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A Procedure for Analysis of Guyline Tension

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Abstract

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Most cable logging operations use a spar held in place near the landing by a system of guylines and anchors. Safety and economic considerations require that overloads be avoided and that the spar remain stable. This paper presents a procedure and a computer program to estimate the guyline and anchor loads on a particular system configuration by a specific set of operating line tension loads. A brief description of the analytical model used for the computations is included. There are instructions on the use of the computer program, a description of the necessary outputs, and a program listing for those who wish to prepare the program for use on other computer facilities.

Keywords: Logging equipment engineering, cable skidding equipment, models, computer programs/programing.

Contents

Introduction

An important component of any cable logging system, once it is set in place for yarding, is the lift that can be provided to suspend the logs. The deflection available to the system is a measure of this lift and is usually provided by a spar tree or tower at the landing. Spars must be stabilized by a system of anchors and guylines capable of resisting the yarding loads. This paper describes the analytical model and a computer technique needed to analyze the guyline tension response to the yarding loads.

Both safety and economic considerations dictate that operators of cable systems be concerned about the proper anchoring of the spar. The upset or collapse of a spar results in economic losses and can also produce injury or loss of life. State safety records, however, show that such mishaps are common in the logging industry. The causes of these mishaps are generally traced to a guyline tension overload resulting in failure of an anchor, a guyline, or a spar. These overloads are often the result of a poor arrangement of guylines or anchors, or a lack of understanding of just how severely the system was loaded. Our objective in this analysis was to provide a means by which the relationships betweeen the tensions produced in a multiguyline system may be examined as a function of the loads applied to the tower by the operating lines.

When provided with the operating line tensions and the geometric arrangement of the anchor system, the computer program can calculate the loads in the guylines, anchors, and the spar itself. The model is applicable to the spar-guyline-anchor system shown in figure 1. This is the system generally used for high-lead, live skyline (often called shotgun or flyer) systems, or other skylines that employ more than two operating lines. The spars are usually made of steel and are free to pivot at their base, the latter being a requirement for proper application of this program.

The analytical and computational approach described can be used in most areas of forest engineering for: (1) determining anchor loads, (2) selecting stump anchors or placing artificial anchors if required, (3) training forest engineers in spar tower anchor layout, and **(4)** analyzing tail and support trees. In summary, this program provides a means for a case by case, numerical examination of the spar-guyline-anchor system loads caused by the forces encountered during logging.

Analytical Model

The analysis and the computer algorithms were developed as a cooperative effort. Our first attempt to develop a program was based on an analytical model that represented the guylines of the system as linear springs and was reported by Bramwell (1977). In January 1977, a field test of a guyline anchor system was performed (Jorgensen and others 1977); the results of our linear spring model were found inadequate as an accurate predictor of guyline tensions, particularly when the system had low guyline pretensions. Therefore, a second program was developed based on a model that accounts for the influence of the changing catenary shape of the guylines (Reutebuch 1978). In addition, a more direct computational algorithm was developed to alleviate several instabilities that would occur in the original approach. The results of this model agreed well with our experiments. The program presented here is based on it. The basic elements of this analysis will give the user an appreciation for the applicability of the program.

Figure 1—Guylines supporting
a steel logging tower.

Coordinate System and System of Units

A right-handed rectangular coordinate system with its origin at the tower base (fig. 2A) is used in this analysis.

The location of each anchor point is described by the azimuth direction, distance, and elevation relative to the tower (spar) base. The direction of pull by an operating line is given by its angular orientation in terms of the azimuth and elevation angle. The latter is defined with respect to the horizontal base plane (X-Y plane). The traditional survey method of measuring azimuth is in a clockwise direction. In this analysis, azimuth 0° is alined with the positive X axis as shown in figure 2B.

The British Engineering System (Halliday and Resnik 1961) of units is used throughout this analysis and in the computer program.

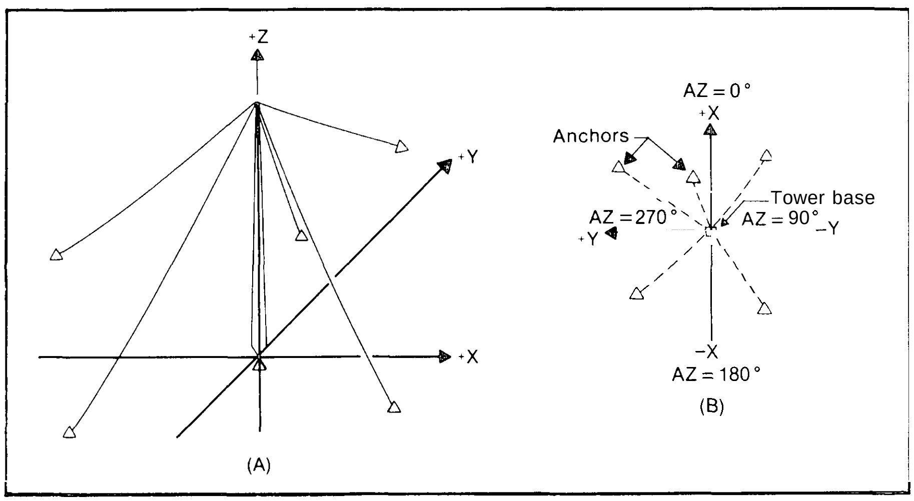

Figure 2.—Tower system coordinate system.

Static Equilibrium of the Tower System

The operation of a yarding tower system can be divided into two phases: (1) the setup phase in which yarding is not underway and (2) the yarding phase in which yarding is underway. In both these phases, the tower system is considered to be in static equilibrium.

If we assume that the operating lines and the guylines are attached to a common point at the top of the tower, the tower system can be modeled as a system of concurrent forces in space acting through the top of the tower as shown in figure 3.

Such a system of concurrent forces is in static equilibrium when the sum of the moments (M) about any given point is equal to zero. The resultant, R, of the forces at the tower top equals zero:

$$\Sigma M_{base} = Rh = 0,$$

where h = tower height;
therefore, R = 0.

It follows that the sum of the components of the concurrent forces F (that is, the guyline tensions, T_i ; the operating line tensions, f_j ; and the compressional force in the tower, C) must be equal to zero:

$$\Sigma F_x = \Sigma T_{xi} + \Sigma f_{xj} + C_x = 0. \quad (1)$$
$$\Sigma F_y = \Sigma T_{yi} + \Sigma f_{yj} + C_y = 0. \quad (2)$$
$$\Sigma F_z = \Sigma T_{zi} + \Sigma f_{zj} + C_z = 0. \quad (3)$$

The tower system is in static equilibrium when equations (1), (2), and (3)are satisfied.

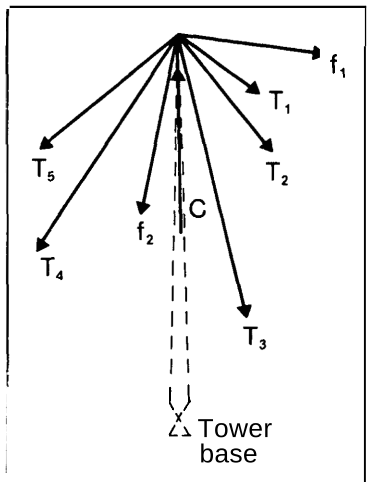

Figure 3.—Free body diagram of tower top.

Analytical Description of the Guyline

In this section, the properties of a guyline as a structural member in a yarding tower system are presented so that the guyline tensions needed to solve equations (1), (2), and (3) may be calculated.

Tension stretch relationship of wire rope.—Wire rope is used for the guyline material. Within its elastic limits, up to 65 percent of the cable breaking strength (Broderick & Bascom Rope Company 1966), the stretch in a guyline, ΔS, caused by a tension, T, obeys Hook's law:[1]

$$\Delta S = \frac{T\ell}{AE},$$

or $\Delta S = \frac{T}{k}$;

where $k = \frac{AE}{\ell}$,

ℓ = wire rope length,
A = metallic cross-sectional area of wire rope,
E = modulus of elasticity of wire rope material, and
k = guyline coefficient of stretch.

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

When the tension in a guyline exceeds its elastic limits, cable stretch cannot be accurately computed using the relationship given above. Therefore, if a guyline is tensioned beyond the elastic limit, the results of this analysis are invalid.

If we use the above relationships, the guyline stretched length, S_i, may be expressed in terms of the guyline unstretched length, S_{oi}, and its associated tension, T_i:

$$S_i = S_{oi} + T_i / k_i. \qquad (4)$$

Catenary description **of** the guyline.—A guyline in a tower system is a cable evenly loaded along its length and hanging under its own weight. Such a cable assumes the shape of a catenary curve. An analytical description of the catenary curve and the formulation of various catenary problems commonly encountered in cable logging systems have been presented by Carson (1977).

Carson formulated the general catenary equations that relate guyline geometry, as shown in figure **4,** to guyline length and tension. The stretched length of the ith guyline is given by the equation:

$$S_i = [Y_i^2 + (2 m_i \sinh (d_i / 2 m_i))^2]^{1/2} \qquad (5)$$

The tension at the upper end of the guyline is given by the equation:[2]

$$T_i = w_i / 2(S_i \coth(d_i / 2 mi) + Y_i) ; \qquad (6)$$

where m_i is the catenary parameter and is equal to the horizontal component of tension, H,, at any point along the guyline divided by the weight per foot of the guyline, w_i:

$$m_i = H_i / w_i .$$

Since the value of H_i is not always known for a guyline, equations (5) and (6) are often transcendental and require an iterative solution technique.

Geometric Compatability **of** the Tower System

Each guyline in the tower system has a stationary, rigid anchor at a known distance, **A,,** from the base of the tower and a common anchor point at the top. To solve equations (5) and (6), the relative location of the tower top with respect to each stationary guyline anchor must be determined.

[2]Unless otherwise stated, guyline tension refers to the tension in the guyline at the top of the tower.

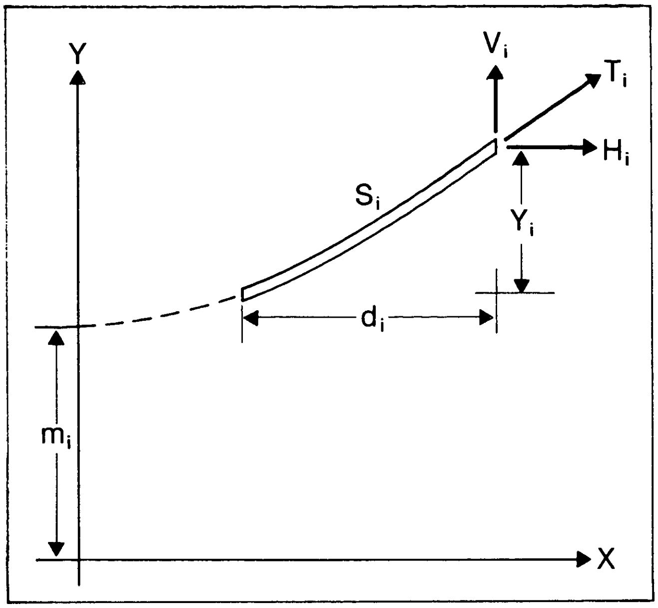

Figure 4. — Coordinate system and geometry for a single guyline.

All possible locations of the tower top lie on the surface of a sphere, with its center at the tower base and its radius equal to the tower height as shown in figure 5.

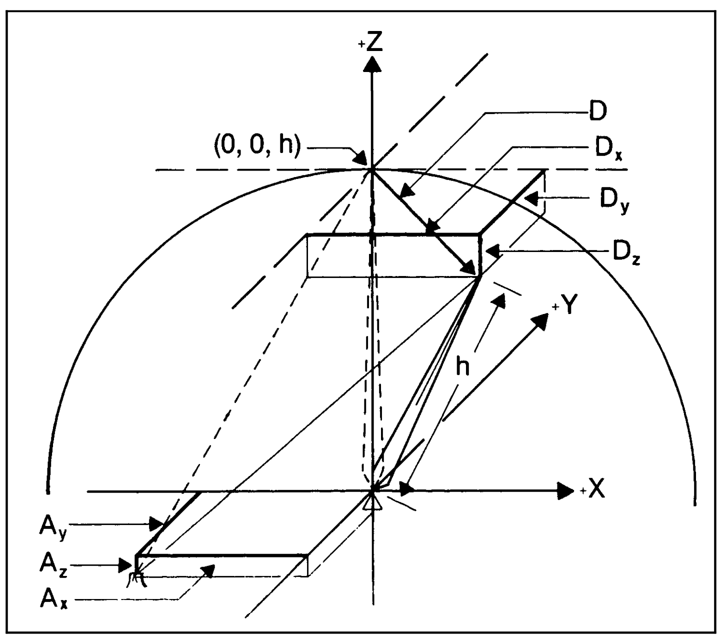

Figure 5. — Spherical surface of possible location of tower top.

