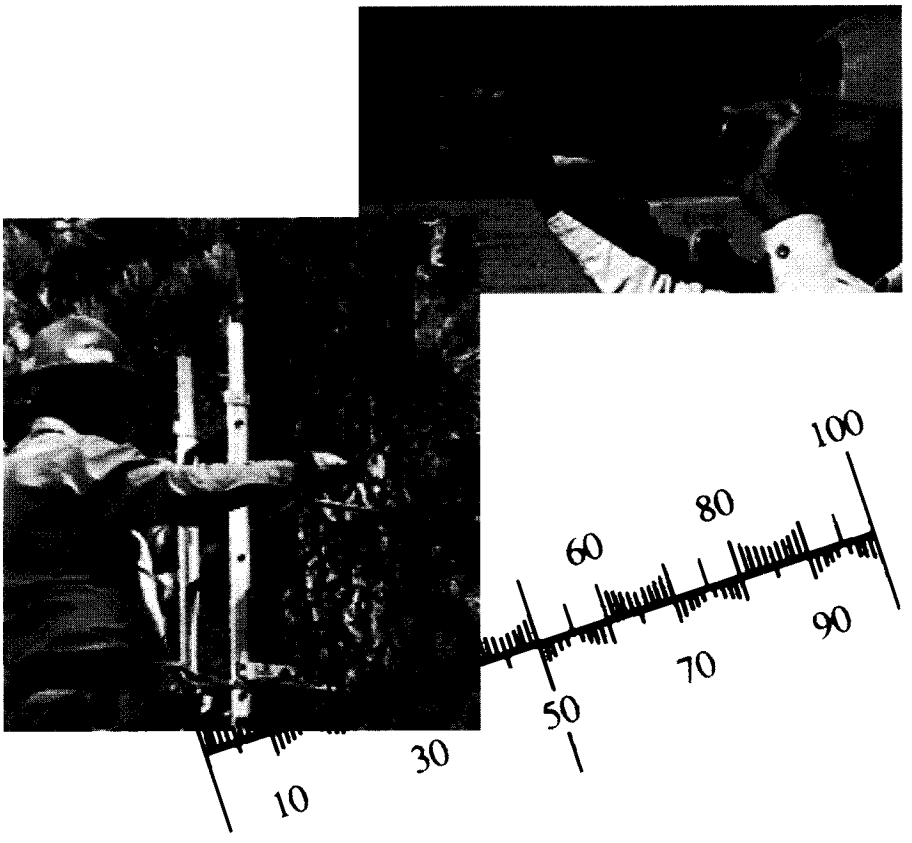
United States
Department of
Agriculture

Forest Service

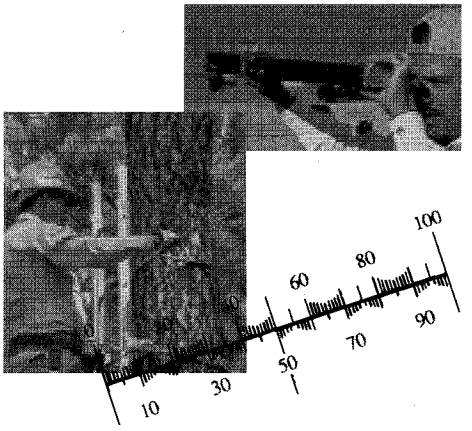
**Technology &
Development
Program**

2400—Timber Management
March 1997
9724 1801—SDTDC

INSTRUMENTS FOR MEASURING STEM DIAMETERS



INSTRUMENTS FOR MEASURING STEM DIAMETERS



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March 1997

This publication is the result of a field comparison, conducted by the San Dimas Technology and Development Center, of tools commonly used for measuring stem diameters, in the cruising of timber. More accurate field data will result in better management of National Forest resources.

The Stem Profile project was initiated by the Timber Sale Technology Committee. This group meets annually to discuss field needs in the area of timber sales, ranging from initial sale layout to the transport of forest products. Work is prioritized and future projects are developed to address needs which appear to be multi-regional in scope.

Field personnel are encouraged to contact their Regional representative on this committee if they see a need for the distribution of information, the application of new technology, or have ideas for new product development.

