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Standard Test Methods for Conducting Machining Tests of Wood and Wood-Base Materials[1]

This standard is issued under the fixed designation D1666; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

One of the significant characteristics of wood is the facility with which it can be machined and fabricated. Different species, however, vary greatly in their behavior under cutting tools, so that some systematic method is needed for determining their suitability for uses where the character of the machined surface is of prime importance. Such uses include cabinetwork, millwork, and other products where favorable machining properties are essential to good finish. For such products as common boards, on the other hand, good machining properties are secondary, although still an asset.

The machining test procedures presented in these test methods cover such common operations as planing, shaping, turning, boring, mortising, and sanding. They are the result of many years of extensive research and development and include practical methods for qualitatively evaluating and interpreting the results. Because of their satisfactory use with a wide range of materials, it is believed that the methods are equally applicable to species, hardwoods and softwoods, and to wood-base materials, such as plywood, particleboard, and hardboard.

1. Scope

1.1 These test methods cover procedures for planing, shaping, turning, mortising, boring, and sanding, all of which are common wood-working operations used in the manufacture of wood products. These tests apply, in different degrees, to two general classes of materials:

1.1.1 Wood in the form of lumber, and

1.1.2 Wood-base panel materials.

1.2 Because of the importance of planing, some of the variables that affect the results of this operation are explored with a view to determining optimum conditions. In most of the other tests, however, it is necessary to limit the work to one set of fairly typical commercial conditions in which all the different woods are treated alike.

1.3 Several factors enter into any complete appraisal of the machining properties of a given wood. Quality of finished surface is recommended as the basis for evaluation of machining properties. Rate of dulling of cutting tools and power consumed in cutting are also important considerations but are beyond the scope of these test methods.

1.4 Although the methods presented include the results of progressive developments in the evaluation of machining properties, further improvements may be anticipated. For example, by present procedures, quality of the finished surface is evaluated by visual inspection, but as new mechanical or physical techniques become available that will afford improved precision of evaluation, they should be employed.

1.5 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents of inch-pound units may be approximate.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Definitions and Descriptions of Terms

2.1 A number of special terms relating to wood and to machining are used in describing the procedures for the various machining studies. Definitions and descriptions of a number of the important terms used are presented in Appendix X1.

3. Significance and Use

3.1 Machining tests are made to determine the working qualities and characteristics of different species of wood and of different wood and wood-base materials under a variety of machine operations such as are encountered in commercial

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manufacturing practice. The tests provide a systematic basis for comparing the behavior of different species with respect to woodworking machine operations and of evaluating their potential suitability for certain uses where these properties are of prime importance.

4. Apparatus

4.1 *Machines*—To yield data that can be duplicated for comparative purposes, all machines used in these tests shall be modern commercial size machines of good make, in good mechanical condition, and operated by fully qualified persons. Numerous machines meet these requirements, and no attempt is made to do more than describe the preferred type of machine for each test in very general terms (Note 1). Complete information on the machine used, the cutting tool, and the operating conditions of each test shall be made part of the record.

NOTE 1—Where machines with all of these qualifications are not available, machines that are inferior in some respects have limited uses, such as for comparing the machining properties of species for local use under local conditions.

4.2 *Sharpness of Knives and Cutters*—Carbide-tipped knives and cutters shall be the preferred type because of the much longer sharpness life of that material. High-speed steel shall be second choice and carbon steel third. The cutting tool material used shall be made part of the record. Every precaution shall be taken to keep the sharpness uniformly good in all tests by resharpening when necessary.

NOTE 2—A practical measure of the deterioration of a machined lumber surface because of dulling of the cutting tool can be had by the use of two check samples. They should come from the same board of some species that machines exceptionally well, such as mahogany. Both should be machined with a freshly sharpened cutting tool at the outset. One will be retained in that condition as a control, and the other, at intervals of 1 h or so as experience dictates, shall be machined with the regular test specimens and compared with the control. When the machined surface deteriorates perceptibly, as indicated by this comparison, the cutting tool should be resharpened.

Similarly with particle board or hardboard, some well-known product that has good machining properties may be used as a control material for comparison.

5. Shipment and Protection of Samples

5.1 All test material shall be properly protected in shipment to ensure its delivery in satisfactory condition for the required tests. On receipt, the material shall be carefully protected to prevent deterioration pending the preparation for the tests.

