Designation: D1666 – 22

Standard Test Methods for Conducting Machining Tests of Wood and Wood-Base Panel 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 and wood-base panels is the facility with which they can be machined and fabricated. Different species and products, 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 applications 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, routing/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 all species of hardwoods and softwoods, and to wood-base panel materials, such as plywood, particleboard, fiberboard, and hardboard.

1. Scope

1.1 These test methods cover procedures for planing, routing/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 such as plywood and wood-base fiber and particle panels.

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 or wood-base panel. 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 are 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 standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

[1] These test methods are under the jurisdiction of ASTM Committee D07 on Wood and are the direct responsibility of Subcommittee D07.01 on Fundamental Test Methods and Properties.

Current edition approved Aug. 1, 2022. Published August 2022. Originally approved in 1959. Last previous edition approved in 2017 as D1666 – 17. DOI: 10.1520/D1666-22.

Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards:*
D9 Terminology Relating to Wood and Wood-Based Products
D1038 Terminology Relating to Veneer, Plywood, and Wood Structural Panels
D1554 Terminology Relating to Wood-Base Fiber and Particle Panel Materials
D2395 Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials
D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials
D4933 Guide for Moisture Conditioning of Wood and Wood-Based Materials
D7438 Practice for Field Calibration and Application of Hand-Held Moisture Meters

3. Terminology

3.1 For definitions of terms used in this standard, refer to Terminology D9, D1038, and D1554.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *chip marks*—shallow dents in the surface caused by shavings that have clung to the knives instead of passing off in the exhaust as intended.

3.2.2 *planer knife clearance angle*—planer cutterhead knife angle *(c)* depicted for both knife alternatives in Fig. 1.

3.2.3 *planer knife cutting angle*—planer cutterhead knife angle *(a)* depicted for both knife alternatives in Fig. 1.

3.2.4 *planer knife cutting bevel*—planer cutterhead knife bevel angle *(b)* depicted for Knife Alternative 2 in Fig. 1.

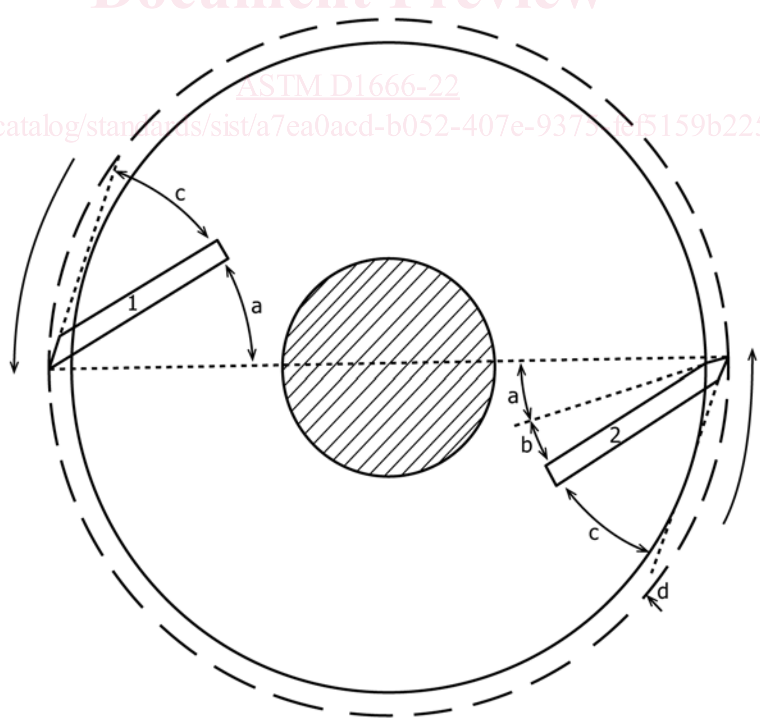
3.2.5 *planer knife cutting circle*—the circumference *(d)* defined by the outer limits of the planer knives of a cutterhead and depicted in Fig. 1.

3.2.6 *computer numeric controller (CNC) machine*—a computer automated machine center often used to machine wood and wood-based panel materials that are typically integrated with drafting software and may have the capabilities to perform machining activities that include cutting, routing, drilling, shaping, and turning.

