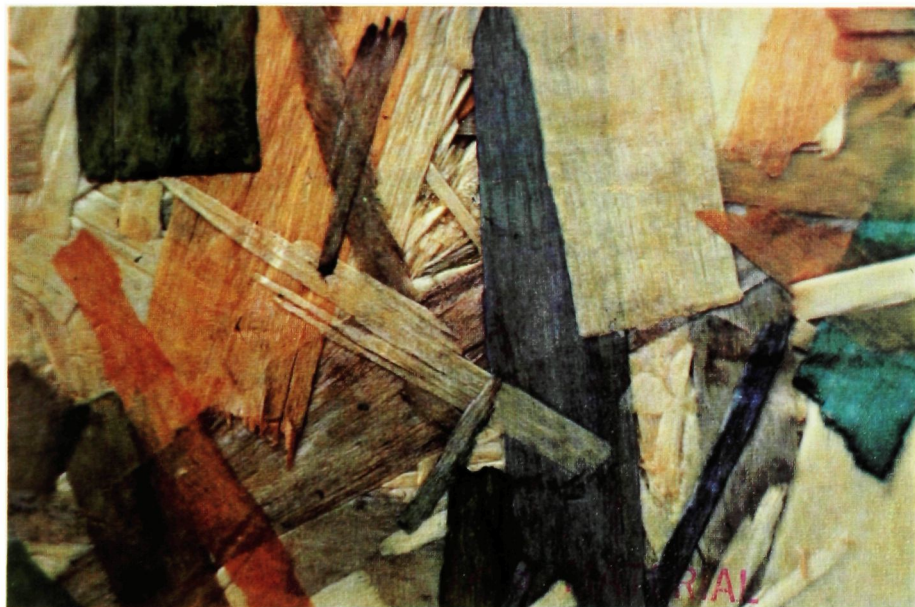
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Eastern Spruce Flakeboard Resin Distribution and Decorative Panel Evaluation

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Eastern Spruce Flakeboard Resin Distribution and Decorative Panel Evaluation^{1,2}

Robert A. Kelly³, Norman P. Kutscha⁴
and Craig E. Shuler⁴

SUMMARY

A standard urea-formaldehyde liquid adhesive was used in the manufacture of eastern spruce flakeboard panels. The resin application system, resin viscosity, furnish moisture content, and application period were all conducive to the formation of a fine resin spray. The average resin droplet diameter was approximately 20 microns, while the average resin area coverage, over the entire wood furnish, was 8.05 percent. Resin distribution in the microscopically observed panel specimens appeared in the form of "spot-welds" and intermittent glue lines. The use of various histological and commercial stains was effective in producing decorative panels.

INTRODUCTION

Eastern spruce flakeboard was produced under laboratory conditions and evaluated for its mechanical properties. Flakes for the board were cut on a rotary lathe in 1- and 3-inch lengths, and with 0.010- and 0.020-inch thicknesses. Using a 6 percent (by weight) application of urea-formaldehyde adhesive, boards were pressed to ½-inch thickness at densities of 40 and 50 pcf. The effects of flake geometry and board density on the mechanical and physical properties of the final flakeboard were reported by Kelly (1974).

The purpose of this bulletin is to present the results of the resin distribution analysis conducted on the flakeboard panels. Various fluorescent and non-fluorescent dyes were added to the adhesive before application to the flakes. Randomly selected flakes were then analyzed by light

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and fluorescence microscopy to determine adhesive droplet size and average adhesive coverage on the wood flake. Further observations were performed to evaluate the bonding characteristics within the panels and certain decorative possibilities of the finished panels.