The current Timber Sales Technology Committee representatives are:

Dan Castillo	R01A
Don Martinez	R02F03A
Alan Lucas	R03A
Gerry Thompson	R04A
Alan Quan	R05F15A
Rick Toupin	R06C
Jim Sherar	R08F11A
Tom Peterson	R09A
Don Golnick	R10A
Rod Sallee	W01C

BOB SIMONSON, W07A
Program Leader, Timber

PROJECT PROPOSAL
USDA Forest Service
Technology and Development Program

SDTDC solicits input from the field for suggestions for future projects. Your suggestions are important to us, so please take a few moments to complete this form and return to the address provided.

Project Originator: Name _____ Date _____

Title _____

Unit _____

Mailing address _____

DG address _____ Telephone _____

Project Title: _____

Current Problem/Need
Describe how work is currently being done; current problem/need, location; why improvement is needed.

Proposed Solution
Describe your concept of the end product, i.e., new equipment design, video production, handbook, etc.

Potential Benefits
Describe how this product will improve safety, resource management; increase efficiency, customer satisfaction, productivity; reduce cost, time.

- affix here -

USDA, Forest Service
SDTDC
Attn: Timber Program Leader
444 E. Bonita Avenue
San Dimas, CA 91773-3198

User Feedback Survey

User Name (optional) _____
Title _____
Unit _____

Instruments for Measuring Stem Diameters
9724 1801

Benefits	YES	NO	Amount
Improves safety			
Saves money			
Saves time			
Increases efficiency			
Other			

How effective or relevant is this information?

What would you change?

General comments:

Contents

INTRODUCTION

Instruments that measure tree stem diameters and heights are useful tools for forest management. As the Forest Service moves towards more tree measurement timber sales, it has become more important that quantities stated in contracts are as accurate as possible. In addition, due to the use of taper equations in volume estimates, the need for accurate measurements of upper stem diameters has increased. Regardless of which tool is used to measure stem diameters, the user should check the accuracy by measuring a few known exact diameters, such as steel poles or metal drums which are perfectly round.

Five different instruments and three different tripods were tested to determine which ones were the most accurate and most efficient under varying field conditions for this project. The five instruments compared were the Barr and Stroud dendrometer, relaskop, tele-relaskop, Jim-Gen Wheeler pentaprism, and the Criterion 400 laser.

