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# **Logging Planning with the Hewlett-Packard 41-C Series Calculator**

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Logging planning with the  
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Logging Planning with the Hewlett-Packard  
41C Series Calculator

John J. Garland  
Donald D. Studier  
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# Introduction

## INTRODUCTION

### BACKGROUND

For a number of years, logging professionals have been developing programs for various hand-held calculators. These programs save many hours of tedious hand computations. The bulk of the work has been done by employees of the Forest Service, U.S.D.A., and students and faculty members of Oregon State University; thus, the programs are in the public domain.

Several types of calculators, for which various programs exist, have evolved over time. One in common use is the Hewlett-Packard 41 series calculator with various attachments and memory capabilities. (Mention of trade names does not constitute an endorsement but is only provided for reader identification.) Many programs have been written for the early HP-67/97 series calculators. While the HP-67/97 calculator programs can be readily used on the HP-41 series calculators, the programs themselves do not take full advantage of the capabilities and technology of later calculators. For this reason, there was a need to update many of the earlier calculator programs to current levels of technology.

The Forest Engineering Extension program and various Forest Service units have provided, at cost, the commonly used calculator programs for those doing logging planning. However, the proliferation of the number and types of programs makes it difficult to continue this kind of service without some effort toward more efficient distribution. Over 45 programs that a planner might find useful in the field are available for logging planning, economics, and forestry operations. Users should review the full availability of programs for their needs; however, it seems appropriate to collect some of the more commonly used programs into a package. A custom ROM (remote only memory) allows such programs to be more easily available than in the scattered formats now occurring.

## PURPOSE

The purpose of this publication is to collect, in one place, the reference material for a "Users Guide" for 14 of the commonly used programs for logging planning. Examples allow users already familiar with planning programs to use the programs more effectively. Readers should be familiar with the HP-41C series calculator and its capabilities as well.

However, the publication is not intended to be a documentation of the theory on which these programs are based, nor does it provide full documentation for the particular programs of interest. Readers will have to make program listings once they have copies of programs in hand in order to fully document the programs. If questions arise, they will need to contact the authors of the particular programs, or perhaps the authors of this publication.

## PROGRAM SELECTION

The programs for this collection were selected because they are in current use, both in classes and in the field and because they meet a range of needs for logging planning and forestry operations. Many programs not selected were useful, and no negative attributes should be attached because they were not selected for this particular collection.

Several programs collected here were originally written for earlier calculators and have been updated and rewritten for the HP-41C series calculators to enable program users to take advantage of improved calculator capability in later models. In one case, two earlier programs were combined into a single program. Updating and combining programs has meant that some of the names of the original programs have been altered. Readers should note carefully the current name in use for the collection as well as the former names of the programs.

## HOW TO OBTAIN PROGRAMS

Readers may obtain copies of the programs collected here, in the form of a custom ROM titled: "LOGGING PAC", from Forestry Business Office, Oregon State University, Corvallis, OR 97331-5704. The

price for this collection is \$100.00, which includes shipping and handling. Once the readers have copies of the programs in hand, they may more effectively use this publication and may wish to review the program listings to better understand the program structure.

### LIABILITY

The authors have checked the programs contained in this collection for accuracy against existing program examples to help assure that these programs work as intended. Furthermore, these programs have been in use for a number of years. Hopefully, most existing problems have already been corrected and improvements incorporated into the programs contained here. The authors and Oregon State University make no statement of warranty for the programs provided here other than the replacement of defective ROMs within 30 days of purchase.

### COMMENTS ON THE CUSTOM ROM

Users should observe the same care in treatment of the custom "LOGGING PAC" ROM as in caring for other ROMs or the calculator itself. Excessive moisture, strong magnetic fields, and physical abuse are some of the reasons that ROMs become defective.

Also because of the size of the "LOGGING PAC" ROM, users should insert the ROM in ports 1 or 3. The ROM will also use the addresses of ports 2 and 4 respectively; e.g., ports 1 and 2 go together and ports 3 and 4 go together. This means users will not be able to use other ROMs or accessories in the ports occupied by the "LOGGING PAC". Printer attachments should be inserted into the port nearest the "LOGGING PAC;" e.g. with "LOGGING PAC" in port 1, printer should be in port 3, or alternately, with the ROM in port 2, the printer should be in port 4.

The Quad Memory Module for the HP-41C calculator should be inserted in a higher numbered port than the "LOGGING PAC" ROM.

# Format of the Publication

Because space is limited for explanation, readers need to understand the publication format in order to make full use of the programs. Each section begins as shown:

PROGRAM TITLE (and name for HP-41C series)

FORMER TITLE AND USFS NO. (if the program has been altered or adapted  
from HP-67-97 program)

AUTHOR AND ADDRESS

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Program descriptions are divided into four main parts:

- I. BACKGROUND INFORMATION
  - A. General Assumptions
  - B. References
  - C. Figures and Formulas
  
- II. CONVENTIONS AND MEMORY
  - A. Conventions (program dimensions--signs, angular measurement, reference points, etc.)
  - B. Size and Capacity (storage registers; number of steps)
  
- III. EXAMPLE OF PROGRAM USE
  - A. Information Needed
  - B. Step-by-Step Example (keystrokes and output)
  
- IV. CAUTIONS, LIMITATIONS, AND COMMENTS

# Skyline Planning (Bodenhausen Series)

A series of skyline planning programs have been developed by Craig Bodenhausen as part of the requirements for a Master of Forestry degree at Oregon State University. A more complete description can be obtained from the paper cited in the References (page 151). The entire series consists of five programs that are presented here in the following sequence:

- Profile Reduction (PR)
- Profile Plot with Reverse Profile (PLOT1)
- Skyline Payload Analysis for Live and Running Skylines (LOAD)
- Standing Skyline Payload Analysis (SSL)
- Clamped Carriage Payload Analysis (CLCAR)

## Profile Reduction (PR)

AUTHOR AND ADDRESS:

Craig Bodenhausen  
Eldorado National Forest  
100 Forni Road  
Placerville, CA 95667

### I. BACKGROUND INFORMATION

- A. General Assumptions: None stated
- B. References: Bodenhausen, 1982
- C. Figures

Figure 1. Profile for Sample Problem with Slope and Slope distance.  
Figure 2. Profile for Sample Problem with x,y Coordinates

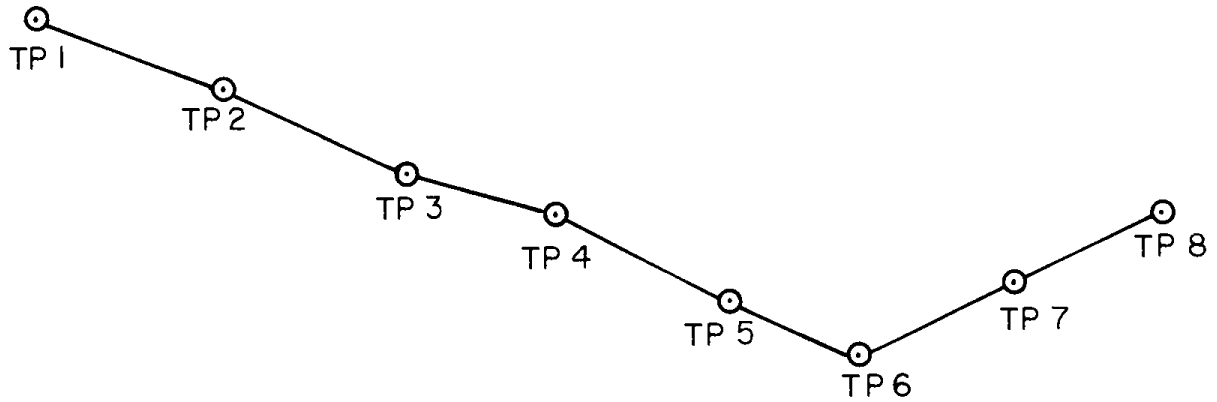
### II. CONVENTIONS AND MEMORY

- A. Conventions

"% Slope?": If a reading of slope is taken uphill to the next point, the "% Slope?" is positive; if it is taken downhill to the next point, it is negative.

"Y=?": If an initial "Y" point is zero in profiles using coordinates, then the next "Y" must be negative for going downhill, and positive for going uphill.

FIGURE 1. PROFILE FOR SAMPLE PROBLEM WITH SLOPE AND SLOPE DISTANCE

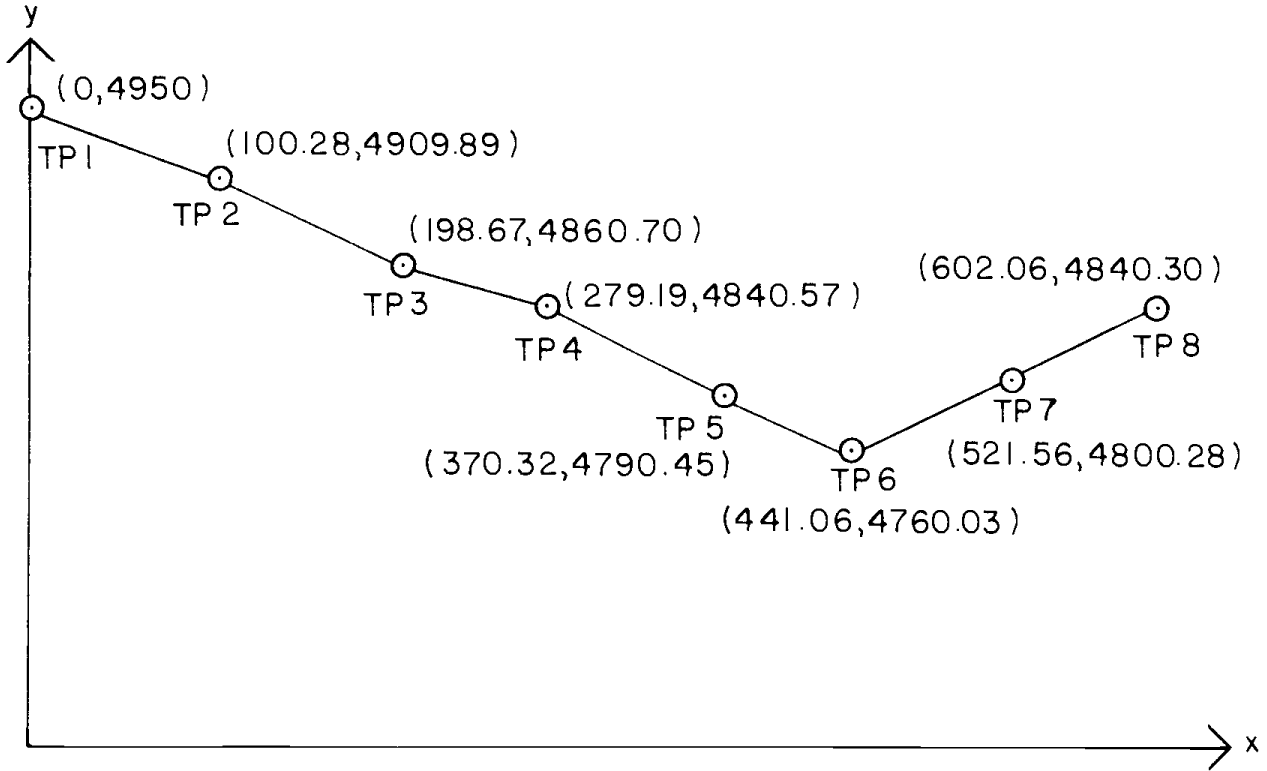


The initial station is 0 + 00 and the initial elevation is 4950 ft.

Terrain Point (TP) No.	Leg No.	Slope Distance (ft)	% Slope
1	1	108	-40
2	2	110	-50
3	3	83	-25
4	4	104	-55
5	5	77	-43
6	6	90	50
7	7	90	50
8			



FIGURE 2. PROFILE FOR SAMPLE PROBLEM WITH X, Y COORDINATES



## B. Size and Capacity

The calculator must be sized to 033. The program uses 47 registers. Total calculator capacity must be 80 registers. The program consists of 124 steps.

## III. EXAMPLE OF PROGRAM USE

### A. Information Needed

1. "DATA TYPE?": Asks which data input style users want (coordinates, or percent slope and slope distance).
2. "COORD=0" and "%,SL.DIST=1": Prompt for data type desired (enter zero or one).
3. "TP n": Shows terrain-point number (n) when coordinates are the data input (output).
4. "x=?": Prompt for horizontal coordinate in feet.
5. "y=?": Prompt for vertical coordinate in feet.
6. "OK? Y=1 N=0": After coordinates or percent slope and slope distances are entered, they will be displayed again for review. The prompts, "OK? Y=1 N=0", will appear. If the numbers displayed are correct, enter a one. If they aren't correct, enter a zero (input).
7. "INITIAL STA": If users have chosen "%,SL.DIST", "INITIAL STA" prompts for the initial station in feet (input).
8. "INITIAL ELEV.": Prompt for initial elevation for terrain point one in feet (input).
9. "LEG n": Shows leg of the profile users will next enter; "n" is the leg number (output).
10. "SLOPE DIST?": Prompt for slope distance in feet (input).
11. "% SLOPE?": Prompt for the slope of the leg in percent (input).

B. Step-by-Step Example

Given: Profile coordinates (Figure 2)

Terrain Point	x	y
1	0	4950
2	100.28	4909.89
3	198.67	4860.70
4	279.19	4840.57
5	370.32	4790.45
6	441.06	4760.03
7	521.56	4800.28
8	602.06	4840.30

Percent slope and slope distance (Figure 1)

Initial Station = 0, Initial Elevation = 4950

Program Execution (with percent slope and slope distance):  
 Access profile reduction with program by XEQ ALPHA PR ALPHA

<u>Prompt</u>	<u>Response</u>	<u>Keystrokes</u>
"DATA TYPE"	No response	No keystroke
"COORD=0"	No response	No keystroke
"%,SL.DIST.=1"	1	<u>R/S</u>
"INITIAL STA"	0	<u>R/S</u>
"INITIAL ELEV"	4950	<u>R/S</u>
"LEG 1.000"	No response	No keystroke
"SLOPE DIST?"	108	<u>R/S</u>
"% SLOPE?"	40	<u>CHS</u> <u>R/S</u>
"DIST = 108.000"	No response	No keystroke
"SLOPE = -40.000"	No response	No keystroke
"OK? Y=1, N=0"	1	<u>R/S</u>
"LEG 2.000"	No response	No keystroke
"SLOPE DIST?"	110	<u>R/S</u>

"% SLOPE?"	50	<u>CHS</u> <u>R/S</u>
"DIST = 110.000"	No response	No keystroke
"SLOPE = -50.000"	No response	No keystroke
"OK? Y=1, N=0"	1	<u>R/S</u>
"LEG 3.000"	No response	No keystroke
"SLOPE DIST?"	83	<u>R/S</u>
"% SLOPE?"	25	<u>CHS</u> <u>R/S</u>
"DIST = 83.000"	No response	No keystroke
"SLOPE = -25.000"	No response	No keystroke
"OK? Y=1, N=0"	1	<u>R/S</u>
"LEG 4.000"		
"SLOPE DIST?"	104	<u>R/S</u>
"% SLOPE?"	55	<u>CHS</u> <u>R/S</u>
"DIST = 104.000"	No response	No keystroke
"SLOPE = -55.000"	No response	No keystroke
"OK? Y=1, N=0"	1	<u>R/S</u>
"LEG 5.000"	No response	No keystroke
"SLOPE DIST?"	77	<u>R/S</u>
"% SLOPE?"	43	<u>CHS</u> <u>R/S</u>
"DIST = 77.000"	No response	No keystroke
"SLOPE = -43.000"	No response	No keystroke
"OK? Y=1, N=0"	1	<u>R/S</u>
"LEG 6.000"	No response	No keystroke
"SLOPE DIST?"	90	<u>R/S</u>
"% SLOPE?"	50	<u>R/S</u>

"DIST = 90.000"	No response	No keystroke
"SLOPE = 50"	No response	No keystroke
"OK? Y=1, N=0"	1	<u>R/S</u>
"LEG 7.000"	No response	No keystroke
"SLOPE DIST?"	90	<u>R/S</u>
"% SLOPE?"	50	<u>R/S</u>
"DIST = 90.000"	No response	No keystroke
"SLOPE = 50.000"	No response	No keystroke
"OK? Y=1, N=0"	1	<u>R/S</u>

At this point the profile is stored, so the next prompt can be ignored. Profile can also be stored using x,y coordinates.

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

This program is simply for profile storage. It is used in conjunction with other programs developed by Craig Bodenhausen:

Skyline Payload Analysis for Live and Running Skylines (LOAD).

Standing Skyline Payload Analysis (SSL)

Clamped Carriage Payload Analysis (CLCAR)

Profile Plot (PLOT1)

A maximum of 30 terrain points can be stored in "PR".

"PR" uses terrain points entered as reference points in other programs. Terrain points of interest must be identified in advance of using other programs. Should some point on the terrain be of interest but not be entered as a specific terrain point in "PR", a new profile must be entered including the point of interest as a terrain point.

# Profile Plot with Reverse Profile Option (PLOT1)

AUTHOR AND ADDRESS: Craig Bodenhausen  
Eldorado National Forest  
100 Forni Road  
Placerville, CA 95667

## I. BACKGROUND INFORMATION

### A. General Assumptions

It is assumed that a profile has already been entered into the calculator with Profile Reduction (PR).

### B. References: Bodenhausen, 1982.

### C. Figures

Figure 3A. Profile Plot Output on Printer  
3B. Profile Plot Output in Reverse Order

## II. CONVENTIONS AND MEMORY

### A. Conventions: None

### B. Size and Capacity

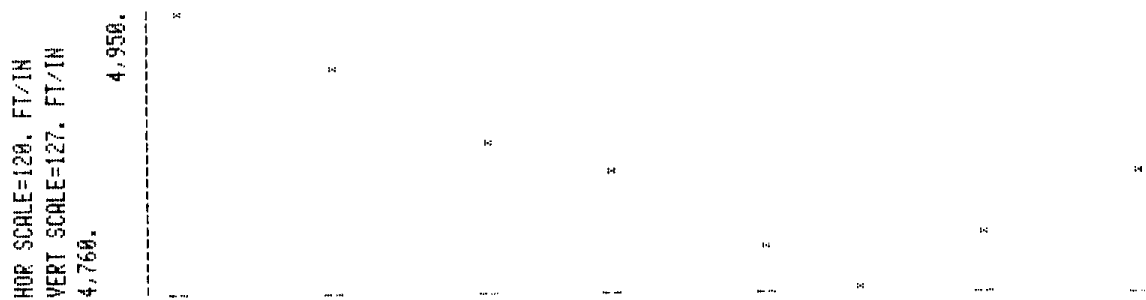
The calculator must be sized to 065. The program uses 66 registers. Total calculator capacity must be 131 registers. The program consists of 200 steps.

## III. EXAMPLE OF PROGRAM USE

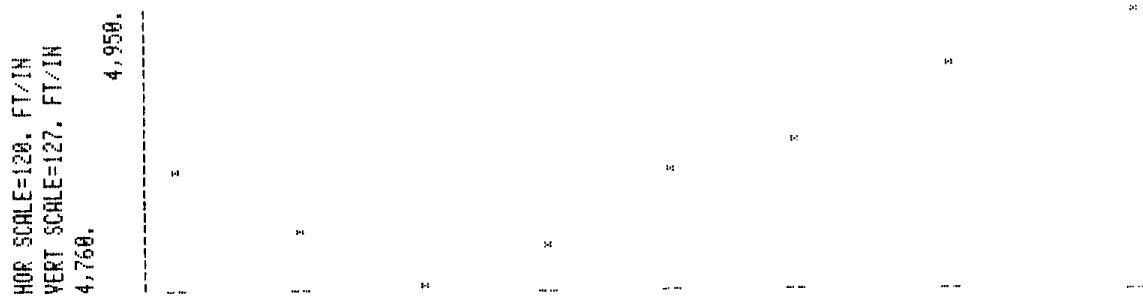
### A. Information Needed

1. A profile must be stored with the Profile Reduction (PR) program before the program can be executed.
2. "REV.PROFILE? YN": Asks if users want to reverse all of the profile points and plot them in reverse order (input). Enter "Y" for yes and "N" for NO.
3. "1ST TP=?": Prompt asking users which terrain point they want printed first (input).
4. "LAST TP=?": Asks users which terrain point they want printed last (input). Must be less than or equal to the total number of terrain points provided by the Profile Reduction (PR) program.

FIGURE 3. PROFILE PLOT OUTPUT ON PRINTER



A. Plotted as terrain points were entered.



B. Plotted in reverse order of terrain-point entry.

5. "HOR SCALE?": Prompt for horizontal scale in feet per inch (input).
6. All output is printed on the line printer (see Figure 3).

B. Step-by-Step Example

Given: All profile data has been entered through the Profile Reduction (PR) program. The profile used is the same as that used in the example of (PR) (see page 9).

Horizontal scale ("HOR SCALE?") = 120 feet/inch.

Beginning terrain point ("1ST TP") = 1.

Ending terrain point ("LAST TP") = 8.

Determine: Plot the profile in the order the terrain points were entered.

Reverse the profile and plot it with the given conditions.

Solution: Figure 3A.

Figure 3B.

Program Execution: Access Program by XEQ ALPHA PLOT1 ALPHA  
(Remember to use shift key for "1" in alpha mode.)

<u>Prompt</u>	<u>Response</u>	<u>Keystrokes</u>
"REV.PROFILE? YN" (asks users if they want to reverse the profile, yes, Y, or no, N)	N	<u>R/S</u>
"1ST TP=?" (requests beginning terrain point)	1	<u>R/S</u>
"LAST TP=?" (requests ending terrain point)	8	<u>R/S</u>
"HOR SCALE?"	120	<u>R/S</u>

At this point the profile is printed out on the printer as Figure 3A.

"8" No keystroke



When program execution is over the last terrain point is displayed.

Now reverse the profile plot. Since we are at the end of the program we simply press R/S to start the program again.

R/S (Start  
program again)

"REV.PROFILE? YN" (to reverse the profile, enter Y)	Y	<u>R/S</u>
"1ST TP=?"	1	<u>R/S</u>
"LAST TP=?"	8	<u>R/S</u>
"HOR SCALE?"	120	<u>R/S</u>

At this point the profile is printed out like Figure 3B.

The profiles have now been plotted. If the users wish to continue to use the profile data in the calculator, they must reverse the profile again to return the terrain points to their original positions. The profile can also be analyzed as a reversed profile by reversing it only once instead of twice (to return the points to their original positions.)

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

Before a profile can be plotted, it must be entered using the Profile Reduction (PR) program.

Users planning to analyze each terrain point in their original position by using programs (LOAD), (CLCAR), and/or (SSL) after reversing with (PLOT1) must reverse the profile again to return terrain points to their original positions.

The horizontal scale printed may not be exactly what was entered because the distance the printer advances to the next line is a fixed distance.

An HP 82162A Thermal Printer by Hewlett Packard must be used with this program.

# Skyline Payload Analysis for Live and Running Skylines (LOAD)

AUTHOR AND ADDRESS: Craig Bodenhausen  
Eldorado National Forest  
100 Forni Road  
Placerville, CA 95667

## I. BACKGROUND INFORMATION

### A. General Assumptions

Carriage clearance on fully suspended loads equals (choker length) + [(log length) x (tie point ratio)] and is constant for each terrain point.

For partially suspended loads, a log-to-ground angle of 15° is assumed. (If the user desires, this can be edited by changing the number in Step 03 of the program.)

The coefficient of friction is set as 0.6 (Step 09 contains this number).

The log's center of gravity is assumed to be at 50% of the log's length (Step 05).

The choker tie point on the log is located at 90% of the log length from the dragging end (Step 07).

The yarder is always assumed to be at the left side of the profile. (Profile terrain points increase in number left to right).

An unclamped carriage is used (frictionless sheaves).

Rigid-link formulations are used in calculating line tensions.

In the running-skyline analysis, tension in the slackpulling line is assumed to be zero.

The effects of line stretch are neglected.

It is assumed that the profile has already been stored in (PR) before the program ("LOAD") execution.

### B. References: Bodenhausen, 1982; Carson, 1975; Carson and Mann, 1976; Falk, 1981; and Tobey, 1980.

C. Figures and Formulas Full documentation in Bodenhausen, 1982.

Figure 4. Skyline Geometry Model

Figure 5. Log-Skidding Geometry

Figure 6. Free Body Diagram for Analyzing Live and Standing Skylines With Unclamped Carriages Skyline Limiting

Figure 7. User Keys for LOAD

Formulas for log drag of Live and Running Skylines can be found in Carson, 1975.

Formulas for line tension calculations can be found in Carson and Mann, 1976 and Falk, 1981.

Formulas for payload analysis for live and running skyline systems can be found in Tobey, 1980 and Falk, 1981.

II. CONVENTIONS AND MEMORY

A. Conventions

"W=": If this output, net payload, is negative for full suspension, it shows loads cannot be fully suspended over the terrain point with a given system.

B. Size and Capacity

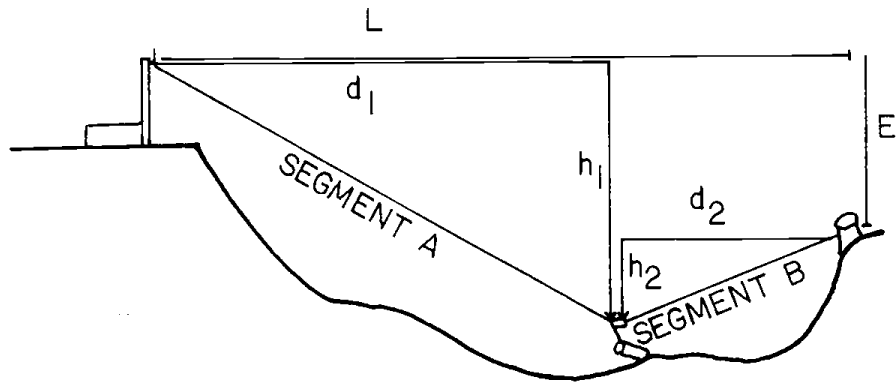
The calculator must be sized to 065. The program uses 135 registers. The program "PR", used in conjunction with this program, requires 47 registers. Total calculator capacity must be 247 registers. The program consists of 524 steps.

III. EXAMPLE OF PROGRAM USE

A. Information Needed

1. "LIVE=1, RUN=0": Asks users if they want to run a live skyline analysis or a running skyline analysis (input).
2. "HS HT": Prompt for tower height in feet (input).
3. "TS HT": Prompt for tailtree height in feet (input).
4. "CAR WT": Prompt for weight of carriage in pounds (input).
5. "CHOK LNG": Prompt for length of choker in feet (input).
6. "LOG LNG": Prompt for length of log in feet (input).

FIGURE 4. SKYLINE GEOMETRY MODEL



$d_1$  = horizontal distance from yarder to load point.

$d_2$  = horizontal distance from tailspar to load point.