LITERATURE REVIEW

Superior resin efficiency resulted when particle surface contacts were maximized in all parts of a board, with the lowest possible density. Such conditions encouraged the use of low density woods to obtain maximum wood-adhesive bonding from the limited quantity of resin applied (Carroll, McVey, 1962). Lack of adhesive bonding was attributed to the soaking of resin into the flakes, its flowing away from flake contact points, or its premature curing (Carroll, 1963; Carroll, McVey, 1962). Investigations were conducted to determine which method of resin distribution, discrete droplet or continuous film, was more beneficial in the development of strong glue lines. Marian (1958) suggested that the resin should be applied over the surface of a particle in a continuous film. He stated that bonding strength increased as particle surface area increased and resin spread per unit of surface area decreased. Lehmann (1965) concluded that a fine resin atomization and a suitable application period were the two most important factors controlling optimum resin distribution. In another study by Lehmann (1968), urea-formaldehyde resin sprays were classified as being either fine or coarse, depending upon the average diameter of the resin droplets produced. Boards produced from particles to which a fine resin spray was applied possessed continuous glue lines and physical properties superior to those boards fabricated from particles subjected to a coarse resin spray application system. Wood particles bonded together by uniformly distributed discrete resin droplets were referred to by Lehmann (1968) as "spot-welded."

Investigations by Schneider and Côté (1967) showed that a fluorochrome, when added to a polymer, aided in differentiating wood substrates from polymer coatings. This technique assumed that the fluorochromed coating maintained previous penetration and distribution characteristics. The observation of resin on flakes and within a panel was simplified by the addition of dye to a urea-formaldehyde adhesive (Bossard, 1960). Fluorescent dyes, coriphosphine and rhodamine B, were used by Bossard (1960) and Lehmann (1968) to study resin distribution and droplet size on flakes and within panels. Ginzel and Stegmann (1970) concluded that 12 coloring agents were acceptable for use with urea-formaldehyde resins. It was concluded by Lehmann (1965) that no appreciable strength loss was evident in a panel prepared from a fluorescent-dyed adhesive.

Employing a photoelectric reflection photometer, Lehmann (1970) determined resin area coverage by measuring reflected light intensity differences between wood surfaces where dyed adhesive was present and those where it was lacking. He estimated that an average resin area coverage of 44.4 percent existed on particles subjected to a fine resin spray, while those particles receiving a coarse spray possessed a lower resin coverage area of 31.5 percent. Lehmann (1970) also mentioned that the coalescence of resin droplets on adjacent bonding surfaces increased as the average resin coverage increased. The coalescence of the droplets produced thicker or more continuous glue lines.

In a comparative fluorescence study involving incident and transmitted light, Côté and Robinson (1968) concluded that improved resolution was obtained by transmitted illumination of thin sections. Thin section preparation techniques normally require that the specimen be soaked in water or another liquid prior to sectioning. Particleboard fabricated with a non-waterproof adhesive cannot be sectioned unless the sample has been impregnated with a resin or similar polymeric compound (Kelly, 1974). Methyl methacrylate impregnation was a technique followed by Lehmann (1968) to obtain thin sections of flakeboard illustrating continuous and intermittent glue lines.

MATERIALS AND METHODS

Panel Preparation

Sixteen-inch long bolts of green eastern spruce were placed in a modified metal lathe and turned in a manner similar to a veneering operation. A specially designed knife holder attached to the crossfeed incorporated a 6-inch planer knife and a system of scoring knives to produce ribbons of uniform thickness and width. (Ribbon width corresponds to flake length.) These ribbons were then placed in a screened tumbler and dried in a laboratory kiln at 160°F. The tumble drying broke the ribbons into flakes of uniform lengths and thicknesses with varying widths. Adhesive was then sprayed on the flakes as they were mixed in a vane tumbler. After spraying, mats were hand formed and pressed in a 90-ton hydraulic press with electrically heated platens. All boards were of the homogeneous type.

Resin Evaluation Methods

Prior to spray application, various dyes were added to the resin to aid in the resin distribution study. Two panels were fabricated using concentrations of 1.0 and 2.0 percent aniline blue (C.I. No. 42755), based on the total adhesive weight. Two other blending cycles were run with the fluorescent dyes, coriphosphine O and rhodamine B. The concentra-

tion of coriphosphine O was 0.1 percent of the resin solids weight while rhodamine B concentration was 0.6 percent. Immediately following the completion of each of the four adhesive applications, a sample of flakes was randomly removed from the blender. These sample flakes were used to study the resulting resin droplet size and the percent resin area coverage. No physical strength tests were conducted on the boards containing dyed resin.