Defining tower top displacement, D, as the distance from the point (0,0,h) to the actual location of the top of the tower (fig. 5), the equation of this sphere may be expressed in terms of tower height and tower top displacement:

$$h = [D_x^2 + D_y^2 + (h+D_z)^2]^{1/2} \quad (7)$$

The relative location (D_i, Y_i) of the tower top with respect to each anchor can then be expressed:

$$D_i = [(A_{xi} + D_x)^2 + (A_{Yi} + D_Y)^2]^{1/2}; \quad (8)$$

$$Y_i = -(A_{zi} - h - D_z); \quad (9)$$

where A_i is the distance from the tower base to the ith anchor location.

Computational Model of the Yarding Tower System

The mathematical relationships developed for the tower system are the equilibrium equations (1), (2), and (3); the cable stretch equation (4); the catenary relation equations (5) and (6); and the geometric compatibility relation equations (7), (8), and (9).

In this section, these components are used to construct a computational model of the tower system (fig. 6), which can be used to predict the static loads that develop in the guylines for a given tower loading.

The program is divided into two segments corresponding to the phases of the tower system, the setup phase and the yarding phase.

Setup phase.—As in the field, the computational model of the tower system must start with a setup phase in which the system geometry, equipment specifications, and initial operating line loads are specified. The model must then solve equations (1), (2), and (3) to find the guyline pretensions which put the system into equilibrium. There are generally four to eight unknown guyline pretensions and only the three equations of equilibrium; therefore, an iterative approach (Reutebuch 1978) must be used to solve these equations. As in the field, there is an infinite number of sets of pretensions that satisfy the equations of equilibrium for a given system geometry. The setup phase provides a means of determining a reasonable set of pretensions.

The pretensions that satisfy equations (1), (2), and (3) are then used in equation (5) to compute the stretched length of each guyline. Because the catenary parameter, m, is not known, an iterative method (Carson 1977) must be used to solve equation (5). The unstretched length of each guyline is then computed using the tension-stretch relationship given in equation (4). In the field, the guyline drums are locked in place by the end of the setup procedure; therefore, the unstretched guyline lengths, S_{oi}, are constant in the yarding phase of tower operation.

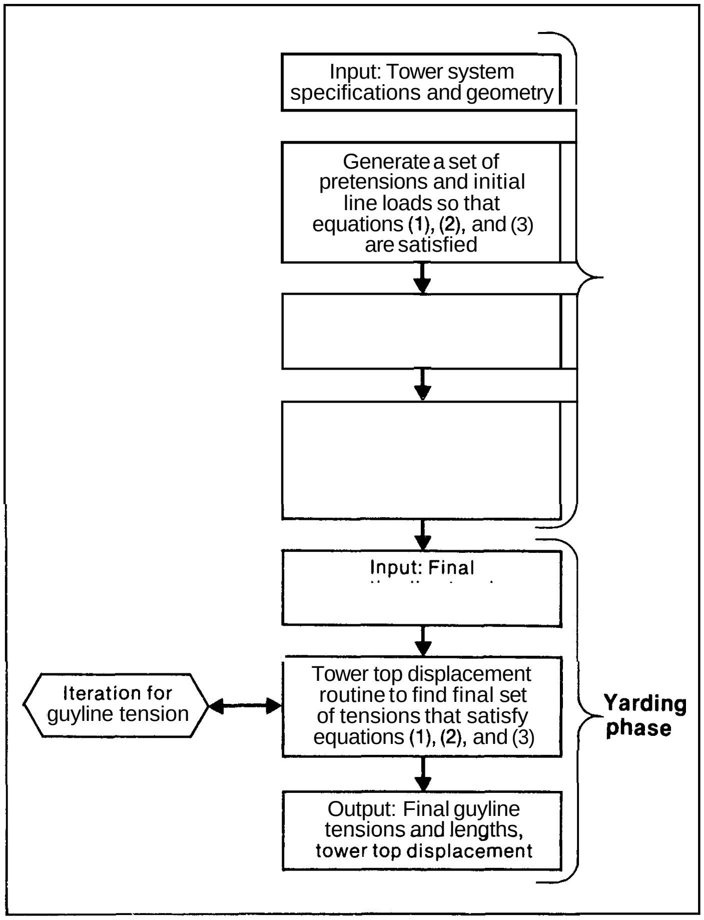

Figure 6.—Computational model of the yarding tower system.

Yarding phase.—The tower system is in a state of static equilibrium for the given initial tower system geometry. The final operating loads, f_j', on the system are now introduced.[3] With these new line loads, equations (1), (2), and (3) are no longer satisfied; the system is no longer in equilibrium. New guyline tensions, Ti', and a new tower compressional force, C', must be found to satisfy the conditions of equilibrium:

$$\Sigma F_x' = \Sigma T_{xi}' + \Sigma f_{xj}' + C_x' = 0. \qquad (1A)$$
$$\Sigma F_y' = \Sigma T_{yi}' + \Sigma f_{yj}' + C_y' = 0. \qquad (2A)$$
$$\Sigma F_z' = \Sigma T_{zi}' + \Sigma f_{zj}' + C_z' = 0. \qquad (3A)$$

The action of the operating loads will cause the tower top displacement to change. An iterative technique is used, by successive trials of system geometries (Reutebuch 1978), that yields an associated set of guyline tensions, until equations (1A), (2A), and (3A) are satisfied and the system again is in static equilibrium.

[3]These final operating loads can be assumed to be the yield point of the operating lines, or they may be computed by the "chain and board" method or one of several computational methods introduced in recent years.

In the displacement iteration routine, successive estimates of x and y components of tower top displacement, D_x' and D_y' are made and then used in equation (7) to solve for D_z':

$$D_z' = (h^2 - D_x' - D_y'^2)^{1/2} - h. \qquad (7A)$$

With each trial of a tower top displacement, there is a new guyline geometry, D_i and Y_i, which is used in equation (5) to solve for the stretched guyline length, S_i'. Equation (4) is then used to find the tension, T_i', in each guyline, given the guyline's stretched and unstretched lengths:

$$T_i' = (S_i' - S_{oi})/k_i. \qquad (4A)$$

The iteration on tower top displacement continues until a set of guyline tensions that satisfies equations (1A), (2A), and (3A) is found. At this point, the problem for that specific set of operating loads is complete and all pertinent information is printed.

The Guyline Tension Analysis Program

General Information

The program is written in the American Standard Code for Information Interchange (ASCII) BASIC language common to many computer systems. It was developed on a Hewlett-Packard 9845 desk-top calculator/plotter system at the Pacific Northwest Forest and Range Experiment Station Forestry Sciences Laboratory, Seattle, Washington. A FORTRAN version currently running on the PDP-11/44 in the Mechanical Engineering Department at the University of Washington is also available from the university.

The program listed in appendix B is the version for the HP9845 system. This system must include the following minimum features:

- BASIC MODEL 9845 calculator with 62650 bytes of read/write memory.
- Additional read only memory graphics.
- Internal thermal page printer.
- Dual inboard tape cartridge drives.

Although the program was prepared on a particular computer system and some familiarity with the mechanics of its operation is presumed, it is not limited to this system. The ASCII BASIC language is a common computer code, and the program can be executed on many other computers.

Using the Program

To produce a program that could be used without complicated instructions, we used "visual prompters." These are questions or other printed messages to prompt the user to input the necessary information. These prompters are described in table 1.

The mechanics of program execution is best described by a specific example that allows the user to work through the program at least once. The user can treat other examples as variations of the one presented here.

Table 1—Description of inputs for guyline tension analysis program

VISUAL PROMPTER	KEYBOARD RESPONSE	DESCRIPTION
NEW SETTING (Y/N)?	Y	Note: Data could be read from a previously stored data file.
SETTING NAME?	SNOQUALMIE	Assigns a name for output identification.
TOWER HEIGHT?	**106**	Height of spar from pinned base to guyline circle in feet (fig. 7).
DISTANCE FROM THE GUYLINE DRUMS TO THE TOWER TOP?	100	Distance from guyline circle to guyline drums in feet.
ELEVATION AT TOWER BASE?	**1968**	The elevation of the tower pivot or pin joint.
NUMBER OF POSSIBLE ANCHORS (UP TO 12)?	10	The number of stumps or artificial anchors being considered for guyline anchors.
AZIMUTH, HORIZONTAL DISTANCE, ELEVATION FOR ANCHOR 1?	**193,193,1954**	These entries describe the anchor locations with respect to the base of the tower. They are, respectively, the azimuth, the horizontal distance from the tower to anchor, and the elevation of the anchor point.
AZIMUTH, HORIZONTAL DISTANCE, ELEVATION FOR ANCHOR 2?	**248,365,1996**	
AZIMUTH, HORIZONTAL DISTANCE, ELEVATION FOR ANCHOR 3?	**304,193,1988**	
AZIMUTH, HORIZONTAL DISTANCE, ELEVATION FOR ANCHOR 4?	**332,191,1980**	
AZIMUTH, HORIZONTAL DISTANCE, ELEVATION FOR ANCHOR 5?	**002,162,1962**	
AZIMUTH, HORIZONTAL DISTANCE, ELEVATION FOR ANCHOR 6?	**034,194,1943**	
AZIMUTH, HORIZONTAL DISTANCE, ELEVATION FOR ANCHOR 7?	**081,218,1894**	
AZIMUTH, HORIZONTAL DISTANCE, ELEVATION FOR ANCHOR 8?	**117,232,1902**	
AZIMUTH, HORIZONTAL DISTANCE, ELEVATION FOR ANCHOR 9?	**124,196,1921**	
AZIMUTH, HORIZONTAL DISTANCE, ELEVATION FOR ANCHOR 10?	**141,227,1919**	

Table 1—Description of inputs for guyline tension analysis program (continued)

VISUAL PROMPTER	KEYBOARD RESPONSE	DESCRIPTION
PLOT OF ALL POSSIBLE ANCHORS (Y/N)?	Y	Provides a plot of all possible anchors (fig. 8).
DO YOU WANT TO STORE SETTING (Y/N)?	Y	Setting stored on tape. Printed record shown in table 2.
FILE NAME (UP TO 6 CHARACTERS)	SNOQUL	Name of file on left tape in which setting is stored for later use.
INITIAL TOWER LEAN, ANGLE, AZ?	0,0	Inputs the angle from vertical and the direction (azimuth) in which the tower is initially leaning.
SAME DIAMETER FOR ALL GUYLINES (Y/N)?	Y	Provides an opportunity to input guylines of different diameters.
DIAMETER OF GUYLINES?	1.375	Inputs the diameter of guylines, in inches.
SELECT UP TO 8 ANCHORS	pause	
GUYLINE #1 - ANCHOR #?	1	Indicates that guyline 1 will be attached to anchor 1.
GUYLINE #2 - ANCHOR #?	2	Indicates that guyline 2 will be be atached to anchor 2, etc.
GUYLINE #3 - ANCHOR #?	3	
GUYLINE #4 - ANCHOR #?	4	
GUYLINE #5 - ANCHOR #?	6	
GUYLINE #6 - ANCHOR #?	7	
GUYLINE #7 - ANCHOR #?	9	Guyline 7 attached to anchdr 9.
GUYLINE #8 - ANCHOR #?	0	Indicates that there are no more guylines.
GUYLINE CABLE FACTOR OF SAFETY?	3	Inputs the factor of safety, which is to be used to determine the wire rope working tension.
SAME PRETENSION FOR ALL GUYLINES (Y/N)?		Provides an opportunity to input a different pretension for each guyline.
DESIRED PRETENSION IN GUYLINES?	6000	Inputs a base guyline pretension for all guylines, which will then be adjusted until system is in static equilibrium.