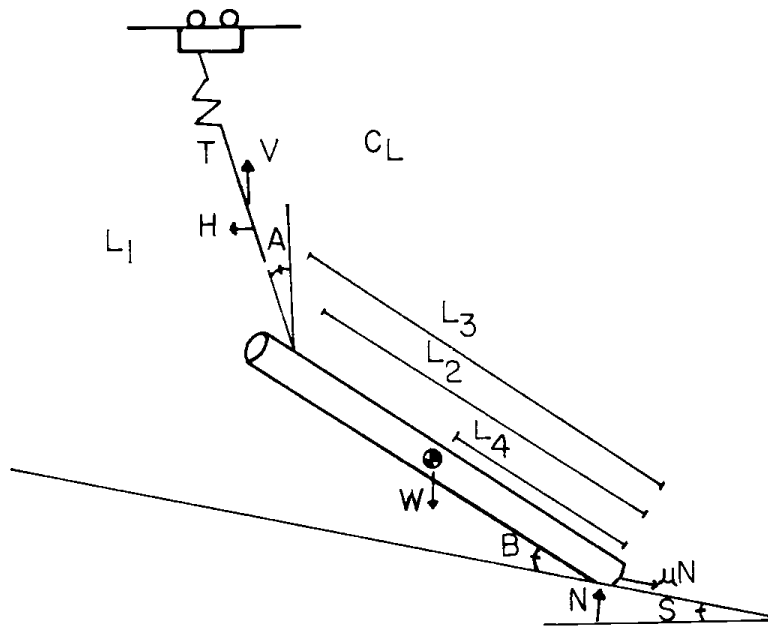
$E$  = vertical distance from headspar top to cable attachment point on tailspar.

$h_1$  = vertical distance from headspar top to load point.

$h_2$  = vertical distance from point of cable attachment on tailspar to load point.

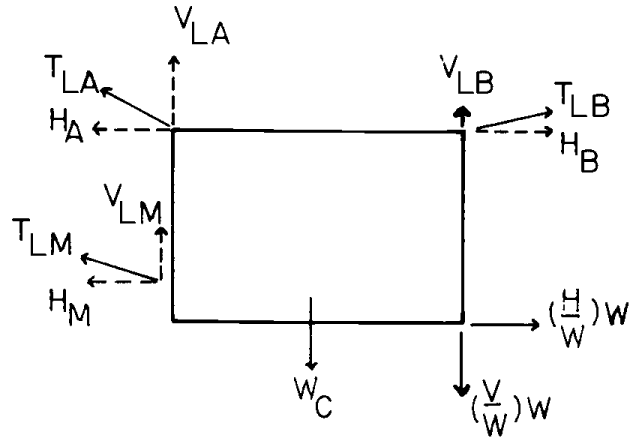
$L$  = horizontal distance from headspar to tailspar.

FIGURE 5. LOG-SKIDDING GEOMETRY



- A = choker angle during partial suspension (measured from vertical).
- B = log-to-ground angle.
- $C_L$  = carriage clearance; the vertical distance from the ground to the load analysis point on the skyline.
- H = horizontal component of choker cable tension.
- $L_1$  = choker length.
- $L_2$  = log length from dragging end to choker tie point.
- $L_3$  = total log length.
- $L_4$  = length from dragging end of the log to the log's center of gravity.
- $\mu$  = coefficient of friction.
- N = normal force applied to the ground by the log.
- S = ground slope angle.
- T = tension in choker cable.
- V = vertical component of choker cable tension.
- W = weight of the log.

FIGURE 6. FREE BODY DIAGRAM FOR ANALYZING LIVE AND STANDING SKYLINES WITH UNCLAMPED CARRIAGES SKYLINE LIMITING



NOTE: Refer to Figure 4 for skyline-segment determination.

$H$  = horizontal component of the load.

$H_A$  = horizontal tension component in skyline segment A.

$H_B$  = horizontal tension component in skyline segment B.

$H_M$  = horizontal tension component in the mainline.

$T_{LA}$  = tension in the lower end of skyline segment A.

$T_{LB}$  = tension in the lower end of skyline segment B.

$T_{LM}$  = tension in the lower end of the mainline.

$V$  = vertical component of the load.

$V_{LA}$  = vertical component of tension in the lower end of skyline segment A.

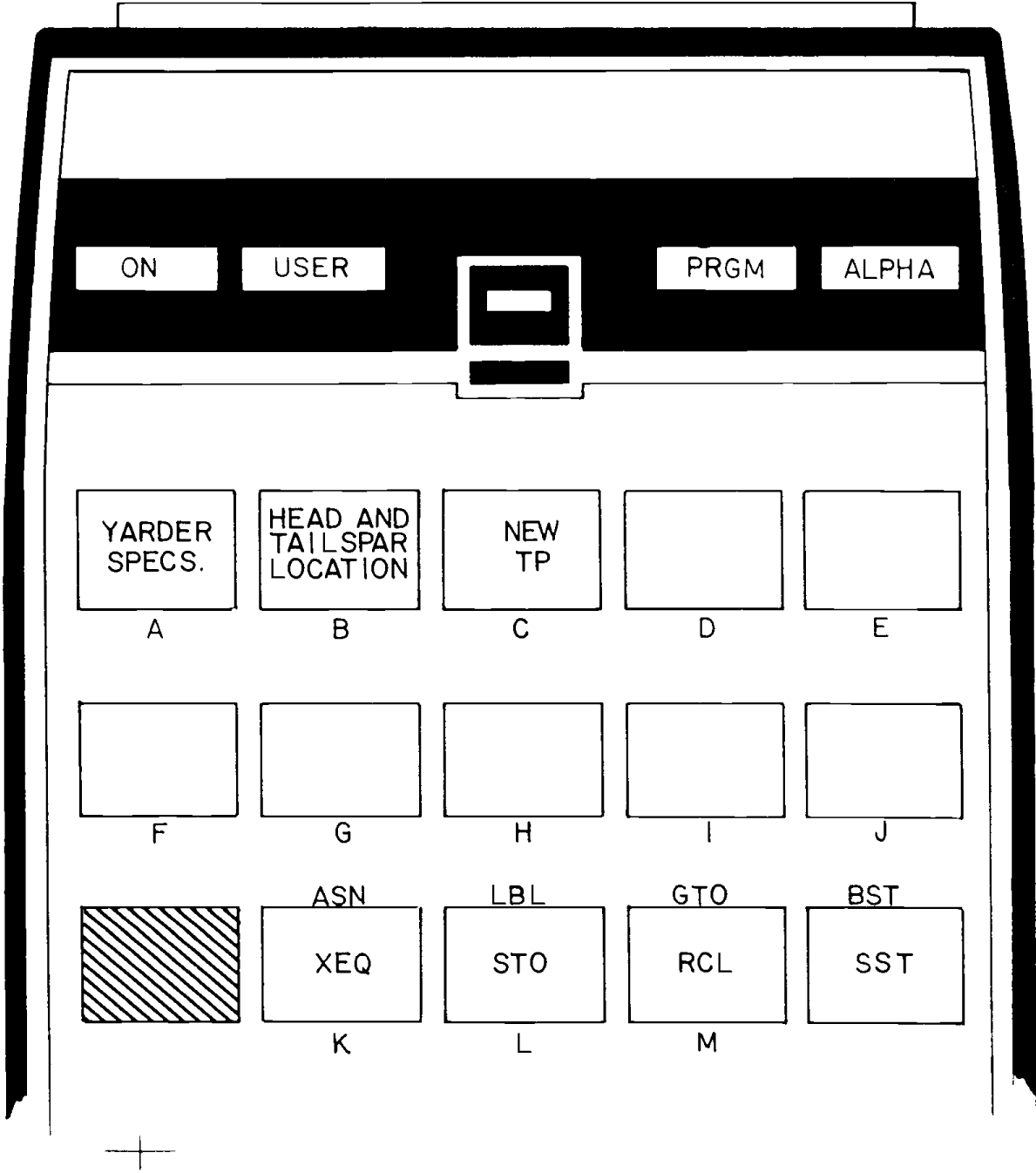
$V_{LB}$  = vertical component of tension in the lower end of skyline segment B.

$V_{LM}$  = vertical component of tension in the lower end of the mainline.

$W$  = weight of the payload.

$W_C$  = weight of the carriage.

FIGURE 7. USER KEYS FOR LOAD



7. "W SL": Prompt for weight of skyline in pounds per foot (input).
8. "SWL SL": Prompt for safe working load of skyline in pounds (input).
9. "W ML": Prompt for weight of mainline in pounds per foot (input).
10. "SWL ML": Prompt for safe working load of the mainline in pounds (input).
11. "HEADSPAR TP": Prompt for headspar terrain point number (input).
12. "TAILSPAR TP": Prompt for tailspar terrain point number (input). (Tailspar terrain point number must be greater than headspar terrain point number).
13. "LOAD TP": Prompt for the terrain point at which the user wants the load analyzed (input).
14. "FULL SUSP = 0", "PART SUSP = 1": Asks users if they want the load to be analyzed for full log suspension or partial log suspension (input).
15. "T ML=": The calculated mainline tension in pounds (output). ("TML=" is only briefly displayed, but can be recalled by pressing X><Y).
16. "W=": The calculated net payload in pounds (output).
17. "W HB": Prompt for weight of haulback line in pounds per foot.
18. "SWL HB": Prompt for haulback safe working load in pounds (input).
19. "ML LIM": Shows the system is mainline limiting. If this prompt appears, the "W=" displayed immediately after is the net payload based on the mainline safe working load (output).
20. "HB REQ": Shows the system is skyline limited but needs a haulback to maintain loaded equilibrium (output).
21. "HB T=": Tension in haulback in pounds (output).



22. "HB LIM": Shows system is haulback limited. The display "W=" appearing immediately after the "HB LIM" prompt is the net payload based on the haulback safe working load (output).
23. Key "A": Can be pressed in "User" mode and calculator will prompt user for new yarder specifications.
24. Key "B": Can be pressed in "User" mode and calculator will prompt user for new headspar and tailspar terrain points.
25. Key "C": Can be pressed in "User" mode and calculator will prompt user for a new load terrain point to be analyzed. This can be done at any time (e.g. after new desired specifications have been entered).

#### B. Step-by-Step Example

Given: Profile Data from the Profile Reduction (PR) example problem is assumed to have been entered and is used with this program.

##### Live Skyline Analysis

Tower height = 50 ft.	Skyline weight = 1.85 lb/ft.
Tail tree height = 20 ft.	Skyline safe working load =
Carriage weight = 500 lbs.	34,500 lbs.
Choker length = 16 ft.	Mainline weight= 1.42 lb/ft.
Log length = 40 ft.	Mainline safe working load =
Headspar at terrain point 1	26,500 lbs.
Tailspar at terrain point 2	Haulback weight= 0.72 lb/ft.
	Haulback safe working load =
	13,700 lbs.

##### Running Skyline Analysis

Tower height = 50 ft.	Skyline weight = 10.4 lb/ft.
Tail tree height = 20 ft.	Skyline safe working load =
Carriage weight = 500 lbs.	19,600 lbs.
Choker length = 16 ft.	Mainline weight= 1.04 lb/ft.
Log length = 40 ft.	Mainline safe working load =
Interlock tension =	19,6000 lbs.
20,000 lbs.	Slackline weight=1.04 lb/ft.
Headspar at terrain point 1	
Tailspar at terrain point 7	

Determine: Live Skyline Analysis

Net payload (W) and mainline tension (T ML) for terrain points 2 through 6 using partial and full suspension.

Running Skyline Analysis

Net payload (W) and mainline tension (T ML) for terrain points 2 through 6 using partial and full suspension.

Solution:

	Terrain Point	Net Payload (lb)	Mainline Tension (lb)
<u>Live Skyline</u>			
Partial suspension	2	19,900	12,452
	3	21,858	11,864
	4	13,487	7,561
	5	27,543	13,110
	6	50,889	2,784
Full suspension	2	388	364
	3	3,936	1,635
	4	1,689	876
	5	8,247	2,552
	6	16,804	2,747
<u>Running Skyline</u>			
Partial suspension	2	12,894	(ML LIM) 19,600
	3	14,398	(ML LIM)
	4	10,485	(ML LIM)
	5	17,417	(ML LIM)
	6	49,963	(ML LIM)
Full suspension	2	524	(ML LIM)
	3	4,153	(ML LIM)
	4	1,947	(ML LIM)
	5	8,225	(ML LIM)
	6	16,548	(ML LIM)

Program Execution: Live Skyline Analysis Partial Suspension

Access program by XEQ ALPHA LOAD ALPHA

<u>Prompt</u>	<u>Response</u>	<u>Keystrokes</u>
"LIVE=1,RUN=0" (choose live skyline by entering 1)	1	<u>R/S</u>
"HS HT" (request for headspar height)	50	<u>R/S</u>
"TS HT" (request for tailspar height)	20	<u>R/S</u>
"CAR WT" (request for carriage weight)	500	<u>R/S</u>
"CHOK LNG" (request for choker length)	16	<u>R/S</u>
"LOG LNG" (request for log length)	40	<u>R/S</u>
"W SL" (request for weight per foot of skyline)	1.85	<u>R/S</u>
"SWL SL" (request for skyline safe working load)	34,500	<u>R/S</u>
"W ML" (request for mainline weight per foot)	1.42	<u>R/S</u>
"SWL ML" (request for mainline safe working load)	26,500	<u>R/S</u>
"W HB" (request for haulback line weight per foot)	0.72	<u>R/S</u>
"SWL HB" (request for haulback safe working load)	13,700	<u>R/S</u>
"HEADSPAR TP" (request for headspar terrain point)	1	<u>R/S</u>
"TAILSPAR TP" (request for tailspar terrain point)	7	<u>R/S</u>
"LOAD TP" (request for the terrain point the users want analyzed)	2	<u>R/S</u>

"FULL SUSP = 0"	No response	No keystroke
"PART SUSP = 1"	1	<u>R/S</u>
(request for full or partial suspension, we entered 1 for partial suspension)		

At this point the program calculates the net partial suspension payload for terrain point 2. It returns:

"T ML = 12,541.821"	No response	
(the tension in the mainline at TP 2 in lbs)		
"W = 19,988.917"	No response	<u>R/S</u>
"LOAD TP"	3	<u>R/S</u>

At this point, after previous answers have been computed, the other terrain points can be computed by pressing R/S or "USER" C. The program only displays the mainline tension for a moment then goes on to net payload. If users wish, they can redisplay the mainline tension by pressing X><Y. To determine net payload and mainline tension for full suspension, re-enter that terrain point and enter a "0" when prompted for full or partial suspension. To change head or tailspar points press "USER" key "B" and to change yarder specs press "USER" key "A".

#### Running Skyline Analysis

All data is entered just as for the live skyline analysis except that zero is entered at the prompt for live or running skyline, and a haulback isn't used so no haulback weight or safe working load is entered. Remember to enter the combined weight of the mainline and slackpulling line when prompted for the mainline weight. In this case, enter 2.08 lb/ft.

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

Line tensions are calculated using Falk's (1981) improved rigid link equations, which combine catenary relationships with rigid link assumptions concerning the weight of the line segment. When used in worst case geometry for a live skyline, the improved rigid link approximation formula still predicts net payloads within 2% of the catenary result. The resulting error for a running skyline system worst case was 2.5% from the catenary solution.

The horizontal distance from the carriage to the end of the log must be less than the distance between terrain points in order to correctly analyze log drag forces. Loads are analyzed with the carriage over the terrain point. Fractional terrain points cannot be analyzed.

If negative full suspension payloads occur, it shows that loads cannot be fully suspended over the terrain point with the given system. Reduced loads in the full suspension example are due to the high carriage clearance required to fully suspend the logs.

# Standing Skyline Payload Analysis (SSL)

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## I. BACKGROUND INFORMATION

### A. General Assumptions

Rigid link formulations are used in calculating line tensions.

An unclamped carriage is assumed.

The yarder is always assumed to be at the left side of the profile. (Profile terrain points numbered from left to right.)

Minimum carriage clearance on fully suspended loads is based on choker length, log length, and tie point ratio.

Carriage clearance is determined based on an assumed elliptical load path.

The coefficient of friction for partially suspended loads is assumed as 0.6 (Step 07 of program "SSL" contains this number).

The log's center of gravity is assumed to be at 50% of the log's length (Step 03).

The choker is assumed to be tied at 90% of the log length from the dragging end (Step 05).

A terrain point should be inserted near midspan to assess maximum payloads crossing midspan.

### B. References: Bodenhausen, 1982.

## II. CONVENTIONS AND MEMORY

### A. Conventions

"W": If this output, net payload, is negative for full suspension, the loads cannot be fully suspended over the terrain point with the given system. Other payloads are calculated by safe working tensions of lines.

B. Size and Capacity

The calculator must be sized to 073. The program uses 199 registers. Program "PR", used in conjunction with this program, requires 47 registers. Total calculator capacity must be 319 registers. The program consists of 774 steps.

C. Figures and Formulas: Full documentation of formulas in Bodenhausen, 1982 and references therein.

Figures are those shown for the "LOAD" program.

Formulas for determining whether the skyline, mainline, or haulback tensions limit payload, "W", are described in Bodenhausen, 1982. First, the skyline-limiting payload is determined, then mainline and haulback tensions computed. If their safe working load is exceeded for either line, a new payload, "W", is calculated for safe working load of either the mainline or haulback.

III. EXAMPLE OF PROGRAM USE

A. Information Needed

1. "HS HT": Prompt for tower height in feet (input).
2. "TS HT": Prompt for tailtree height in feet (input).
3. "CAR WT": Prompt for weight of carriage in pounds (input).
4. "CHOK LNG": Prompt for length of choker in feet (input).
5. "LOG LNG": Prompt for length of log in feet (input).
6. "W SL": Prompt for weight of skyline in pounds per foot (input).
7. "SWL SL": Prompt for safe working load of skyline in pounds (input).
8. "W ML": Prompt for weight of mainline in pounds per foot (input).
9. "SWL ML": Prompt for safe working load of mainline in pounds (input).
10. "W HB": Prompt for weight of haulback line in pounds per feet (input).

11. "SWL HB": Prompt for haulback safe working load in pounds (output).
12. "HEADSPAR TP": Prompt for headspar terrain point number (input).
13. "TAILSPAR TP": Prompt for tailspar location point number (input). (Tailspar terrain point number must be greater than headspar terrain point number).
14. "IN YD LIM": Prompt for terrain point number that is the inner yarding limit (generally the headspar).
15. "OUT YD LIM": Prompt for terrain point number that is the outer yarding limit.
16. "FULL SUSP = 0", "PART SUSP = 1": Asks users if they want the load to be analyzed for full log suspension or partial log suspension (input). If partial suspension is selected, "MIN CAR CLR" is displayed. Enter minimum acceptable carriage clearance.
17. "CRIT PT": Critical point establishing minimum skyline length is displayed a few seconds (output).
18. "S MIN": Minimum skyline length is displayed a few seconds (output).
19. "LOAD TP": Prompt for the terrain point at which the users want the load analyzed (input).
20. "T ML=": The calculated mainline tension (output) in pounds. ("TML=" is only briefly displayed, but can be recalled by pressing X><Y).
21. "W=": The calculated net payload in pounds (output).
22. "ML LIM": Shows the system is mainline limiting. If this prompt appears, the "W=" displayed immediately after is the net payload based on the mainline safe working load (output).
23. "HB REQ": Shows the system is skyline limited but needs a haulback to maintain loaded equilibrium.
24. "HB T=": Tension in haulback in pounds (output). "W" payload displayed is payload system with haulback limited.



25. "HB LIM": Shows system is haulback limited. The prompt "W=" appearing right after the "HB LIM" prompt is the net payload based on the haulback safe working tension (output).
26. "GROUND LEAD": Indicates the carriage is too low to maintain suspension on the leading edge of the log at the terrain point being analyzed. "W" payload displayed is based on no partial suspension. R/S will display loaded carriage clearance.
27. Key "A": Can be pressed in "User" mode and calculator will prompt for new yarder specifications.
28. Key "B": Can be pressed in "User" mode and calculator will prompt for new headspar and tailspar terrain points.
29. Key "C": Can be pressed in "User" mode and calculator will prompt for a new load terrain point to be analyzed. This can be done at any time (e.g. after new desired specifications have been entered).

#### B. Step-by-Step Example

Given: Profile data from profile reduction "PR" is assumed to be entered for use with this program.

The following yarder and line specifications will be used to analyze the example profile for a standing skyline configuration:

Tower height = 50 ft.	Skyline weight = 1.85 lb/ft.
Tail tree height = 20 ft.	Skyline safe working load =
Carriage weight = 500 lbs.	34,500 lbs.
Choker length = 16 ft.	Mainline weight= 1.42 lb/ft.
Log length = 40 ft.	Mainline safe working load =
	26,500 lbs.
	Haulback weight= 0.72 lb/ft.
	Haulback safe working load =
	13,700 lbs.

Analyze for the yarder at TP 1 and the tailtree at TP 7. Partial suspension is acceptable over the profile.

Yarding limits are from TP 1 to TP 7 and the minimum carriage clearance is 25 feet.

Determine: Net payload, mainline tension, and carriage clearance for the system with partial suspension permissible.

Solution: Results of "SSL"

Terrain Point	Net Payload (lb)	Mainline Tension (lb)	Carriage Clearance
2	17,629	10,827	25.0
3	13,121	6,631	34.2
4	11,630	6,350	26.1
5	9,928	3,438	48.7
6	11,737*	2,656	61.9

Program Execution: Access program by XEQ ALPHA SSL ALPHA

<u>Prompt</u>	<u>Response</u>	<u>Keystrokes</u>
"HS HT"	50	<u>R/S</u>
"TS HT"	20	<u>R/S</u>
"CAR WT"	500	<u>R/S</u>
"CHOK LNG"	16	<u>R/S</u>
"LOG LNG"	40	<u>R/S</u>
"W SL"	1.85	<u>R/S</u>
"SWL SL"	34,500	<u>R/S</u>
"W ML"	1.42	<u>R/S</u>
"SWL ML"	26,500	<u>R/S</u>
"W HB"	.72	<u>R/S</u>
"SWL HB"	13,700	<u>R/S</u>
"HEADSPAR TP"	1	<u>R/S</u>
"TAILSPAR TP"	7	<u>R/S</u>
"IN YD LIM"	1	<u>R/S</u>
"OUT YD LIM"	7	<u>R/S</u>
"FULL SUSP=0"	1	<u>R/S</u>
"PART SUSP=1"		

"MIN CAR CLR" 25 R/S

OUTPUT:

"CRIT PT = 2.00" (TP 2 is critical point for skyline length)

"S MIN = 556.107" (Minimum skyline length = 556.107 ft.)

"LOAD TP" 2 R/S

At this point the net partial suspension payload for TP 2 is calculated. It returns:

"T ML = 10,826.971"

"W = 17,629.234"

To display loaded carriage clearance, press R/S

OUTPUT:

"25.0" (The loaded carriage clearance is at minimum specified for TP 2)

To continue with the next sequential terrain point load analysis, press R/S.

Program execution can be returned to the "LOAD TP" prompt at any time by pressing "USER" key "C". To change head or tailspar terrain points, press "USER" key "B". To change yarder specifications, press "USER" key "A".

#### IV. CAUTIONS, LIMITATIONS, and COMMENTS

If full suspension is desired over a terrain point and partial suspension desired over the rest of the profile, the user can check the carriage clearance after evaluating the load at the terrain point of interest. If the carriage clearance is greater than choker and log length, the turn is fully suspended. If the load was dragging, the user can raise the minimum carriage clearance until logs are flying.

Program SSL sets flag 03 during operation for partial suspension and leaves it set when the program is terminated. Users should clear flag 03 before running other programs.

# Clamped Carriage Payload Analysis (CLCAR)

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Placerville, CA 95667

## I. BACKGROUND INFORMATION

### A. General Assumptions

A clamping carriage is assumed.

Rigid link formulations are used for line tensions.

The mainline or haulback is assumed to be slack during log pick up. Program calculates tensions only during log pickup. Once the carriage is unclamped, analyze with "LOAD" or "SSL".

Yarder is assumed to be at the left side of profile.

User has entered profile into calculator memory with program "PR". (Profile terrain points are numbered left to right).

Users supply loaded carriage clearance for payload analysis at each point.

To analyze standing skyline with clamped carriage, it is assumed users first run program "SL" and note loaded carriage clearance values for each terrain point of interest.

The mainline attaches to the carriage. A mainline passing through the carriage is not analyzed.

### B. References: Bodenhausen, 1982.

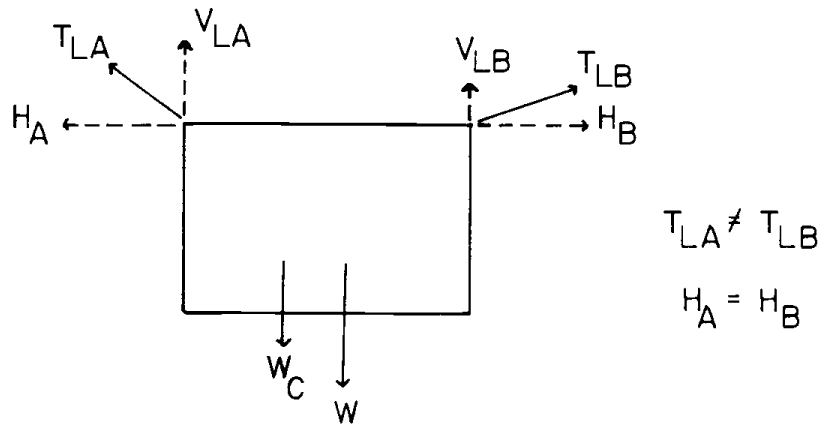
### C. Figures and Formulas: Full documentation of formulas may be found in Bodenhausen, 1982 and references therein.

Figure 8. Clamped Carriage Free Body Diagram

## II. A. Conventions

"W": If this output, net payload, is negative for full suspension, loads cannot be fully suspended over the terrain point of interest with the system configuration.

FIGURE 8. CLAMPED CARRIAGE FREE BODY DIAGRAM



$H_A$  = horizontal tension component in skyline segment A.

$H_B$  = horizontal tension component in skyline segment B.

$T_{LA}$  = tension in the lower end of skyline segment A.

$T_{LB}$  = tension in the lower end of skyline segment B.

$V_{LA}$  = vertical component of tension in the lower end of skyline segment A.

$V_{LB}$  = vertical component of tension in the lower end of skyline segment B.

$W$  = weight of the payload.

$W_C$  = weight of the carriage.

$H_A = H_B$  because the carriage does not move

$T_{LA} = T_{LB}$  because the carriage is clamped

$W = V_{LA} - V_{LB} - W_C$  at skyline limiting value and carriage clearance

## B. Size and Capacity

The calculator must be sized to 052. The program "CLCAR" uses 60 registers and program "PR" used in conjunction requires 47 registers. Total calculator capacity must be 159 registers. The program consists of 221 steps.

## III. EXAMPLE OF PROGRAM USE

### A. Information Needed

1. "HS HT": Prompt for tower height in feet (input).
2. "TS HT": Prompt for tailtree height in feet (input).
3. "CAR WT": Prompt for carriage weight in pounds (input).
4. "WT SL": Prompt for weight per foot of skyline in pounds (input).
5. "SWL SL": Prompt for safe working load of skyline in pounds (input).
6. "HEADSPAR TP": Prompt for terrain point number (input).
7. "TAILSPAR TP": Prompt for tailspar terrain point number (input).
8. "LOAD TP": Prompt for terrain point at which user wants load analyzed.
9. "MIN CAR CLR": Prompt for loaded carriage clearance at terrain point of interest (input).
10. "W": The calculated net payload in pounds for a clamped carriage (output).
11. Key "A": Can be pressed in "User" mode and the calculator will provide prompts for new yarder specifications.
12. Key "B": Can be pressed in "User" mode and the calculator will provide prompts for new headspar and tailspar locations.
13. Key "C": Can be pressed in "User" mode and the calculator will prompt for a new terrain point to be analyzed. Users normally use Key "R/S" to analyze terrain points sequentially.

B. Step-by-Step Example

Given: Profile data from "PR" is assumed to have been entered and will be used with this program.

Live Skyline Analysis:

Tower height = 50 ft.	Skyline weight = 1.85 lb/ft.
Tailtree height = 20 ft.	Skyline safe working load =
Carriage weight = 500 lbs.	34,500 lbs.
Headspars at terrain point 1	
Tailspars at terrain point 8	
Minimum carriage clearance is	
52 ft.	