6. General Requirements of Samples

6.1 The tests shall be made on seasoned material.

6.2 Lumber shall be clear (Note 3), sound, well-manufactured, and accurately identified as to species. It may be either rough or dressed.

NOTE 3—Clear means free from all defects, including knots, stain, incipient decay, surface checks, end splits, compression wood, and tension wood.

6.3 Particleboard and hardboard samples may be typical commercial products or samples of new boards under development as the occasion requires. In either case, the kind or kinds of wood, the density, and the amount and kind of binder should be known and made part of the record. Particleboard and hardboard shall be typical of the product under consideration as they are manufactured and marketed. For the planing and sanding tests, the particleboard and hardboard samples should be procured in the unsurfaced condition, whenever possible, so that these evaluations may be made on the same part of the material that will be removed from the board in the normal use conditions where planing and sanding are done.

6.4 Test samples of lumber shall be so selected as to exclude the small amount at each extreme that is not fairly typical of the species under consideration in number of rings per inch (average ring width per millimetre).

NOTE 4—Number of rings per inch is determined by visual count along a line perpendicular to the growth rings. Different samples of a given species often differ widely in this respect, and often the samples at both extremes are not typical in their properties.

7. Dimensions and Weight of Samples

7.1 Lumber samples shall be dried to a uniform moisture content of 6 % before testing, or to such other moisture content as may be specified.

7.2 Samples must be large enough to yield the minimum acceptable size (0.75 by 5 in. by 4 ft) (19 by 127 mm × 1.2 m) when at the prescribed moisture content and surfaced smoothly on two sides. Where it is desired to make more planer cuts than are specified, lumber thicker than 1 in. (25 mm) may be used.

7.3 Lumber test samples shall be so selected as to exclude the small amount at each extreme of weight that is not typical of the species under consideration.

NOTE 5—Different samples of a species sometimes vary in density by as much as a 2-to-1 ratio. The properties exhibited by samples at either extreme of density are not typical of the species as a whole.

7.4 Particleboard and hardboard test material shall be typical in dimensions and weight of the products under consideration as they are manufactured and marketed.

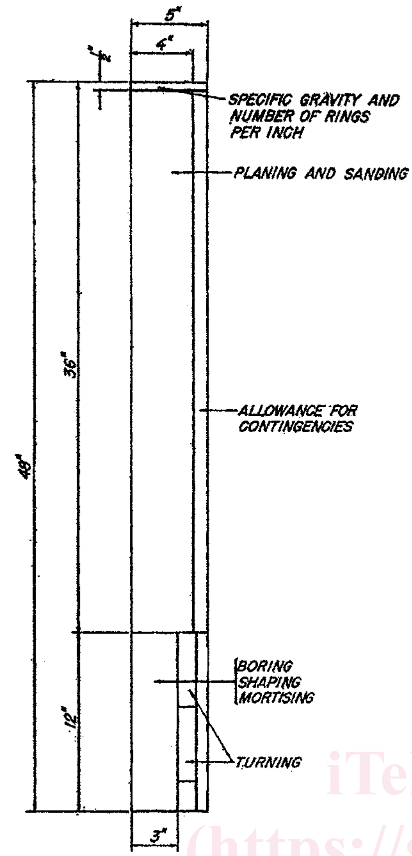
8. Sampling

8.1 A total of 50 test samples of lumber is required for each species tested (Note 6). Except in the few species where the making of some quartered lumber is standard practice, the samples shall be commercial flat grain. The test material shall be selected by one fully qualified to identify the species, to judge if it is fairly representative of the product being shipped, and if it meets the specifications. If only exploratory tests are to be made, a smaller number of samples may be selected.

NOTE 6—It is desirable that the samples represent numerous different trees and logs. The material for tests should preferably be obtained in log form and then sawn to the desired size. When this is not possible, it will be necessary to select random samples from a lumber pile.

8.2 For each type of particleboard tested, five samples (Note 7) shall be selected, one from each of five different sheets. The size of these samples (Fig. 1) shall be 2 by 4 ft (610 by 1220 mm), and the thickness in different products shall be as manufactured (Note 8).

NOTE 7—Particleboard and hardboard of any one process and mill are much more uniform in their properties than different boards of a given species. For this reason, five samples selected as described in 8.2 are



METRIC EQUIVALENTS

in.	½	3	4	5	12	36	48
cm	1.3	7.6	10.2	12.7	30.5	91	122

FIG. 1 Diagram for Sawing Lumber Samples into Smaller Samples for Individual Tests

considered sufficient to give representative results.