3.2.7 *feed rate*—the resultant rate of movement measured in feet (meters) per minute at which material moves through a machining tool that includes the combination of machining tool and material motion.

3.2.8 *fuzzy grain*—small particles or groups of fibers that did not sever clearly in machining but stand up above the general level of the surface.

3.2.9 *jointing*—an equalization of the projection of all the knives in the cutterhead performed by bringing a sharpening stone into contact with the knife edges while the cutterhead revolves.



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

FIG. 1 Terms Used in Connection with Planer Knives

3.2.10 *land (or heel)*—the part of the cutting edges of the knives that conforms to the cutting circle, has no clearance, and that comes into contact with the sharpening stone in the jointing operation.

3.2.11 *speed, cutterhead*—the rate measured in revolutions per minute at which a cutterhead is turning.

3.2.12 *speed, rim*—the rate measured in feet (meters) per minute at which the periphery of a cutting tool (usually a saw) is turning.

4. Significance and Use

4.1 Machining tests are made to determine the working qualities and characteristics of different species of wood and of different wood-based panel materials under a variety of machine operations such as are encountered in commercial manufacturing practice. The tests provide a systematic basis for comparing the behavior of different products with respect to woodworking machine operations and of evaluating their potential suitability for certain uses where these properties are of prime importance.

5. Apparatus

5.1 *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. 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 may be useful for limited purposes, such as for comparing the machining properties of a species for local use under local conditions.

5.2 *Feed Rates*—While either automated or manual feed machines shall be permitted, preference shall be given to machines with automated feed systems. To the extent possible, the feed rates used for the tests shall be chosen to correspond with the desired cutting conditions that will be employed for production. The feed rates and cutting conditions shall be kept constant throughout each test type and reported.

5.3 *Knives and Cutters*—Insert tooling or one-piece cutters shall be permitted for testing. 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, manufacturer, and any relevant grade information shall be made part of the record. Every precaution shall be taken to keep the sharpness uniformly good in all tests by resharpening or replacing the knives and cutters when necessary.

NOTE 2—A practical measure of the deterioration of a machined lumber surface because of dulling of the cutting tool can be obtained by the use of two check samples. They should come from the same board of some species that machines exceptionally well, such as maple or any other closed-grain species. 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, should 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 or replaced.

Similarly with wood-base panels, some well-known product that has good machining properties may be used as a control material for comparison.

NOTE 3—Whenever possible, preference should be given to carbide insert tooling (Fig. 2). Carbide insert tools are inexpensive and can be readily replaced in the tool holder. Replacing the tooling in place of resharpening will increase the repeatability of the method. Tooling manufactures have tables of recommended carbide tooling for the various wood-based products. Preference should be given to the grade and type of tooling recommended. Experience has shown that there can be a difference in performance between carbide tools produced by different manufacturers.

6. Shipment and Protection of Samples

6.1 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.

7. General Requirements of Samples

7.1 The tests shall primarily be made on seasoned material brought to an equilibrium moisture content in a conditioned environment of 68 ± 11°F (20 ± 6°C) and 65 % (±5 %) relative humidity. Methods for determination of completion of conditioning are given in Guide D4933. Alternative conditioning shall be permitted provided that it is recorded.

7.2 Lumber shall be clear, sound, well-manufactured, and accurately identified as to species. It shall be permitted to be either rough or dressed.

NOTE 4—Clear means free from all defects, including knots, stain, incipient decay, surface checks, end splits, compression wood, and tension wood.

7.3 Wood-base panel samples shall 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 shall be recorded where known. Wood-base panels shall be typical of the product under consideration as they are manufactured and marketed. For the sanding tests, the wood-base panel samples are to be procured in the unsurfaced condition, whenever possible, so that these evaluations are made on the same part of the material that will be removed from the board in the normal use conditions where sanding is done.

7.4 Test samples of lumber shall be so selected as to exclude extremely high or low ring counts per inch (average ring width in millimeters) that are not typical of the species under consideration.

FIG. 2 Illustration of a Router Head With Insert Tooling

NOTE 5—Number of rings per inch (or average ring width in millimeters) 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.