Table 1—Description of inputs for guyline tension analysis program (continued)

VISUAL PROMPTER	KEYBOARD RESPONSE	DESCRIPTION
AZIMUTH FROM TOWER BASE TO OPERATING LINE DRUMS?	319	Azimuth from the tower base to the operating line drums.
TENSION IN THE OPERATING LINE AT TOWER TOP (LB)?	0	Indicates that operating lines are slack when system is pretensioned.
	pause	Program execution. The initial guyline tension is displayed on screen.
ARE PRETENSIONS SATISFACTORY?	Y	Provides an opportunity to try a different pretension arrangement.
SETUP NUMBER?	1	For output label.
DO YOU WANT A PLOT?	Y	Provides a plot of the system in its initial loaded condition (fig. 9).
RUN NAME OR NUMBER (UP TO 25 CHARACTERS)	1	Inputs the name or number with which the run will be labeled.
		The initial guyline tension data are printed. See table 3. Program enters the yarding phase.
AZIMUTH FROM TOWER BASE TO OPERATING LINE DRUMS?	319	Described earlier.
TENSION IN THE OPERATING LINE AT TOWER TOP (LB)?	100000	Inputs the tension in operating line number 1 (skyline to carriage).
OPERATING LINE ANGLE FROM THE HORIZONTAL (DEG.)?	20	Inputs the angle from the horizon to operating line number 1 (positive for downhill).
AZIMUTH OF OPERATING LINE LEAD (DEG.)?	139	Inputs the direction to the carriage from top to tower (skyline lead).
DISTANCE FROM TOWER BASE TO OPERATING LINE DRUM 1?	10	Inputs the distance (feet) from the tower to the operating line drum number 1.

Table 1—Description of inputs for guyline tension analysis program (continued)

VISUAL PROMPTER	KEYBOARD RESPONSE	DESCRIPTION
TENSION IN THE OPERATING LINE AT TOWER TOP (LB)?	30000	Inputs the tension in operating line number 2 (main line from tower top to carriage).
OPERATING LINE ANGLE FROM THE HORIZONTAL (DEG.)?	25	Inputs the angle from the horizon to operating line number 2.
AZIMUTH OF OPERATING LINE LEAD (DEG.)?	139	Inputs the direction to the carriage from top of tower (main line lead).
DISTANCE FROM TOWER BASE TO OPERATING LINE DRUM 2?	15	Inputs the distance (feet) from tower base to the operating line drum number 2.
TENSION IN THE OPERATING LINE AT TOWER TOP (LB)?	0	Indicates all operating lines have been input.
	pause	Computer will go into solution procedure. Periodically it will flash the iteration number on the screen.
	1	Start iterations.
	•	
	•	
	•	
	8	Total iterations.
DO YOU WANT A PLOT?	Y	Provides a plot of the system in its final loaded condition (fig. 10 and table 4).
1 = NEW LOAD		Provides menu.
2 = NEW PRETENSIONS		
3 = NEW ANCHOR ARRANGEMENT		
4 = STOP		
CHOOSE ONE OF THE ABOVE (1-4)?	2	New final operating line loads, new guyline pretensions, or a new anchor arrangement can be tried by entering the appropriate number. In this case, a new set of pretensions is tried.

Table 1—Description of inputs for guyline tension analysis program (continued)

VISUAL PROMPTER	KEYBOARD RESPONSE	DESCRIPTION
SAME PRETENSIONS FOR ALL GUYLINES (Y/N)?	N	Described earlier.
DESIRED PRETENSION IN GUYLINE 1 F/V?	5500	Inputs desired pretension in guyline 1.
?	V	Indicates that pretension can **be** adjusted while balancing system (guyline tension variable).
DESIRED PRETENSION IN GUYLINE 2 F/V?	4000	Same as above.
?	V	
DESIRED PRETENSION IN GUYLINE 3 F/V?	4000	Same as above.
?	V	
DESIRED PRETENSION IN GUYLINE 4 F/V?	4000	Same as above.
?	F	Indicates that pretension will not be adjusted while balancing system (guyline tension fixed).
DESIRED PRETENSION IN GUYLINE 5 F/V?	9000	Same as above.
?	V	
DESIRED PRETENSION IN GUYLINE 6 F/V?	12000	Same as above.
?	V	
DESIRED PRETENSION IN GUYLINE 7 F/V?	4000	Same as above.
?	V	
AZIMUTH FROM TOWER BASE TO OPERATING LINE DRUMS?	319	
TENSION IN THE OPERATING LINE AT TOWER TOP (LB)?	0	Described earlier.

Table 1—Description of inputs for guyline tension analysis program (continued)

VISUAL PROMPTER	KEYBOARD RESPONSE	DESCRIPTION
	pause	Iterations as described above. Iteration numbers will flash on display.
ARE PRETENSIONS SATISFACTORY?	Y	
SETUP NUMBER?	1	For labeling output.
DO YOU WANT A PLOT?	Y	See figure 11 and table 5.
RUN NAME OR NUMBER UP TO 25 CHARACTERS?	2	
AZIMUTH FROM TOWER BASE TO OPERATING LINE DRUMS?	319	Described earlier.
TENSION IN THE OPERATING LINE AT TOWER TOP (LB)?	100000	Described earlier
OPERATING LINE ANGLE FROM THE HORIZONTAL (DEG.)?	20	
AZIMUTH OF OPERATING LINE LEAD (DEG.)?	139	
DISTANCE FROM TOWER BASE TO OPERATING LINE DRUM 1?	10	
TENSION IN THE OPERATING LINE AT TOWER TOP (LB)?	0	Indicates all operating lines have been input.
	pause	Iterations as described above. Iteration numbers will flash on display.
	1 e ● 9	Total iterations.
DO YOU WANT A PLOT?	Y	See figure 12 and table 6.
1 = NEW LOAD 2 = NEW PRETENSIONS 3 = NEW ANCHOR ARRANGEMENT **4** = STOP		

Table 1—Description of inputs for guyline tension analysis program (continued)

VISUAL PROMPTER	KEYBOARD RESPONSE	DESCRIPTION
CHOOSE ONE OF THE ABOVE (1-4)?	1	New final operating line loads will be tried with the same set of anchors and pretensions.
RUN NAME OR NUMBER (UP TO 25 CHARACTERS)?	3	
AZIMUTH FROM TOWER BASE TO OPERATING LINE DRUMS?	319	
TENSION IN THE OPERATING LINE AT TOWER TOP (LB)?	200000	
OPERATING LINE ANGLE FROM THE HORIZONTAL (DEG.)?	20	
AZIMUTH OF OPERATING LINE LEAD (DEG.)?	0	
DISTANCE FROM TOWER BASE TO OPERATING LINE DRUM 1?	15	
TENSION IN THE OPERATING LINE AT TOWER TOP (LB)?	0	
	pause	Iterations as described above. Iteration number will flash on display.
	1 · · · 10	Total iterations.
DO YOU WANT A PLOT?	Y	Described earlier (fig. 13 and table 7).
1 = NEW LOAD 2 = NEW PRETENSIONS 3 = NEW ANCHOR ARRANGEMENT 4 = STOP	4	Program stops. If an opportunity to try a new guyline geometry and tower lean is desired, input "3".

Input.—The input necessary to this program is explained in the "Description" column of table 1. The remarks in this column explain what an operator does in response to the input requests that appear under the "Visual Prompter" column. The "Keyboard Response" column shows the input necessary for the specific example presented. Figure 7 describes the terminology used.

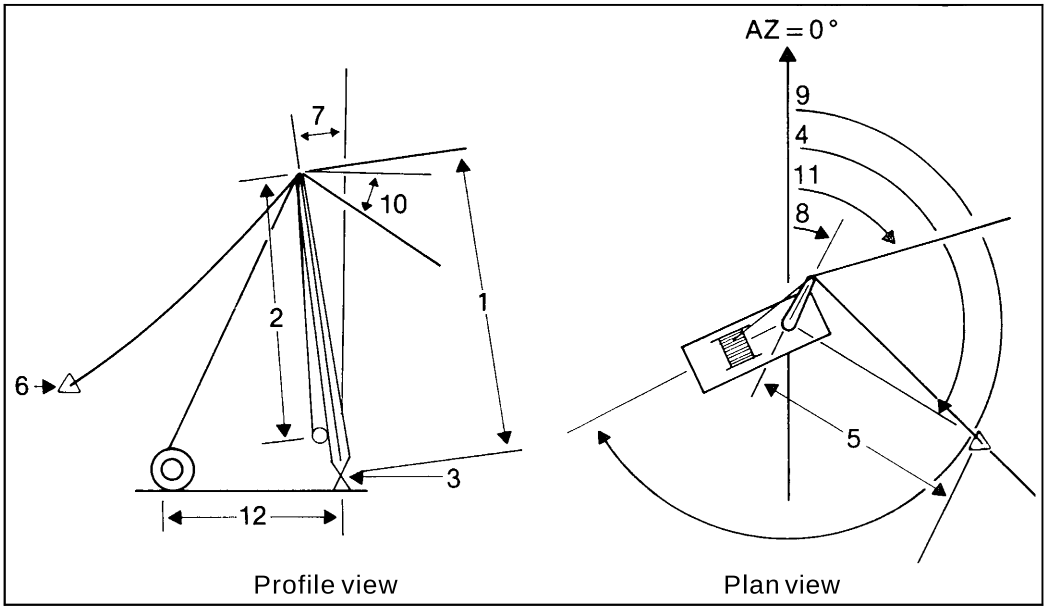

Figure 7. — Geometric inputs required for program use:
(1) tower height
(2) distance from guyline drums to tower top
(3) elevation at tower base
(4) azimuth from tower base to anchor
(5) horizontal distance from tower base to anchor
(6) elevation of anchor
(7) angle of tower lean (a positive value)
(8) azimuth of tower lean
(9) azimuth from tower base to tower operating line drums
(10) angle operating line from horizontal at tower top (positive for downhill, negative for uphill)
(11) azimuth of pull of operating line
(12) horizontal distance from tower base to operating line drum

Description of Program Output

The output of the program provides the user with an analysis of the force-tension distribution that can be expected in the tower. Provided are the guyline angles, tensions and lengths, tower compression, and tower top displacement for whatever range of operating line arrangements the operator wants to examine. Both printed and plotted output are produced. Tables 2 to 7 show the text portion of the output produced when the example given in table 1 is run.

The printed output, like the model itself, is divided into two sections. Table 2 describes the setting. Table 3 describes the anchors chosen and the pretensions selected for the guylines. Table 3 also provides a summary of the force-tension components acting through the tower top at the end of the setup phase of the program. The second segment of the printed output (table **4** for the first setting) is a summary of the force-tension distribution and the changes that have occurred because of the imposition of the final operating line loads on the tower system. If a computed guyline tension is greater than the working strength of the guyline cable as specified by the safety factor, the output is flagged so that overstresses can be easily identified. If stresses beyond the elastic limit are present, a statement to indicate this condition is also provided. Tables 5 to 7 show the output for the initial section and the final sections for the other examples treated in table 1.

