DETECTION OF DECAY IN TREES[1]

by Walter C. Shortle

Abstract. New ideas and new tools give the arborist new opportunities to better assess the hazard potential of decayed trees. Before using electronics to help detect decay in trees, today's arborist must first train the "mind's eye" to "see" inside the living tree. A model system called CODIT has been developed to explain the patterns of discoloration and decay in wounded trees. With an understanding of the model, a battery-powered drill, and a pulsed-current resistance meter, the arborist can get a good picture of what the inside of a tree is like. With better detection comes the need for better professional judgment to determine how to treat decayed trees.

New ideas about how decay takes place in trees (Shigo 1973, 1975, 1976, Shigo and Hillis 1973, Shigo and Marx 1977, and Shigo et al. 1977a) and new tools using electric current to probe inside trees (Shigo and Berry 1975, Shigo and Shigo 1974, Shigo et al. 1977c, Shortle et al. 1977, 1978, and Skutt et al. 1972) give the arborist some new opportunities for better detection of decay in trees. Decay must be detected and corrective measures taken before the tree becomes a hazard to people and property (Tattar 1976 and Shortle 1977).

This paper describes an approach to detecting decay in trees that requires —

1. Training the "mind's eye" to "see" patterns of decay inside trees.
2. Using a battery-powered drill to detect voids in trees.
3. Using a pulsed electric current meter, the Shigometer,® [2] to detect changes in the electrical resistance of wood.

The problem of professional judgment in evaluating the hazard potential of trees and proper treatment of decaying trees is also considered.

To train the "mind's eye" to picture what goes on inside living trees, we must first know what decay is. Decay is the process by which microorganisms break down wood. When this process takes place in dead trees and parts of trees in nature, it is highly beneficial because it recycles nutrients. However, decay in living trees is the most damaging disease of all species of trees all over the world. This disease usually does not kill trees, but continues for many years until the tree becomes useless for products or dangerous to people and property.

Decay begins with a wound. A wound is a break in the bark that exposes wood. To understand decay, a person must know what happens after all kinds of wounds. Wounds come in many sizes and shapes. Wounds may occur at any point on the stem or underground on the roots. The amount of damage that will result from wounds depends on how many wounds the tree receives, how big the wounds are, how deeply they penetrate into the tree, how old they are, and where they are on the tree.

Some wounds are caused by loss of branches or broken tops which leave stubs of exposed wood (Fig. 1). Eventually these stubs will rot away, leaving a hole that often indicates extensive internal decay. Machinery and fire often scar the trunk, especially near the base of the tree, and allow decay to begin (Fig. 1). Animals, such as birds, insects, squirrels, beavers, and bears, can cause wounds. And people's activities cause many wounds in forests, parks, recreation areas, and homesites. Roots are often wounded at homesites during construction, road repair, or similar soil disturbances around trees. Root wounds often go unseen, but can lead to decay at the base of the tree where a break can be disastrous (Fig. 1).

Before we briefly consider what happens inside the wounded tree, we must clear up one misconception. Most textbooks on tree pathology will tell you that decay in trees is mostly "heartrot" — decay of dead heartwood by heartrot fungi that enter through wounds, such as branch stubs and trunk scars.

It is true that wounds initiate the decay process and that the decay fungi that produce fruit bodies, commonly called "conks," on trees do decompose wood. But the presence of heartwood in

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[2]Use of trade, firm, or corporation names in this paper does not constitute endorsement by the Forest Service or the U.S. Department of Agriculture.