8. Dimensions, Weight, and Moisture Content of Samples

8.1 Samples must be large enough to yield the minimum acceptable size of 0.75 in. by 5 in. by 4 ft (19 mm by 127 mm by 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) shall be permitted.

8.2 Lumber test samples shall be so selected as to exclude extreme specific gravities (or densities) that are not typical of the species under consideration.

NOTE 6—Different samples of a species sometimes vary in specific gravity (or density) by as much as a 2-to-1 ratio. The properties exhibited by samples at either extreme of specific gravity (or density) are not typical of the species as a whole.

8.3 Wood-base panel test material shall be typical in dimensions and density of the products under consideration as they are manufactured and marketed.

8.4 The moisture content of a representative sampling of test material shall be determined and recorded. The moisture content of sawn lumber materials shall be determined using either the oven dry method of Test Methods D4442 or a hand-held meter in accordance with Practice D7438. If a pin-type hand-held meter is used to determine the moisture content prior to machining, then the moisture content reading shall be taken away from the surface that will be machined. The moisture content of composite materials shall be determined in accordance with Test Methods D4442.

9. Sampling

9.1 A total of 50 test samples of lumber is required for each species tested. 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 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 shall be permitted to be selected.

NOTE 7—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.

9.2 For each type of wood-base panel tested, five samples shall be selected, one from each of five different sheets. The size of these samples (Fig. 3) shall be 2 ft by 4 ft (0.6 m by 1.2 m), and the thickness in different products shall be as manufactured.

NOTE 8—Wood-base panels from 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 9.2 are considered sufficient to give representative results.

NOTE 9—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. (19 mm), a sufficient number of pieces shall be laminated together to provide the 0.75 in. (19 mm) thickness.

10. Preparation of Test Specimens from Lumber

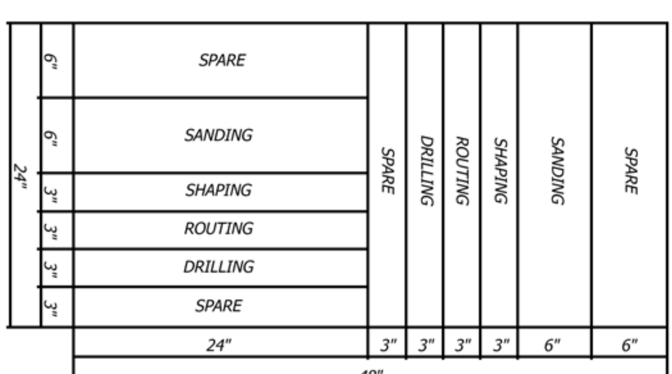
10.1 Each different test has its own procedure as described in Sections 12 – 17. The following steps in preparing the test specimens apply to all tests with lumber:

10.1.1 Mark each board, nominal 1 in. by 5 in. by 4 ft (25 mm by 127 mm by 1.2 m) to identify adequately the species source and individual sample.

10.1.2 Cut a 0.5 in. (13 mm) cross section from one end of each nominal 1 in. by 5 in. by 4 ft (25 mm by 127 mm by 1.2 m) board for specific gravity determination in accordance with Test Methods D2395 and for counting the number of annual rings per inch (or average ring width in millimeters) (Note 5).

10.1.3 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).

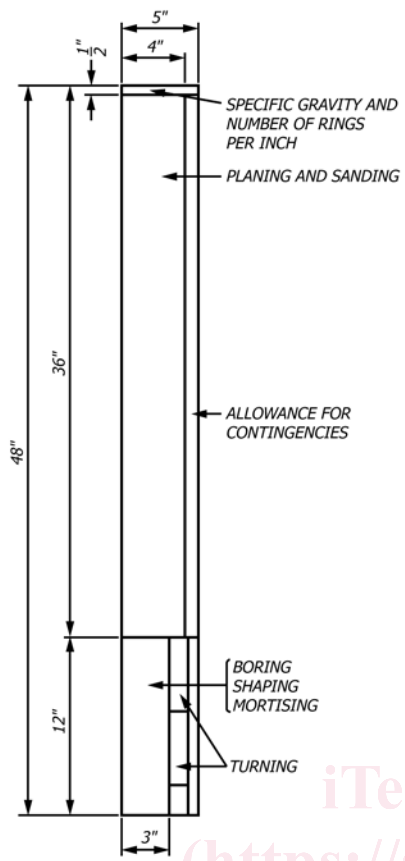
10.1.4 Saw the boards into the specified smaller sizes for the different tests as shown in Fig. 4. Each of the test specimens shall bear the same number as the board from which it was cut; take care to place the number where it will not be lost in the



