United States
Department
of Agriculture

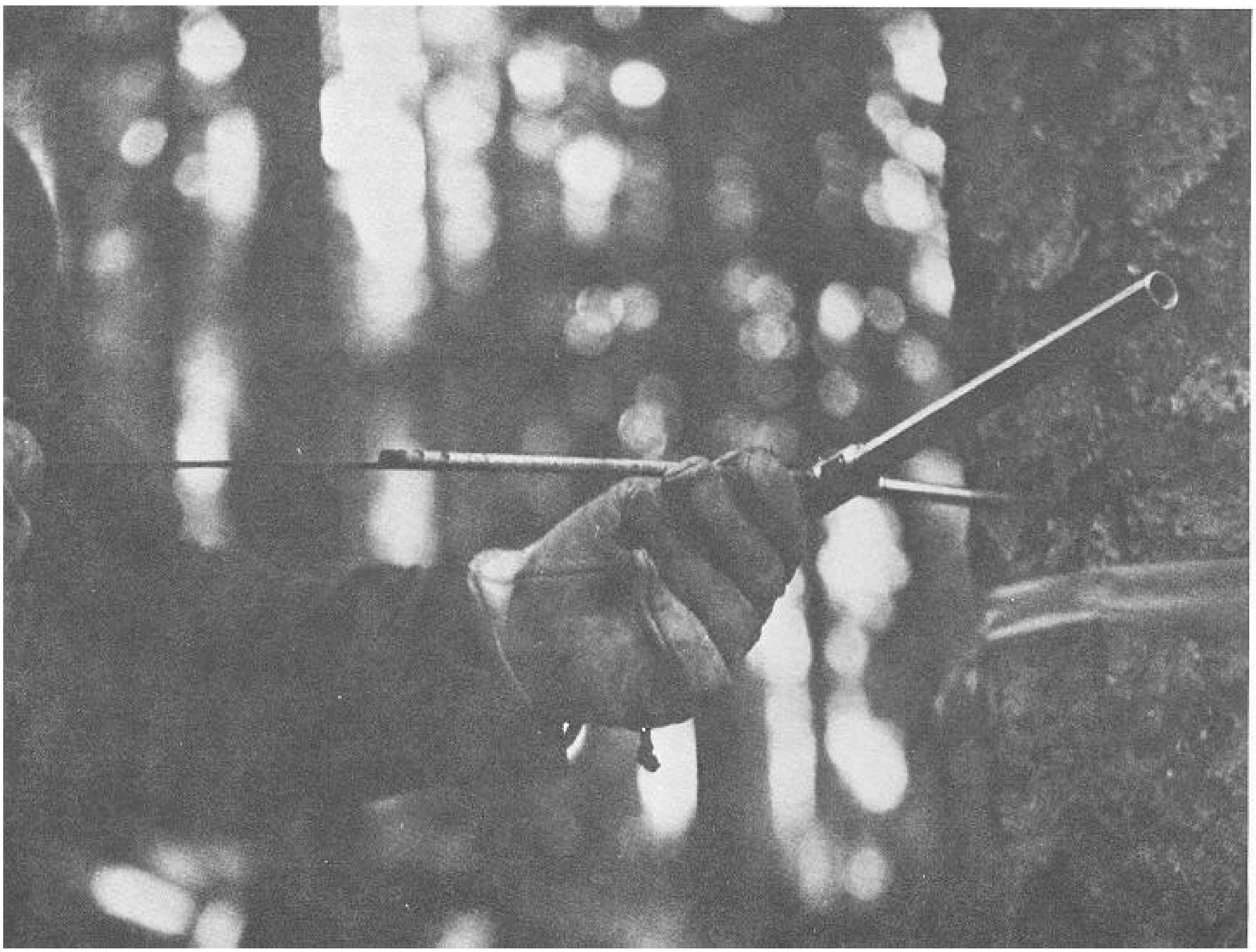
FOREST SERVICE

Forest
Products
Laboratory

General
Technical
Report
FPL 25

1979

INCREMENT CORES
How to Collect, Handle, and Use Them



Abstract

This paper describes increment cores (a useful tool in forestry and wood technology) and their uses which include age determination, growth increment, specific gravity determination, fiber length measurements, fibril angle measurements, cell measurements, and pathological investigations. Also described is the use and care of the increment borer which is essential in obtaining good cores. A caution is also given as to the tree damage that boring can cause, with suggestions for minimizing damage.

Table of Contents

United States Department. of Agriculture
FOREST SERVICE
Forest Products Laboratory[1]
General Technical Report FPL 25
1979

INCREMENT CORES
How to Collect, Handle, and Use Them

By
ROBERT R. MAEGLIN,
Technologist

Introduction

Increment cores (a useful tool in forestry and wood technology) are pencil-like pieces of wood usually extracted perpendicular to the long axis of a tree. They are used to determine the ages and growth rates of trees, for evaluation of wood properties, decay detection, to determine preservative penetration in poles and ties, and many other uses. Cores are cut and removed using an increment borer which is an essential tool in obtaining cores.

The Increment Borer

Increment borers, also known as Pressler borers or Swedish-increment borers, are available commercially in various lengths from 57 mm (2.25 in.) to 508 mm (20 in.) and in various diameters from 3.8 mm (0.150 in.) to 12 mm (0.472 in.). Increment borers are available through forestry and agricultural supply houses.*

The collection of good increment cores from trees, poles, or ties depends mainly on the condition of the increment borer. As with other cutting tools, the increment borer must be well sharpened to perform suitably. The people who have trouble getting good increment cores (they get rough and broken cores and then only with difficulty) don't properly maintain their borers.

Basically two things are necessary for proper care of borers: (1) keep them sharp, and (2) keep them clean.

Sharpening

A well-sharpened borer will, if properly used, cut numerous cores before resharpening is required. The number of cores depends on the density of the wood being bored. High-density woods such as oak, hickory, and Pacific yew will dull the borer sooner than will lower-density woods such as spruce, fir, and aspen.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
[2] A list of supply sources can be found in the appendix Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product by the U.S Department of Agriculture.

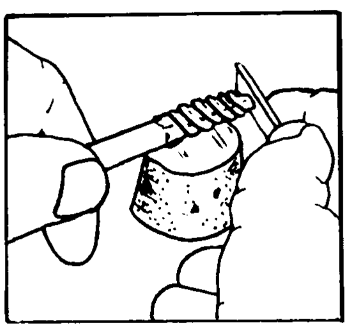
An increment borer needs sharpening when it does not easily engage the wood, cuts a rough core, or if the edge feels dull when the bit is touched lightly to the finger. Don't assume a new borer is sharp.

Techniques are available for hand-sharpening dull borers, as well as professional sharpening services through dealers.

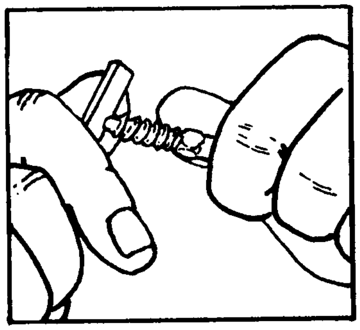
A simple technique developed by Bauck and Brown (1955) and modified here, requires two sharpening stones, some lightweight oil, and a cork. The stones required are a 102 mm (4 in.) flat, tapered, fine, India stone; and a 76 mm (3 in.) conical tapered, engraver's point stone.

The four steps used in borer sharpening are in the following order.

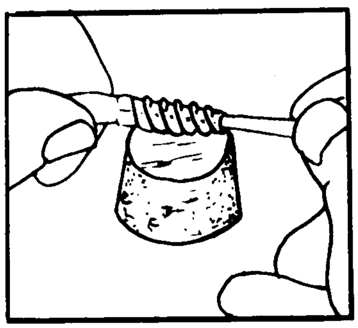
1. True (or make perpendicular) the cutting edge with the long axis of the borer using the flat India stone. Pass the stone over the cutting edge lightly, rotating the bit slightly at each pass. Use the cork as a work rest.



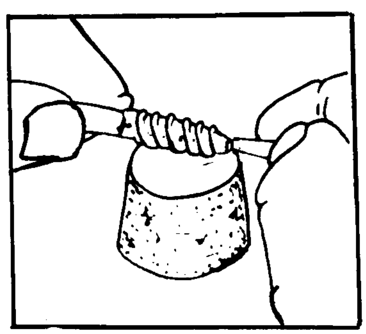
2. Sharpen beveled cutting edge by holding the blt in one hand and the India stone in the other. Rotate the bit away from you and against the stone. Keep the stone parallel to the beveled edge. Continue until sharp.



