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DAVID TAYLOR MODEL BASIN
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# THE SUITABILITY OF *MOLDWOOD* FOR THE MANUFACTURE OF SHIP PROPELLERS



by

M. Kirstein and H.R. Thomas

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DAVID TAYLOR MODEL BASIN

Rear Admiral H.S. Howard, USN
DIRECTOR

Captain H.E. Saunders, USN
TECHNICAL DIRECTOR

Commander R.B. Lair, USN
NAVAL ARCHITECTURE

Captain W.P. Roop, USN
STRUCTURAL MECHANICS

K.E. Schoenherr, Dr.Eng.
HEAD NAVAL ARCHITECT

D.F. Windenburg, Ph.D.
HEAD PHYSICIST

M.C. Roemer
ASSOCIATE EDITOR

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## PERSONNEL

The propeller tests were carried out by members of the Naval Architecture Section under the direction of M. Kirstein; the tensile, bending, and hydrostatic pressure tests were performed by members of the Structural Mechanics Section, directed by H.R. Thomas. Commander R.B. Lair, USN, was in charge of the project and coordinated the work. The report was written by M. Kirstein and H.R. Thomas.

# THE SUITABILITY OF *MOLDWOOD* FOR THE MANUFACTURE OF SHIP PROPELLERS


## ABSTRACT

This report describes a series of tests made at the David Taylor Model Basin to determine certain physical characteristics and the water-resisting properties of a laminated-wood product known as "Moldwood."

This material is remarkably strong and stiff along the grain, with a tensile strength well over 30,000 pounds per square inch, and an elastic modulus of $3.5 \times 10^6$. Across the grain it is, as might be expected, only about one-tenth as strong.

Moldwood absorbs water and changes shape when submerged, especially when subjected to reduced pressures such as obtain on the back or suction side of a propeller blade.

The material in its present form appears not suitable for use in boat or ship propellers.


## INTRODUCTION

There is being produced commercially a laminated and impregnated product known as Moldwood which has been used for the manufacture of airplane propellers as a substitute for aluminum (1).*

This material has been proposed as a substitute for manganese bronze for boat and ship propellers. For this use it must, as recognized by its proponents:

1. Be easily formed and shaped to the helicoidal surface of a propeller;

2. Possess the required physical properties and strength;

3. Be durable, anti-corrosive, and electro-chemically dormant;

4. Inhibit vibration resonance, both sonic and supersonic; in other words, it must possess the property of noise-dampening by hysteresis;

5. Provide strength to resist two different types of impressed loads, that is the static and the alternating load. The physical index which measures the capacity to withstand a static load is the yield point, an elastic property. The index which measures the capacity to withstand an alternating load is the endurance limit, a fatigue property.

To determine whether Moldwood possessed these characteristics in sufficient degree, the Bureau of Ships directed (2) the Engineering Experiment Station and the David Taylor Model Basin to make quantitative tests (3) and to submit recommendations as to the suitability of the material for use in marine propellers.

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* Numbers in parentheses indicate references on page 11 of this report.

## NATURE OF MATERIAL

The sample of Moldwood available for these tests was 8 inches square, 2 inches thick over 2 inches of its length, and 1 1/4 inch thick over the remainder. It appeared to be built up of successive layers or laminations of wood held together by an extremely hard and tough resin. The grains of the successive layers were all placed parallel to each other. Each individual layer was grooved over its entire surface, so that the cross-sectional view presented a "saw tooth" appearance.

It was found in the course of the tests described later in this report that Moldwood can be cut, formed, and machined by any metalworking tool and by all woodworking saws with relatively fine teeth. When so cut and machined it has a surface comparable to that of metal similarly treated. Some procedure could doubtless be devised for giving it a highly polished surface.

A noticeable defect of the Moldwood was its tendency to warp when a thin section was being worked on, due to the heat generated by the forming operation. This was not too serious, however, as the section straightened out again when work was stopped and it cooled off.