NOTE 8—For sawing tests where power consumption is an important factor, material thicker than 0.75 in. (19 mm) shall be reduced to that thickness before test. For material thinner than 0.75 in., a sufficient number of pieces shall be laminated together to provide the 0.75-in. thickness.

8.3 For each type of hardboard tested, five samples shall be selected, one from each of five different sheets. The size of these samples shall be 2 by 4 ft (610 by 1220 mm), and the thickness shall be that of the hardboard as manufactured.

9. Preparation of Test Specimens from Lumber

9.1 Each different test has its own procedure as described in Sections 11-16. The following steps in preparing the test specimens apply to all tests with lumber:

9.1.1 Mark each board, nominal 1 by 5 in. by 4 ft (as by 127 mm by 1.2 m) to identify adequately the species source and individual sample.

9.1.2 Cut a 0.5-in. (13-mm) cross section from one end of each nominal 1 by 5 in. by 4 ft board for specific gravity determinations and for counting the number of annual rings per inch (average ring width in millimetres) (Note 4).

9.1.3 Condition the boards to a 6 % equilibrium moisture content (EMC), or to such other EMC as may be specified.

NOTE 9—Conditioning chambers are usually necessary for obtaining constant EMC conditions. The local drying practice may be followed, keeping in mind that the data will apply only to these specific conditions. In any event, the material should be conditioned to a uniform moisture content, and the actual moisture content determined and recorded.

9.1.4 Joint one edge and one side of the boards flat and plane the other side to provide a final board thickness of 0.75 in. (19 mm).

9.1.5 Saw the boards into the specified smaller sizes for the different tests as shown in Fig. 1. Each of the test specimens shall bear the same number as the board from which it was cut; take care to place the number where it will not be lost in the machining process.

NOTE 10—The specimen for shaping, boring, and mortising (Fig. 1) must be accurately cut to size to ensure proper fit in the test jig. The turning specimens also must be accurate since they have to fit special lathe centers. The size of the planing specimen is less critical and, if necessary, it may be 1 in. (25 mm) or so short of the specified 3 ft (910 mm) without serious objection.

10. Preparation of Specimens from Particleboard and Hardboard

10.1 Each different test has its own procedure as described in Sections 18-23. The following steps in preparing the test specimens apply to all tests with particleboard and hardboard:

10.1.1 Mark each 2 by 4-ft (610 by 1210-mm) board to identify the source and the individual sample.

10.1.2 Condition the boards to the standard 6 % EMC (see 9.1.3) or to such other moisture condition as may be specified.

10.1.3 Saw each of the original particleboard, and hardboard samples into smaller sizes for the different tests as shown in Fig. 2.

10.1.4 Each of the test specimens shall bear the same number as the board from which it was cut.

METHODS OF TESTING LUMBER

11. Planing

11.1 A moulder (Fig. 3) is the preferable machine for the planing test because of its relatively wide range of feeds and speeds and because of the ease of changing heads. In the absence of a moulder, a planer or planer-matcher may be used. In any case use only straight knives, and plane only one side of the test specimen at a time.

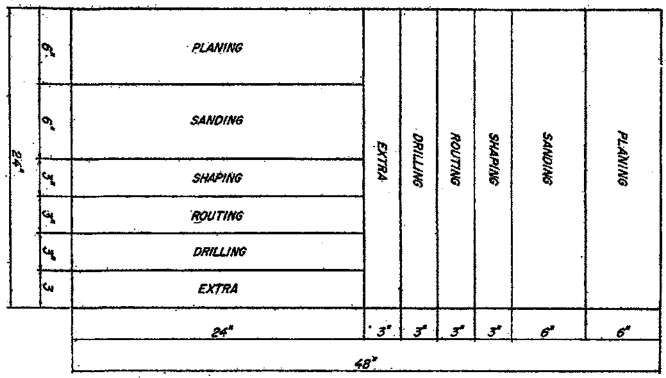
11.2 Steel knives shall be freshly ground at the outset and jointed to a point where each knife shows a hairline land for the entire length of the blade. When the land or jointed portion of the edge becomes as much as 1⁄32 in. (0.80 mm) wide, as a result of repeated jointings, the knives shall be reground before continuing with the test.