Determine: Net payload (W) for terrain points 2 through 7 with a live skyline.

Solution: Results of Live Skyline Analysis with Clamping Carriage

Terrain Point	Fully Suspended Load (lbs)
2	4,672
3	8,699
4	8,095
5	14,829
6	21,872
7	11,677

Program Execution: Access program by XEQ ALPHA CLCAR ALPHA

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"HS HT"	50	<u>R/S</u>
"TS TH"	20	<u>R/S</u>
"CAR WT"	500	<u>R/S</u>
"WT SL"	1.85	<u>R/S</u>
"SW SL"	34,500	<u>R/S</u>
"HEADSPAR TP"	1	<u>R/S</u>

"TAILSPAR TP"	8	<u>R/S</u>
"LOAD TP"	2	<u>R/S</u>
"MIN CAR CLR"	52	<u>R/S</u>

At this point the program calculates the net lift the skyline can develop.

"W = 4672.81"

To continue with the next terrain point analysis, press R/S. Program execution can be returned to "LOAD TP" by pressing "USER" key "C". Other user keys may be pressed to change yarder specifications or headspar and tailspar locations.

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

Program analyzes for a mainline attached to the carriage. "Active" mainlines passing through the carriage to the logs are not covered. Once the carriage begins moving toward the yarder, it must be considered unclamped for analysis.

The clamped carriage yields more conservative results and assumes the mainline is slack during the log pick operation.

Three-drum carriages are also not analyzed.

To analyze for standing skyline, determine carriage clearance at each terrain point with program "SSL" by recalling register 47 for  $C_L$  to determine the load that a standing skyline with a clamped carriage can fully suspend.

Uphill or downhill systems are analyzed.



# Skyline Profiles and Traverse Closure (STC)

USFS NO. 236

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## I. BACKGROUND INFORMATION

### A. General Assumptions

The program assumes users who start entering data with magnetic bearings or azimuths will make all inputs in the format they started.

### B. References: Any text on elementary surveying.

### C. Figures and Formulas

Figure 9. Case 1 of STC Problem  
Figure 10. Case 2 of STC Problem  
Figure 11. Case 3 of STC Problem  
Figure 12. Case 4 of STC Problem  
Figure 13. User Keys for STC

Formulas can be found in any elementary surveying text.

## II. CONVENTIONS AND MEMORY

### A. Conventions

"% SLOPE": When entering the profile data for percent slope, enter negative percentages when it is downhill to the next terrain point and positive percentages when it is uphill to the next terrain point.

### B. Size and Capacity

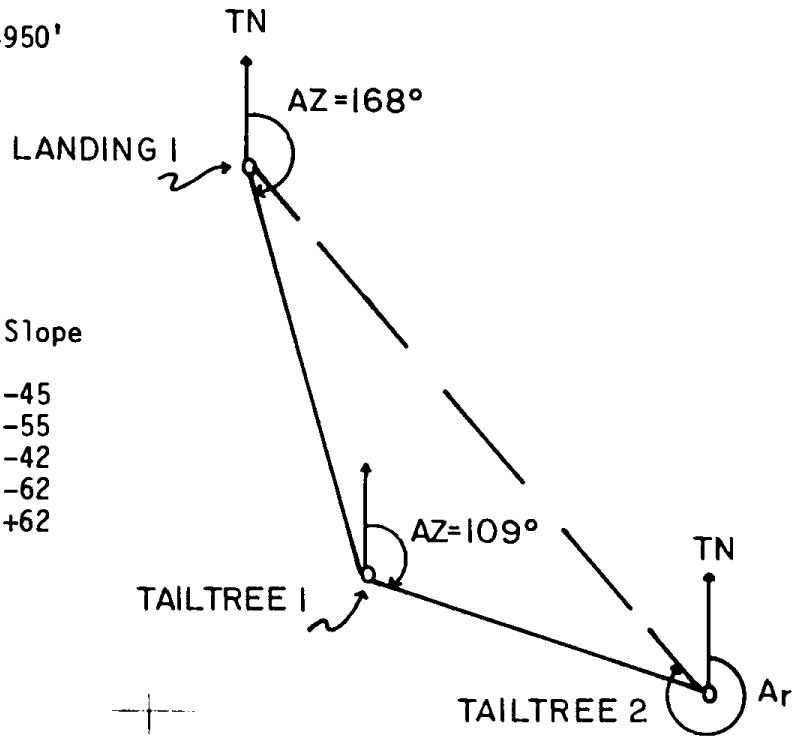
The calculator must be sized to 025. The program uses 186 registers. Total calculator capacity must be 211 registers. The program consists of 576 steps.

FIGURE 9. CASE 1 OF STC

Beginning Station = 0+00'  
 Beginning Elevation = 4950'  
 Declination = 22° E

Profile Data

Terrain point	Slope distance	% Slope
1	122.82	-45
2	247.66	-55
3	355.76	-42
4	390.63	-62
5	382.40	+62



Profile Data

Slope distance	% Slope
50.06 ft.	+ 5%

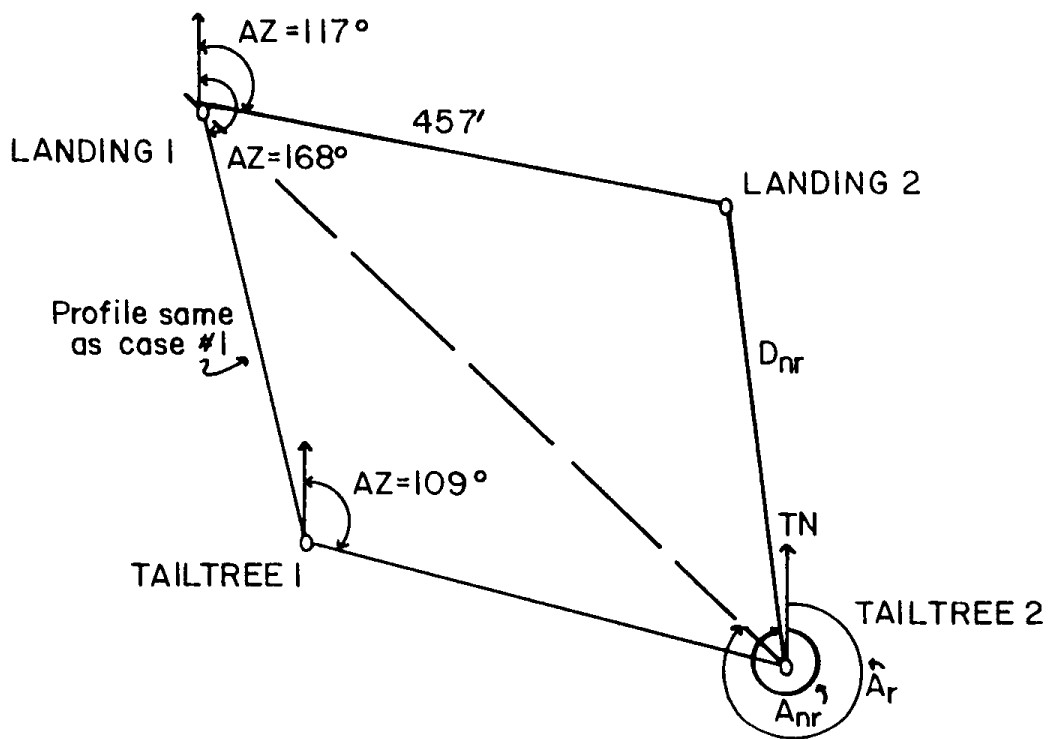
The program will provide:  $A_r = 347.17^\circ$   
 $D_r = 1340.45'$   
 Magnetic Bearing $_r = N 35.83^\circ W$

FIGURE 10. CASE 2 OF STC

Beginning Station = 0.00'

Beginning Elevation = 4950'

Declination = 22° E



Profile Data

Slope distance	% Slope
50.06 ft.	+5
372.00 ft.	0

The program will provide:  $A_{nr} = 347.70^\circ$        $D_{nr} = 1243.77'$   
 $A_r = 334.71^\circ$        $D_r = 1573.50$   
 Magnetic Bearing<sub>nr</sub> = N 34.30° W  
 Magnetic Bearing<sub>r</sub> = N 47.29° W

FIGURE 11. CASE 3 OF STC

Declination  $22^\circ$  E means you have magnetic north east of true north and the compass declination would be set at  $22^\circ$  W to compensate, but the users must enter where magnetic north is located with respect to true north.

Beginning Station = 0+00

Beginning Elevation = 4950'

The program will provide:

AZ =  $346.17^\circ$

RET. MAG. BRG. = N  $35.83^\circ$  W

RET. DIS. = 1340.45'

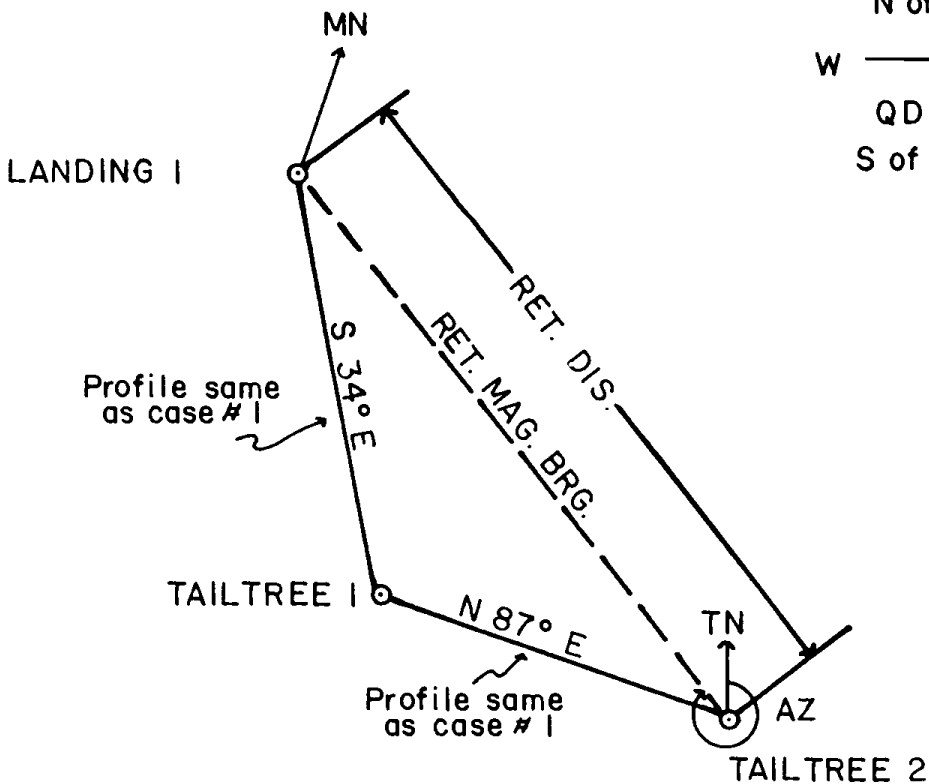
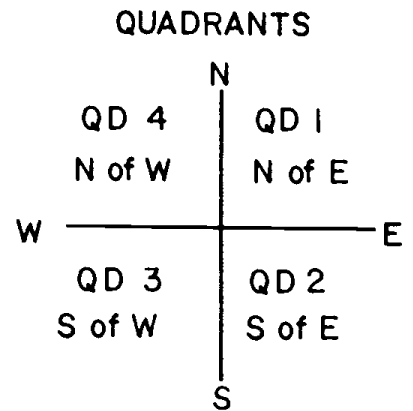
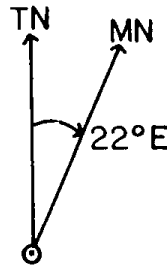
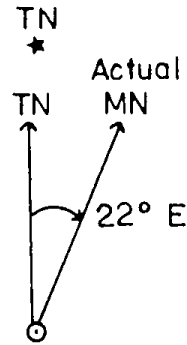


FIGURE 12. CASE 4 OF STC

Declination = 22° E

All bearings are magnetic bearings

Beginning Station = 0+00  
Beginning Elevation = 4950



The program will provide:

AZ = 334.71° (MAG. BRG. = N 47.29° W)

RET. DIS = 1,573.50 feet.

AZ 2 = 347.70° (MAG. BRG. 2 = N 34.30° W)

HD 2 = 1243.77 feet.

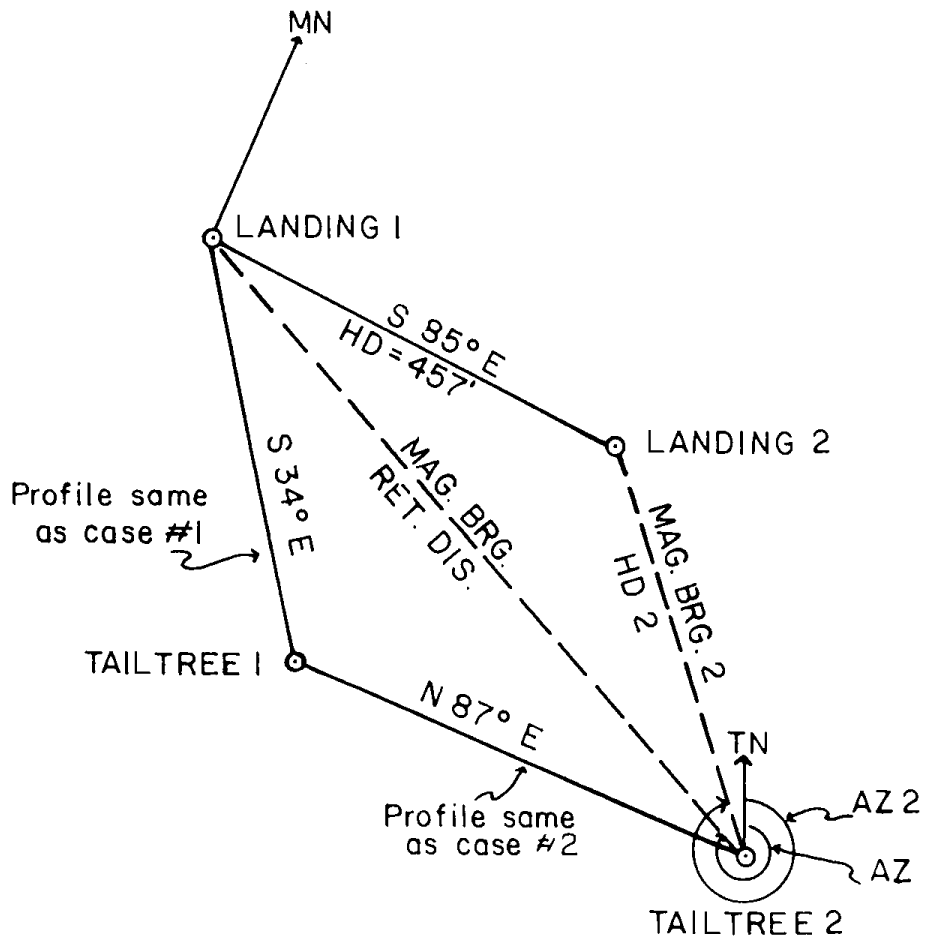
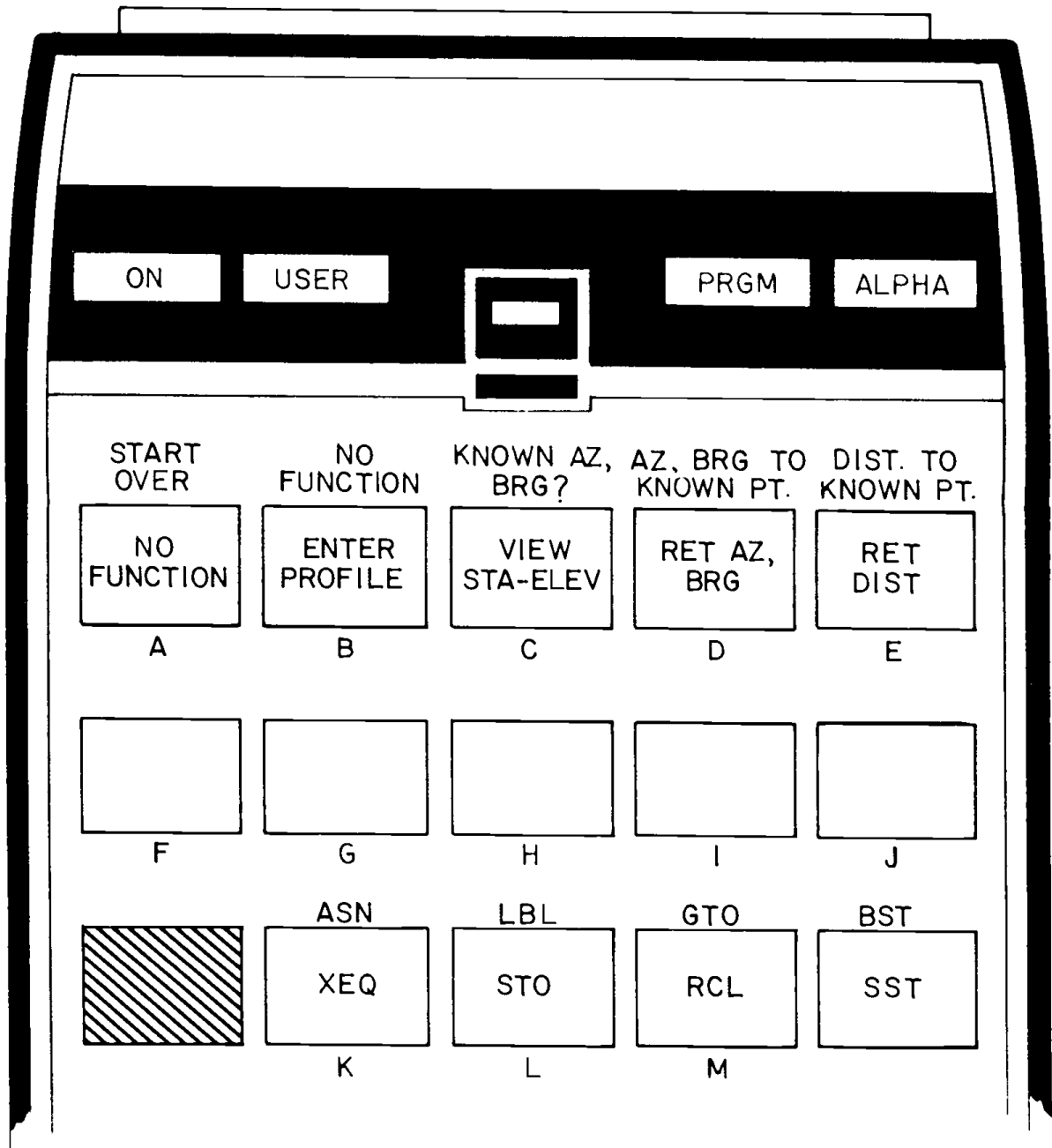


FIGURE 13. USER KEYS FOR STC



### III. EXAMPLE OF PROGRAM USE

#### A. Information Needed

1. "BEG. STA.=?": Prompt for the stationing at terrain point number one in feet (input).
2. "BEG. ELEV.=?": Prompt for the elevation at terrain point number one in feet (input).
3. "TRUE AZ.=0" or "MAG. BRG.=1": These prompts are given simultaneously so that users can choose to enter input data as true azimuths (enter 0) or as magnetic bearings (enter 1) (input).
4. "BEG. AZ.=?": Prompt for starting azimuth from landing one or any starting point to Tailtree 1 (or any other desired point). This is entered in whole degrees and fractions expressed as decimal degrees (input).
5. "A B C D E": Prompt is a menu for users' next choice. The key definitions are as follows (see figure 13):

SHIFT A: Starts program over.

B: Prompts and stores profile data corresponding to the last bearing or azimuth entered.

C: Views present station and elevation both in feet.

D: Computes and shows return azimuth with the option of a magnetic bearing output.

E: Computes and shows horizontal distance from present terrain point to the beginning terrain point in feet.

Shift C: Prompts for azimuth or bearing from the starting point to a known point (e.g. Landing 2 for Cases 2 and 4).

Shift D: Reviews azimuth from a point (e.g. Tailtree 2) to a known point (e.g. Landing 2) with the option of viewing the magnetic bearing also.

Shift E: Computes distances and allows users to view or review horizontal distance from a point (e.g. Tailtree 2) to a known point (e.g. Landing 2).

You must execute Shift C before Shift D or Shift E.

6. "VIEW STA.? Y,N": Asks whether users want to view elevation and station at each terrain point as profile data is entered. If yes, enter "Y"; if no, enter "N" (input).
7. "% SLOPE=?": Prompt for slope in percent to the next terrain point (input).
8. "SLOPE DIST.=?": Prompt for slope distance in feet to the next terrain point (input).
9. "% SLOPE=X.XX%": Reviews the "% SLOPE" just entered in percent (output).
10. "SL.DIST=XX,XX": Reviews the "SLOPE DIST." just entered in feet (output).
11. "ACCEPT? Y,N": This prompt appears after "% SLOPE" and "SLOPE DIST." are reviewed. If a mistake was made, users can enter "N" for no, and the calculator will prompt for the information again at that same point. If users are satisfied, they can enter "Y" for yes (input).
12. "STA=X.XX": Shows present stationing in feet (output).
13. "ELEV.=XX.XX": Shows present elevation in feet (output).
14. "TERRAIN PT:n": Shows present terrain point. Users are located at some terrain point "n".
15. "NEW AZ=?": Prompt for azimuth to the next point in whole degrees and fractions expressed as decimal degrees (e.g. from Tailtree 1 to Tailtree 2).
16. "KNOWN AZ.=?": Prompt for azimuth in whole degrees and fractions expressed as decimal degrees from the starting point to a known point (e.g. from Landing 1 to Landing 2 in Case 2) (input).
17. "KNOWN DIST.=?": Prompt for horizontal distance in feet from the starting point to a known point (e.g. from Landing 1 to Landing 2 in Cases 2 and 4) (input).
18. "AZ2=X.XX": Shows azimuth in whole degrees and fractions expressed as decimal degrees from some point on the traverse to a known point (e.g. from Tailtree 2 to Landing 2 in Cases 2 and 4) (output).



19. "HD2=X.XX": Shows the horizontal distance in feet from some point on a traverse to a known point (e.g. from Tailtree 2 to Landing 1) (output).
20. "AZ=X.XX": Shows azimuth in whole degrees and fractions expressed as decimal degrees from the present point on a traverse to the starting point (e.g. from Tailtree 2 to the landing in Cases 1 and 3) (output).
21. "RET.DIS.=X.XX": Shows horizontal distance in feet from the present point on a traverse to the starting point (e.g. from Tailtree 2 to Landing 1 in Cases 1 and 3) (output).
22. "MAG.DECL.}=?": Prompt for the magnetic declination angle (difference between true and magnetic north) in whole degrees and fractions expressed as decimal degrees (input).
23. "E OR W?": Prompt for direction between true North and Magnetic North, "E" for east and "W" for west.
24. "BEG.BRG.}=?": Prompt for the beginning bearing angle in whole degrees and fractions expressed as decimal degrees from the beginning terrain point to the next destination point (e.g. from the landing to Tailtree 1 in Cases 1 and 3). This angle will always be less than or equal to 90 degrees or greater than or equal to 0 degrees (e.g. Bearing S 12.4° E has a bearing angle of 12.4°), (input).
25. "\*REVIEW QDS\*": Prompt alerts users to review the quadrants. The bearing angle will fall into one of four quadrants (output).
26. "QD1 = N of E"  
"QD2 = S of E"  
"QD3 = S of W"  
"QD4 = N of W"

The above output makes up the quadrant review (Figure 11).

27. "QD=? 1,2,3,4?": Asks users to enter one of the four quadrants in which their bearing falls (e.g. N 21° W is in quadrant number 4) (input).
28. "NEW BRG.}=?": Prompt for the new bearing angle in whole degrees and fractions expressed as decimal degrees (e.g. from Tailtree 1 to Tailtree 2 in all four cases),

29. "BEARING <-2=?": Prompt for bearing angle in whole degrees and fractions expressed as decimal degrees from a point on a traverse to some known point (e.g. from Landing 1 to Landing 2 in Case 4) (input).
30. "MAG.BRG.? Y,N": Ssks users if they want to see the azimuth output as a magnetic bearing. If yes, enter "Y"; if no, enter an "N".

B. Step-by-Step Example

Case #1: (Figure 9) Azimuth, return to Landing 1.

Given: Using azimuths, a field crew went from Landing 1 on an initial azimuth (true) of  $168^\circ$  to Tailtree 1 taking profile data as shown in Figure 9. After the field crew reached Tailtree 1, they proceeded to Tailtree 2 on an azimuth of  $109^\circ$  and took profile data from Tailtree 1 to Tailtree 2 as shown in Figure 1.

Determine: The return azimuth, magnetic bearing, and horizontal distance back to the landing if the declination is  $22^\circ$  E.

Solution: Return azimuth =  $346.17^\circ$   
 Return magnetic bearing = N  $35.83^\circ$  W  
 Return horizontal distance = 1340.45'

Case #2: (Figure 10) Azimuths, return to Landing 2

Given: Using azimuths, all factors (azimuths, and profile from Landing 1 to Tailtree 1) are the same as case one except the crew realized they were at the wrong Tailtree 2, so they extended their profile another 372 feet at 0% slope. They also learned from the other crew that landing 2 was 457 feet (horizontal distance) at an azimuth of  $117^\circ$  from Landing 1.

Determine:

The return azimuth (to Landing 1) from the new Tailtree 2.  
 The return magnetic bearing with a declination of  $22^\circ$  E.  
 The return horizontal distance from Tailtree 2 to Landing 1.  
 The azimuth from Tailtree 2 to Landing 1.  
 The magnetic bearing from Tailtree 2 to Landing 2 (declination =  $22^\circ$  E).  
 The horizontal distance from Tailtree 2 to Landing 2.

Solution:

Return azimuth =  $334.71^{\circ}$ .  
Return magnetic bearing = N  $47.29^{\circ}$  W  
Return horizontal distance = 1573.50'  
Azimuth from Tailtree 2 to Landing 2 =  $347.70^{\circ}$   
Magnetic Bearing from Tailtree 2 to Landing 2 = N  $34.30^{\circ}$  W  
Horizontal Distance from Tailtree 2 to Landing 2 =  
1243.77'

Case #3: (Figure 11) Magnetic bearings, return to Landing 1

Given: Using magnetic bearings, a field crew went from Landing 1 on an initial bearing of S  $34^{\circ}$  E to Tailtree 1 taking profile data as shown in Figure 1. After the field crew reached Tailtree 1, they proceeded to Tailtree 2 on a bearing of N  $87^{\circ}$  E and they took profile data from Tailtree 1 to Tailtree 2 as shown in Figure 1. The magnetic declination is  $22^{\circ}$  E.

Determine: The return azimuth, magnetic bearing, and horizontal distance to Landing 1.

Solution: Return azimuth =  $346.17^{\circ}$   
Return magnetic bearing = N  $35.83^{\circ}$  W  
Return horizontal distance = 1340.45'

Case #4. (Figure 12) Magnetic bearings, return to Landing 2.

Given: Using magnetic bearings, all factors (bearing from Landing 1 to Tailtree 1, bearing from Tailtree 1 to Tailtree 2, profile data from Landing 1 to Tailtree 1, and the profile data from Tailtree 1 to Tailtree 2) are the same as case three except the crew realized they were at the wrong Tailtree 2, so they extended their profile out another 372 feet at zero percent slope. They also learned from the other crew that Landing 2 is 457 feet (horizontal distance) at a bearing of S  $85^{\circ}$  E from Landing 1. The declination is  $22^{\circ}$  E.

Determine:

The return azimuth (to Landing 1) from the new Tailtree 2.  
The return magnetic bearing with a declination of  $22^{\circ}$  E.  
The return horizontal distance from Tailtree 2 to Landing 1.