Table 2—Listing of possible anchor locations

SETTING--SNOQUALMIE

TOWER HEIGHT= 106 FEET.
DIST: GUYLINE DRUMS TO TOWER TOP 100 FEET.
ELEVATION AT TOWER BASE= 1968 FEET.
NUMBER OF POSSIBLE ANCHORS= 10

POSSIBLE ANCHOR LOCATIONS

NUMBER	AZIMUTH	DISTANCE	ELEVATION
1	193	193.0	1954.0
2	248	365.0	1996.0
3	304	193.0	1988.0
4	332	191.0	1980.0
5	2	162.0	1962.0
6	34	194.0	1943.0
7	81	218.0	1894.0
8	117	232.0	1902.0
9	124	196.0	1921.0
10	141	227.0	1919.0

Table 3—Anchor location selection and pretensisning of the guylines

GUYLINE NUMBER	*SELECTED ANCHOR LOCATIONS* AZIMUTH	DISTANCE	ELEVATION	*GUYLINE* DIAMETER	ANGLE
1	193	193.0	1954.0	1.375	32
2	248	365.0	1996.0	1.375	12
3	304	193.0	1988.0	1.375	24
4	332	191.0	1980.0	1.375	26
5	34	194.0	1943.0	1.375	34
6	81	218.0	1894.0	1.375	40
7	124	196.0	1921.0	1.375	38

GUYLINE CABLE FACTOR OF SAFETY IS 3

** INITIAL OPERATING LINE AND GUYLINE TENSIONS **

AZIMUTH: TOWER BASE TO OPER. LINE DRUMS= 319 DEGREES

OPERATING LINES	TENSION	ANGLE	AZIMUTH	DRUM DIST
OPER. LINES VECTOR RESULTANT	0	0	0	

GUYLINE NUMBER	*PRETENSIONS* INPUT	BALANCED	*INITIAL LENGTHS* STRETCHED	UNSTRETCHED
1	6000	6078	227.39	227.23
2	6000	6078	373.97	373.74
3	6000	4584	211.50	211.39
4	6000	4584	213.08	212.97
5	6000	5752	234.24	234.09
6	6000	5752	282.94	282.77
7	6000	7627	248.74	248.53

INITIAL TOWER TOP DEFLECTION: DIST, AZ 0.00 0

INITIAL TOWER COMPRESSION 60398 POUNDS

Table 4—Final guyline tensions for setup 1, run 1

FINAL OPERATING LINE TENSIONS FOR SETUP # 1 RUN--1

AZIMUTH: TOWER BASE TO OPER. LINE DRUMS= 319 DEGREES

OPERATING LINES	TENSION	ANGLE	AZIMUTH	DRUM DIST
OPER. LINE 1	100000	20	139	10
OPER. LINE 2	30000	25	139	15
OPER. LINES VECTOR RESULTANT	206388	59	139	

GUYLINE	*STRETCHED LENGTHS*			*GUYLINE TENSIONS*		
NUMBER	INITIAL	FINAL	CHANGE	INITIAL	FINAL	CHANGE
1	227.39	227.29	-.10	6078	2385	-3693
2	373.97	374.14	.17	6078	10606	4527
3	211.50	212.98	1.48	4584	62992	58408
4	213.08	214.52	1.43	4584	60955	56371
5	234.24	234.46	.22	5752	14027	8276
6	282.94	282.86	-.09	5752	2995	-2757
7	248.74	248.58	-.16	7627	2158	-5469

UNBALANCED X-FORCE=-375 UNBALANCED Y-FORCE= 32
FINAL TOWER DEFLECTION: DIST, AZ 1.90 137
FINAL TOWER COMPRESSION 398997 POUNDS
NUMBER OF ITERATIONS= 8

Table 5—New pretension selection for anchor setup 1

** INITIAL OPERATING LINE AND GUYLINE TENSIONS **

AZIMUTH: TOWER BASE TO OPER. LINE DRUMS= 319 DEGREES

OPERATING LINES	TENSION	ANGLE	AZIMUTH	DRUM DIST
OPER. LINES VECTOR RESULTANT	0	0	0	

GUYLINE	*PRETENSIONS*		*INITIAL LENGTHS*	
NUMBER	INPUT	BALANCED	STRETCHED	UNSTRETCHED
1	5500	7652	227.34	227.14
2	4000	5565	374.11	373.91
3	4000	3730	211.61	211.52
4	4000	4000	213.15	213.05
5	9000	5761	234.24	234.08
6	12000	7682	282.84	282.61
7	4000	3821	249.04	248.94

INITIAL TOWER TOP DEFLECTION: DIST, AZ 0.00 0
INITIAL TOWER COMPRESSION 57166 POUNDS

Table 6—Final guyline tensions for setup 1, run 2

```
  FINAL OPERATING LINE TENSIONS FOR SETUP #  1  RUN--2

AZIMUTH: TOWER BASE TO OPER. LINE DRUMS=  319  DEGREES

OPERATING LINES              TENSION     ANGLE  AZIMUTH   DRUM DIST
    OPER. LINE 1              100000       20      139        10
OPER. LINES VECTOR RESULTANT  158256       58      139

GUYLINE       *STRETCHED LENGTHS*          *GUYLINE TENSIONS*
 NUMBER   INITIAL    FINAL    CHANGE    INITIAL     FINAL    CHANGE
   1       227.34   227.21     -.13      7652       2732     -4920
   2       374.11   374.23      .12      5565       8670      3105
   3       211.61   212.78     1.17      3730      49771     46041
   4       213.15   214.29     1.14      4000      48903     44903
   5       234.24   234.38      .14      5761      11044      5282
   6       282.84   282.70     -.13      7682       3354     -4328
   7       249.04   248.99     -.05      3821       2031     -1790

UNBALANCED X-FORCE= 138    UNBALANCED Y-FORCE= 343
FINAL TOWER DEFLECTION: DIST, AZ           1.65    135
FINAL TOWER COMPRESSION  314675  POUNDS
NUMBER OF ITERATIONS= 9
```

Table 7—Final guyline tensions for setup 1, run 3

```
  FINAL OPERATING LINE TENSIONS FOR SETUP #  1  RUN--3

AZIMUTH: TOWER BASE TO OPER. LINE DRUMS=  319  DEGREES

OPERATING LINES              TENSION     ANGLE  AZIMUTH   DRUM DIST
    OPER. LINE 1              200000       20        0        15
OPER. LINES VECTOR RESULTANT  339177       52      355

GUYLINE       *STRETCHED LENGTHS*          *GUYLINE TENSIONS*
 NUMBER   INITIAL    FINAL    CHANGE    INITIAL     FINAL    CHANGE
   1       227.34   232.75     5.41      7652    210781!!! 203129
   2       374.11   374.84      .73      5565      24465     18900
   3       211.61   211.54     -.07      3730       1117     -2613
   4       213.15   213.07     -.08      4000       1006     -2994
   5       234.24   234.11     -.12      5761       1287     -4475
   6       282.84   282.81     -.02      7682       6969      -713
   7       249.04   252.38     3.35      3821    121860!!! 118039
!!!-GUYLINE WORKING LOAD EXCEEDED WITH SAFETY FACTOR OF  3
ELASTIC LIMIT OF CABLE EXCEEDED--THIS LOADING IS BEYOND THE RANGE OF THE MODEL

UNBALANCED X-FORCE= 10    UNBALANCED Y-FORCE=-83
FINAL TOWER DEFLECTION: DIST, AZ           7.08    351
FINAL TOWER COMPRESSION  828323  POUNDS
NUMBER OF ITERATIONS= 10
```

Three plan view plots of the tower setting are provided to aid the user in visualizing the anchor arrangement and operating line loads. The first plot of all possible anchors (fig. 8) is provided so the user can decide which combination of anchors to select. The next plot (figs. 9 and 11) provides a visual display of the tower system in the particular trial setup showing the initial tension distribution when the tower is unloaded. The tower top is at the intersection of the guylines. The final plot (figs. 10, 12, or 13) provides the user with a visual display of the tower system after final operating line loads have been imposed on the tower top. The resultant of the final operating line loads is represented on the plot by a dashed line terminated by an "R". The magnitude (MAG), angle, and azimuth (AZ) of the resultant are also listed. These plots allow the operator to quickly spot guylines with excessive tensions or poor distributions.

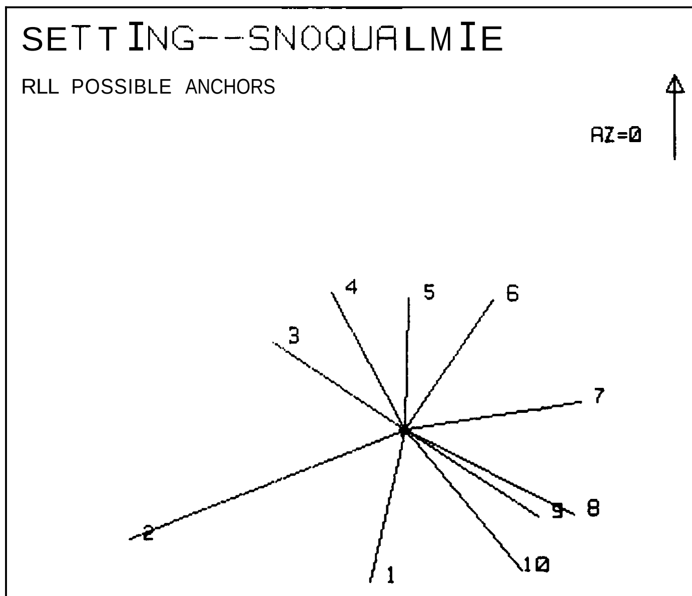

Figure 8.—Setting, Snoqualmie, all possible anchors.

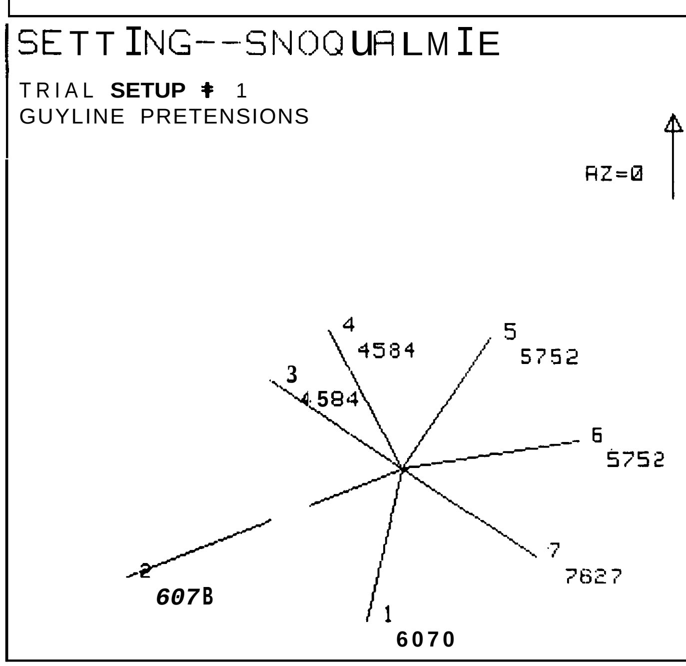

Figure 9.—Setting, Snoqualmie, guyline pretensions.

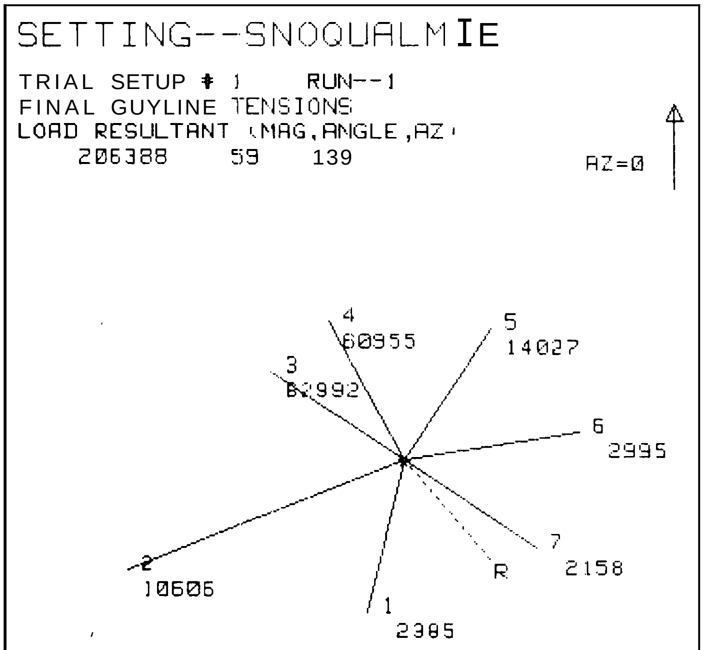

Figure 10.—Setting, Snoqualmie, final guyline tensions, run 1.

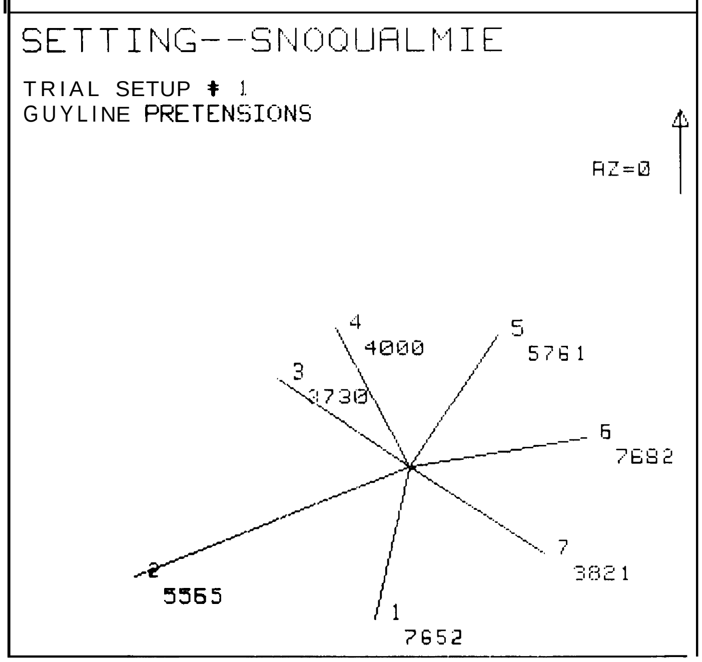

Figure 11.—Setting Snoqualmie, guyline tensions revised.

