TREE CHECK

SONIC WAVE TREE DECAY DETECTOR

USER MANUAL

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OVERVIEW

Tree Check is designed for professional use by researchers, arborists and urban foresters as a low cost, simple to use, reliable field tool to detect the likely presence of significant decay, cavity or cracks in standing trees. Used properly it can "see inside the tree" revealing areas of concealed severe deterioration that undiscovered could result in tree structural failure and resultant property damage or personal injury.

Items included in the Tree Check case:

1. Control Box with screen
2. Two Sensors with two set screws each
3. Two telephone-type cables
4. Two Scratch Awls
5. One hammer
6. Four AA batteries
7. User Manual
8. Micro SD memory card

HOW IT WORKS

The tool consists of two sensors that are connected to an electronic circuit board box by simple telephone cables. The sensors are secured with setscrews on carpenter's awls that penetrate through the bark and slightly into the tree wood on opposite sides of the trunk. After turning on the device, the user taps the start sensor awl with a light hammer creating a sonic or stress wave traveling through the trunk and at the same time creating an electronic signal to the circuit board box starting the "stop watch" timer.

When the leading edge of the sonic wave arrives at the opposite sensor, it creates an electronic signal to stop the timer. The circuit board box displays both the wave transit time in microseconds and a graphic representation of the waveform itself. The user measures the distance between the sensors, calculates the transit time per inch or centimeter comparing it to an expected transit time for defect-free wood of that species. Longer than expected transit times can be an indication that the sound wave movement was obstructed by internal decay, cavity or cracks.

THE SCIENCE BEHIND TREE CHECK

The science behind its operation is simple and well researched. The tool measures the time it takes for an impact-induced stress wave to travel from one sensor to another across the diameter of a trunk or large limb. Defects such as decay, cavities and cracks create obstacles requiring the wave to bypass the defect thus taking more time than a wave moving directly through defect-free wood between sensors. Average transit times across defect-free wood vary by tree species. Published tables with transit time's normal range and average reference numbers for select species can be found in Chapter 7 from the USDA publication Nondestructive Evaluation of Wood: Second Edition edited by Robert Ross (2015).

Normal defect-free wave transit times are largely influenced by wood density, but moisture, growing conditions and temperature also influence transit times. Ideally one would make a reference check for comparison on a known defect free part of the subject tree or a same species tree growing nearby.

However, as a preliminary inspection for concealed severe deterioration during a pre-climb safety check, tree risk assessment or urban forest inventory it is helpful to know that researchers observe normal defect-free transit time ranging from 600-800 microseconds per meter (183-245 microseconds per foot) on more dense hardwood to 800-900 microseconds per meter (245 – 274 microseconds per foot) on less dense softwoods. Transit times greater than 50% longer than expected could indicate signficant internal defect and justify additional tests such as micro-drill resistance or acoustic tomography.

TESTING PROCEDURE

1. Determine an elevation on the trunk to conduct the first test.
   - Typically, within the first 3 feet of the base

2. Use the hammer to place the first awl through the bark into the wood to a shallow but wobble-free secure depth.
   - Attach the second awl at the same elevation on the opposite side
   - Five or six inch long wood screws are an alternative to the awls

3. Connect the sensors on the opposite awls tightening the set-screws to be sure the sensors' metal base is snug against the awls or screws
   - Be sure that the white arrow marked on each sensor is pointing toward the trunk.
   - Make sure the telephone cables are properly snapped into the sensors and into the top of the main box.

4. Turn on the device using the switch on the top of the main box.
   - The screen will light up and indicate which sensor connection leads to the START sensor.
   - SETTINGS allows you to adjust the internal clock to the current time in your time zone. It is displayed as 24 hour military time and is noted on all saved files.
   - When ready to begin the test use a finger to press the touch screen where it says " ARM."

5. Use the provided hammer to lightly strike the end of the START awl.
   - Do not hit the sensor directly as that will cause damage to the exposed mini-circuit board.