3. Hone the inside edge of the bit using the conical tapered stone. Lubricate with oil. Keeping the straight edge of the stone parallel with the long axis of the borer, insert the tip of the stone till it occupies three-fourths of the bit opening. Rotate the stone lightly against the cutting edge.



4. Hone the outside beveled cutting edge using the tip of the conical stone and the cork rest as illustrated. Use very light strokes over a small arc of the beveled edge, rotating the bit until completely sharpened.



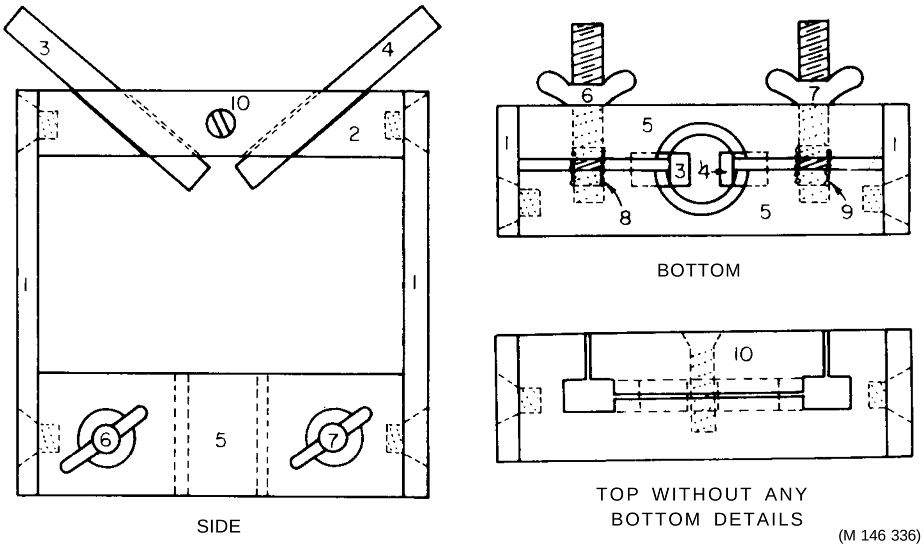
A problem with the above method of sharpening is the difficulty of maintaining a uniform outside beveled cutting edge. To overcome this problem Goodchild (1962) developed a metal framed sharpening tool, figure 1. Heinrichs (1964) modified the tool to use a wood frame, figure 2. The fixed angle of the India stones assures a proper bevel edge. The borer is inserted through the bottom of the sharpener frame until the borer bevel edge engages the stones evenly, figure 3. The borer, or the sharpener, is then rotated using lightweight oil or kerosene as a cutting fluid. Pressure on the borer shaft is maintained by tightening the bottom framing plate. Honing of the inside cutting edge is accomplished using a conical engraver's point stone as in step three of the hand method above.

Keep the extractor sharp also. Use the conical stone to sharpen the leading edge, maintaining the original bevel angle.

Cleaning

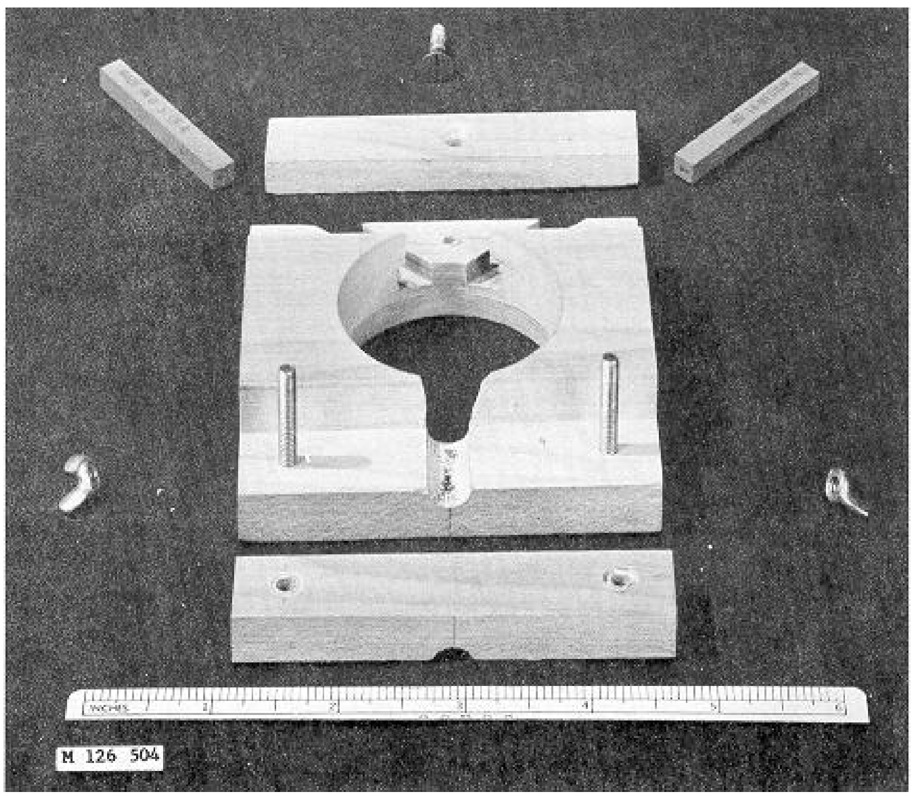
Tools and materials needed for cleaning increment borers are a cleaning rod, cloth patches or cotton twine, solvent, lightweight oil, and a soft cloth.

For increment borers with a diameter of 4.7 mm (0.185 in.) or greater, a .22 caliber rifle cleaning rod will work nicely (do not use a wire brush to clean the borer). For smaller-diameter borers a smaller rod will be required. Such a cleaning rod may be constructed from a large-diameter, soft iron, coat hanger or heavy wire (either soft iron or aluminum), figure 4. The hanger is straightened to the desired



1. FRAME SIDE MEMBERS
2. TOP FRAME MEMBER
3&4 FINE INDIA STONES
5. BOTTOM FRAME MEMBERS
6&7. SPRING LOADED CLAMPS
8&9 SPRINGS
10. STONE RETAINER

Figure 1.–Goodchild increment borer sharpener.



(M 126 504)
Figure 2.–Wooden modification of Goodchild's borer sharpener-developed by J. F. Heinrichs.

length (fig. 4b), one end of the wire is flattened with a hammer, and a slot bored into the flattened end (fig. 4c). A loop is bent in the end opposite the slot, completing the rod.

The following steps are taken to clean the borer:

1. Place a cloth patch or cotton twine through the slot on the cleaning rod. Saturate the cloth with solvent (mineral spirits, kerosene, etc.) and run the rod back and forth in the tube of the borer.
2. Put some solvent in the borer tube while holding a finger over one end. Close the other end and swish the solvent to rinse inside the tube.
3. Repeat step one using lightweight oil instead of solvent.
4. Clean the exterior of the borer and extractor with solvent and soft cloth, rinse, and oil lightly.

If the borer is to be used for pathological evaluations, alternative cleaning and sterilizing materials should be used. Such materials are discussed in the section on pathological evaluations.

When boring trees high in tannins, e.g., oaks, unless the borer is cleaned after each core, subsequent cores may turn a bluish-black color making it difficult to mark or count rings. The color results from a chemical reaction between the iron of the borer and the tannins in the wood and bark forming iron tannates, a blue-black stain.

Collecting Increment Cores

Cutting Cores

Even though cutting and extracting increment cores is a simple operation, a few tips can help to get better cores-easier.

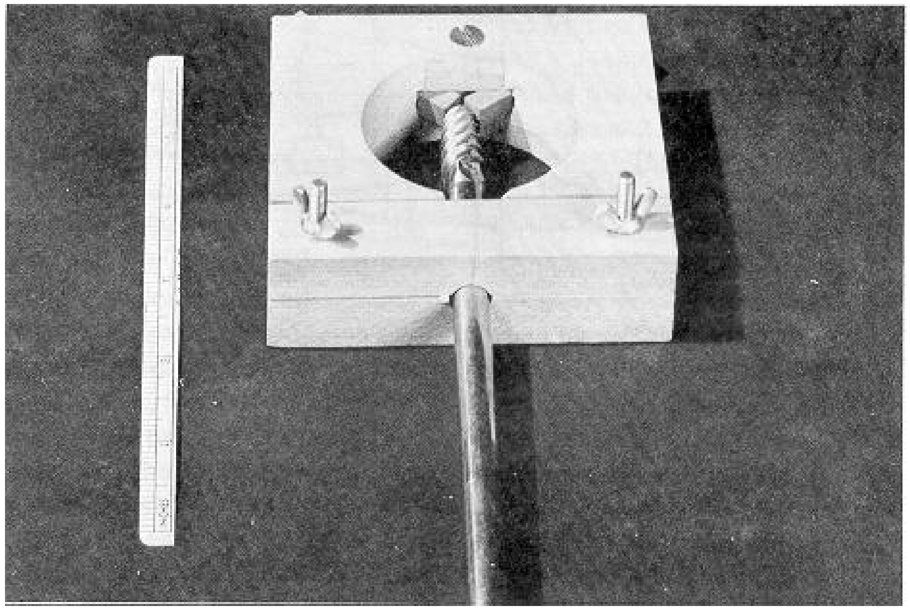
1. When boring manually, start the borer slowly and carefully to avoid "corkscrewing" of the outside end of the core. This can be done by holding the borer shaft near the threaded bit with one hand, while applying pressure toward the tree and turning the borer with the other hand, figure 5. Keep the borer in line while engaging the bit in the wood. Corkscrewing results when the borer shaft wavers from side to side and up and down while turning. Once the complete threaded bit is in the wood, both hands may be used to turn the borer.

