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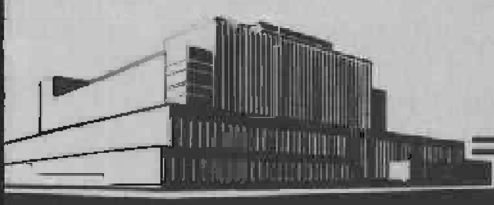

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

DEVELOPMENT OF METHODS FOR EVALUATING THE MACHINING QUALITIES OF WOOD AND WOOD-BASE MATERIALS

Foreword

One of the important properties of wood for many uses is that of machinability or ease of fabricating and working. The various species of wood differ widely in their machining properties, as influenced by the characteristics or density and fiber structure, such as presence of interlocked grain, mineral streaks, tension wood, and other features. A knowledge of the ease of machining and fabrication and of methods of overcoming fabricating difficulties is important in the marketing of new species and in the conversion of wood for many important products.

While much consideration has been given to the development of unified methods for evaluating the physical and mechanical properties of wood and wood-base materials, much less attention has been given to the standardization of practices in the evaluation of machining characteristics. However, some work on machining properties of different woods has been carried on for many years at the U. S. Forest Products Laboratory, in which the effectiveness of certain machining operations, such as planing and turning, were evaluated. From this there have evolved a fairly systematic series of machining evaluation tests and operations that serve as a means of providing comparable data among different species and are furthermore also applicable to many types of fiberboards. Unfortunately there is, as yet, no instrumentation for precisely evaluating the smoothness or perfection of various machining operations, so that visual methods of classification are relied on.

It is the purpose of this paper to present a detailed description of the methods employed in evaluating machining characteristics so that it may serve as a basis for similar studies for others planning to carry on work in this field, as a basis for further improvement and refinement, and as procedures for consideration in the development of standards.

This paper is presented as a contribution to the program for the Working Party on Sawing and Machining of the FAO Conference on Wood Technology.

--L. J. Markwardt
Member, Working Party on
Sawing and Machining

DEVELOPMENT OF METHODS FOR EVALUATING THE MACHINING QUALITIES OF WOOD AND WOOD-BASE MATERIALS[1]

By

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Introduction

Machining properties are involved in all the common woodworking operations. Different woods probably vary as much in machining properties as they do in other respects. The importance of machining properties in any given case depends largely upon the prospective use of the wood. For cabinet work, good machining properties are essential to good finish and are therefore of prime importance. For common boards, on the other hand, good machining properties are secondary, although they are still an asset.

Systematic study in this field is of relatively recent origin as compared with research on some other phases of wood properties. Publications on machining properties of wood are therefore relatively meager. Meanwhile the field for research along these lines is broadening because of the increased volume and variety of woods in world markets, because of new species brought into commercial use, and because of the increased use of minor species and of wood in other forms than lumber, such as plywood, hardboard, and particle board.

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[1]For presentation on the program of the Working Party on Sawing and Machining of the Fourth FAO Conference on Wood Technology, Madrid, Spain, April 1958.

[2]Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.

The U. S. Forest Products Laboratory has been carrying on intensive research in the machining of wood for many years. This work included planing, shaping, turning, sanding, boring, and mortising. Two separate phases were involved: the development of workable tests and the development of practical means of evaluating the results.

To date, 78 species have been investigated including 35 hardwoods (4) and 6 softwoods (6) native to the U. S.; 20 Caribbean hardwoods (5); 9 Liberian hardwoods (9) and 8 Philippine hardwoods (10).[3]

In addition, 7 different brands of particle board and 5 of hardboard have been tested.

On the basis of the experience gained in conducting these machining investigations, it is believed that the methods developed are about equally applicable to all woods and, with some modifications, to wood-base materials, such as particle board and hardboard.

The tests that have been developed and successfully used in the work on machining characteristics of different woods and wood-base materials include planing, shaping, turning, mortising, boring, and sanding. The procedures and test methods employed have been described in general from time to time in various reports presenting test results, but the methods have not heretofore been published in sufficient detail to permit them to be duplicated closely by others who may be interested in similar work.

It is the purpose of this paper to present in specification form a description of the various machining methods developed with the thought that it will be helpful to others planning work in this field. It is hoped that its use will stimulate research resulting in further improvement and refinement, and that it may be available for consideration as a basis for the development of standard methods that will permit the unification of results obtained at different research centers.

Other reports by the author on applied research in the field of the machining of wood are listed in Literature Cited at the end of this text (2 to 10). The work of those other authors cited lies in the field of pure research in a more limited scope (1, 11 to 18).

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[3]Underlined numbers in parentheses refer to Literature Cited at the end of this report..

Methods of Conducting Machining Tests of

Wood and Wood-Base Materials

Purpose of Tests

1. Machining tests are required to provide a systematic method for obtaining comparable results in the evaluation of machining properties of different species of wood or of wood-base products. It is the purpose of this report to present detailed methods for conducting a number of machining tests that will provide data for comparing the characteristics of different species and that will permit the duplication and comparison of results.

Scope of Tests

2. (a) The proposed tests include planing, shaping, turning, mortising, boring and sanding; all of which are common woodworking operations used in the manufacture of wood products. These tests apply, in different degrees, to two general classes of material: (1) wood in the form of lumber, and (2) wood-base fiber and particle panel materials in the form of hardboard and particle board.

(b) 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.

(c) 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 methods.

(d) 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.

Definitions and Descriptions of Terms

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

Materials and Manufacture

4. (a) The tests shall be made on seasoned material.

(b) Lumber shall be clear, (Note 1), sound, well-manufactured, and accurately identified as to species. It may be either rough or dressed.

Note 1.--Clear means free from all defects, including knots, stain, incipient decay, surface checks, and end splits.

(c) Particle board 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.

Physical Requirements of Samples

5. (a) 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 (Note 2).

Note 2.--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.

(b) Particle board and hardboard shall be typical of the product under consideration as they are manufactured and marketed.

Dimensions, Weights, and Permissible Variations

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

(b) Samples must be large enough to yield the minimum acceptable size (3/4 by 5 in. by 4 ft.) (2 by 12.5 by 120 cm.) 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 inch (2.5 cm.) may be used.

(c) 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 3).

Note 3.--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.

(d) Particle board and hardboard test material shall be typical in dimensions and weight of the products under consideration as they are manufactured and marketed.

Sampling

7. (a) A total of 50 test samples of lumber is required for each species tested (Note 4). 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.

Note 4.--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.

(b) (1) For each type of particle board tested, 5 samples (Note 5) shall be selected, one from each of 5 different sheets.

Note 5.--Particle board 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, 5 samples selected as described above are considered sufficient to give representative results.

(2) The size of these samples (fig. 2) shall be 2 by 4 feet (60 by 120 cm. and the thickness in different products shall be as manufactured (Note 6).

Note 6. -- For sawing tests where power consumption is an important factor, material thicker than 3/4 inch (2 cm.) shall be reduced to that thickness before test. For material thinner than 3/4 inch (2 cm.), a sufficient number of pieces shall be laminated together to provide the 3/4 inch (2 cm.) thickness.

(c) (1) For each type of hardboard tested, 5 samples shall be selected, 1 from each of 5 different sheets.

(2) The size of these samples shall be 2 by 4 feet (60 by 120 cm.), and the thickness shall be that of the hardboard as manufactured.

Shipment and Protection of Material

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

Preparation of Lumber Test Material

9. Each different test has its own procedure which is detailed in the following pages. The following steps in preparing the test samples apply to all tests with lumber:

a. Each board, 1 by 5 inches by 4 feet (2.5 by 12.5 by 120 cm.) shall be marked to identify adequately the species source and individual sample.

b. A 1/2 inch (1 cm.) cross section shall be cut from one end of each 1 by 5 inch by 4 foot (2.5 by 12.5 by 120 cm.) board for specific gravity determinations and for counting the number of annual rings per inch or centimeter (Note 2).

c. The boards shall be conditioned to a uniform moisture content of 6 percent, or to such other moisture content as may be specified (Note 7).

Note 7. -- Dry kilns are usually necessary for the conditioning of the test material to 6 percent moisture content. 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 should be determined and recorded.

d. One edge and one side of the boards shall be jointed flat and the other side planed to 3/4 inch (2 cm).

e. The boards shall be sawed into the specified smaller sizes for the different tests as shown in figure 1. Each of the smaller samples shall bear the same number as the board from which it was cut, taking care to place the number where it will not be lost in the machining process (Note 8).

Note 8. -- The sample for shaping, boring, and mortising (fig. 1) must be accurately cut to size to insure proper fit in the test jig. The turning samples also must be accurate since they have to fit special lathe centers. The size of the planing sample is less critical and, if necessary, it may be an inch (2.5 cm.) or so short of the specified 3 feet (90 cm.) without serious objection.

Preparation of Particle Board and Hardboard Test Material

10. The following steps in preparing the test samples apply to all tests with particle board and hardboard.

a. Each 2- by 4-foot board (60 by 120 cm.) shall be marked to identify the source and the individual sample.

b. The boards shall be conditioned to the equilibrium moisture content, at room temperature and 30 percent relative humidity or to such other moisture condition as may be specified.

c. Each of the original particle board and hardboard samples shall be sawed into smaller sizes for the different tests as shown in figure 2.

d. Each of the smaller samples shall bear the same number as the board from which it was cut.

General Instructions for Tests

11. a. The 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 men. 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 9).

Note 9.--Where machines with all the above 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.

Complete information on the machine used on the cutting tool and on the operating conditions of each test shall be made part of the record.

b. 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 10).

Note 10.--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 an hour or so as experience dictates, shall be machined with the regular test samples and compared with the control. When the machined surface deteriorates perceptibly, as indicated by this comparison, the cutting tool will 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.

c. Evaluation of Machining Defects

Promptly upon the completion of a test, each piece shall be carefully examined visually for raised, torn, or fuzzy grain, or any other machining defect. When a sample is defect-free, it shall be so recorded. To give a quantitative measure, each defect found shall be given a numerical grade to indicate whether it is present in a slight, medium, or advanced degree. The technique is fully described under the section entitled Planing (Note 11). All results shall be recorded on prepared forms (see sample form in fig. 3).

Note 11.--The quality of a machined surface depends not only upon the frequency of occurrence of machining defects but also upon the severity of any defects that may be present. From the finishing standpoint, the area covered by a given defect is usually less important than its depth. The worst point in a defective sample determines its quality, because it determines the amount of additional finishing work that must be done to make it commercially acceptable.

Method of Tests - Lumber

12. a. Planing

(1) A moulder (fig. 4) is the preferable machine for this 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 will serve. In any case only straight knives shall be used, and only one side of the test material shall be planed at a time.

(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 inch wide, as a result of repeated jointings, the knives shall be reground before continuing with the tests.

(3) All samples used in this test (50 per species) shall be 3/4 by 4 inches by 3 feet (2 by 10 by 90 cm.).

(4) The moisture content shall be 6 percent or such other value as may be specified.

(5) All cuts shall be 1/16 inch (2 mm.) deep. A test piece 3/4 inch (2 cm.) thick will permit making 6 cuts before the piece becomes thin enough to introduce a new variable.

(6) When several species are being tested, they shall be well mixed to equalize the effect of the gradual dulling of the knives.

(7) The samples shall be fed into the machine, so that half are machined with the grain and half against the grain.

(8) The end of each piece shall be marked as the piece emerges from the machine to indicate the direction of feed and the side that has just been machined Individual pieces shall be fed in the same direction at each cut.

(9) Four runs shall be made with knives at cutting angles (Note 12) of 15, 20, 25, and 30 degrees. The feed rates and cutterhead speeds shall be adjusted to give 20 knife marks per inch.

Note 12. --Because there are no accepted standards, the terms used in connection with planer knives vary considerably. Figure 5, which shows the cross section of a cutterhead, illustrates a common usage; the one that is followed in this report. 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 degrees to 30 degrees 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 figure 5. This means 1 cutterhead with, say, 4 sets of knives back-bevelled at 4 different degrees achieves 4 different cutting angles.

(10) Three runs shall be made with a 20-degree cutting angle, while feed rates and cutterhead speeds are adjusted to give 8, 12, and 16 knife marks per inch (Note 13).

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:

$$\frac{\text{r.p.m. of cutterhead} \times \text{No. of knives in head}}{\text{feed rate in f.p.m.} \times 12} = \text{No. of knife cuts per inch}$$

where r.p.m. is revolutions per minute, and f.p.m. is feet per minute. If the theoretical number does not agree with the actual number, the jointing is probably inadequate. This should always be checked visually (fig. 3).

(11) Each test sample (Note 14) shall be carefully examined visually for planing defects after each run. For each sample, any planing defect that may be present shall be graded according to degree and recorded on prepared forms.

Note 14. -- The above-mentioned runs cover the more critical conditions. If additional runs are desired for any reason, additional test material will be needed.

The planing characteristics of each sample shall be classified 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; and grade 5, very poor.