11.3 All specimens used in this test (50 per species) shall be 0.75 by 4 in. by 3 ft (19 by 102 by 910 mm).

11.4 The moisture content shall be 6 % or such other value as may be specified.

11.5 All cuts shall be 1⁄16 in. (1.6 mm) deep. A test specimen 0.75 in. (19 mm) thick will permit making seven cuts before the specimen becomes thin enough to introduce a new variable.

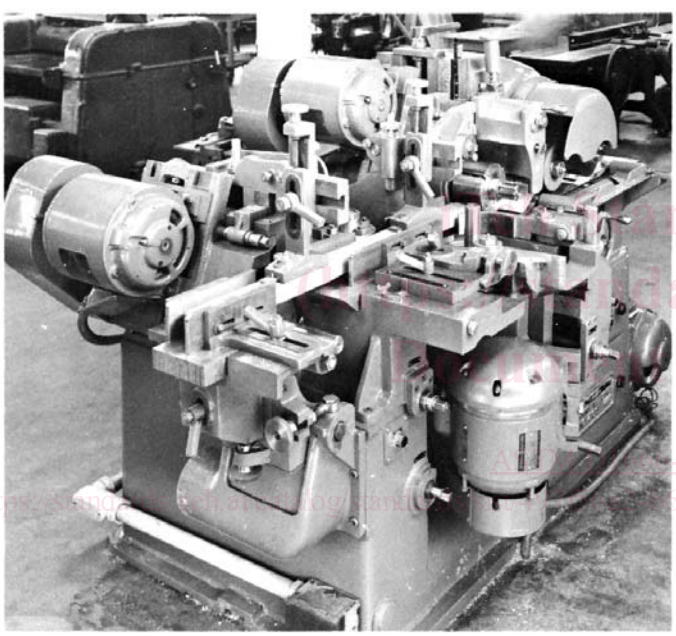
11.6 When several species are being tested, mix them well to equalize the effect of the gradual dulling of the knives.



METRIC EQUIVALENTS

in.	3	6	24	48
cm	7.6	15.2	61	122

FIG. 2 Diagram for Sawing Hardboard and Particleboard Samples into Smaller Samples for Individual Tests



NOTE 1—This moulder offers a much wider range of cutterhead speeds and feed rates than does the typical planer. The slip-on heads are easy to change as desired. Moulders come with four and sometimes five cutterheads to permit machining four sides with one pass. In planing tests, however, only one cutterhead is used, the top head equipped with straight blades, as shown in this figure.

FIG. 3 Desirable Type of Machine for Use in Planing Tests

11.7 Feed the specimens into the machine, so that half are machined with the grain and half against the grain.

NOTE 11—It is suggested that alternative cuts be made on opposite faces to avoid cupping from the release of interior stress.

11.8 Mark the end of each specimen as it emerges from the machine to indicate the direction of feed and the side that has just been machined. Feed individual specimens in the same direction at each cut.

11.9 Make four runs with knives at cutting angles (Note 12) of 15, 20, 25, and 30°. Adjust the feed rates and cutterhead speeds to give 20 knife marks/in. (0.8/mm).

NOTE 12—Because there are no accepted standards, the terms used in connection with planer knives vary considerably. Fig. 4, which shows the cross section of a cutterhead, illustrates a common usage; the one that is followed in this method. With both knives, angle *a* is the cutting angle and angle *c* the clearance bevel. Knife No. 2 has a cutting bevel or back bevel, *b*, and the cutting circle is *d*.

Cutting angles, which have an important influence on the quality of work in planer-type machines, may be changed in two general ways: (*1*) By changing the angle of the knife slot or slot that holds the knife in the head. This, of course, means a different cutterhead for every different knife angle. Heads with knife slots ground at 20 to 30° are common, but there are definite limits beyond which this method cannot be carried without danger of weakening the cutterhead too much. (*2*) By grinding a "back-bevel" on knives, as shown on knife 2 in Fig. 4. This means one cutterhead with, say, four sets of knives back-bevelled at four different degrees achieves four different cutting angles.

11.10 Make three runs with a 20° cutting angle, while feed rates and cutterhead speeds are adjusted to give 8, 12, and 16 knife marks/in. (0.3, 0.5, and 0.6/mm).

