Application of Impreg for Patterns and Die Models

RAY M. SEBORG
Chemist, Forest Products Laboratory,' Forest Service, U. S. Department of Agriculture

and

A. E. VALLIER
Manager, Experimental Fabricating Department, Engineering Staff,
Ford Motor Company, Dearborn, Mich.

An investigation has been made on the suitability of impreg for patterns and die models. Approximately five thousand board feet of impreg panels were produced from phenolic-resin-impregnated mahogany veneer. When exposed to various moisture conditions, the die models made from mahogany impreg changed in dimensions only about one-third as much as the die models made from the untreated mahogany ,lumber. Additional tests made on the impreg panels showed that it is highly resistant to heat, is readily carvable, and can be glued with but slight modification of the present methods used in gluing untreated wood. From this investigation the conclusion was reached that impreg panels made from mahogany veneer are superior to the standard mahogany lumber now used for patterns and die models.

WOOD IS ONE of our few natural products that has been used throughout the history of mankind with almost no modification of its propertes. Few materials have as versatile applications and have been as universally accepted as wood. Nevertheless, we know that for certain applications some properties of wood are not desirable, such as the tendency to decay when subjected to high moisture conditions, and the tendency to change dimensions with changes in moisture content.

The impregnation of wood with chemical preservatives greatly increases the resistance of the wood to decay. Even though the preservative treatment of wood is relatively new, having been developed chiefly during the last few generations, this process has been widely accepted by the wood industry.

The impregnation of wood with phenolic resins greatly increases the dimensional stability of the wood. This method of treatment is of more recent development than the preservative treatment of wood. The process of impregnating wood with phenolic resins to reduce moisture absorption and dimensional changes, however, has been described rather extensively in many reports, magazines, and technical journals during the past two decades. The wood industry, nevertheless, has been slow in adopting this process to reduce the dimensional changes of wood. This fact may be due partly to the relatively high costs of the treated wood, which has been produced primarily for rather specialized applications where its desirable properties can be utilized and where the relatively high costs of the wood can be justified.

In order better to discuss new applications for this material, a brief review is given here of the methods of treatment, properties, and current application of resin-impregnated wood.

Wood impregnated with phenolic resin-forming chemicals, followed by drying and curing the resin within the wood structure without the application of pressure, is known as irripreg (4, 7, 8, 10, 11). This process is, however, chiefly limited to the treatment of thin sections of wood such as veneer, because of the difficulty encountered in obtaining uniform impregnation and in the subsequent drying of wood in lumber-size dimensions. Of course, laminated panels of any desired thickness can be built up from the treated veneer.

In the manufacture of impreg, the veneer is impregnated by forcing the resin solution into the sheets by the application of pressure or by soaking the veneer in the resin solution until the proper amount of resin is absorbed. The impregnating resin should be a slightly polymerized phenolic resin, i.e., a resin of low molecular weight in which the resin molecules are sufficiently small to penetrate the cell-wall structure. Only resin entering the cell wall reduces the shrinking and swelling; that deposited in the voids is of no value. Many resin manufacturers are now producing impregnating resins suitable for the stabilization of wood. The solids content of the resins made by different manufacturers varies considerably, generally ranging from 35 to 75 percent.

ABOUT THE AUTHOR: SEBORG, RAYMOND M. Co-author, Session V, Glues and Gluing, "Application of Impreg For Die Models" . . . Chemist, Division of Derived Products, U. S. Forest Products Laboratory, Madison, Wis. . . . He joined the FPL in 1928 after receiving a BS in chemistry from Montana State College in the same year . . . He is a member of the FPRS, the American Chemical Society, and Sigma Xi.

ABOUT THE AUTHOR: VALUER, A. E. Jr. Manager, Experimental Fabricating Dept., Engineering Div., Ford Motor Co., Dearborn, Mich. Received B.S. in mechanical engineering from Iowa State College. Has been associated with Allis—Chalmers, Ethyl Corp., and U. S. Army Ordnance. Member of Society of Automotive Engineers and A.S.M.E.

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To obtain uniform impregnation throughout the wood without the absorption of too great a quantity of resin, the treating resins are first diluted with water to a solids content of approximately 30 percent. Veneer is impregnated by the application of pressure or by soaking in the resin solution until the weight of the solution absorbed is approximately that of the untreated wood, i. e., approximately 100 percent solution uptake. This will give a resin content of approximately 30 percent based on the weight of the untreated dry wood. The treated veneer is then solid-stacked under nondrying conditions for approximately 1 day to allow time for the resin solution to diffuse into the wood structure before drying and curing. The treated veneer is dried in a commercial veneer roller drier or in an oven or kiln that has circulating air. The drying temperature (less than 200° F.) is kept below the boiling point of water to prevent the solution and the dissolved impregnating agent from being forced to the surface of the wood during the early stage of drying by the steam pressure developed in the wood. Veneer in thicknesses up to one-eighth inch can be dried to a moisture content of from 10 to 15 percent in about 30 minutes in a roller drier. Considerably longer time is required if the veneer is dried in an oven or kiln. The resin in the dried treated veneer is then cured by heating at a high temperature. This is a time - temperature reaction; at 310° F. the curing time is approximately 30 minutes.

The treated and cured but uncompressed impregnated veneer can be glued with many of the same glues and gluing processes now used for gluing of untreated wood. It may, however, be necessary to vary certain gluing conditions, such as the amount of spread, assembly conditions, and curing conditions, somewhat from those used with the same untreated species in order to obtain the desired high-quality bonds of the treated veneers.

This treatment of wood will greatly reduce the moisture absorption, swelling, and shrinking of wood with virtually no sacrifice in paintability or thermal insulating properties, and with serious effects on its gluability. Much less moisture is absorbed by or passes through impreg than by or through untreated wood. The f ace checking of impreg under weathering conditions is markedly less than that of untreated veneer.

