NITRATE COVERING FOR PROPELLER BLADES

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Reprinted from the November 1946 issue of MODERN PLASTICS.

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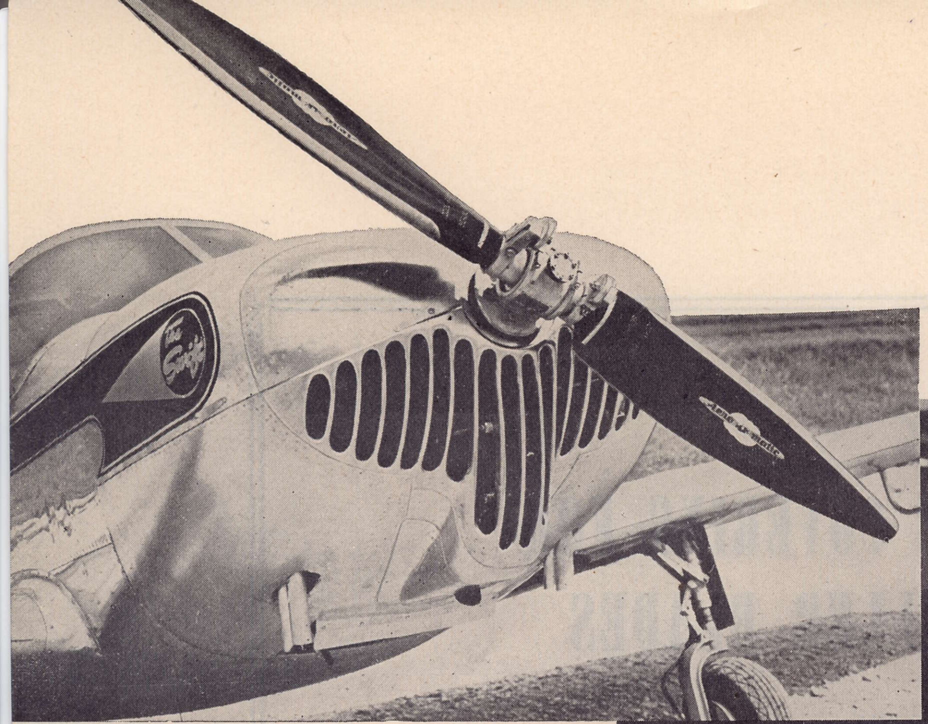
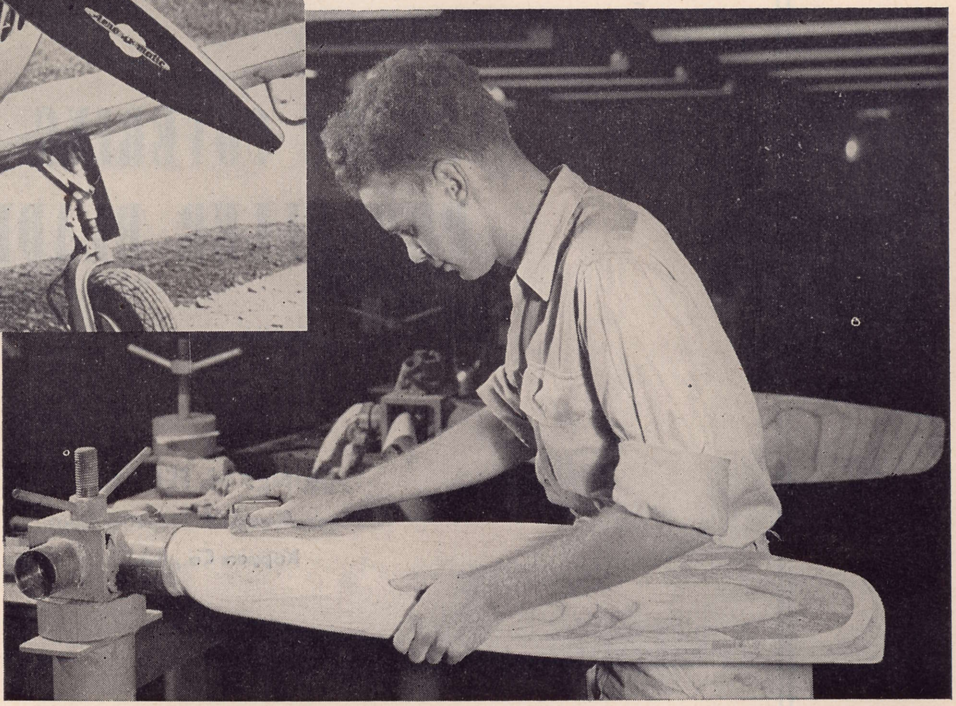