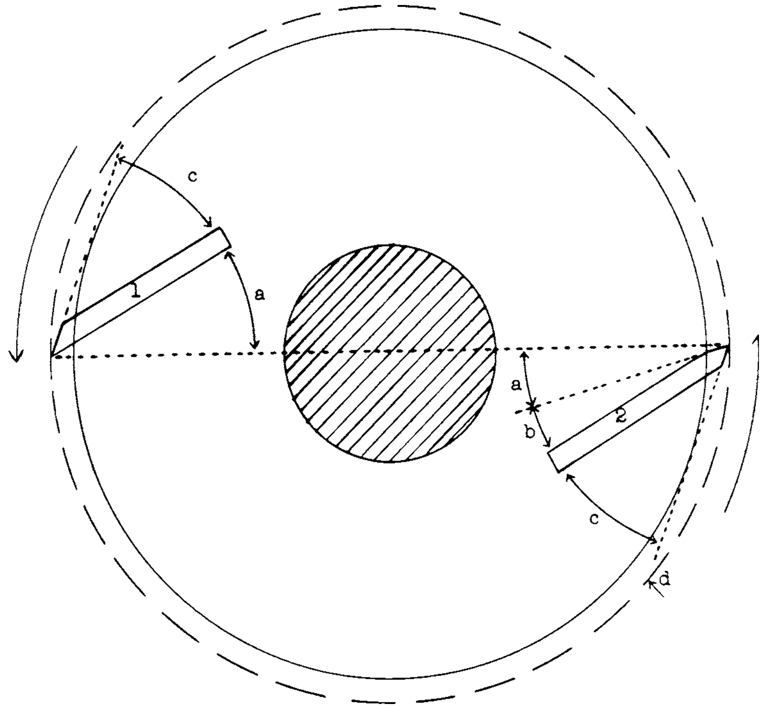
NOTE 13—Where each knife in the cutterhead is doing its share of the work, the number of knife marks per inch will agree with the following formula:

No. of knife cuts per inch = $(A \times B)/(C \times 12)$
No. of knife cuts per millimetre = $(A \times B)/C$

where:
A = revolutions per minute,
B = number of knives in head, and
C = feed rate, ft/min (mm/min).

If the theoretical number does not agree with the actual number, the jointing is probably inadequate. This should always be checked visually (Fig. 5).

11.11 Visually examine each test specimen (Note 13) carefully for planing defects after each run. For each specimen, grade any planing defect that may be present according to degree and record on prepared forms. Classify the planing characteristics of each specimen by visual examination on the basis of five grades or groups as follows:



(*a*) Cutting angle.
(*b*) Cutting bevel.
(*c*) Clearance bevel.
(*d*) Cutting Circle.

FIG. 4 Terms Used in Connection with Planer Knives

Grade 1, excellent
Grade 2, good
Grade 3, fair
Grade 4, poor
Grade 5, very poor

NOTE 14—The runs described in Section 11 cover the more critical conditions. If additional runs are desired for any reason, additional test material will be needed.

NOTE 15—The characteristic of black walnut with respect to planing qualities is illustrated by Grades Nos. 1 and 5 in Fig. 6. The top sample, Grade No. 1, is easy to classify because it is practically free from any and all machining defects. Traces of chipped grain can be seen around the small burls in this specimen. They would not be visible, except in oblique light, and represent about as large defects as are admissible in this grade. Knife marks, which are quite plainly visible in this specimen, are not considered a machining defect, because they are largely unavoidable in planing. They vary in visibility according to the number per inch and, to some extent, with the species. For exacting uses, they are customarily removed by sanding as would be the traces of chipped grain. The second specimen, also black walnut, shows torn grain too extreme to be allowed in any grade above No. 5. In this instance, the degrade was no doubt due to a dip in the grain. The third sample, which illustrates an extreme degree of fuzzing in quartered mahogany, probably due to abnormal fibers, is also a Grade No. 5.

While the extreme conditions seen in the two lower specimens may occur in any species, they are usually lacking or negligible in most species, except when planing under very unfavorable conditions. Figs. 7-10 show the intermediate grades, Nos. 2, 3, and 4, which may be considered as slight, medium, and advanced degrees.

11.12 Base comparisons of planing properties of different species on percentages of defect-free pieces. Most of the planing specimens were either defect-free or only slightly defective. Although Grade Nos. 3, 4, and 5 were of relatively infrequent occurrence, they served to give a more complete picture of the degree of any defects that were present. Two things should be kept in mind: (*1*) Consecutive grades merge gradually without any abrupt change in quality or any sharp dividing line. (*2*) Any given grade is not completely uniform in quality, but has some range between the best and the poorest examples within the grade.