2. For most purposes it is desirable to bore in a radial line to the pith. This is often difficult because trees aren't perfectly round. Ghent (1955) describes a device with which a correction can be made to hit pith center by taking a second core if the first core missed the pith. If, however, it is not desirable to take a second core and the first is off center, a pith locator has been designed by Applequist (1958) for estimating the number of rings to pith.

3. Grano (1963) has developed an increment borer starter that helps when boring dense woods, or when precision starts are required repeatedly. The starter also eliminates corkscrewing. The starter, figure 6, engages the borer threads in a threaded wood block stabilizing and easing the borer into the tree.

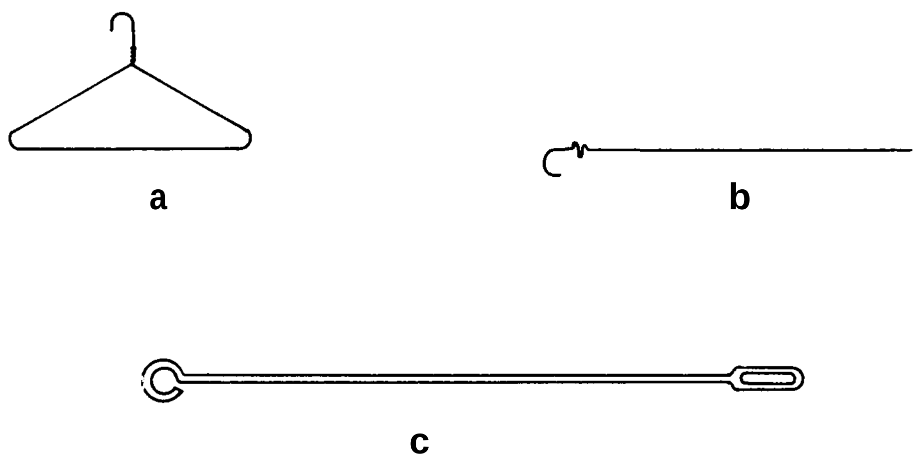
Another borer starter utilizes a spring-loaded strap that wraps around the tree and helps to pull the borer into the tree.[3] Both starters are especially good for use with large-diameter borers.

4. Mechanical and power devices have been developed to ease the taking of increment cores. Among the first devices were adaptations of mechanical ratchets (Duffield and Greeley, 1957; Herman, 1971, 1972). These



(M 126 506)

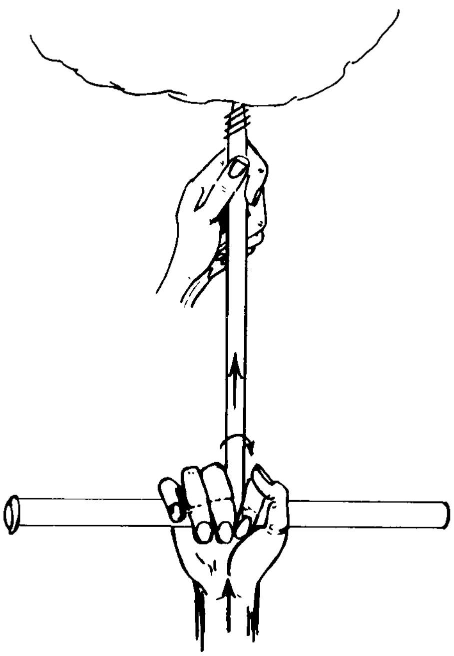
Figure 3.–Increment borer in sharpening position.



(M 145 981)

Figure 4.–Increment borer cleaning rod made from coat hanger or heavy wire.

[3] See Appendix.



(M 148 064)
Figure 5–Technique for hand-starting an increment borer without corkscrewing.

tools utilize mechanical ratchets, such as used with socket wrenches, to hold and turn the increment borer. They permit the returning of the borer handle to the horizontal position for each power stroke, maximizing the work effort.

Stonecypher and Cech (1960) developed an electrically powered borer that required a trailer-mounted generator for power. Echols (1969) developed a hydraulic powered borer that requires a trailer-mounted hydraulic pump and gas engine. An electric drill operating off a 12-volt auto battery is described by Prestemon (1965) for use with a special borer bit. Yelf (1962) developed a gasoline powered special borer for cutting ¾-inch diameter cores. All of these units require special conditions because of the bulk of the power source or of the boring device itself. Greig (1971), however, reports on two chain saw power heads (Jonsered and McCulloch) that are adapted for use with increment borers. He notes that both units are easy to use and well balanced, but only the McCulloch unit was reversible.

Other power units have been reported in the literature but the preceding are typical of what has been developed.

5. When inserting the extractor be careful not to jam it into the wood, but rotate it if necessary until it slips easily into the borer. Turn the borer until the groove of the extractor is up (at least one-half turn) and remove the extractor and core. Remove carefully so the core isn't dropped.

(M 145 978)
Figure 6.–Mechanical increment borer starter to help ease the borer into the tree, and to prevent corkscrewing.

6. After the increment core has been cut and extracted, back the borer out of the tree as soon as possible. If the borer is left in the tree it may seize in place and be impossible to remove.

7. Occasionally an increment core will become jammed in the borer due to rotten or other very low-density wood accumulating in the tip. DON'T try to pound it out from the screw end with any metal tool. This will inevitably result in a chipped cutting edge. Another questionable practice involves turning the borer into a solid tree to force the core out with another core. This causes great pressure at the cutting edge which also may chip the borer. The best method for removing a stuck core is to patiently remove the wood with the extractor, a little at a time:

8. Tie a piece of brightly-colored plastic tape or cloth to the extractor to prevent loss if dropped in the woods. Fluorescent colors are excellent for this purpose.