The characteristic of black walnut with respect to planing qualities is illustrated by grades Nos. 1 and 5 (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 small burls in this sample. 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 sample, 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 sample, 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 sample.

While the extreme conditions seen in the two lower samples may occur in any species, they are usually lacking or negligible in most species, except when planing under very unfavorable conditions.

Figures 7 to 10 illustrate the intermediate grades, Nos. 2, 3, and 4, which may be considered as slight, medium, and advanced degrees.

(12) Comparisons of planing properties of different species shall be based on percentages of defect-free pieces.

Most of the planing samples were either defect-free or only slightly defective. Although grades 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.

b. Sanding

(1) The machine shall preferably be a 3-drum sander with either endless bed or roll feed.

(2) Drum speed shall be approximately 1,200 r.p.m. on the first 2 drums at the infeed end and 1,800 r.p.m. on the third drum.

(3) The first drum shall carry No. 1/2 garnet grit paper, the second drum No. 1/0 garnet grit paper, and the third drum No. 2/0 garnet grit paper.

(4) Feed rates shall be on the order of 12 feet per minute.

(5) The test samples (50 per species) shall be 5/16by 4 inches by 1 foot (1 by 10 by 30 cm.) cut from the 5/16-inch (1 cm.) material left after the planing test, and shall be conditioned to 6 percent moisture content, or to such other moisture content as may be specified.

(6) The samples shall be examined and graded for scratching and fuzzing, and the basis of comparison shall be the percentage of samples that are free from these defects (Note 15).

Note 15.--The remaining 2 feet (60 cm.) of the 5/16-inch (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.

c. Boring

(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.)

(2) The bit shall be a 1 inch size of the single-twist, solid-center brad-point type (fig. 9). It shall be sharpened lightly at intervals of not more than 1 hour of work.

(3) The test samples shall measure 3/4 by 3 by 12 inches (2 by 7.5 by 30 cm.), and shall be conditioned to 6 percent moisture content, or such other moisture content as may be specified.

(4) The borer shall be run at a spindle speed of 3,600 revolutions per minute.

(5) Two holes shall be bored through each sample (Note 16).

Note 16.--The same samples are used for three different tests, first for boring, then for shaping, and finally for mortising. Where the samples 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 figure 11 is used. The jig is positioned on the table of the borer with the point of the bit 1 inch (2.5 cm.) from one edge of the recess, 8-1/2 inches (21 cm.) from one end, and 10-3/8 inches (26 cm.) 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, all holes are bored completely through the blank and about 1/16 inch (2 mm.) into a hardboard backing. (This backing can be removed and replaced when desirable.) The openings through the bottom of the jig, one at each end, permit the shavings to fall through as the blanks are slid back and forth.

(6) The boring properties of different woods shall be based on examination of the holes for crushing, tearouts, fuzziness, and general smoothness of cut. Each hole (Note 17) shall be graded on a scale of 5 as in preceding tests, and the comparison of different species shall be based on the percentage of grades No. 1 and No. 2 holes present.

Note 17.--In tests with 23 native hardwoods it has been found that, although the size of the holes in different species varies, in different degrees, from the size of the bit, the amount of the variation is not enough to affect the strength of dowelled joints significantly. For this reason, measuring the size of the holes with a plug gage, as was done in early tests, appears to be unnecessary.

d. Shaping

(1) The machine shall be a commercial size, hand feed spindle shaper with either 1 or 2 spindles.

Note 18.--Shapers are designed primarily to cut patterns on curved surfaces, such as a quarter-round pattern on the edge of a round table top. By far the commonest type of shaper is the spindle shaper, that carries 1 or 2 vertical spindles on which knives or cutters are mounted. When there are 2 spindles, these revolve in opposite directions, so that the cut can always be made with the grain. Single-spindle machines typically run at higher speeds that are relied on to make a satisfactory cut either with or against the grain.

(2) The knives shall be ground as shown in No. 1, figure 12, and maintained in good cutting condition.

(3) The test samples (50 for each species) shall be 3/4 by 3 by 12 inches (2 by 7.5 by 30 cm.) in size and conditioned to 6 percent moisture content, or to such other moisture condition as may be specified.

(4) The samples shall be band sawed to pattern as shown in figure 13.

(5) A preliminary roughing cut shall be made with the shaper making use of the jig (Note 19) shown in figures 13 and 14 and taking care to cut with the grain as far as possible.

Note 19.--Figure 13 illustrates a jig (disassembled) that has been found satisfactory in the shaping test. It should be made from a hard, fine-textured wood such as birch or hard maple. The base of this jig (No. 3) is of 2-inch (5 cm.) material, and the other 2 pieces (Nos. 1 and 2) are 1 inch (2.5 cm.). Flathead wood screws are used to fasten the parts together. Test sample No. 4 has merely been band sawed from the rectangular blank; No. 5 has been both band sawed and shaped. The edges of the blanks are parallel for half of their length, while the remainder of the length is a parabola. The bolts, which pass through the holes in the test samples, are 3/4 inch (2 cm.) in diameter, whereas the holes are 1 inch (2.5 c.m.). The knurled nuts that hold the samples in place are tapered at the base to exert a centering effect when tightened on the test samples. Figure 14 shows this same jig assembled.

(6) A finishing cut 1/16 inch (2 mm.) deep shall be made.

(7) If a 1-spindle shaper is used, the speed shall not be less than 10,000 revolutions per minute. If a 2-spindle shaper is used, the speed shall not be less than 7,200 revolutions per minute.

(8) The test material shall be graded piece by piece for raised, fuzzy, and chipped grain and rough end grain and the results recorded on prepared forms. A separate record shall be kept for side-grain and end-grain cuts.

(9) Comparisons of shaping properties shall be based on percentage of grades Nos. 1 and 2 samples present.

f. Mortising

(1) The mortising machine shall be of the hollow chisel type equipped with power feed and spindle speed of 3,600 revolutions per minute. As a second choice, hand or foot feed may be used.

(2) The chisel shall be the 1/2 inch size.

(3) Both the bit and the chisel shall be resharpened at intervals of not more than 1 hour of work.

(4) The same samples used for the shaping and boring tests also shall be used for mortising, figure 15.

(5) The machine shall be operated at a spindle speed of 3,600 revolutions per minute.

(6) Two mortises shall be made in each sample extending through into a hardwood backing.

(7) The mortises shall be cut with 2 sides parallel to the grain and 2 sides perpendicular to it. They need not be placed in any specific part of the sample.

(8) All mortises (Note 20) shall be graded on a scale of 5, as in previous tests, and the comparison of species shall be based on the percentage of No. 3 and better mortises. The defects to be considered in grading the mortises are crushing, tearing, and general smoothness of cut.

Note 20.--In tests with 23 native hardwoods, there showed a measurable variation between species in the difference between the size of the hollow chisel and the size of the mortise made by it. For the customary uses, this difference in size was too small to be significant. For any applications where unusually close tolerances are required, however, it is quite practical to measure small openings with a tapered plug gage.

e. Turning

(1) The lathe shall be a well-made machine of the hand lathe type with a swing over the bed of not less than 12 inches (30 cm.) and with several speeds the maximum being not less than 3,200 revolutions per minute.

(2) It shall be equipped with a compound rest, such as is used in metal turning.

(3) A 1-piece, milled-to-pattern knife, as shown in figures 16 and 17, shall be made, together with a suitable tool holder, to hold this knife in place on the compound rest (Note 21). The knife may be hardened to reduce the amount of sharpening that will be necessary.

> Note 21.--The design of this knife embodies such turning features as the bead and the cove, as well as the ability to cut at different angles to the grain of the turning. The advantage is that it enables the operator to make several hundred rather complicated but uniform turnings in the course of a day's work. Figure 18 shows the knife in operation with a half-completed turning. In this method, the cut is made on the lower side of the test sample instead of at or slightly above the center line, as is customary in hand turning. This necessitates reversing the usual direction of rotation of the test sample. In some belt-driven lathes this can be accomplished by twisting the belt. With some types of motor it can be accomplished by changing the wiring.

(4) Lathe centers, like those shown in figure 18, are desirable if a large number of turnings are to be made. They are made with square recesses 3/8 inch (1 cm.) deep that taper from 13/16 inch (2 cm.) on the entrance end to 5/8 inch (16 mm.) at the bottom. These automatically center the squares and hold them firmly against the thrust of the knife. The tail center at the right is ball bearing.

(5) Each 3/4 by 3/4 by 5 inch-turning sample (2 by 2 by 12.5 cm.) shall be numbered near one end, where the mark will not be machined off.

(6) The position of the knife shall be adjusted to make turnings 3/8 inch thick at the thinnest point, using trial pieces to ensure correct size.

(7) The test shall be made at 3,200 revolutions per minute or as near thereto as possible. One of the 2 turning samples from each board shall be at 6 percent moisture content and the other at 12 percent moisture content.

(8) The test samples shall be graded piece by piece making a record of all defects found on a scale of 5, as in the previous machining operations. Results for both moisture contents shall be averaged and comparisons shall be based on percentage of the two best grades. The common defects of turning are fuzzy grain, roughness, and torn grain.

(9) Comparisons of turning properties shall be based on the proportion of grades Nos. 1, 2, and 3 pieces present.

Figure 19 illustrates typical turning grades from the best to the poorest. In this instance, grades Nos. 2, 3, and 4 are determined by different degrees of fuzzy grain and grade No. 5 by tearouts and a broken corner (Note 22).

> Note 22. --An apparent inconsistency results from basing planing quality on percentage of defect-free pieces, while shaping quality is based on percentage of No. 1 and No. 2 pieces, and turning quality is based on percentage of Nos. 1, 2, and 3 pieces. This was done because those grades or combination of grades best reflected the spread between the best and the poorest of some 20 native hardwood species.

Method of Tests - Particle Board and Hardboard

13. General Considerations

Although particle board and hardboard can be machined with the same equipment used for machining lumber, the following differences should be kept in mind:

Since these panel materials, unlike lumber, are fabricated, their properties can be controlled to a considerable degree by controlling such factors as size and shape of the component particles and fibers, the degree of compression, and the amount of binder. In practice, this means that they are so engineered as to be suitable for the prospective use.

They are often concealed in use. Particle board, for instance, is often used as core stock and faced with veneer, while hardboard is often faced with some plastic overlay. Edges may be covered with metal molding or with solid wood "banding." In such cases, smoothness of finish in the boards is less important than with finish lumber, and a lower quality of surface smoothness is generally adequate.

Particle board and hardboard differ from lumber in their structure. Particle board, as the name suggests, is made of small chips or particles, which often have fairly conspicuous voids between them. It may or may not have a definite "grain" direction depending on the manufacturing process that was used. Hardboard is made of whole-wood fibers and fiber bundles produced by the same processes as mechanical pulps. It is without definite fiber orientation.

14. a. Sawing

(1) A power-feed table saw equipped with a 10-inch crosscut saw with 3 to 4 points per inch shall be used.

(2) The speed shall be 3,600 revolutions per minute, and the feed rate 40 to 50 feet per minute.

(3) The saw shall be adjusted to project approximately 1/4 inch (6 mm.) through the test material.

(4) The saw cuts made in cutting the 2-by 4-foot boards (60 by 120 cm.) into smaller test samples, as in figure 2, shall be used in the grading. Particle board shall be graded for sharp edges and corners free from chipping. Hardboard shall be graded for chipping and fuzzing at the edges and for any tendency to spark during sawing.

(5) For particle boards made by the extrusion process, separate records shall be kept for saw cuts parallel to the extruded direction and for saw cuts perpendicular to it (Note 23).

Note 23.--Particle boards of the extruded type possess a definite orientation of particles and must be machined in two directions, parallel to the extruded direction and perpendicular to it. Dividing the original 2- by 4-foot board (60 by 120 cm.) in the middle and then sawing each half, as shown in figure 2, provides duplicate sets of samples, one set for each direction.

On the other hand, boards of the conventional flat-press type now on the market with random orientation of particles have no such orientation in the plane of the board, and therefore adjacent edges machine alike. This is also true of hardboard. For this reason, half of a flat-press board or of a hardboard cut, as in figure 2, will suffice for the test described here.

b. Planing

(1) A cabinet planer or moulder with knives at a 30-degree cutting angle shall be used (Note 24).

Note 24.-- Much particle board is used for cores in furniture, cabinets, and similar applications in which a smaller thickness tolerance is required than is obtained in particle board as it comes from the press. The object of planing is to provide a more uniform thickness and a surface that will glue readily. For use in cores, the smoothness of the planed surface may be of less importance than for exposed surfaces.

Hardboard is often faced on one side with a plastic laminate for counter tops or imprinted with a wood grain pattern for such uses as television cabinets. For such uses, uniformity of thickness is critical, and hardboard is often planed to obtain the required close tolerance. In most types of hardboard, a wire mesh pattern shows on one side and the planing is done on that side.

(2) The test material shall consist of samples 6 inches by 2 feet (15 by 60 cm.) cut as shown in figure 2.

(3) The feed rate and cutterhead speed shall be adjusted to give 20 knife cuts per inch.