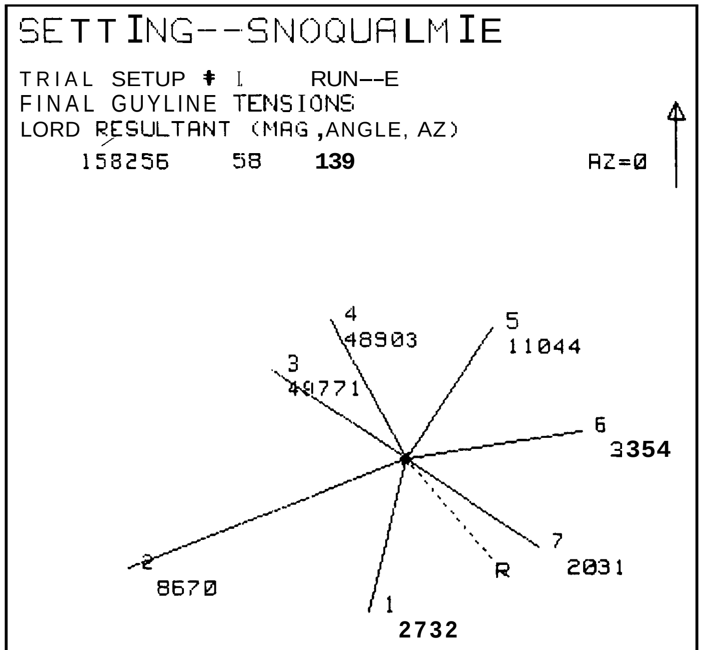

Figure 12.—Setting Snoqualmie, final guyline tensions, run 2.

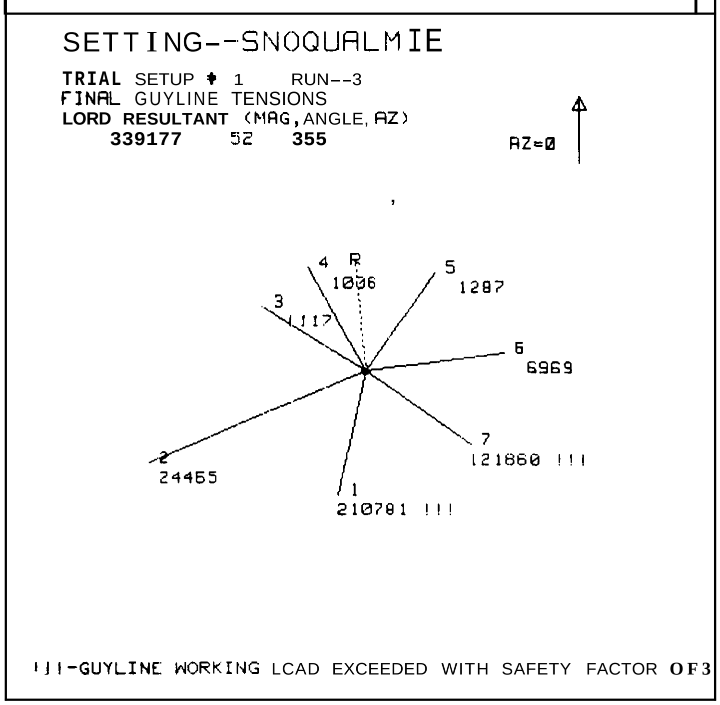

Figure 13.—Setting Snoqualmie, final guyline tensions, run 3.

Limitations

This program is based on a static analysis of a logging system tower held in position by a set of cable guylines. Several assumptions were required to define the system configuration and its mode of operation. These assumptions restrict the application of the program.

To gain a full appreciation of the limitations of this program, a user should be familiar with the analytical model on which it is based. A more complete description is given by Reutebuch (1978). Some obvious limitations are listed and discussed here.

1. The tower is a weightless, rigid member, free to pivot in any direction. The weight of the tower is ignored since it is presumed that other loads and tensions will make the tower weight insignificant by comparison. This assumption is necessary so the tower can be assumed to bear the compressive loads only.

2. Guyline and operating line loads are applied at a single point on the tower top. Minor variations from this arrangement are assumed to have an insignificant influence on the results.

3. Anchors are rigid. It is assumed that the guyline anchor motion will be negligible during loading in comparison with the top of the tower.

4. Guylines are considered to be 6 x 19 IWRC (Independent Wire Rope Core) class of wire rope, stretched linearly and hanging as catenaries. These assumptions were required to identify properties of the cable—such as ultimate strength, elastic modulus, and weight-to-size relationship. The assumption of linear stretch limits the application of this program to cases where the guylines are tensioned to less than 65 percent of breaking strength. The inelastic stretch of wire rope beyond this limit will make the results of this program invalid.

5. The effective direction of guyline forces is along the chord from the tower top to the respective anchor point. This assumption was made for convenience of computations. It does limit the program applications where they are being used to determine loadings for slack guylines, whose loading direction is of interest.

6. The guyline pretensions must be a reasonable representation of actual conditions. This limitation is important because the final solution for loaded guyline tensions is based on their initial pretensions. These pretensions may have a major influence and must be carefully selected.

7. Guylines are rigged from winches near the tower base, up through sleeves at the top, and out to attachment points at the anchors. The program is not applicable to towers rigged with two-part guylines where one end dead ends at the top of the tower.

Metric Conversions

Multiply	by	to get metric equivalent in
Length:		
Inches	25.4	millimeters
Feet	0.305	meters
Force:		
Pounds	4.45	newtons

Literature Cited

Bramwell, William J., III. A computer model for determination of tensions in cable logging guylines. Seattle: University of Washington; 1977. Thesis.

Broderick & Bascom Rope Company. Wire rope handbook. St. Louis, MO: Broderick & Bascom Rope Company; 1966: 99.

Carson, W. Analysis of the single cable segment. For. Sci. 23(2): 238-252; 1977.

Halliday, David; Resnik, David. Physics for students of sciences and engineering. Combined edition. John Wiley & Sons, Inc.; 1961: 75-79.

Jorgensen, Jens E.; Carson, Ward W.; Chalupnik, James O.; Garbini, Joseph L. Skyline anchor dynamics test. Tech. Rep. FE-UW-7702. Seattle, WA: University of Washington, Mechanical Engineering; 1977.

Reutebuch, Stephen E. A computer model to predict the static guyline tensions in cable logging tower systems. Seattle, WA: University of Washington; 1978. Thesis.

Appendix A
List of Variables

Variable	Description
A1	Intermediate, used in catenary routine to find guyline lengths
A(1, 1)	Summation of x-components of loads and tensions
A(1, 2)	Summation of y-components of loads and tensions
A(2, 1)	Summation of x-components of variable tensions
A(2, 2)	Summation of y-components of variable tensions
A(3, 1)	Intermediate sum of x-components of loads and tensions
A(3, 2)	Intermediate sum of y-components of loads and tensions
A(4, 1)	Intermediate sum of x-components of loads and tensions
A(4, 2)	Intermediate sum of y-components of loads and tensions
A(5, 1)	Summation of z-components of loads and tensions
A(5, 2)	Summation of magnitudes of all tensions

The A matrix is used for a variety of functions in the yarding segment of the program.

Variable	Description
A$	String variable in plot routine
B(I, 1)	Azimuth from tower base to ith anchor
B(I, 2)	Horizontal distance from tower base to ith anchor
B(I, 3)	Elevation of ith anchor
B$	String variable in plot routine
C	Tower compression
C1	x-component of tower compression
c 2	z-component of tower compression
c 3	z-component of tower compression
c 4	z-component of tower base location vector
D	Horizontal distance from a guyline anchor to tower top
DO	Tower top displacement in x-y plane
D1	Tower top displacement in x-direction
D2	Tower top displacement in y-direction
D3	Tower top displacement in z-direction
D(1)	Previous D1 value used to compute tower system spring rates for a displacement in the x-direction
D(2)	Previous D2 value used to compute tower system spring rates for a displacement in the y-direction
D(3)	Intermediate to store D1
D(4)	Intermediate to store D2
D(5)	Initial x-component of tower top displacement
D(6)	Initial y-component of tower top displacement
E	Elevation of tower base
F	Error term in catenary tension iteration: |known unstretched length-computed unstretched length|
FO	Magnitude of line load resultant
F1	Summation of x-components of line loads
F2	Summation of y-components of line loads
F3	Magnitude of z-components of line loads
F(1)	x-component of ith operating line load
F(2)	y-component of ith operating line load
F(3)	z-component of ith operating line load
F8	Previous value of error term
F9	Numerical value of the derivative of the error term
G	Constant to convert degrees to radians
H	Tower height: from pivot to top

Variable	Description
I	Counter, flag
I9	Counter
J	Counter, flag
K	Counter
K1	Counter
K2	Flag
K3	Tolerance in final force balance
K(I, 1)	Diameter of ith guyline
K(I, 2)	Stretch coefficient of ith guyline
L(1)	Change in x-component of tower top displacement
L(2)	Change in y-component of tower top displacement
L(3)	Previous trial x-component of displacement
L(4)	Previous trial y-component of displacement
L$	String variable in plot routine
M	Catenary parameter
M(I, 1)	Initial x-component of ith anchor location vector
M(I, 2)	Initial y-component of ith anchor location vector
M(I, 3)	Initial z-component of ith anchor location vector
M(I, 4)	Final x-component of ith anchor location vector
M(I, 5)	Final y-component of ith anchor location vector
M(I, 6)	Final z-component of ith anchor location vector
N	Number of guylines
N1	Number of possible anchor locations
N(I, 1)	Initial x-direction cosine for ith guyline
N(I, 2)	Initial y-direction cosine for ith guyline
N(I, 3)	Initial z-direction cosine for ith guyline
Q	Distance from guyline drums to tower top
R	Distance from tower base to operating line drum
R1	Resultant of guyline weight
S	Stretched guyline length
SØ	Unstretched guyline length
S(I, 1)	Initial chord length of ith guyline
S(I, 2)	Final chord length of ith guyline
S(I, 3)	Initial stretched length of ith guyline
S(I, 4)	Initial unstretched length of ith guyline
S(I, 5)	Final stretched length of ith guyline
T	Guyline tension
T1	Computed guyline tension
T(I, 1)	x-component of ith guyline tension
T(I, 2)	y-component of ith guyline tension
T(I, 3)	z-component of ith guyline tension
T(I, 4)	ith guyline pretension
T(I, 5)	First trial pretension for ith guyline (later final tension for ith guyline)
T$(I, I)	ith element of string variable indicating whether the ith guyline pretension is fixed or variable

Variable	Description
U	Angle of resultant of operating line loads
V	Azimuth of resultant of operating line loads
V(1)	Change in unbalanced force in x-direction
V(2)	Change in unbalanced force in y-direction
W	Guyline weight per foot
X	intermediate
X1	System spring rate for change in the y-summation of guyline tensions and tower compression caused by a change in the displacement in the x-direction
x2	System spring rate for change in the x-summation of guyline tensions and tower compression caused by a change in the displacement in the x-direction
X$	String variable flag
Y	Intermediate variable
Y1	System spring rate for change in the x-summation of guyline tensions and tower compression caused by change in displacement in the y-direction
Y2	System spring rate for change in the x-summation of guyline tensions and tower compression caused by change in displacement in the y-direction
Y$	String variable flag
Z$	String variable flag