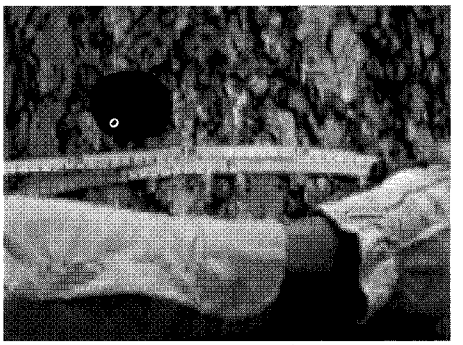
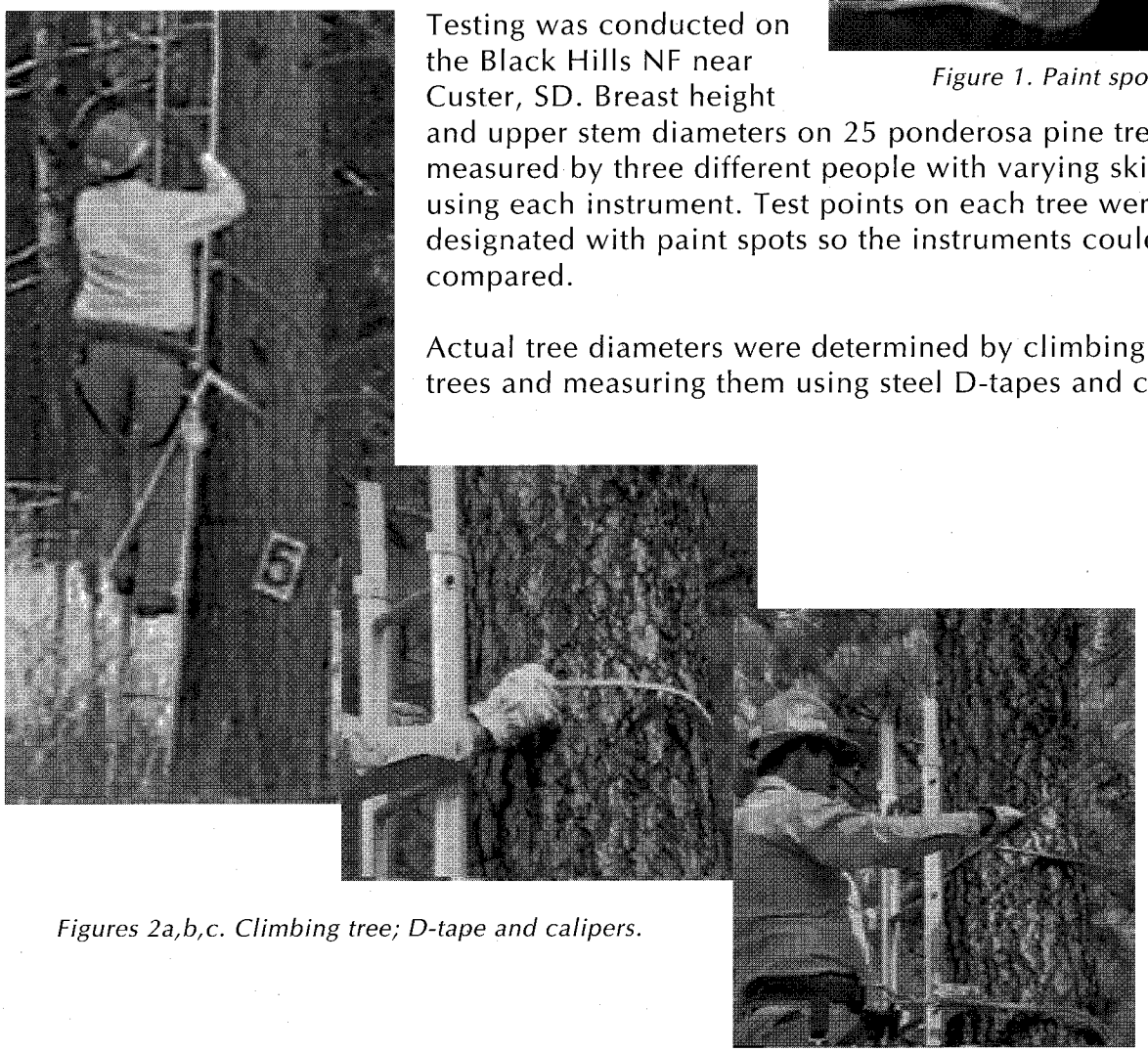


Figure 1. Paint spot.

Testing was conducted on the Black Hills NF near Custer, SD. Breast height and upper stem diameters on 25 ponderosa pine trees were measured by three different people with varying skill levels using each instrument. Test points on each tree were designated with paint spots so the instruments could be compared.

Actual tree diameters were determined by climbing the trees and measuring them using steel D-tapes and calipers.



Figures 2a,b,c. Climbing tree; D-tape and calipers.

The test was conducted in two phases, one in winter with very cold temperatures—0 to -15 degrees F (-18 to -26 degrees C) and one in summer with warm weather—70 to 80 degrees F (21 to 26 degrees C), to determine the effect, if any, of differing field conditions.

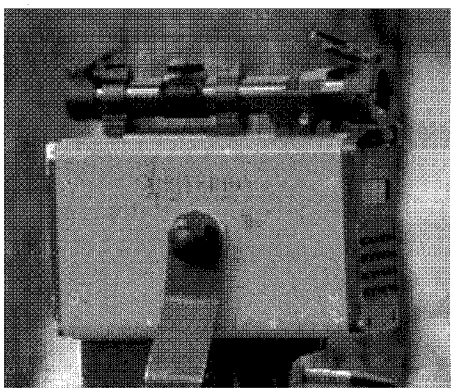


Figure 3. Criterion 400.