(4) The depth of cut shall be 1/16 inch (2 mm.).

(5) The planed surface shall be examined and graded for smoothness of cut and the results recorded.

(6) For particle boards made by an extrusion process, separate records shall be kept for cuts parallel to the extruded direction and for cuts perpendicular to it.

c. Sanding

(1) A 3-drum sander of either the roll-feed or the endless bed type shall be used.

(2) The garnet grit paper used on the 3 drums beginning at the infeed end shall be, respectively, No. 1, No. 1/2, and No. 1/0.

(3) The test material shall consist of samples 6 inches by 2 feet (15 by 60 cm.), cut as shown in figure 2.

(4) The drum speed on the first 2 drums at the infeed end of the sander shall be 1,200 revolutions per minute and at the third drum 1,800 revolutions per minute.

(5) The depth of cut shall be 1/16 inch (2 mm.).

(6) The feed rate shall be 12 to 24 feet per minute (4 to 7 m.).

(7) The sanded surface shall be examined and graded for smoothness of surface and the results recorded (Note 25).

Note 25.--Sanding is another method frequently used to bring particle board and hardboard to close thickness tolerance. Many types of particle board are presanded at the origin before shipment. Sanding produces a smoother surface than planing because it avoids the tear-outs often found in planed surfaces, particularly when planing across the grain. Neither planing nor sanding removes the voids that occur throughout the thickness of many particle boards. The sanding of hardboard is typically done on the mesh side and produces a smoother surface than planing, because it avoids knife marks.

(8) For boards made by an extrusion process, separate records shall be kept for cuts parallel to the extruded direction and for cuts perpendicular to it.

d. Shaping

(1) The machine shall be a spindle shaper operated at not less than 7,200 revolutions per minute.

(2) The knife pattern may be either in quarter round or, in the case of particle board, a standard flooring tongue as desired, see Nos. 2 and 3 in figure 12.

(3) The test material shall consist of 3-inch by 2-foot strips (7.5 by 60 cm.) cut as shown in figure 2.

(4) A preliminary roughing cut shall be made with particle board to remove most of the excess material where the cut is deepest.

(5) The final cut shall be 1/16 inch (2 mm.) deep.

(6) The cut shall be a straight line cut for the full length of the test sample. A guide or fence of the conventional type shall be used when cutting.

(7) The shaped surface shall be examined and graded for smoothness of cut, chipping, and fuzzing, and the results recorded (Note 26).

Note 26.--Although corners and edges of particle board are not customarily exposed in use, they are sometimes shaped to receive metal fittings or for other reasons. When hardboard edges are exposed in use, they are often shaped with a quarter-round or half-round pattern.

(8) For boards made by an extrusion process, separate records shall be kept for cuts parallel to the extruded direction and for cuts perpendicular to it.

e. Routing

(1) A high speed router shall be used, preferably of the stationary type.

(2) The bit shall be the standard 1/4-inch (6 mm.) single-fluted type without spiral as No. 4 in figure 11.

(3) The test material shall consist of 3-inch by 2-foot strips (7.5 by 60 cm.), cut as shown in figure 2.

(4) The speed shall be 15,000 to 20,000 revolutions per minute.

(5) A groove 1/4 inch wide by 3/8 inch deep (6 by 10 mm.) for particle board and 1/8 inch (3 mm.) deep for hardboard shall be cut at 1/4 inch (6 mm.) from the edge of the strips.

(6) The groove shall be a straight line cut for the full length of the test sample. A guide or fence of the conventional type shall be used when cutting.

(7) The groove shall be examined and graded for breakouts, sharp corners, chipping, fuzzy edges, and general smoothness of cut.

(8) For particle boards made by the extrusion process, separate records shall be kept for cuts parallel to the extruded direction and cuts perpendicular to it.

f. Drilling

(1) The test shall preferably be made with a single-spindle electric machine equipped with power feed.

(2) A 3/8-inch (1 cm.) twist drill with a 120-degree point shall be used.

(3) The test material shall consist of five 3-inch by 2-foot strips (7.5 by 60 cm.) cut as shown in figure 2.

(4) In particle board, a series of 5 holes 1 inch (2.5 cm.) deep shall be drilled in the center of the edge of each sample.

(5) In hardboard, the holes shall be drilled through each sample at 1/4 inch (6 mm.) from the edge into a hardwood backing.

(6) The spindle speed shall be 3,600 revolutions per minute.

(7) The holes shall be examined and graded for chipping, fuzzing, thickening of the edges, and general smoothness of cut.

(8) For particle board made by the extrusion process, separate records shall be kept for holes bored parallel to the grain and for holes bored perpendicular to it.

Appendix A

Definitions and Descriptions of Terms

1. Lumber -- Lumber is the product of the saw and planing mill not further manufactured than by sawing, resawing, passing lengthwise through a standard planing machine, crosscutting to length, and matching.

2. Particle board -- Particle board is a panel material composed of small discrete pieces of wood or other ligno-cellulosic materials that are bonded together in the presence of heat and pressure by a synthetic resin adhesive. Particle boards are further defined by the method of pressing. When the pressure is applied in the direction perpendicular to the faces, as in a conventional multi-platen hot press, they are defined as flat-platen pressed, and when the applied pressure is parallel to the faces, they are defined as extruded.

3. Hardboard -- Hardboard is a fibrous-felted homogeneous or laminated panel having a density range of approximately 50 to 80 pounds per cubic foot, manufactured under carefully controlled optimum combinations of consolidating pressure, heat, and moisture so that a softening of lignin occurs, and the board produced has a characteristic natural ligneous bond.

4. Annual rings -- Annual rings consist of the annual growth layer, as viewed on a cross section of a stem, branch, or root. The growth layer is put on in a single growth year and includes springwood and summerwood.

5. Edge-grained lumber -- Lumber that has been sawed so that the wide surfaces extend approximately at right angles to the annual growth rings. Lumber is considered edge-grained when the rings form an angle of 45° to 90° with the wide surface of the piece. Vertical-grained and quartersawed lumber are other terms for edge-grained lumber.

6. Flat-grain and slash grain lumber -- This is lumber that has been sawed in a plane approximately perpendicular to a radius of the log. Lumber is considered flat-grained when the annual growth rings make an angle of less than 45° with the surface of the piece.

7. Hardwoods -- Hardwoods are generally one of the botanical groups of trees that have broad-leaves in contrast to the conifers. The term has no reference to the actual hardness of the wood.

8. Softwoods -- Softwoods are generally one of the botanical groups of trees that, in most cases, have needle or scale-like leaves; also the wood produced

by such trees. The term has no reference to the actual hardness of the wood.

9. Cutterhead speed -- Cutterhead speed is the rate measured in revolutions per minute at which a cutterhead is turning.

10. Rim speed -- Rim speed is the rate measured in feet per minute at which the periphery of a cutting tool (usually a saw) is turning.

11. Feed rate -- Feed rate is the rate measured in feet per minute at which material is passing through a machine.

12. Cutting angle -- See figure 14 and explanation in text.

13. Cutting bevel -- See figure 14 and explanation in text.

14. Clearance angle -- See figure 14 and explanation in text.

15. Cutting circle -- See figure 14 and explanation in text.

16. Raised grain -- Raised grain is a roughened condition of the surface of lumber in which the hard summerwood is raised above the soft springwood but not torn loose from it.

17. Torn grain -- Torn grain is that part of the wood torn out in dressing.

18. Fuzzy grain -- Fuzzy grain consists of small particles or groups of fibers that did not sever clearly in machining but stand up above the general level of the surface.

19. Chip marks -- Chip marks are shallow dents in the surface caused by shavings that have clung to the knives instead of passing off in the exhaust as intended.

20. Jointing -- Jointing in planing consists of equalizing the projection of all the knives in the cutterhead. It is performed by bringing a sharpening stone into contact with the knife edges while the cutterhead revolves.

21. Land -- Land (or heel) is the part of the cutting edges of the knives that comes in contact with the sharpening stone in the jointing operation. The land conforms to the cutting circle and has no clearance.

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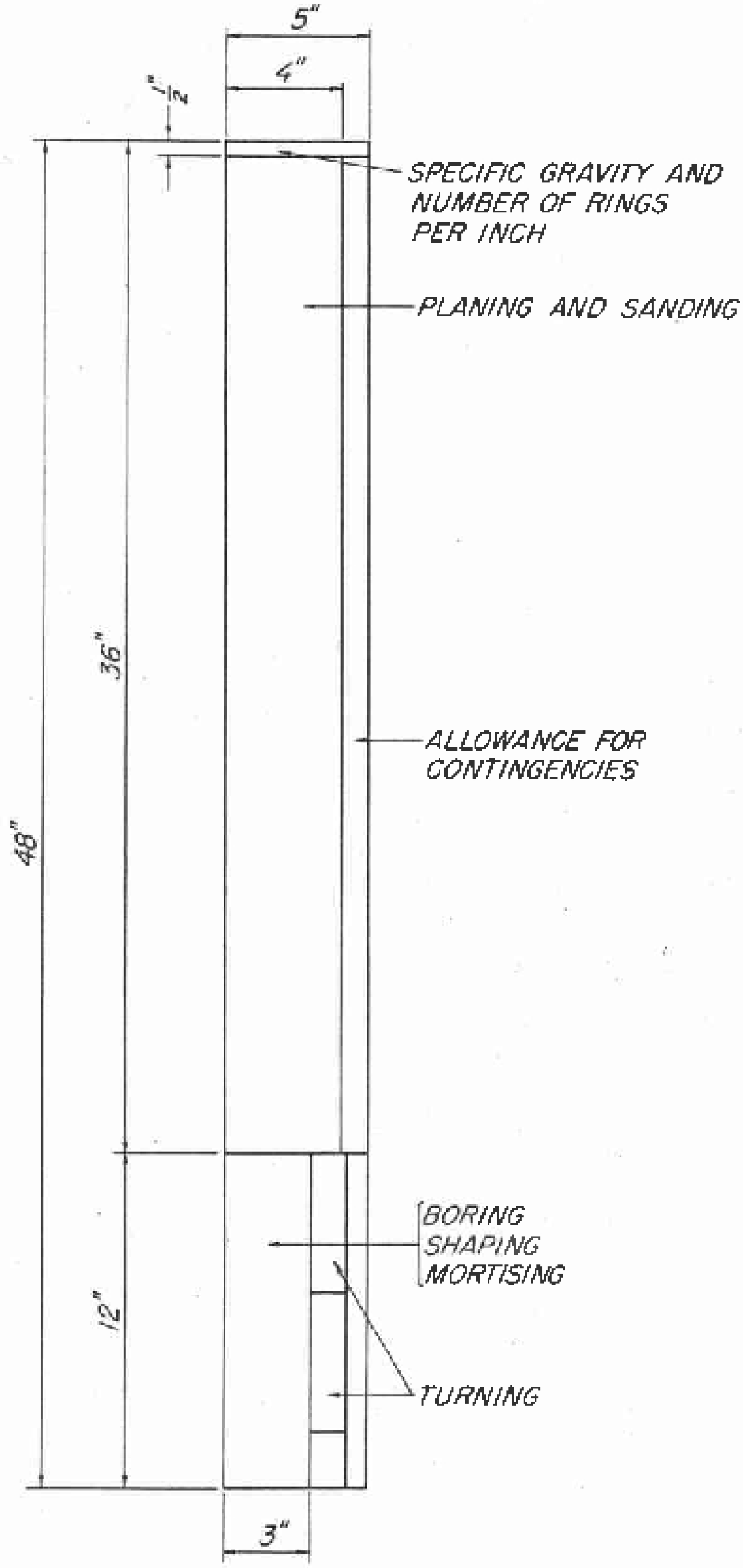

Figure 1. --Diagram for sawing lumber samples into smaller samples for individual tests.

