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MOISTURE RESISTANT FINISHES FOR AIRPLANE WOODS

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REPORT No. 85

MOISTURE RESISTANT FINISHES FOR AIRPLANE WOODS

BY

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FOREWORD.

This publication is one of a series of eight monographs prepared by the Forest Products Laboratory of the Forest Service, United States Department of Agriculture, for publication by the National Advisory Committee on Aeronautics.

The purpose of the series of monographs is to discuss in detail the various requirements of wood for use in aircraft and to make public some of the results obtained in the experimental and testing work of the Forest Products Laboratory undertaken for the Army and Navy during the war.

The subjects discussed will include: (1) Kiln-drying of airplane woods, (2) the effect of kiln-drying on strength, (3) the care of airplane stock, (4) the composition and use of glues, (5) the manufacture and testing of plywood, (6) wood in airplane construction, (7) moisture-resistant finishes, and (8) wood airplane parts.

REPORT No. 85.

MOISTURE-RESISTANT FINISHES FOR AIRPLANE WOODS.

By M. E. Dunlap.

In an investigation made at the Forest Products Laboratory to find an airplane-propeller coating which would prevent moisture changes in the propeller, a great many varnishes, enamels, and other coatings were studied. The study was confined to the ability of the coatings to prevent the passage of moisture either into or out of the wood. Other problems, such as the durability of the finish and how to apply stain, were not studied.

This report deals with the various coatings which were tested and their effectiveness as moisture-proofing agents. The terms "moisture proof" and "moisture resistant" indicate resistance to the passage of moisture through the coating. They do not refer to resistance to discoloration in the presence of moisture.

METHOD OF TESTING.

The tests were made by applying the coatings to panels of yellow birch ⅝ by 4 by 8 inches in size. The surfaces of the panels were carefully smoothed and the corners were rounded. In general, a coat of filler was first applied, followed by three coats of the varnish or other material which was being studied. Some materials which were studied required special methods of application, depending upon their character.

After the panels had dried thoroughly they were subjected for 17 days to an atmosphere with a humidity of 95 to 100 per cent. The absorption of moisture during this period, calculated in grams per square foot of surface exposed, was taken as a measure of the effectiveness of the coating.

MATERIALS USED.

In general, materials of the following types were tested: Oil, wax, oil varnish, enamel, spirit varnish, cellulose varnish, condensation varnish, rubber coating, and metal coating.

Linseed oil and wax treatment.—The first specification issued by the Air Service for coating propellers required five coats of linseed oil applied hot and two coats of floor wax. This coating reduced the absorption of moisture only very slightly.

Impregnation treatments.—Test panels were treated by forcing various material, including varnish, china-wood oil, and cellulose varnishes, into the wood. These treatments were made by immersing the specimens in the liquid in a treating cylinder and drawing a vacuum until a considerable amount of the air had been removed from the wood. The vacuum was then released and atmospheric pressure was allowed to force the liquid into the wood. Specimens were usually allowed to stand in the liquid overnight, after which they were removed, wiped off, and dried. The moisture resistance of the wood was only slightly increased by these treatments.

Condensation varnish.—Considerable time was spent in experimenting with this material. It is a patented product made from formaldehyde and phenol and is usually thinned with alcohol. It is extremely hard to apply as a coating because of the rapid evaporation of the thinner and because it must be baked for several hours at a temperature of about 180° F.

The resulting coating was not very effective on account of holes, was extremely hard and brittle, and if it became broken it was subsequently further cracked by the swelling of the wood through absorption of moisture. This type of coating was given up as entirely unsuitable. Crazing was also a fault of this material when used as a varnish.

Oil varnish.—In panels made by applying three coats of varnish over a filler, the reduction in moisture absorption of the natural wood averaged about 66 per cent for 43 spar varnishes and about 85 per cent for 3 rubbing varnishes.

Enamels.—These are varnishes to which pigment has been added. Some interesting points were brought out in this test. It was found that the addition of a pigment to a spar varnish added materially to the moisture resistance of the coating. This was true of all pigments which were tried, including white lead, red lead, orange mineral, and barytes. The pigment barytes showed great superiority over the others tested. It has poor covering properties, and where equal parts of barytes and varnish by weight are mixed and ground together the transparency of the coating is little affected. This coating prevented the absorption of about 92 per cent of the moisture which would be absorbed by natural wood under the same conditions.

In this connection it might be mentioned that if a varnish be allowed to dry almost dust free, and then be rubbed with aluminum powder, a slight improvement in the moisture resistance of the coating will be obtained. Aluminum powder added to the varnish itself will also produce beneficial results.

Cellulose varnishes (pyroxylin).—A number of tests were made on these materials, although they are not commonly used for wood. In ability to prevent moisture absorption they fell in the same class as spar varnishes. The most successful way to apply them is by means of dipping machines or air brushes.