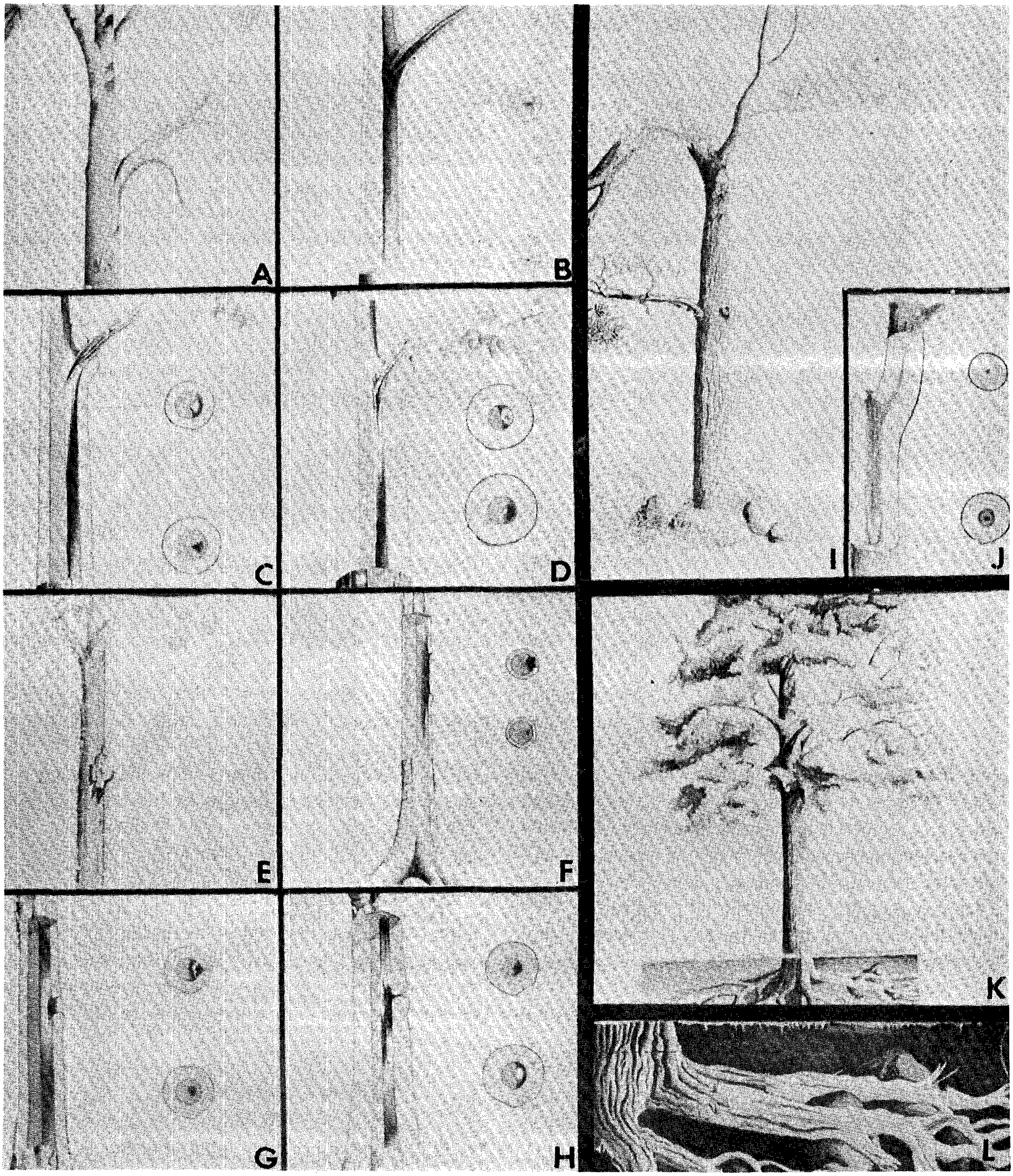

Fig. 1. Branch stub (A) showing progress of discoloration and decay at 3 (B), 20 (C), and 40 (D) years; trunk wound (E) over same time (F,G,H); broken top (1) at 20 years (J); and branch death (K) indicating root wounds (L).

trees is not necessary for wood decay. Wood discoloration is necessary for decay, but it takes place in both sapwood and heartwood (Fig. 2). Furthermore, the discoloration process, which precedes decay in trees, takes place in specific patterns. These patterns are described by a simple model system called CODIT — Compartmentalization Of Decay in Trees (Shigo and Marx 1977) (Fig. 2).

A quick review before we briefly consider the CODIT system: decay is a powerful natural recycling process caused by microorganisms; decay in trees is a disease initiated by wounds; heartwood is not essential for a tree to get this disease, but discoloration is; discoloration occurs in specific patterns in living trees; and these patterns are described by a simple model called CODIT.

