Field Measurement of Cable Tensions for Skyline Logging Systems

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John Sessions
Graduate Student, Forest Management
and
Logging Specialist, U.S. Forest Service

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CONTENTS

SUMMARY

Two methods for measuring cable tensions for skyline logging systems have been discussed. The wave cycle method is generally more useful for tension measurement on unloaded skylines. The Abney method is more applicable for tension measurement on loaded skylines. Choice of the specific method and its application will depend on the particular situation and the judgement of the observer.

FIELD MEASUREMENT OF CABLE TENSIONS FOR SKYLINE LOGGING SYSTEMS

INTRODUCTION

In recent years, a great deal of research in North America has been directed toward refining methods of assessing the load-carrying capability of skyline systems. Little effort has been directed, however, toward field measurement of cable tensions for skyline logging systems to facilitate initial tensioning of unloaded skylines or to provide means of field checking to see whether skyline systems are overloaded.

The two surest methods of preventing overloads are to have continuous-reading tension meters on the line or to have self-regulating mechanisms, such as adjustable skyline brakes or tensioning devices. Often these devices, however, are not available.

This paper describes two alternative methods of measuring skyline tension and their application.

WAVE CYCLE METHOD

For many years, European loggers used a simple principle of physics to determine skyline tensions. By striking a skyline of known length and unit weight and measuring the time required for the created wave to travel along the skyline and return (Figure 1), the approximate tension in the skyline can be determined.

The formula, which is easily derived from the one-dimensional wave equation for the vibrating string (2), is

$$\partial^2 y/\partial t^2 = (Tg/w)(\partial^2 y/\partial x^2), \qquad \text{Equation 1}$$

where x is longitudinal displacement of the wave from the origin, y is perpendicular height of the wave, t is elapsed time since wave left origin, T is line tension, w is unit weight of line, and g is gravitational acceleration.

Observing that Tg/w has the units of $(\text{length/time})^2$ or velocity^2 and that the wave travels up the skyline and returns through a length, 2L, we can derive a direct expression for the skyline tension, T.

Letting travel distance for the wave = 2L, velocity = $(Tg/w)^{1/2}$, and the wave cycle time = R, we have wave cycle time = wave travel distance/wave velocity = $2L/(Tg/w)^{1/2}$. Squaring both sides and rearranging,

$$T = (4L^2 w)/(gR^2), \qquad \text{Equation 2}$$

where T is skyline tension (pounds), L is skyline length (feet), w is weight per foot of skyline (pounds per foot), R is round trip time for wave (seconds), and g is gravitational acceleration (32.2 feet per second per second).

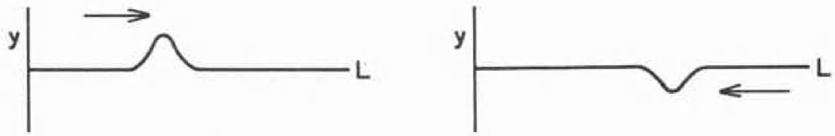

Figure 1. Wave traveling along line and returning.

The wave equation assumes constant tension, uniform weight, no sag, and no damping of the traveling wave. Even with these assumptions, predictions from the wave equation have deviated in recent tests less than 5 percent from field measurements by tension meters placed on skylines.

The wave cycle method is used most easily at the headspar for short towers or at the tail anchor, if no tail tree is used. When measurements are taken with a load on the line or with some other obstruction, such as an intermediate support, the appropriate length to use is the length of skyline from the point of measurement to the obstruction. If wave returns are rapid, at intervals less than 2 seconds, the time for the first two or three waves to return generally is summed and averaged. A stopwatch should be used.

Calculating a skyline tension in the field can be done quickly if you know the length, diameter, and weight of the skyline and the wave cycle time measured after striking the skyline with a heavy object. An example of this calculation follows. Given the skyline length as 1,000 feet (unobstructed), skyline diameter as 7/8 inch, skyline weight as 1.42 pounds per foot, and wave cycle time as 3 seconds, the skyline tension = $[(4)(1{,}000)^2(1.42)]/[(32.2)(3)^2] = 19{,}600$ pounds.

Nomographs provide the easiest method for reducing field data. Sample nomographs for different line sizes are in the Appendix. Programmable handheld calculators, with the wave equation, offer an additional method for quick reduction of field measurements.

ABNEY METHOD

Field measurements from the landing can be made with an Abney level to obtain a rapid measurement of the deflection in percent of the loaded skyline at midspan. Comparison of the observed deflection and log load with allowable safe values tabulated in the U.S. Forest Service publication PNW-39 Supplement will indicate whether or not the skyline is overloaded (1).