## FABRICATION OF TEST SPECIMENS

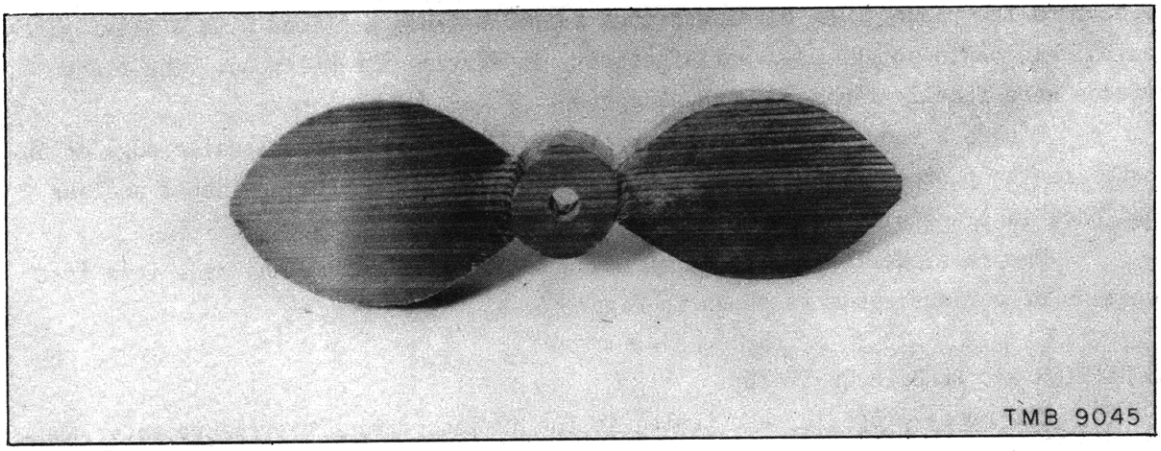
Although it was recognized that Moldwood was probably never intended to be formed in such thin sections, it was decided that the manufacture of a model propeller would be advantageous, since this would indicate not only the ability of Moldwood to be machined into a helicoidal surface with the attendant fine leading and trailing edges of a propeller, but the testing of such a model in the 12-inch variable pressure water tunnel under simulated full-scale conditions of use would give a qualitative indication of the properties of the material in service.

The dimensions of the Moldwood propeller, TMB Model 2451, were as follows:

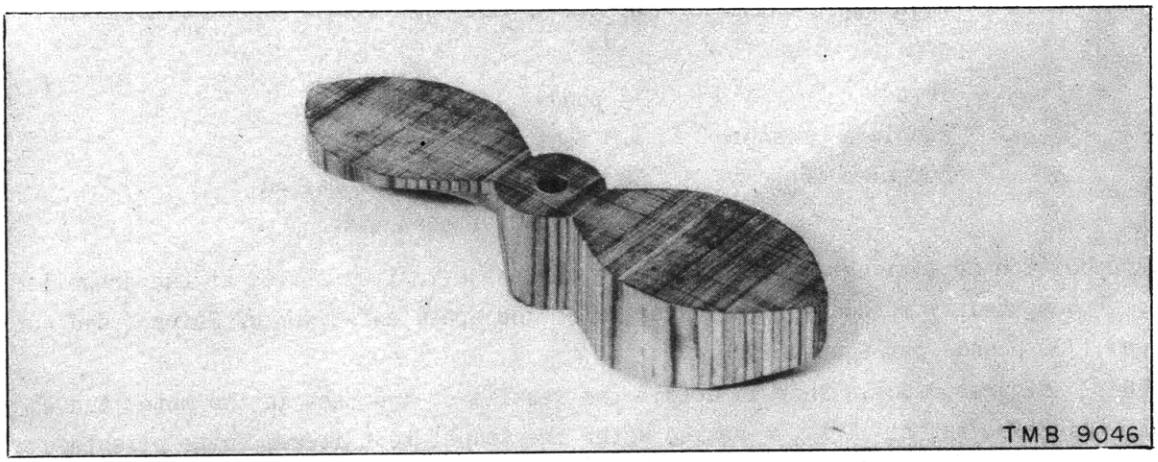
| | |
|---|---|
| Diameter | 7.80 inches |
| Number of blades | 2 |
| Pitch | 7.05 inches |
| Pitch ratio | 0.904 |
| Blade thickness fraction | 0.042 |
| Projected area | 11.47 square inches |

The propeller outline was roughed out of the Moldwood sample by a band saw as shown in Figure 1. As the propeller sections were of ogival type, having constant pitch, they were finished in the propeller-profiling machine to within 0.005 inch of the final pitch surface.