A 5-millimeter square was drawn in the center portion on the front and back surfaces of five randomly selected flakes. Using incident light, three of these surfaces were scanned with a Zeiss Photomicroscope with a 16x objective. Resin droplets, stained with rhodamine B, fluoresced under ultraviolet light and were easily measured. Over 1,000 droplets were measured on the three surfaces and tabulated into specific droplet size classifications.

In the determination of average percent resin area coverage of the furnish, all ten flake surfaces were used. The centermost surface of each flake was photographed and enlarged to an 8 x 10-inch print. The area covered by the resin was then measured by means of a 1-inch-square photogrammetric grid with 256 sub-square divisions. An estimated average percent resin coverage was obtained by comparing those squares containing resin to the total number of squares. This procedure was followed on each of the ten 8 x 10-inch enlargements.

Observations concerning the bonding characteristics of the adhesive on the flake surfaces and within the pressed panel were made on the panel that had been fabricated from rhodamine B-stained resin. Samples for microscopic examination were cut from the rhodamine B panel into 1/2-inch lengths, 3/8-inch wide and 1/2-inch thick.

An attempt was made to produce microscopic sections of flake-board as outlined by Lehmann (1968). The method was modified by embedding small specimens with a butyl-methyl methacrylate mixture. Sectioning on the sliding microtome was difficult and the methacrylate tended to distort the adhesive image. A paraffin technique was followed because of the problems encountered with the methacrylate.

The paraffin method involved the placing of specimens into aluminum trays and encasing them in hot paraffin wax, which was then cooled. After solidification, all the paraffin was removed except a 1/16-inch strip, directly in contact with the sample. Leaving this wax border reduced the sample disintegration that was encountered in microtoming the various surfaces. The paraffin-encased samples were then surfaced with a sliding microtome at a knife tilt angle of 3 degrees. Sprayed flakes and microtomed surfaces were examined with a Zeiss Photomicroscope set for incident light illumination.

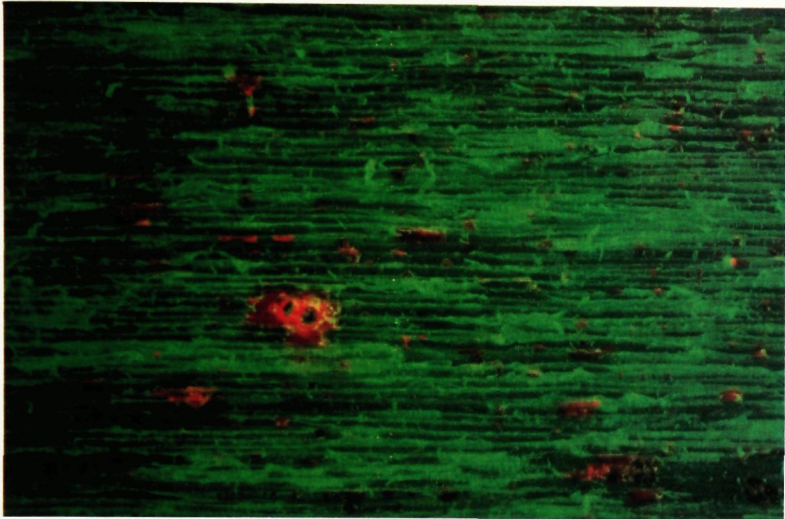


FIGURE 1. A flake surface showing small and large resin droplets dyed with rhodamine B.
Incident dark field fluorescence. Film 98, frame 15. Magnification 55x.