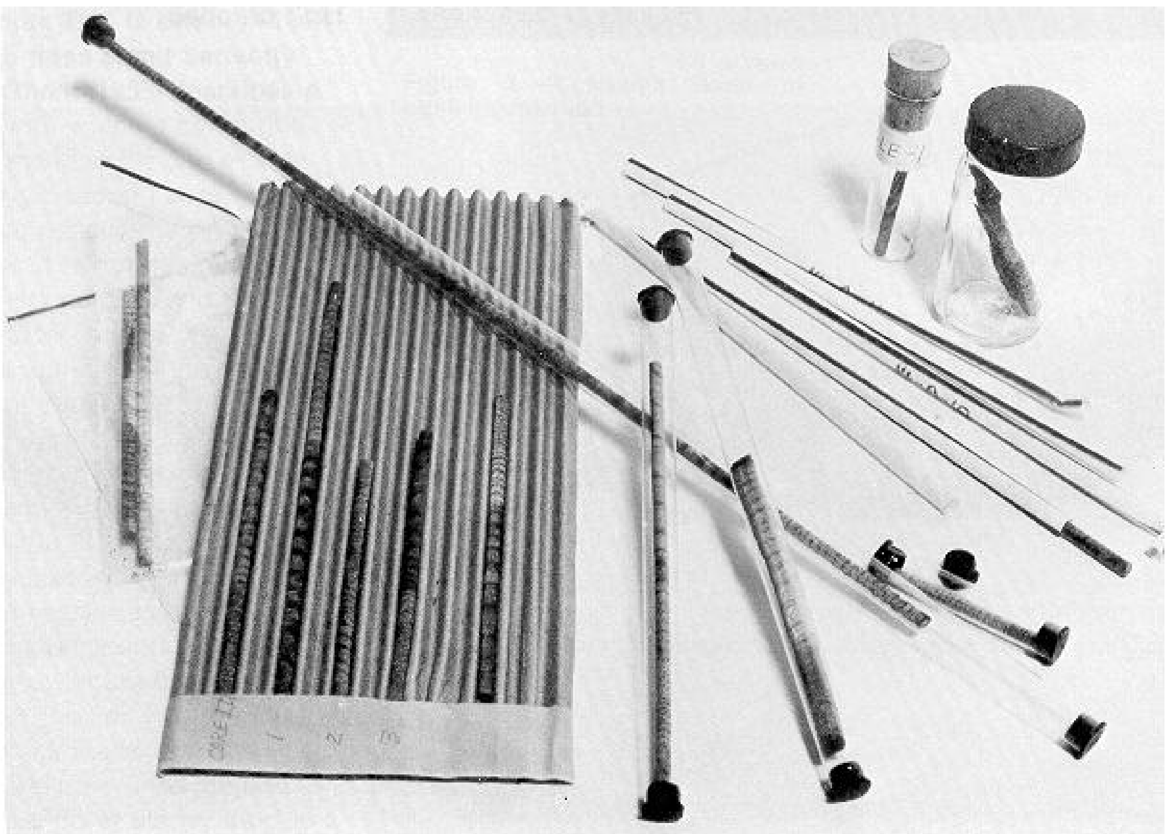
Transport and Storage of Cores

When the cores have been cut and extracted from the tree the utility of the core comes into its own. For some purposes the core may be evaluated immediately, such as for age counts or quick growth rate evaluations. But, for many purposes the cores must be carried to a laboratory or office for evaluation.

A wide variety of containers or core holders have been used depending on the purpose of the core, figure 7. For age counts, growth increment-measurement, and some wood quality evaluations, the cores may be placed on corrugated fiberboards, in drinking straws or in plastic tubes.

The use of inexpensive corrugated fiberboards permits labeling of the cores on the board, but it leaves the cores open to loss, and requires taping to hold the cores on the board. Long boards make it possible to hold oversized cores.

Drinking straws are probably one of the most widely used containers. The ends may be



(M 145 979)

Figure 7.–A variety of increment core holders for storage and transport.

[4] The information in item 7 was provided by Blaisdell of the Mt. Baker Snoqualmie Natl. Forest, U.S. Forest Service.

crimped and identification written directly on the straws (Larson 1954, U.S. Forest Service, 1965). A 50 mm (2 in.) diameter mailing tube which will hold about 50 straws may be used as a holder.

Clear plastic tubes with plastic stoppers[3] are also a good container for cores. The tubes are available in 46 cm (18 in.) lengths and in diameters from 8 mm (9/16 in.) to 22 mm (7/8 in.). The tubes may be cut to any desired length with scissors. Wax or solvent type markers may be used to label the tubes. Plastic tubes are more expensive than straws but have the advantage of being reusable, sealable, clear for viewing, and will accept 8 mm cores.

For uses where the cores must be maintained in the green or swollen condition, sealed containers are needed. Such containers may be plastic, glass, or metal bottles, vials, or tubes of various types. The cores may also be wrapped in polyethylene film or one of the household plastic wraps. Small sealable plastic bags may also be used.

Cores in the green condition should not be kept in sealed containers for long periods, unless refrigerated or frozen. The high moisture atmosphere in the container may result in fungal growth and decay.

When cores are to be kept for long periods it is best either to dry them, keep them immersed in water or alcohol, or to freeze them.

Using Increment Cores

Counting Rings

Probably the most common use of increment cores is to determine tree age and growth. With some trees there is no trouble in determining rings on a good core. However, with other trees ring determinations are made only with difficulty.

Wood Anatomy

A little background on some of the basic differences in wood may aid in ring determinations.

In softwoods (coniferous trees) there are two types of wood. One has an abrupt transition between the earlywood and latewood within a ring.

Earlywood is that wood formed in the spring and consists of larger thin-walled cells. Latewood is formed in mid to late summer and consists of smaller thick-walled cells. These woods have a dark band (latewood) separating one ring from another. The second type has a gradual transition between early and latewood and may or may not have a dark latewood separating band between rings. Typical examples of the abrupt transition woods are southern pine, ponderosa pine, Douglas-fir, red pine, hemlock, and larch (tamarack), figure 8. Typical of the gradual transition woods are, white pines, true firs (balsam, grand, etc.), and spruces, figure 9.

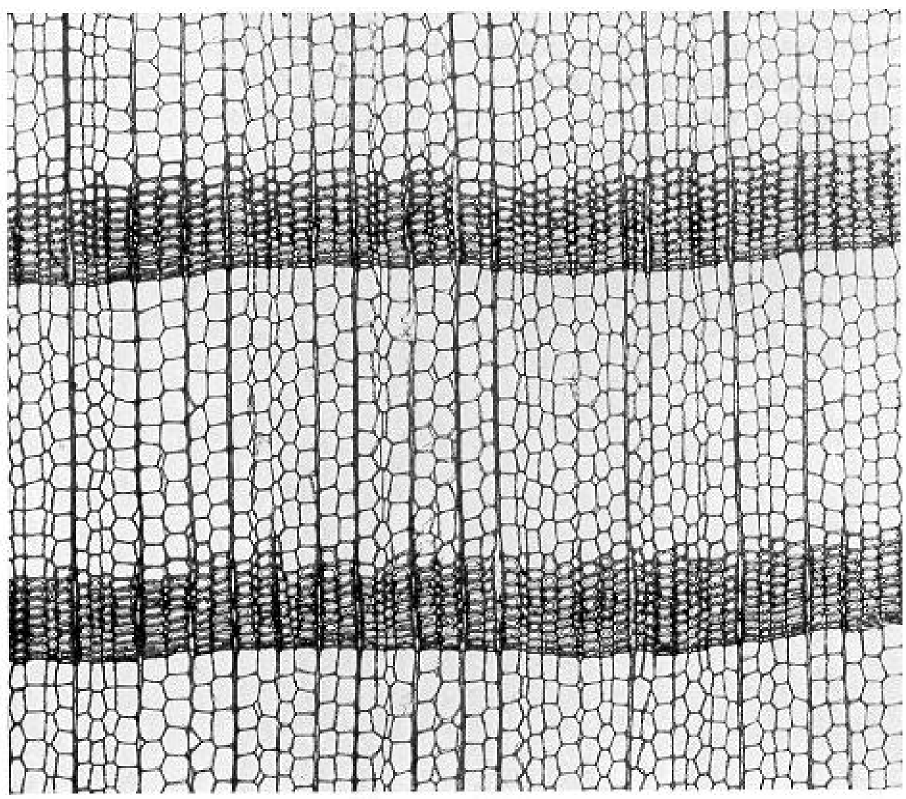


Figure 8.–Photomicrograph of Western larch (*Larix occidentalis*) showing abrupt transition to latewood.

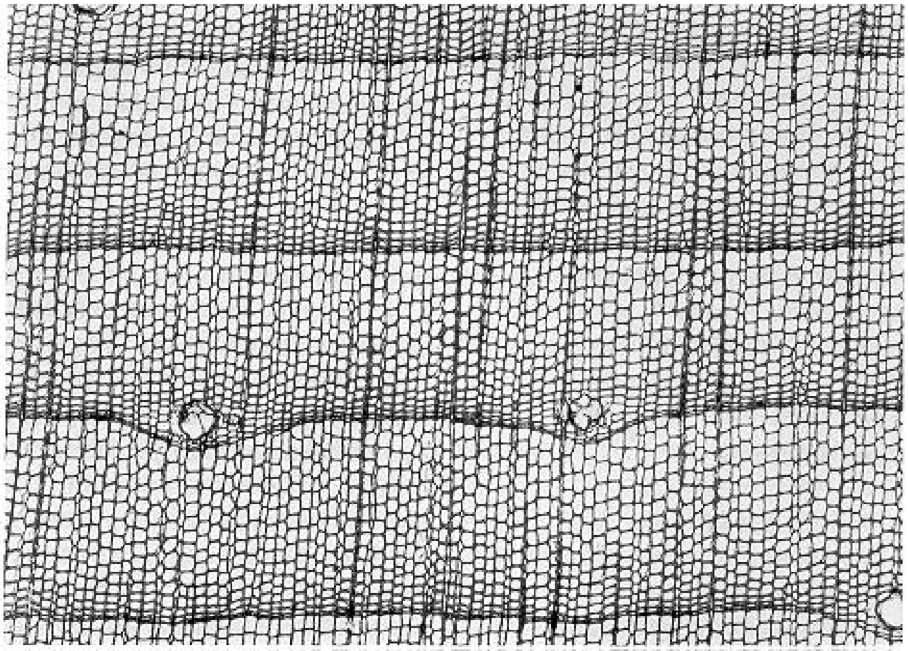


Figure 9.–Photomicrograph of Northern white pine (*Pinus Strobus*) showing gradual transition to latewood. (M 2149)

In hardwoods (broadleafed trees) there are also two basic types of wood, ring porous and diffuse porous. Ring porous woods have large vessels (pores) concentrated in the earlywood, with smaller vessels in the latewood. Diffuse porous woods have nearly uniform vessel size and distribution throughout the ring. Woods typical of the ring porous type are oak, ash, locust, hickory, and elm, figure 10. Examples of diffuse porous woods are maple, birch, poplar, magnolia, willow, and gum, figure 11.