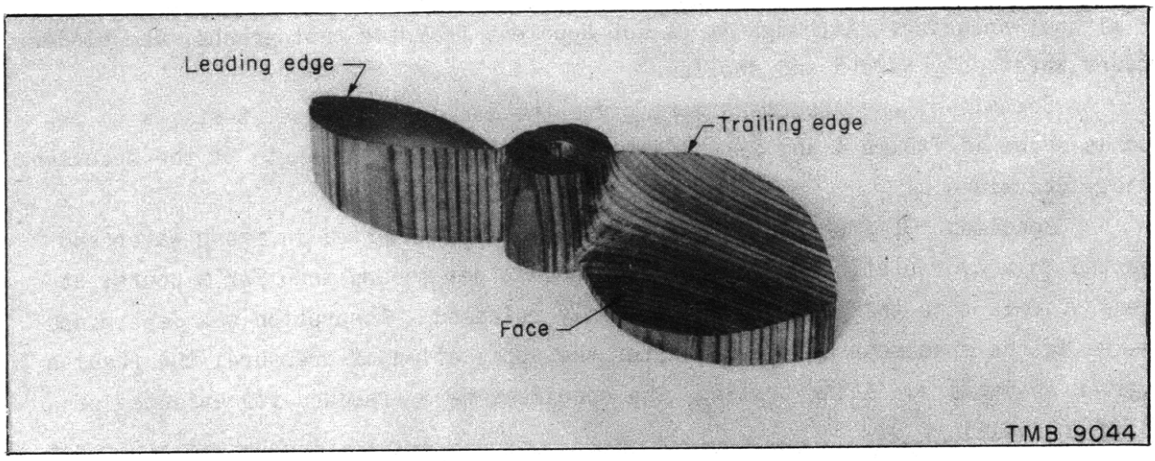
For cutting the back a special wood supporting jig was constructed, having a face cut to fit the face of the propeller blade. With the face of the propeller blade supported by the jig, the back of the blade was cut to the same pitch as the face, using the line of maximum blade thickness as a reference. The sections at every tenth of the propeller radius were then trimmed down to shape by hand across




The propeller face has been cut on a roughed-out block by a profiling machine to a helicoidal surface having a right-hand pitch of 7.05 inches. The face has been cut to within 0.005 inch of the finished surface.




The roughed-out block before the propeller back has been shaped.




The laminated structure of the Moldwood can be clearly seen here.

Figure 1 - Moldwood Propeller 2451

the back of the blade. The blade was then faired between sections with a file, since wood chisels could not be used satisfactorily in working the Moldwood. The blade surfaces were finally finished with sandpaper.

Figure 2 shows the finished propeller. The chip in the leading edge as indicated in the photographs was broken out while the blade was being shaped and was glued back in place with Weldwood glue.

The remainder of the block of Moldwood was then cut up and made into test specimens of various kinds as shown in Figure 5.

## DESCRIPTION AND RESULTS OF TESTS

The model propeller was tested in the 12-inch variable pressure water tunnel under the following conditions:

| | |
|---|---|
| Water speed | 10 knots |
| Slip ratio | 0.27 |
| RPM | 2375 |
| Thrust | 15 pounds |
| Absolute pressure | 3.0 feet of water |
| Duration of test | 50 minutes; the model failed at the end of that time. |

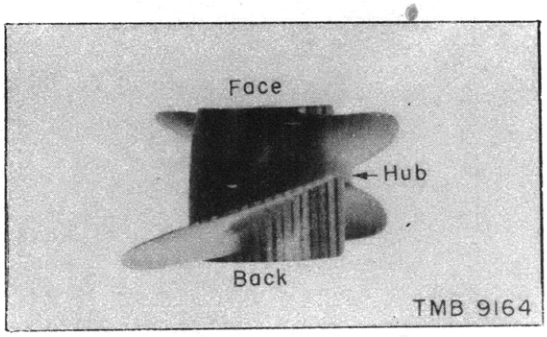
This condition of loading was not excessive since the maximum stress at the propeller hub, as computed by methods given in Taylor's "The Speed and Power of Ships," did not exceed 1700 pounds per square inch.