INSTRUMENTS

The Criterion 400 laser instrument can be handheld or mounted on a monopod or tripod for increased accuracy. It is a rapid measuring total station, custom made for the forest industry. It includes a numeric keypad, laser slope distance measurement flux-gate compass, tilt-angle sensor, reticle scope, data collector, and serial port (for down loading data). Tree diameters are determined by looking through the reticle scope and counting the number of tick marks across the tree and entering this into the keypad. The software uses the distance to the tree and number of tick marks, which is input by the user, to calculate the diameter and displays it on the screen. This device weighs approximately 6.5 pounds (3 kg) and costs about $11,000.

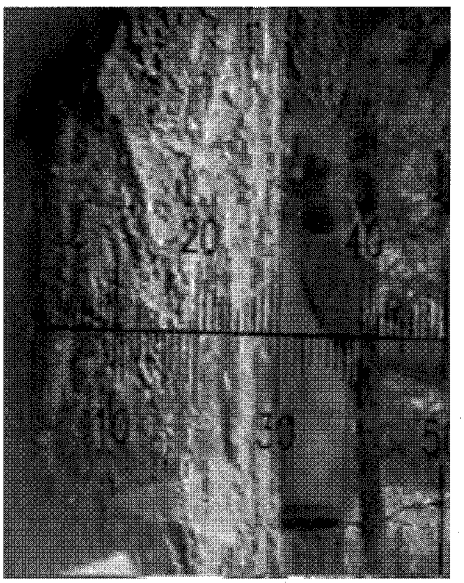


Figure 4. Tick marks.

The Laser Technology, Inc.'s Criterion 400 laser instrument is gaining popularity with Forest Service users. As these users have gained experience with the laser, most are pleased with its accuracy when measuring tree heights, but there has been some concern about its use in measuring upper stem diameters, due to the difficulty in reading the marks (ticks) that are used to determine diameter.

The Bar and Stroud dendrometer is a precision optical rangefinder with an incorporated inclinometer that can be handheld or mounted on a staff or tripod. The eyepiece is inclined so the line of sight is downward for comfortable viewing. The scale is viewed through a magnifier and is uniformly divided into arbitrary units which are converted into ranges and tree diameters by calculating with an equation or using provided tables. This device weighs approximately 5 pounds (2.3 kg) and is no longer commercially available. (However, this instrument is still in use by some, including researchers developing stem taper algorithms, and is considered by many to be the best instrument for measuring diameters with precision.)

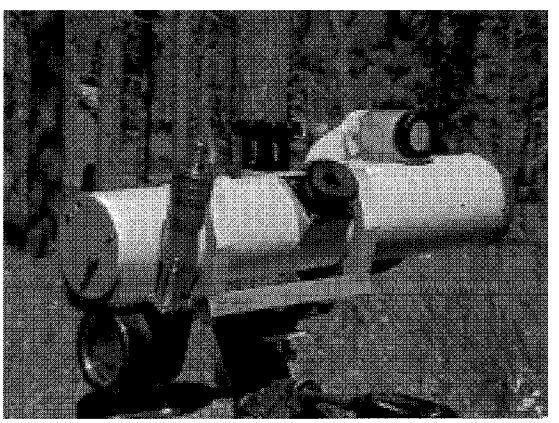
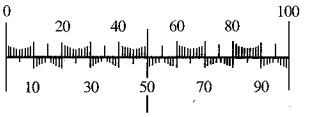


Figure 5. Dendrometer.



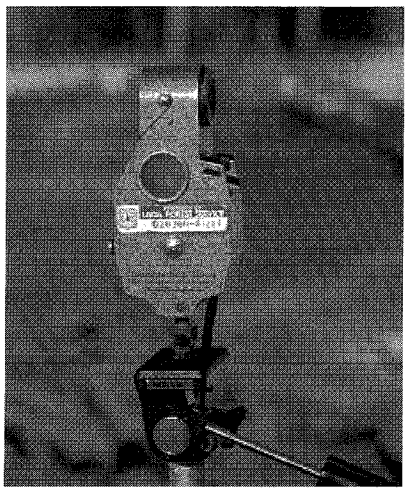


Figure 6. Relaskop

The relaskop is a small, lightweight optical device that can be handheld or mounted on a staff or small tripod. It is designed to be used at either 33 or 66 feet (10 to 20 m) from the tree. Looking through the eye window, the field of view is divided into two halves, the upper half is the terrain and trees and lower half is a series of scales and bars. To take a reading, the brake button is released and the scale wheel rotates on a pendulum to correct for slope. Diameter is calculated at a distance of 33 or 66 feet (10 to 20m). The number of bars covering the width of the tree are each equal to two or four inches (51 or 102mm) each respectively. This device weighs approximately 1 pound (0.45 kg) and costs about $1200.