The azimuth from Tailtree 2 to Landing 1.  
 The magnetic bearing from Tailtree 2 to Landing 2.  
 The horizontal distance from Tailtree 2 to Landing 2.

Solution:

Return azimuth =  $334.71^\circ$   
 Return magnetic bearing = N  $47.29^\circ$  W  
 Return horizontal distance = 1573.50'  
 Azimuth from Tailtree 2 to Landing 2 =  $347.70^\circ$   
 Magnetic bearing from Tailtree 2 to Landing 2 = N  $34.30^\circ$  W  
 Horizontal distance from Tailtree 2 to Landing 2 = 1243.77'

Program Execution: Put calculator in "USER" mode, then access the program by XEQ ALPHA STC ALPHA.

Case #1. (Inputs are true azimuths).

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"BEG.STA.=?" (request for beginning station)	0	<u>R/S</u>
"BEG.ELEV.=?" (request for beginning elevation)	4950	<u>R/S</u>
"TRUE AZ.=0"	No Response	No Keystroke
"MAG.BRG.=1"	0	<u>R/S</u>
(INPUT CHOICE)	(CHOOSE AZIMUTHS)	
"BEG.AZ=?"	$168^\circ$	<u>R/S</u>
"A B C D E"	No Response	<u>B</u> "B" key corresponds to entering and storing profile data.
"VIEW STA? Y,N" (request to view station and elevation at each terrain point)	Y	<u>R/S</u> Yes, view the station elevation.
"TERRAIN PT:1"	No Response	No Keystroke
"% SLOPE=?"	45	<u>CHS</u> <u>R/S</u>

"SLOPE DIST.=?"	122.82	<u>R/S</u>
"% SLOPE = -45.00%" (review percent slope)	No Response	No Keystroke
"SL.DIST.=122.82" (review slope distance)	No Response	No Keystroke
"ACCEPT? Y,N" (asks if user accepts two reviewed inputs. if no, calculator reprompts same terrain point)	Y	<u>R/S</u>
"STA=112.00" (gives station of next terrain point in feet)	No Response	<u>R/S</u>
"ELEV.=4,899.60" (elevation of next terrain point in feet)	No Response	<u>R/S</u>
"TERRAIN PT:2"	No Response	No Keystroke
"% SLOPE=?"	55	<u>CHS</u> <u>R/S</u>
"SLOPE DIST.=?"	247.66	<u>R/S</u>
"% SLOPE = -55.00%"	No Response	No Keystroke
"SL.DIST. = 247.66"	No Response	No Keystroke
"ACCEPT? Y,N"	Y	<u>R/S</u>
"STA = 329.01"	No Response	<u>R/S</u>
"ELEV. = 4,780.25"	No Response	<u>R/S</u>
"TERRAIN PT:3"	No Response	No Keystroke
"% SLOPE=?"	42	<u>CHS</u> <u>R/S</u>
"SLOPE DIST.=?"	355.76	<u>R/S</u>
"% SLOPE = -42.00%"	No Response	No Keystroke
"SL.DIST. = 355.76"	No Response	No Keystroke
"ACCEPT? Y,N"	Y	<u>R/S</u>
"STA = 657.01"	No Response	<u>R/S</u>

"ELEV. = 4,642.49"	No Response	<u>R/S</u>
"TERRAIN PT:4"	No Response	No Keystroke
"% SLOPE=?"	62	<u>CHS</u> <u>R/S</u>
"SLOPE DIST.=?"	390.63	<u>R/S</u>
"% SLOPE = -62.00"	No Response	No Keystroke
"SL. DIST. = 390.63"	No Response	No Keystroke
"ACCEPT? Y,N"	Y	<u>R/S</u>
"STA. = 989.01"	No Response	<u>R/S</u>
"ELEV. = 4,436.65"	No Response	<u>R/S</u>
"TERRAIN PT:5"	No Response	No Keystroke
"% SLOPE=?"	62	<u>R/S</u>
"SLOPE DIST.=?"	382.40	<u>R/S</u>
"% SLOPE = 62.00%"	No Response	No Keystroke
"SL. DIST. = 382.40"	No Response	No Keystroke
"ACCEPT? Y,N"	Y	<u>R/S</u>
"STA. = 1,314.01"	No Response	<u>R/S</u>
"ELEV. = 4,638.15"	No Response	<u>R/S</u>
"TERRAIN PT:6"	No Response	No Keystroke
"% SLOPE=?"	0 (enter zero when finished with profile)	<u>R/S</u>
"SLOPE DIST.=?"	0 (enter zero when finished with profile)	<u>R/S</u>
"NEW AZ=? (azimuth to Tailtree 2)"	109	<u>R/S</u>
"A B C D E"	No Response	<u>B</u> ("B" key corresponds to entering and storing profile data)

"VIEW STA.? Y,N"	Y	<u>R/S</u>
"TERRAIN PT:1" (profile from Tailtree 1 to Tailtree 2)	No Response	No Keystroke
"% SLOPE=?"	5	<u>R/S</u>
"SLOPE DIST.=?"	50.06	<u>R/S</u>
"% SLOPE = 5.00%"	No Response	No Keystroke
"SL.DIST. = 50.06"	No Response	No Keystroke
"ACCEPT? Y,N"	Y	<u>R/S</u>
"STA. = 1,364.01"	No Response	<u>R/S</u>
"ELEV. = 4,640.65"	No Response	<u>R/S</u>
"TERRAIN PT:2"	No Response	No Keystroke
"% SLOPE=?" (enter zero when finished with profile)	0	<u>R/S</u>
"SLOPE DIST=?" (enter zero when finished with profile)	0	<u>R/S</u>
"A B C D E"	No Response	<u>D</u> ("D" key corresponds to the return Azimuth from the last entered terrain point to the first terrain point).
"AZ = 346.17" (azimuth from last terrain point to the landing)	No Response	<u>R/S</u>
"MAG.BRG.? Y,N" (asks if users want the return magnetic bearing displayed)	Y	<u>R/S</u>
"MAG.DECL. <del>?</del> ?" (asks for the magnetic declination angle)	22	<u>R/S</u>
"E or W?" (magnetic declination, east or west)	E	<u>R/S</u>
"N 35.83 W" (return magnetic bearing)	No Response	<u>R/S</u>

"A B C D E"	No Response	<u>E</u> ("E" Key corresponds to the return horizontal distance in feet from the last terrain point to the first terrain point)
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"RET.DIS.=1,340.45"	No Response	<u>R/S</u>
"A B C D E"		

At this point we have completed Case #1.

Case #2. (Return to Landing 2 rather than Landing 1, using azimuths.) Case #2 is executed in the same way as Case #1 for all inputs from Landing 1 to Tailtree 2. The following procedure is used for the azimuth, magnetic bearing, and horizontal distance from Tailtree 2 to Landing 2 after the survey crew has gone from Landing 1 to Tailtree 1 to Tailtree 2 and entered all data up to that point. Note users must add another leg to Tailtree 2 with slope = 0% and slope distance = 372.00 feet.

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
All data has been entered as described above and the calculator is displaying the menu. Users must re-enter or enter profile data to Tailtree 2.		
"A B C D E"	No Response	<u>SHIFT C</u> (These keystrokes correspond to input and storage of data from Landing 1 to Landing 2)
"KNOWN AZ.=?" (azimuth from Landing 1 to Landing 2)	117	<u>R/S</u>
"KNOWN DIST.=?"	457	<u>R/S</u>
"AZ2 = 347.70" (azimuth from Tailtree 2 to Landing 2)	No Response	<u>R/S</u>
"MAG.BRG.? Y,N" (do users want magnetic bearing from Tailtree 2 to Landing 2?)	Y	<u>R/S</u>



"MAG. DECL. }=?"	22	<u>R/S</u>
"E OR W?"	E	<u>R/S</u>
"N 34.30° W" (magnetic bearing from Tailtree 2 to Landing 2)	No Response	<u>R/S</u>
"A B C D E"	No Response	<u>SHIFT E</u> (Keystrokes correspond to output of horizontal distance from Tailtree 2 to Landing 2).
"HDZ = 1243.77" (horizontal distance from Tailtree 2 to Landing 2)	No Response	No keystroke
"A B C D E"		

At this point users can see the return azimuth, return magnetic bearing, and return horizontal distances by pressing D and E

Case #3. (input magnetic bearings)

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"BEG. STA.=?"	0	<u>R/S</u>
"BEG. ELEV.=?"	4950	<u>R/S</u>
"TRUE AZ = 0"	No Response	No Keystroke
"MAG. BRG. = 1"	1	<u>R/S</u>
"MAG. DECL. } = ?"	22	<u>R/S</u>
"E OR W?"	E	<u>R/S</u>
"BEG. BRG. }=?" (beginning bearing angle from landing to Tailtree 1)	34	<u>R/S</u>
"*REVIEW QDS.*"	No Response	No Keystroke
"QD1 = N OF E"	No Response	No Keystroke
"QD2 = S OF E"	No Response	No Keystroke
"QD3 = S OF W"	No Response	No Keystroke

"QD4 = N OF W"	No Response	No Keystroke
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"QD = ? 1,2,3,4?"	2	$\overline{R/S}$
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(enter the quadrant 1,2,3,4 of the bearing angle).

"A B C D E"	No Response	$\overline{B}$ (Enter profile data)
-------------	-------------	--

At this point, enter profile data as in Case #1. After profile data to Tailtree 1 has been entered and zero entered for "% SLOPE" and "SLOPE DIST.", the following prompt will be seen:

"NEW BRG. <del>z</del> =?"	87	$\overline{R/S}$
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(enter bearing angle from Tailtree 1 to Tailtree 2)

"*REVIEW QDS*"	No Response	No Keystroke
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"QD1 = N OF E"	No Response	No Keystroke
----------------	-------------	--------------

"QD2 = S OF E"	No Response	No Keystroke
----------------	-------------	--------------

"QD3 = S OF W"	No Response	No Keystroke
----------------	-------------	--------------

"QD4 = N OF W"	No Response	No Keystroke
----------------	-------------	--------------

"QD = ? 1,2,3,4?"	1	$\overline{R/S}$
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"A B C D E"	No Response	$\overline{B}$ (Enter profile data to Tailtree 2)
-------------	-------------	--

Profile data is the same as Case #1. After profile data has been entered and zero entered for "% SLOPE" and "SLOPE DIST.", the following prompt will be seen:

"A B C D E"	No Response	$\overline{D}$ (Output return azimuth from Tailtree 2 to the landing)
-------------	-------------	--

At this point the procedure in Case #1 can be followed and the same output will be shown.

Case #4. (Magnetic bearing inputs, return to Landing 2 - same as Case #2). Enter all angle and profile data from Landing 1 to Tailtree 1 to Tailtree 2 in Figure 12. Follow the same procedure for entering the data as Case #3. After all data has been entered and you are back at the menu, the following procedure is suggested. Users can press keys D and E to determine azimuth, magnetic bearing, and horizontal distance to Landing 1. To determine the azimuth, magnetic bearing, and horizontal distance from Tailtree 2 to Landing 2, the following procedure must be used after all angles and profile data are entered from Landing 1 to Tailtree 1 to Tailtree 2 in Figure 12:

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"A B C D E:	No Response	<u>SHIFT C</u>
"BEARING <del>X</del> -2=?" (Bearing angle from Landing 1 to Landing 2)	85	<u>R/S</u>
"*REVIEW QDS.*"	No Response	No Keystroke
"QD1 = N OF E"	No Response	No Keystroke
"QD2 = S OF E"	No Response	No Keystroke
"QD3 = S OF W"	No Response	No Keystroke
"QD4 = N OF W"	No Response	No Keystroke
"QD=? 1,2,3,4?"	2	<u>R/S</u>
"KNOWN DIST.=?" (Distance from Landing 1 to Landing 2)	457	<u>R/S</u>
"AZ2 = 347.70"	No Response	<u>R/S</u>

At this point users can follow the procedure of Case #2. The outputs will be exactly the same as the outputs in Case #2. The outputs are also shown in the solution section for Case #4.

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

This program requires the HP 82180A Extended Functions/Memory Module for use with either the HP-41C or HP-41CV calculator.

The calculator must be in "USER" mode.

If users choose to enter magnetic bearings, they must enter positive bearing angles between  $0^{\circ}$  and  $90^{\circ}$  (refer to quadrant diagram in Figure 11).

When entering declinations into the calculator, remember they are entered in the direction from true north to actual magnetic north.

Outputs will always be true azimuths first, then the magnetic bearing can be obtained when prompted.

True bearings can be entered instead of magnetic bearing if users desire simply by entering zero for declination. True bearings would be used with a compass that had the declination properly accounted for by setting the correct declination as an adjustment.

Magnetic bearings are used with a compass whose declination adjustment is set at zero.

# Yarding Cost Estimation Program (YDCOST)

"YDCOST" can be used for ground-based systems by entering zero to non-applicable areas.

USFS NO. 420

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## I. BACKGROUND INFORMATION

- A. General Assumptions: None stated
- B. References: Miflin and Lysons, 1978, and any text on engineering economy

- C. Figures

- Figure 14. Program Flowchart with Corresponding Formulas

- Figure 15. User Keys for YDCOST

## II. CONVENTIONS AND MEMORY

- A. Conventions: None stated
- B. Size and Capacity

- The calculator must be sized to 025. The program uses 185 registers. Total calculator capacity must be 210 registers. The program consists of 435 steps.

## III. EXAMPLE OF PROGRAM USE

- A. Information Needed

- 1. "OWNER COST": Tells users they are in the "ownership cost" section.
  - 2. "EQUIP COST=?": Prompt for the delivered equipment cost in dollars (input).
  - 3. "LINE COST=?": Prompt for the cost of the line in dollars (input).
  - 4. "RIG COST=?": Prompt for rigging cost (all other rigging) in dollars (input).
  - 5. "TIRE COST=?": Prompt for the tire or track replacement cost in dollars (input).

FIGURE 14. PROGRAM FLOW CHART WITH CORRESPONDING FORMULAS

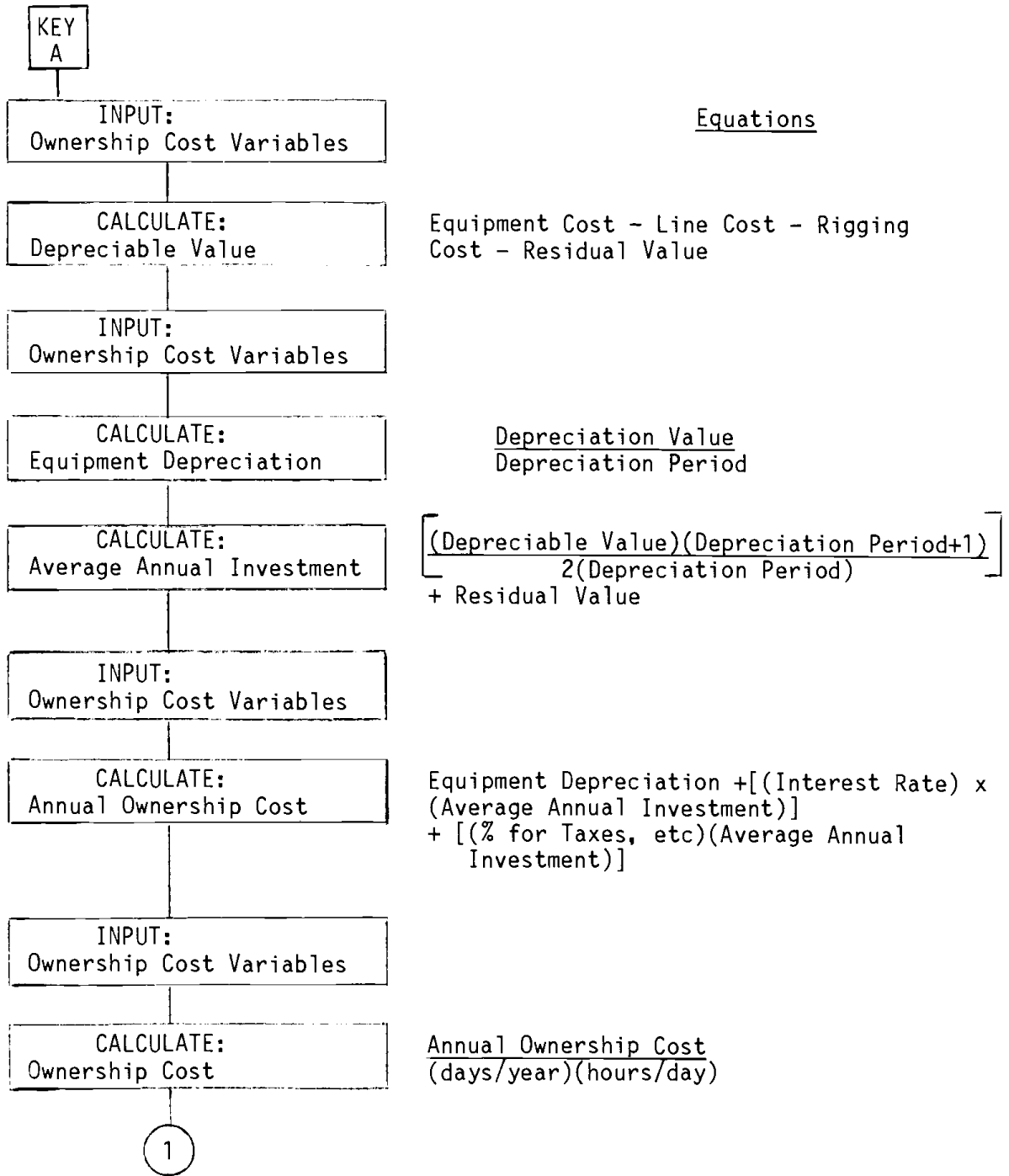


FIGURE 14. Continued

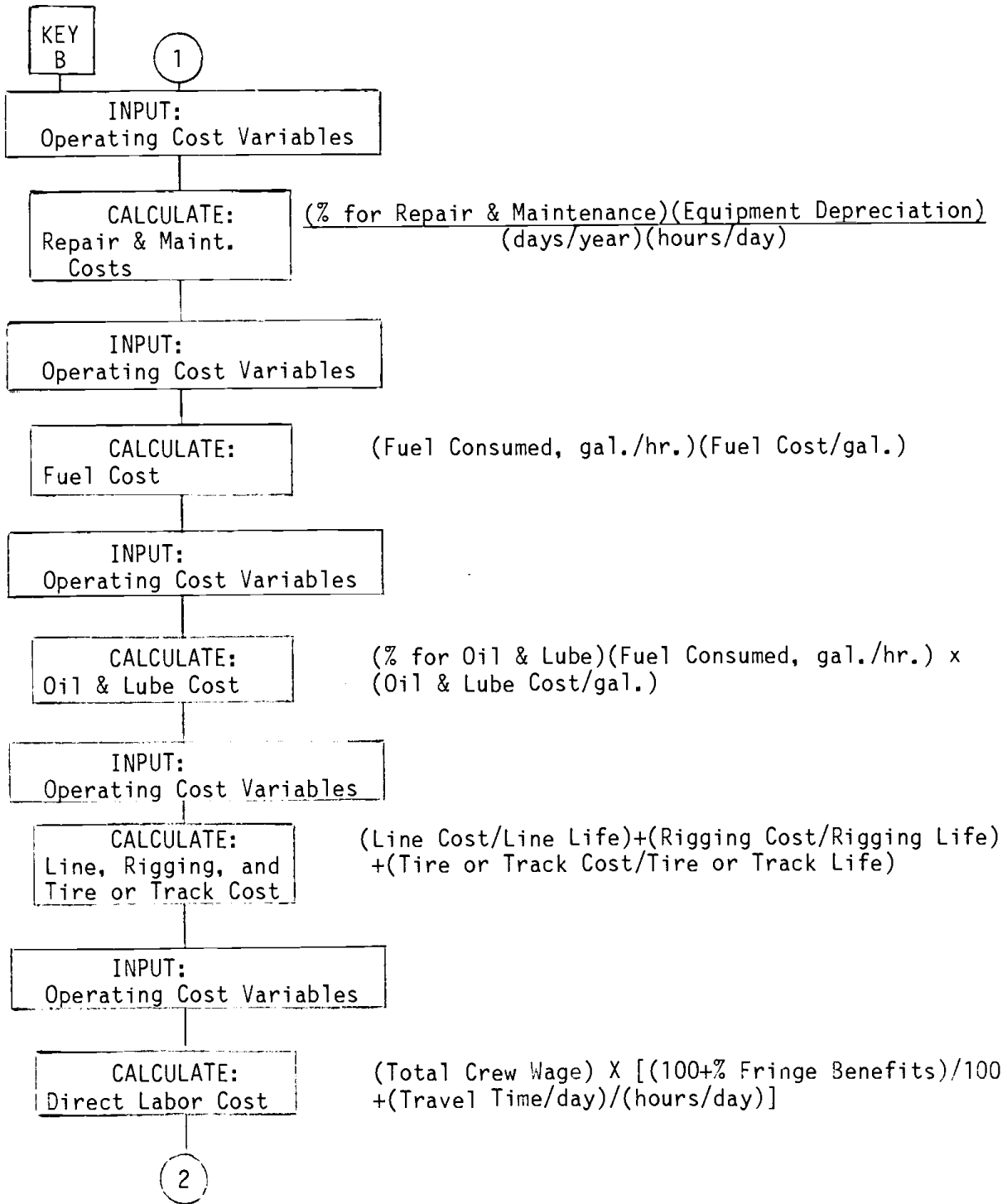


FIGURE 14. Continued

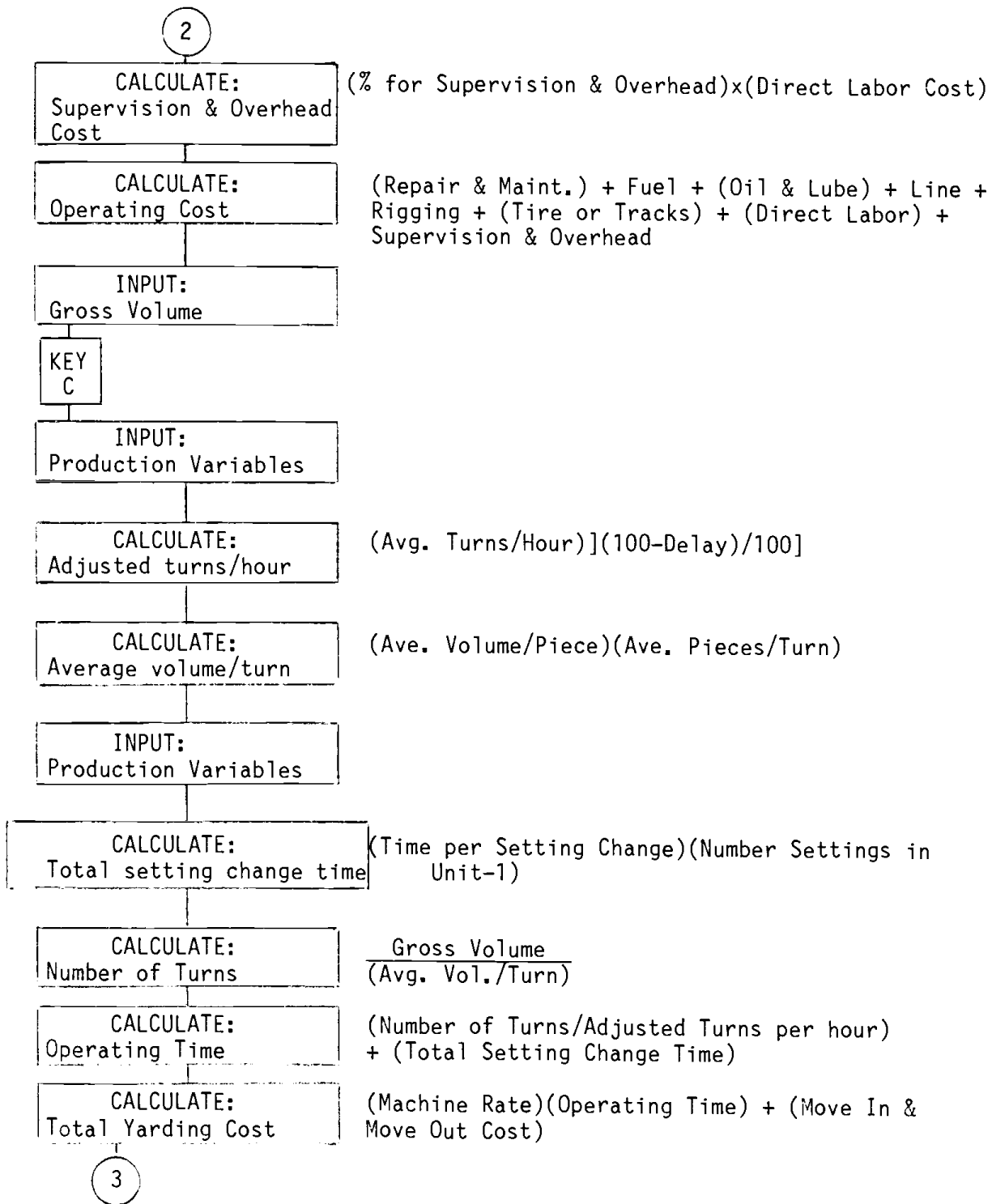




FIGURE 14. Continued.