Appendix B
Guyline Analysis Program Listing; HP 9845 Version

```
10   OPTION BASE 1
20   REM THIS PROGRAM PERFORMS A STRUCTURAL ANALYSIS OF THE VERTICAL
30   REM CABLE LOGGING TOWER SYSTEM.  GUYLINE TENSIONS ARE PREDICTED
40   REM FOR THE PARTICULAR TOWER SETUP AND OPERATING LINE
50   REM CONFIGURATION SPECIFIED BY THE USER.
60   REM FOR SPECIFIC DETAILS CONCERNING THE PROGRAM, REFER TO:
70   REM REUTEBUCH, STEPHEN E.  "A COMPUTER MODEL TO PREDICT STATIC
80   REM      GUYLINE TENSIONS IN CABLE LOGGING TOWER SYSTEMS," MS THESIS,
90   REM      UNIVERSITY OF WASHINGTON, SEATTLE, WA. 1978.
100  REM UP-DATED 5/2/78
110  REM CONVERTED TO HP 9845 BY S.E. REUTEBUCH 11/28/78
120  REM ***PROGRAM TO CALCULATE GUYLINE TENSION***
130  PRINTER IS 0
140  PRINT LIN(3);"         **GUYLINE TENSION AND DEFLECTION PROGRAM**";LIN(2)
150  DIM A(5,2),B(12,3),D(7),F(3),K(8,2),M(8,6),N(8,3),S(8,5),T(8,5)
160  DIM N$[10],T$[25],X$[2],Y$[40],Z$[2]
170  PRINTER IS 16
180  PRINT PAGE;LIN(3);"INSERT TOWER SETTING DATA TAPE IN THE LEFT TAPE DRIVE'
190  PRINT LIN(1);"PRESS CONT WHEN READY"
200  PAUSE
210  PRINT PAGE
220  PRINTER IS 0
230  G=PI/180
240  INPUT "NEW SETTING  (Y/N) ?",X1$
250  IF X1$="Y" THEN 500
260  INPUT "FILE NAME  (UP TO 6 CHARACTERS) ? ",N$[1,6]
270  N$[7,10]=":T14"
280  ON ERROR GOTO 310
290  ASSIGN N$ TO #1
300  GOTO 370
310  BEEP
320  BEEP
330  BEEP
340  DISP "!!!";N$[1,6];" DOES NOT EXIST ON THIS TAPE!!!"
350  WAIT 2500
360  GOTO 260
370  OFF ERROR
380  READ #1;B(*),E,N1,Y$
390  PRINT TAB(15),"PREVIOUSLY STORED SETTING--";Y$
400  PRINT
410  PRINT TAB(10);"NUMBER OF POSSIBLE ANCHOR LOCATIONS=";N1
420  PRINT TAB(10);"ELEVATION AT BASE OF TOWER=";E
430  PRINT TAB(17);"*POSSIBLE ANCHOR LOCATIONS*"
440  PRINT TAB(10);"NUMBER    AZIMUTH    DISTANCE    ELEVATION"
450  FOR I=1 TO N1
460  PRINT USING 470;I,B(I,1),B(I,2),B(I,3)
470  IMAGE M13D ,M10D ,M9D.1D ,M10D.1D
480  NEXT I
490  GOTO 530
500  DISP "SETTING NAME";
```

```
510  LINPUT Y$
520  PRINT TAB(100),"SETTING--";Y$
530  PRINT
540  DISP "TOWER HEIGHT";
550  INPUT H
560  PRINT TAB(10);"TOWER HEIGHT=";H;"FEET."
570  DISP "DISTANCE FROM THE GUYLINE DRUMS TO THE TOWER TOP";
580  INPUT Q
590  PRINT TAB(10);"DIST:  GUYLINE DRUMS TO TOWER TOP ";Q;" FEET.'
600  IF X1$="N" THEN 740
610  DISP "ELEVATION AT TOWER BASE";
620  INPUT E
630  PRINT TAB(10);"ELEVATION AT TOWER BASE=";E;"FEET."
640  DISP "NUMBER OF POSSIBLE ANCHORS  (UP TO 12) ";
650  INPUT N1
660  PRINT TAB(10);"NUMBER OF POSSIBLE ANCHORS=";N1
670  PRINT TAB(17);"*POSSIBLE ANCHOR LOCATIONS*"
680  PRINT TAB(10);"NUMBER    AZIMUTH    DISTANCE    ELEVATION"
690  FOR I=1 TO N1
700  DISP "AZIMUTH,HORIZONTAL DISTANCE,ELEVATION FOR ANCHOR ";I;
710  INPUT B(I,1),B(I,2),B(I,3)
720  PRINT USING 470;I,B(I,1),B(I,2),B(I,3)
730  NEXT I
740  N=X=I=1
750  DISP "PLOT OF ALL POSS. ANCHORS (Y/N)";
760  LINPUT Z$
770  GOTO 1480
780  PRINT
790  IF X1$="N" THEN 990
800  X1$="N"
810  DISP "DO YOU WANT TO STORE SETTING";
820  LINPUT Z$
830  IF Z$="N" THEN 990
840  INPUT "FILE NAME (UP TO 6 CHARACTERS) ? ",N$[1,6]
850  N$[7,10]=":T14"
860  ON ERROR GOTO 900
870  CREATE N$,2
880  ASSIGN N$ TO #1
890  GOTO 960
900  BEEP
910  BEEP
920  BEEP
930  DISP "!!! ";N$;" IS AN IMPROPER OR DUPLICATE FILE NAME!!!"
940  WAIT 2500
950  GOTO 840
960  OFF ERROR
970  PRINT #1;B(*),E,N1,Y$
980  PRINT " STORED ON FILE ";N$[1,6]
990  PRINT
1000 PRINT "GUYLINE      *SELECTED ANCHOR LOCATIONS*           *GUYLINE*"
```

```
1010 PRINT " NUMBER    AZIMUTH   DISTANCE   ELEVATION      DIAMETER   ANGLE"
1020 N=1
1030 DISP "INITIAL TOWER LEAN: ANGLE,AZ";
1040 INPUT X,Y
1050 D0=H*SIN(X*G)
1060 D1=D0*COS(Y*G)
1070 D2=-D0*SIN(Y*G)
1080 D3=SQR(H^2-D1^2-D2^2)-H
1090 D(5)=D1
1100 D(6)=D2
1110 D(7)=D3
1120 DISP "SAME DIAMETER FOR ALL GUYLINES(Y/N)";
1130 LINPUT X$
1140 IF X$="N" THEN 1170
1150 DISP "DIAMETER OF GUYLINES";
1160 INPUT X
1170 DISP "SELECT UP TO 8 ANCHORS"
1180 WAIT 2500
1190 FIXED 0
1200 DISP "GUYLINE #";N;"= ANCHOR #";
1210 INPUT I
1220 IF I=0 THEN 1440
1230 IF X$="Y" THEN 1270
1240 DISP "DIAMETER FOR GUYLINE";N;
1250 INPUT K(N,1)
1260 GOTO 1280
1270 K(N,1)=X
1280 M(N,1)=B(I,2)*COS(B(I,1)*G)-D1
1290 M(N,2)=-B(I,2)*SIN(B(I,1)*G)-D2
1300 M(N,3)=B(I,3)-E-H-D3
1310 S(N,1)=SQR(M(N,1)^2+M(N,2)^2+M(N,3)^2)
1320 N(N,1)=M(N,1)/S(N,1)
1330 N(N,2)=M(N,2)/S(N,1)
1340 N(N,3)=M(N,3)/S(N,1)
1350 K(N,2)=K(N,1)^2*6.504E6/(S(N,1)+Q)
1360 PRINT USING 1370;N,B(I,1),B(I,2),B(I,3),K(N,1)
1370 IMAGE #,M3D ,M11D ,2(M9D.1D ),M9D.3D
1380 PRINT USING 1390;ATN(ABS(M(N,3)/SQR(M(N,1)^2+M(N,2)^2)))/G
1390 IMAGE M7D
1400 N=N+1
1410 IF N=9 THEN 1440
1420 IF N>N1 THEN 1440
1430 GOTO 1200
1440 N=N-1
1450 INPUT "GUYLINE CABLE FACTOR OF SAFETY ? ",Safety_factor
1460 PRINT USING "38A,3D";"      GUYLINE CABLE FACTOR OF SAFETY IS',Safety_factor
1470 GOTO 1960
1480 REM *** PLOT ROUTINE ***
1490 IF Z$="N" THEN 1530
1500 PLOTTER IS 13,"GRAPHICS"
```

```
1510 GRAPHICS
1520 LOCATE 15,85,10,80
1530 B1=0
1540 FOR I=1 TO N1
1550 IF B(I,2)<B1 THEN 1570
1560 B1=B(I,2)
1570 NEXT I
1580 IF Z$="N" THEN 780
1590 SHOW -B1,B1,-B1,B1
1600 GOTO 1660
1610 LINE TYPE 3
1620 MOVE -B1-.1*B1,0
1630 DRAW B1+.1*B1,0
1640 MOVE 0,-B1-.1*B1
1650 DRAW 0,B1+.1*B1
1660 LINE TYPE 1
1670 LDIR 0
1680 MOVE 0,0
1690 LORG 5
1700 LABEL USING "A";"*"
1710 LORG 1
1720 CSIZE 3
1730 FOR I=1 TO N1
1740 MOVE 0,0
1750 DRAW B(I,2)*SIN(B(I,1)*G),B(I,2)*COS(B(I,1)*G)
1760 LABEL USING "2D";I
1770 NEXT I
1780 SETGU
1790 CSIZE 5
1800 MOVE 5,90
1810 LABEL USING "9A,40A";"SETTING--",Y$
1820 CSIZE 3,.5
1830 LABEL USING "30A";"ALL POSSIBLE ANCHORS"
1840 MOVE 75,80
1850 LORG 5
1860 LABEL USING "4A";"AZ=0"
1870 MOVE 82,77
1880 DRAW 82,87
1890 DRAW 83,85
1900 DRAW 81,85
1910 DRAW 82,87
1920 WAIT 8000
1930 DUMP GRAPHICS
1940 EXIT GRAPHICS
1950 GOTO 780
1960 Z$="A"
1970 DISP "SAME PRETENSION FOR ALL GUYLINES  (Y/N)";
1980 LINPUT X$
1990 IF X$="Y" THEN 2100
2000 FOR I=1 TO N
```

```
2010 DISP "DESIRED PRETENSION IN GUYLINE ";I;"F/V";
2020 INPUT T(I,4),T$[I,I]
2030 IF T(I,4)>=S(I,1)*K(I,1)^2*1.85*3 THEN 2070
2040 DISP "TENSION IN GUYLINE";I;"MUST BE";S(I,1)*K(I,1)^2*1.85*3
2050 WAIT 3000
2060 GOTO 2010
2070 T(I,5)=T(I,4)
2080 NEXT I
2090 GOTO 2230
2100 DISP "DESIRED PRETENSION IN GUYLINES";
2110 INPUT T0
2120 J=0
2130 FOR I=1 TO N
2140 IF T0>=S(I,1)*K(I,1)^2*1.85*3 THEN 2180
2150 J=1
2160 DISP "TENSION IN GUYLINE ";I;"MUST BE";S(I,1)*K(I,1)^2*1.85*3
2170 WAIT 4000
2180 T(I,4)=T0
2190 T$[I,I]="V"
2200 T(I,5)=T(I,4)
2210 NEXT I
2220 IF J<>0 THEN 2100
2230 PRINT
2240 PRINT CHR$(130)
2250 PRINT TAB(10);"** INITIAL OPERATING LINE AND GUYLINE TENSIONS **"
2260 PRINT CHR$(128)
2270 DISP "AZIMUTH FROM TOWER BASE TO OPERATING LINE DRUMS";
2280 INPUT R
2290 PRINT LIN(1);"AZIMUTH: TOWER BASE TO OPER. LINE DRUMS= ";R;" DEGREES"
2300 PRINT
2310 F1=0
2320 F2=0
2330 F3=0
2340 I=1
2350 PRINT "OPERATING LINES                     TENSION     ANGLE   AZIMUTH   DRUM DIST
"
2360 DISP "TENSION IN THE OPERATING LINE AT TOWER TOP (LB)";
2370 INPUT F0
2380 IF F0=0 THEN 2600
2390 DISP "OPERATING LINE ANGLE FROM THE HORIZONTAL (DEG.)";