1—*Front view of the F-200 Aeromatic installed on the Globe "Swift," a two-place, all-metal light plane. Plastic covering protects laminated wood of propeller from abrasion, moisture*



ALL PHOTOS, COURTESY BARTLETT HAYWARD DIV., KOPPERS CO., INC.

2—*A light sanding of wood blade is performed locally to bring the blade to an accurate template fit. The blade is carved from laminated maple veneers*

AIRCRAFT propellers, by virtue of their use, are subjected to the most rigorous set of operating conditions that afflict an aircraft and its components. Designed to transmit engine horsepower into thrust through aerodynamic action, propeller blades are carefully designed and engineered to perform with maximum efficiency. To accomplish this, the surfaces of the blades must be smoothly finished and protected against the effects of weather, humidity and abrasion.

The laminated wooden propeller blade is still the type that is most practical and most widely used in both fixed and variable pitch propellers for light personal planes. This type of blade is covered with varnish or lacquer to seal the pores of the wood and is wrapped near the tip with fabric to strengthen the thin section which is subject to abrasion and possible splitting due to high loads. Running from the tip to the inner quarter of the blade is a metal sheath, usually of copper, brass or stainless steel, which fends off small stones picked up during take-off, and long grass encountered during take-off and landing, even raindrops, which can damage a blade operating in a rainstorm.

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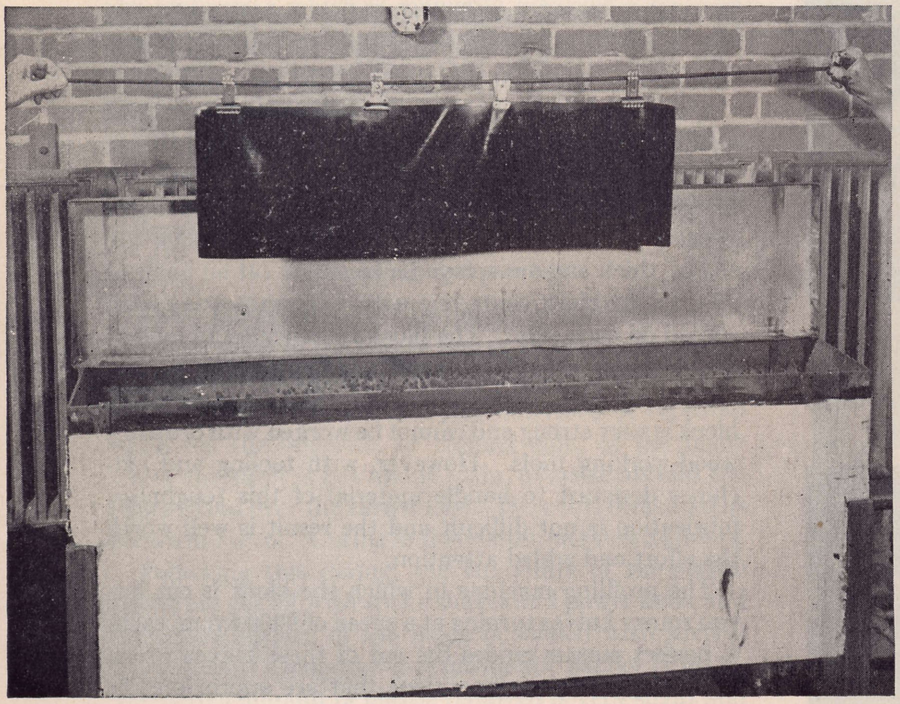
The possibility of injury to the blades due to even such apparently harmless objects as raindrops is due to the high speed of rotation of the propeller blades near the tip. In many instances the blade tip will be traveling in the neighborhood of 900 to 1000 ft. per second. Besides abrasion, moisture absorption is perhaps the element most harmful to the blades. Unless adequate protective covering is applied to the blades they will absorb moisture, usually unevenly, if the propeller is positioned vertically when inoperative. This absorption causes an out-of-balance condition with attendant vibration and rough engine operation.