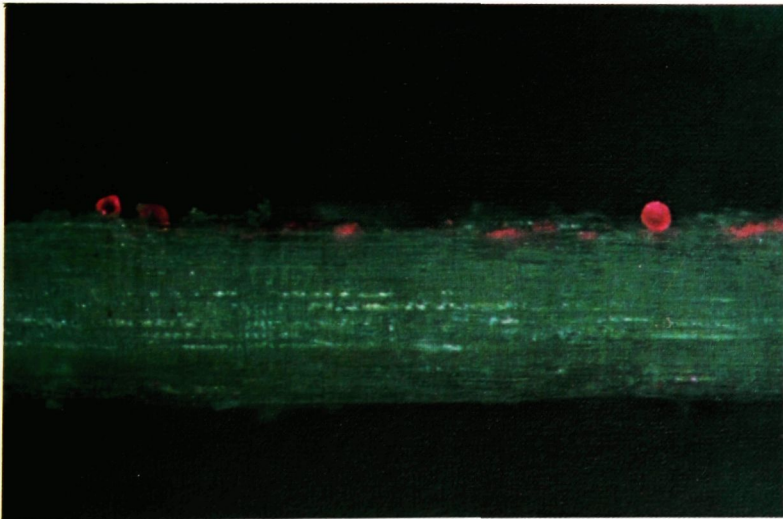


FIGURE 2. Longitudinal edge view of flake showing small and large resin droplets, dyed with rhodamine B, on the upper and lower surfaces.
Incident bright field. Film 94, frame 17. Magnification 100x.

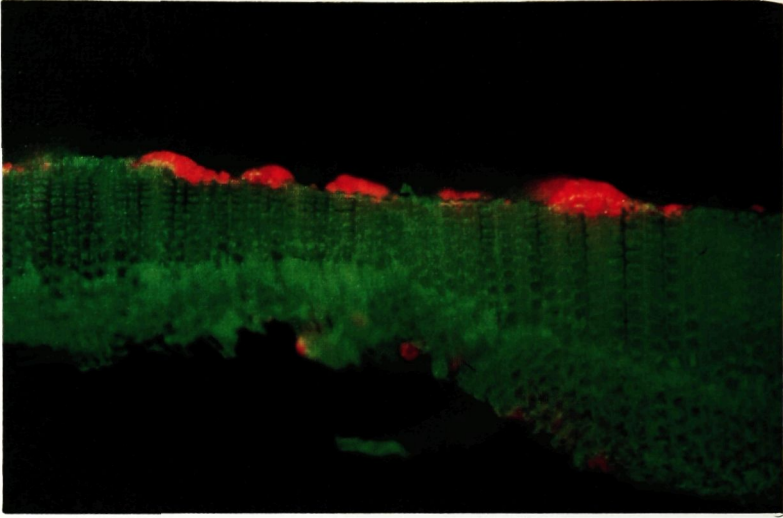


FIGURE 3. Cross sectional view of a flake showing small and large resin droplets, dyed with rhodamine B, on the upper and lower surfaces.

Incident dark field fluorescence. Film 97, frame 18. Magnification 86x.

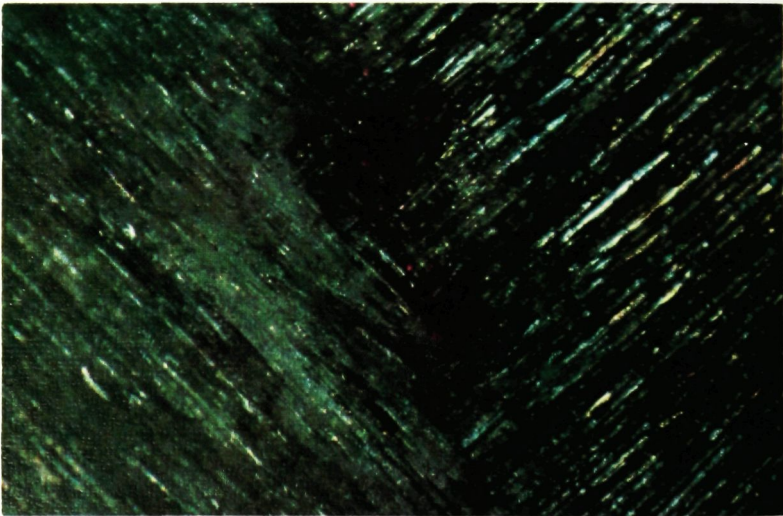


FIGURE 4. Surface view of eastern spruce flakeboard showing adhesive at the junction of two flakes.