The procedure is simple, and the calculation is done in two parts. First, the approximate deflection in percent of the loaded skyline at midspan is calculated.

In Figure 2, the loaded midspan deflection is approximately:

Percent midspan deflection = $50\,(H/L) + (S_2 - S_1)/2$, Equation 3

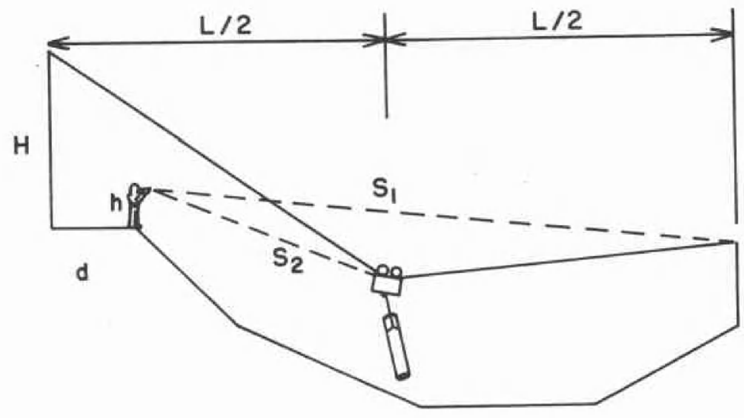

Figure 2. Measurements for calculating percent deflection of the loaded skyline at midspan.

where H is headspar height (feet), L is horizontal span (feet), S_1 is percent slope from landing to tailspar, and S_2 is percent slope from landing to carriage at midspan.

Second, the approximate deflection is corrected for the position of the observer on the landing by subtracting an adjustment that is calculated as follows:

$$\text{Adjustment for observer position} = [100h + 2dS_2 - dS_1]/2L, \qquad \text{Equation 4}$$

where d is horizontal distance of observer from headspar (feet) and h is height to eye of observer (feet).

The magnitude of the adjustment decreases as the span increases. For longer spans or downhill yarding, or both, the adjustment is often neglected as insignificant.

The midspan deflection is then used with U.S. Forest Service publication PNW-39 Supplement to determine if the skyline is overloaded.

The following example shows how the loaded skyline deflection is calculated and used to check the skyline tension. Let the skyline = 1 3/8 inches, breaking strength = 192,000 pounds, H = 110 feet, L = 2,000 feet, S_1 = 20 percent, S_2 = 30 percent, h = 5 feet, and d = 40 feet.

From Equation 3, the midspan deflection = 50(110/2,000) + (30-20)/2 = 7.75 percent. From Equation 4, the adjustment = [5(100) + 2(40)(30) - 40(20)]/2(2,000) = 0.53 percent, and the adjusted midspan deflection = 7.75 - 0.53 = 7.22 percent. On page 19, U.S. Forest Service publication PNW-39 Supplement, we find that for this span, skyline size, skyline slope, and a midspan deflection of about 7 percent, the weight of log plus carriage cannot be greater than 14,000 pounds, or the skyline is overloaded.

LITERATURE CITED

1. CAMPBELL, Charles O. Supplement to Skyline Tension and Deflection Handbook. U.S. Dept. Agric., Forest Service, Pac. N.W. For. and Range Expt. Sta., Portland, Oregon. Res. Paper PNW-39 (Supp.). 1970.

2. WYLIE, C. R. Advanced Engineering Mathematics. 3rd ed., McGraw Hill. P. 284. 1966.

APPENDIX

Wave Equation Nomographs

Procedure: step 1, Select nomograph with appropriate cable diameter (Figures 3, 4); step 2, enter graph with cable length and wave cycle time; and step 3, read cable tension.