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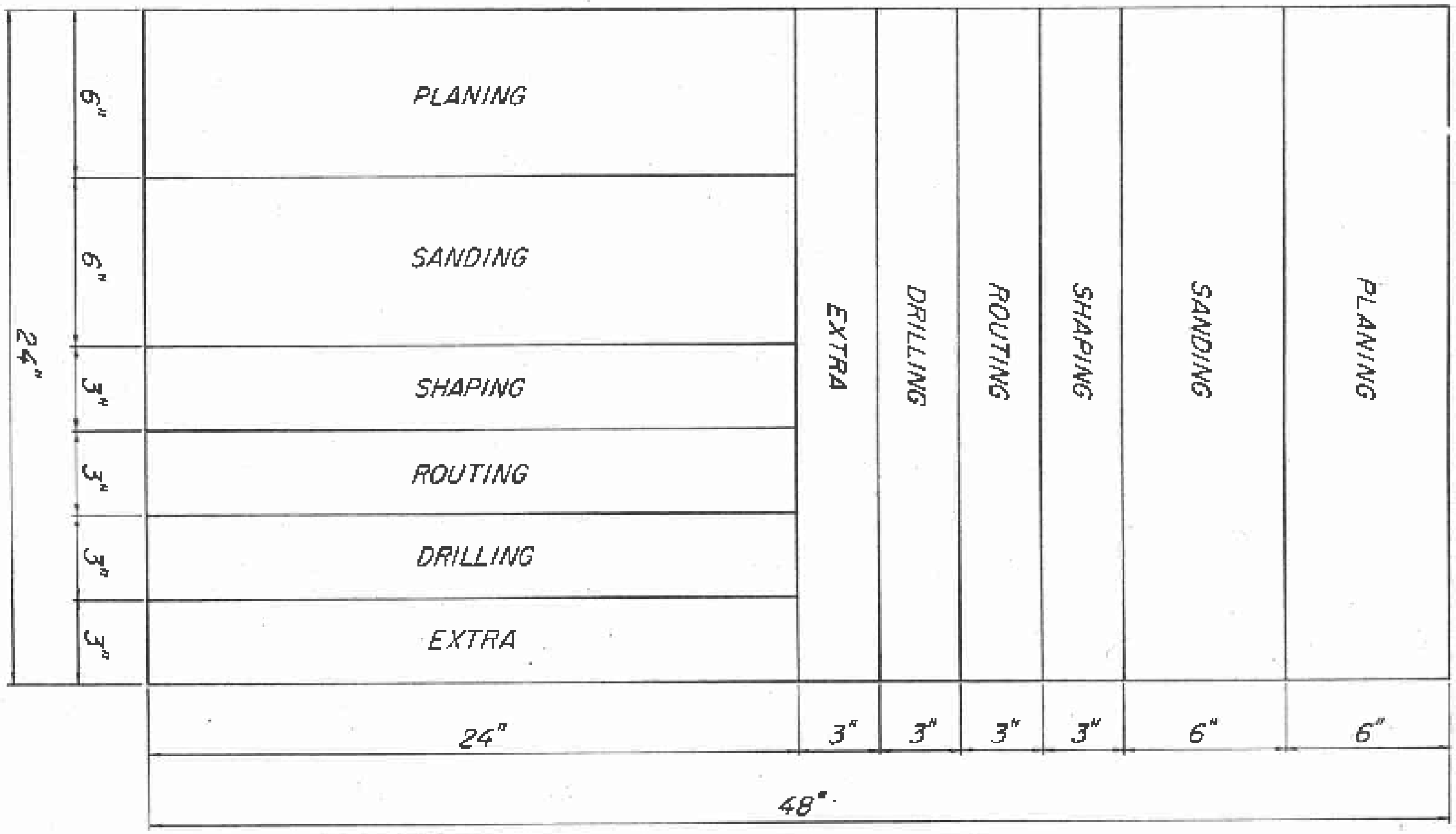

Figure 2. --Diagram for sawing hardboard and particle board samples into smaller samples for individual tests.

M 112 519

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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									
AV.	76%									

Figure 3.--Sample data sheet used in planing test. This form may be modified for use in other tests. The numbers in the columns refer to the grade of the specific defect under consideration.

M 113 161

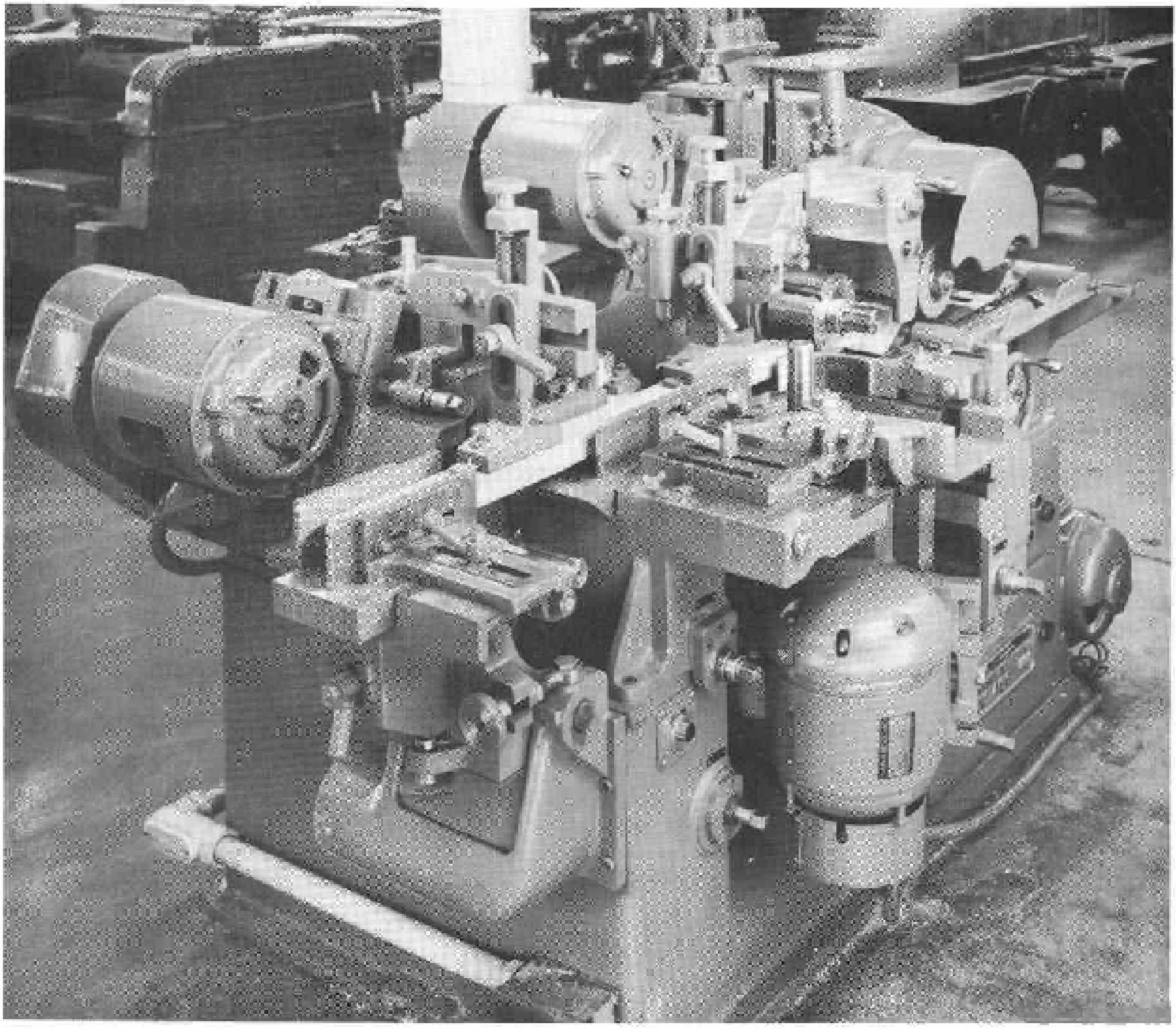

Figure 4.--A desirable type of machine for use in planing tests. This moulder offers a much wider range of cutterhead speeds and feed rates than does the typical planer. The slip-on heads are easy to change as desired. Moulders come with 4 and sometimes 5 cutterheads to permit machining 4 sides with one pass. In planing tests, however, only one cutterhead is used, the tophead equipped with straight heads, as shown here.

ZM 95290 F

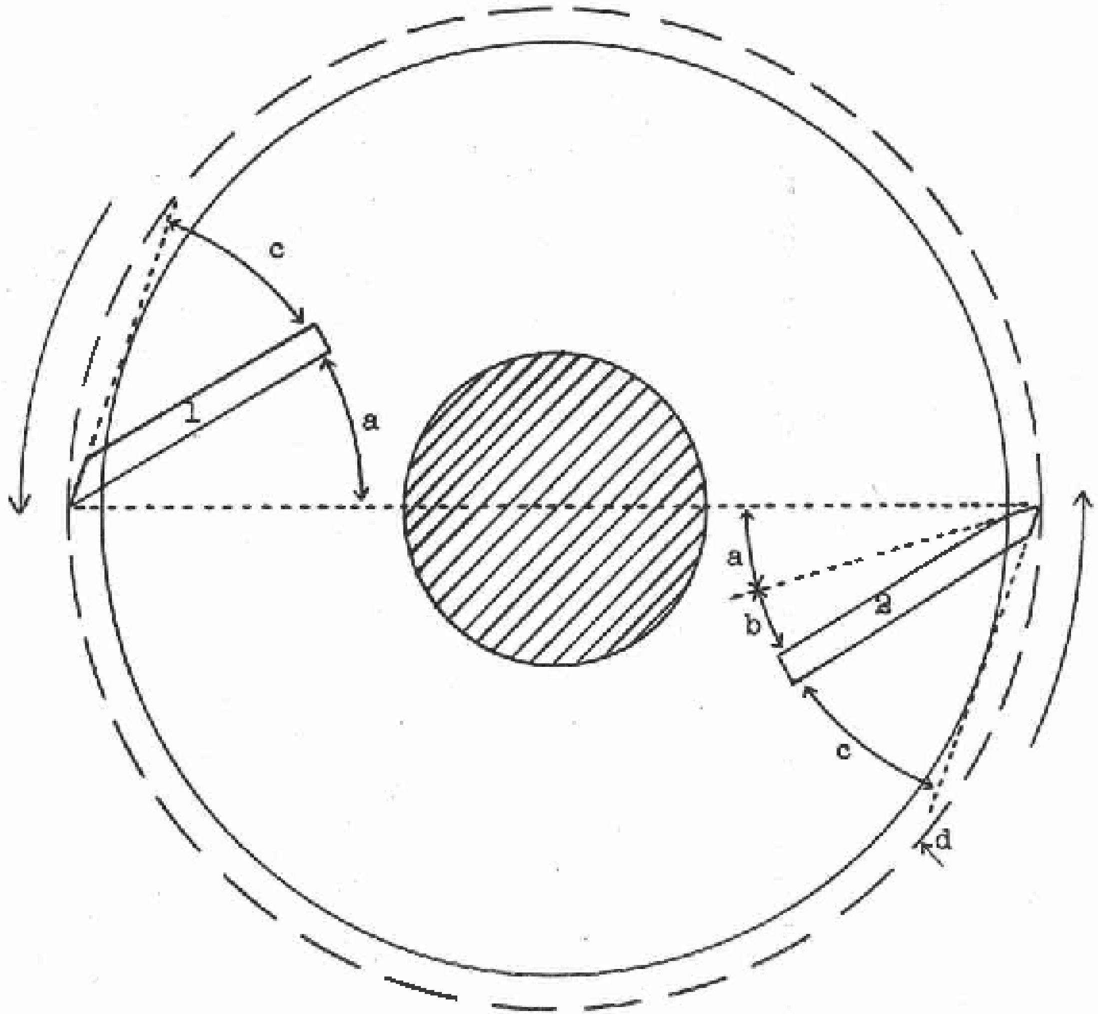

Figure 5.--Terms used in connection with planer knives: _a_, cutting angle; _b_, cutting bevel; _c_, clearance bevel; and _d_, cutting circle.

M 34155 F

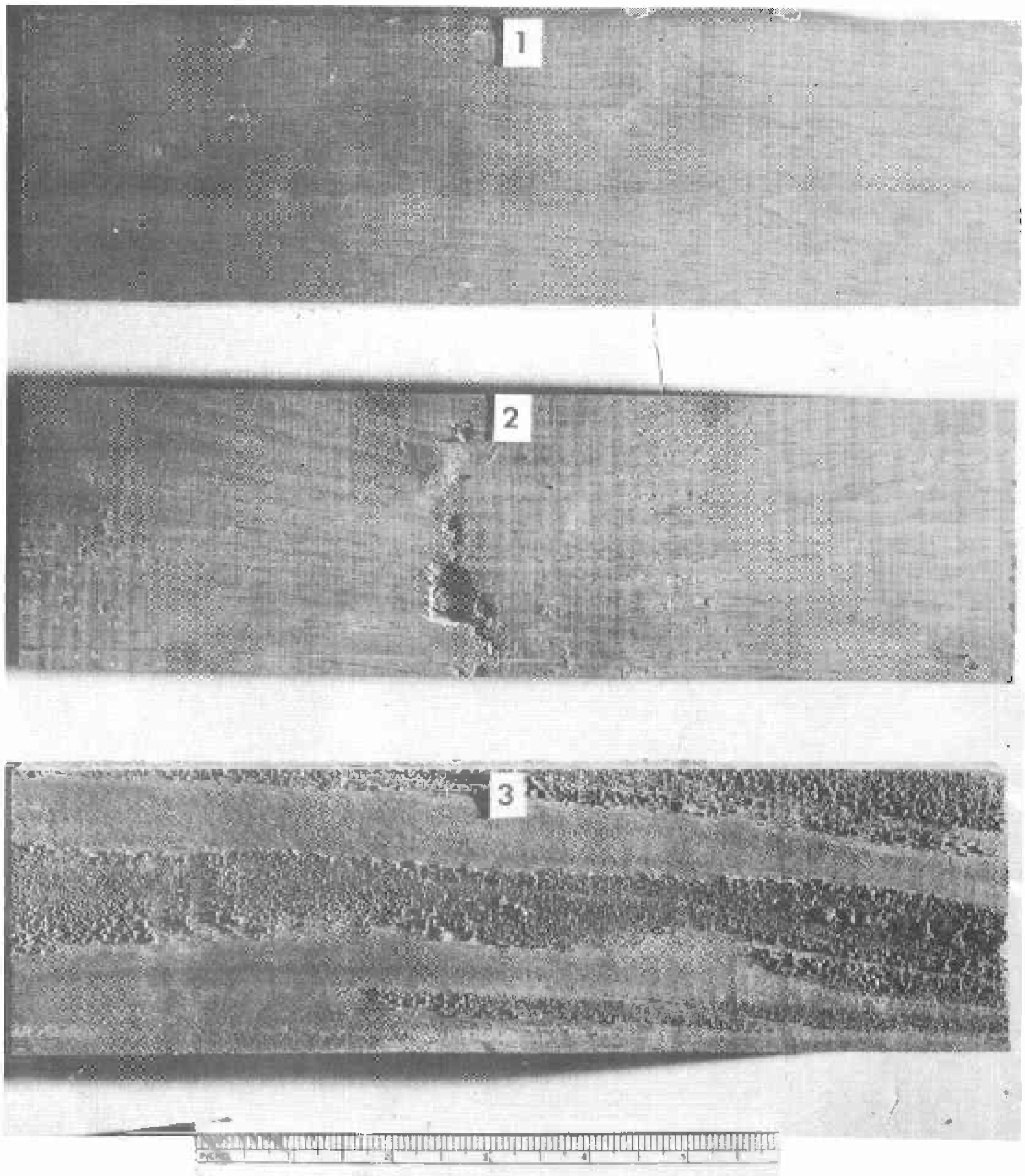

Figure 6.--Planing grades Nos. 1 and 5, Sample 1, black walnut grade No. 1; sample 2, black walnut grade No. 5; and sample 3, mahogany grade No. 5.