A more complete description of the anatomy of American woods can be found in Panshin et al. (1964).

Generally the abrupt transition softwoods and ring porous hardwoods present little difficulty in ring determination. Most difficulties arise with the gradual transition softwoods and diffuse porous hardwoods.

Enhancement Techniques

Many techniques have been tried to enhance ring boundaries to help in the counting and measuring of rings. Rubbing soft chalk on the core and then lightly wiping the core (Maeglin, 1969), backlighting the core with sunlight, smoothing the core surface, and using a hand lens may all help. Another helpful device is a core holder, which permits cutting surfaces, assembly of broken cores, etc. Such a holder is pictured in figure 12.

A number of special treatments to enhance rings for counting are described below.

Vihrov (1959) suggests brushing glycerine on the core. For birch it is suggested that rings be counted or measured immediately. For oak, aspen, and ash, Vihrov recommends two or three treatments at 30- to 40-minute intervals.

Trujillo (1975) states that aspen cores which have been smoothed, ovendried, wiped with a 4 percent solution of pentachlorophenol in kerosene or mineral spirits, and ovendried again, can be read with ease.

Holz (1959) reports a number of possible treatments. These include exposure of the core to ammonia fumes; light scorching over a flame; dyeing the wood

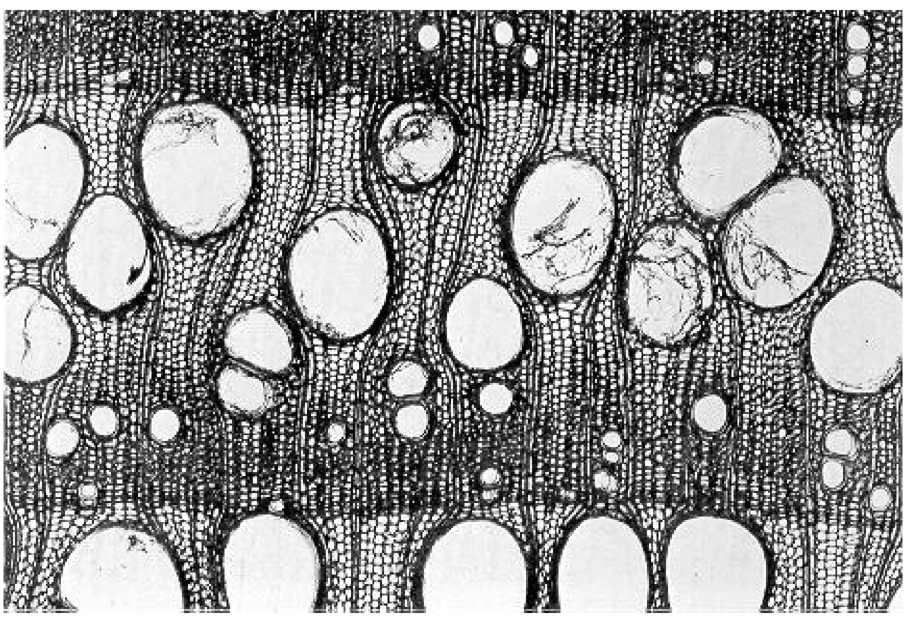


Figure 10.–Photomicrograph of green ash (*Fraxinus pennsylvatica*) representative of ring porous hardwoods. (M 2113)

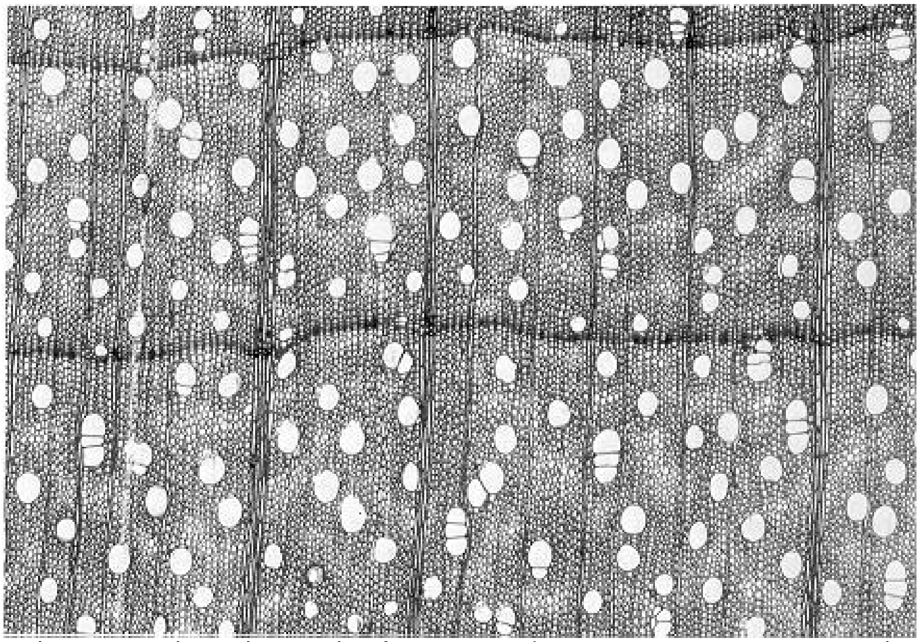


Figure 11.–Photomicrograph of sugar maple (*Acer saccharum*) representative of diffuse porous hardwoods.

(M 2363)

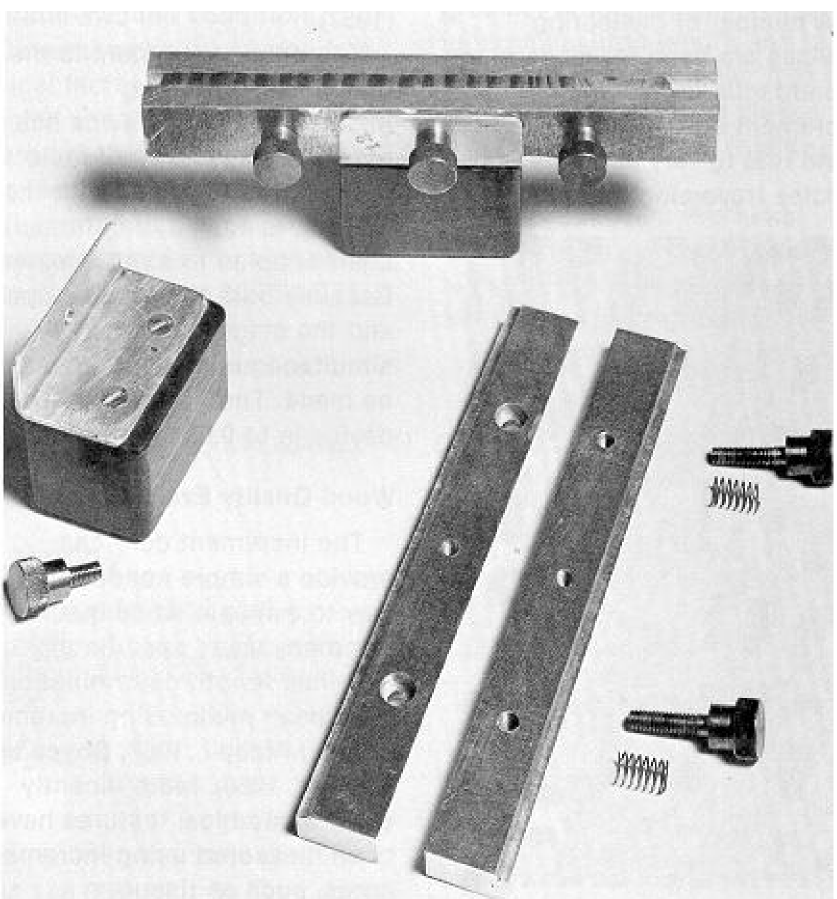


Figure 12.–Increment core holder.

and then shaving the surface until the latewood is natural and the earlywood dyed; short dips in concentrated sulphuric acid followed by a water rinse; and overnight soaking in a 10 percent solution of potassium or sodium hydroxide. The last treatment (hydroxide soak) is especially effective, according to Holz, for beech, oak, birch, basswood, and poplar. It is even better if coloring dye is added to the solution.