Figures 3 and 4 show in detail the results of the test in the water tunnel. While the model was still water-soaked after the tunnel test it was quite pliable, but as soon as it dried out it became rigid again. It can be noted from the photographs that a chip came out of the leading edge and that there were numerous cracks in the trailing edge of the blades. The leading edge of one blade bent back on itself without breaking. Although it is not apparent from the photographs, the blade surfaces were badly warped and swollen.

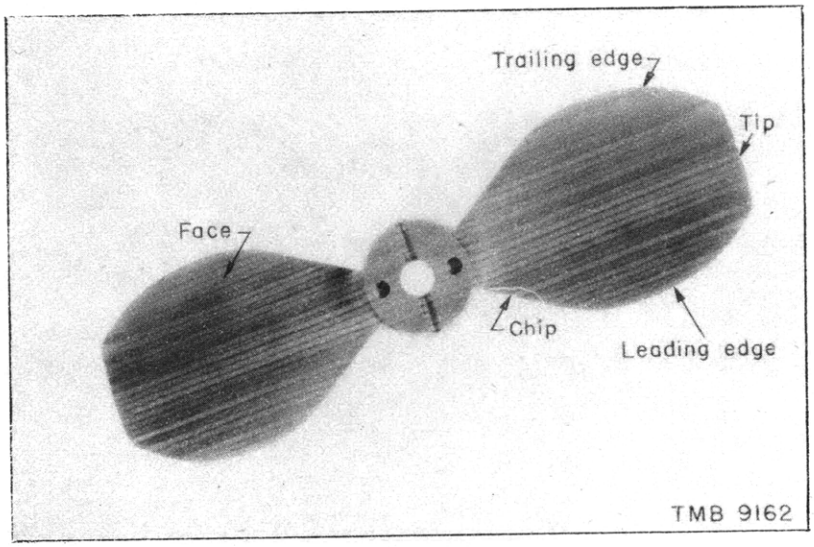
Certain of the specimens were given the standard physical tests, with results as shown in Tables 1 and 2. Unfortunately, the yield strength of the specimens was not determined.

Specimens 9, 10, 3-1, 3-2, 5-1, and 5-2 were immersed in fresh water and subjected to a hydrostatic pressure of 2000 pounds per square inch for 6 hours; at the end of this time the pressure was suddenly released. Absorption was determined by weighing the specimens before and after the application of pressure; the results are given in Table 3. After testing, the specimens were examined for evidence of warping or swelling.

The specimens were next immersed in a 3 per cent salt water solution for one week, after which they were examined for evidence of further warping or swelling.




Note that the blade sections are quite thin.

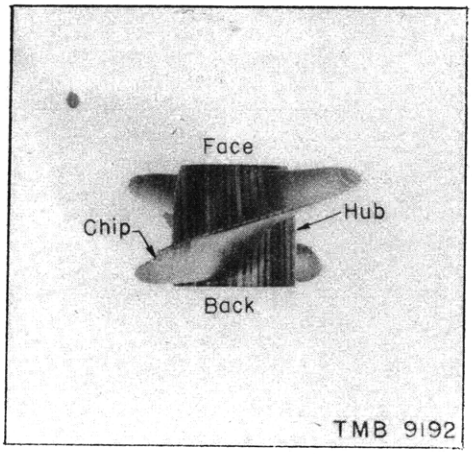



Propeller Face
Note the chip glued in place on one leading edge.