Rubber coatings.—Some tests were made of hard-rubber coatings which were applied to wood and vulcanized. The coating was found to be moisture proof. It did not adhere well enough to the wood, however, to pass whirling tests applied to propellers.

Sprayed metal.—The Schoop process of coating wood with molten metal was studied, using aluminum and copper. It was found that the coating produced was not perfect and did not adhere to the wood well enough for the purpose intended. The coating is also quite heavy. This method is used ordinarily in ornamental work.

Electroplated coatings.—In this case a moisture-proof coating was obtained. It was found, however, that the coating showed little strength, did not adhere sufficiently to the wood, and was quite heavy. For these reasons it appeared to be entirely unsuitable for use on propellers. No information is available concerning the method used in applying this coating. It appears that a coating of finely powdered copper was applied over the surface of the wood, which was then placed in a bath and the coating of copper applied electrolytically.

Metal-leaf coatings.—The most successful practical coating found consisted of a varnish or enamel coating in which aluminum leaf was incorporated.

Two types of aluminum-leaf finishes were used, which are about equally resistant to moisture transmission. One makes use of spirit varnish and the other of oil varnish, the successive coats being as follows:

> *Spirit-varnish type.*—Filler, plus 1 or 2 coats orange shellac, plus 1 coat spar varnish used as a size, plus 1 coat aluminum leaf, plus 2 coats of orange shellac with desired color, plus 1 coat spar varnish.
>
> *Oil-varnish type.*—Filler, plus 1 or 2 coats spar or rubbing varnish, plus 1 coat spar varnish used as a size, plus 1 coat aluminum leaf, plus 2 coats spar varnish or enamel.

Coating wood with metal leaf is not nearly so slow a process as laying leaf in sign making. As soon as the size reaches the right condition, the leaf can be applied by unskilled workmen directly from the book without the aid of gilders' tips. The time required to apply leaf to a propeller should not be more than 40 or 50 minutes, and this could be reduced as the finisher becomes more experienced.

It is important to allow the size to reach the proper condition before attempting to lay the leaf; the right point is just before the varnish sets dust free. The time required after application to reach this condition varies with the type of varnish used, but for spar varnishes it