Whenever a tree is wounded, the tree responds. Young wood and bark cells become callus to seal the wound. The rate of callus formation depends on how well the tree is growing (Neely 1970). Young wood cells become a new tissue called barrier zone, coded Wall 4 (Fig. 2). Discoloration and the microorganisms growing in discolored wood do not cross Wall 4 into new wood formed after wounding. It is very important for arborists to know this. If a 6-inch tree capable of growing to 24 inches is wounded and not rewounded, the maximum column of decay will be 6 inches in diameter. There will be plenty of sound wood to support the tree. But if a 22-inch tree is wounded and it will only grow to 24 inches, then a 22-inch-diameter column of decay can result and the tree becomes a hazard.

Mature wood cells surrounding injured and infected wood respond to form a protective zone that has three components, coded Wall 1, Wall 2, and Wall 3 by the CODIT system (Fig. 2). This response is more difficult to understand than the formation of callus and Wall 4, which is new tissue. Think for a minute about the composition of mature wood (Fig. 2). Each growing season a new ring is laid down. In each ring are ray cells made up of many small living cells called parenchyma. Mixed in among the small live cells are large, dead cells called vessels and fibers in hardwood trees, and tracheids in conifers. These large dead cells are used for food by microorganisms during decay. This causes loss of strength. The only way to protect these large dead cells is for the small live cells to do something. These live cells can use their food reserves to make plugging materials, which are coded Wall 1. Wall 1 is the weak wall because the openings in the cells they plug are very large compared to the size of the microorganisms that try to move through them. The resulting columns of discoloration and decay spread up and down the stem faster than across it (Figs. 1 & 2).

It is easier to plug cells with small openings than those with large openings. The last wood a tree makes each year is very dense and therefore is much harder to move through. This area of dense wood becomes what we call Wall 2.

But the strongest defense mature wood can have against becoming discolored and decayed is the response of the small live cells clustered in rays. Not only can they make plugging materials, but they can form wood-preserving substances as they die. This layer of preservation substances is strongest along the rays, and is coded Wall 3. Note that this is how some trees produce a durable heartwood — by forming preservative substances as cells die with age.

Like other life processes, the effectiveness of a tree at compartmentalizing decay is determined by its genes (Shigo et al. 1977b). Some trees make strong compartments to wall off the microorganisms, including the decay fungi that grow in discolored wood. Some trees make weak compartments and discoloration and decay spreads rapidly so that only Wall 4 is effective.

The CODIT system tells us that decay will be limited to wood present at wounding, that decay will spread up and down faster than across, and that the amount of spread will vary with the genes of the tree and with the number and severity of wounds.

We should note briefly that the genes of the microorganisms are also important. Decay fungi do not work alone in discolored wood. Pioneer bacteria and fungi help alter this tissue. Decay fungi vary in capacity to become established and to decay wood. Therefore, the kind of wound, tree, and microorganism all affect how much discolored wood and how much decay will occur