Except in hardness and compressive strength, which are slightly increased, the mechanical properties (2) are not improved by this treatment. Toughness and impact strength are materially reduced. Decay resistance is greatly increased. This increase appears to be due to the fact that the cell walls of the treated wood cannot take up sufficient moisture readily to support decay. Limited tests of resin-treated specimens exposed to marine-borer attack indicate that impreg may have good resistance to these marine pests. Also because of the reduced equilibrium moisture content of resin-treated wood, the electrical resistivity (13) of the material has been greatly increased.

The acid resistance of impreg is high. Its fire resistance is not markedly greater than that of untreated wood. The resistance to heat, however, is greatly increased by resin impregnation. Impreg heated for 60 minutes at 300° F., and then for 60 minutes at each 25 degree increase in temperature up to 550° F., showed no significant charring or disintegrating of the wood until temperatures of 525° and 550° were reached. Also, impreg was heated at 400° F. for 1 hour and then allowed to cool. This cycle was repeated over 50 times with no apparent disintegration of the wood. Untreated wood will char and disintegrate badly when subjected to these conditions of heating.

Impreg has been used for military purposes, such as housings for electrical control equipment, in which its improved electrical properties were utilized. At present impreg is being produced for the construction of acid tanks, in which advantage is taken of its high acid-resistant property. Industry, however, has been slow to take advantage of the most improved property, dimensional stability, imparted to wood by resin impregnation.

• At present, resin-treated wood has been chiefly used in its compressed form. This stable form of compressed resin-treated wood (compreg) (4, 5, 6, 9, 10, 12), which is highly compressed prior to the setting or curing of the resin, is sold under various trade names by the manufacturers of this product. Some of the applications of compreg with which we are familiar are tooling jigs and forming dies, cutlery handles, musical instruments, strain insulators (and other applications in the electrical field where a strength, high-dielectric material is required), electrical transformer parts, spar and connector plates, shuttles and picker sticks in the textile industry, sporting goods, and decorative applications.

Considerable publicity has been given to the products that are currently being made from compreg. Until recently, however, industry has paid little attention to the possible uses of the uncompressed resin-treated wood (impreg), even though the lack of dimensional stability of the untreated wood has been a problem of major importance. In many of these applications the increased cost of impreg over that of untreated wood could be readily justified.

One of these applications is the use of impreg for die models in the automobile industry. Since the beginning of mass production of cars, the body parts have been stamped out by steel dies. In order to make the steel dies, models of the correct size and shape must be first made of wood, and from these wooden models the surfaces are duplicated in steel by keller machines (fig. 1). Since the wooden models determine the shape of the steel dies, it is highly important that these models do not change dimensions appreciably from the time the models are made until the steel dies have been completed and production has started. This period of time may vary from a few months to several years, and with changes in moisture conditions the dimensions of the wood models also change. Changes in dimension in the wood models, unless corrected, would be reflected in the dimensions of the steel dies with the result that the final products (car body parts) would not fit together exactly as designed. Frequently these changes may be of sufficient magnitude to require reworking of the entire surface of the models. Since each step in the engineering and tooling for production of a new model is closely timed, any delay is costly from a time and monetary standpoint. The fact that wood changes in dimensions with changes in moisture content therefore presents a serious problem in the automobile industry, and one that has been faced with difficulty for the last 40 or more years.

Most of the efforts that have been made to eliminate or reduce this difficulty involve attempting to prevent mechanically the entrance and exit of moisture with surface coatings (1, 3) such as paint, varnish, water repellents, and related products. These treatments have proved effective in retarding the rate of moisture changes, and are therefore effective in reducing changes in moisture content and dimensional changes when exposures to high or low moisture conditions are for short periods of time. Since surface coatings only affect the rate of moisture absorption and do not significantly change the amount of moisture that the wood can absorb, this type of treatment is not effective in reducing changes in moisture content or dimensional changes of wood when expos e d to long humidity-change cycles such as seasonal changes.

The most effective means of reducing the equilibrium swelling and shrinking of wood that has been found up to the present time is the foregoing process of bonding and fixing active chemicals within the cell-wall structure of

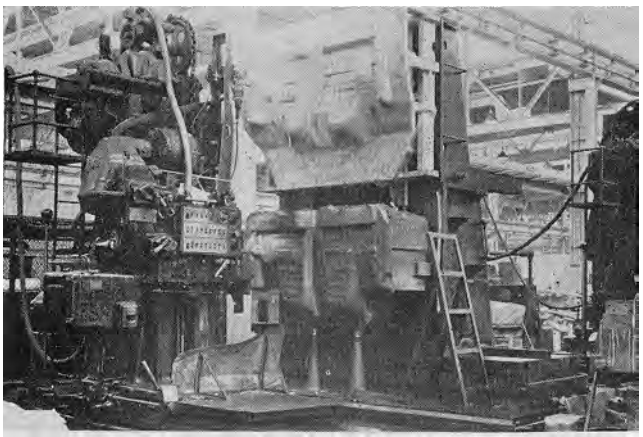
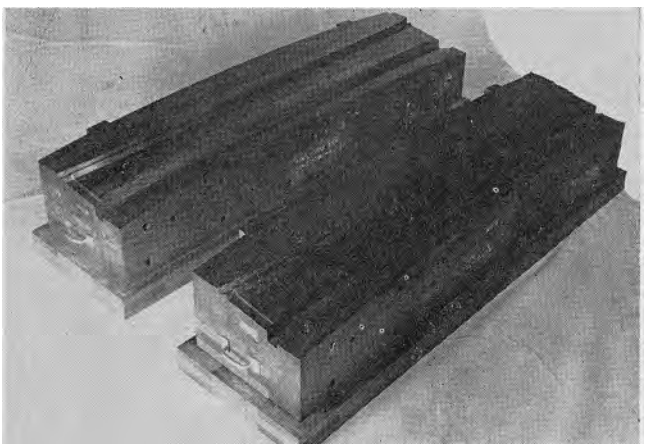


Figure 1.—Keller duplicating machine.