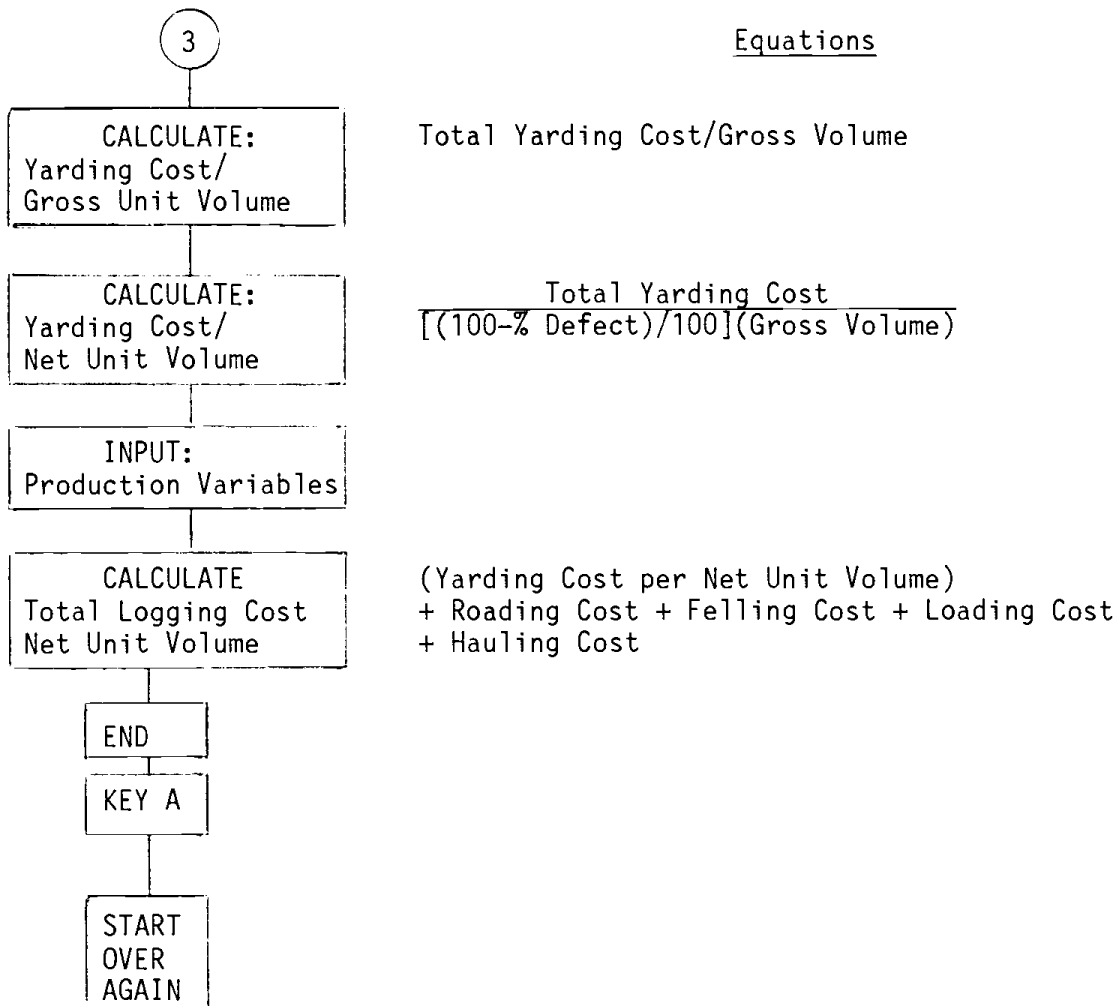
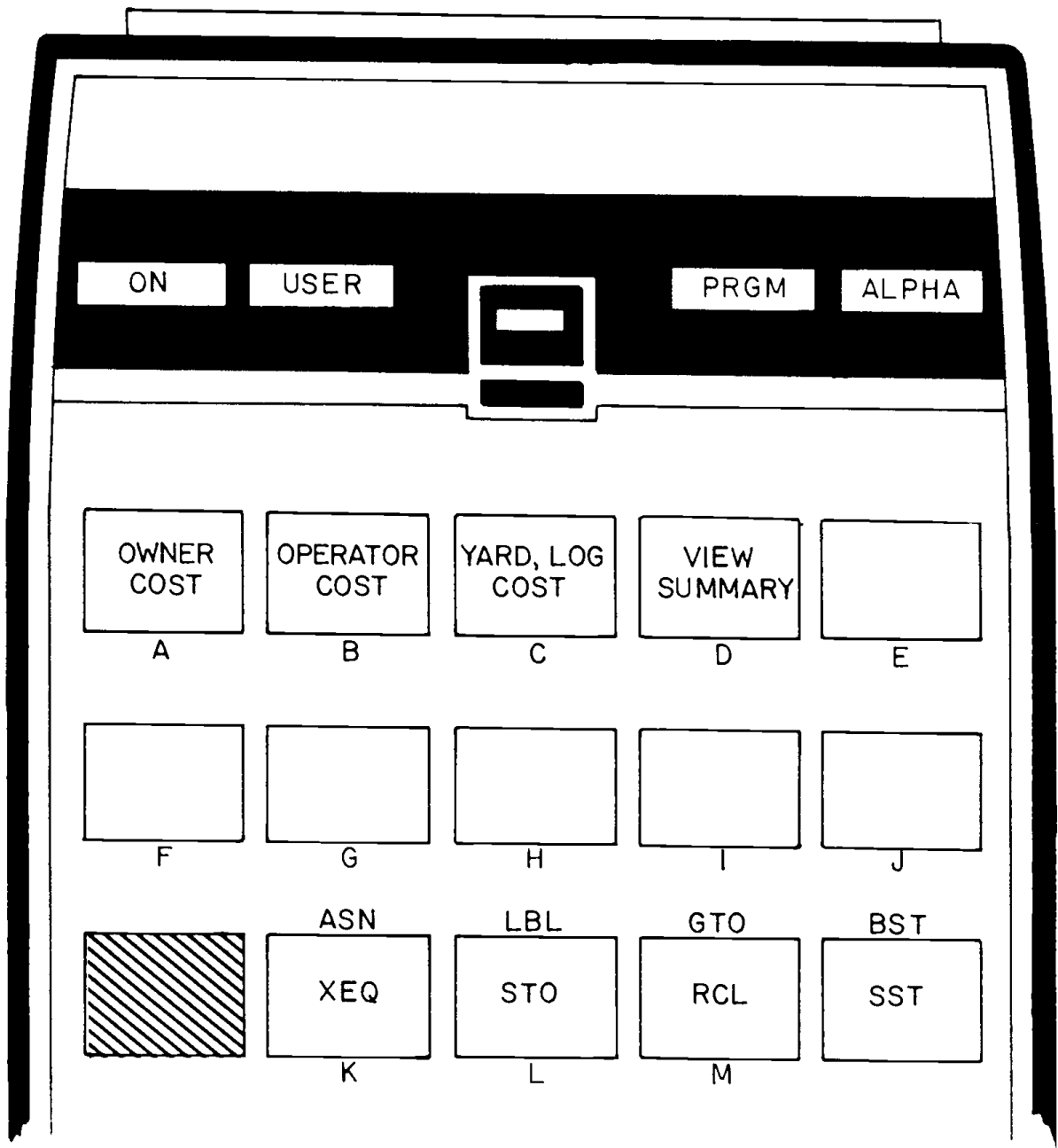


FIGURE 15. USER KEYS FOR YDCOST



6. "TOT.EQ. COST=\$": Shows total delivered equipment cost less line, rigging and tire or track cost in dollars (output).
7. "RES. VALUE=?": Prompt for the salvage value of the piece of equipment in dollars (input).
8. "DEP. PERIOD=?": Prompt for the desired depreciation period in years (input).
9. "AAI=\$": Shows calculated average annual investment in dollars per year (output).
10. "% A.I.R.=?": Prompt for the annual interest rate of money borrowed for machine as a percent of average annual investment (input).
11. "% TAX, ETC.=?": Prompt for tax, license, insurance, and storage as a percent of average annual investment (input).
12. "EQ. DEP.=\$": Shows calculated yearly equipment depreciation in dollars per year. This is straight line depreciation (output).
13. "DAYS WORK=?": Prompt for number of working days per year (input).
14. "HOURS/DAY=?": Prompt for number of hours worked per working day (input).
15. "OWNER COST=\$": Shows calculated ownership cost in dollars per hour (output).
16. "OPERATE COST": Tells users they are in the Operating Cost section.
17. "REP-MAINT=?": Prompt for repairs and maintenance in percent as percent of equipment depreciation (input).
18. "REP-MAINT=\$": Shows calculated repairs and maintenance cost in dollars per hour (output).
19. "FUEL USED=?": Prompt for fuel consumed in gallons per hour (input).
20. "FUEL COST=?": Prompt for fuel cost in dollars per gallon (input).
21. "FUEL=\$": Shows calculated fuel cost per hour to operate the piece of machinery (output).

22. "% OIL-LUBE=?": Prompt for oil and lube in percent as percent of equipment depreciation (input).
23. "OIL-LUBE COST=?": Prompt for oil and lube cost in dollars per gallon (input).
24. "O-L COST =\$": Shows calculated oil and lube cost in dollars per hour (output).
25. "LINE LIFE=?": Prompt for expected life of the line in hours (input).
26. "RIG LIFE=?": Prompt for expected rigging life in hours (input).
27. "TIRE LIFE=?": Prompt for expected tire or track life in hours (input).
28. "L-COST=\$": Shows calculated line cost in dollars per hour (output).
29. "TOT.WAGES=?": Prompt for total crew wages in dollars per hour (input).
30. "% FRINGE BEN.=?": Prompt for fringe benefits in percent as a percent of total crew wages (input).
31. "TRAVEL TIME?": Prompt for crew travel in hours per day; added as fringe-benefit percent to direct labor (input).
32. "% OVERHEAD=?": Prompt for supervision and overhead in percent as percent of direct labor cost (input).
33. "MACH.RATE=\$": Shows total calculated operating cost in dollars per hour, called machine rate (output).
34. "YARD,LOG COST": Tells users they are in the Yarding and Logging Cost per Net Unit Volume section.
35. "UNIT AREA=?": Prompt for area of unit in acres (input).
36. "YIELD=?": Prompt for the potential yield of the unit in MBF (thousand board feet) per acre (output).
37. "MBF/PIECE=?": Prompt for average volume per piece as bucked in MBF per piece (input).

38. "% DEF/PIECE=?": Prompt for percent defect in pieces as yarded (input).
39. "GROSS VOL=": Shows calculated gross volume in MBF for the unit (output).
40. "NO.SETTINGS=?": Prompt for number of settings for the unit (input).
41. "PIECES/TURN?": Prompt for average number of pieces per turn (input).
42. "TURNS/HR=?": Prompt for average number of turns per hour (input).
43. "% DELAY=?": Prompt for delay in percent as percent of turns per hour (input).
44. "SET.CHG.TIME=?": Prompt for time per setting change in hours (input).
45. "MOVE,IN-OUT\$=?": Prompt for move in and move out cost in dollars (input).
46. "MACH.RATE=\$": Shows recalled machine rate from operating cost section in dollars per hour (output).
47. "YARD COST=\$": Shows calculated yarding cost per net unit volume in dollars per MBF (output).
48. "ROAD COST=?": Prompt for roading cost per net unit volume in dollars per net MBF (input).
49. "FELL COST=?": Prompt for felling and bucking cost per net unit volume in dollars per net MBF (input).
50. "LOAD COST=?": Prompt for loading cost per net unit volume in dollars per net MBF (input).
51. "HAUL COST=?": Prompt for hauling cost per net unit volume in dollars per net MBF (input).
52. "TOT.LOG=\$": Shows total calculated logging cost per net unit volume in dollars per net MBF (output).
53. "RIG.COST=\$": Shows the calculated rigging cost in dollars per hour (output).
54. "TIRE COST=\$": Shows the calculated tire or track cost in dollars per hour (output).

55. "NET VOL.=": Shows calculated net volume in MBF for the unit (output).
56. "HARVEST TIME=": Shows total calculated time in hours to harvest the unit (output).
57. "OWNER COST=\$": Shows total calculated ownership cost in dollars (output).
58. "DIRECT LABOR=\$": Shows total calculated direct labor cost in dollars (output).
59. "MACH.OP.COST=\$": Shows total calculated machine operating cost in dollars to harvest the unit (output).
60. "SUPERVISION COST=\$": Shows total calculated supervision and overhead cost in dollars (output).
61. If the users want to review total logging cost per net unit volume, total ownership cost, total direct labor cost, machine operating cost, and supervision and overhead cost, they simply press User Key "D" at the end of program execution (after getting supervision and overhead cost).

B. Step-by-Step Example

Problem description is on pages 69-70 and example worksheet is on 71-72.

## EXAMPLE PROBLEM DESCRIPTION

### Section I - Ownership Cost

1.	Delivered equipment cost	\$250,000
	Line cost	\$ 9,500
	Rigging cost	\$ 2,500
	Tire or track replacement cost	0
	Display (delivered equipment cost less line, rigging and tire/track cost)	(\$238,000)
2.	Residual value	\$ 50,000
	Depreciation period	7 years
	Display (average annual investment)	(\$157,428.57)
3.	Annual interest rate as percent of average annual investment	10%
	Taxes, license, insurance and storage as percent of average annual investment	9%
	Display (equipment depreciation)	(\$26,857.14/yr)
4.	Days worked per year, enter	200 days/yr
	Hours worked per day	8 hrs/day
	Display (ownership cost, \$/hr)	(\$35.48/hr)

### Section II--Operating Cost

1.	Repairs and maintenance as percent of equipment depreciation	50%
	Display (repairs and maintenance cost/hr)	(\$8.39/hr)
2.	Fuel consumed (gal. per hour)	7 gal/hr
	Fuel cost per gal.	\$1.00/gal
	Display (fuel cost \$/hr)	(\$7.00/hr)
3.	Oil and lube as percent of fuel consumption	4%
	Oil and lube cost per gal.	\$2.00/gal
	Display (oil and lube cost/hr)	(\$0.56/hr)

4.	Line life (hours)	800 hrs
	Rigging life (hours)	3,200 hrs
	Tire or track life (hours)	0
	Display (line cost, \$/hr)	(\$11.88/hr)
	(rigging cost, \$/hr)	(\$0.78/hr)
	(tire or track cost, \$/hr)	(\$0.00/hr)
5.	Total crew wage	\$42.50/hr
	Percent fringe benefits	30%
	Travel time (hr/day)	0.5 hrs/day
	Supervision and overhead as percent of direct labor cost	15%
	Display (machine rate, \$/hr)	(\$130.68/hr)

Section III--Yarding and Logging Cost per Net Unit Volume

1.	Area of unit	35 acres
	Yield	40 MBF/acre
	Average volume per piece as bucked	0.25 MBF
	Percent defect in pieces as yarded	6%
	Display (gross unit volume, MBF)	(1400 MBF)
	(net volume, MBF)	(1316 MBF)
2.	Number of settings in cutting unit	8
	Average number of pieces per turn	3.2 pieces/turn
	Average number of turns per hour	12.5 turns/hr
	Delay as percent of turns per hour	15%
3.	Time per setting change (hours)	0.67 hours
	Move in and move out cost	\$2000
	Display (machine rate, \$/hr)	(\$130.68/hr)
	(yarding cost per net unit volume)	(\$18.34/MBF)
4.	Roading cost per net unit volume	\$16.72/MBF
	Felling cost per net unit volume	\$12.21/MBF
	Loading cost per net unit volume	\$6.28/MBF
	Hauling cost per net unit volume	\$19.23/MBF
	Display (total logging cost per net unit volume)	(\$72.78/MBF)
	(total harvest time, hours)	(169.50 hrs)
	(total ownership cost)	(\$6,010.23)
	(total direct labor cost)	(\$9,809.08)
	(machine operating cost)	(\$4,846.26)
	(supervision and overhead cost)	(\$1,471.36)



WORKSHEET (1/2)

Section I - Ownership Cost

1. Delivered equipment cost \_\_\_\_\_  
Line cost \_\_\_\_\_  
Rigging cost \_\_\_\_\_  
Tire or track replacement cost \_\_\_\_\_

Display (delivered equipment cost less line,  
rigging and tire/track cost)

2. Residual value \_\_\_\_\_  
Depreciation period \_\_\_\_\_

Display (average annual investment)

3. Annual interest rate as percent of  
average annual investment, enter \_\_\_\_\_  
Taxes, license, insurance and storage  
as percent of average annual investment \_\_\_\_\_

Display (equipment depreciation)

4. Days worked per year, enter \_\_\_\_\_  
Hours worked per day \_\_\_\_\_

Display (ownership cost, \$/hr)

Section II--Operating Cost

1. Repairs and maintenance as percent of  
equipment depreciation \_\_\_\_\_

Display (repairs and maintenance cost/hr)

2. Fuel consumed (gal. per hour) \_\_\_\_\_  
Fuel cost per gal. \_\_\_\_\_

Display (fuel cost \$/hr)

3. Oil and lube as percent of fuel consumption \_\_\_\_\_  
Oil and lube cost per gal. \_\_\_\_\_

Display (oil and lube cost/hr)

4. Line life (hours) \_\_\_\_\_  
 Rigging life (hours) \_\_\_\_\_  
 Tire or track life (hours) \_\_\_\_\_

Display (line cost, \$/hr)  
 (rigging cost, \$/hr)  
 (tire or track cost, \$/hr)

5. Total crew wage \_\_\_\_\_  
 Percent fringe benefits \_\_\_\_\_  
 Travel time (hr/day) \_\_\_\_\_  
 Supervision and overhead as percent of  
 direct labor cost \_\_\_\_\_

Display (machine rate, \$/hr)

Section III--Yarding and Logging Cost per Net Unit Volume

1. Area of unit \_\_\_\_\_  
 Yield \_\_\_\_\_  
 Average volume per piece as bucked \_\_\_\_\_  
 Percent defect in pieces as yarded \_\_\_\_\_

Display (gross unit volume, MBF)  
 (net volume, MBF)

2. Number of settings in cutting unit \_\_\_\_\_  
 Average number of pieces per turn \_\_\_\_\_  
 Average number of turns per hour \_\_\_\_\_  
 Delay as percent of turns per hour \_\_\_\_\_

3. Time per setting change (hours) \_\_\_\_\_  
 Move in and move out cost \_\_\_\_\_

Display (machine rate, \$/hr)  
 (yarding cost per net unit volume)

4. Roading cost per net unit volume \_\_\_\_\_  
 Felling cost per net unit volume \_\_\_\_\_  
 Loading cost per net unit volume \_\_\_\_\_  
 Hauling cost per net unit volume \_\_\_\_\_

Display (total logging cost per net unit volume)  
 (total harvest time, hours)  
 (total ownership cost)  
 (total direct labor cost)  
 (machine operating cost)  
 (supervision and overhead cost)

Program Execution: Access program by XEQ ALPHA YDCOST ALPHA  
in "USER" mode

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"OWNER COST" (ownership cost section)	No Response	No Keystroke
"EQUIP COST=?" (delivered equipment cost)	250,000	<u>R/S</u>
"LINE COST=?"	9,500	<u>R/S</u>
"RIG COST=?" (cost of rigging)	2,500	<u>R/S</u>
"TIRE COST=?" (cost of tire or track replacement)	0	<u>R/S</u>
"TOT.EQ.COST = \$238,000.00" (delivered equipment cost less line, rigging and tire/track cost)	No Response	<u>R/S</u>
"RES. VALUE=?" (salvage value of equipment)	50,000	<u>R/S</u>
"DEP. PERIOD=?" (depreciation period)	7	<u>R/S</u>
"AAI = \$157,428.57" (average annual investment)	No Response	<u>R/S</u>
"% A.I.R." (annual interest rate as percent of AAI)	10	<u>R/S</u>
"% TAX, ETC.=?" (taxes, license, insurance, and storage as percent of AAI)	9	<u>R/S</u>
"EQ.DEP. = \$26,857.14/YR" (yearly straight-line equipment depreciation)	No Response	<u>R/S</u>
"DAYS WORK=?" (working days per year)	200	<u>R/S</u>
"HOURS/DAY=?" (hours worked per day)	8	<u>R/S</u>
"OWNER COST = \$35.48/HR" (ownership cost)	No Response	<u>R/S</u>

"OPERATE COST" (entering operating cost section)	No Response	<u>R/S</u>
"REP-MAINT=?" (repair and maintenance as percent of equipment depreciation)	50	<u>R/S</u>
"REP-MAINT = \$8.39/HR" (repair and maintenance cost)	No Response	<u>R/S</u>
"FUEL USED=?" (fuel consumed per hour)	7	<u>R/S</u>
"FUEL COST=?" (fuel cost per gallon)	1.00	<u>R/S</u>
"FUEL = \$7.00/HR" (fuel cost per hour)	No Response	<u>R/S</u>
"% OIL-LUBE=?" (oil and lube as percent of fuel consumption)	4	<u>R/S</u>
"OIL-LUBE COST=?" (oil and lube cost per gallon)	2.00	<u>R/S</u>
"O-L COST = \$0.56/HR" (oil and lube cost per hour)	No Response	<u>R/S</u>
"LINE LIFE=?" (life of line in hours)	800	<u>R/S</u>
"RIG LIFE=?" (rigging live in hours)	3200	<u>R/S</u>
"TIRE LIFE=?" (tire or track life in hours, nonapplicable section in this case)	0	<u>R/S</u>
"L-COST = \$11.88/HR" (line cost per hour)	No Response	<u>R/S</u>
"RIG.COST = \$0.78/HR" (rigging cost per hour)	No Response	<u>R/S</u>
"TIRE COST = \$0.00/HR" (tire or track cost per hour)	No Response	<u>R/S</u>
"TOT. WAGES=?" (total crew wages per hour)	42.50	<u>R/S</u>

"% FRINGE BEN.=?"	30	<u>R/S</u>
(fringe benefits as percent of total crew wages)		
"TRAVEL TIME?"	0.5	<u>R/S</u>
(travel time in hours per working day)		
"% OVERHEAD=?"	15	<u>R/S</u>
(supervision and overhead as percent of direct cost)		
"MACH. RATE = \$130.68/HR"	No Response	<u>R/S</u>
(machine rate)		
"YARD, LOG COST"	No Response	No Keystroke
(entering yarding and logging cost section)		
"UNIT AREA=?"	35	<u>R/S</u>
(area of unit in acres)		
"YIELD=?"	40	<u>R/S</u>
(unit yield in MBF per acre)		
"MBF/PIECE=?"	0.25	<u>R/S</u>
(volume per bucked piece in MBF)		
"% DEF/PIECE=?"	6	<u>R/S</u>
(percent defect in pieces yarded)		
"GROSS VOL = 1,400.00 MBF"	No Response	<u>R/S</u>
(gross volume for unit in MBF)		
"NET VOL - 1,316.00 MBF"	No Response	<u>R/S</u>
(net volume for unit in MBF)		
"NO. SETTINGS=?"	8	<u>R/S</u>
(number of settings in cutting unit)		
"PIECES/TURN?"	3.2	<u>R/S</u>
(average number of pieces per turn)		
"TURNS/HR=?"	12.5	<u>R/S</u>
(average number of turns per hour)		
"% DELAY=?"	15	<u>R/S</u>
(delay as percent of turns per hour)		
"SET. CHG TIME=?"	0.67	<u>R/S</u>
(time per setting change in hours)		

"MOVE, IN-OUT\$=?" (move in and move out costs)	2000	<u>R/S</u>
"MACH.RATE = \$130.68/HR" (recalled machine rate)	No Response	<u>R/S</u>
"YARD COST = \$18.34/MBF" (yarding cost per net unit volume, MBF)	No Response	<u>R/S</u>
"ROAD COST=?" (road cost per net unit volume)	16.72	<u>R/S</u>
"FELL COST=?" (felling and bucking cost per net unit volume)	12.21	<u>R/S</u>
"LOAD COST=?" (loading cost per net unit volume)	6.28	<u>R/S</u>
"HAUL COST=?" (hauling cost per net unit volume)	19.23	<u>R/S</u>
"TOT.LOG = \$72.78/MBF" (total logging cost per net unit volume)	No Response	<u>R/S</u>
"HARVEST TIME = 169.40 HRS" (total time in hours to harvest the unit)	No Response	<u>R/S</u>
"OWNER COST = \$6,010.23" (total ownership cost)	No Response	<u>R/S</u>
"DIRECT LABOR = \$9,809.08" (total direct labor cost)	No Response	<u>R/S</u>
"MACH.OP.COST = " "\$4,846.26" (total machine operating cost)	No Response No Response	No Keystroke <u>R/S</u>
"SUPERVISION COST =" "\$1,471.36" (total supervision and overhead cost)	No Response No Response	No Keystroke <u>R/S</u>

At this point, users can modify values in Section II (Operating Costs; user key "B"), modify values in Section III (Yarding and Logging Costs; user key "C"), review ending output (total logging cost per net unit volume, total harvest time, total ownership cost, total direct labor cost, machine operating cost, and supervision and overhead cost; user key "D"), or start a new problem (user key "A").

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

Values for all variables must be entered. If variables are not applicable or are zero, they must be entered as zero.

If a mistake is made while entering values, users must either continue through the section entering variables, or press "A" in "USER" mode to begin entering data again.

If it is desired to change one or more variables in a section, the entire section's variables must be re-entered. Also, if Section I is redone, Section II and Section III must also be redone. However, Section II or Section III can be modified alone by pressing "B" or "C", respectively, in "USER" mode.

Once a machine rate has been established, only Section III need be accessed to predict yarding or logging costs for varying production parameters.

Users may find it helpful to attach a peripheral printer (HP-82162A) while running the program rather than writing down each output as displayed.

This program was originally designed for skyline yarding, but can be used as well for ground-based systems by entering zero into costs that do not apply to the particular system.

If users wish to review logging cost per net unit volume, total harvest time, total ownership cost, total direct labor cost, machine operating cost, and supervision and overhead cost after program execution is over, press "D" in "USER" mode.

The calculator must be in "USER" mode during program execution.

# Guyline Analysis and Column Failure Analysis (TALHOLD)

USFS NO. 101 and 112

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Salmon, ID 83467

## I. BACKGROUND INFORMATION

### A. General Assumptions

"Guyline" subprogram assumes static and weightless line conditions.

Guyline subprogram assumes two guylines with one guyline on each side of the skyline.

"Column Failure" ("Tailtree") subprogram assumes diameters entered are inside bark.

"Column Failure" subprogram assumes a K-value equal to 1.0 if the user does not enter some other value.

The "Column Failure" subprogram will assume the following values:

	<u>Modulus of Elasticity (psi)</u>	<u>Maximum Allowable Compressive Stress</u>
Douglas-fir ("DF")	1,560,000	3800 psi
Ponderosa Pine ("P")	1,000,000	2500 psi
Western Hemlock ("WH")	1,040,000	3400 psi
Redwood ("R")	1,180,000	3100 psi
Sitka Spruce ("SS")	1,230,000	2700 psi

Users can also enter their own values.

The material (wood) considered in the column failure subprogram is assumed to be homogeneous.

"P-CRIT," determined in the "Column Failure" subprogram, is assumed to be a static compressive load.



The buckling equation assumes a slender, evenly tapered column. This is not strictly true for the bole of the tree but is a necessary assumption to make the problem workable.

B. References: (For Modulus of Elasticity and Maximum Compressive Stresses)

Wood Structural Design Data. 1979 ed. National Forest Products Association: Washington, D.C. 240 p.

National Design Specifications, Wood Construction. 1982. National Forest Products Association: Washington, D.C.