Ostermann (1957) notes that for beech, immersion of carefully smoothed cores in a solution of 6 parts nitric acid and 4 parts water results in easier ring counting.

A technique combining oil impregnation and backlighting of aspen cores is described by Rose (1957). Rose recommends keeping the core immersed in oil while viewing with transmitted light and a low-power microscope.

For gums (*Nyssa, Liquidambar*) and yellow poplar (three of the more difficult genera to make ring counts on), Patterson (1959) describes a treatment using phloroglucinol. A 1 percent solution of phloroglucinol in 95 percent ethyl alcohol and a 50 percent solution of hydrochloric acid are needed. Soak the cores in the phloroglucinol for about 1 minute, then in the acid for about one minute, rinse with water when the cores begin to turn red. Viewing under a fluorescent light will aid in counting or measuring.

False Rings

False rings can confound both ring counting and measuring. To detect false rings some magnification of the core is required, either a hand lens or low-power binocular microscope will suffice.

Two types of false rings occur. One is due to colored bands that appear as rings. Such false rings are discussed by Beaufait and Nelson (1957) for cypress. The other type is due to a change in the wood anatomy, usually caused by a slowing of growth during ring formation, followed by a resumption of growth.

Normal growth patterns result in latewood cells at the end of one annual ring followed by an abrupt change to earlywood in the following ring. A false ring will have a gradual transition out of the latewood-like cells into larger thin-walled cells which will then phase into normal latewood and ring termination, figure 13.

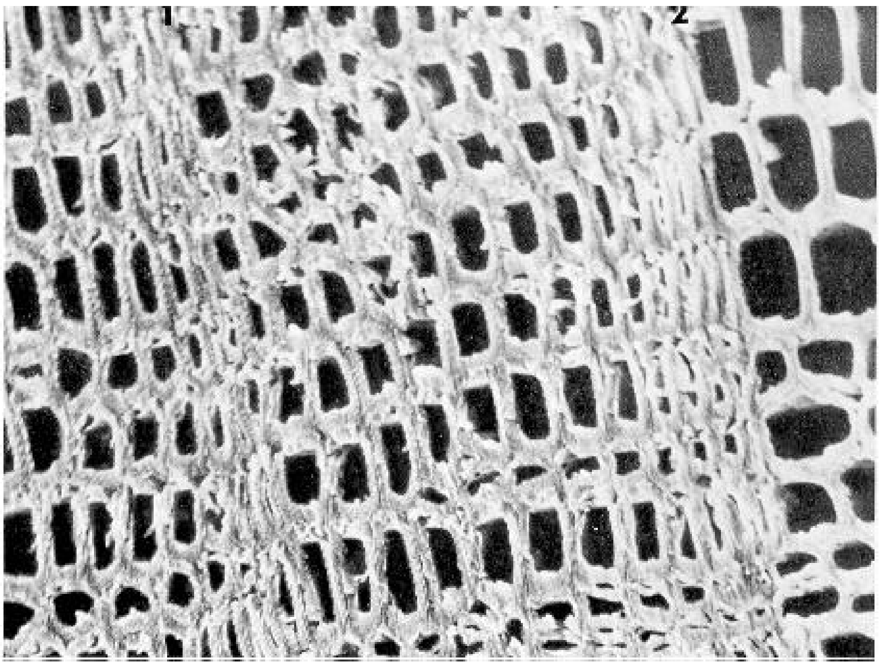


Figure 13.–False ring in eastern red cedar (*Juniperus virginiana*).
(1) False ring with gradual change in cell size into and out of latewood.
(2) Normal ring boundary with gradual change in cell size into latewood, and abrupt transition to earlywood.

Missing Rings

In arid areas or on stressed sites where tree growth is very slow, incomplete rings may occur. That is, the rings will not form completely around the tree. Incomplete rings cannot be detected from a single increment core, and multiple cores only raise the probability of detection. Where very accurate ring counts are needed, missing rings may present a problem.

Growth Increment

Measuring growth increment requires the determination of annual rings and, as such, the previous information may be applied directly.

A number of measuring devices are used for measuring incremental growth on increment cores from a simple hand rule to very accurate and precise traversing micrometers.

For most purposes a good, carefully etched, hand rule will suffice. A magnifying lens or binocular microscope can aid one in accurately measuring increment.

Among the mechanical devices for measuring increment, only two will be mentioned. First, the Addo-X[3] a Swedish-manufactured device for increment measurement. This machine, has a movable stage on a threaded shaft, which is moved past a fixed microscope with crosshairs. The stage is coupled to an adding machine for data recording. The accuracy of the device is to 0.1, 0.2, or 0.01 mm with different replaceable drive gears, Spurr (1957).

The other instrument is the dual-linear traversing microscope.[3] This device has a movable stage, and movable microscope. Each, as with the Addo-X, is moved on a threaded shaft coupled to a micrometer. Because both the microscope and the stage move, two simultaneous measurements can be made. The accuracy of the device is to 0.001 mm.

Wood Quality Evaluations

The increment core can provide a simple nondestructive way to evaluate wood quality. For many years specific gravity and fiber length determinations have been made using increment cores (Mitchell, 1958, Boyce and Kaeiser, 1960). More recently other anatomical features have been measured using increment cores, such as tissue proportions, and various cell dimensions (Smith, 1965, Maeglin, 1977).

Wood Permeability and Moisture Content

Markstrom and Hann (1972) describe techniques for evaluating permeability and moisture content from increment cores. Permeability measurement is useful for determining preservative treatability and wood-drying potential. Moisture content also indicates drying potential as well as information on log weights.

Specific Gravity

Wood specific gravity (density) is based on two measured values, ovendry weight, and volume. For most purposes the volume is measured in the green or water-swollen condition.

Determination of volume is a critical factor in establishing precise specific gravity values. There are three basic methods for measuring core volume: (1) using core length and micrometer measurement of core diameter, $V = 0.7854\ D_c^2 L_c$, where D_c is core diameter and L_c is core length; (2) using core length and the bore diameter of the increment borer, $V = 0.7854\ D_b^2 L_c$, where D_b is bare diameter and L_c is core length; (3) displacement of water, mercury, or other liquid.

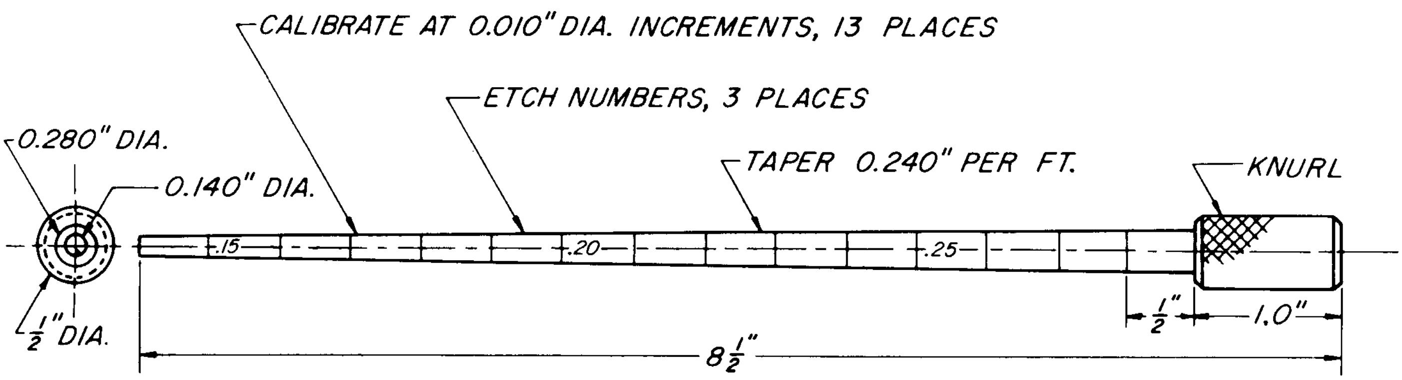
Walters and Bruckman (1964) evaluated the three basic methods using combinations of green and dried cores. They concluded that the "best" method was the calculation based on measured length and average midpoint diameter of green cores. The midpoint diameter was measured with a machinists micrometer at two points, one at a right angle to the other. They showed that the greatest precision was obtained using measured length and bore diameter; but concluded that the bore diameter method gave a smaller diameter that might not be accurate.

The U.S. Forest Products Laboratory in several extensive wood density studies used the bore diameter method for determining core volume (U.S. Forest Serv., 1965a; 1965b; Wahlgren et al., 1966; 1968; Pronin, 1971; Wahlgren and Schumann, 1972; Maeglin and Wahlgren, 1972; Maeglin, 1973a; 1973b). The values derived are considered valid.