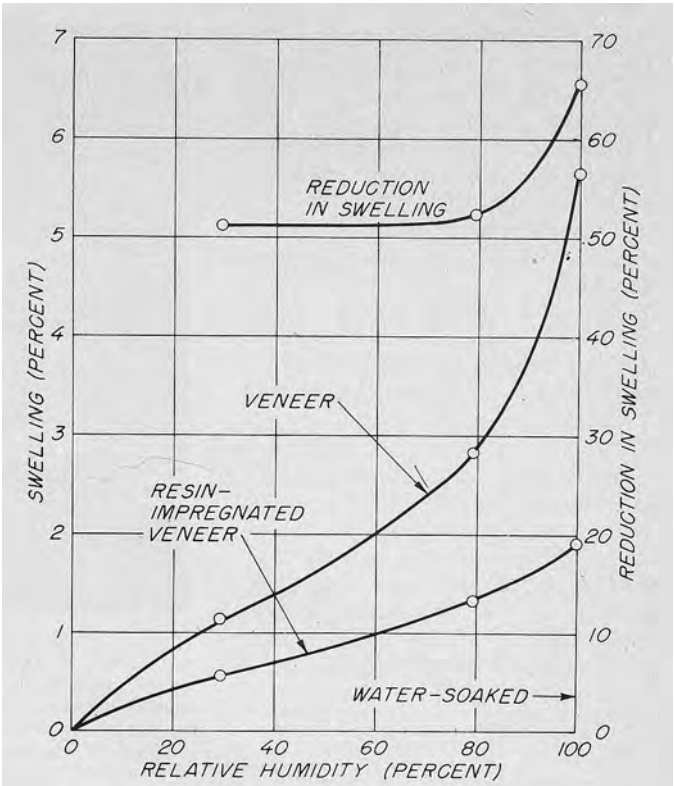


Figure 3.—Effect of resin impregnation on the reduction in swelling of mahogany veneer between ovendry and various moisture conditions.

Figure 4.—Die model made from mahogany lumber, left, and one made from resin-impregnated laminated lumber, right.

wood. Phenol-formaldehyde is, to our knowledge, the most effective resin-forming system that is practical to accomplish this objective.

The Ford Motor Company sponsored a research project at the Forest Products Laboratory to determine the suitability of using impreg for making die models and patterns.

The properties of impreg, in general, have been well established. However, the effect of phenolic resins on mahogany for this particular application had yet to be determined. Tests were therefore made to determine the effectiveness of resin impregnation in reducing dimensional changes of the veneer, the laminated panels, and the completed die models. Bakelite resin BR 15100 was used as the impregnating resin for making impreg for these tests. The effect of resin on the gluing and carving properties of this material was also determined.

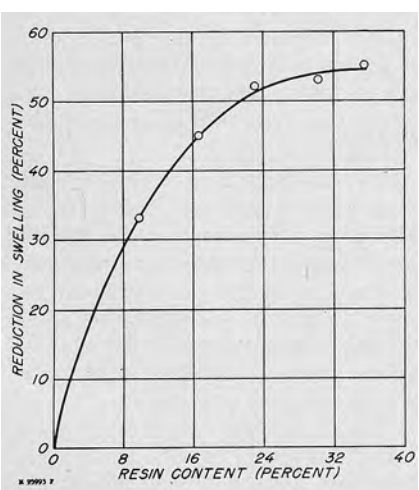


Figure 2.—Effect of resin content on the reduction in swelling of mahogany veneer between ovendry and water-soaked conditions.

The effect of varying amounts of resin on reduction in swelling of mahogany veneer from ovendry to water-soaked conditions is shown in figure 2. The resin content was based on the weight of the untreated ovendry wood. The dimensional stability increased with increase in resin content up to approximately 30 percent, at which point a reduction in swelling of 50 to 55 percent was obtained. Additional amounts of resin do not significantly increase stabilization.

The effect of resin impregnation on the reduction in swelling of mahogany veneer between ovendry and various moisture conditions is shown in figure 3. A reduction in swelling of 50 to 55 percent was obtained when the swelling was determined between ovendry and 30 or 80 percent relative humidity. The reduction was considerably greater, approximately 65 percent, when the swelling was measured between ovendry and water-soaked conditions. The reduction in swelling was' still greater when the swelling was determined between 80 percent relative humidity and water-soaked conditions. Under these conditions the percent swelling (as indicated in the graph) was 0.6 for impreg and 2.8 for the untreated veneer. The amount of swelling of the resin-treated veneer is, therefore, only 21.5 percent of that of the untreated veneer. This is a reduction of 78.5 percent. This high degree of stability at the high moisture levels is important when the models come in contact with wet materials such as plaster of Paris in the making of duplicate casts and plastics in the making of duplicate models.

Since the standard die models are built up from mahogany boards, this practice was followed in the fabrication of impreg die models, that is, the treated veneer was first made into boards or panels of comparable thickness and width of mahogany lumber. A conventional hot-press phenol-resin glue was used in the gluing of the veneer into panels. Impreg die models were then built up from these panels by using a room-temperature-setting resorcinol or epoxy resin as the bonding agent.

The first batch of impreg for this application was made at the Forest Products Laboratory. This batch con-

sisted of approximately 200 board feet of laminated panels (approximately 1 x 12 x 48 inches). Each panel was laminated from 17 plies of one-sixteenth inch sliced Honduras mahogany (Swietenia) veneer. Later tests have shown that either well-cut sliced or rotary-cut veneer in thicknesses up to one-tenth inch is suitable for this application.