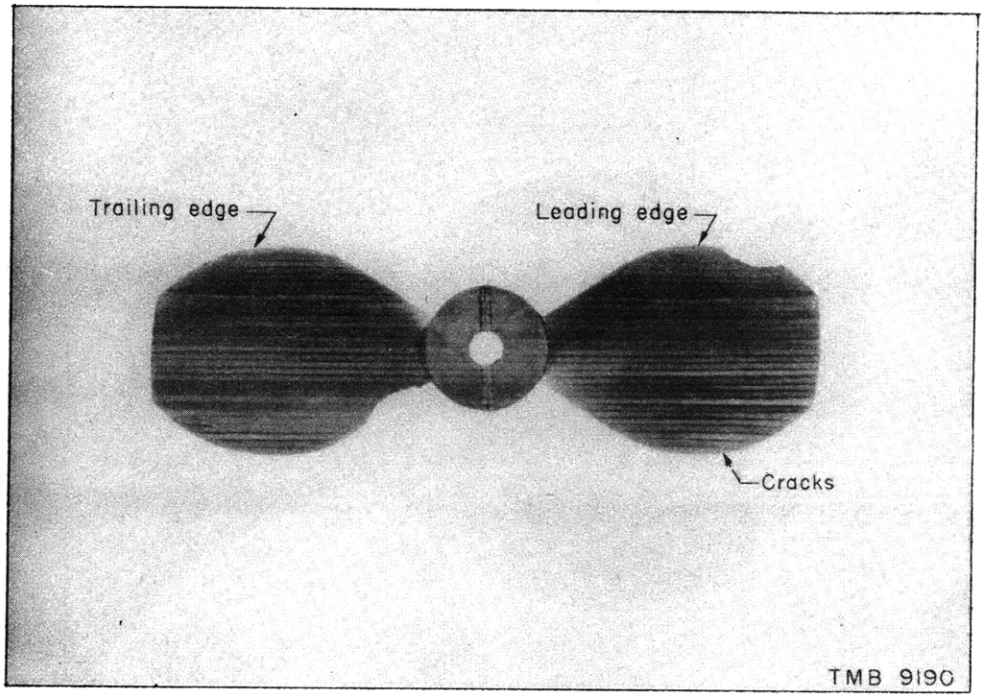
**Figure 2 - Moldwood Propeller 2451**

Right Hand
2 Blades

Pitch, 7.05 inches
Diameter, 7.80 inches




End-on View



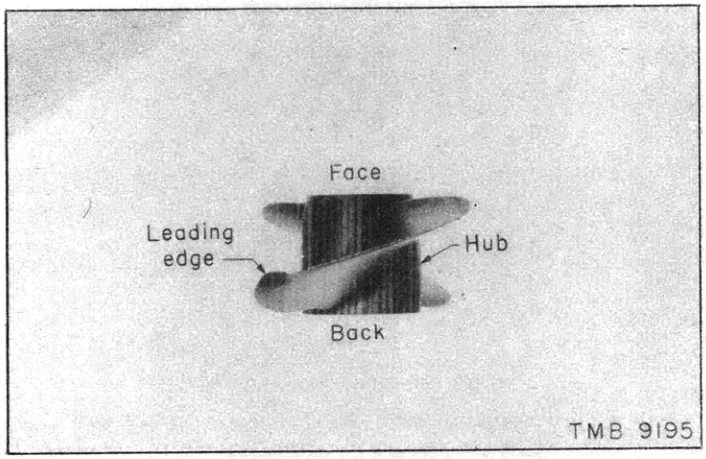

Back of Propeller

There are cracks in the trailing edges, and a chip is broken out in the leading edge near the tip.

## Figure 3 - Moldwood Propeller 2451

Effects on the propeller subjected to cavitation at reduced pressure for 50 minutes.

Absolute pressure, 3.0 feet $H_2O$ Thrust on propeller, 15 pounds
Water speed, 10 knots Slip, 27 per cent
RPM, 2375




Note the distortion of one leading edge.