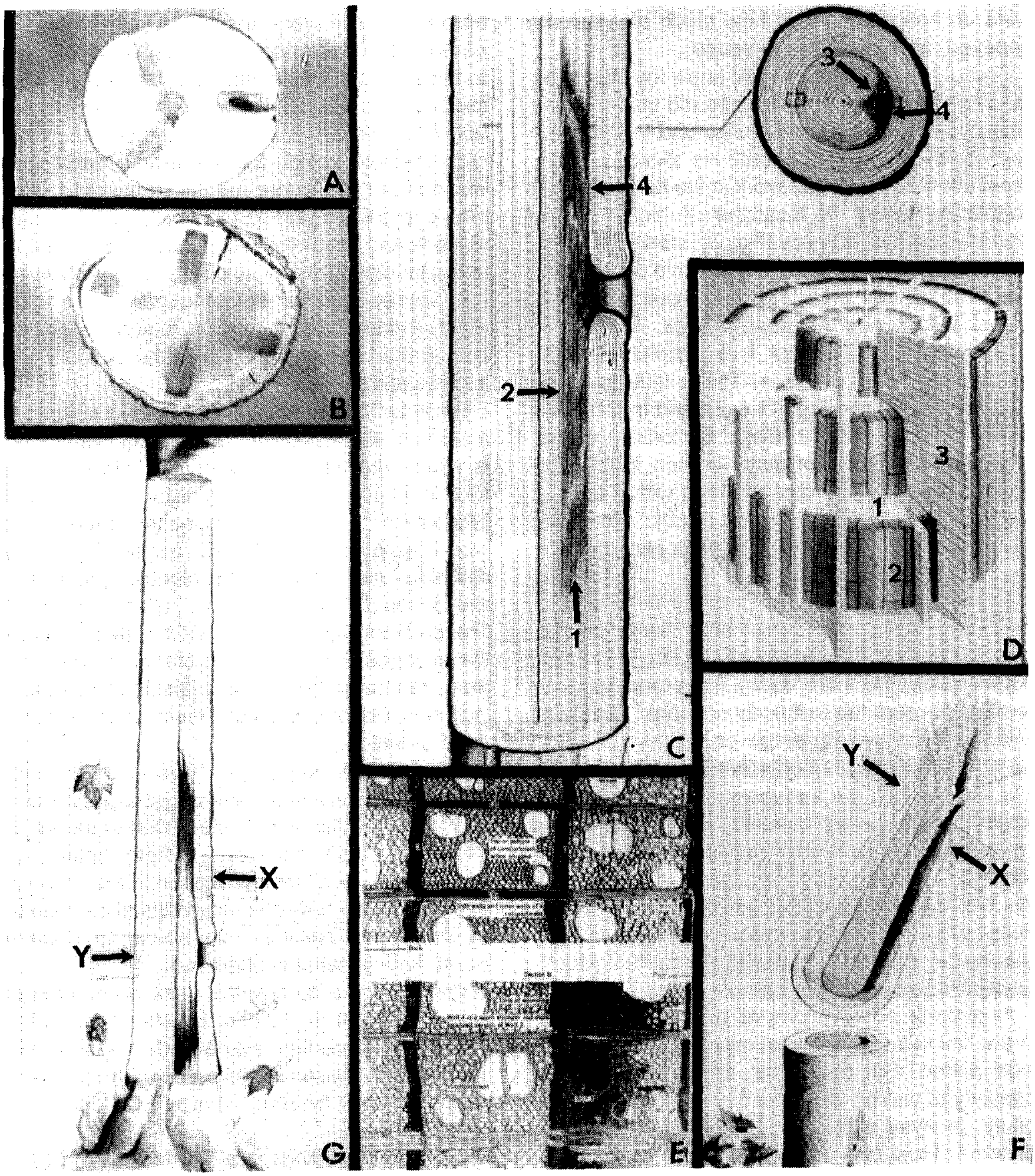

Fig. 2. Cross-section of wounded maple (A) showing discoloration without heartwood and oak (B) with heartwood; CODIT model (C,D) system showing position of Walls 1,2,3, and 4; wood that makes the walls (E); and compartmentalized wounds of trees with (F) and without (G) heartwood. Note drill points x and y in F and G.

in a tree. However, we can give some ground rules on how to estimate how much of a tree is decayed, and how much is sound.

First of all, an arborist should know the history of the area where he works. When did major wounding events, such as fires, wind and ice storms, and construction work occur? He should ask his client about construction work at the homesite. He should be aware of locations of high risk for wounds, such as corners (Fig. 3), close proximity to walks and buildings, and children's play areas. The arborist can then focus on trees that have probably sustained the most wounds.

Next the arborist must look carefully for indicators of decay in trees. These indicators include both wounds (Figs. 1 & 2), and fruit bodies of decay fungi (Fig. 3). Begin by looking at the crown for evidence of large branch stubs and broken tops; partially closed stubs with a hole in the middle may indicate serious trouble. Also note the condition of the crown; dieback may indicate root problems (Fig. 1).

Move down the bole toward the base of the tree. Look for scars, old partially closed stubs, and fruit bodies. The more and the larger the fruit bodies seen, the more decay has progressed internally. Be sure the fruit body or "conk" is actually in the wood and not simply on the surface. Probe wood on faces of open scars to see how rotten it is. Remember, the surface may be hard but the wood may be punky beneath. Finally, look very carefully at the base of the tree for evidence of root injury. "Frost cracks" or seams at the base of the tree generally indicate severe root and butt decay (Fig. 3). These cracks have formed from the inside out and are useful decay indicators. Look for fungi fruiting at the root collar (Fig. 3).