Incident bright field, partial polarization. Film 94, frame 11. Magnification 72x.

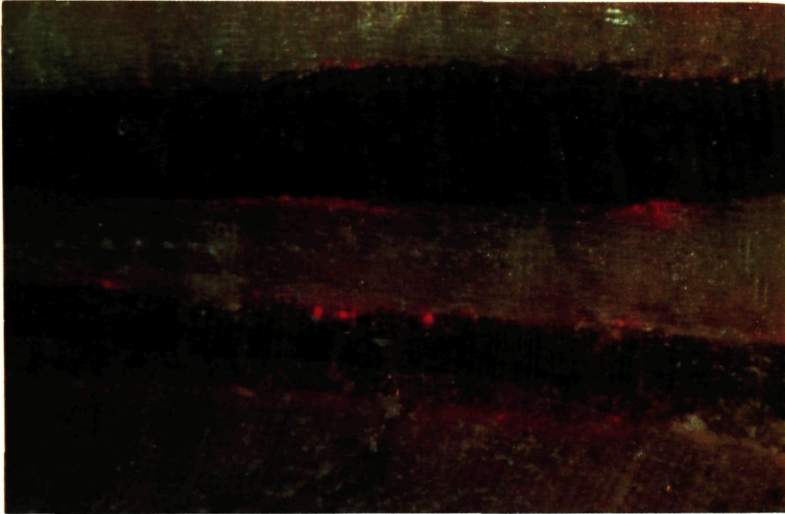


FIGURE 5. Edge view of eastern spruce flakeboard showing "spot-welding" and partially extended glue lines. The red areas represent rhodamine B-dyed adhesive between adjacent flake surfaces.

Incident bright field. Film 94, frame 8. Magnification 80x.

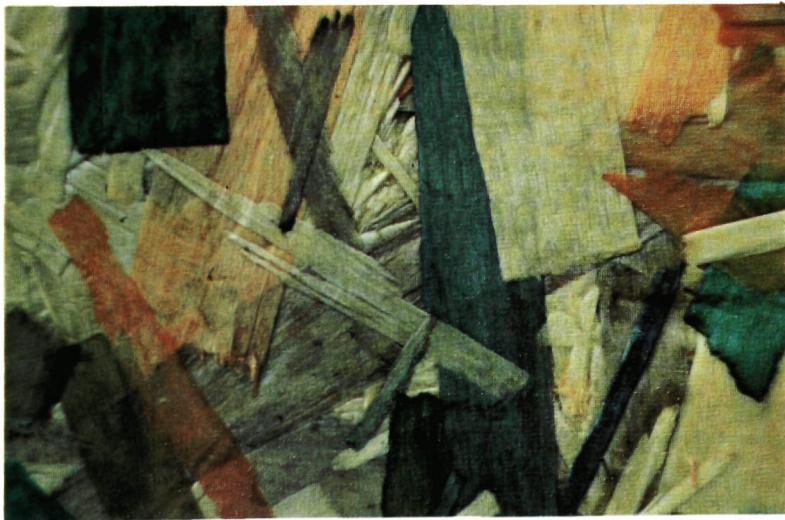


FIGURE 6. Decorative panel composed of flakes dyed with histological stains. Film 108, frame 1.



FIGURE 7. Decorative panel composed of flakes stained with a commercial water-soluble walnut stain.

Film 107, frame 11.