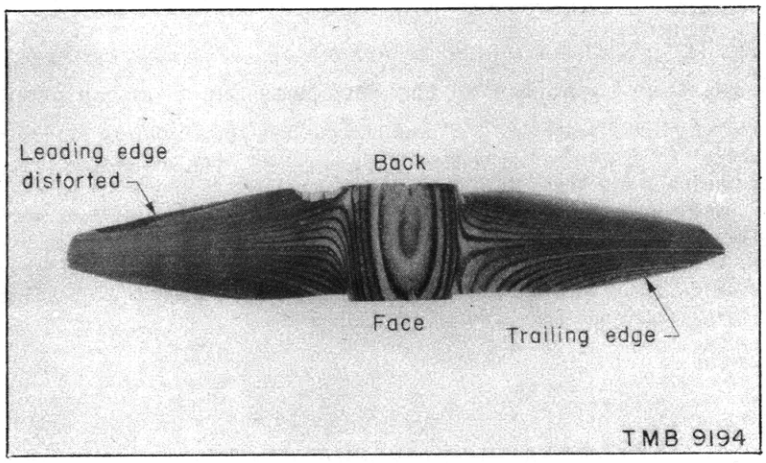



Figure 4 - Moldwood Propeller 2451

Effects on the propeller subjected to cavitation at reduced pressure for 50 minutes.

Absolute pressure, 3.0 feet $H_2O$ Thrust on propeller, 15 pounds
Water speed, 10 knots Slip, 27 per cent
RPM, 2375

