Studies on the Impregnated Woods.

V. The relation between the penetration of synthetic resin and impregnating conditions.

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Introduction

The dimentional stability and the mechanical strength of wood increase by the impregnation of synthetic resin, and the rate of increase is influenced by the impregnated chemicals, the properties of chemicals and the heating treatment, but it seems to be most important whether the impregnation of resin is sufficient or not, and when the material to be impregnated is large, whether the penetration is uniform or not, in other words, whether the synthetic resin can be impregnated to wood sufficiently deep and uniform by some methods or not.

M. A. MILLETT and A.J.STAMM[1] impregnated the synthetic resin into woods of 4 and 6 feet length and indicated the rate of the penetration by antishrinking ratio. They studied closely on the dimensional stability of wood treated with urea-formaldehyde resin. There are other many researches on the dimensional stability of the impregnated wood.[3,4] But the studies on the impregnating method, and conditions are done only in the preservation field.

The penetration of resin into wood is influenced by the impregnating conditions, the resin's properties, and the sort of resin and wood. These factors have the close relation to each other but the impregnating conditions must be estimated at first to determine the other factors. In this view, we study on the relation between the penetration of the synthetic resin and the impregnating conditions.

Materals Used

In the preparation of specimens for treatment, long and stock lumber were cut into lengths measuring 6 by 6 by 20 cm., and air dried to between 12 and 14 percent moisture

contents. The dried material was cut and planed to provide test specimens measuring 4 by 4 by 15 cm., and with the plane of the annual rings as nearly parallel to two opposite faces as possible. Such specimens were provided for the heartwood of japan cypress (*Chamaecyparis obtusa*).

Dimethylol urea was obtained fresh from the commercial manufacture and used under treating conditions so chosen as to represent practical commercial practice. This properties are shown in Table I.

Table I. The several properties of dimethylol urea.

molecular weight	120
specific gravity	1.070 (20° C)
viscosity	1.34 c. p. (20° C)
surface tension	52.9 dynesé/cm (20° C)
pH	7.2
N-contents	23.4 %

As an aid for determining the extent of resin penetration, 2 percent of an ultraviolet fluorescence agent (4-aminonaphtalin-1-sulfonic acid sodium salt) was added to the treating solution.

Treatment of Specimens.

Five specimens matched as well as possible, were selected for the same treatment. The treatment solution was proportioned to provide up to a 15 percent resin-forming-solids content, and buffered at pH 8, as was reported to be most suitable in previous publication.

Treatment was applied by the vaccum-pressure-cylinder method, the pressure-cylinder method, and the vaccum method. The air pressure of the two former were used as shown in Table II. In the latter, the release of 40 mm. were used for time showing in Table II.

Following this treatment, the specimens were stored under nondrying conditions for 48 hours to permit diffusion of the resin through the wood, after which period each specimen was weighed and end-coated, stickered in a dry kiln, and dried to a moisture content of about 6 to 8 percent using a drying schedule. This kiln schedule started at

Table II. The conditions of the treating methods.

code address.	vaccum		pressure	
	mm.	mins.	kg/cm.	mins.
VP_1-a	40	20	1	10
-b	〃	〃	〃	30
-c	〃	〃	〃	60
VP_2-a	〃	〃	3	10
-b	〃	〃	〃	30
-c	〃	〃	〃	60
VP_3-a	〃	〃	7	10
-b	〃	〃	〃	30
-c	〃	〃	〃	60
P_1-a	—	—	3	10
-b	—	—	〃	30
-c	—	—	〃	60
P_2-a	—	—	7	10
-b	—	—	〃	30
-c	—	—	〃	60
V-a	40	30	—	—
-b	〃	60	—	—
-c	〃	120	—	—

60°C., and 85 percent relative humidity and at the end of 5 days had reduced the moisture content to 30-40 percent, after which 70°C., and 50 percent relative humidity were used for 3 days. Curing of the resin-impregnated specimens was done in a hot-plate press under contact-pressure conditions with the plate at 110°C. for 5 hours.

Following this drying treatment, each specimens were weighed again. In order to determine the extent and thoroughness of resin distribution, each treated and cured specimens were cut into 1.5 cm. cross section for penetration tests.

The sections were irradiated by ultraviolet rays, and the fluorescent parts show the extent of resin penetration. After the fluorescent parts were copied to the transparent graph paper, the cross points in the parts were measured and the percentage of penetrating area was caluculated for both the cross points of the penetrated and the all area of specimens. The penetrated parts divided by the all area of specimen and multiplied by 100 gave what has been termed the penetrated area efficiency. Table III gives a summary of the data obtained on longitudinal resin distribution in the 15-cm. specimens as measured by the penetrated area efficiency. The values given are averages of the five treated specimens.