From this material the first impreg die model (upper back panel) was made by Deutsch and Sons Pattern and Machine Works, Milwaukee, Wis. A comparable model was also made from mahogany lumber (fig. 4). Both models were subjected to 90 percent relative humidity at 80° F. for a month and then to 30 percent relative humidity for the same length of time. The dimensional changes were determined periodically. The comparative dimensional changes of the 2 die models when subjected to 90 percent relative humidity are shown in figure 5. Each value represents the average of measurements made at 24 different positions on each model. The results show that a 65 percent reduction in swelling was obtained for the impreg model. Similar values for reduction in shrinkage were obtained when the models were subjected to 30 percent relative humidity.

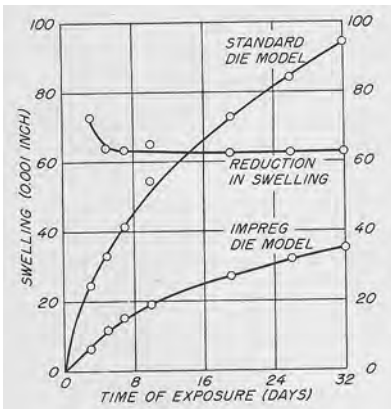


Figure 5.—Comparative dTIME sional changes of a die model made from mahogany lumber and one made from resin-impregnated Laminated lumber. Data represent average of 24 measurements.

The irregular surface, resulting from swelling during exposure to 90 percent relative humidity, can be readily observed on the end section of the standard model (fig. 6). This irregular surface (indicated by shadow lines) is the result of differential swelling of the adjacent boards in transverse and longitudinal directions. No surface irregularities are noticed on the impreg model.

Impreg blocks (6 x 6 x 12 inches) were also made from mahogany lumber and from the impreg panels. These blocks were subjected to a moisture condition of 80 percent relative humidity for approximately 3 months. Dimensional changes in the two directions, parallel to, and across the laminates were determined at various distances from the end of the blocks. The results (fig. 7) show approximately 65 percent reduction in swelling for the impreg blocks. The decrease in the amount of swelling for each successive point of measurement from the end of the block indicates that equilibrium swelling throughout the block had not been attained in this period of time.

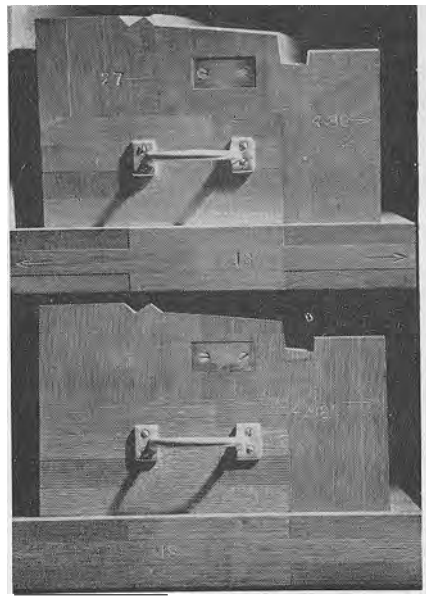


Figure 6.—End view of die models showing surface irregularity of standard die model (upper) after exposure to 90 percent relative humidity for 1 month. Shadow lines on end of top model are due to differential swelling of the adjacent boards in transverse and longitudinal directions.

The greater degree of stability of the impreg die model and impreg block as compared to that of the treated veneer is at least partly the result of laminated construction that in itself tends to reduce dimensional changes.

The reduction in dimensional changes of phenolic-resin-impregnated wood is not affected by the length of time of exposure to humidity conditions, as the equilibrium moisture content of the wood is permanently reduced by this treatment. This effect is apparent by the fact that the reduction in swelling of impreg blocks over a period of 3 months was the same as that obtained for the impreg model for a period of 30 days. While the stability of die models has not been determined over long periods of time, it is reasonable to assume that the dimensional stability of the impreg models is as permanent as the stability of the impreg veneer and panels from which they are made.

It has been emphasized that impregnants that do not penetrate the cell wall of the wood fibers do not permanently reduce the equilibrium moisture content of the wood. They, therefore, are not effective in materially reducing dimensional changes that occur over long periods of time. There are commercial processes using water repellents and other impregnants together with wood preservatives that are effective in reducing moisture absorption, dimensional changes, and decay of wood in application where shedding of liquid water is a factor. However, at this time we know of no impregnant that is so effective, economical, and practical to use as phenolic resins in an application where a high degree of permanent stability is required.

In the fabrication of models from untreated mahogany lumber, polyvinyl resin glues are currently being used for gluing the boards together. This type of glue depends on the partial loss of moisture to the wood; that is, the partial drying of the glue to give a good initial bond. Such a glue appears to be satisfactory for gluing untreated wood that will absorb moisture from the glue sufficiently rapidly to give a satisfactory bond during the desired pressure period. This type of glue, however, was found to be unsatisfactory for the bonding of impreg panels, since the absorption of water by the treated wood is too slow and incomplete to give a good bond during the period of time that the material is clamped together. It has therefore been necessary to use a glue that does not depend primarily on the absorption of moisture by the wood to give a good glue bond. The various thermosetting resin glues, which harden or cure by undergoing a chemical reaction, naturally suggest themselves for such an application. Such glues, which are capable of reaction at normal room temperatures, are most desirable. Resorcinol resins or epoxy resins that set up at a room temperature of 70° F. or higher have proven satisfactory for this purpose when properly used. Certain other types of glues are under investigation.