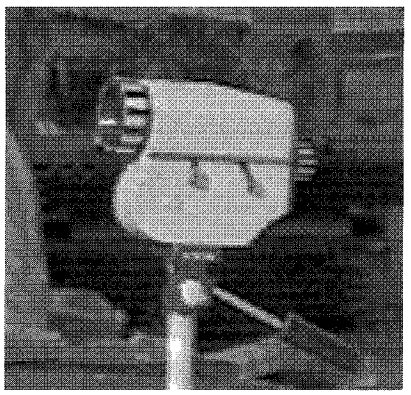


Figure 7. Tele-relaskop.

The tele-relaskop is very similar to the relaskop but has an 8x magnification lens and is designed to measure tree diameters at any distance from the tree (distance has to be measured or known). It could be handheld but works better if a medium duty tripod is used. The tree diameter is read off the scale, is slope corrected, and is a percentage of the distance between the instrument and the tree. This device weighs approximately 4 pounds (1.8 kg) and costs about $8350.

The Jim-Gen Wheeler pentaprism caliper is either handheld or mounted on a tripod and can be used at any distance from the tree to be measured. Looking through the viewing slot, two images of the tree can be seen (like a rangefinder). The upper image is the left edge of the tree and the lower image is the right edge of the tree reflected in the stationary prism. By sliding the movable prism until the two tree edges are aligned, the diameter is indicated on the scale by the pointer. This device weighs approximately 2.2 pounds (l kg) and costs about $470.

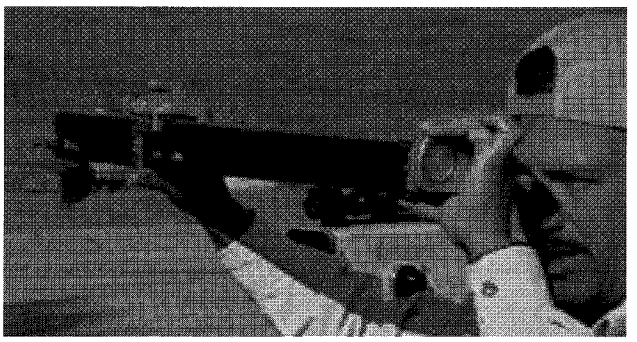


Figure 8. Pentaprism.

Preliminary testing revealed that all of the instruments except the pentaprism were easier to use and more accurate when mounted on a tripod. (Tripods were used for all instruments except the pentaprism for this testing.) In addition, the quality of the tripod can be critical. Three different models were used during testing and are evaluated below.

TRIPODS

The Bogen model 3046 (with model 3039 head attachment) is a high quality, heavy duty tripod with a mid-leg stabilizer that has large knobs that are easy to adjust. It worked well with the laser and tele-relaskop. Cost, about $335.

The Welt model PT-3 is a medium duty tripod with no stabilizers. It worked well with the dendrometer. Cost, around $150.

The Slik (no model number) is a lightweight, no-stabilizer tripod. It worked well with the relaskop. Cost, about $30.

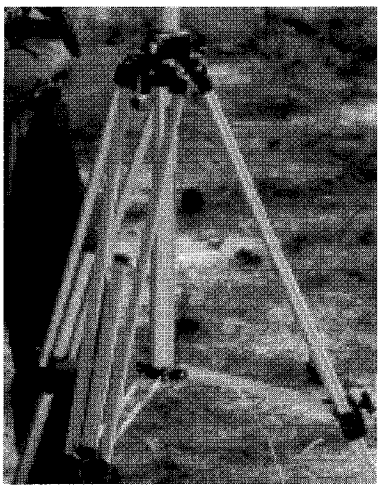


Figure 9. Bogen model 3046.