C. Figures and Formulas

Figure 16. Guyline Configuration and Guyline Forces used in Guyline Analysis

Figure 17. Guyline Force Diagram for Sitka Spruce Example

Figure 18. Guyline Force Diagram for Douglas-fir Example

Figure 19. Example of Vertical Forces on a Tailtree

Figure 20. User Keys for TALHOLD

$$P\text{-CRIT}_B = \frac{K^2 E D^4}{64 L^2} \quad \text{Buckling Force}$$

Where:

$P\text{-CRIT}_B$  = critical buckling force (lbs)

K = end factor condition

E = modulus of elasticity

D = diameter at 1/3 length from the small end for tapered columns (inches)

L = column length (inches)

Maximum compressive stresses on columns by Euler's equation:

$$P\text{-CRIT}_C = (\sigma \text{ max})A \left[ 1 - \frac{1}{3} \left( \frac{2/3(\sigma \text{ max})A}{P\text{-CRIT}_B} \right) \right]$$

Where:

$P\text{-CRIT}_C$  = critical compressive force

$\sigma \text{ max}$  = maximum compressive stress

A = area of small end

Maximum compressive stress felt by the Column:

$$\text{Max Stress} = \frac{P\text{-CRIT}(B \text{ or } C)}{A}$$

FIGURE 16. GUYLINE CONFIGURATION AND GUYLINE FORCES IN GUYLINE ANALYSIS

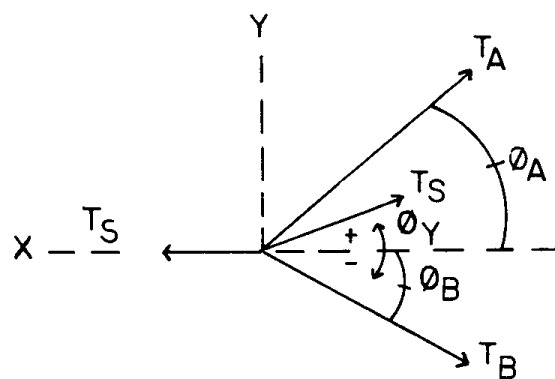
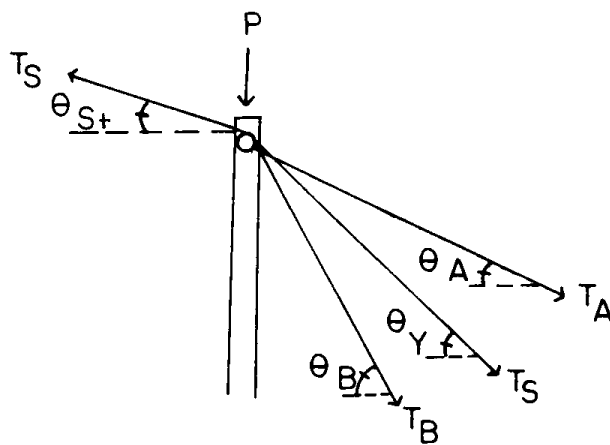
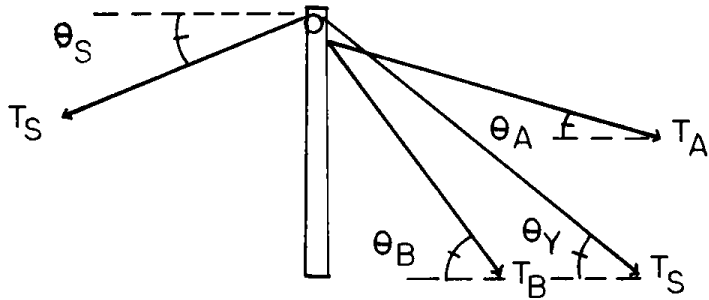
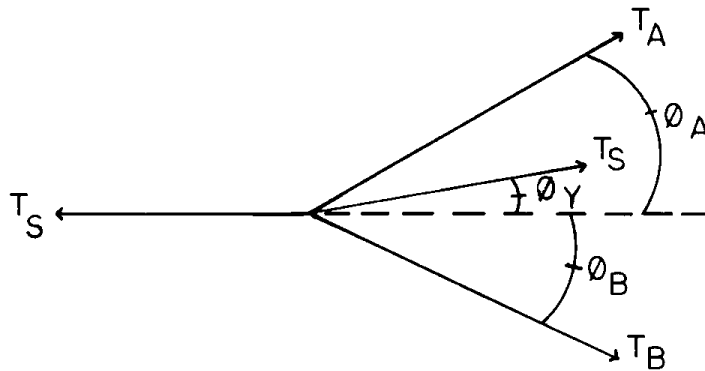


FIGURE 17. GUYLINE FORCE DIAGRAM FOR SITKA SPRUCE EXAMPLE



Input:

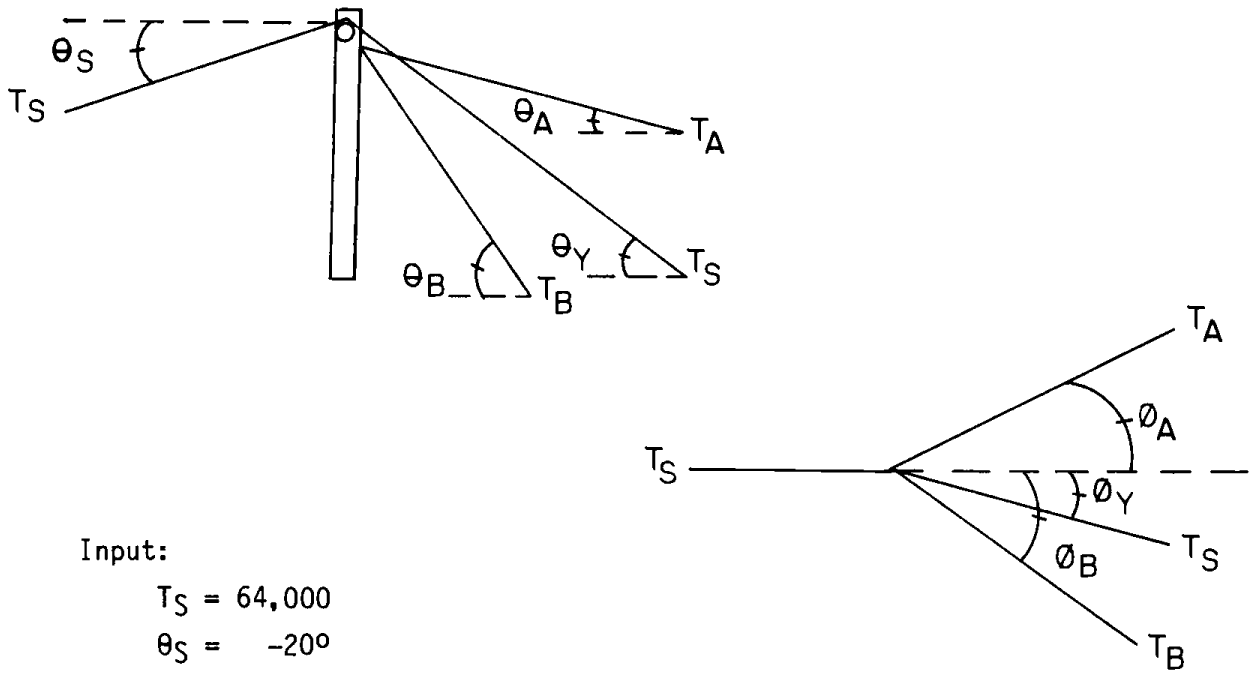
- $T_S = 100,000$
- $\theta_S = -21^\circ$
- $\theta_Y = 50^\circ$
- $\theta_A = 25^\circ$
- $\theta_B = 35^\circ$
- $\phi_Y = 10^\circ$
- $\phi_A = 30^\circ$
- $\phi_B = 25^\circ$



Output:

- D Tension guyline A ( $T_A$ ) = 3,483.32 lbs
- E Tension guyline B ( $T_B$ ) = 36,801.82 lbs
- fa Axial load on tailtree (P) = 135,022.01 lbs
- fb Horizontal force, guyline A = 3,156.96 lbs
- fc Vertical force, guyline B = 1,472.12 lbs
- fd Horizontal force, guyline B = 30,146.28 lbs
- fe Vertical force, guyline B = 21,108.66 lbs

FIGURE 18. GUYLINE FORCE DIAGRAM FOR DOUGLAS-FIR EXAMPLE



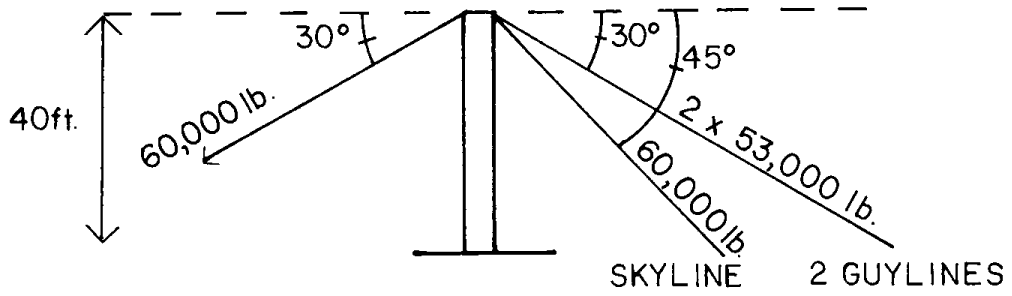
Input:

$T_S = 64,000$   
 $\theta_S = -20^\circ$   
 $\theta_Y = 48^\circ$   
 $\theta_A = 15^\circ$   
 $\theta_B = 30^\circ$   
 $\phi_Y = -10^\circ$   
 $\phi_A = 30^\circ$   
 $\phi_B = 30^\circ$

Output:

D Tension guyline A ( $T_A$ ) = 18,437.62 lbs  
 E Tension guyline B ( $T_B$ ) = 3,390.93 lbs  
 fa Axial load on tailtree ( $P$ ) = 75,918.03 lbs  
 fb Horizontal force guyline A = 17,809.37 lbs  
 fc Vertical force guyline A = 4,772.01 lbs  
 fd Horizontal force guyline B = 2,936.63 lbs  
 fe Vertical force guyline B = 1,695.46 lbs

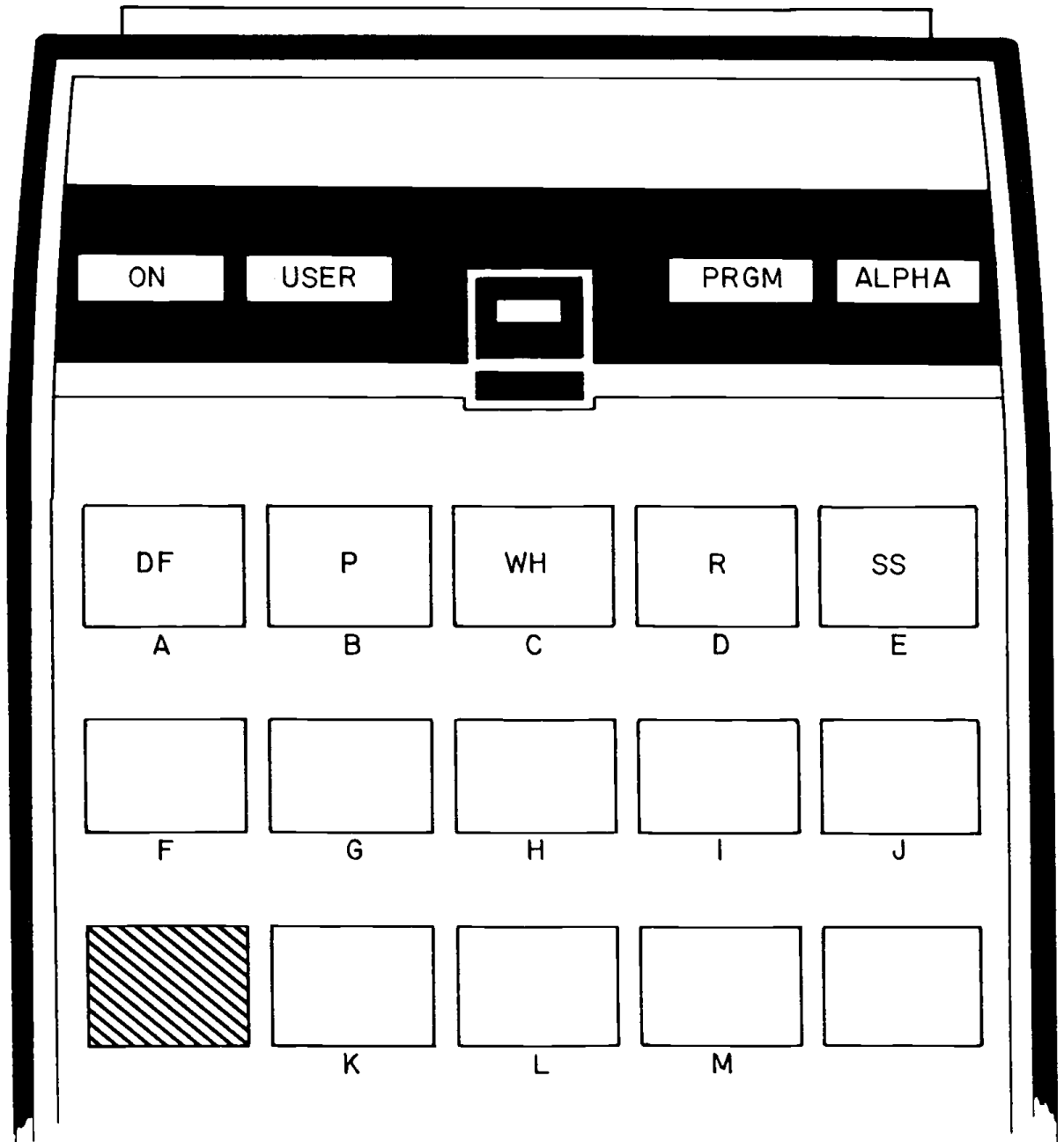
FIGURE 19. EXAMPLE OF VERTICAL FORCES ON A TAILTREE



Total vertical loading on tree:

$$\begin{aligned} & 60,000 \times \sin 30^\circ \\ + & 60,000 \times \sin 45^\circ \\ + & 53,000 \times \sin 30^\circ \\ + & 53,000 \times \sin 30^\circ \\ & = 125,426 \text{ lbs} \end{aligned}$$

FIGURE 20. USER KEYS FOR TALHOLD



Tension felt by guylines (Figure 16)

Guyline B:

$$T_B = \frac{T_A \cos\theta_A \sin\theta_A + T_S \cos\theta_Y \sin\theta_Y}{\cos\theta_B \sin\theta_B}$$

Guyline A:

$$T_A = \frac{T_S \cos\theta_S - T_S \cos\theta_Y \cos\theta_Y - T_S \cos\theta_Y \sin\theta_Y \cot\theta_B}{\cos\theta_A \cos\theta_A + \cos\theta_A \sin\theta_A \cot\theta_B}$$

Axial load felt by tailtree from guylines (Figure 19):

$$P = T_S \sin\theta_Y T_A \sin\theta_A + T_B \sin\theta_B - T_S \sin\theta_S$$

## II. CONVENTIONS AND MEMORY

### A. Conventions (Refer to Figure 16)

"SKY-YARD~~S~~": Positive if headspar is higher than tailhold (uphill yarding) and negative if headspar lower than tailhold (downhill yarding).

"SKY HORZ~~S~~": With the headspar at your back and facing the tailspar, if the skyline anchor is to the left the angle is positive, and if it is to the right the angle would be negative.

### B. Size and Capacity

The calculator must be sized to 025. The program uses 148 registers. Total calculator capacity must be 173 registers. The program consists of 401 steps.

## III. EXAMPLE OF PROGRAM USE

### A. Information Needed

For Guyline Analysis Subprogram (Figure 16)

1. "GUY ANAL? Y,N": Asks users if they want a guyline analysis. If yes, enter "Y"; if no, enter "N". The program goes to tailtree (column) failure analysis if "N" is entered.
2. "SKY TENSION?" ( $T_S$ ): Prompt for tension in skyline in lbs (input).

3. "SKY-YARD  $\alpha$ =" ( $\theta_S$ ): Prompt for angle of skyline from tailtree to yarder in degrees (input).
4. "SKY VERT  $\alpha$ =" ( $\theta_Y$ ): Prompt for angle of skyline from tailtree to skyline anchor in degrees (input).
5. "GUY VERT  $\alpha_A$ =" ( $\theta_A$ ): Prompt for angle of guyline A from tailtree to guyline anchor in degrees (input).
6. "GUY VERT  $\alpha_B$ =" ( $\theta_B$ ): Prompt for angle of guyline B from tailtree to guyline anchor in degrees (input).
7. "SKY HORZ  $\alpha$ =" ( $\theta_Y$ ): Prompt for horizontal angle of skyline in degrees (input).
8. "GUY HORZ  $\alpha_A$ =" ( $\theta_A$ ): Prompt for horizontal angle of guyline A in degrees (input).
9. "GUY HORZ  $\alpha_B$ =" ( $\theta_B$ ): Prompt for horizontal angle of guyline B in degrees (input).
10. "TA=" ( $T_A$ ): Shows tension in guyline A in lbs (output).
11. "TB=" ( $T_B$ ): Shows tension in guyline B in lbs (output).
12. "P=" (P): Shows axial load on tailtree (column) in lbs (output).
13. "HORZ F-A=" ( $T_{AX}$ ): Shows horizontal force in guyline A in lbs (output).
14. "VERT F-A=" ( $T_{AY}$ ): Shows vertical force in guyline A in lbs (output).
15. "HORZ F-B=" ( $T_{BX}$ ): Shows vertical force in guyline A in lbs (output).
16. "VERT F-B=" ( $T_{BY}$ ): Shows vertical force in guyline B in lbs (output).
17. "CHECK TREE? Y,N": Asks if the user wants to compare results of the guyline analysis with the tailtree (column) failure analysis and to determine if tree is safe. In order for the program to check this, the user has to run both a guyline analysis and a tailtree (column) failure analysis. If the user has not run both subprograms, but has said yes to "CHECK TREE", the computer says "NOT DONE" and prompts the user with "GUY ANAL? Y,N" so the other program can be run. When both



subprograms have been run and the computer checks the tailtree, it prompts "TREE IS GOOD" if the tailtree is safe and "TREE IS BAD" if the tailtree is unsafe.

For Tailtree (Column) Failure Subprogram (Figure 19).

1. "OWN MOD-E? Y,N": Asks if the users want to enter their own modulus of elasticity (in million psi) and maximum compressive stress (in psi). If yes, enter a Y. Enter an N if you want to use the ones built into the program for Douglas-fir, ponderosa pine, western hemlock, redwood, or Sitka spruce.
2. "MODULUS E=?": Prompt for users to enter their own modulus of elasticity in million ( $10^6$ ) psi; e.g., DF = 1,560,000 (input).
3. "MAX STRESS=?": Prompt for the maximum compressive stress chosen by the user that the tailtree (column) can support before failure. The units are psi, e.g., DF = 3800 (input).
4. "HEIGHT=?": Prompt for the vertical height from the base of the tailtree (column) to the intersection of the skyline and tailspar in feet (input).
5. "L-DIAM=?": Prompt for the diameter inside bark in inches at the base of the tailspar (input).
6. "S-DIAM=?": Prompt for the diameter inside bark in inches at the point the skyline intersects the tailspar (input).
7. "OWN K-FACT? Y,N": Asks users if they want to enter their own K factor. If users don't want to enter a K factor, the calculator will assume it is equal to 1.00. The K factor indicates how securely the top and bottom ends of the tailtree (column) are held in place. The K factor of 1.00 is appropriate for a topped, guyed spar. Users should use a smaller factor--about 0.3--to analyze raised or partially tipped spars. A range of K factors from 0.25 (for the least securely held top and bottom ends) to 1.5 (for the most securely held top and bottom ends) may cover most cases.
8. "K-FACTOR=?": Prompt appears if users choose to enter their own K factor value. Some suggested values are described above (input).

9. "DF P WH R SS": Prompt appears if users want to use the calculator's modulus of elasticity and maximum compressive stress by pressing the appropriate key. "DF"=Douglas-fir, "P"=ponderosa pine, "WH"=western hemlock, "R"=redwood, and "SS"=Sitka spruce. The values for each are shown on page 78.
10. "FS=?": Prompt for a design factor of safety. A minimum value used is usually 3 (input).
11. "COMP. FAILURE": Indicates that if the spar would fail, it would probably fail in compression at the critical force that follows this display. The computer will always display the limiting case.
12. "BUCKLE FAIL": Indicates that if the spar would fail, it would probably fail in buckling at the critical force that follows this display. The computer will always display the limiting case.
13. "P-CRIT=": Shows the calculated limiting axial load in pounds, with the design factor of safety built in, that will cause the tailspar (column) to fail (output).
14. "STRESSES=": Shows the compressive stress which occurs at "P-CRIT" and must be less than maximum compressive stress entered (output).

## B. Step-by-Step Example

### Problem Description

There are two probable tailspars, one is a 32-inch Douglas-fir and the other is a 36-inch Sitka spruce. Because of the terrain, the Sitka spruce tree would have to be rigged 105 feet up. The Douglas-fir tree could be rigged 40 feet up and topped. All skyline tensions and angles are described below.

### Given

#### Douglas-fir

Use built in modulus of elasticity and maximum compressive stress  
 Height = 40 feet  
 Large-end diameter = 32 inches  
 Small-end diameter = 21 inches  
 Factor of safety = 3 since tree appears sound with no major defects  
 K factor =1 (topped, guyed spar)

Sitka spruce

Height = 105 feet

Large-end diameter = 36 inches

Small-end diameter = 18.5 inches

Factor of safety = 5 because there may have been  
past failures at a safety factor of 3

K factor = 0.5 (partially tipped)

#### Guyline Configuration and Skyline Tensions

Douglas-fir (Figure 18)

Tension in skyline = 64,000 lbs

Angle of skyline from tailtree to the yarder =  $-20^\circ$

Angle of skyline from tailtree to skyline anchor =  $48^\circ$

Angle of guyline A from tailtree to guyline anchor =  $15^\circ$

Angle of guyline B from tailtree to guyline anchor =  $30^\circ$

Horizontal angle of the skyline =  $-10^\circ$

Horizontal angle of guyline A =  $30^\circ$

Horizontal angle of guyline B =  $30^\circ$

Sitka spruce (Figure 17)

Tension in skyline = 100,000 lbs

Angle of skyline from tailtree to yarder =  $-21^\circ$

Angle of skyline from tailtree to skyline anchor =  $50^\circ$

Angle of guyline A from tailtree to guyline anchor =  $25^\circ$

Angle of guyline B from tailtree to guyline anchor =  $35^\circ$

Horizontal angle of skyline =  $10^\circ$

Horizontal angle of guyline A =  $30^\circ$

Horizontal angle of guyline B =  $25^\circ$

Determine: The safety of each tailtree; then choose the best  
one or the one that is safe.

Solution:

Douglas-fir

Tailtree failure analysis:

Failure would be in compression

Critical axial load = 362,374.31 lbs

Compressive stress exerted by critical axial  
load = 1046.23 psi.

Guyline analysis:

Tension in guyline A = 18,437.62 lbs  
Tension in guyline B = 3,390.93 lbs  
Axial load exerted on tailtree = 75,918.03 lbs  
Horizontal force in guyline A = 17,809.37 lbs  
Vertical force in guyline A = 4772.01 lbs  
Horizontal force in guyline B = 2936.63 lbs  
Vertical force in guyline B = 1695.46 lbs  
Tree is safe ("TREE IS GOOD"); P-CRIT>P

Sitka spruce

Tailtree failure analysis:

Failure would be in buckling  
Critical axial load = 13,159.52 lbs  
Compressive stress exerted by critical axial  
load = 48.96 psi

Guyline analysis:

Tension in guyline A = 3,483.22 lbs  
Tension in guyline B = 36,801.82 lbs  
Axial load exerted on tailtree = 135,022.01 lbs  
Horizontal force in guyline A = 3,156.96 lbs  
Vertical force in guyline A = 1,472.12 lbs  
Horizontal force in guyline B = 30,146.28 lbs  
Vertical force in guyline B = 21,108.66 lbs  
Tree is "NOT" safe ("TREE IS BAD"); P-CRIT<P

NOTE: The tailtree to use for this example would be the Douglas-fir tree.

Program Execution: Access the beginning of the program by XEQ ALPHA TALHOLD ALPHA in "User" mode. First the Douglas-fir tree with its guyline configuration will be analyzed.

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"GUY ANAL? Y,N"	N	<u>R/S</u>
"TAILTREE ANAL"	No Response	No Keystroke
"OWN MOD-E? Y,N"	N	<u>R/S</u>
"DF P WH R SS"	No Response	<u>A</u> (must be in "User" mode)
"DOUGLAS-FIR"	No Response	No Keystroke

"HEIGHT=?"	40	<u>R/S</u>
"L-DIAM=?"	32	<u>R/S</u>
"S-DIAM=?"	21	<u>R/S</u>
"OWN K-FAC? Y,N"	N	<u>R/S</u>
"FS=?"	3	<u>R/S</u>
"COMP.FAILURE"	No Response	No Keystroke
"P-CRIT = 362,374.31"	No Response	<u>R/S</u>
"STRESS = 1,046.23"	No Response	<u>R/S</u>
"CHECK TREE? Y,N"	N	<u>R/S</u>
*START OF GUYLINE ANALYSIS FOR DOUGLAS-FIR*		
"GUY ANAL? Y,N"	Y	<u>R/S</u>
"GUYLINE ANAL."	No Response	No Keystroke
"SKY TENSION?"	64,000	<u>R/S</u>
"SKY.-YARD <del>X</del> =?"	20	<u>CHS</u> <u>R/S</u>
"SKY VERT <del>X</del> =?"	48	<u>R/S</u>
"GUY VERT <del>X</del> A=?"	15	<u>R/S</u>
"GUY VERT <del>X</del> B=?"	30	<u>R/S</u>
"SKY HORZ <del>X</del> A=?"	10	<u>CHS</u> <u>R/S</u>
"GUY HORZ <del>X</del> =?"	30	<u>R/S</u>
"GUY HORZ <del>X</del> B=?"	30	<u>R/S</u>
"TA = 18,437.62 LBS"	No Response	<u>R/S</u>
"TB = 3,390.93 LBS"	No Response	<u>R/S</u>
"P = 75,918.03 LBS"	No Response	<u>R/S</u>
"HORZ F-A = 17,809.37 LBS"	No Response	<u>R/S</u>
"VERT F-A = 4,772.01 LBS"	No Response	<u>R/S</u>

"HORZ F-B = 2,936.63 LBS"	No Response	<u>R/S</u>
"VERT F-B = 1,695.46 LBS"	No Response	<u>R/S</u>
"CHECK TREE? Y,N"	Y	<u>R/S</u>
"TREE IS GOOD"	No Response	<u>R/S</u>

At this point follow the above procedure for analyzing the Sitka spruce tree. The answers should be those in the "solution" section of the "Step-by-Step Example." Remember to analyze both guylines and column failure before checking to see if the tree is safe.

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

Shock loads while under compression, decay, shake, or eccentric loads can cause failure at much lower loadings that may not be easily predicted. Selecting only sound trees for spars and using a generous factor of safety will help prevent tree failures.

All diameter measurements should be inside bark measurements.

The factor of safety used in the "Column Failure" subprogram must be greater than zero.

Make sure the calculator is in the "USER" mode during program execution.

Pay particular attention to signs of angles when entering data. Use CHS to change signs before pressing R/S.

The guyline analysis subprogram can also be used to check line tension with safe working loads in the guylines.

Program "TALHOLD" combines two subprograms that can either be used together or separately for other purposes.

# Field Skyline Analysis Program (FSAP)

NOTE: "FSAP must be read into the calculator with the calculator in "USER" mode.

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## I. BACKGROUND INFORMATION

### A. General Assumptions

Full log suspension is assumed.

Power from the yarder is assumed to be sufficient to yard any loads, and the line strength is considered the limiting factor.

A live skyline or shotgun system with a non-clamping carriage is assumed (haulback line weight can be added to carriage weight if haulback is used).