6. The screen will display the transit time in microseconds on the upper right corner and also display the waveform as a graph moving across the screen.

7. The screen will display an option to DISCARD or SAVE the reading. Discard the first two or three readings to repeat the tapping procedure until a consistent average transit time is determined.
   - It is rare to have the exact number on each tap but with a few taps of fairly equal force numbers clustered around an average can be obtained.

8. When satisfied that a good average number has been obtained on the last tap use that number as your transit time for that location.

- If further analysis of the waveform on your computer is desired, touch the SAVE option placing that test result on the inserted memory card. In most cases it is unnecessary to save the results.
- Make note of the average transit time and characteristics of the waveform then touch the DISCARD.

9. Use a tape measure or caliper to measure the diameter distance between the tips of the awls to the nearest centimeter or inch. A diameter-tape can also be used to help in the proper placement of the awls and to determine an average diameter distance between the sensors. Calculate the transit time per unit measurement by simply dividing the average total transit time by the number of centimeters or inches in the measured trunk diameter distance.

- For example, if the average transit time is 600 microseconds and the distance is 24 inches, then 600/24 is 300 microseconds per foot or 25 microseconds per inch.

10. To disconnect Tree Check from the trunk, first remove the sensors from the awls by loosening the set screws. Then remove the awls from the trunk.

11. To have the best chance to capture defects in the transverse section of the trunk being tested, reposition the awls at the same elevation but in a new diameter position at right angles to the first test.

- Repeat the tapping procedure as above.

12. To preserve battery life, turn off the device after each use. Replace the 4 AA batteries as needed by sliding open the battery cover door, removing the old batteries and inserting fresh ones.

- *It is very important to match the positive and negative ends of the batteries with the corresponding plus and minus markings on the plastic in the battery box*.

Interpreting the Results

Transit Time

The following two tables show transit time or time-of-flight per unit length for various tree species as determined by Mattheck and Bethge (1993) and Divos and Szalai (2002), taken from the USDA Forest Products Laboratory “Assessment of Decay in Standing Timber Using Stress Wave Timing Nondestructive Evaluation Tools.”

Table 7.1—Radial stress wave velocity and time-of-flight measured in healthy trees (Mattheck and Bethge 1993)

	Radial stress wave velocity		Time-of-flight per unit length	
Species	m/s	ft/s	µs/m	µs/ft
Hardwoods				
Ash	1162–1379	3810–4520	725–861	221–262
Birch	967–1150	3170–3770	870–1034	265–315
Black locust	934–1463	3060–4800	684–1071	208–326
Black poplar	869–1057	2850–3470	946–1151	299–351
Horse chestnut	837–1557	2860–5110	642–1145	196–349
Lime	940–1183	3080–3880	845–1064	258–324
Maple	1006–1600	3300–5250	625–994	191–303
Oak	1382–1610	4530–5280	621–724	189–221
Pine poplar	967–1144	3170–3750	874–1034	266–315
Plane	950–1033	3120–3390	968–1053	295–321
Red beech	1206–1412	3960–4630	708–829	216–253
Silver poplar	821–1108	2690–3640	903–1218	275–371
Sweet chestnut	1215–1375	3990–4510	727–823	222–251
Willow	912–1333	2990–4370	750–1096	229–334
Softwoods				
Douglas-fir	905–1323	2970–4340	756–1105	230–337
Fir	910–166	2990–3830	858–1099	261–335
Larch	1023–1338	3360–4390	747–978	228–298
Pine	1066–1146	3500–3760	873–938	266–286
Spruce	931–1085	3050–3560	922–1074	281–327

Table 7.2—Reference stress wave velocity and time-of-flight in healthy trees (Divos and Szalai 2002)