All of these observations will help build a picture in the "mind's eye" of what may be happening inside a tree. But remember, trees vary in their capacity to wall off decay and some trees may be badly decayed without showing any external indicators. How can the arborist help confirm his mental picture of the tree's internal problems?

Two tools can help. The first is a battery-powered drill with an 8-inch (20 cm) or longer drill bit 3/32 inch (2.4 mm) in diameter. As the bit is drilled into the tree, a sudden release in torque indicates a pocket we call a "void." Voids are either hollow or have very punky wood in them. To determine how big the void is, drill a second hole to the point of release, stop the drill, measure how much bit sticks out of the tree, then push the bit in until it hits sound wood again, and you know how wide the void is. You also know how much sound wood is left. Use your mental picture to tell you where to drill. A good pattern is to drill above basal wounds and below top wounds, and then from the opposite side of the wound (Fig. 2). This tells you how decay is advancing and how deep it has gone. If there are no obvious indicators, try one hole at the base and another at the opposite face 1.5 meters above ground.

But what if there are no voids? There still may be a serious decay problem developing inside. Here is where the second tool comes into play. This tool is a pulsed current resistance meter, the Shigometer®, which measures the resistance of wood to a pulsed electric current. As wood discolors and decays, its electrical resistance decreases (Skutt et al. 1972, Tattar et al. 1972). The problem facing an arborist is how to interpret the changes in electrical resistance he sees in a tree. He knows that a drop in electrical resistance indicates trouble, but how much drop and how much trouble?

Unfortunately, we do not have all the answers yet, but there are two ways to get a good idea of how much trouble is indicated. One is to use the meter on fresh samples of both sound and decayed stems of trees common in the arborist's work area. See how electrical resistance changes as the probe passes from sound to decayed wood, and list what is observed.

The second is to test the rules given for utility poles (Shigo et al. 1977c, Shortle et al. 1978). Unpublished studies indicate that these rules seem to apply even in living trees. These are the basic rules for locating what are called "decay centers :

A. If some readings are off scale (> 500 K ohms):
   1. all readings > 250: wood sound
   2. some readings < 125: wood decayed
   3. some readings 125 to 250: wood questionable