### B. References: None stated

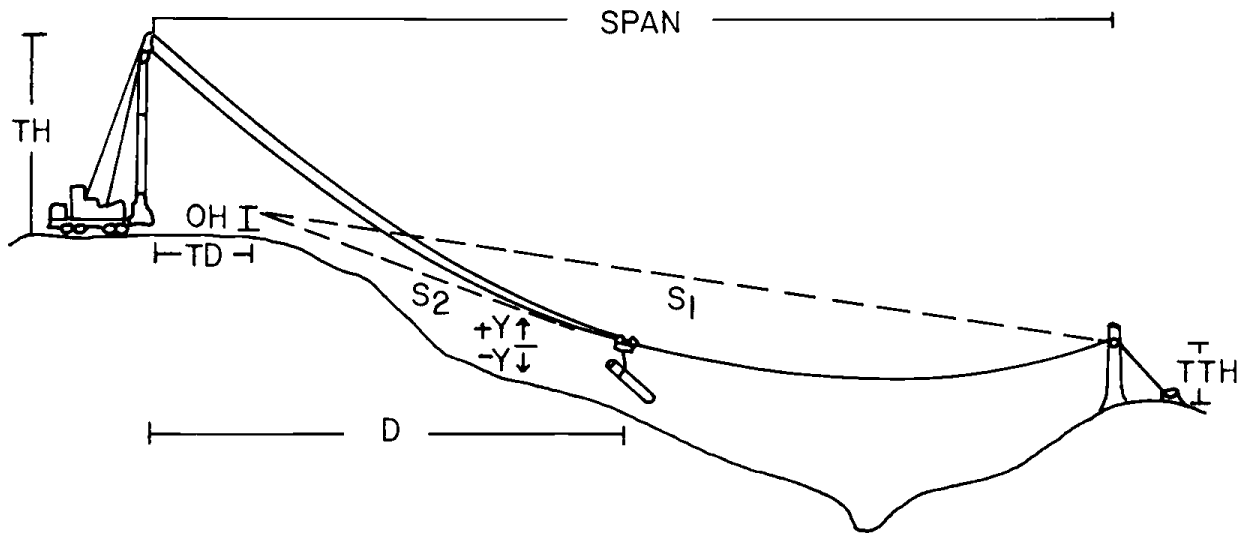
### C. Figures:

Figure 21. Variables and Nomenclature for FSAP

Figure 22. Graphs of Percentage of Error in Tension from Span and Payload Estimates

Figure 23. User Keys for FSAP

FIGURE 21. VARIABLES AND NOMENCLATURE FOR FSAP



Span = horizontal length from tower to tailhold

TH = tower height

OH = observation height above base of tower

TD = tower distance to observer at edge of landing

$S_1$  = percent slope reading to tailhold location

$S_2$  = percent slope reading to carriage at known distance

D = horizontal distance to carriage

TTH = tailtree height

Y = elevation change of carriage



FIGURE 22. GRAPHS OF PERCENTAGE OF ERROR IN TENSION FROM SPAN AND PAYLOAD ESTIMATES

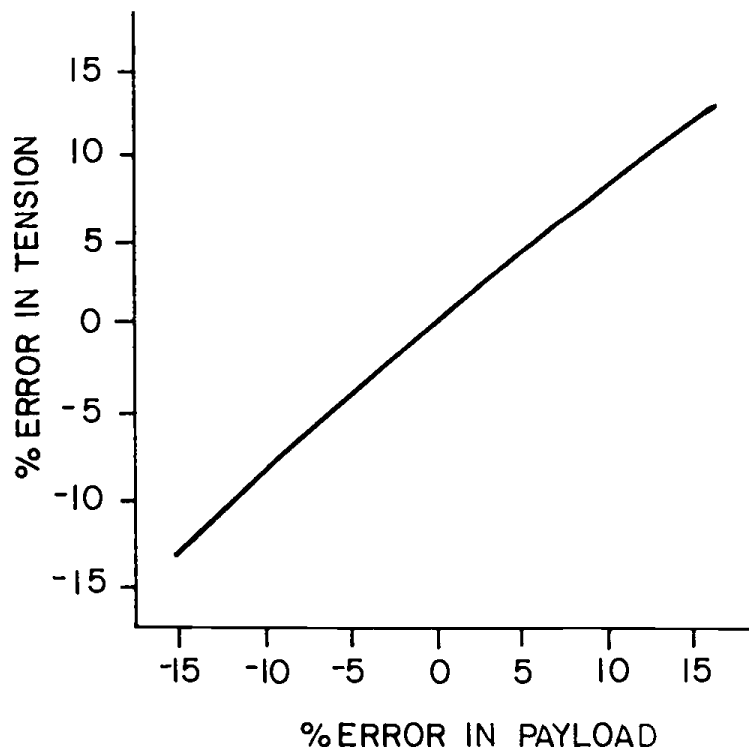
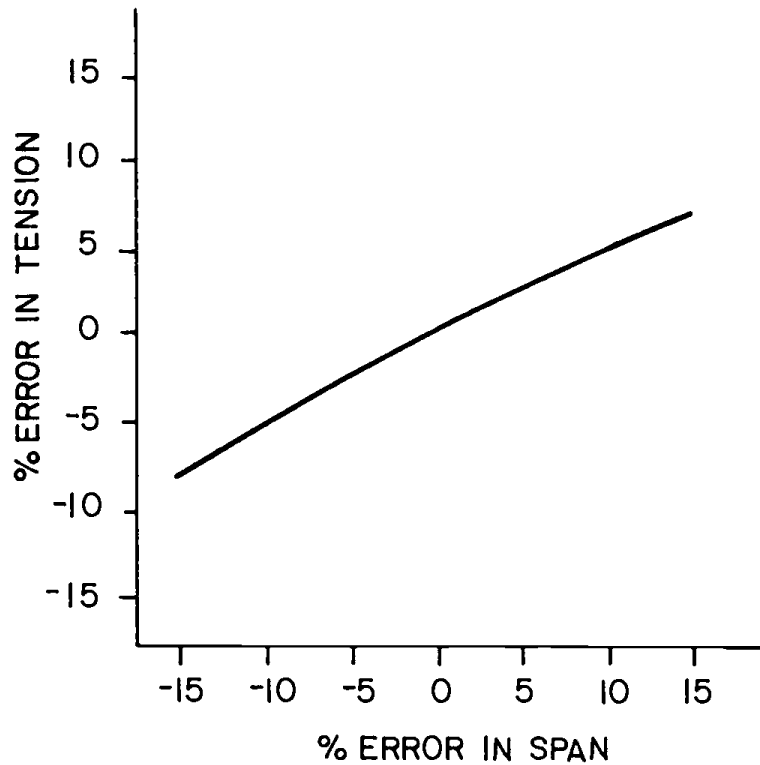


FIGURE 23. USER KEYS FOR FSAP

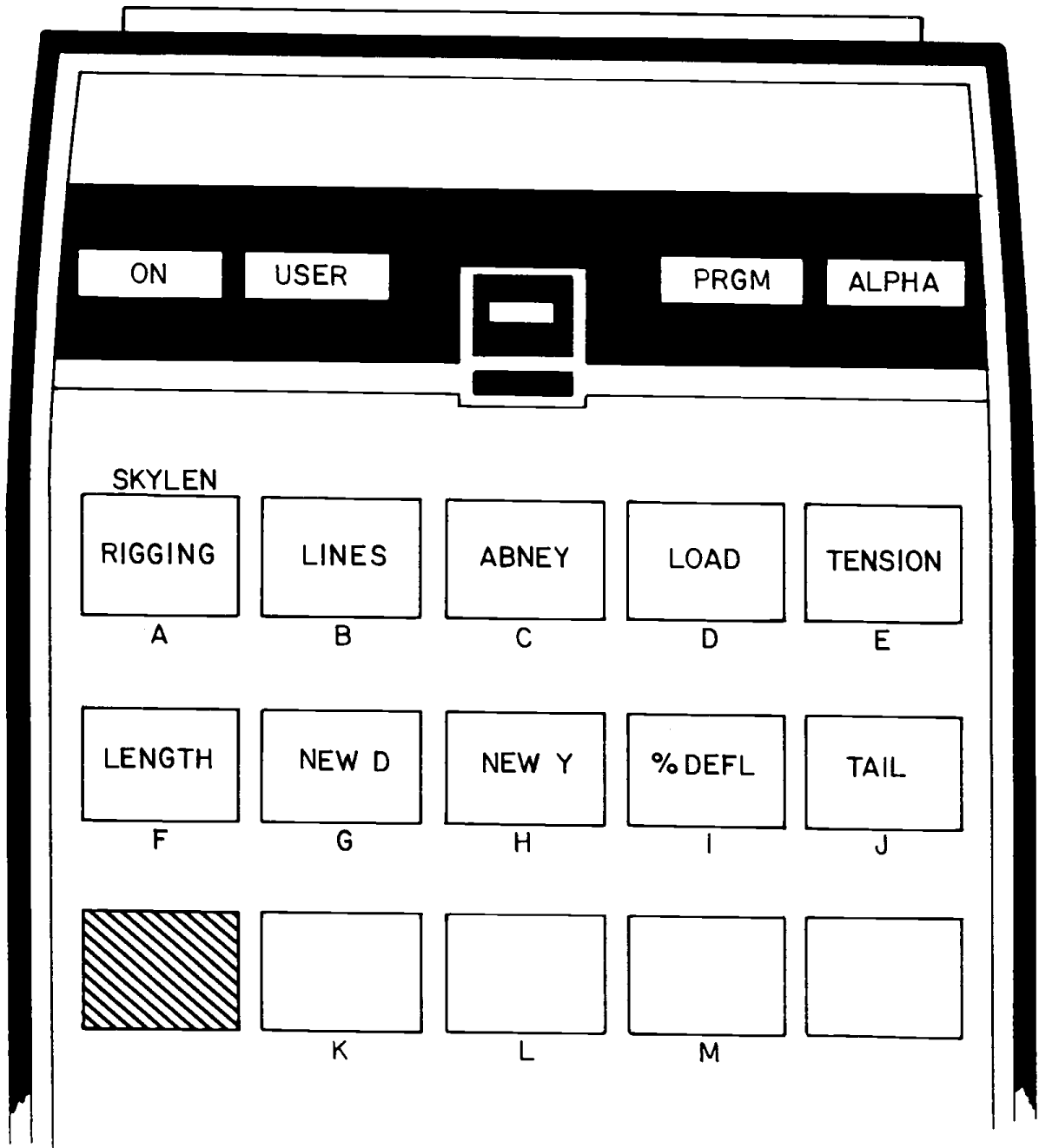


TABLE 1. WIRE ROPE WEIGHTS, STRENGTHS, AND K VALUES  
6 x 19, 6 x 21, or 6 x 25 IWRC\*

Diameter (inches)	K**	Weight (lb/ft)	Extra-Improved Plow Steel	
			Safe Working Load Safety Factor=3 (kips)	Breaking Strength (kips)
1/4	3.29	0.116	2.27	6.80
5/16	2.21	0.18	3.51	10.54
3/8	1.58	0.26	5.0	15.1
7/16	1.19	0.35	6.8	20.4
1/2	0.925	0.46	8.9	26.6
9/16	0.741	0.59	11.2	33.6
5/8	0.607	0.72	13.7	41.2
3/4	0.428	1.04	19.6	58.8
7/8	0.308	1.42	26.5	79.6
1	0.239	1.85	34.5	103.4
1-1/8	0.191	2.34	43.3	130.0
1-1/4	0.152	2.89	53.3	159.8
1-3/8	0.127	3.50	64.0	192.0
1-1/2	0.107	4.16	76.0	228.0
1-5/8	0.0886	4.88	88.0	264.0
1-3/4	0.0770	5.67	102.0	306.0
1-7/8	0.0675	6.50	116.0	348.0
2	0.0597	7.39	132.0	396.0

\*Independent Wire Rope Core

\*\*This value gives only approximate capacities because it is based on a constant tension when spooling the wire, and the same number of wraps of rope in each layer.

(After Studier and Binkley, 1974).

## II. CONVENTIONS AND MEMORY

### A. Conventions

% to TAIL : (-) for downhill, (+) for uphill  
% TO CARR : (-) for downhill, (+) for uphill  
ELEV. CHANGE : (-) to lower carriage, (+) to raise carriage  
OBSER. HT. : (+) observer above base of tower, (-) observer below base of tower

### C. Size and Capacity

The calculator must be sized to 031. The program requires 183 registers. Total calculator capacity must be 214 registers (including the 031 register size). The program consists of 562 steps.

## III. EXAMPLE OF PROGRAM USE

### A. Information Needed

1. TOWER HT: Prompt for height in feet of the headspar for the skyline system (input).
2. TOWER DIST: Prompt for horizontal distance in feet from the observer to the tower (input).
3. OBSER. HT.: Prompt for height in feet of the observer above the tower base (input).
4. SPAN: Prompt for horizontal distance in feet from the headspar to the tailspar (input).
5. SKYLINE WT.: Prompt for weight in pounds of skyline per foot (obtained from Table 1) (input).
6. MAIN WT.: Prompt for weight in pounds of mainline per foot (obtained from Table 1) (input).
7. % TO TAIL: Prompt for percent slope from the observer to the tailspar (sight taken to intersection of skyline and tail spar) (input).
8. % to CARR.: Prompt for percent slope from the observer to the loaded carriage (sight at the carriage sheaves) at any specified location (input).

9. CARR. DIST.: Prompt for horizontal distance in feet from the yarder to a desired carriage location. This distance is the same place the percent slope measure to the carriage is taken (input).
10. AVE. DIAM.: Prompt for large-end diameter plus small-end diameter, the sum divided by two (input).
11. DENSITY: Prompt for log density in pounds per cubic foot (input).
12. LENGTH: Prompt for log length in feet (input).
13. CARR. WT.: Prompt for weight in pounds of the carriage alone (input).
14. ELEV. CHANGE: Prompt for change in elevation (feet) of the loaded carriage, either up or down (optional input).
15. % DEFLECTION: Prompt for percent change in the midspan deflection with the specified loaded carriage (optional input).
16. TAILTREE HT.: The height in feet from the ground to the intersection of the skyline and tailtree (optional input, otherwise assumes zero).
17. SKY. LENGTH: Length of skyline in feet (optional input).

B. Step-by-Step Example

Problem Description

Tower Height = 90 ft  
 Tower Distance to Observer = 50 ft  
 Observer Height = 6.0 ft  
 Span Length = 1000 ft  
 Skyline Weight = 3.50 lbs/ft  
 Mainline Weight = 1.85 lbs/ft  
 % to Tailhold = -5.5%  
 % to Carriage = -16.0%  
 Distance to Carriage = 500 ft (Case 1).  
 Two logs per turn:  
     Log 1 - Average Diameter = 26.0 inches  
             Length = 32 ft  
             Density = 47 lbs/ft<sup>3</sup>  
     Log 2 - Average Diameter = 32 inches  
             Log Length = 27 ft  
             Density = 57 lbs/ft<sup>3</sup>  
 Carriage Weight = 3200 lbs

Case #1 Beginning conditions

Output:

Skyline Tension = 56.37 kips  
Skyline Length = 1,024.20 ft  
Midspan Deflection = 8.79%  
Gross Load = 17,340.66 lbs

Case #2 Skyline tension at a given point

Input:

New Carriage Distance = 300 ft

Output:

Skyline Tension = 50.44 kips

Case #3 Skyline tension if carriage raised 25 ft at 300-foot point.

Input:

Carriage Elevation Change = +25 (raise 25 ft)

Output:

Skyline Tension = 72.44 kips  
Skyline Length = 1,016.57 ft  
Midspan Deflection = 6.15%

Case #4 Test skyline tension at midspan by raising carriage 25 ft at the 300-foot point.

Input:

New Carriage Distance = 500 ft

Output:

Skyline Tension = 80.16 kips

Case #5 Skyline tension and length at last entered carriage point (500 ft) with a desired midspan deflection

Input:

New Desired Midspan Deflection = 9.5%

Output:

Skyline Tension = 52.25 kips  
Skyline Length = 1026.71 ft

Case #6 Test skyline tension and length at last entered carriage point (500 ft) by raising the tailhold 20 feet.

Input:

Desired tailtree height = 20 ft  
(NOTE: If input at this point, program assumes tailhold is raised 20 feet)

Output:

Skyline Tension = 47.43 kips  
Skyline Length = 1,028.19 ft

Case #7 New skyline length

Input:

New desired skyline length = 1,026 ft

Output:

Skyline Tension = 49.91 kips  
Midspan Deflection = 9.96%

Program execution: Access program by XEQ ALPHA FSAP ALPHA in standard mode. Make sure the calculator is in "USER" mode, after start step.

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"TOWER HT.?"	90	<u>R/S</u>
"TOWER DIST.?"	50	<u>R/S</u>
"OBSER. HT.?"	6	<u>R/S</u>
"SPAN?"	1000	<u>R/S</u>
"READY"	No Response	<u>R/S</u>
"SKYLINE WT.?"	3.5	<u>R/S</u>
"MAIN WT.?"	1.85	<u>R/S</u>
"READY"	No Response	<u>R/S</u>
"% to TAIL.?"	5.5	<u>CHS</u> <u>R/S</u>
"% to CARR.?"	16	<u>CHS</u> <u>R/S</u>
"CARR. DIST.?"	500	<u>R/S</u>
"MIDSPAN DEFL. = 8.79%"	No Response	<u>D</u>
"AVE. DIAM.?"	26	<u>R/S</u>

"LENGTH"	32	<u>R/S</u>
"DENSITY"	47	<u>R/S</u>
"LOG WT. = 5,545.26 LBS"	No Response	No Keystroke
"TURN WT. = 5,545.26 LBS"	No Response	No Keystroke
"AVE. DIAM.?"	32	<u>R/S</u>
"LENGTH?"	27	<u>R/S</u>
"DENSITY?"	57	<u>R/S</u>
"LOG WT. = 8,595.40 LBS"	No Response	No Keystroke
"TURN WT. = 14,140.66 LBS"	No Response	No Keystroke
"AVE. DIAM.?"	0	<u>R/S</u>
"CARR WT.?"	3200	<u>R/S</u>
*** CASE 1 OUTPUT ***		
"GROSS LOAD = 17,340.66 LBS"	No Response	<u>E</u>
"SKY. TENSION = 56.37 KIPS"	No Response	<u>F</u>
"LENGTH = 1,024.20 FT"	No Response	<u>G</u>
*** CASE 2 ***		
"CARR. DIST.?"	300	<u>R/S</u>
"SKY. TENSION = 50.44 KIPS"	No Response	<u>H</u>
*** CASE 3 ***		
"ELEV. CHANGE?"	25	<u>R/S</u>
"SKY. TENSION = 72.44 KIPS"	No Response	No Keystroke
"LENGTH = 1016.57 FT "	No Response	No Keystroke
"MIDSPAN DEFL. = 6.15%"	No Response	<u>G</u>



\*\*\* CASE 4 \*\*\*

"CARR. DIST.?" 500 R/S

"SKY. TENSION = 80.16 KIPS" No Response I

\*\*\* CASE 5 \*\*\*

"% DEFLECTION?" 9.5 R/S

"SKY. TENSION = 52.25 KIPS" No Response No Keystroke

"LENGTH = 1026.71 FT " No Response J

\*\*\* CASE 6 \*\*\*

"TAILTREE HT?" 20 R/S

"SKY. TENSION = 47.43 KIPS" No Response No Keystroke

"LENGTH = 1028.19 FT" No Response SHIFT A

\*\*\* Case 7\*\*\*

"SKY. LENGTH?" 1026 R/S

"SKY. TENSION = 49.91 KIPS" No Response No Keystroke

"MIDSPAN DEFL. = 9.96%" No Response Choice of any other desired keystroke.

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

The accuracy of FSAP is dependent on the user's ability to determine payloads, estimate distances, and read instruments for percent readings.

Accuracy in distance is less critical than estimates in payload (Figure 22)

Tensions in mainline are not computed, only tensions in skyline are computed.

A profile is not used, but the system can be analyzed at any critical point.

The program is limited to a live skyline system with a non-clamping carriage.

Span length can be determined from unit maps, scale aerial photos, or through use of simple surveying equipment and techniques. In most instances, a visual estimate of distance is adequate for rough estimates.

When percent readings on the carriage and distances to the carriage are not taken at midspan, the computer will determine the midspan carriage location and midspan deflection through simulation.

The FSAP program incorporates analysis of a load path, the path a loaded carriage makes along the skyline during inhaul.

Subprograms associated with computer keys during FSAP program execution are illustrated in Figure 23.

After users have entered all desired logs for the next turn, they can continue the program by entering zero when next prompted for average diameter.

# Rubber-Tired Skidder Mobility Simulation Model (MOBILTY)

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## I. BACKGROUND INFORMATION

### A. General Assumptions

Skid breakout force is assumed to be 110% of skid resistance.

The coefficient of friction for skid resistance is assumed to be 1.3 (program step #111).

Maximum skidder velocity is assumed to be 528 ft/min (6 mph).

Maximum allowable sinkage is assumed to be 20 inches.

### B. References: Olsen, E.D. and D.J. Gibbons (1983).

### C. Figures

Figure 24. Skidder Illustration with Labeled Dimensions

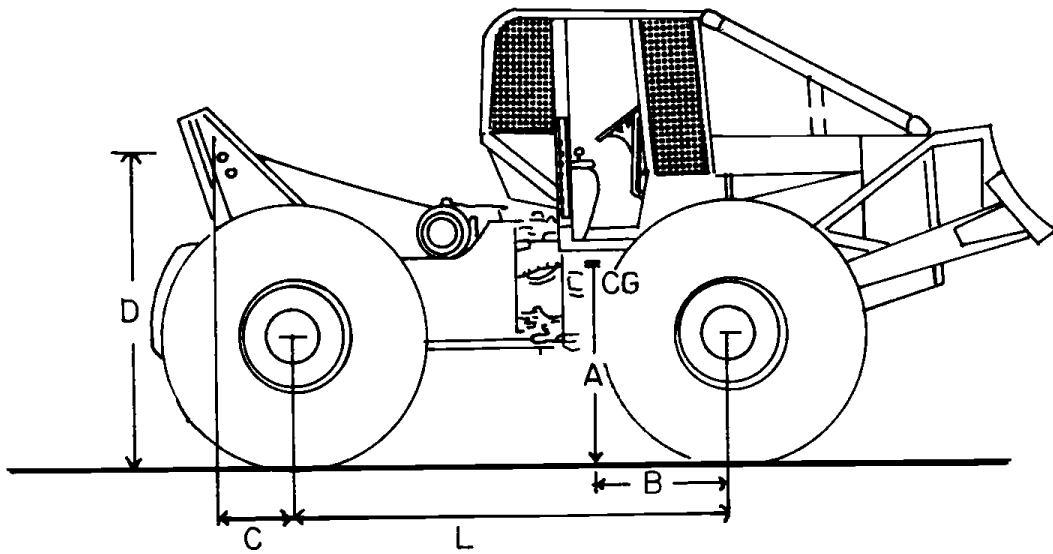
TABLE 2. SAMPLE SKIDDER-DIMENSION INPUT FOR THE MOBILITY MODEL

Name & Model	Skidder dimensions (in.)*					Tire diameter/ tire width (in.)	Skidder weight (lb)	Fly-wheel horse-power
	A	B	C	D	L			
Clark 664 C	42 <sup>b</sup>	43.1	19	76	104	61/18.4	17,000	91
Clark 667C	44 <sup>b</sup>	48.1	18.8	77	112.5	68/23.1	20,500	126
Clark 880	53.8	69.4	46	121.7	178	84/30	61,000	267
CAT 518	43.6	43.3	19	80	114	61/18.4	20,500	120
CAT 528	46.1	49.9	19.5	91	128	77/24.5	30,700	175
John Deere 440	40	29.4	15	74	89	61/18.4	12,400	70
John Deere 540	42**	32.8	17.9	77	106	68/23.1	16,700	90
John Deere 640	43**	36.2	19.8	79.6	113	77/24.5	19,900	110

\*A = height of center of gravity of skidder, B = distance from front axle to center of gravity; C = distance from rear axle to lead point on arch; D = height of lead point on arch; L = length of skidder wheel base.

\*\*Estimated

FIGURE 24. SKIDDER ILLUSTRATION WITH LABELED DIMENSIONS



- A = height of center of gravity of skidder
- B = distance from front axle to center of gravity
- C = distance from rear axle to lead point on arch
- D = height of lead point on arch
- L = length of skidder wheel base

## II. CONVENTIONS AND MEMORY

### A. Conventions

"SLOPE": Positive when skidding uphill and negative when skidding downhill.

### B. Size and Capacity

The calculator must be sized to 059. The program uses 158 registers. Total calculator capacity must be 217 registers. The program consists of 559 steps.

## III. EXAMPLE OF PROGRAM USE

### A. Information Needed

#### 1. Skidder dimensions: (all inputs: Figure 24)

Dimension A: height in inches of center of gravity of skidder.

Dimension B: distance in inches from front axle to center of gravity.

Dimension C: distance in inches from rear axle to lead point of arch.

Dimension D: height in inches of lead point on arch.

Dimension L: length in inches of skidder wheel base.

Tire D: tire diameter in inches.

Tire B: tire width in inches.

WGT: operating weight of skidder in lbs.

HP: flywheel horsepower of skidder.

#### 2. "HOOKTIME?": Prompt for hook-unhook and decking time, in minutes (input).

#### 3. "AV. STEM LTH?": Prompt for average stem length in feet for the skid (input).

#### 4. "SKID SEGMENTS?": Prompt for number of different skid segments (slope changes) during the skidding cycle (input).

5. "SKID WGHT?": Prompt for weight of the turn to be skidded in pounds (input).
6. "SLOPE/DIST?": Asks users to enter the segment slope in percent, then press the "ENTER" key and enter the distance in feet for that segment (input).
7. "CONE INDEX?": Prompt for cone index (soil strength) in pounds per square inch. (200 is a strong soil, and 50 is a weak soil), (input).
8. "SEG n": Shows users the segment for which to enter slope, distance, and cone index--"n" represents the segment number (output).
9. "UNSTABLE": Indicates front tires have left the ground (output).
10. "NEW TURN WT?": Prompt for a new turn weight in pounds (input).
11. "SINK=": Shows amount the rear tires will sink in inches when loaded (output).
12. "NEW CON IND?": Prompt for new cone index in pounds per square inch. (If no new cone index is desired simply press R/S).
13. "OVERLOAD": Shows skidder does not have the tractive ability to move turn with the given conditions (output).
14. "VEL L=": Shows loader skidder velocity in feet per minute (output).
15. "VEL U=": Shows unloaded skidder velocity in feet per minute (output).
16. "PRODUCTION": Indicates users are entering production phase of program (output).
17. "TT=": Shows total turn time in minutes (output).
18. "AVAIL %?": Prompt for estimated availability in percent of the machine for full production (input).
19. "PROD=": Shows production of machine in tons per hour (output).
20. "A<sup>^</sup>,B<sup>^</sup>,C<sup>^</sup>,D?": Prompt for skidder dimension A, then B, then C, then D (input).

21. "TIRE D, B?": Prompt for tire diameter, then tire width (input).
22. "WGT/HP?": Prompt for skidder weight, then skidder flywheel horsepower (input).