While lacquers and varnishes have generally served well under conditions that are not too severe, entirely satisfactory operation cannot be achieved unless the maximum abrasion-resistant and moisture-excluding practices are introduced. To this end, the Aeromatic propeller, manufactured by the Bartlett Hayward Division of Koppers Company, Inc., has been fitted with plastic-covered blades since 1943 when military usage demanded unusually rigid protective measures against tropical climatic effects which had been deteriorating the conventionally covered blades. All produc-

covering for propeller blades

Cellulose nitrate sheeting as cover on propeller blades offers maximum resistance to abrasion and moisture adsorption



3—*(Left) After suspension for an hour in a softening solution the nitrate sheet is ready for application to the blade.* 4—*(Right) Plastic cement is first applied to top side of blade and to half of plastic sheet*

tion models now have the plastic Aeroloid covering of cellulose nitrate as a standard finish, the Nixon Nitration Works supplying all the cellulose nitrate used.

This propeller differs from all variable-pitch types used on light personal planes in that it features a scheme of pitch changing which is entirely automatic and requires no motivating mechanism whatsoever. The scheme employs centrifugal force and aerodynamic thrust to cause blade movement.

The practice of applying a plastic coat or sheet to the exterior of wooden propeller blades is not new in concept or practice. It was first practiced in Germany over 10 years ago. The German propeller firms of Heine and Schwarz were apparently the first to recognize that a better protective covering for wooden blades could be obtained than from the commercial varnishes and lacquers in current use. Accordingly Schwarz proceeded to develop a cellulose acetate covering about $^1/_8$ in. thick which covered the entire wooden blade and featured a tacked bronze wire gauze strip embedded in the plastic along the leading edge of the blade. To this gauze a metal sheath was sweated. A coarse weave fabric tacked to the blade, was also employed to assist the adhesion of the cellulose acetate plastic to the blade.

The success of this German development inspired several British firms to adopt similar methods and to obtain direct licenses to use the patented German method. About 1937 the Schwarz process of laminating wood blades and plastic covering was licensed in the United States where some quantity was manufactured. The success of the process was unquestioned and would have become more widely used had not improved methods of laminating and impregnating wood been developed by several firms in this country. With the advent of war the Schwarz process was very largely abandoned because of slow production, a matter of the involved method of laminating the wood and of splicing a high-density root into the lower-density blade proper. Then, too, application of the many pieces of plastic and wire and canvas which made up the protective covering prevented a straightforward production procedure.

Not long after Aeromatic propellers began to see world-wide use, military technical people communicated the fact that under tropical conditions the usual varnish blade covering was deteriorating rapidly and some type of protection would have to be applied. For-

5—*The plastic sheet is hand rolled to the blade for the purpose of eradicating irregularities and achieving bond*

6—(*Above*) *With the blade covered with the plastic sheet, it is left to cure after which overlap is cemented flat on the thrust face.* 7—(*Below*) *Sanding of the cured blade is accomplished after the lap joint has been cut off. Templates are used to check uniformity*

tunately, this condition has been prepared for by the engineering staff of our company which had been experimenting with protective coverings.

Production speed had been a guide to decisions made throughout this experimental investigation because it had been decided that an involved process, such as that of Schwarz, would not be feasible. Direct bonding of a plastic sheet was attempted with all obtainable types of plastic. Adhesion difficulties were experienced, as well as crazing, severe weather checking and discoloration. But by 1943 the process described in this article had been proved the most practical and the least expensive.