Decorative Panel Evaluation

The potential of eastern spruce flakeboard as a possible decorative wallboard panel was evaluated. Histological stains including methyl orange (C.I. No. 13025), fast green (C.I. No. 42053), crystal violet (C.I. No. 42555), and Congo red (C.I. No. 22120), mixed at 1.0 percent concentrations in water, were used to dye flakes. The dyed flakes were placed in the blended mix to obtain decorative panels and color combinations. Boards were also finished with walnut, dark oak-oil, and suntan wood stains. A satin varnish finish was utilized to bring out wood grain detail in certain of the flakeboard panels.

RESULTS AND DISCUSSION

Microscopy

In differentiating between adhesive and wood substrates, rhodamine B, a fluorescent dye, was very effective when incorporated into the resin prior to blending (Figure 1). Coriphosphine O may have been more effective at higher concentrations, but tended to lack the differentiating color contrast required when using a lightly colored, highly lustrous wood like spruce. Aniline blue (C.I. No. 42755), a non-fluorescent dye, provided a good visual indication of resin distribution, but tended to stain the wood more fully, indicating possible separation of the dye from the adhesive. Therefore, rhodamine B was utilized throughout the microscopic evaluation of resin distribution. Figure 1 illustrates the differentiation between resin and wood substrate. The red dots are resin droplets dyed with rhodamine B, while the surrounding areas represent the wood. Incident fluorescence microscopy proved to be an acceptable means for differentiating between adhesive and wood substrate.

In a comparative fluorescence study involving incident and transmitted light, Côté and Robinson (1968) concluded that improved resolution was obtained by transmitted illumination of thin sections. In the present study, an attempt was made to produce thin sections of flakeboard using a sliding microtome. Samples were embedded in an 80:20 mixture of butyl:methyl methacrylate and sectioned. The sectioning of the embedded samples presented some problems. The multiple grain orientations, characteristic of flakeboard, coupled with the high cutting resistance of methacrylate resulted in distorted and damaged sections. Therefore, an effort was made to view the surfaced blocks with incident fluorescence. This procedure proved inadequate since both the fluorescence of the adhesive and the reflectivity of the methacrylate tended to distort the depth and continuity of the glue lines. An additional technique that included the encasing of the sample blocks in paraffin prior to surfacing was attempted. The paraffin served to reduce possible sample

disintegration encountered in sectioning. All samples were then surfaced in a dry state and examined under the light microscope. Rhodamine B proved adequate when employing both incident fluorescence and incident ordinary light for the observation of glue lines and resin distribution in flakeboard.

Resin Distribution

Investigations were conducted to determine which resin distribution phenomenon, droplet or continuous film, was more beneficial in the development of strong glue lines (Lehmann, 1965; Marian, 1958).

Diameters of resin droplets on the surfaces of three randomly selected flakes were measured (Figure 1 and Table 1). A greater percentage of droplets was present in the 12.0, 24.0, and 36.0 micron diameter classes than any of the other 13 classes. Lehmann (1968) has stated that fine and coarse resin sprays consist of average droplet diameters of 32 microns and 56 microns, respectively. In this study, the resin application system, adhesive viscosity, furnish moisture content, and period of application were conducive to the formation of a fine resin spray with an average resin droplet diameter of approximately 20 microns. The consolidation of several droplets, during resin application, was suggested by the low percentage of the larger droplet diameters (158.0-243.0 microns).

Table 1
Resin Droplet Size Analysis on Three Randomly Chosen Flake Surfaces.¹

Size Classification (Microns)	Percent Occurrence
6.00	9.52
12.00	47.89
18.00	3.68
24.00	18.33
36.00	12.67
48.00	3.86
60.00	1.80
73.00	0.99
85.00	0.27
97.00	0.09
121.00	0.36
146.00	0.18
158.00	0.09
170.00	0.09
231.00	0.09
243.00	0.09

¹ Values based on measurement of 1113 resin droplets.

Figures 2 and 3 clearly indicate that the resin droplets form either spherical or bead-like structures on the surface of a flake. Figure 2 represents a longitudinal edge view of a flake showing small and large resin droplets on both surfaces. Due to focusing, the greater number of droplets on the top surface appear more pronounced. Figure 3

depicts a cross sectional view of a flake with the bead-like structure of the resin droplets on both surfaces.