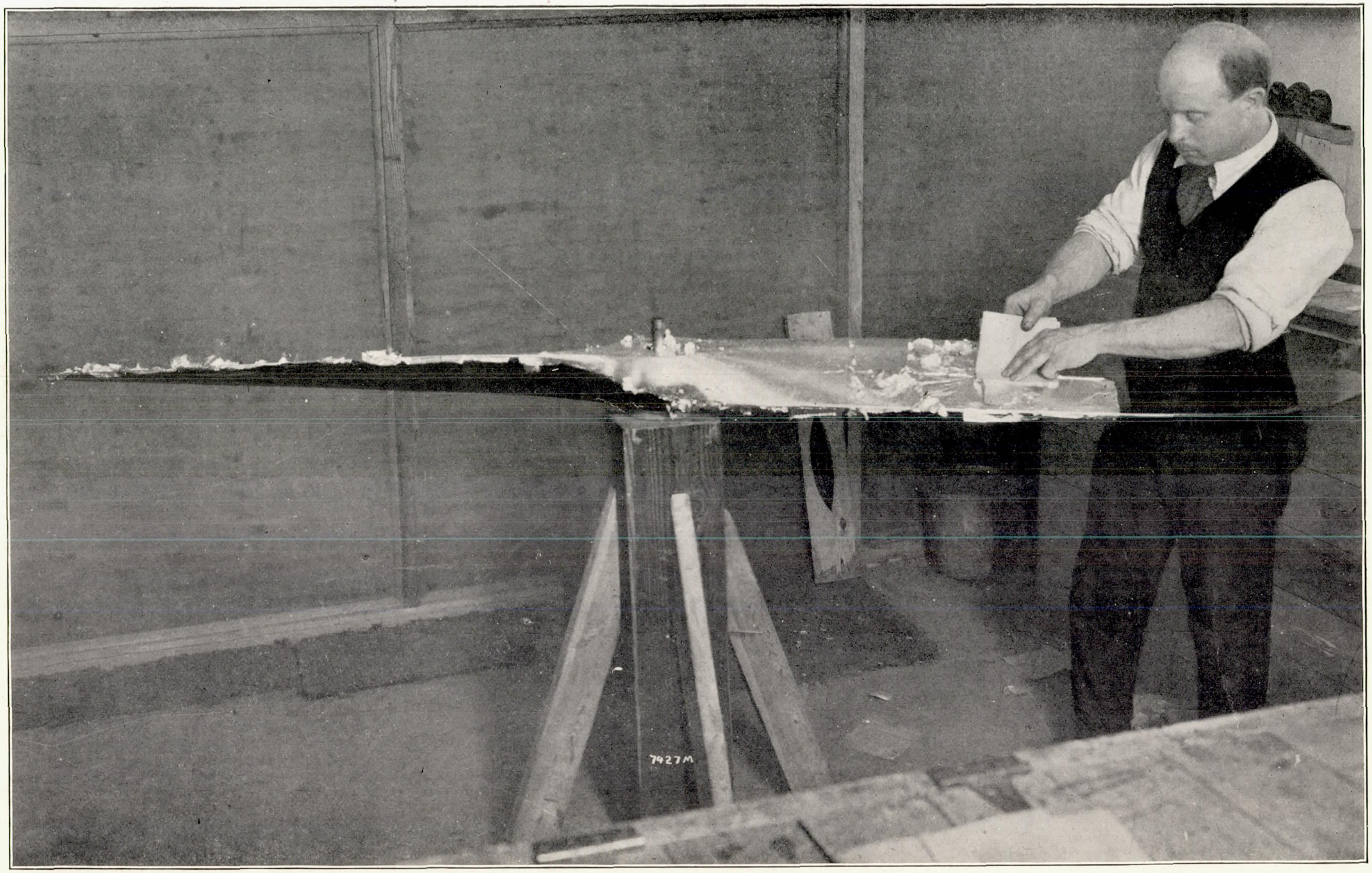

PLATE I.—METHOD OF APPLYING ALUMINUM LEAF TO PROPELLER.

is usually from 1½ to 2 hours. The workman will soon learn how to judge the condition of the size by touching it lightly with his fingers. The size will dry much more quickly if it is thinned about one-fourth with turpentine. It should be applied as sparingly as possible.

To apply the complete finish of the spirit-varnish type requires in the neighborhood of 10 hours and to dry the various coats about 90 hours, making the total time about 100 hours. The oil-varnish finish takes longer to dry and would probably total about 240 hours. The latter finish is possibly the more durable.

Different numbers of coats of varnish.—An interesting series of experiments was carried out by applying different numbers of coats of varnish (from 2 to 12) to standard test specimens. These tests were made in such a way that all panels received their final coat on the same day. Two spar varnishes of medium moisture resistance and one of good moisture resistance were used. The two varnishes of medium grade gained in resistance as the number of coats increased up to about six coats; after this point there was practically nothing gained by the addition of subsequent coats. In the case of the more resistant varnish an increase in moisture resistance was observed with the increased number of coats up to 12, although the gain became less as the number of coats increased.

Dipping tests.—A dipping machine was used in carrying out part of the tests, and it was found that a very smooth and uniform coating could be applied. The panel was completely immersed in the varnish and drawn out very slowly. The thickness of the coating can be easily regulated by using a suitable speed of withdrawal. Slightly greater moisture resistance is obtained by this method than by the brush method. This is due probably to the greater uniformity of the coating.

Brush coating.—Practically all of the varnish was applied by brush except as already noted.

Forced drying.—A series of panels was tested by drying in an oven at 110° F. The process used is as follows: Apply the varnish and allow it to set over night, place the specimens in the oven and dry them for four hours, remove, cool, and recoat. This method was found better than putting the panels in the oven immediately after coating, since there was less tendency to blister.

Effectiveness of the same coating applied to different woods.—Three coats of spar varnish were applied to a number of specimens of about a dozen different species, and it was found that there was little difference in the results obtained.

Figure 1 shows the relative effectiveness of different materials and methods of treatment in preventing the absorption of moisture by wood.