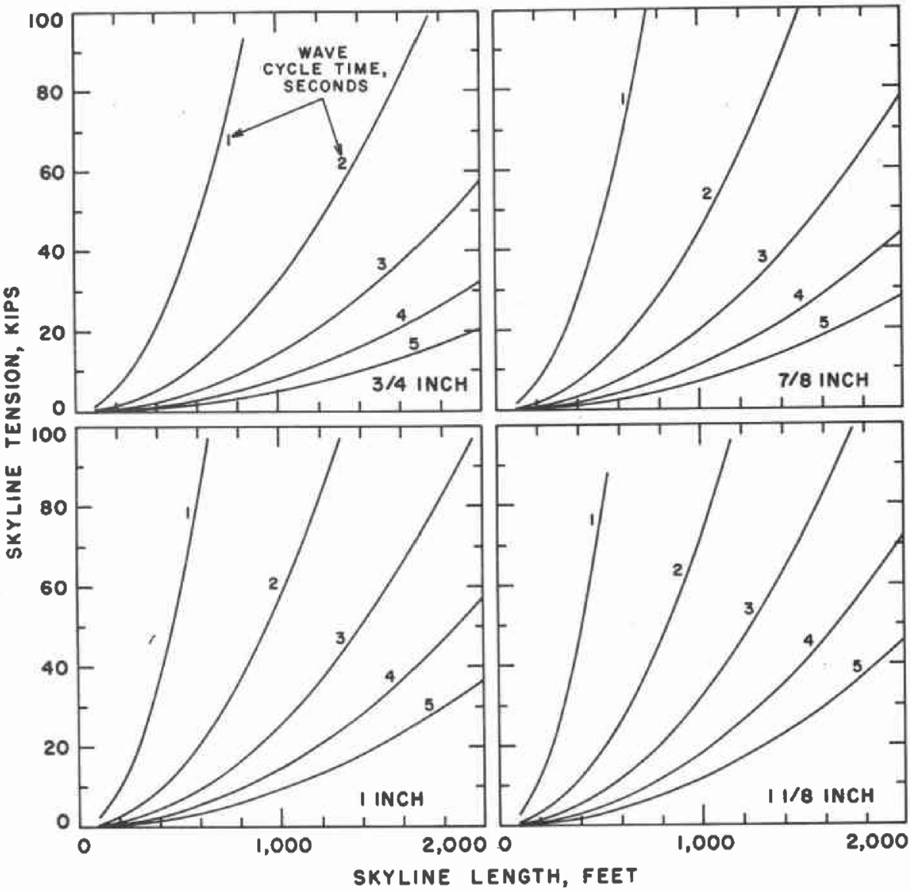

Figure 3. Sample nomographs for cable diameters of ¾, 7/8, 1, and 1 1/8 inches and skyline lengths less than 2,000 feet.

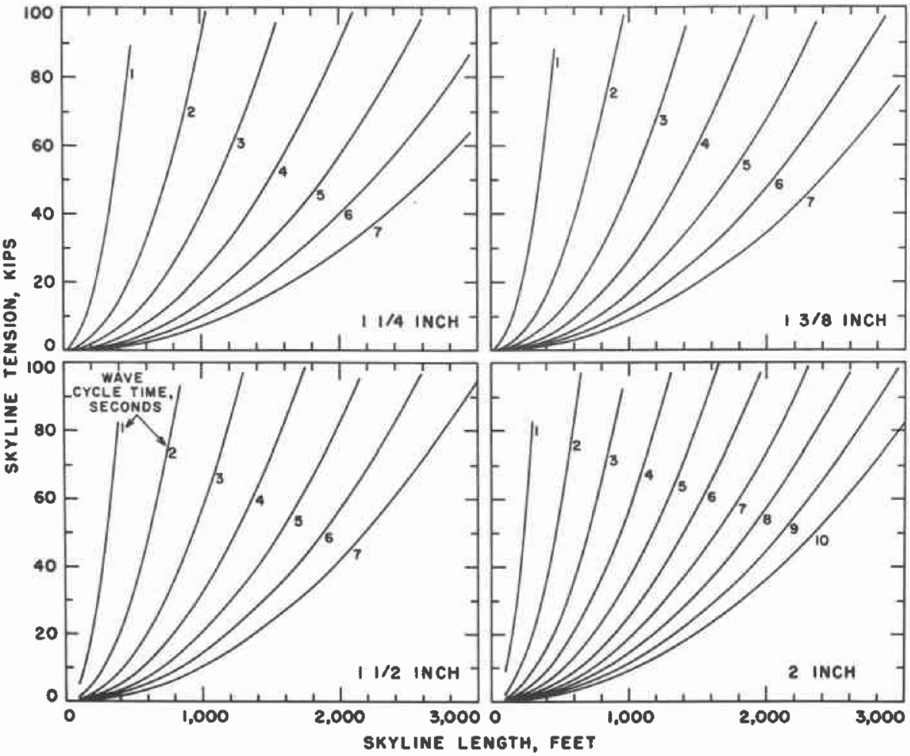

Figure 4. Sample nomographs for diameters of 1¼, 13/8, 1½, and 2 inches and skyline lengths less than 3,000 feet.