The centermost portion of both surfaces from five randomly chosen flakes was examined in order to determine the percent resin area coverage on the flake surfaces (Table 2). Flake #1 and Flake #4 represented a resin coverage difference of over 3.00 percent between the front and back surfaces, whereas Flake #3 varied by only 0.33 percent. When both surfaces on Flakes #1 and #4 were averaged, a resin coverage difference of 4.10 percent existed between the two flakes. When all ten surfaces were considered, an average resin coverage of 8.05 percent resulted. This approximate mean value could be used to represent total adhesive

Table 2
Percent Resin Area Coverage on Five Randomly Chosen Flakes.¹

Flake Number	Surface Viewed	Percent Coverage
1	A—front	8.90
1	B—back	12.32
	Average	10.61
2	A—front	6.95
2	B—back	8.48
	Average	7.71
3	A—front	7.60
3	B—back	7.27
	Average	7.44
4	A—front	4.96
4	B—back	8.06
	Average	6.51
5	A—front	6.94
5	B—back	9.01
	Average	7.97

Combined Percent Resin Coverage for Ten Flake Surfaces
8.05 Percent

¹ Values based on five flakes, ten surfaces, with adhesive dyed with rhodamine B. Measurements were made on 1.0-inch flake lengths.

coverage on the furnish utilized in fabricating a flakeboard panel. According to a study by Lehmann (1970), this resin coverage is extremely low for a system designed to give a fine resin spray. One possible explanation for this low value is that much of the resin volume may be tied up in the few large droplets which are present, as shown in Figure 1. The reduced resin coverage obtained could have resulted in a lack of sufficient resin flow and droplet coalescence under heat and pressure, which is required for the formation of continuous glue lines. Boards produced under this system and tested for mechanical properties did show low internal bond strength, but favorable bending and screw withdrawal properties (Kelly, 1974).

The presence of noncontinuous glue lines and "spot-welds" was evident in samples viewed with the light microscope. Figure 4 is a surface

view of a sample flakeboard. Figure 5 is an edge view. Figure 5 illustrates the "spot-welding" effect in which the wood particles are bound together by discrete resin droplets distributed over the flake surfaces (Lehmann, 1968). In analyzing the resin droplet diameter distribution, it was concluded that the resin application system employed in this study favored a finer resin spray which should provide continuous glue lines. The lack of continuous glue lines in the finished panel suggests possible problems in adhesive pre-cure, adhesive flow under heat and pressure, press-closure, and resin coverage. In Figure 4, resin is located at the junction of two flake surfaces. This micrograph emphasizes the random orientation of the flake surfaces and the sporadic resin distribution.

Decorative Panel Evaluation

Figures 6 and 7 illustrate the potential of eastern spruce flakeboard as a decorative wallboard panel. Various histological stains including methyl orange, fast green, and crystal violet (Figure 6), as well as a commercial water-soluble walnut stain (Figure 7), produced the most interesting and unique color patterns. This color flexibility could be useful in matching room color schemes in a home. Panels made from flakes dyed with rhodamine B, a fluorescent dye, could possibly be used in establishments such as night clubs which currently utilize black (ultra-violet) lighting. Various wood stains, walnut or dark-oak stain, could also be used in highlighting flake and grain orientations by varying color tones across panels.

CONCLUSIONS

On the basis of this study the following conclusions were drawn:

1. The resin application system, resin viscosity, furnish moisture content, and period of application were all conducive to the formation of a fine resin spray, having an average droplet diameter of 20 microns.
2. A relatively low average resin area coverage of 8.05 percent was estimated to exist over the entire wood furnish of a panel.
3. Resin distribution in the laboratory fabricated panel appeared as "spot-welds" and intermittent glue lines.
4. Through utilization of various histological and commercial stains, it appears possible that full-sized decorative panels could be readily fabricated from eastern spruce flakeboard.

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