Figure 14 illustrates a taper gage for measuring bore diameter. The gage is simply inserted into the threaded end of the borer and read to the nearest 0.001 inch. A similar gage with metric measure could also be made.

Recent improvements in top-bottom loading digital microbalances permit the determination of volumes by water immersion techniques such as described by Heinrichs and Lassen (1970).

An excellent technique yielding good accuracy for increment core specific gravity is the maximum moisture content method (Smith, 1954). The technique requires only the weight of the completely saturated sample and the weight



M 148 065

Figure 14.–Taper gage for measuring bore diameter of increment borers.

of the ovendry sample applied in the equation:

$$G_f = \frac{1}{\frac{M_m - M_o}{M_o} + \frac{1}{G_{so}}}$$

where:

G_f = Specific gravity at green volume

M_m = weight of sample at maximum moisture content

M_o = weight of ovendry sample

G_{so} = specific gravity of wood substance (1.53)

Another technique for determining increment core specific gravity is by X-ray radiographs that are evaluated with a densitometer. Details of this technique are given by Harris and Polge (1967), and Echols (1972, 1973).

Fiber Length

For many years increment cores were rejected as a source of material for fiber-length measurements. It was thought that too many fibers would be cut and an accurate average couldn't be determined. For conifers with fibers 3 to 6 mm long, a 5 mm increment core wouldn't suffice. An 8 or 10 mm core might suffice.

Polge (1967) showed that by boring a tree at an angle, full-length conifer fibers could be extracted, even with a 5 mm borer. He showed better results with an angled 5 mm core than with a horizontal 10 mm core.

Boyce and Kaeiser (1960) demonstrated that horizontally extracted 5 mm cores can be used for fiber-length material where the fibers are 2 mm or less in length (most hardwoods).

Fibril Angle

Several methods are available for measuring fibril angle (Hiller, 1964, 1968; Meylan, 1967; Page, 1969). All systems measure either cracks in the fiber wall (separations of fibrils) or cracks extending from pit apertures in fiber walls.

The author found a quick and reliable method using increment cores. The cores are split radially, saturated in water under a vacuum, then dried at 120° C (250° F) for one-half hour. The cores are then viewed microscopically with reflected light at 300X to 500X, using a crosshair and protractor eyepiece.

Tissue Proportions

Increment cores are ideal for determining tissue proportions. The cores can be smoothed on the transverse (cross-section) surface with a single edged razor blade, a scalpel, or a sliding microtome (Maeglin and Harris, 1976).

Using reflected light the surface can be viewed directly. Cell types can be counted using a dot grid or Zeiss integrating eyepiece in the microscope (Poetsch, no date; Smith, 1967; Maeglin, 1974). The proportions of cell wall and cell void may also be measured with an integrating eyepiece.

Cell Dimensions

Cell dimensions such as wall thickness, cell diameters, lumen diameters, ray widths, etc. can be measured on transverse surfaces of cores. Either a micrometer eyepiece in a conventional microscope or instruments such as the Addo-X or dual-linear microscope can be used. Once again the core must be lighted from above.

Mechanical Properties

Wood hardness can be measured on increment cores by using a simple abrasion test devised by Tryon et al. (1976). Reineke and Davis (1966) developed a hand pliers for testing fiber strength in increment cores.

Pathological Evaluations

The use of the increment core for assessing the presence of and/or damage due to pathological sources requires special care. The area is very specialized and will only be briefly touched here.

Cleaning of the increment borer is necessary after every core extraction to eliminate transfer of pathological agents from one sample to the next. Ward[5] emphasizes that kerosene, toluene, and other solvents previously mentioned, although useful for conifers, are useless for bacterially infected trees, especially oaks. After extensive screening of solvents, he found 1,1,1-trichloroethane (TCE) to be the best solvent for cleaning borers used on oaks and other species high in tannins. He also found TCE to be a good sterilant for borers and extractors before taking cores for isolation and cultivation of microorganisms.

Personal communication. J. Ward. U. S. Forest Products Laboratory.

The following papers are examples of the use of increment cores in pathological investigations: Bulgrin and Ward 1968; Sachs, Ward, and Kinney, 1974; Zeikus and Ward, 1974; and Ward and Kozlik, 1975.

A Word of Caution

Even though the increment core has been called a nondestructive method for sampling growth, age, and wood quality, this is not totally true. For example, boring at breast height (4.5 ft) in a prime black walnut veneer tree is destructive. It will lower the value of the butt veneer bolt just by the presence of the bore hole.

Also, bore holes can be the entrance source for decay and disease (Toole and Gammage, 1959; Schopfer, 1961; Hart and Wargo, 1965; Shigo, 1967).

Lorenz (1944) showed that northern hardwoods (basswood, sugar maple, yellow and paper birch) are all affected with stain when bored. Similarly, Hepting et al. (1949), found that white oak, scarlet oak, yellow poplar, sugar maple, red maple, yellow birch, magnolia, and beech all stained after boring. Pines (pitch, shortleaf, and white) were not stained but were pitch soaked. Toole and Gammage (1959) found stain in all trees they bored and later sampled (Nuttal oak, green ash, sugarberry, sweetgum, and cottonwood).

Both Lorenz and Hepting, et al., tried plugging with black locust heartwood pegs. Lorenz showed a slight retarding of decay, but no effect on stain. Hepting, et al., felt that there was no advantage to plugging.

Stains and pitch streaking are apparently due to physiological causes rather than organisms, and probably can't be prevented. Decay, however, is organism caused. Many systems, including plugging, have been tried to prevent decay development. Disinfecting both the borer and the bore hole have been tried with little or no success. Klepac (1962) describes a gun for firing grafting wax plugs into the bore hole. The wax is impregnated with fungicides and insecticides. Robert Fisher, horticulturist at the Mt. Vernon estate near Washington, D.C., has suggested using lanolin to fill and seal the bore holes. Fungicides can be easily added to the lanolin for further protection. A combination of lanolin or grafting wax and a wooden plug may also be used to seal holes.

An important thing to remember when using plugs is to seat the plug inside the cambium (inner bark) so callus can form over the plug.

Increment cores are a useful tool for many assessments of tree growth and wood quality. They, however, should not be taken unless absolutely necessary. Millions of trees, around the world, have been bored and left to develop decay or other forms of degrade. Use the tool when necessary but also use common sense.

APPENDIX

Increment Borers and Accessories

Ben Meadows Company
3589 Broad Street
Atlanta, GA 30366

Forestry Suppliers, Inc.
205 Rankin Street
Box 8397
Jackson, MS 39204

TSI Company
P.O. Box 151
Highway 206
Flanders, NJ 07836

Plastic Tubing

Brockway Glass Company,
Plastics Division
Route 101A, Cellu Drive
Nashua, NH 03060

Measuring Devices

Addo-X
Ab Addo, Malmö,
Sweden

Dual-Linear
Gaertner Scientific
1201 Wrightwood Avenue
Chicago, IL 60614

Literature Cited

Appelquist, M. B.
1958. A simple pith locator for use with off-center increment cores. J. For. 56(2):141.

Bauck, R., and R. M. Brown.
1955. Sharpening an increment borer. Minn. For. Notes No. 39.

Beaufait, W. R., and T. C. Nelson.
1957. Ring counts in second-growth Baldcypress. J. For. 55(8):588.

Boyce, S. G., and M. Kaeiser.
1960. Small increment cores can be used for sampling cotton fibers. J. For. 58(6):484-485.

Bulgrin, E. H., and J. C. Ward.
1968. Factors contributing to heartwood-boundary stain in living oak. Wood Science 1(1):58-64.

Duffield, J. W., and W. B. Greeley.
1957. A ratchet wrench for over-sized increment borers. For. Sci. 3(1):21.

Echols, R. M.
1969. Powered drive for large increment borers. J. For. 67(2):123-125.

Echols, R. M.
1972. Product suitability of wood determined by density gradients across growth rings. USDA For. Serv. Res. Note. PSW-273, Berkeley, Calif.

Echols, R. M.
1973. Uniformity of wood density assessed from X-rays of increment cores. Wood Sci. Tech. 7(1):34-44.

Goodchild, R.
1963. An instrument for sharpening Swedish-type increment bores. Comm. For. Rev. 42(1):16-18.

Grano, C. X.
1963. Increment borer starting device, J. For. 61(9):678-679.

Greig, B. J. W.
1971. The adaptation of boring attachments on motor-driven chain saws, for the detection of decay in trees, and other uses. Forestru. 44(2):151-153.