APPROXIMATE SI EQUIVALENTS

in.	3	6	24	48
(mm)	(76)	(152)	(610)	(1220)

FIG. 3 Diagram for Sawing Wood-Base Panel Samples into Smaller Samples for Individual Tests



APPROXIMATE SI EQUIVALENTS

in.	½	3	4	5	12	36	48
(mm)	(13)	(76)	(102)	(127)	(305)	(910)	(1220)

FIG. 4 Diagram for Sawing Lumber Samples into Smaller Samples for Individual Tests

machining process. The specimen for routing/shaping, boring, and mortising (Fig. 4) shall be accurately cut to size to ensure proper positioning. The turning specimens also shall be accurate since they have to fit special lathe centers.

NOTE 10—The size of the planing specimen is not critical and, if necessary, it may be 1 in. (25 mm) or so short of the specified 3 ft (0.9 m) without serious objection.

11. Preparation of Specimens from Wood-Base Panels

11.1 Each different test has its own procedure as described in Sections 19 – 22. The following steps in preparing the test specimens apply to all tests with wood-base panels:

11.1.1 Mark each 2 ft by 4 ft (0.6 m by 1.2 m) board to identify the source and the individual sample.

11.1.2 Saw each of the original wood-base panel samples into smaller sizes for the different tests as shown in Fig. 3.

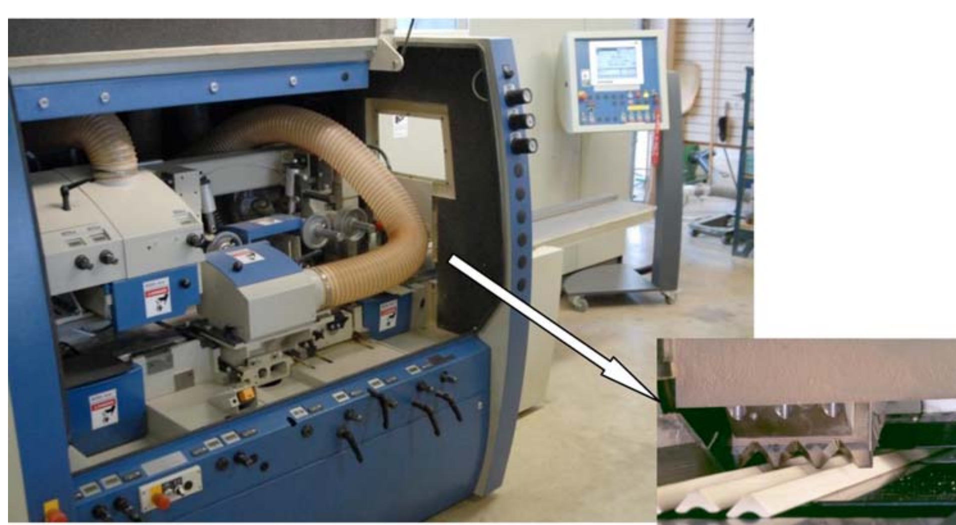
11.1.3 Each of the test specimens shall bear the same number as the board from which it was cut.

METHODS OF TESTING LUMBER

12. Planing

12.1 A moulder (Fig. 5) 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 shall be permitted. In any case use only straight knives, and plane only one side of the test specimen at a time.

12.2 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. (0.79 mm) wide, as a result of repeated jointings, the knives shall be reground before continuing with the test. Provided that the feed rates are adjusted to



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 two or more cutterheads to permit machining up to four sides with one pass. In planing tests, however, only one cutterhead is used, the bottom head equipped with straight blades.

FIG. 5 Desirable Type of Machine for Use in Planing Tests

maintain the required knife marks per inch as outlined in 12.8, it shall also be acceptable to use a single knife finish instead of a jointed knife finish.