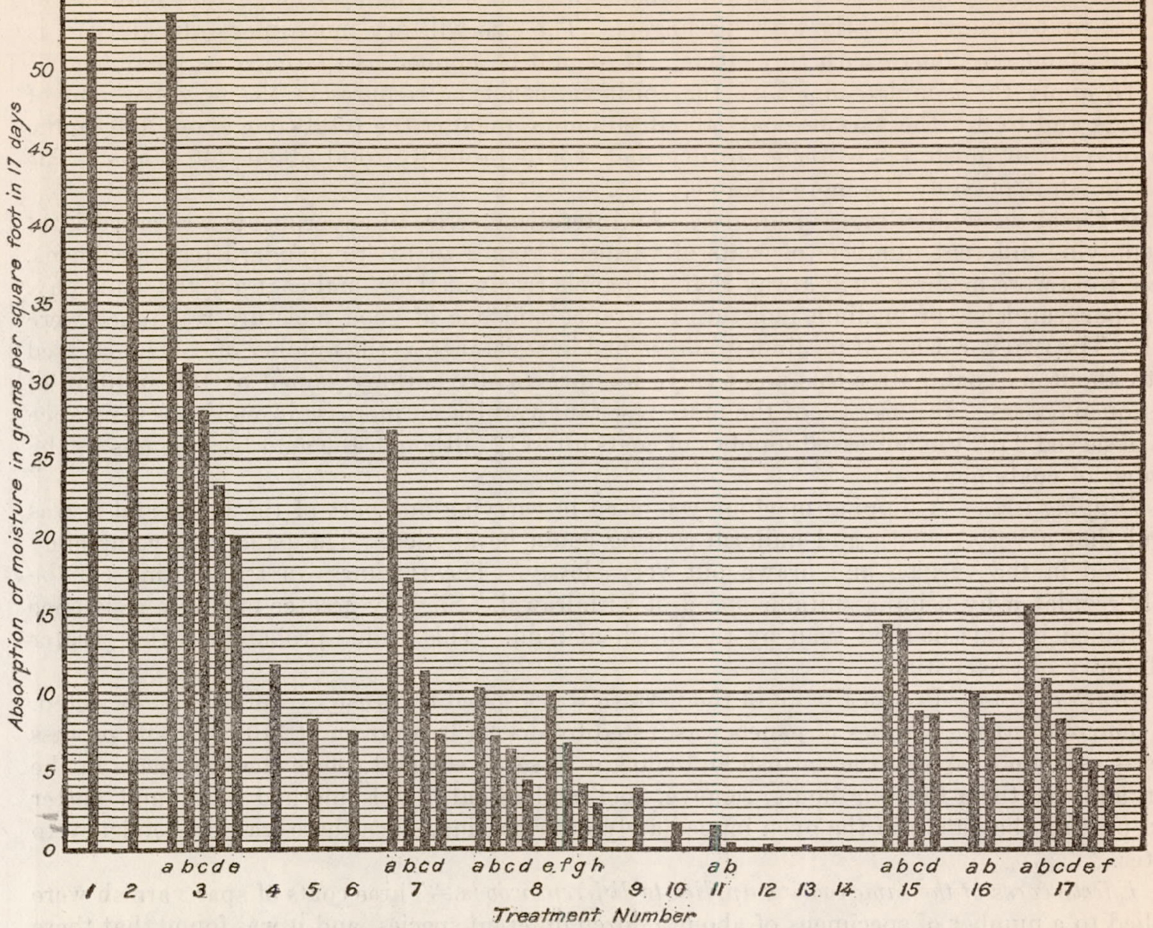

FIG. 1.—The relative effectiveness of different materials and methods of treatment in preventing the absorption of moisture by wood when exposed for 17 days to a humidity of 95 to 100 per cent.

TREATMENT.

1. Natural wood—no treatment.
2. 5 coats of linseed oil plus 2 coats of wax.
3. Impregnation treatments—
   a Linseed oil (soaking).
   b Paraffin and gasoline (vacuum and pressure).
   c Beeswax (vacuum and pressure).
   d Spar varnish (vacuum and pressure).
   e Cellulose varnish (vacuum and pressure).
4. 3 coats of cellulose varnish.
5. Filler plus 3 coats of orange shellac.
6. Filler plus 3 coats of rubbing varnish.
7. Filler plus 3 coats of spar varnish.
   a Poorest of 43 varnishes tested.
   b Average of 43 varnishes tested.
   c Average of 10 best varnishes tested.
   d Best varnish tested.
8. Enamels—Filler plus—
   a 2 coats enamel (red-lead pigment) plus varnish.
   b 2 coats enamel (aluminum powder) plus varnish.
   c 2 coats enamel (white-lead pigment) plus varnish.
   d 2 coats enamel (barytes pigment) plus varnish.
   e 3 coats commercial enamel (average of 11 brands).
   f 3 coats commercial enamel (best brand).
   g 2 coats laboratory mixture plus varnish (average of 10 best mixtures).
   h 3 coats laboratory mixture plus varnish (best laboratory mixture).
9. Filler plus 3 coats of shellac and aluminum powder.
10. 5 coats of bakelite plus 5 coats of varnish.
11. Metal leaf coatings—Filler plus shellac or varnish under coat plus varnish size plus aluminum leaf plus 2 coats of varnish shellac or enamel.
    a Average of all types.
    b Best type.
12. Sprayed with copper or aluminum and coated with 3 coats of varnish.
13. Electroplated with copper.
14. Vulcanized rubber coating (1 small specimen tested).
15. Forced drying (filler and 3 coats)—
    a Average of 23 varnishes (room dried).
    b Same varnishes (dried at 110° F.).
    c Average of 5 enamels (room dried).
    d Same enamels (dried at 110° F.).
16. Brushed versus dipped coatings—
    a Filler plus 3 brushed coats (average of 7 varnishes).
    b Filler plus 3 dipped coats (average of same varnishes).
17. Filler plus different numbers of coatings—
    a 2 brushed coats.
    b 4 brushed coats.
    c 6 brushed coats.
    d 8 brushed coats.
    e 10 brushed coats.
    f 12 brushed coats.

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