Tests on the impreg die model made from the original 200 board feet of mahogany impreg and on the conventional die model made from mahogany lumber showed that impreg is far superior to normal wood for this application. It was therefore desirable to test further the suitability of this material in larger die models. Consequently, 2 roof die models were made, 1 from impreg (fig. 8) and 1 from mahogany lumber. A roof model was chosen because it is one of the largest die models made, and also because experience has shown that it will change

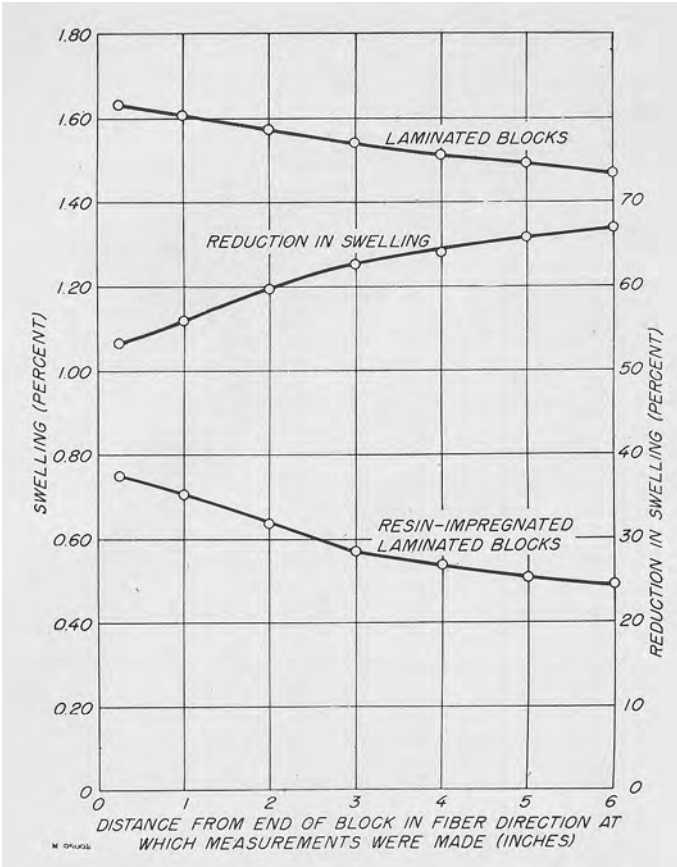


Figure 7.—Comparative swelling of resin-treated and untreated laminated blocks (6 x 6 x 12 inches) when exposed to 80 percent relative humidity for 112 days after prior conditioning to equilibrium in 30 percent relative humidity. Data represent average values for radial and tangential measurements.

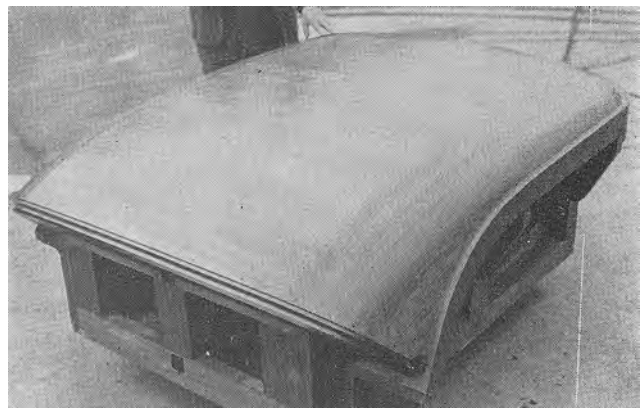


Figure 8.—Roof die model made from mahogany impreg.

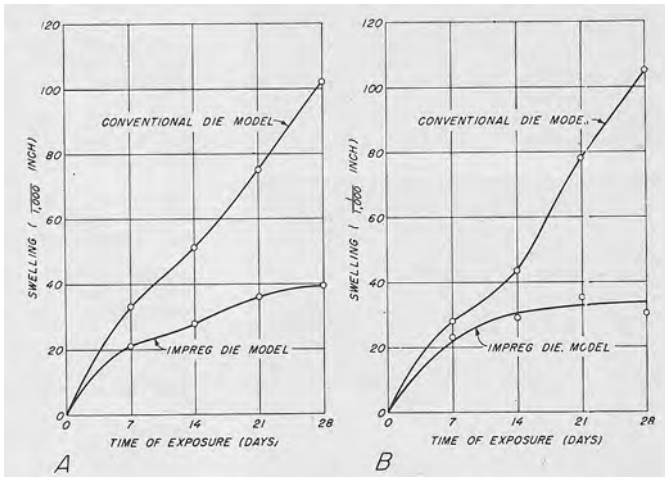


Figure 9.—Comparative dimensional changes in A, width, and B, length, of a roof die model made from mahogany lumber and one made from resin-impregnated laminated lumber when subjected to 90 percent relative humidity.

in dimensions extensively due to moisture changes.

Comparative exposure tests at 90 percent relative humidity and at 80° F. were made at the Forest Products Laboratory on the 2 models. Dimensional changes were determined after each week of exposure for a period of 4 weeks. Comparable dimensional changes in the width and length directions of the 2 models are shown in figure 9. The reduction in swelling of the impreg die model as compared to that of the conventional die model is in close agreement with the results obtained on the smaller die models previously tested (fig. 5).

Comparable sectional views (figs. 10, 11, 12) of a roof panel die model made from conventional mahogany lumber and a similar die model made from impreg taken after the models had been exposed to 90 percent relative humidity for 4 weeks, clearly show the lack of movement in impreg as compared to untreated mahogany lumber.

For the construction of the roof die model and for various other tests, approximately 5,000 board feet of impreg panels were produced by Haskelite Corporation, Grand Rapids, Mich., and by Nickey Brothers, Memphis, Tenn., in cooperation with Koppers Company, Wood Preserving Division, Orrville, Ohio. From this supply of material, each die-model shop and pattern shop in the Chicago, Milwaukee, and Detroit areas that make models for the Ford Motor Company made experimental models from this new material. From their experience, there is no indication that it is any more difficult to make a model from impreg than from conventional mahogany lumber. In fact, there is every indication that it will be easier. Generally, no increased dulling of the tools was experienced while working with this new material, and the surface of the models made from impreg was easier to sand to a smooth finish than the surface of the models made from conventional mahogany.

Several die models for the 1956—model cars have been made from this material. They are now at the various tool and die shops where the hard dies are being kellered from them. It is expected that no difficulty will be experienced. The use of models from this new material will enable the tool manufacturers to take from the die model as many plaster or plastic casts as desired without experiencing any change of dimension or extortion of the original model. Also, from a practical usage standpoint, the model will be dimensionally stable throughout its life.