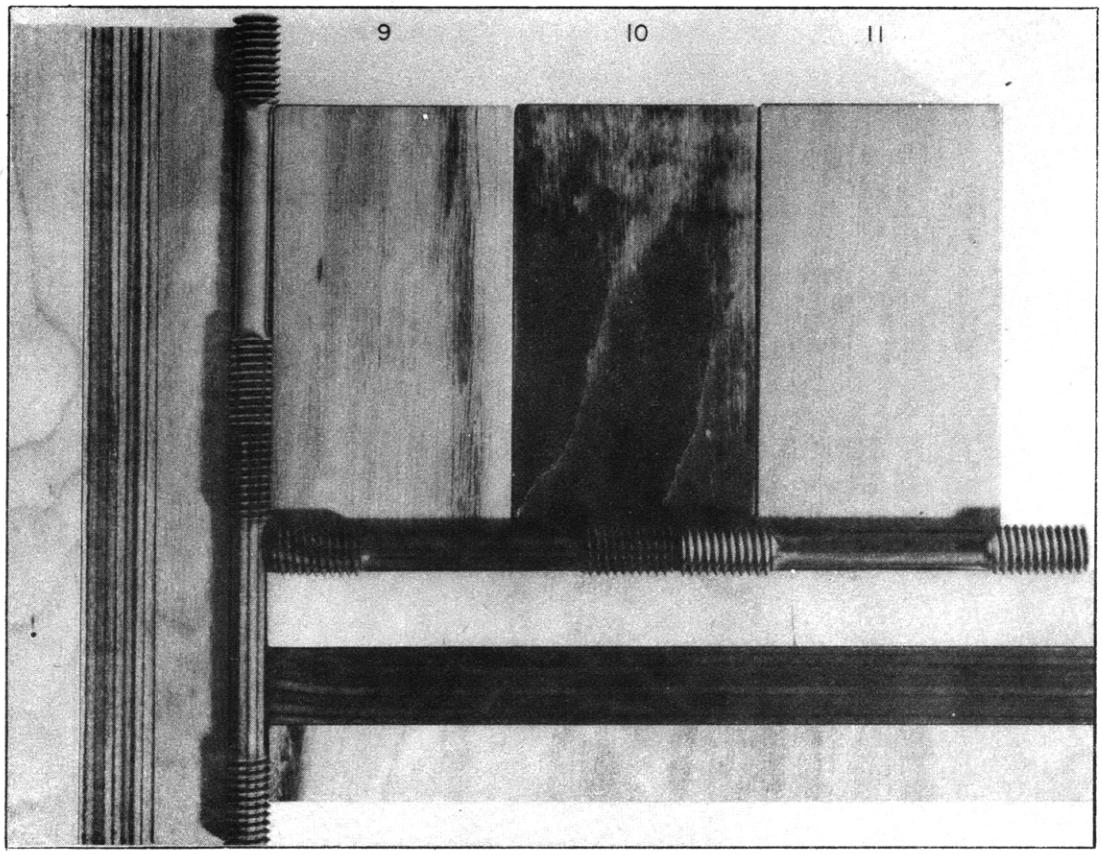



Figure 5 - Relative Locations of the Specimens Cut from the Sample of Moldwood

The block remaining after the propeller had been cut out was approximately 6 inches wide, 8 inches long and 1 1/4 inch thick. In preparing these specimens, 4 slices were cut parallel to the direction of the grain of the wood the full thickness of the block for Specimens 1 to 4 and then 4 slices at right angles to the first for Specimens 5 to 8. Each slice was split so that two specimens were obtained from each, as indicated by the numbering. Blocks 9, 10, and 11 were cut from the remaining material. The threaded tensile specimens, 4-1, 4-2, 8-1 and 8-2, were machined to fit standard holders. They had a minimum section of 0.05 square inch. The twelve straight specimens for use in the bending tests and immersion tests were 0.562 inch square and approximately 6 inches long.

TABLE 1

Tensile Test Results

| Specimen Number | Direction of Grain | Tensile Strength pounds per square inch | Modulus of Elasticity pounds per square inch |
|---|---|---|---|
| 4-1 | Longitudinal | 35,300 | 3,500,000 |
| 4-2 | Longitudinal | 35,200 | 3,600,000 |
| | Average | 35,250 | 3,550,000 |
| 8-1 | Transverse | 3,800 | 500,000 |
| 8-2 | Transverse | 3,400 | 642,000 |
| | Average | 3,600 | 571,000 |

TABLE 2

Bending Test Results

| Specimen Number | Direction of Grain | Modulus of Rupture pounds per square inch | | Modulus of Elasticity | |
|---|---|---|---|---|---|
| | | Plies horizontal | Plies vertical | Plies horizontal | Plies vertical |
| 2-1 | Longitudinal | | 35,400 | 3,400,000 | 3,390,000 |
| 2-2 | Longitudinal | 35,400 | | 3,550,000 | 3,440,000 |
| | Average | | | 3,470,000 | 3,410,000 |
| 7-1 | Transverse | 7,600 | | 640,000 | 657,000 |
| 7-2 | Transverse | | 5,050 | 650,000 | 640,000 |
| | Average | | | 645,000 | 648,000 |

There was no appreciable change after this long immersion so the test was discontinued. Figure 6 shows the condition of the specimens after being subjected to a pressure of 2000 pounds per square inch for 6 hours.

The remaining test specimens, 1-1, 1-2, 6-1, 6-2, and 11, were immersed in water in a closed vessel which was evacuated to an absolute pressure of less than 1 millimeter of mercury. This vacuum was maintained for 8 hours, after which time the pressure was increased to atmospheric and maintained for 16 hours. After 8

TABLE 3

Results of Absorption Tests under Increased Pressure

| Specimen Number | Absorption per cent by weight |
|---|---|
| 9 | 3.7 |
| 10 | 1.2 |
| 3-1 | 2.8 |
| 3-2 | 1.8 |
| 5-1 | 6.1 |
| 5-2 | 13.1 |