ZM 112 573

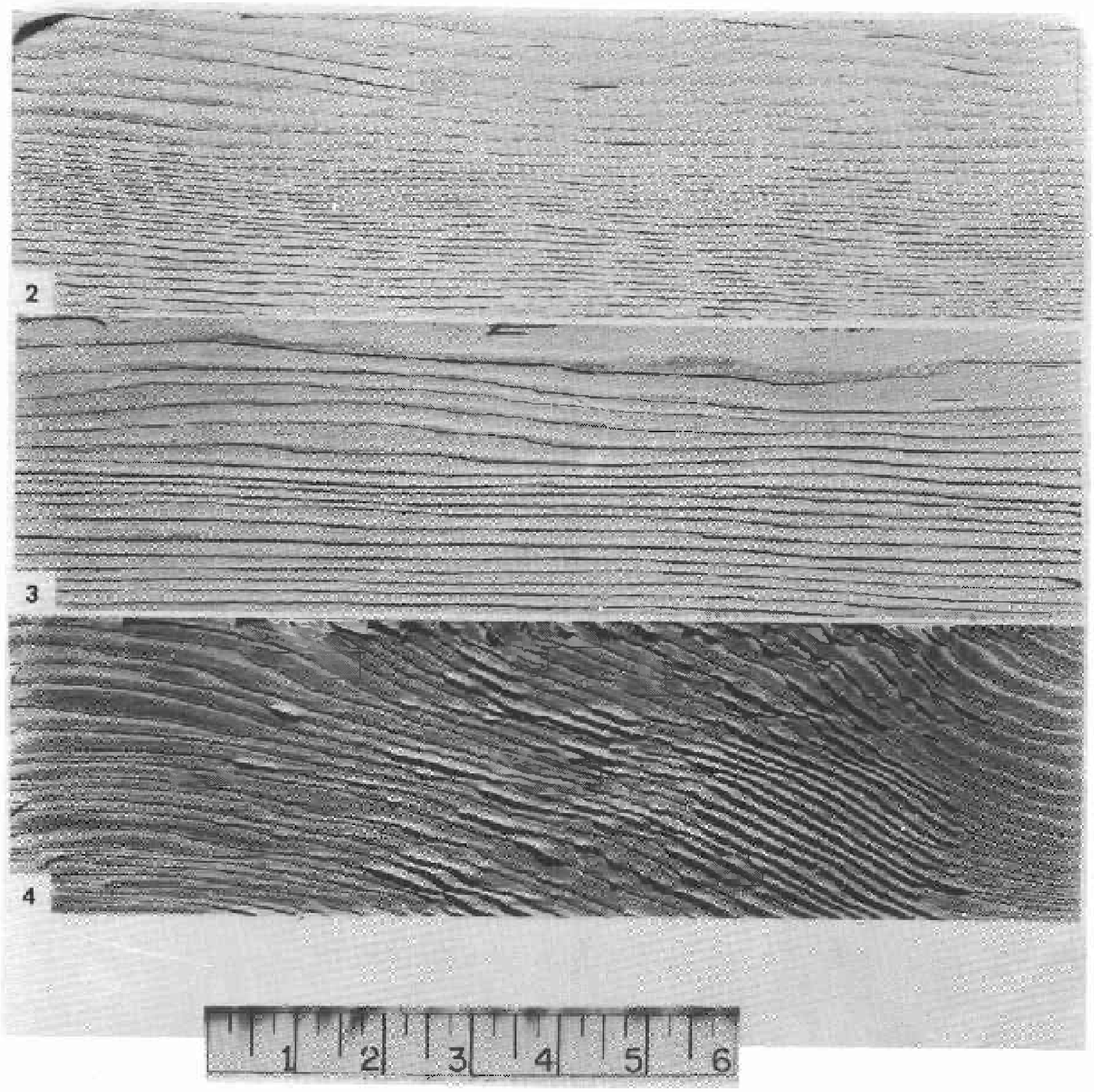

Figure 7.--Raised grain in Douglas-fir, grades Nos. 2, 3, and 4.

ZM 93418 F

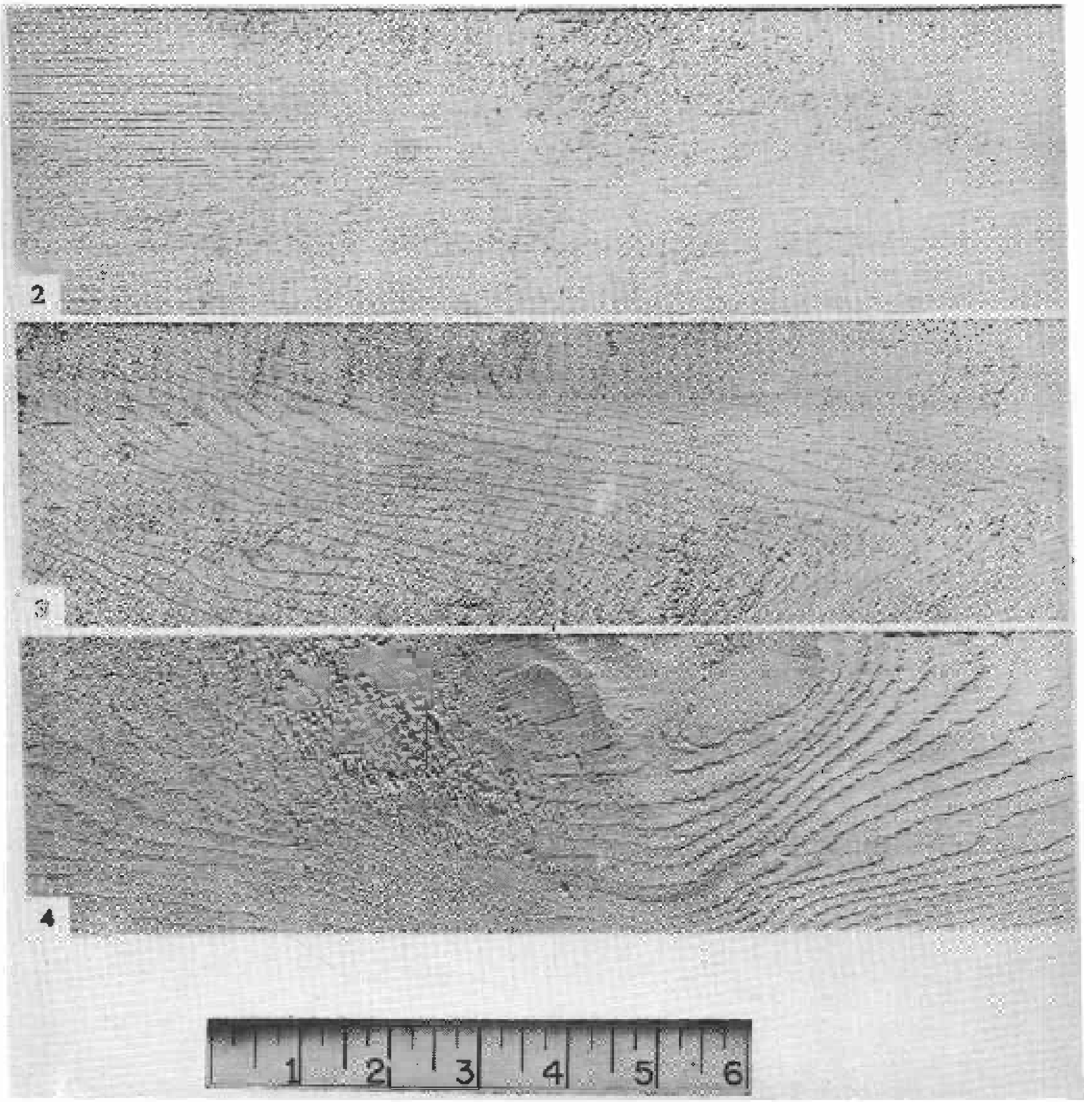

Figure 8.--Fuzzy grain in Engelmann spruce, grades Nos. 2, 3, and 4.

ZM 93421 F

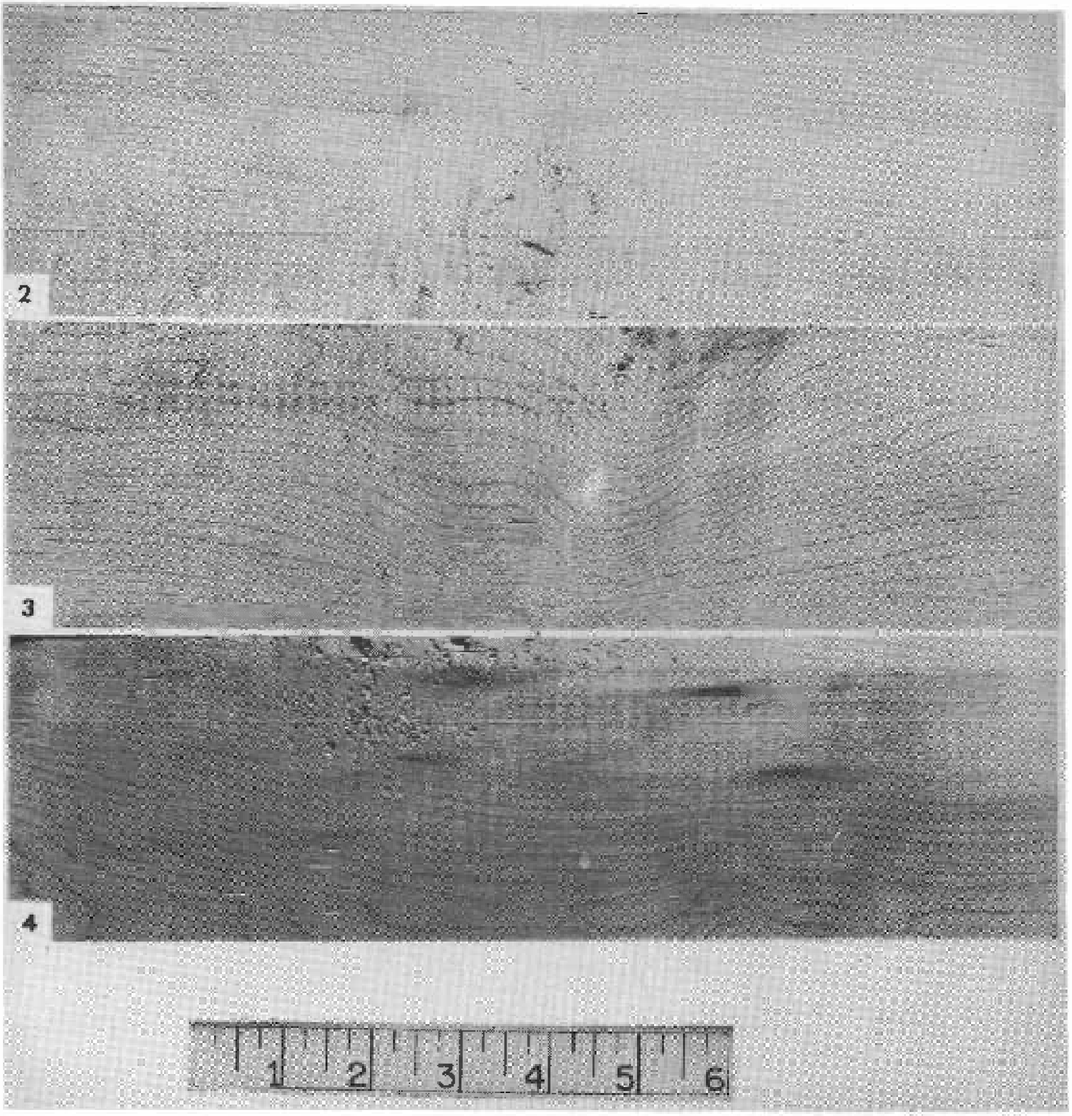

Figure 9.--Torn grain in hard maple, grades Nos. 2, 3, and 4.