Grent, A. W.
1955. A guide to the realignment of off-center increment borings. For. Chron. 31(4):353-355.

Harris, J., and H. Polge.
1967. A comparison of X-ray and beta ray techniques for measuring wood density. J. Inst. Wood Sci. 4(1):34-42.

Hart, J. H., and P. M. Wargo.
1965. Increment borer wounds—penetration points for *Ceratocystis fagacearum.* J. For. 63(1):38-39.

Heinrichs, J. F.
1964. Pocket-sized sharpener for increment borers. J. For. 62(10):653.

Heinrichs, J. F., and L. E. Lassen.
1970. Improved technique for determining the volume of irregularly shaped wood blocks. For. Prod. J. 20(4):24.

Hepting, G. H., E. R. Roth, and B. Sleeth.
1949. Discolorations and decay from increment borings. J. For. 47(5):366-370.

Herman, F. R.
1971. A ratchet wrench and cleaning equipment for increment borers. J. For. 69(1):26-27.

Herman, F. R.
1972. Improved adapter for increment borer ratchet assembly. USDA For. Serv. Res. Note PNW-192.

Maeglin, R. R.
1974. The effect of site factors and growth rate on the anatomical proportions of northern red oak (*Quercus rubra* L.) wood. Ph.D. dissertation, Univ. Mich., Ann Arbor. (Diss. Abstr. 35, No. 11: 5217-5218b).

Maeglin, R. R., and J. Harris.
1976. A freezing technique for microtoming increment cores. Wood Sci. 8(3):162-163.

Maeglin, R. R.
1977. Natural variation of tissue proportions and vessel and fiber lengths in mature northern red oak. Silv. Genet. 25(3-4):122-126.

Markstrom, D. C., and R. A. Hann.
1972. Seasonal variation in wood permeability and stem moisture content of three Rocky Mountain softwoods. USDA For. Serv. Res. Note RM-212. Ft. Collins, Colo.

Meylan, B. A.
1967. Measurement of microfibril angle by X-ray diffraction. For. Prod. J. 17(5):51-58.

Mitchell, H. L.
1958. Wood quality evaluation from increment cores. Tappi 41(4):150-156.

Ostermann, W.
1957. Bringing out the rings on beech increment cores. Holz-Zbl. 83(120):1459. Original not seen. Abstr. in For. Abstr. 19(2) No. 2153.

Page, D. H.
1969. A method for determining the fibrillar angle in wood tracheids. J. of Microsc. 90(pt. 2):137-143.

Hiller, C.
1964. Estimating size of the fibril angle in latewood tracheids of slash pine. J. For. 62(4):249-252.

Hiller, C.
1968. Trends in fibril angle variation in white ash. USDA For. Serv. Res. Pap. FPL 99. Madison, Wis.

Holz, D.
1959. Increasing the color contrast in annual rings on cross-sections and increment cores. Arch. Forstw. 8(8):743-749. Original not seen. Abstr. in For. Abstr. 21 No. 3571.

Klepac, D.
1962. How to reduce damage caused by taking increment cores with a Pressler borer. Sum. List 86(3/4):120-122. Original not seen. Abstr. in For. Abstr. 24(3) No. 4009.

Larson, P. R.
1954. Labeling and storing increment cores. J. For. 52(4):252.

Lorenz, R. C.
1944. Discolorations and decay resulting from increment borings in hardwoods. J. For. 42(1):37-43.

Maeglin, R. R.
1969. Simplified determination of age on increment cores. North. Logger 18(5):23.

Maeglin, R. R., and H. E. Wahlgren.
1972. Western wood density survey: Report No. 2. USDA For. Serv. Res. Pap. FPL 183. Madison, Wis.

Maeglin, R. R.
1973a. Wisconsin wood density survey. USDA For. Serv. Res. Pap. FPL 202. Madison, Wis.

Maeglin, R. R.
1973b. Increment core specific gravity of Wisconsin hardwoods and minor softwoods. USDA For. Serv. Res. Pap. FPL 203. Madison, Wis.

Panshin, A. F., C. DeZeeuw, and H. P. Brown.
1964. Textbook of wood technology. Vol. 1, 2nd ed. McGraw-Hill Book Co., New York. 643 p.

Patterson, A. E.
1959. Distinguishing annual rings of diffuse porous tree species. J. For. 57(2): 126.

Poetsch, G.
No date. Integrating eyepiece 1. Carl Zeiss, Oberkochen, West Germany. 14 p.

Polge, H.
1967. Determination of fiber length using 5 mm increment core. Tappi 50(9):460-462.

Prestemon, D. R.
1965. Improving the power increment borer for hardwoods. J. For. 63(10):763-765.

Pronin, D.
1971. Estimating tree specific gravity of major pulpwood species of Wisconsin. USDA For. Serv. Res. Pap. FPL 161. Madison, Wis.

Reineke, L. H., and C. N. Davis.
1966. A hand instrument for evaluating wood compression. For. Prod. J. 16(5):15-18.

Rose, A. H.
1957. A technique for differentiating annual rings in increment cores from diffuse porous woods. For. Chron. 33(2):139-140.

Sachs, I. B., J. C. Ward, and R. E. Kinney.
1974. Scanning electron microscopy of bacterial wetwood and normal heartwood in poplar trees. Scanning Electron Microscopy/1974 (Part II). Proceedings of workshop on scanning electron microscopy and the plant sciences. IIT Research Institute, Chicago, Ill. 60616.

Schopfer, W.
1961. The effect of increment borings in spruce stands. Allg. Forst.-u. Jagolztg. 133(2):43-50. Original not seen. Abstr. in For. Abstr. 23(4) No. 5627.

Shigo, A. L.
1967. International Review of Forestry Research. Vol. II, p. 255-256.

Smith, D. M.
1954. Maximum moisture content method for determining specific gravity of small wood samples. USDA For. Serv., Forest Products Lab. Rep. 2014. Madison, Wis.

Smith, D. M.
1965. Rapid measurement of tracheid cross-sectional dimensions in conifers. For. Prod. J. 15(8):325-334.

Smith, D. M.
1967. Microscopic methods for determining cross-sectional cell dimensions. USDA For. Serv. Res. Pap. FPL 79. Madison, Wis.

Spurr, S. H.
1957. Recording micrometer. For. Sci. 3(1):66.

Stonecypher, R. W., and F. C. Cech.
1960. An efficient way of taking large increment cores. J. For. 58(8):644-645.

Toole, E. R., and J. L. Gammage.
1959. Damage from increment borings in bottomland hardwoods. J. For. 57(12):909-911.

Trujillo, D. P.
1975. Preparing aspen cores for ring counts. J. For. 73(7):428.

Tryon, E. H., P. J. Litwin, J. R. Hamilton, and J. J. Renton.
1976. Three methods of determining hardness of increment core segments. Wood and Fiber 7(4):287-292.

U.S. Forest Service.
1965a. Southern wood density survey: 1965 status report. USDA For. Serv. Res. Pap. FPL 26. Madison, Wis.

U.S. Forest Service.
1965b. Western wood density survey: Report number 1. USDA For. Serv. Res. Pap. FPL 27. Madison, Wis.

Vihrov, V. E.
1959. A simple method of displaying annual rings. Lesn. Hoz. 12(12):73. Original not seen. Abstr. No. 4650A/224. Oxford cat. of World For. Lit.

Wahlgren, H. E., A. C. Hart, and R. R. Maeglin.
1966. Estimating tree specific gravity of Maine conifers. USDA For. Serv. Res. Pap. FPL 61. Madison, Wis.

Wahlgren, H. E., G. Baker, R. R. Maeglin, and A. C. Hart.
1968. Survey of specific gravity of eight Maine conifers. USDA For. Serv. Res. Pap. FPL 95. Madison, Wis.

Wahlgren, H. E., and D. R. Schumann.
1972. Properties of major southern pines: Part 1 wood density survey. USDA For. Serv. Res. Pap. FPL 176. Madison, Wis.

Walters, C. S., and G. Bruckman.
1964. A comparison of methods for determining volume of increment cores. J. For. 62(3):172-177.

Ward, J. C., and C. J. Kozlik.
1975. Kiln drying sinker heartwood from young-growth western hemlock: preliminary evaluation. In: Proceedings, Western Dry Kiln Clubs 26th Annual meeting, May 1-2, 1975. Oregon State Univ., Corvallis, Ore. 97331.

Yelf, J. T.
1962. The development of a power increment borer. For. Chron. 38(3):309-317.

Zeikus, J. G., and J. C. Ward.
1974. Methane formation in living trees: a microbial origin. Science 184(6): 1181-1183.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980-651-111/52