12. Sanding

12.1 The machine shall preferably be a two-head, wide-belt sander. If such a machine is not available then the machine shall be fully described. Conduct the sanding operation using a contact roll or drum. Do not use a stroke sanding machine.

12.2 The first head shall carry an 80-grit, aluminum-oxide cloth or paper-back belt. The second head shall carry a 120-grit, aluminum-oxide cloth or paper-back belt.

12.3 Feed rates shall be on the order of 20 ft/min (6.1 m/min).

12.4 The test specimens (50 per species) shall be $\frac{5}{16}$ by 4 in. by 1 ft cut from the $\frac{5}{16}$-in. material left after the planing test, and shall be conditioned to 6 % EMC, or to such other moisture content as may be specified.

12.5 Examine the specimens and grade them for scratching and fuzzing, and the basis of comparison shall be the percentage of specimens that are free from these defects.

NOTE 16—The remaining 2 ft (610 mm) of the $\frac{5}{16}$-in. (1-cm) material left from the planing test may, if desired, be used in testing the splitting tendencies of different woods with nails and screws.

FOREST PRODUCTS LABORATORY, MADISON, WISCONSIN

Kind of test Planing Date

Species Red oak Moisture content 6 % Feed rate f.p.m. 100

Speed r.p.m. 3600 Knives H.S. Steel Cutting angle 20°

Sample Number	Defect-free	Raised grain	Fuzzy grain	Torn grain	Chip marks
1		4	4	3	4
2		4	4	3	4
3	✓				
4	✓				
5	✓				
6	✓				
7	✓				
8	✓				
9	✓				
10		4	4	3	4
11		4	4	3	4
12	✓				
13	✓				
14	✓				
15	✓				
16	✓				
17	✓				
18	✓				
19	✓				
20		4	4	3	4
21	✓				
22		4	4	3	4
23	✓				
24	✓				
25	✓				
26	✓				
27	✓				
28	✓				
29	✓				
30		4	4	3	4
31	✓				
32	✓				
33	✓				
34		4	4	3	4
35	✓				
36	✓				
37	✓				
38	✓				
39		4	4	2	4
40	✓				
41	✓				
42	✓				
43	✓				
44	✓				
45		4	4	3	4
46		4	4	3	4
47	✓				
48	✓				
49		4	4	3	4
50	✓				
TOTAL	38	3			
AV.	76 %				

NOTE 1—This form may be modified for use in other tests. The numbers in the column refer to the grade of the specific defect under consideration.

FIG. 5 Sample Data Sheet Used in Planing Test

13. Boring

13.1 The borer shall preferably be a single-spindle electric machine equipped with power feed. (If necessary, a smaller machine with hand or foot feed may be used.)

13.2 The bit shall be a 1-in. (25-mm) size of the single-twist, solid-center, brad-point type (Fig. 9). Sharpen it lightly at intervals of not more than 1 h of work.

13.3 The test specimens shall measure ¾ by 3 by 12 in. (19 by 76 by 305 mm), and shall be conditioned to 6 % EMC, or such other moisture content as may be specified.

13.4 The borer shall be run at a spindle speed of 3600 r/min.

13.5 The rate of boring shall be low enough to enable the drill to cut rather than tear through the specimen.

13.6 Bore two holes through each specimen.

NOTE 17—The same specimens are used for three different tests, first for boring, then for shaping, and finally for mortising. Where the specimens are to be bolted on a shaping jig for a later test, as in this case, the holes must be accurately and uniformly placed. Although the identical procedure and spacing described here need not necessarily be followed elsewhere, the details are presented as descriptive of a satisfactory method.

In order to locate the holes accurately and uniformly, the boring jig shown on the top in Fig. 11 is used. The jig is positioned on the table of the borer with the point of the bit 1 in. (25 mm) from one edge of the recess, 8½ in. (216 mm) from one end, and 10⅜ in. (216 mm) from the other. The jig is then fastened in that position with C clamps and remains stationary.

The blank is placed in the recess on the top of the jig, slid to the extreme left, and hole No. 1 is bored. The blank is then slid to the extreme right, and hole No. 2 is bored. In order to prevent splintering out at the bottom,