Making die models from this material will also allow the automotive industry the opportunity of using to a greater extent duplicate plastic die models. This is because the original model made from impreg will not change dimensionally due to the application of plastic over it.

The Ford Motor Company has made wood crankshaft patterns from impreg that were used to make experimental shell-molded crankshafts. In this application advantage is taken both of the dimensional stability and heat-resistant properties (figs. 13, 14) of this material, inasmuch as the pattern is heated for an hour to 400° F. before the mixture is set and resin is applied. Because of the heat that the patterns are subjected to, a heat-resistant glue, such as resorcinol glue, must be used for bonding the boards together for this application. The shells obtained are very satisfactory, and the use of impreg in this experimental application appears promising.

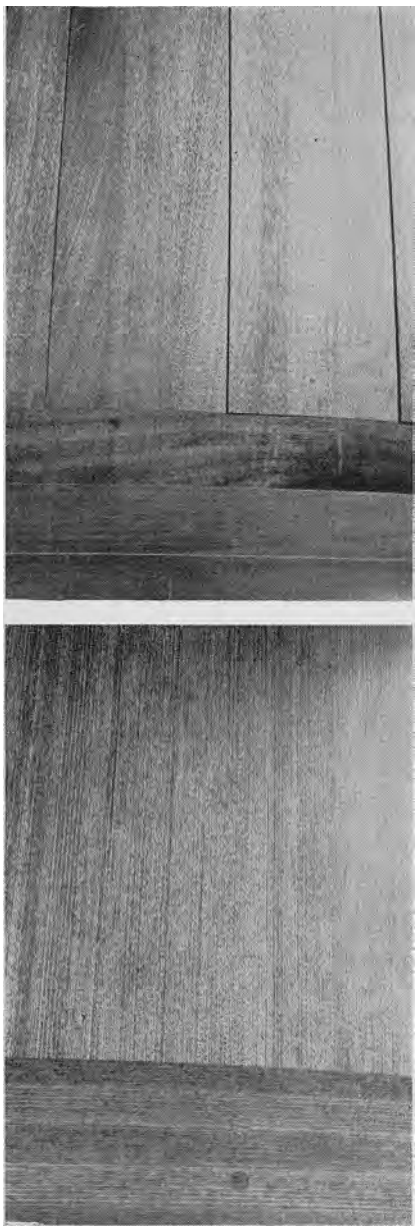
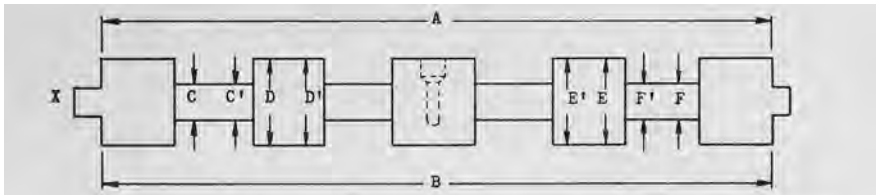


Figure 10.-Top center surface of die model made from mahogany lumber (above) and the some surface of one made from impreg (below). The shadow lines on left show raising of the boards due to the swelling and movement of the wood. No raising or distortion of the wood occurred on the model made from impreg.

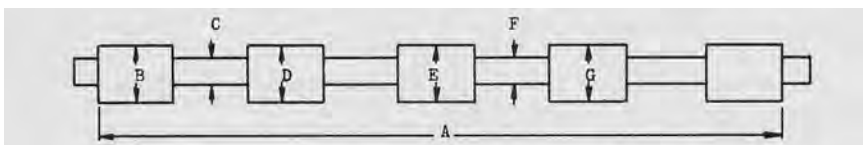
Also, the Ford Motor Company is experimenting with impreg for the construction of other types of wooden patterns.

Since the presentation of this paper, 30,000 board feet of mahogany impreg has been produced by Haskelite Corporation and by Nickey Brothers, Inc., for the Ford Motor Company and manufactured under specifications set up by the Forest Products Laboratory. This material is being used for making pattern and die models for the production of the new-model cars. Plans are being made for ordering additional material from these firms.