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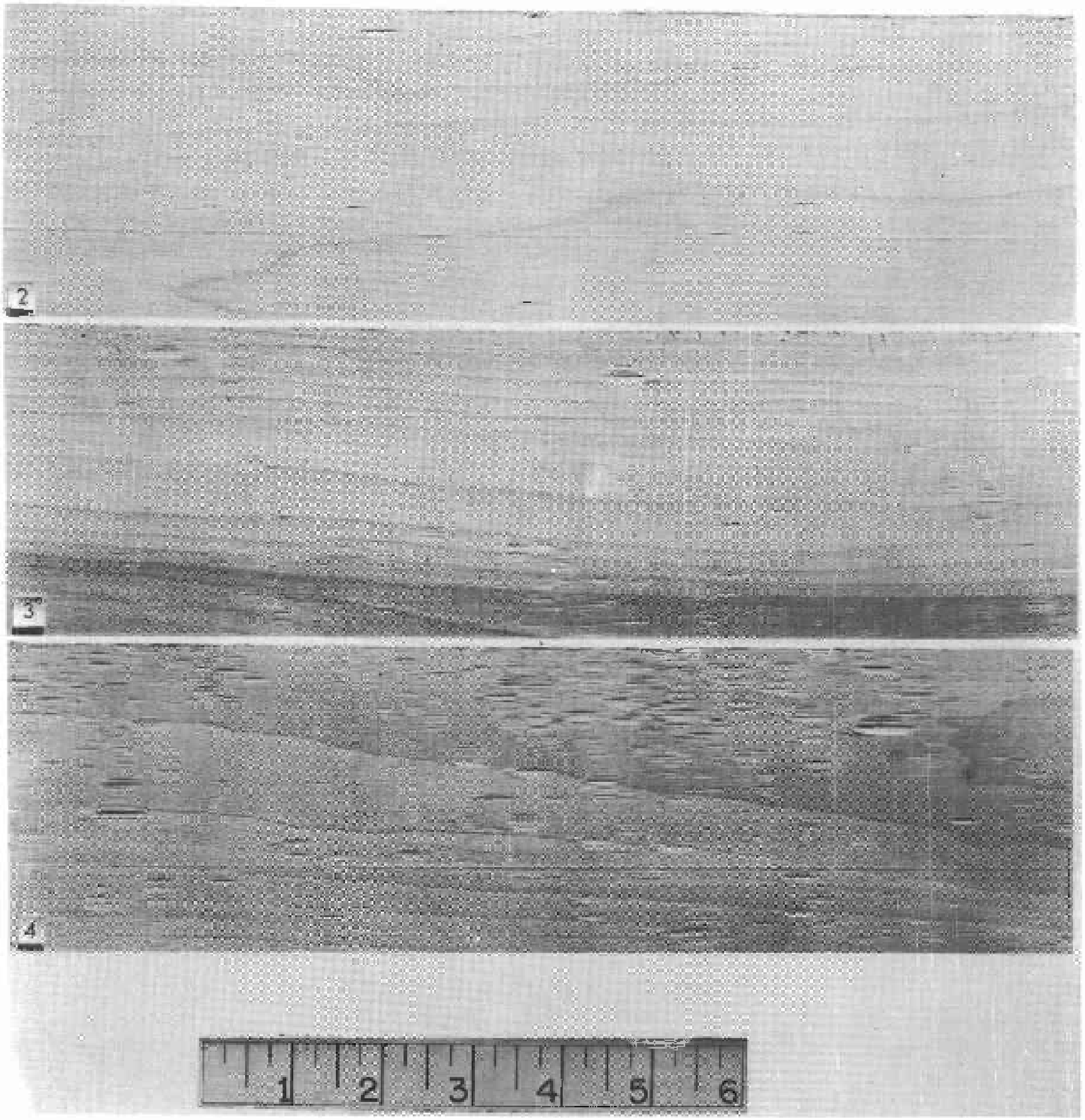


Figure 10.--Chip marks in yellow-poplar, grades Nos. 2, 3, and 4.

ZM 93419 F

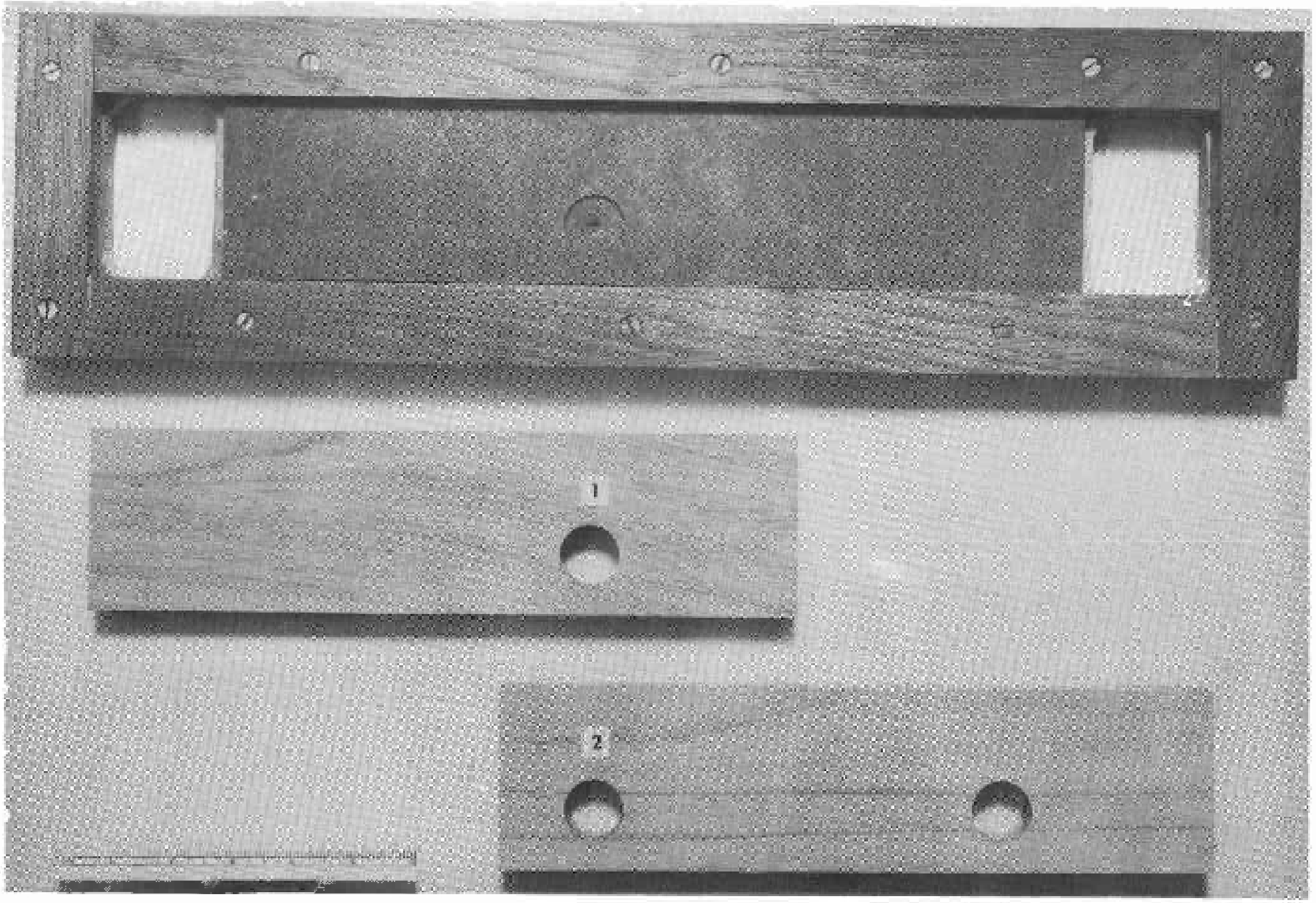


Figure 11.--A type of boring jig to ensure that holes in all samples are spaced accurately and uniformly. The jig remains stationary. Hole No. 1 was bored with the sample at the extreme left end of the recess in the top of the jig. Hole No. 2 was bored after sliding the sample to the extreme right end of the jig.

ZM 112 516

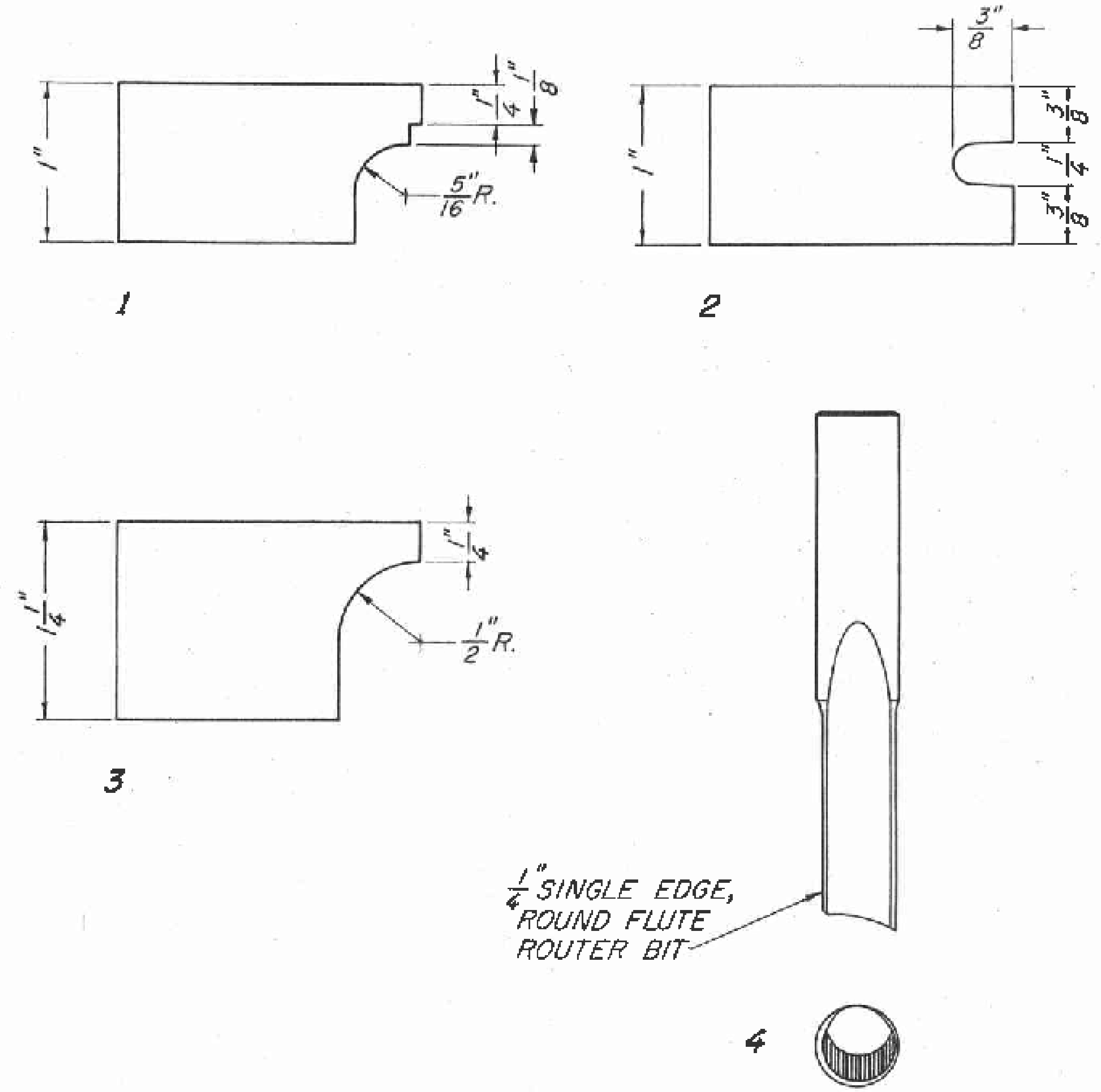


Figure 12.--Cutting tools used in certain machining tests. (1) Shaper knife used in cutting a pattern on the edge of lumber test-samples. (2) Shaper knife used in cutting a tongue (for banding) on the edge of particle board test-samples. (3) Shaper knife used in cutting quarter-round pattern on the edge of particle board test-samples. (4) Type of bit used in routing tests with hardboard and particle board.