2400 INPUT U
2410 DISP "AZIMUTH OF OPERATING LINE LEAD (DEG.)";
2420 INPUT V
2430 DISP "DISTANCE FROM TOWER BASE TO OPERATING LINE DRUM";I;
2440 INPUT R1
2450 PRINT "    OPER. LINE";I;
2460 PRINT USING "20D,3(9D)";F0,U,V,R1
2470 I=I+1
2480 F(1)=R1*COS(R*G)
2490 F(2)=-R1*SIN(R*G)
2500 F(3)=-H
```

```
2510 X=SQR((F(1)-D1)^2+(F(2)-D2)^2+(F(3)-D3)^2)
2520 F(1)=(F(1)-D1)/X
2530 F(2)=(F(2)-D2)/X
2540 F(3)=(F(3)-D3)/X
2550 X=F0*COS(U*G)
2560 F1=F1+X*COS(V*G)+F0*F(1)
2570 F2=F2-X*SIN(V*G)+F0*F(2)
2580 F3=F3-F0*SIN(U*G)+F0*F(3)
2590 GOTO 2360
2600 F0=SQR(F1^2+F2^2+F3^2)
2610 U=-ATN(F3/(SQR(F1^2+F2^2)+1E-50))/G
2620 V=0
2630 IF F2<>0 THEN 2670
2640 IF F1>=0 THEN 2700
2650 V=180
2660 GOTO 2700
2670 V=90+ATN(F1/F2)/G
2680 IF F2<0 THEN 2700
2690 V=V+180
2700 IF Z$="B" THEN 2730
2710 F4=F1
2720 F5=F2
2730 PRINT "OPER. LINES VECTOR RESULTANT";
2740 PRINT USING 2750;F0,U,V
2750 IMAGE 9D ,2(9D )
2760 IF Z$="B" THEN 4080
2770 A(1,1)=0
2780 A(1,2)=0
2790 A(2,1)=0
2800 A(2,2)=0
2810 A(5,1)=0
2820 A(5,2)=0
2830 FOR I=1 TO N
2840 T(I,1)=T(I,4)*N(I,1)
2850 T(I,2)=T(I,4)*N(I,2)
2860 T(I,3)=T(I,4)*N(I,3)
2870 A(1,1)=A(1,1)+T(I,1)
2880 A(1,2)=A(1,2)+T(I,2)
2890 A(5,1)=A(5,1)+T(I,3)
2900 A(5,2)=A(5,2)+T(I,4)
2910 IF T$[I,I]="F" THEN 2940
2920 A(2,1)=A(2,1)+ABS(T(I,1))
2930 A(2,2)=A(2,2)+ABS(T(I,2))
2940 NEXT I
2950 I9=0
2960 GOTO 4910
2970 IF ABS(F4+A(1,1))<100 THEN 3010
2980 J=1
2990 K=2
3000 GOTO 3040
```

```
3010 IF ABS(F5+A(1,2))<100 THEN 3410
3020 J=2
3030 K=1
3040 A(3,1)=A(1,1)+F1
3050 A(3,2)=A(1,2)+F2
3060 A(4,1)=A(2,1)
3070 A(4,2)=A(2,2)
3080 A(1,1)=A(1,2)=A(2,1)=A(2,2)=A(5,1)=A(5,2)=0
3090 FOR I=1 TO N
3100 IF T$[I,I]="F" THEN 3250
3110 IF ABS(T(I,J))<.1 THEN 3250
3120 R=ABS((T(I,J)-ABS(T(I,J))/A(4,J)*A(3,J))/T(I,J))
3130 T(I,J)=T(I,J)*R
3140 T(I,K)=T(I,K)*R
3150 T(I,3)=T(I,3)*R
3160 T(I,4)=SQR(T(I,1)^2+T(I,2)^2+T(I,3)^2)
3170 IF T(I,4)>=S(I,1)*K(I,1)^2*1.85*2 THEN 3250
3180 IF X>20 THEN 3380
3190 X=X+1
3200 T(I,4)=20*S(I,1)*K(I,1)^2*1.85
3210 T(I,1)=T(I,4)*N(I,1)
3220 T(I,2)=T(I,4)*N(I,2)
3230 T(I,3)=T(I,4)*N(I,3)
3240 GOTO 3100
3250 A(1,1)=A(1,1)+T(I,1)
3260 A(1,2)=A(1,2)+T(I,2)
3270 A(5,1)=A(5,1)+T(I,3)
3280 A(5,2)=A(5,2)+T(I,4)
3290 IF T$[I,I]="F" THEN 3320
3300 A(2,1)=A(2,1)+ABS(T(I,1))
3310 A(2,2)=A(2,2)+ABS(T(I,2))
3320 X=0
3330 NEXT I
3340 I9=I9+1
3350 DISP "ITERATION # ";I9
3360 IF I9>25 THEN 3380
3370 GOTO 4910
3380 PRINT "!!!!!!PRETENSION CONVERGENCY PROBLEM!!!!!!"
3390 PRINT "TRY A NEW PRETENSION ARRANGEMENT"
3400 GOTO 1970
3410 REM ****INITIAL UNSTRETCHED CATENARY LENGTH******
3420 DEF FNS(X)=X+X^3/6+X^5/120
3430 DEF FNC(X)=1+X^2/2+X^4/24+X^6/720
3440 DEF FNA(X)=1/X+X/3-X^3/45+2*X^5/945
3450 FOR I=1 TO N
3460 T=T(I,4)
3470 D=SQR(M(I,1)^2+M(I,2)^2)
3480 Y=-M(I,3)
3490 W=K(I,1)^2*1.85
3500 R1=W*S(I,1)
```

```
3510 X=D/2
3520 J=0
3530 K=1
3540 A1=SQR((R1*Y*X/D^2)^2-(1+(Y/D)^2)*(R1^2*(X/D)^2-T^2))
3550 M=(-R1*Y*X/D^2+A1)/(1+(Y/D)^2)/W
3560 D0=D/2/M
3570 S=SQR(Y^2+(2*M*FNS(D0))^2)
3580 R1=W*S
3590 X=D/2-Y/S*(M-D/2*FNA(D0))
3600 T1=W/2*(S*FNA(D0)+Y)
3610 IF ABS(T1-T)<T/10000 THEN 3680
3620 IF K>20 THEN 3650
3630 K=K+1
3640 GOTO 3540
3650 PRINT "!!!!!PRETENSION IN GUYLINE ";I;"TOO LOW!!!!!!"
3660 PRINT "TRY A NEW PRETENSION ARRANGEMENT"
3670 J=1
3680 S(I,3)=S
3690 S(I,4)=S-(T-W*Y/2)/K(I,2)
3700 S(I,5)=S
3710 NEXT I
3720 IF J<>0 THEN 1970
3730 PRINT
3740 PRINT "GUYLINE           *PRETENSIONS*              *INITIAL LENGTHS*"
3750 PRINT "NUMBER          INPUT       BALANCED      STRETCHED    UNSTRETCHED"
3760 FOR I=1 TO N
3770 PRINT USING 3780;I,T(I,5),T(I,4),S(I,3),S(I,4)
3780 IMAGE M3D ,M14D ,M12D ,M12D.2D ,M10D.2D
3790 NEXT I
3800 FIXED 3
3810 IF (D1>0) AND (D2<=0) THEN X=-ATN(D2/D1)/G
3820 IF D1<0 THEN X=180-ATN(D2/D1)/G
3830 IF (D1>0) AND (D2>=0) THEN X=360-ATN(D2/D1)/G
3840 IF (D1=0) AND (D2=0) THEN X=0
3850 IF (D1=0) AND (D2>0) THEN X=270
3860 IF (D1=0) AND (D2<0) THEN X=90
3870 IF INT(X)=360 THEN X=0
3880 PRINT USING "45A,2D.2D,7D";"INITIAL TOWER TOP DEFLECTION: DIST, AZ   ";SQR(
D1^2+D2^2+D3^3),X
3890 FIXED 0
3900 PRINT "INITIAL TOWER COMPRESSION   ";SQR(C1^2+C2^2+C3^2);" POUNDS"
3910 DISP "ARE PRETENSIONS SATISFACTORY";
3920 LINPUT X$
3930 IF X$="N" THEN 1960
3940 DISP "SETUP NUMBER";
3950 INPUT A9
3960 DISP "DO YOU WANT A PLOT";
3970 LINPUT X$
3980 IF X$<>"Y" THEN 4000
3990 GOSUB 6750
4000 REM *** Z$="B" INDICATES FINAL LOADS SECTION OF PROGRAM****
```

```
4010 DISP "RUN NAME OR NUMBER (UP TO 25 CHARACTERS) ";
4020 LINPUT T$[1,25]
4030 Z$="B"
4040 PRINT CHR$(132);"   FINAL OPERATING LINE TENSIONS FOR SETUP #";
4050 PRINT USING "3D,2X,5A,25A";A9,"RUN--",T$
4060 PRINT CHR$(128)
4070 GOTO 2270
4080 K1=0
4090 ON ERROR GOTO 4330
4100 L3=D(5)
4110 L4=D(6)
4120 K3=2000
4130 MAT A=(0)
4140 D1=(F1-F4)/(K(1,2)*N/3)+D(5)
4150 IF ABS(F1)>1000 THEN 4170
4160 D1=D(5)+.49
4170 D2=D(6)
4180 GOTO 4280
4190 X1=(A(1,2)+F5)/(D1-D(5))
4200 X2=(A(1,1)+F4)/(D1-D(5))
4210 D(1)=D(5)
4220 A(3,1)=-F4
4230 A(3,2)=-F5
4240 D1=D(5)
4250 D2=(F2-F5)/(K(1,2)*N/3)+D(6)
4260 IF ABS(F2)>1000 THEN 4280
4270 D2=D(6)+.49
4280 REM ********SOLUTION FOR FINAL CATENARY TENSION******
4290 DEF FNB(X)=4/S*M*A1*A3
4300 DEF FND(X)=4/S*M*A2*A3
4310 DEF FNE(X)=-X^3/3-X^5/30
4320 IF H^2-D1^2-D2^2>0 THEN 4370
4330 PRINT "!!!!!!!YOUR TOWER JUST WENT DOWN THE HILL!!!!!"
4340 PRINT "LOAD WAS TOO LARGE OR SYSTEM IS UNSTABLE"
4350 OFF ERROR
4360 GOTO 6250
4370 D3=SQR(H^2-D1^2-D2^2)-H
4380 FOR I=1 TO N
4390 F=0
4400 S0=S(I,4)
4410 M(I,4)=M(I,1)-(D1-D(5))
4420 M(I,5)=M(I,2)-(D2-D(6))
4430 M(I,6)=M(I,3)-(D3-D(7))
4440 D=SQR(M(I,4)^2+M(I,5)^2)
4450 Y=-M(I,6)
4460 S(I,2)=SQR(D^2+Y^2)
4470 W=K(I,1)^2*1.85
4480 K=K(I,2)
4490 J=1
4500 IF K1>0 THEN 4530
```

```
4510 S=S(I,3)
4520 GOTO 4540
4530 S=S(I,5)
4540 X=W*S/(2*K*(S-S0))
4550 X=LOG((1+X)/ABS(1-X))
4560 M=D/X
4570 D0=D/2/M
4580 A1=FNS(D0)
4590 A2=FNC(D0)
4600 A3=FNE(D0)
4610 A4=A2/A1
4620 S=SQR(Y^2+(2*M*A1)^2)
4630 F8=F
4640 F=S0-S+W/2/K*S*A4
4650 IF J=1 THEN 4670
4660 IF ABS(F)<.0001 THEN 4780
4670 F9=-FNB(D0)+W/2/K*(S*(1/A1)^2*D/2/M^2+FND(D0))
4680 X=M-F/F9
4690 IF X>.01 THEN 4720
4700 F9=F9*2
4710 GOTO 4680
4720 M=X
4730 IF ABS(F)>.001 THEN 4750
4740 IF ABS(ABS(F)-ABS(F8))<.0001 THEN 4780
4750 IF J=40 THEN 4780
4760 J=J+1
4770 GOTO 4570
4780 T(I,5)=W/2*(S*A4+Y)
4790 S(I,5)=S
4800 NEXT I
4810 A(1,1)=0
4820 A(1,2)=0
4830 A(5,1)=0
4840 A(5,2)=0
4850 FOR I=1 TO N
4860 A(1,1)=A(1,1)+T(I,5)*M(I,4)/S(I,2)
4870 A(1,2)=A(1,2)+T(I,5)*M(I,5)/S(I,2)
4880 A(5,1)=A(5,1)+T(I,5)*M(I,6)/S(I,2)
4890 A(5,2)=A(5,2)+T(I,5)
4900 NEXT I
4910 IF Q>0 THEN 4930
4920 A(5,2)=0
4930 REM *****COMPUTE THE COMPRESSION IN THE TOWER*****
4940 C4=H+D3
4950 C3=A(5,2)*C4/H-A(5,1)-F3
4960 IF Z$="A" THEN 4990
4970 IF K1>1 THEN 4990
4980 C3=A(5,2)*C4/H-A(5,1)
4990 C1=C3*D1/C4
5000 C2=C3*D2/C4
```

```
5010 C=SQR(C1^2+C2^2+C3^2)
5020 A(1,1)=A(1,1)+C1-A(5,2)*D1/H
5030 A(1,2)=A(1,2)+C2-A(5,2)*D2/H
5040 IF Z$="A" THEN 2970
5050 K1=K1+1
5060 IF K1>25 THEN 4330
5070 DISP "ITERATION # ";K1
5080 IF X$="A" THEN 6520
5090 IF X$="B" THEN 6670
5100 IF K1=1 THEN 4190
5110 IF K1>2 THEN 5310