Figure 2 shows a blade undergoing a final light sanding, which is performed locally to bring the blade to an accurate template fit. Prior to this operation the blade had been carved from a block of laminated maple veneers. The veneers which compose the block are $^{1}/_{16}$ in. thick and are splayed alternately (at an angle of 15°) to the block centerline with a thermosetting resin spread on each side. The block is subjected to moderate pressure in a platen press and the cure is accomplished by high frequency heat. The resulting blade block is very strong and cannot be worked with ordinary wood-working tools. However, with tooling and machines designed to handle material of this toughness, fabrication is not difficult and the result is well worth the effort and added attention.

The profiling machine in which the block is cut has two rotary knives turning at a speed of 9000 r.p.m. each. A perfect master guides the cut of these knives which carve the blade to dimensions that are approximately 0.010 in. from the finished state. Pneumatic sander are used to erase tool marks and, with hand dressing, a template fit is achieved.

Application of nitrate sheet

The next step consists of preparing the blade for application of the plastic sheet. The plastic cement, composed of cellulose nitrate dissolved in acetone, is brushed over the entire surface of the blade and left to dry for approximately one hour. This coat penetrates the wood and provides a means for adhesion of plastic sheet.

Figure 3 shows a strip of cellulose nitrate sheet which had been suspended for one hour in a tank of softening solution. This softening solution is composed of two parts of water to one part of acetone. The strip has been cut from a larger sheet to dimensions that are oversize approximately $1^{1}/_{2}$ to 2 inches. After one hour in the solution, the sheet is quite pliable, although strong enough so it will not tear. The tank in which the softening solution is kept is regularly drained and filled with a new solution to maintain uniformity of sheet softening. The temperature is also held constant.

Figure 4 illustrates the next operation in the application of the plastic. The blade, which had been impregnated with a coat of plastic cement and left to dry, is placed in the arbor of a doping bench and the pliable plastic sheet, rubbed thoroughly dry, is laid on the blade and half folded back. Plastic cement is then spread thickly over the uncovered portion of the blade so that half of the sheet may be folded over and rolled in before rapid drying takes place. The other half of the blade is then covered with cement, the sheet folded down, and a pressure roller used to smooth out irregularities (Fig. 5).

Critics of this method of applying the plastic sheet generally raise the question of why an autoclave or pneumatic boot is not used to facilitate production. These methods have been tried and as yet do not secure the uniformity which is manually achieved with even greater speed than that obtained with mechanical and pneumatic devices. The chief difficulty with the mechanical methods of bonding the plastic to the wood is that it is impossible thus to eliminate small airpockets and wrinkles, which can be done in seconds by the hand roller. However, several other processes are under experimental development.

Trimming and curing

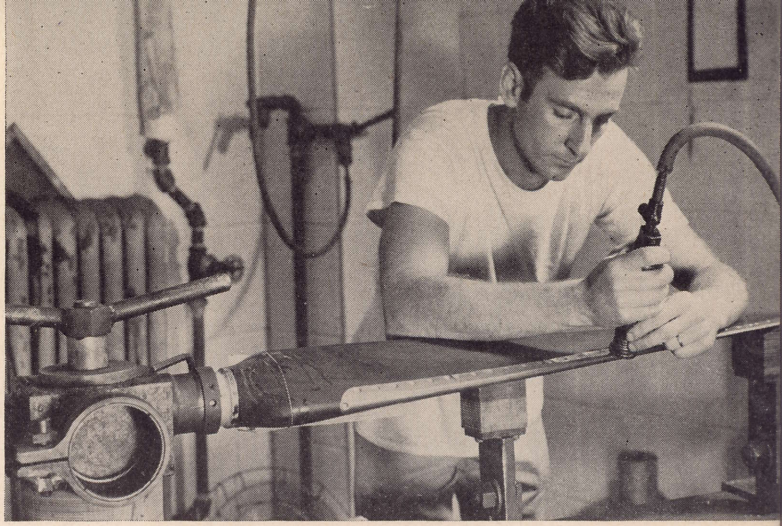
There follows next the trimming of the excess sheet from the edges of the thrust face of the blade even with the edge. The blade is then set aside to cure for 24 hours. The whole process just described is repeated again for the opposite, or camber side, of the blade where the sheet is left about $^1/_2$ in. oversize around the edges to lap over the thrust face. Here it is cemented as shown in Fig. 6. Curing in this condition takes 24 hours.