	Radial stress wave velocity		Time-of-flight per unit length	
Species	m/s	ft/s	µs/m	µs/ft
Beech	1670	5479	599	183
Black fir	1480	4856	676	206
Larch	1490	4888	671	205
Linden	1690	5545	592	180
Maple	1690	5545	592	180
Oak	1620	5315	617	188
Poplar	1140	3740	877	267
Scotch fir	1470	4823	680	207
Silver fir	1360	4462	735	224
Spruce	1410	4626	709	216

As you can see there is a variance not only between species but also between individual trees within a species being tested. So in interpreting transit time do not anticipate there should be a single absolute transit time per unit measured for defect free wood but rather assume instead that there is an anticipated normal range for the movement of the wave through defect free wood. From these tables one can see that the wave transit takes less time (therefore a lower transit number per unit measured) for harder, denser wood and more time (therefore a higher transit time per unit measured) for softer, less dense wood.

It is always preferable to find a part of the subject tree that is known to be defect-free and make a reference check for anticipated transit time per unit measured there. If that is not possible, using the baseline reference numbers from the two tables above, one can assume that a reasonable reference number for an oak, sugar maple, linden or beech would be around 600-800 microseconds per meter or 183-245 microseconds per foot. And for a less dense conifer like a larch, pine, spruce or fir, 800-900 microseconds per meter or 245-274 microseconds per foot. Numbers 50% above an anticipated range would suggest internal obstructions to the wave movement across the trunk diameter. The higher the transit time per unit measured above the reference time the more likely there is a major obstruction or wood deterioration requiring caution and further investigation.

For example, if one assumes the subject tree species reference upper range is 300 microseconds per foot , then caution and further investigation is advised when the transit time is **450 microseconds per foot (37 microseconds per inch)** Always use your own professional judgment, consideration of the individual circumstances and experience with the tool to set a reasonable acceptable threshold.

WAVEFORM

By displaying the waveform graph, Tree Check√ offers the user additional information regarding the sonic wave and its relationship to the wood properties of the subject tree. There is very little published research correlating waveform characteristics to internal tree decay. This tool offers researchers that opportunity and arborists and urban foresters using the tool regularly in the field a chance to serve as citizen scientists making observations and seeing relationships between waveform variations and tree wood defects.

Waveform characteristics to observe are as follows:
1. Amplitude, the vertical distance between the crest and the trough of the wave;
2. Wavelength, the horizontal distance between the oscillations of the wave;
3. Frequency, the total number of vibrations or oscillations made within a certain amount of time;
4. Attenuation, the gradual loss of wavelength intensity due to absorption within the wood medium; exhibited as the waveform flattening.

Researchers may want to transfer field data from the tool into a computer program for further analysis. They can do so by selecting the SAVE option on the touch screen rather than the DISCARD option. This records the last measurement taken to the memory card inserted into the top panel of the main circuit board box. There is a real time clock within the main circuit board that will stamp the time and the chronological number of the test onto the file.

TROUBLESHOOTING

Once you have taken your newly acquired Tree Check√ tool out of the shipping box, give yourself plenty of time to become familiar with its proper use. Have fun tap testing a variety of trees, some you know are defect-free and others with obvious cavities or defects. Note how the transit time and waveforms vary between test areas.

With practice you will develop a steady, regular tap strike with the hammer; not too light, not too hard, one that gives consistent transit times in the diameter tested. The more practice time you have with the tool, the more expert you will become in its use and interpretation and the more useful it will become as a tool to reveal significant concealed and potentially dangerous tree structural defects.

Problem:	Cause and Solution:
Screen does not light up when switch turned on	Batteries need to be replaced or are not positioned properly positive to positive in the box
Transit times too scattered or too low or high	Hammer taps inconsistent, too hard or too soft; or not hitting correct sensor awl or sensors' white arrow not pointing in toward the tree.
Tap does not produce transit time or waveform	Not tapping the correct sensor awl – initial screen shows start side; or white arrow on the sensors not pointing in toward the tree; or awl not deep enough into the wood.
Other problems	Email other questions to: rbruce@allisontree.com