5120 Y1=(A(1,1)+F4)/(D2-D(6))
5130 Y2=(A(1,2)+F5)/(D2-D(6))
5140 D(2)=D(6)
5150 IF ABS(F1-F4)>ABS(F2-F5) THEN 5250
5160 A(3,1)=-F4
5170 A(3,2)=-F5
5180 K2=1
5190 D1=D(5)
5200 D2=-(F2-F5)/Y2+D(6)
5210 IF ABS(D2-D(2))<.5 THEN 4320
5220 GOSUB 6620
5230 D2=D2+SGN(D2)*.5
5240 GOTO 5310
5250 K2=2
5260 D2=D(6)
5270 D1=-(F1-F4)/X2+D(5)
5280 IF ABS(D1-D(1))<.5 THEN 4320
5290 GOSUB 6470
5300 D1=D1+SGN(D1)*.5
5310 REM ******CHECK FORCE BALANCE IN X-Y DIRECTIONS******
5320 IF K2=2 THEN 5570
5330 IF ABS(F1+A(1,1))<K3 THEN 5570
5340 L3=D1
5350 L4=D2
5360 K2=2
5370 L1=-(F1+A(1,1))/X2
5380 A(4,1)=A(4,1)+1
5390 IF A(4,1)<5 THEN 5410
5400 GOSUB 6410
5410 D1=D1+L1
5420 IF ABS(D1)<ABS(D(1))+.5 THEN 5440
5430 GOSUB 6410
5440 V2=L1*X1
5450 L2=-V2/Y2
5460 D2=D2+L2
5470 K2=1
5480 IF ABS(D2)<ABS(D(2))+.5 THEN 5500
5490 GOSUB 6410
5500 K2=2
```

```
5510 V1=L2*Y1
5520 L1=-V1/X2
5530 D1=D1+L1
5540 IF ABS(D1)<ABS(D(1))+.5 THEN 5560
5550 GOSUB 6410
5560 GOTO 4320
5570 IF ABS(F2+A(1,2))<K3 THEN 5810
5580 L3=D1
5590 L4=D2
5600 K2=1
5610 L2=-(F2+A(1,2))/Y2
5620 A(4,2)=A(4,2)+1
5630 IF A(4,2)<5 THEN 5650
5640 GOSUB 6410
5650 D2=D2+L2
5660 IF ABS(D2)<ABS(D(2))+.5 THEN 5680
5670 GOSUB 6410
5680 V1=L2*Y1
5690 L1=-V1/X2
5700 D1=D1+L1
5710 K2=2
5720 IF ABS(D1)<ABS(D(1))+.5 THEN 5740
5730 GOSUB 6410
5740 K2=1
5750 V2=L1*X1
5760 L2=-V2/Y2
5770 D2=D2+L2
5780 IF ABS(D2)<ABS(D(2))+.5 THEN 5800
5790 GOSUB 6410
5800 GOTO 4320
5810 IF ABS(F1+A(1,1))>K3 THEN 5340
5820 K3=500
5830 IF ABS(F1+A(1,1))>500 THEN 5340
5840 IF ABS(F2+A(1,2))>500 THEN 5580
5850 PRINT
5860 PRINT "GUYLINE        *STRETCHED LENGTHS*             *GUYLINE TENSIONS*"
5870 PRINT " NUMBER   INITIAL     FINAL     CHANGE     INITIAL     FINAL     CHANGE"
5880 OFF ERROR
5890 J=0
5900 Elastic_flag=0
5910 FOR I=1 TO N
5920 IF T(I,5)>100000*K(I,1)^2/Safety_factor THEN 5960
5930 PRINT USING 5940;I,S(I,3),S(I,5),S(I,5)-S(I,3),T(I,4),T(I,5),T(I,5)-T(I,4)
5940 IMAGE M3D ,M9D.2D ,M5D.2D ,M6D.2D ,M9D ,M8D ,M9D
5950 GOTO 6000
5960 PRINT USING 5970;I,S(I,3),S(I,5),S(I,5)-S(I,3),T(I,4),T(I,5),T(I,5)-T(I,4)
5970 IMAGE M3D ,M9D.2D ,M5D.2D ,M6D.2D ,M9D ,M8D ,"!!!",M6D
5980 J=1
5990 IF T(I,5)>100000*K(I,1)^2*.6 THEN Elastic_flag=1
6000 NEXT I
```

```
6010 IF J=0 THEN 6050
6020 PRINT USING "55A,3D";"!!!-GUYLINE WORKING LOAD EXCEEDED WITH SAFETY FACTOR
OF",Safety_factor
6030 IF Elastic_flag=0 THEN 6050
6040 PRINT USING "80A";"ELASTIC LIMIT OF CABLE EXCEEDED--THIS LOADING IS BEYOND
THE RANGE OF THE MODEL"
6050 PRINT
6060 FIXED 0
6070 PRINT "UNBALANCED X-FORCE=";F1+A(1,1);"   UNBALANCED Y-FORCE=";F2+A(1,2)
6080 FIXED 3
6090 IF (D1>0) AND (D2<=0) THEN X=-ATN(D2/D1)/G
6100 IF D1<0 THEN X=180-ATN(D2/D1)/G
6110 IF (D1>0) AND (D2>=0) THEN X=360-ATN(D2/D1)/G
6120 IF (D1=0) AND (D2=0) THEN X=0
6130 IF (D1=0) AND (D2>0) THEN X=270
6140 IF (D1=0) AND (D2<0) THEN X=90
6150 IF INT(X)=360 THEN X=0
6160 PRINT USING "43A,2D.2D,7D";"FINAL TOWER DEFLECTION: DIST, AZ  ";SQR(D1^2+D2
^2+D3^2),X
6170 FIXED 0
6180 PRINT "FINAL TOWER COMPRESSION ";SQR(C1^2+C2^2+C3^2);" POUNDS"
6190 PRINT "NUMBER OF ITERATIONS=";K1
6200 PRINT TAB(100),TAB(100)
6210 DISP "DO YOU WANT A PLOT";
6220 LINPUT X$
6230 IF X$<>"Y" THEN 6250
6240 GOSUB 6750
6250 D1=D(5)
6260 D2=D(6)
6270 D3=D(7)
6280 D(1)=0
6290 D(2)=0
6300 D(3)=0
6310 D(4)=0
6320 X$="Y"
6330 PRINTER IS 16
6340 PRINT "1=NEW LOAD";TAB(30);"2=NEW PRETENSIONS"
6350 PRINT "3=NEW ANCHOR ARRANGEMENT";TAB(30);"4=STOP"
6360 INPUT "CHOOSE ONE OF THE ABOVE  (1-4) ? ",X
6370 PRINT PAGE
6380 PRINTER IS 0
6390 ON X GOTO 4000,1960,740,6400,7710
6400 STOP
6410 REM ***SUBROUTINE TO UPDATE SPRING RATES***
6420 A(3,1)=A(1,1)
6430 A(3,2)=A(1,2)
6440 IF K2=1 THEN 6600
6450 A(4,1)=0
6460 D1=D1+SGN(D1)*.5
6470 X$="A"
6480 D(1)=L3
6490 D(4)=D2
6500 D2=L4
```

```
6510 GOTO 4320
6520 D2=D(4)
6530 X$="Y"
6540 X1=(A(1,2)-A(3,2))/(D1-D(1))
6550 X2=(A(1,1)-A(3,1))/(D1-D(1))
6560 D(1)=D1
6570 L3=D1
6580 D1=D1-SGN(D1)*.5
6590 RETURN
6600 D2=D2+SGN(D2)*.5
6610 A(4,2)=0
6620 X$="B"
6630 D(2)=L4
6640 D(3)=D1
6650 D1=L3
6660 GOTO 4320
6670 D1=D(3)
6680 X$="Y"
6690 Y1=(A(1,1)-A(3,1))/(D2-D(2))
6700 Y2=(A(1,2)-A(3,2))/(D2-D(2))
6710 D(2)=D2
6720 L4=D2
6730 D2=D2-SGN(D2)*.5
6740 RETURN
6750 REM *** PLOT ROUTINE ***
6760 PLOTTER IS 13,"GRAPHICS"
6770 GRAPHICS
6780 LOCATE 15,85,10,80
6790 SHOW -B1,B1,-B1,B1
6800 GOTO 6860
6810 LINE TYPE 3
6820 MOVE -B1-.1*B1,0
6830 DRAW B1+.1*B1,0
6840 MOVE 0,-B1-.1*B1
6850 DRAW 0,B1+.1*B1
6860 LINE TYPE 1
6870 LDIR 0
6880 CSIZE 3
6890 LORG 5
6900 IF (D1=0) AND (D2=0) THEN 6930
6910 MOVE -D2,D1
6920 LABEL USING "A";"*"
6930 J=0
6940 LORG 1
6950 FOR I=1 TO N
6960 MOVE -D2,D1
6970 DRAW -M(I,2),M(I,1)
6980 LABEL USING "2D";I
6990 IF Z$="B" THEN 7020
7000 LABEL USING "6D";T(I,4)
```

```
7010 GOTO 7070
7020 IF T(I,5)>100000*K(I,1)^2/Safety_factor THEN 7050
7030 LABEL USING "6D";T(I,5)
7040 GOTO 7070
7050 LABEL USING "6D,4A";T(I,5)," !!!"
7060 J=1
7070 NEXT I
7080 IF F0=0 THEN 7160
7090 LINE TYPE 3
7100 MOVE -D2,D1
7110 DRAW B1/2*SIN(V*G),B1/2*COS(V*G)
7120 LINE TYPE 1
7130 LORG 5
7140 LABEL USING "A";"R"
7150 LORG 1
7160 SETGU
7170 IF J=0 THEN 7200
7180 MOVE 0,0
7190 LABEL USING "55A,3D";"!!!-GUYLINE WORKING LOAD EXCEEDED WITH SAFETY FACTOR
OF",Safety_factor
7200 MOVE 5,94
7210 CSIZE 5
7220 LABEL USING "9A,40A";"SETTING--",Y$
7230 CSIZE 3
7240 MOVE 5,89
7250 IF Z$="B" THEN 7300
7260 LABEL USING "13A,2D";"TRIAL SETUP #",A9
7270 MOVE 5,86
7280 LABEL USING "30A";"GUYLINE PRETENSIONS"
7290 GOTO 7330
7300 LABEL USING "13A,2D,4X,5A,25A";"TRIAL SETUP #",A9,"RUN--",T$
7310 MOVE 5,86
7320 LABEL USING "30A";"FINAL GUYLINE TENSIONS"
7330 IF F0=0 THEN 7380
7340 MOVE 5,83
7350 LABEL USING "30A";"LOAD RESULTANT (MAG,ANGLE,AZ)"
7360 MOVE 5,80
7370 LABEL USING "4X,3(6D)";F0,U,V
7380 LORG 5
7390 MOVE 75,80
7400 CSIZE 3
7410 LABEL USING "4A";"AZ=0"
7420 MOVE 82,77
7430 DRAW 82,87
7440 DRAW 83,85
7450 DRAW 81,85
7460 DRAW 82,87
7470 WAIT 8000
7480 DUMP GRAPHICS
7490 EXIT GRAPHICS
7500 PRINT LIN(2)
7510 RETURN
```

Carson, Ward W.; Jorgensen, Jens E.; Reutebuch, Stephen **E.;** Bramwell, William J.
A procedure for analysis of guyline tension. Gen. Tech. Rep. PNW-142. Portland, **OR:** U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1982.45 p.

Most cable logging operations use a spar held in place near the landing by a system of guylines and anchors. Safety and economic considerations require that overloads be avoided and that the spar remain stable. This paper presents a procedure and a computer program to estimate the guyline and anchor loads on a particular system configuration by a specific set of operating line tension loads. A brief description of the analytical model used for the computaions is included. There are instructions on the use of the computer program, a description of the necessary outputs, and a program listing for those who wish to prepare the program for use on other computer facilities.

Keywords: Logging equipment engineering, cable skidding equipment, models, computer programs/programing.

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