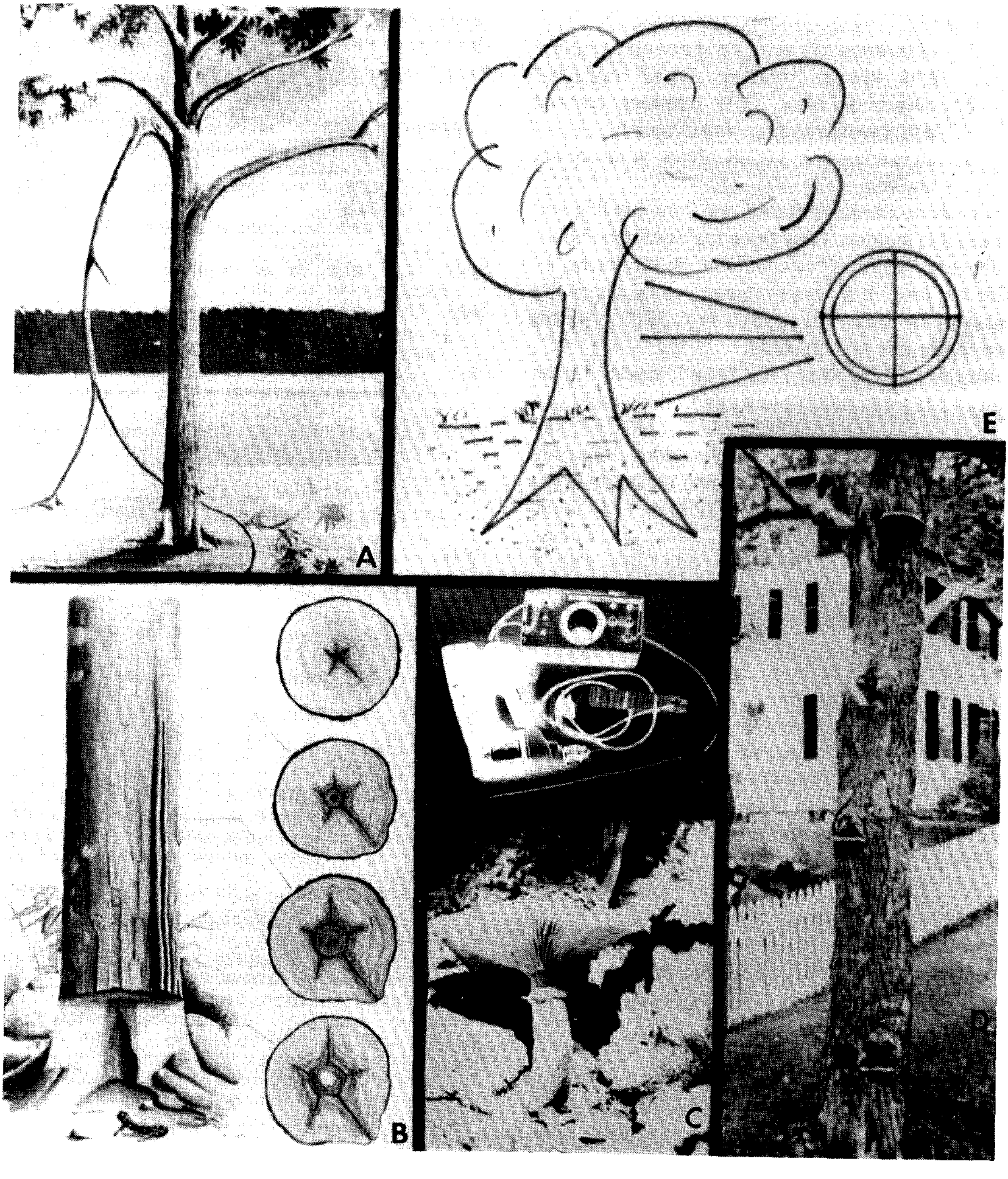

Fig. 3. Corner locations bad for root and top injury (A); seams indicate root and butt decay (B); conk indicators vary in size and shape, and number (C,D); equipment for determining internal condition (center); and simple model for evaluating the hazard of a tree (E).

B. If all but one reading on scale (< 500 K ohms):
   1. difference of > 75% between highest and lowest reading: wood decayed
   2. difference of < 75% between highest and lowest reading: wood sound
   3. all readings < 100 K ohms: wood questionable.

If a decay center is found, ask how big it is and where it is located. How does the center compare with your mental picture of what is happening inside the tree? If a person doesn't understand the patterns of decay described in CODIT, the drill and meter are of little value.

Arborists must learn to "see" inside a tree before they can adapt our tools to their need.

Now let's assume that the arborist has checked the tree for indicators, voids, and decay centers, and has a good idea what is going on inside it. He must now use his professional judgment to assess the decay hazard created by the tree and decide what treatment must be followed. If the tree is sound, the arborist must recommend a good maintenance program to keep it that way. If the tree is unsound, he has several options: removal may be necessary if an extreme hazard is indicated by extensive decay and the tree is where people and property are in danger. Remember, even a sound tree close to a house may go over in a storm and cause damage. Maybe it needs only a part of the crown removed and a good maintenance program to compartmentalize decay within the stem. Maybe cabling and bracing will work. Of course the arborist should stress prevention of decay problems by proper tree care.

As a guide to professional judgment in assessing hazard caused by decay in trees, the arborist might consider a model (Fig. 3) which considers height in the stem, four faces of the bole, and inner versus outer wood. Most of the strength of the stem is in its outer few inches of wood. Consider how much wood has been lost from each quarter inside and outside this cylinder for the crown, trunk, and root areas. Then consider the species (some species are naturally weaker than others). Finally consider where the tree or a part of it is likely to fall if it breaks off.

We do not have definite rules yet, but with new ideas and new tools, better rules can be developed to help detect and evaluate decay in living trees.

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