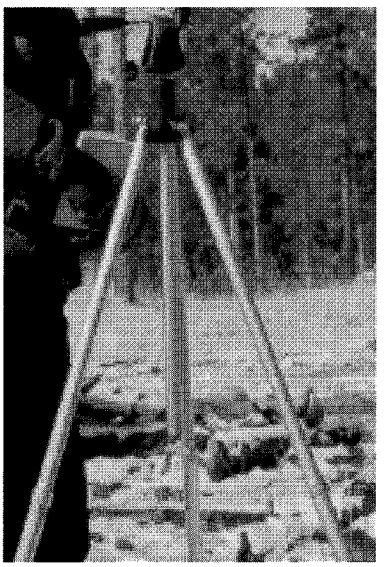
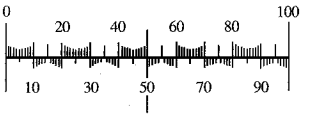


Figure 10. Welt model PT-3

Figure 11. Slik tripod.

The testers noted that high-quality tripods provided a stable platform for more accurate readings, were easier to use, and could withstand more punishment when packed into the woods. The feet should be pointed for sticking into the dirt and should not come off easily. Large knobs for adjusting tilt are preferred, particularly when wearing gloves.

After completing our test we found a tripod made by Vivitar that has all of the features needed and is reasonably priced. The Model V3000 is a medium duty light weight tripod and is available at WalMart at a cost of $69 to $79.



TEST RESULTS

Percent differences were calculated between the standard measurement (calipers) and the tool being tested. (All instrument readings in this test are compared to the caliper readings, which were taken at the same angle (viewing angle) as the instruments.) The caliper measurement itself is not exact since any slight movement on a non round tree could change the diameter by a fraction of an inch.

See Appendix for a statistical summary of test results.
For each group of test measurements (e.g. one operator, 25 measurements of breast-height diameters), the percent inaccuracy and percent bias were calculated. Percent bias indicates whether a tool consistently over-or under-estimates diameters.

From these results, it seems that the only tool that showed significant bias was the telerelaskop in the winter test, however, this may be due to the experience level of the operator rather than the instrument itself. The inaccuracy of the instruments ranged from about 5 to 12 percent difference from the caliper measurements. The data shows that these instruments fall into two groups with the Laser and the dendrometer tending to be the most accurate and the other three instruments being somewhat less accurate.

It is interesting to note that there were small differences (averaging 2 percent but ranging up to 5 percent) between the readings with the caliper and D-tape since most of the trees used in this test were not round. This means that using any of the instruments tested to measure diameters causes some inaccuracy simply due to the oblong shape of the trees. For cruising, as long as a large enough sample of tree diameters is measured, this should not be a problem since these inaccuracies will cancel each other out.

One aspect of the procedure used in this test may have had an effect on the accuracy of this data. All diameter readings were taken at the same place on the tree (marked by a spot of paint) with each instrument, so they could be compared to each other. However, with the relaskop, this meant that the black and white bars had to be read by estimating fractions of a bar, whereas in normal use, the relaskop would simply be tilted up until the tree's edges lined up with a whole bar, and then the height of that point would be measured. When using the relaskop in the normal manner, better accuracy than is shown in the results is possible.

In addition to the accuracy testing, test personnel subjectively rated the instruments (compared to each other) on several factors as shown below:

	Ease to Learn	Ease of Use	Ease to Carry	Speed of Use	Recommended Tripod
(5=most difficult, slowest, worst,)					
Instrument					
Laser	5	4	5	2	Model 3046
Dendrometer	4	5	4	5	PT-3
Tele-relaskop	2	2	2	4	3046-PT-3
Pentaprism	3	3	3	1	Slik/none
Relaskop	1	1	1	3	slik

	Must walk to tree	Problems with interference from- Hat brim	glasses	sun/shade
Instrument				
Laser	N	N	Y	Y
Dendrometer	N	Y	Y	Y
Tele-relaskop	Y	N	N	N
Pentaprism	N	N	N	N
Relaskop	Y	N	N	N

Test personnel also recorded the following observations:

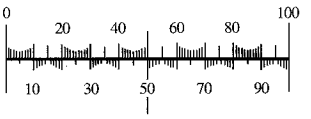
Laser

Pros

- fast, easy to use once menu sequences are learned, user friendly
- very durable but needs heavy duty tripod
- good feedback (reads diameter on screen)- too heavy, too bulky