Table IV shows the data of the impregnating efficiency measured by weight and

Table III. Longitudinal resin distribution in 15-cm. specimens as measured by their penetrated area efficiency

method	penetrated area efficiency[1]				
	1.5 cm. from ends	3.0 cm. from ends	4.5 cm. from ends	6.0 cm. from ends	Center
	Percent	Percent	Percent	Percent	Percent
VP_1-a	96	88	69	34	23
-b	99	98	85	78	53
-c	95	92	93	85	84
VP_2-a	94	89	85	66	61
-b	93	91	91	86	83
-c	99	99	98	95	92
VP_3-a	97	95	89	88	84
-b	99	99	99	89	95
-c	100	100	99	89	95
P_1-a	96	95	93	67	57
-b	95	94	93	88	80
-c	98	97	95	92	87
P_2-a	92	91	88	77	75
-b	99	99	99	98	96
-c	100	100	100	99	97
V-a	88	69	19	13	11
-b	85	67	38	11	10
-c	94	83	46	17	14

[1] Values are average of five treated sxecimens.

volume. In Table IV, A, B, and C were calculated by following formula respectively.

$$A = \frac{W' - W}{W} \times 100$$

where W is weight of the specimens, and W' is weight following the impregnation.

$$B = \frac{W_0' - W_0}{W_0} \times 100$$

where W_0 is weight of absolutely dried specimens, and W_0' is that following the impregnation.

$$C = \frac{V'}{V} \times 100$$

where V is the vacant space of the specimens, and V' is the impregnated volume.

Each of them was incomplete in order to show the extent of the penetration of the resin. Resin is adsorpted to the wood fiber and its adsorption is dependent upon various conditions. In some methods, the resin does not penetrate into woods less deep and is adsorbed in large amount to wood fiber, while in some other methods it penetrated uniformly to deeper extent without so much adsorption to give same weight up-taken. It is thinkable, therefore, that if the increase of weight is larger, the area of penetration is not necessarily larger.

Table IV. The resin impregnating efficiency measured by weight and volume.

method	impregnating efficiency[1]		
	just after treatment. by weight. (A)	just after treatment. by volume. (B)	just after dry. by weight. (C)
	Percent	Percent	Percent
VP_1-a	68	40	13
-b	92	52	21
-c	81	54	24
VP_2-a	107	63	17
-b	115	56	19
-c	178	80	30
VP_3-a	106	66	19
-b	137	78	23
-c	151	94	27
P_1-a	71	49	16
-b	100	51	19
-c	82	53	18
P_2-a	78	58	18
-b	76	64	20
-c	89	58	22
V-a	62	30	17
-b	64	33	19
-c	83	44	20

[1] Values are average of five treated specimens.
A, B, C are explained in this text.

A study of Table IV shows that the treatment of the pressure-cylinder method was exceptionally uniform throughout the length of specimens. The vaccum-pressure-cylinder method with the pressure 1 kg/cm^2 showed only a slight falling of resin content toward the center of the specimens, but it gave satisfactory results when it was given a longer treating time. The vaccuum method gave miserable results through it was given a very long treating time (120 mins.).

This measuring method by ultraviolet fluorescence agent was gotten a hint from the

study of Y. KONISHI and T. YAMAMOTO[5].

In the impregnation efficiency from weight, that of the vaccum method of 120 mins. was larger than that of the pressure method of 30 mins., but the former showed a slight falling off of resin penetration toward the center of the specimens in comparison with the latter as shown in Table IV. This fact shows that resin is impregnated sufficiently in the amounts, but not in uniformity by some method.

Summary

Solid wood specimens measuring 4 by 4 by 15 cm., taken from the heartwood of japan cypress (*Chamaecypris obtusa*), were treated by the vaccum-pressure-cylinder method (Full cell process), the pressure-cylinder method (Empty cell process), and the vaccum method with the solution of dimethylol urea, all at a resin forming-solids content of 15 percent. After 8 days of kiln drying, the treated specimens were cured under contect pressure in a hot-plate press at 110°C. for 5 hours.

Each specimen was weighted, and then impregnating efficiecy measurements were taken on 1.5-cm. cross sections cut from each specimen along its length. A fluorescent agent added previously to resin solution in order to determine the penetration of resin.

The data indicated that reasonably uniform and deep resin penetration is possible by the method of pressure-cylinder. In the vaccum-pressure-cylinder method, as resin is impregnated as much as in the pressure-cylinder method, it is not necessary that vaccum is conducted before the pressure. The effects of vaccum is not remarkable as the data indicated with vaccum method (see Table IV).

The test results indicate that pressure-cylinder method is most suitable in the impregnation of resin to woods, and the addition of the middle pressure for long time is better than that of the high pressure for short time in order to penetrate at uniform and depth.

References

1) M. A. Millett and A. J. Stamm ; Forest Products Laboratory Report No. R1703 (1947).
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3) Ibid. ; Modern Plastics 202 (1947).
4) J. F. T. Berlinder ; Chem. Ind. **54** 680 (1944).
5) Y. Konishi and T. Yamamoto ; Wood Research (Japan) **11**, 1 (1953).