12.3 All specimens used in this test (50 per species) shall be 0.75 in. by 4 in. by 3 ft (19 mm by 102 mm by 0.9 m).

12.4 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.

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

12.6 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.

12.7 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.

12.8 *Cutting Angles and Knife Mark Frequencies*—The cutting angles and knife mark frequencies used for the testing shall be as required to satisfy the test objectives:

12.8.1 *Optimization Testing*—If the goal of the test program is to optimize the cutting angle or knife mark frequency, or both, then make four runs with knives at cutting angles of 15, 20, 25, and 30°. The feed rates and cutterhead speeds for these tests shall be adjusted to give 20 knife marks/in. (0.8/mm). Three additional runs shall then be made with a fixed 20° cutting angle. Feed rates and cutterhead speeds for these additional runs shall be adjusted to give 8, 12, and 16 knife marks/in. (0.3, 0.5, and 0.6 knife marks/mm).

12.8.2 *Representative Testing*—If the cutting angle and knife mark frequency are recommended by the tooling manufacturer or otherwise known, then make four runs using the known conditions. The cutting angle and knife mark frequency used for the test shall be recorded.

NOTE 12—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. 1. This means one cutterhead with, say, four sets of knives back-beveled at four different degrees can be used to achieve four different cutting angles.

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

$$\text{No. of knife cuts per inch} = (A \times B)/(C \times 12)$$
$$\text{No. of knife cuts per millimeter} = (A \times B)/C$$

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.

12.9 Visually examine each test specimen carefully for planing defects after each run. A datasheet similar to Fig. 6, where the numbers in the column refer to the grade of the specific defect under consideration shall be used. For each specimen, grade any planing defect 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:

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

NOTE 14—The runs described in Section 12 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. 7. 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 a defect that is 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 (knife marks per millimeter) 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 can occur in any species, they are usually lacking or negligible in most species, except when planing under very unfavorable conditions. Figs. 8-11 show the intermediate grades, Nos. 2, 3, and 4, which is considered as slight, medium, and advanced degrees.

12.10 Base comparisons of planing properties of different species on percentages of defect-free pieces in each dataset.

NOTE 16—Planing specimens are usually either defect-free or only slightly defective. Although Grade Nos. 3, 4, and 5 are relatively infrequent, they serve to give a more complete picture of the degree of any defects present. Two things to be kept in mind when grading: (*1*) Consecutive grades merge gradually without any abrupt change in quality or any sharp dividing line, and (*2*) Any given grade is not completely uniform in quality, but has some range between the best and the poorest examples within the grade.

13. Sanding

13.1 The machine shall preferably be either a two-head, wide-belt sander or a drum sander. If neither of these machines are available, then the machine used shall be reported including the type of roll or drum employed. Conduct the sanding operation using a contact roll or drum. Report the roll or drum hardness in Shore A durometer units. Do not use a stroke sanding machine.

13.2 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.

13.3 Feed rates shall be on the order of 20 ft/min (6100 mm/min) or representative of the proposed production conditions.

13.4 The depth of cut shall be 1/16 in. (1.2 mm).

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. 6 Sample Data Sheet Used in Planing Test

13.5 The test specimens (50 per species) shall be 5⁄16 in. by 4 in. by 1 ft (8 mm by 102 mm by 0.3 m) cut from the 5⁄16 in. (8 mm) material left after the planing test.

13.6 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.

14. Boring

14.1 The borer shall be a single-spindle electric machine equipped with power feed. The preferred option is to use a drill bit mounted on a computer numeric controlled (CNC) router. If necessary, a manual machine with hand or foot feed shall be permitted.

14.2 The bit shall be a 1 in. (25 mm) size of the single-twist, solid-center, brad-point type (Fig. 12). Sharpen it lightly at intervals of not more than 1 h of work.

14.3 The test specimens shall measure 0.75 in. by 3 in. by 12 in. (19 mm by 76 mm by 305 mm).

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

14.5 The rate of boring shall be consistent between specimens and low enough to enable the drill to cut rather than tear through the specimen.

14.6 Bore two holes through each specimen.

NOTE 17—The same specimens are used for three different tests, first for boring, then for router/shaping, and finally for mortising. If a CNC