	A	B	C	C'	D	D'	E'	E	F'	F	REMARKS
Before Heat	18.472	18.460	1.016	1.014	1.901	1.901	1.905	1.905	1.010	1.012	
300°1/2 hour	18.475	18.463	1.023	1.020	1.902	1.902	1.909	1.907	1.014	1.017	
300°1 hour	18.476	18.467	1.020	1.019	1.899	1.901	1.906	1.905	1.013	1.015	
	.004	.007	.004	.005	.002	--	.001	--	.003	.003	
Before 350°	18.471	18.460	1.013	1.010	1.890	1.889	1.895	1.895	1.005	1.006	
350°1/2 hour	18.478	18.470	1.020	1.018	1.898	1.898	1.903	1.904	1.012	1.015	
350°1 hour	18.479	18.471	1.0185	1.016	1.894	1.894	1.900	1.901	1.010	1.013	
	.008	.011	.0055	.006	.004	.005	.005	.006	.005	.007	
Before 400°	18.472	18.460	1.014	1.010	1.884	1.883	1.888	1.889	1.005	1.007	
400°1/2 hour	18.479	18.467	1.018	1.019	1.898	1.896	1.902	1.902	1.011	1.016	
400°1 hour	18.481	18.466	1.021	1.016	1.895	1.894	1.905	1.906	1.018	1.026	
	.009	.006	.007	.006	.011	.011	.007	.007	.013	.019	
Before 425°	18.467	18.452	1.013	1.008	1.883	1.882	1.889	1.893	1.011	1.018	
425°1/2 hour	18.477	18.466	1.019	1.014	1.896	1.893	1.902	1.905	1.016	1.023	
425°1 hour	18.476	18.463	1.020	1.013	1.895	1.894	1.902	1.903	1.018	1.025	
	.009	.011	.007	.005	.012	.012	.011	.010	.007	.007	
Before 450°	18.466	18.455	1.011	1.006	1.879	1.881	1.890	1.891	1.010	1.016	
450°1/2 hour	18.472	18.463	1.016	1.014	1.893	1.894	1.903	1.904	1.017	1.021	
450°1 hour	18.471	18.459	1.018	1.013	1.887	1.889	1.895	1.897	1.015	1.020	
	.011	.004	.007	.007	.008	.008	.005	.006	.008	.004	
Before 475°	18.456	18.448	1.005	1.001	1.870	1.871	1.878	1.881	1.005	1.011	
475°1/2 hour	18.469	18.458	1.013	1.007	1.887	1.885	1.889	1.892	1.013	1.020	
475°1 hour	18.468	18.456	1.011	1.003	1.879	1.878	1.886	1.887	1.010	1.015	
	.012	.008	.006	.006	.009	.007	.009	.006	.005	.004	
Before 500°	18.455	18.445	1.003	1.000	1.860	1.860	1.873	1.876	1.008	1.013	
500°1/2 hour	18.468	18.456	1.013	1.010	1.876	1.875	1.884	1.884	1.014	1.021	
500°1 hour	18.464	18.455	1.011	1.006	1.874	1.873	1.880	1.880	1.017	1.022	
Before 525°	18.454	18.443	1.000	.998	1.855	1.854	1.863	1.867	1.002	1.005	
525°1/2 hour	18.470	18.457	1.011	1.009	1.871	1.870	1.874	1.879	1.009	1.016	
525°1 hour	18.465	18.450	1.011	1.003	1.867	1.864	1.871	1.873	1.012	1.020	Lamination Separating
Before 550°	18.435	18.420	.998	.997	1.846	1.847	1.846	1.851	.999	1.003	
550°1/2 hour	18.455	18.443	1.012	1.009	1.870	1.866	1.864	1.874	1.019	1.013	
550°1 hour	18.423	18.414	1.016	1.019	1.867	1.867	1.872	1.871	1.025	1.021	

Figure 13.-Dimensional movement of impreg due to heat, showing the results of a test where the impreg was heated for 1 hour at different temperatures. Measurements were taken at the end of ½ hour and at the end of 1 hour.



	A	B	C	D	E	F	G	REMARKS
Before Heat	18.443	1.897	.975	1.889	1.887	.968	1.886	
400°1 hour	18.453	1.895	.980	1.893	1.887	.977	1.882	
Before Heat	18.440	1.885	.975	1.880	1.875	.965	1.870	
400°1 hour	18.447	1.892	.973	1.886	1.879	.968	1.878	
Before Heat	18.438	1.881	.972	1.876	1.868	.962	1.864	
400°1 hour	18.449	1.889	.974	1.886	1.877	.963	1.873	
Before Heat	18.436	1.878	.971	1.871	1.867	.960	1.863	
400°1 hour	18.452	1.890	.973	1.882	1.883	.965	1.883	
Before Heat	18.437	1.875	.963	1.869	1.864	.957	1.862	
400°1 hour	18.447	1.885	.972	1.879	1.876	.966	1.874	
Before Heat	18.431	1.875	.972	1.872	1.867	.960	1.861	
400°1 hour	18.445	1.884	.973	1.879	1.875	.963	1.875	
Before Heat	18.433	1.874	.966	1.867	1.862	.956	1.857	
400°1 hour	18.448	1.884	.973	1.875	1.871	.965	1.870	
Before Heat	18.435	1.872	.964	1.866	1.859	.957	1.857	
400°1 hour	18.448	1.882	.969	1.875	1.870	.961	1.869	
Before Heat	18.436	1.872	.965	1.865	1.861	.955	1.857	
400°1 hour	18.448	1.879	.968	1.872	1.869	.965	1.867	
Before Heat	18.435	1.870	.966	1.865	1.859	.955	1.856	
400°1 hour	18.449	1.878	.969	1.872	1.870	.963	1.865	
Before Heat	18.434	1.869	.963	1.865	1.858	.955	1.853	
400°1 hour	18.448	1.879	.970	1.873	1.868	.961	1.865	

Figure 14.-Dimensional movement of impreg due to heat, showing the results of a test where the impreg mahogany was heated to 400° and allowed to cool 11 times.