Cons

- buttons hard to push with gloves (can use pointer or pencil)
- tick marks in reticle difficult to see (needs different colors or sizes)
- reticle scope - moving head/eye creates a parallax effect (+/- difference) when reading diameter.
- must remember to charge batteries (also needs battery charger that can be plugged into vehicle cigarette lighter)
- expensive



Tele-relaskop

Pros

- good optics
- light, easy to carry but must have good tripod with easy adjustment
- easy to learn, to use but requires calculator or data recorder

Cons

- pendulum difficult to settle down (due to effect of tele)
- must walk to tree to measure distance
- expensive

Relaskop

Pros

- light, small
- can be used to find heights at particular (measured) distances
- inexpensive

Cons

- difficult to subdivide small bars on scale
- must measure distance to tree
- accuracy at close range suspect

Pentaprism

Pros

- can be used without tripod
- light (but somewhat bulky)
- reads diameter direct (good feedback)
- inexpensive

Cons

- hard to slide prism mechanism, especially in cold weather and with gloves
- poor view of tree (needs better optics)
- need clear background (difficult to know if you are on the correct tree)

Dendrometer

Pros

- excellent optics (good look at tree)
- easy to use but must have calculator or field data recorder
- operators were confident of readings

Cons

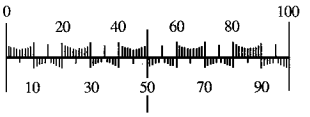
- however no direct feedback because values read are meaningless
- needs medium duty tripod with easy to adjust head
- not commercially available

All these instruments require a clear shot at the tree. Trees behind the one being measured can cause problems and fog or snow can cause difficulty in reading. Good training is required before using any of these devices. Personnel should be tested and checked periodically to make sure they are using these devices properly and that the devices are calibrated.

CONCLUSION

Which instrument is the best? This is a difficult question, and it cannot be based solely on accuracy of upper stem diameters, or any other single parameter. The difference in the amount of time required to walk to each tree to use a tape versus reading heights and distances with a remote instrument is important. How much you can afford and how much heavy and bulky equipment you want to carry in the woods may be the determining factors in the selection process. With the advent of small, inexpensive range finding devices, a combination of these tools to measure distances and heights in conjunction with an inexpensive instrument to determine tree diameters may be the best solution.

For further information on these instruments or this test, please contact Jerry Kempf at 909-599-1267 x236.



APPENDIX

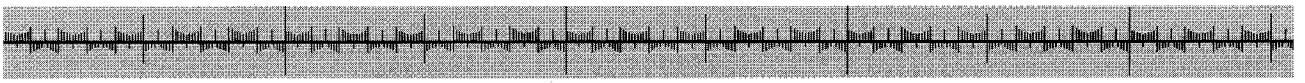
STATISTICAL METHODS AND RESULTS

Percent differences were calculated between the standard measurement method (calipers) and the tool being tested.

Percent bias indicates whether the tool consistently over- or under-estimates diameters. From these results it seems that the only tool that showed significant bias was the telerelaskop, although individual operators obtained bias results in some cases with other tools. While the telescopic optics of the telerelaskop provide the operator with a good look at the tree, they also make it more sensitive to operator input and more difficult to steady and read, which is probably the reason for the bias. If a given instruments' bias can be definitively specified, this can be used as a correction factor for the data. Percent bias was calculated as the difference between the means of the standard and tested tools, divided by the mean standard measurement.

For each group of test measurements (e.g. one operator, 25 measurements of breast-height diameters) the sum of the squares of the percent differences was calculated. (Squaring the plus and minus deviations from the caliper reading prevents cancellation.) The percent inaccuracy is the inaccuracy specification that could be met at the 95% confidence level, assuming that the data taken here was not a 1-in20 or rarer anomaly. This method assumes that the test measurements follow a normal distribution with mean equal to the standard measurement. For these results, it would seem that the dendrometer would satisfy the smallest inaccuracy standard, the other instruments being about equal.

It should be noted that for instruments without bias, the percent inaccuracy falls equally on both the plus and minus side of the true reading; therefore if a large enough sample is measured, these plus and minus inaccuracies will cancel each other out.