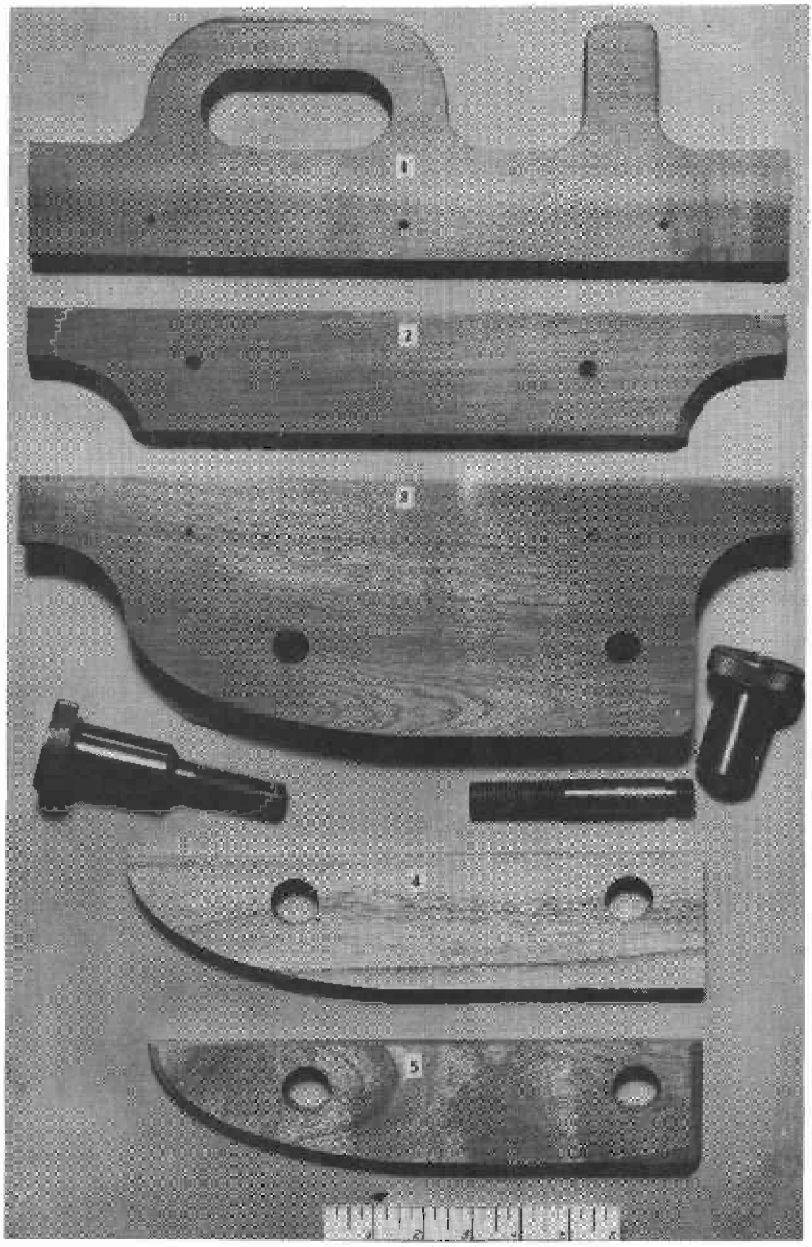


Figure 13.--Type of jig (disassembled) used in shaping test. Board No. 1 serves as a handle for guiding the jig past the cutterhead; No. 2 provides a backing during the cutting operation; No. 3 serves as the base; No. 4 is a test sample that has been band sawed; and No. 5 is a test sample that has been both band sawed and shaped.

ZM 112 572

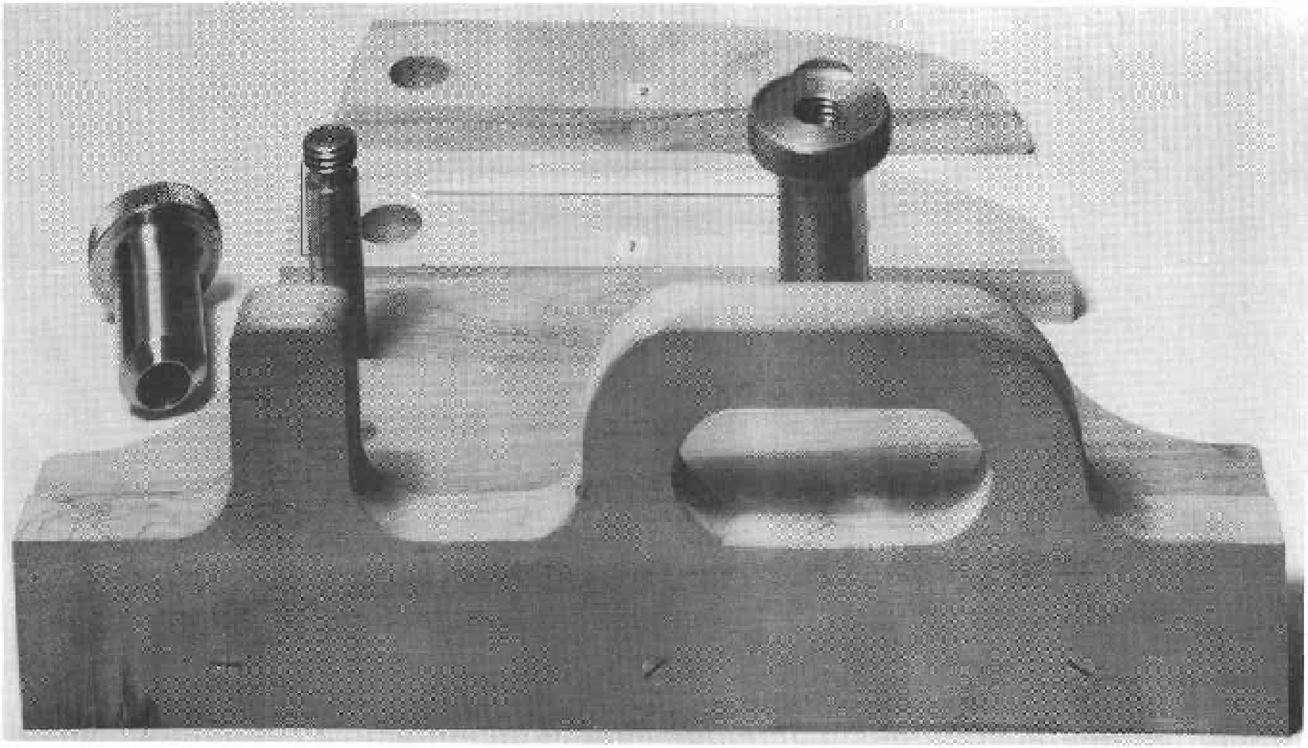


Figure 14.--Type of jig (assembled) used in shaping test. Test sample No. 1 has been band sawed, and sample No. 2 has been both band sawed and shaped.

ZM 112 517

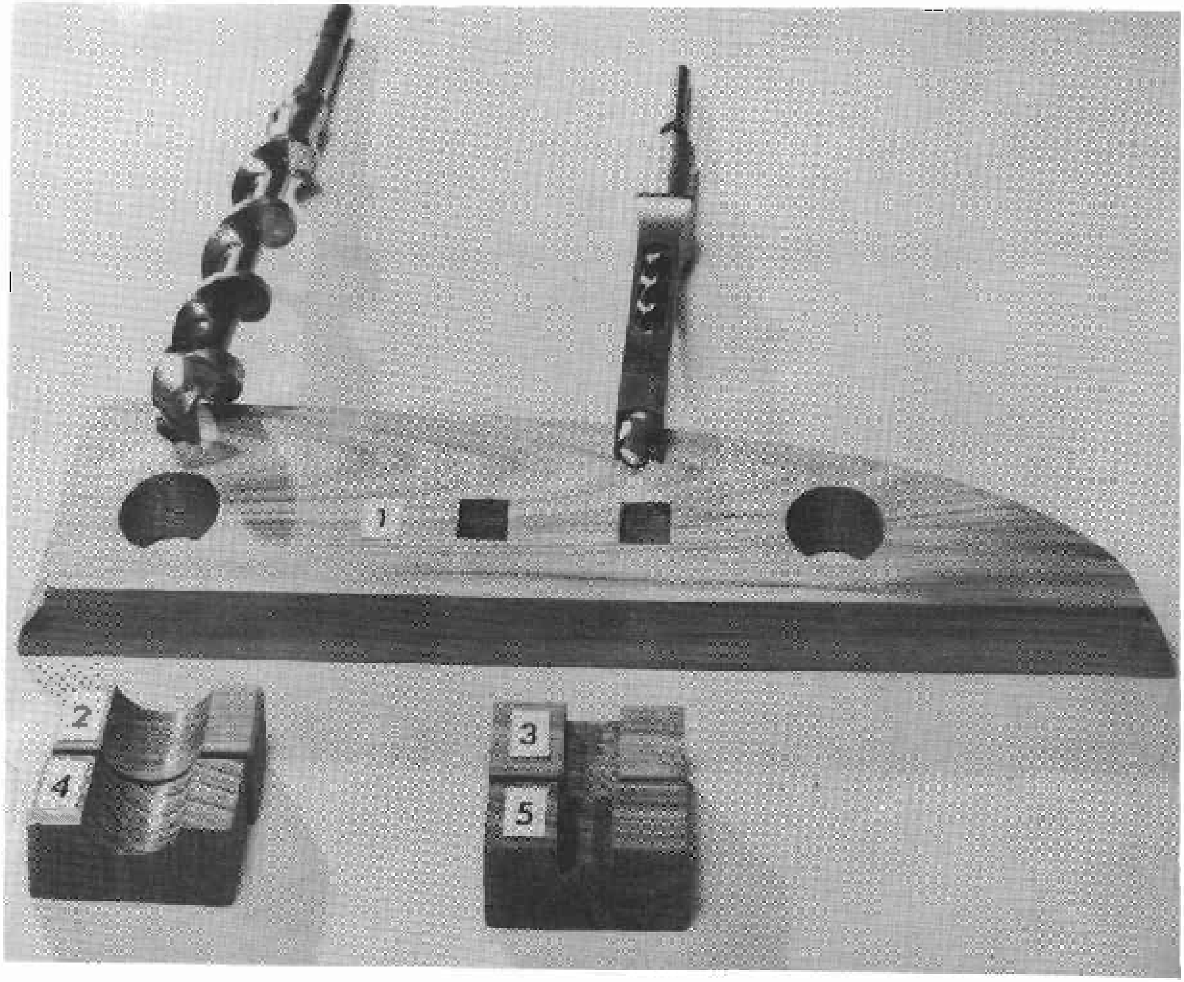


Figure 15.--The No. 1 test sample has already been shaped, bored, and mortised. The 1-inch bit and the 1/2-inch hollow chisel used in the boring and mortising tests are shown, together with views of the inside of the cuts made by these tools. Nos. 2 and 3 are side-grain cuts, while Nos. 4 and 5 are end-grain cuts.