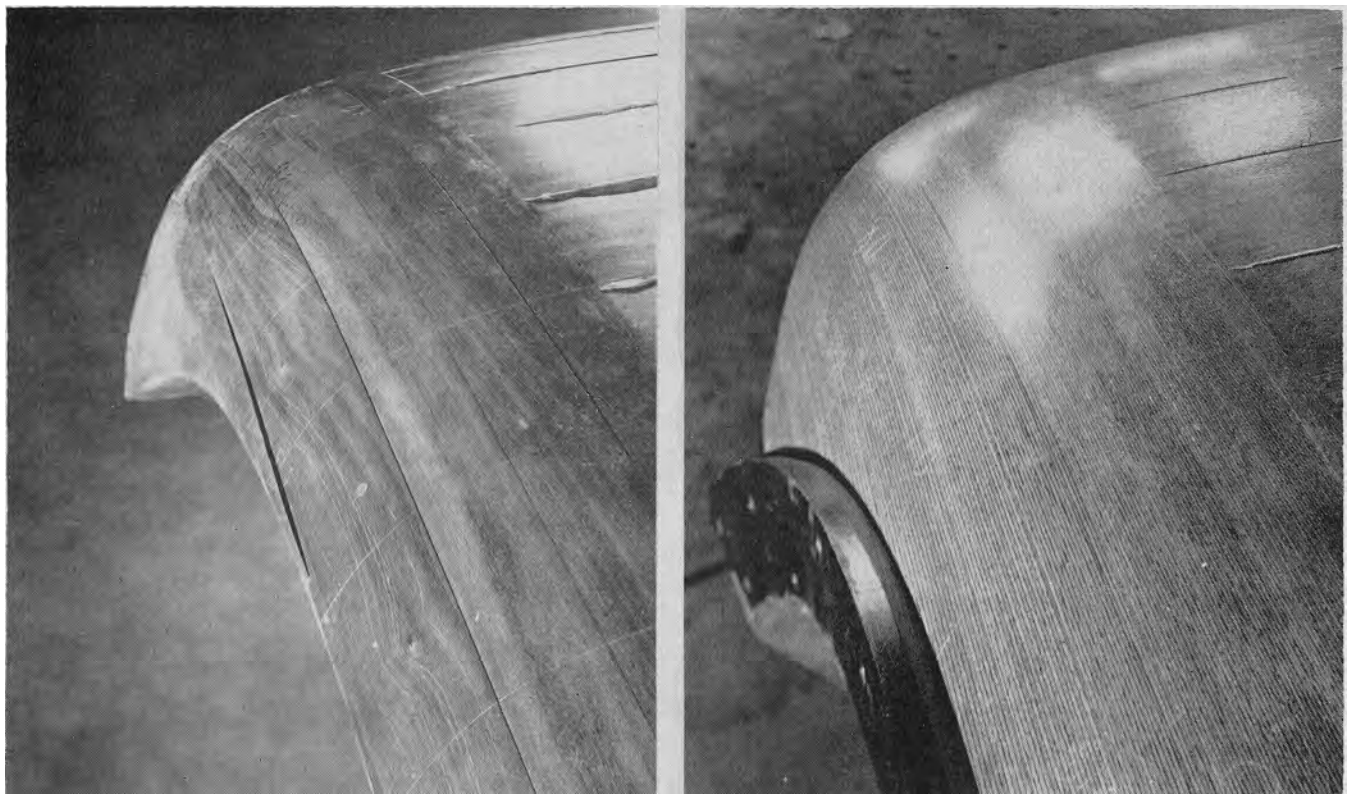


Figure 11.—Surface of rear corner of roof die model made from mahogany lumber (left) and the same surface of one made from impreg (right). The shadow lines on left show raising of the boards due to the swelling and movement of the wood. The upper right corner of the photographs shows the difference in the amount of wax squeezed out of the expansion joints due to the excessive swelling on conventional mahogany.

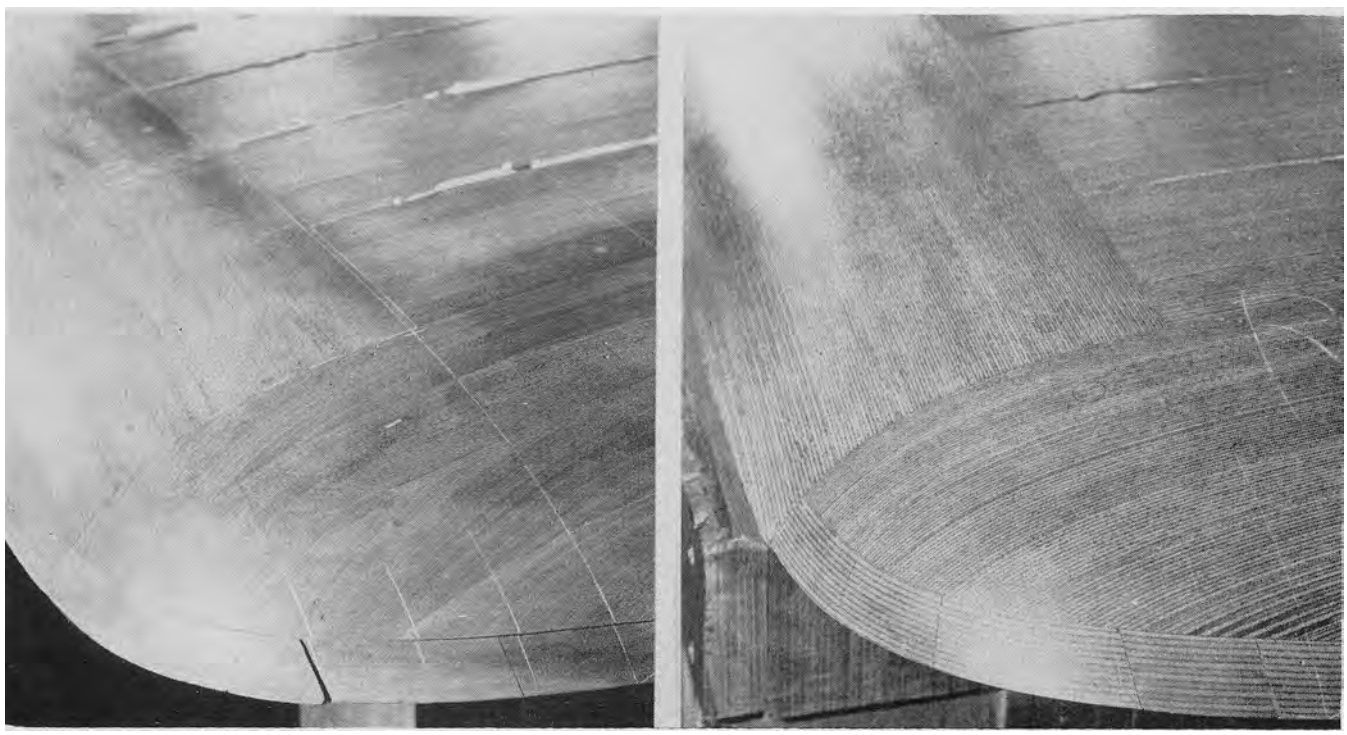


Figure 12.—Surface of front corner of roof die model made from mahogany lumber (left) and the same surface of one made from impreg (right). Notice on photograph left how the offsetting of the scribe lines show the excessive movement of the conventional wood.

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