Following this curing, the lap joints of the plastic sheets are cut off with spoke shaves and power tools, and the entire surface of the blade is sanded with several fine graces of sandpaper in a pneumatic sander (Fig. 7). The actual amount of plastic removed is very slight and templates are used to check to see that uniformity of material is maintained constant over the entire blade. The sheet thickness as bonded to the blade is 0.040 inch. Only in a few instances is hand dressing of the blade in this stage necessary. If scratches or certain irregularities are present, a hand scraper and fine sand paper are used to work them out.

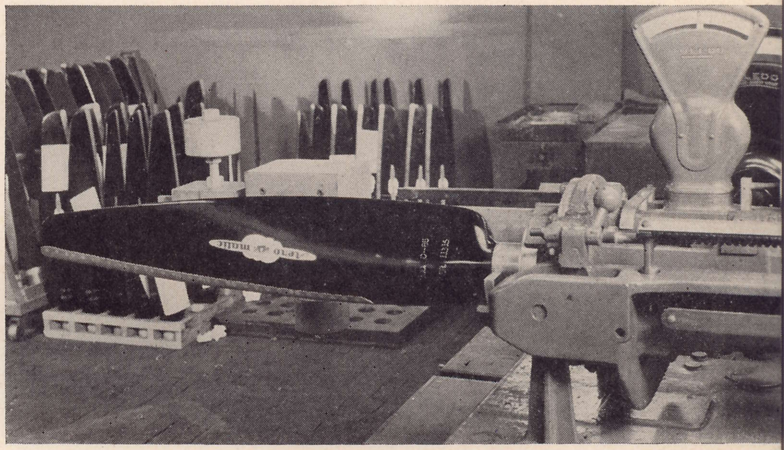
Following dressing, a stainless steel leading edge tip is placed on the end of the blade, drilled and riveted in position with copper rivets. Then the main leading edge sheathing is positioned and the drilling, countersinking and riveting operations repeated. Some screws are applied in the thicker section of the blade.

After riveting the leading edge sheathing in place, the blade is placed on the hammering bench where a pneumatic hammer is applied (Fig. 8) to smooth out the Monel metal, eliminating wrinkles caused by riveting. This operation on the ductile metal also forms it tightly to the blade so that no creep is possible. After hammering, solder is applied to each of the rivets and screw heads.

The final operation before the blades are dipped consists of sanding with a fine wet sandpaper to eliminate all scratches and provide a satisfactory surface for the dipping operation. Dipping simply involves the lowering of the blade tip first into a tank containing a solution of two parts acetone and one part butyl acetate, and raising it immediately. Drying takes place very rapidly, leaving a highly decorative glossy surface.



8—The leading edge sheathing is hammered flat for the purpose of conforming with the leading edge contour



9—Face, edge and horizontal moments are taken on scales

The remainder of the work on the blade consists of applying decals, stamping pertinent blade information into the plastic, and a weight and balance check performed on scales (shown in Fig. 9). Here, face, edge and horizontal moments are taken and lead is applied to apertures in the blades butt to correct any discrepancies from standard weight and moment balance. Small corks are used to plug the weight apertures and the entire end of the blade butt is sealed with synthetic lacquer. This last operation seals the entire wood structure from moisture and insures maintenance of the stability of the blade under the most rigorous conditions. Warping and moisture unbalance is virtually eliminated and the very tough plastic surface is seldom pierced by even large pebbles. When this does occur, plastic cement is applied to the damaged spot and dressed off with no effect on the blade at all.

Figure 1 shows one of the small Aeromatic propellers, for applications of 65 to 150 hp., installed on the Globe Swift lightplane, one of the five new personal type aircraft to which these propellers are applied as factory equipment. It has been found that the selection of black plastic, termed Aeroloid, fits in with the color schemes of most airplanes and has been accepted as being one of the most highly decorative blades produced