ZM 112 635

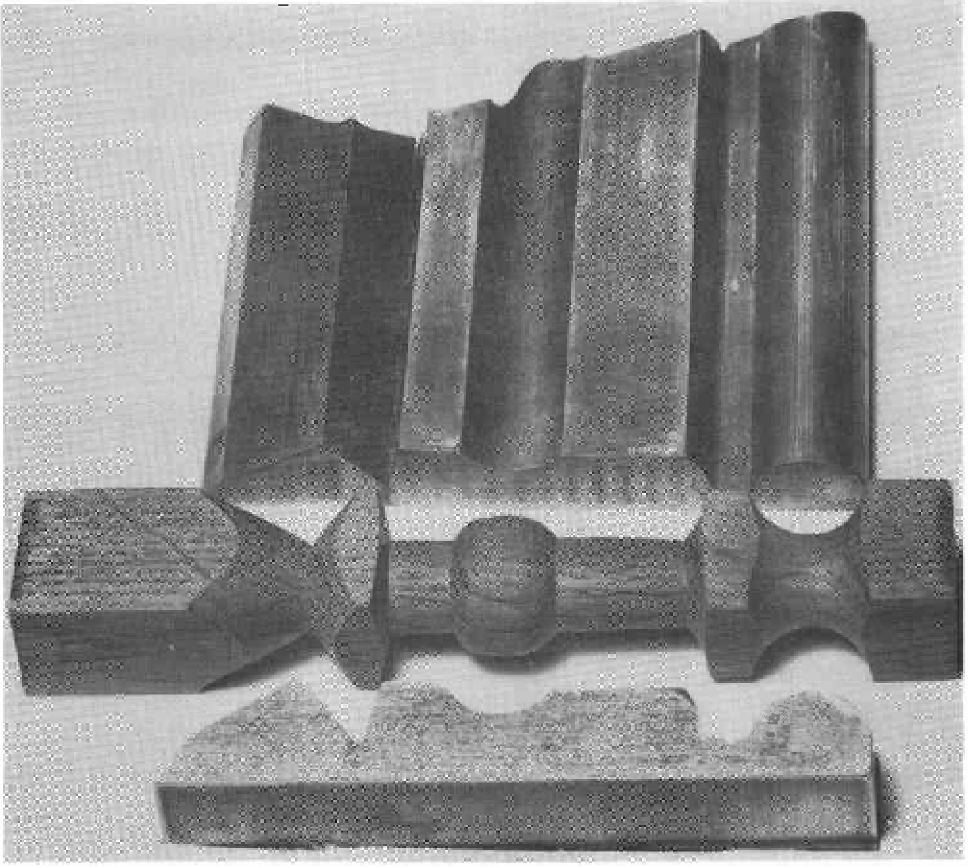
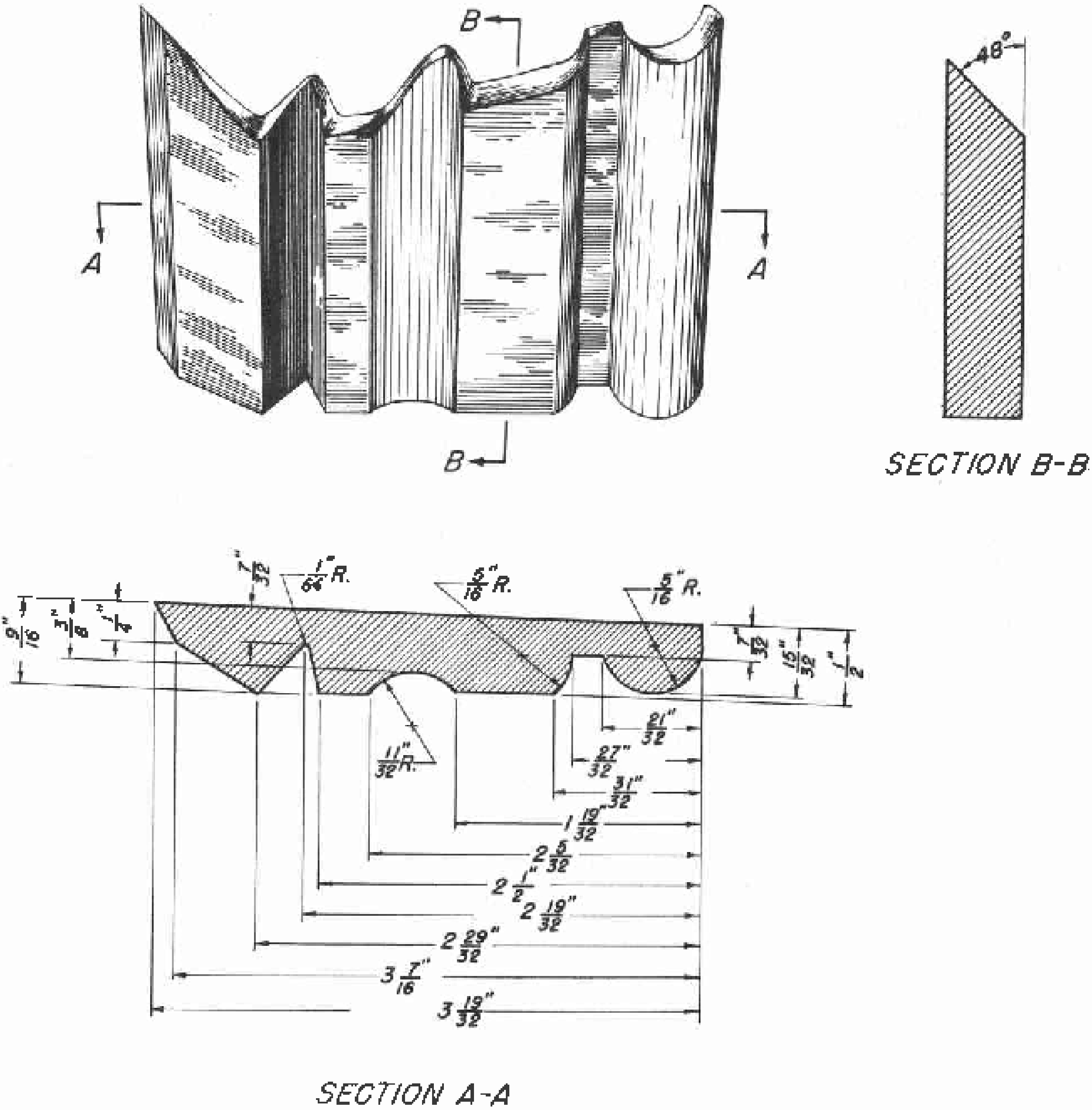


Figure 16.--At the top is a type of 1-piece knife used in the turning test; at the bottom, a cross-section view of a knife; and in the center, a finished turning in oak.

ZM 112 636



Z M 113 162

Figure 17.--Diagram of one-piece turning knife. Top left, general view of knife. A-A, cross section of the knife showing radii and angles. B-B, cross section showing cutting bevel.

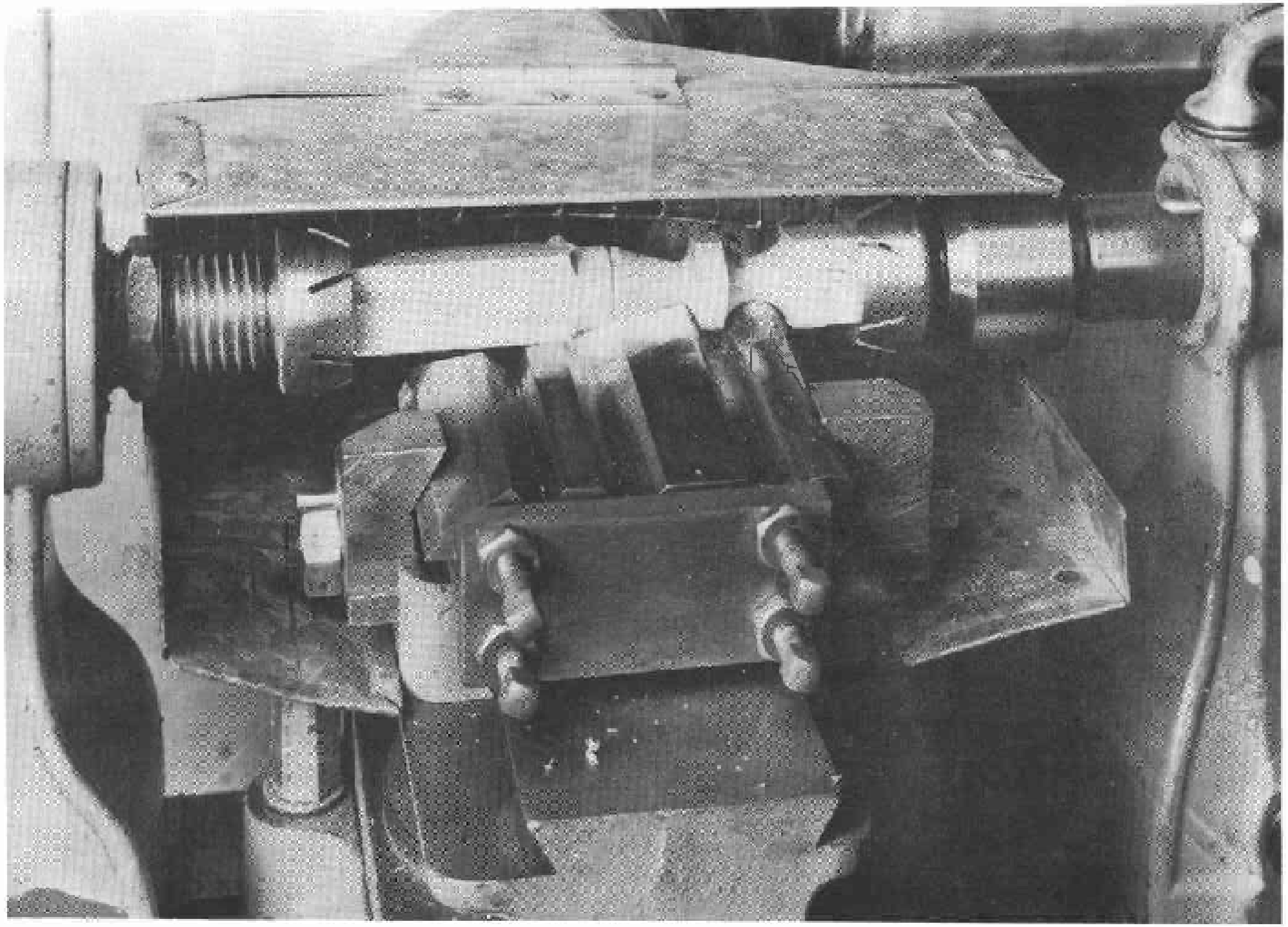


Figure 18.--One-piece knife mounted in the compound rest with a partly completed turning. The special lathe centers are shown, together with an optional exhaust system for carrying away the chips.

ZM 25702 F

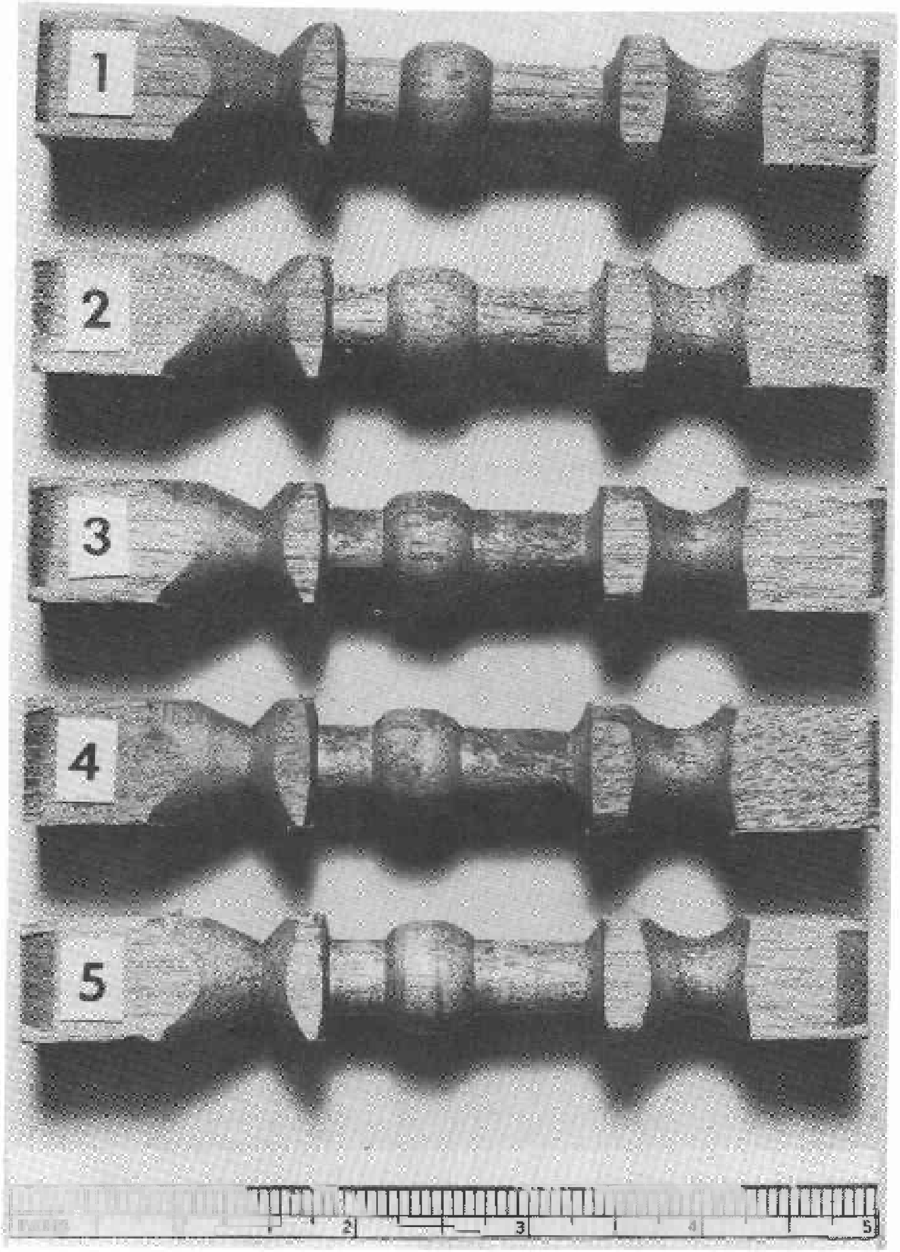


Figure 19.--Grades of turnings. Each number shows the grade of the turning under consideration.

ZM 112 571

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List of publications on Growth, Structure, and Identification of Wood

List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products

Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen

List of publications on Fire Protection

List of publications on Logging, Milling, and Utilization of Timber Products

List of publications on Pulp and Paper

List of publications on Seasoning of Wood

List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components

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List of publications on Wood Preservation

Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

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