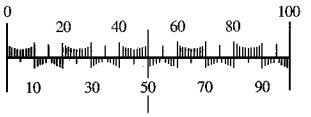


The following results are ranked from least experienced to most experienced operator.

SUMMER RESULTS

1. Measurement of UPPER DIAMETERS using various tools compared to calipers

Tool:	**LASER**	**DEND**	**TELER**	**PENTA**	**RELAS**
Percent inaccuracy:					
Operator 1	5.9	6.4	6.0	11.5	7.5
Operator 2	5.5	3.9	9.8	8.1	14.8
Operator 3	8.4	4.9	6.4	8.4	8.0
All operators	7.3	5.6	8.2	10.2	11.5
Percent bias:					
Operator 1	-1.0	2.8	0.9	-3.9	-2.6
Operator 2	-1.1	1.2	-0.3	-2.0	-4.2
Operator 3	3.4	1.9	-2.0	2.9	-0.7
All operators	0.4	2.0	-0.5	-1.0	-2.5
Range of percent differences: (all operators)					
High	11.6	10.8	13.9	12.9	8.8
Low	-9.0	-3.2	-10.3	-16.7	-28.6



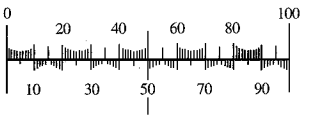
2. Measurement of BREAST HEIGHT DIAMETERS using various tools compared to calipers.

Tool:	**LASER**	**DEND**	**TELER**	**PENTA**	**RELAS**
Percent inaccuracy					
Operator 1	8.5	5.9	6.1	8.2	8.3
Operator 2	5.9	13.8	9.3	7.5	13.4
Operator 3	7.3	2.6	2.8	6.8	5.8
All operators	8.0	9.5	7.2	8.2	10.5
Percent bias					
Operator 1	1.5	0.7	1.2	-0.3	-0.9
Operator 2	-0.1	1.5	0.1	-0.3	-4.4
Operator 3	3.2	1.0	0.0	1.5	-2.0
All operators	1.5	1.1	0.4	0.3	-2.4
Range of percent differences: (all operators)					
High	12.1	29.7	15.2	11.0	15.6
Low	-7.5	-15.3	-6.8	-13.4	-17.5

WINTER RESULTS

1. Measurement of UPPER DIAMETERS using various tools compared to calipers.

Tool:	**LASER**	**DEND**	**TELER**	**PENTA**	**RELAS**
Percent inaccuracy:					
Operator 1	10.5	4.1	14.1	10.0	10.1
Operator 2	7.3	6.3	11.3	8.1	11.6
Operator 3	4.4	6.8	9.3	9.5	8.1
All operators	8.4	6.3	12.7	10.0	10.9
Percent bias:					
Operator 1	-0.7	0.7	6.8	-1.1	-5.3
Operator 2	-2.4	-0.1	5.2	-1.1	-3.1
Operator 3	0.2	0.8	4.5	1.4	-0.7
All operators	-1.0	0.5	5.5	-0.3	-3.0
Range of percent differences: (all operators)					
High	13.2	6.4	15.7	19.0	16.9
Low	-20.5	-15.5	-7.8	-16.2	-15.4



2. Measurement of BREAST HEIGHT DIAMETERS using various tools compared to calipers.

Tool:	**LASER**	**DEND**	**TELER**	**PENTA**	**RELAS**
Percent inaccuracy:					
Operator 1	15.5	10.7	17.2	16.3	14.7
Operator 2	4.8	3.0	8.2	8.5	9.5
Operator 3	6.5	4.6	9.1	7.3	6.6
All operators	10.9	7.5	13.2	12.4	11.7
Percent bias:					
Operator 1	1.0	3.1	8.5	5.1	0.5
Operator 2	0.5	0.7	4.4	1.2	0.5
Operator 3	2.4	1.5	4.6	2.0	1.1
All operators	1.3	1.8	5.8	2.8	0.7
Range of percent differences: (all operators)					
High	22.7	29.1	30.3	37.2	20.9
Low	-31.7	-4.2	-6.2	-9.7	-23.6