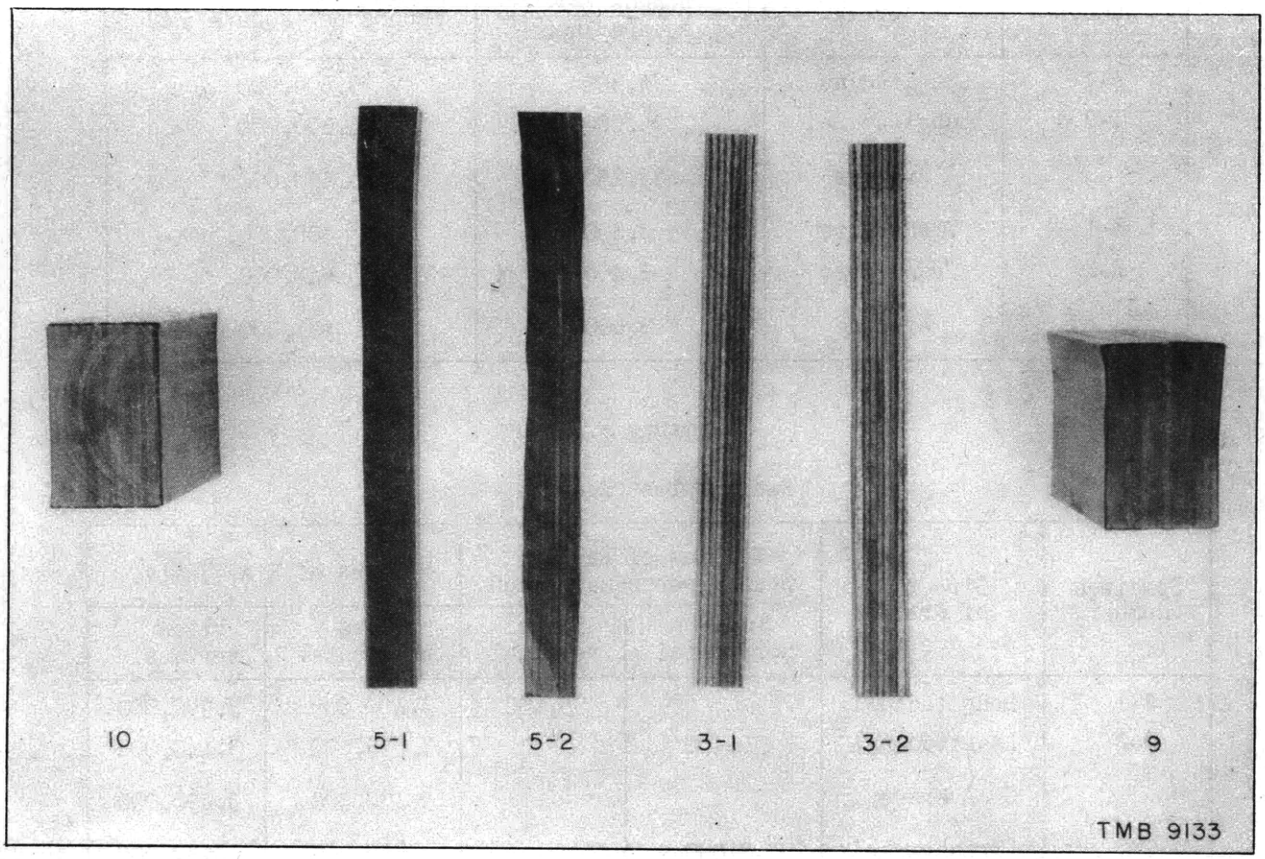



**Figure 6 - Condition of Specimens after Hydrostatic Pressure Test of 2000 Pounds per Square Inch for 6 Hours**

Note that Specimens 3-1 and 3-2, cut parallel to the grain of the wood, showed only minor warping. Specimens 5-1 and 5-2, cut across the grain of the wood, showed warping and swelling. The thickness of Specimens 5-1 and 5-2 perpendicular to the plies was from 1/16 to 3/32 inch greater than before the pressure application. Swelling of Blocks 9 and 10 occurred principally on the edges.

such cycles the specimens were examined for evidence of damage and weighed to determine the absorption. The results are given in Table 4.

Warping and swelling of the specimens occurred as a result of this treatment, but the distortion was less than had been produced in the specimens subjected to 2000 pounds per square inch hydrostatic pressure for 6 hours.

TABLE 4

Results of Absorption Tests at Reduced Pressures

| Specimen Number | Absorption per cent by weight |
|---|---|
| 1-1 | 11.5 |
| 1-2 | 13.9 |
| 6-1 | 18.2 |
| 6-2 | 25.8 |
| 11 | 3.6 |

RECOMMENDATIONS

On the basis of the results of the tests described here, the Taylor Model Basin recommends that Moldwood be considered unsuitable as a material from which to make ship or boat propellers.

REFERENCES

(1) Memorandum prepared by Mr. Salvador Nelson, dated 18 January 1943; TMB file L5-2/N32-3.

(2) BuShips letter JJ39-(11)(454-350) of 25 February 1943 to Taylor Model Basin and to Engineering Experiment Station.

(3) Technical Director Taylor Model Basin Memo L5-2/N32-3 of 8 April 1943 to Naval Architecture and Structural Mechanics; TMB file L5-2/N32-3.