B. Step-by-Step Example

Given: Skidder dimensions: (Figure 25) CAT 518  
 A = 43.6 inches  
 B = 43.3 inches  
 C = 19.0 inches  
 D = 80.0 inches  
 L = 114.0 inches  
 Tire Diameter = 61.0 inches  
 Tire Width = 18.4 inches  
 Skidder Weight = 20,500 lbs  
 Flywheel Horsepower = 120 hp  
 Number of Segments = 3  
 Hook, unhook, and decking time = 6.20 minutes  
 Average stem length = 70 feet  
 Initial desired turn weight = 20,000 lbs

Segment 1

Slope = 35% (uphill skidding)  
 Distance = 260 ft  
 Initial Cone Index = 70 psi  
 New Turn Weight = 12,000 lbs (if unstable)  
 New Cone Index = 90 psi (if excess tire sink)  
 New Turn Weight = 6,000 lbs. (if overloaded)

Segment 2

Slope = 15% (uphill skidding)  
 Distance = 370 feet  
 Cone Index = 120 psi

Segment 3

Slope = -12% (downhill skidding)  
 Distance = 400 feet  
 Cone Index = 150 psi

Machine availability: 75% of time it will be producing

Determine:

For each segment

Rear tire sinkage  
Maximum allowable payload  
Velocity loaded  
Velocity unloaded

For skidding cycle

Total turn time  
Production in tons per hour

Solution:

Segment 1

Rear tire sinkage = 1.44 inches  
Maximum allowable payload = 6,000 lbs  
Velocity loaded = 115 ft/min  
Velocity unloaded = 528 ft/min

Segment 2

Rear tire sinkage = 0.82 inches  
Maximum allowable payload = 6,000 lbs  
Velocity loaded = 326 ft/min  
Velocity unloaded = 528 ft/min

Segment 3

Rear tire sinkage = 0.48 inches  
Maximum allowable payload = 6,000 lbs  
Velocity loaded = 528 ft/min  
Velocity unloaded = 528 ft/min

For skidding cycle

Total turn time = 12.30 minutes  
Production = 11.0 tons/hour

Program Execution: Access program by XEQ ALPHA MOBILTY ALPHA

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"A/,B/,C/,D?" (enter skidder dimensions, A,B,C,D in order shown; for dimensions see Fig. 2).	43.6	<u>ENTER</u>
no prompt (enter dimension B)	43.3	<u>ENTER</u>



no prompt (enter dimension C)	19	<u>ENTER</u>
no prompt (enter dimension D)	80	<u>R/S</u>
"L=?" (enter skidder length)	114	<u>R/S</u>
"TIRE D↑,B?" (enter tire diameter and width; enter diameter first)	61	<u>ENTER</u>
no prompt (enter tire width)	18.4	<u>R/S</u>
"WGT↑ HP?" (enter skidder weight and flywheel horsepower; enter skidder weight first)	20,500	<u>ENTER</u>
no prompt (now enter flywheel horsepower)	120	<u>R/S</u>
"HOOKTIME?" (enter time to hook, unhook, and deck logs per turn)	6.2	<u>R/S</u>
"AV. STEM LTH?" (enter average stem length in feet)	70	<u>R/S</u>
"SKID SEGMTS?" (enter number of skid segments)	3	<u>R/S</u>
"SKID WGHT?" (enter desired weight of turn to be skidded)	20,000	<u>R/S</u>
"SEG 1.0" (signifies it's ready for segment 1 input)	No Response	No Keystroke
"SLOPE↑ DIST?" (enter slope in percent the distance in feet)	35	<u>ENTER</u>
no prompt (enter distance)	260	<u>R/S</u>
"CONE INDEX?" (enter cone index; soil strength)	70	<u>R/S</u>

"UNSTABLE" (front tires have left the ground)	No Response	No Keystroke
"NEW TURN WT?" (asks user for new turn weight since unstable)	12,000	<u>R/S</u>
"SINK = 6.19" (rear tire sinkage = 6.19 inches)	No Response	<u>R/S</u>
"NEW CON IND?" (program asks if users want to enter a new cone index; users enter one because the sinkage seems unreasonable)	90	<u>R/S</u>
"SINK = 2.89" (rear tire sinkage = 2.89 inches)	No Response	<u>R/S</u>
"NEW CON IND?" (program asks if users want to enter a new cone index; users feel the sinkage is now acceptable, so they continue by not entering anything)	No Response	<u>R/S</u>
"OVERLOAD" (skidder doesn't have tractive ability to move the turn with the given conditions)	No Response	No Keystroke
"NEW TURN WT?": (prompts for new turn weight)	6000	<u>R/S</u>
"SINK = 1.44"	No Response	<u>R/S</u>
"NEW CON IND?" (asks if users desire new cone index; they are satisfied with the sinkage so continue)	No Response	<u>R/S</u>
"VEL L = 115" (velocity loaded in ft/min)	No Response	<u>R/S</u>
"VEL U = 528" (velocity unloaded in ft/min)		<u>R/S</u>
"SEG 2" (ready for segment 2 conditions)	No Response	No Keystroke
"SLOPE <sup>^</sup> DIST?" (enter slope in percent then distance)	15	<u>ENTER</u>

no prompt (enter distance)	370	<u>R/S</u>
"CONE INDEX?": (cone index; soil strength in psi)	120	<u>R/S</u>
"SINK = 0.82" (rear tire sinkage = 0.82 inches)	No Response	<u>R/S</u>
"NEW CON IND?" (no new cone index will be entered since sinkage is acceptable)		<u>R/S</u>
"VEL L = 326" (velocity loaded for segment 2 = 326 ft/min)	No Response	<u>R/S</u>
"VEL U = 528" (velocity unloaded for segment 2 = 528 ft/min)	No Response	<u>R/S</u>
"SEG 3" (ready for segment 3 conditions)	No Response	No Keystroke
"SLOPE/ DIST?" (enter slope in percent then distance)	12	<u>CHS</u> <u>ENTER</u>
no prompt (enter distance in feet)	400	<u>R/S</u>
"CONE INDEX?" (enter cone index; soil strength in psi)	150	<u>R/S</u>
"SINK = 0.48" (rear tire sinkage = 0.48 inches)	No Response	<u>R/S</u>
"NEW CON IND?" (acceptable sinkage so continue on)	No Response	<u>R/S</u>
"VEL L = 528" (velocity loaded for segment 3 in ft/min)	No Response	<u>R/S</u>
"VEL U = 528" (velocity unloaded for segment 3 in ft/min)	No Response	<u>R/S</u>
"PRODUCTION" (program is entering production calculation phase)	No Response	No Keystroke
"TT = 12.30" (total skidding cycle turn time in minutes)	No Response	<u>R/S</u>

"AVAIL %" 75 R/S  
(estimated availability of the  
machine for full production)

"PROD = 11.0 T/H"  
(skidder production in tons/hour)

At this point program execution is complete. The program can be started again by pressing R/S twice.

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

Skidder dimensions can be determined by:

Measuring them on the machine.

Obtaining them from a vendor who sells the machines.

Slopes should be limited to  $\pm 35\%$ .

Sinkage estimates over 6 inches should be considered only estimates.

The program doesn't consider terrain roughness or brush.

Cone index can be tested with a portable testing device called a cone penetrometer.

Be sure to enter data carefully, especially noting where enter  $\uparrow$  keystrokes and R/S keystrokes are used.

# Average Skid Distance: Coordinate Input and Variable Density (ASD)

USFS NO. 433

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## I. BACKGROUND INFORMATION

### A. General Assumptions

The program assumes straight lines between coordinates entered.

The program assumes coordinates entered are consecutive (sequential) clockwise or counter-clockwise points around the unit).

### B. References: None stated

### C. Figures and Formulas

Figure 25. Diagram with Formulas for ASD  
Figure 26. Sample Problem for ASD  
Figure 27. User Keys for ASD  
Figure 28. Logic Error Remedy

## II. CONVENTIONS AND MEMORY

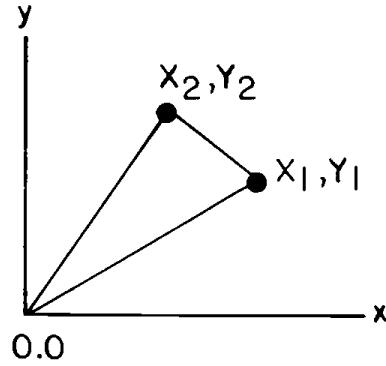
### A. Conventions

The coordinates "X" and "Y" can be positive or negative. The "X" coordinate is negative if the point falls to the left of the landing, and positive if the point falls to the right of the landing. The "Y" coordinate is negative if it falls below the landing and positive if it falls above the landing.

### B. Size and Capacity

The calculator must be sized to 022. The program uses 42 registers. Total calculator capacity must be 64 registers. The program consists of 135 steps.

FIGURE 25. DIAGRAM WITH FORMULAS FOR ASD



For this triangle:

$$ASD = \frac{2}{3} \left[ \frac{(X_2 + X_1)^2}{2} + \frac{(Y_2 + Y_1)^2}{2} \right]^{1/2}$$

$$ASD = \frac{1}{3} \left[ (X_2 + X_1)^2 + (Y_2 + Y_1)^2 \right]^{1/2}$$

Area of triangle:

$$A_i = \frac{1}{2} (X_2 Y_1 - X_1 Y_2)$$

$$\text{Area of unit} = \sum A_i$$

$$\text{Average skid distance of unit} = \frac{\sum A_i (ASD_i)}{\sum A_i}$$

When more than one area and density are given:

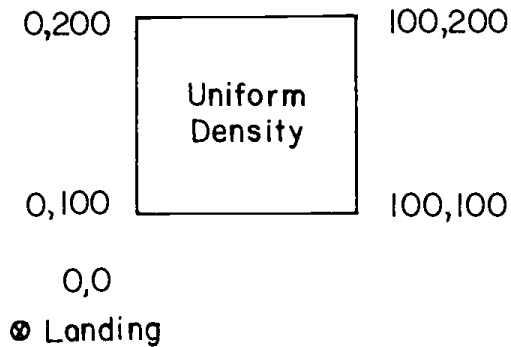
$$\text{Average Skid Distance} = \frac{\sum (ASD)(AREA)(LOG DENSITY)}{\sum (AREA)(LOG DENSITY)}$$

FIGURE 26. SAMPLE PROBLEM FOR ASD

1. Find the average yarding distance ASD using the coordinate input-variable density approach.

Area = 0.23 acres

ASD = 160.26 ft



2. Find the ASD

WEIGHTED ASD = 168.28 ft

NOTE: ASD to A is 183.95 ft, acres 0.1148  
 ASD to B is 136.94 ft, acres 0.1148

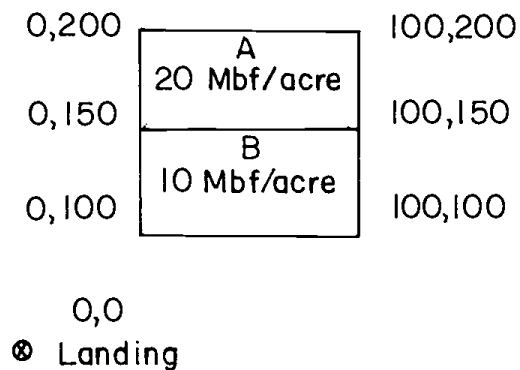


FIGURE 27. USER KEYS FOR ASD

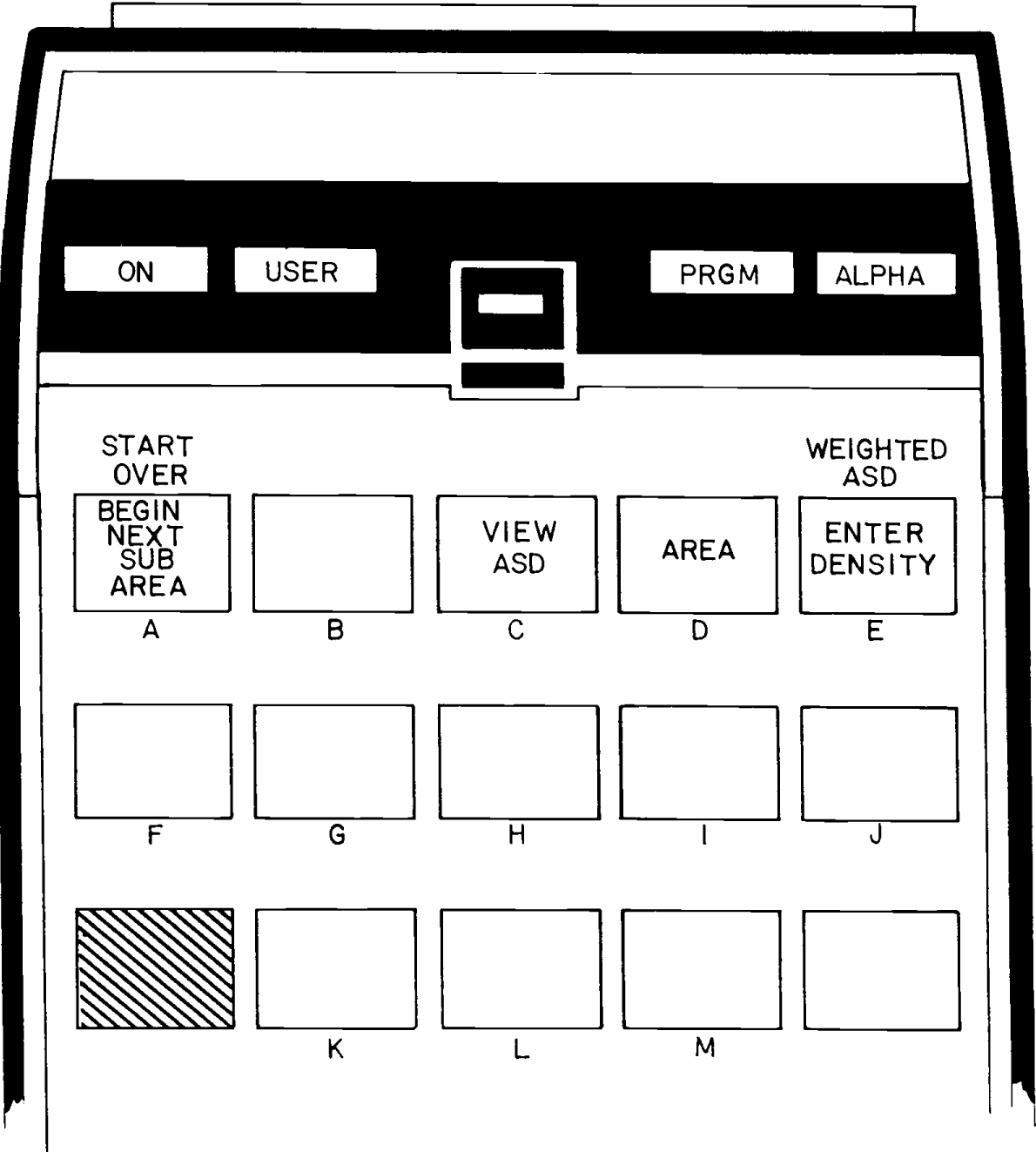
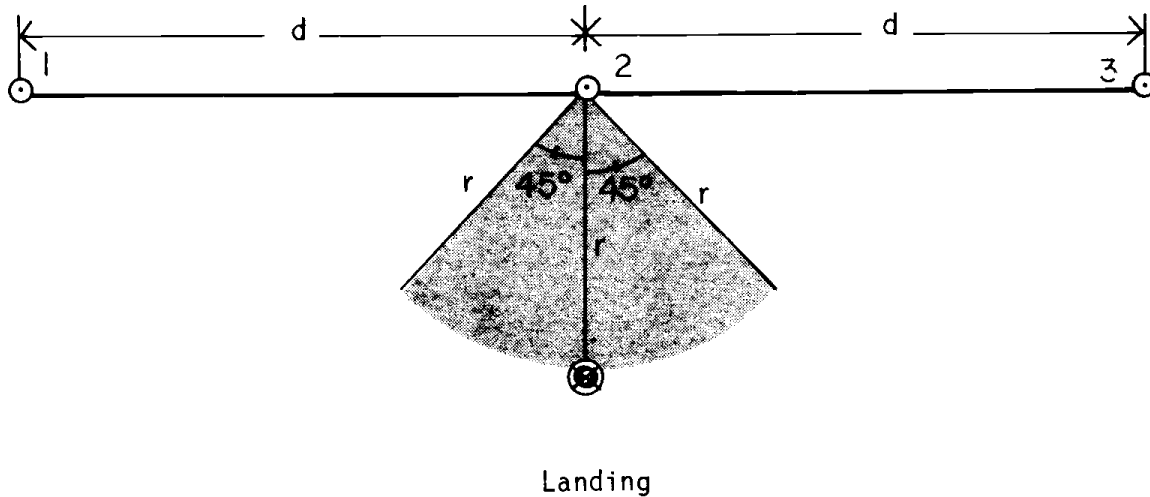




FIGURE 28. LOGIC ERROR REMEDY



Unit Boundary: Points 1, 2, and 3  
Distance from point 2 to landing =  $r$

Caution must be taken if the landing is anywhere within the shaded area relative to the midpoint (point 2) on the line defined by points 1 and 3, and as distance "d" approaches two times the distance "r". Average skid distances may be in error by greater than 6%. The distances and area for caution are illustrated above.

A problem occurs when users enter only the coordinates for points 1 and 3. The error can be reduced by locating and entering the coordinates for point 2 as well as for points 1 and 3. The exact midpoint is not necessary but the line segment must be broken in two.

### III. EXAMPLE OF PROGRAM USE

#### A. Information Needed

1. "X-n=?": Prompt for the nth X-coordinate. This must be in feet (input). Start at X-0 and re-enter those coordinates when done.
2. "Y-n=?": Prompt for the nth Y-coordinate. This must be in feet. Start at Y-0 and re-enter those coordinates when done.
3. "ASD=": Shows calculated unweighted average skid distance in feet for a given area or subarea (output).
4. "AREA=": Shows calculated area in acres for a given area or subarea enclosed by coordinates (X<sub>0</sub>, Y<sub>0</sub>) to (X<sub>n</sub>, Y<sub>n</sub>) (output).
5. "DENS./ACRE=?": Prompt for density per acre when more than one density per area is to be skidded by one landing. This is used to find a weighted average skid distance based on density. The units can be either in logs per acre or MBF per acre (input).
6. "W-ASD=": Shows calculated weighted average skid distance in feet for an area with two or more varying densities (output).
7. "A B C D E": This is the program's menu with specific functions associated with the keys shown. The calculator must be in "USER" mode. The "USER" keys are defined below:

SHIFT A: Start new program or start program again.

A: Used with variable densities. Pressed when ready to enter coordinates for another subarea with a different density.

B: Corresponds to the user's desired (design) payload input for their particular system.

C: Views unweighted average skid distance for last entered area or subarea (only once for the area in current evaluation).

D: Calculates and views area in acres of the last area or subarea entered.

E: Enters and stores density for the previously entered subarea.

SHIFT E: Computes weighted average skid distance after all variable density subareas have been entered.

B. Step-by-Step Example

Example Problem 1: Shown on top of Figure 26 (Uniform Density).

Example Problem 2: Shown on bottom of Figure 26 (Variable Density).

Program Execution: Put calculator in "USER" mode. Access program by XEQ ALPHA ASD ALPHA.

Problem 1 (Uniform Density)

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"X-0=?" (initial X-coordinate)	0	<u>R/S</u>
"Y-0=?" (initial Y-coordinate)	100	<u>R/S</u>
"X-1=?"	0	<u>R/S</u>
"Y-1=?"	200	<u>R/S</u>
"X-2=?"	100	<u>R/S</u>
"Y-2=?"	200	<u>R/S</u>
"X-3=?"	100	<u>R/S</u>
"Y-3=?"	100	<u>R/S</u>
"X-4=?" (enter initial X-point when completed)	0	<u>R/S</u>
"Y-4=?" (enter initial Y-point when completed)	100	<u>R/S</u>
"ASD = 160.26 ft" (average skid distance - uniform density)	No Response	<u>R/S</u>

"A B C D E" (menu)	No Response	$\bar{D}$ ("D" corresponds to function that calculates area)
"AREA = 0.2296 ACRES" (area for area enclosed by coordinates (X <sub>0</sub> , Y <sub>0</sub> ) through (X <sub>n</sub> , Y <sub>n</sub> ))	No Response	$\bar{R/S}$

"A B C D E"

Because this area has uniform density, the average skid equals the weighted average skid distance. At this point the answers have been found.

### Problem 2 (Variable Density)

Since the program has been accessed through Problem 1, a new problem can be started by pressing SHIFT A.

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
no prompt (first enter subarea B with density 1)	No Response	<u>SHIFT A</u>
"X-0=?" (initial X-coordinate)	0	$\bar{R/S}$
"Y-0=?" (initial Y-coordinate)	100	$\bar{R/S}$
"X-1=?"	0	$\bar{R/S}$
"Y-1=?"	150	$\bar{R/S}$
"X-2=?"	100	$\bar{R/S}$
"Y-2=?"	150	$\bar{R/S}$
"X-3=?"	100	$\bar{R/S}$
"Y-3=?"	100	$\bar{R/S}$
"X-4=?"	0	$\bar{R/S}$
"Y-4=?"	100	$\bar{R/S}$
"ASD = 136.94 FT." (average skid distance for subarea B)	No Response	$\bar{R/S}$

"A B C D E"	No Response	$\bar{D}$ (compute and output for subarea B)
"AREA = 0.1148 ACRES" (area for subarea B)	No Response	$\bar{R/S}$
"A B C D E"	No Response	$\bar{E}$ (Key "E" prompts and stores density for subarea B)
"DENS./ACRE=?"	10	$\bar{R/S}$
"A B C D E"	No Response	$\bar{A}$ ("A" tells program users are ready to input next area)
"X-0=?" (initial X-coordinate for subarea A)	0	$\bar{R/S}$
"Y-0=?" (initial Y-coordinate for subarea A)	150	$\bar{R/S}$
"X-1=?"	0	$\bar{R/S}$
"Y-1=?"	200	$\bar{R/S}$
"X-2=?"	100	$\bar{R/S}$
"Y-2=?"	200	$\bar{R/S}$
"X-3=?"	100	$\bar{R/S}$
"Y-3=?"	150	$\bar{R/S}$
"X-4=?"	0	$\bar{R/S}$
"Y-4=?"	150	$\bar{R/S}$
"ASD = 183.95 FT."	No Response	$\bar{R/S}$
"A B C D E" (menu)	No Response	$\bar{D}$ (compute and display area for subarea A)
"AREA = 0.1148 ACRES"	No Response	$\bar{R/S}$

"A B C D E"	No Response	$\bar{E}$ (prompts for density in subarea A and stores it)
"DENS./ACRE=?"	20	$\bar{R/S}$
"A B C D E"		$\overline{\text{SHIFT } \bar{E}}$ (computes weighted average skid distance for entire area, A and B)
"W-ASD = 168.28 FT." (weighted average skid distance for entire area, A and B together)		$\bar{C}$
"ASD = 183.95 FT." (views last unweighted average skid distance for subarea A)	No Response	(END)

At this point, Problem 2 has been solved.

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

For variable-density areas, the density for a specific subarea must be entered after all coordinates have been entered for the corresponding subarea and before coordinates for the next variable-density subarea.

The landing must always be at coordinates  $X=0$ , and  $Y=0$ .

To complete entering the coordinates to an area, the initial X and Y coordinates must be re-entered.

The users must enter coordinates consecutively in a clockwise direction or a counter-clockwise direction.

There is a logic error shown in Figure 28, but it can be remedied if a center point is entered as shown.

Because two subareas usually share one boundary side, all points along that side have to be entered for each subarea. The subareas need to be treated as separate areas.

# Log Weights (LOGWT)

USFS NO. 352

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## I. BACKGROUND INFORMATION

### A. General Assumptions

Log geometry is assumed to be a straight-line tapered cylinder. Cubic-foot volume is determined from the average diameter, with no prismatic correction.

Eight inches trim allowance is added to the nominal log length input, regardless of log length.

### B. References: None stated

### C. Figures and Formulas

Figure 29. User Keys for LOGWT

#### Mathematical Formulation

$V_{BF}$  = Scribner board-foot volume (Knout's Rule)

$V_{CF}$  = cubic-foot volume

$W$  = weight of turn, pounds

$D$  = wood density, pounds per cubic foot

$d_1$  = small-end diameter, inches

$d_2$  = large-end diameter, inches

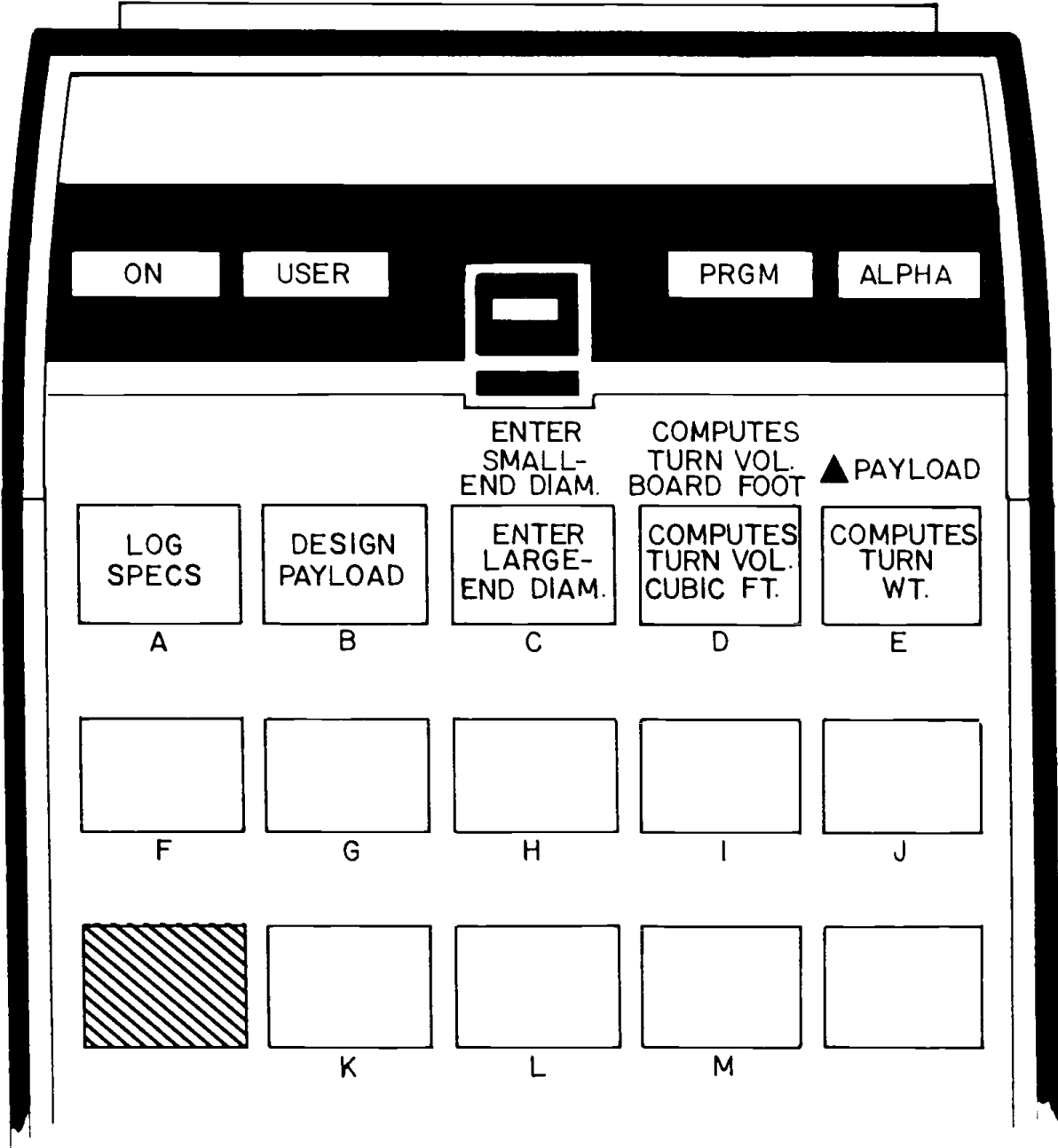
$N$  = number of logs per turn

$L_n$  = nominal log length, feet

$L$  = log length including 8" for trim, feet

$T$  = feet required for log to taper one inch

FIGURE 29: USER KEYS FOR LOGWT





$$d_1 = d_2 - \frac{L}{T} = \frac{576W}{\pi LDN} - \frac{L}{2T}$$

$$d_1 = d_2 + \frac{L}{T} = \frac{576W}{\pi LDN} + \frac{L}{2T}$$

$$V_{CF} = \frac{W}{D}$$

$$V_{BF} = \frac{d_1^2 - 3d_1 L_n}{20}$$

$$W = \frac{\pi LD}{576} \left[ d_2 - \frac{L}{2T} \right]^2$$

## II. CONVENTIONS AND MEMORY

### A. Conventions

"WT. LEFT": If negative, it means the turn weight is greater than the desired (design) payload, and if positive, the turn weight is less than the desired payload.

### B. Size and Capacity

The calculator must be sized to 023. The program uses 53 registers. Total calculator capacity must be 76 registers. The program consists of 161 steps.

## III. EXAMPLE OF PROGRAM USE

### A. Information Needed

1. "TAPER=?": Prompt for stem taper in number of feet to taper one inch (input).
2. "NO. LOGS=?": Prompt for the number of logs per turn (input).
3. "DENSITY=?": Prompt for wood density in pounds per cubic foot (input).
4. "LENGTH=?": Prompt for nominal log length in feet. The program adds 8 inches for trim (input).

5. "A B C D E": Menu display giving the users the option of using one of the following user key functions.
  - A: Corresponds to entering taper, number of logs, density, and length. This can be executed at any time during the program to change the data input that corresponds to it (will give all correct outputs except board foot volume. To correct volume when changing data in "A", users must also re-enter the small- or large-end diameter, user keys SHIFT "C" or "C", respectively.
  - B: Corresponds to the user's desired (design) payload input for their particular system.
  - C: Corresponds to entering large-end diameter instead of small-end diameter. This function will also give the computed small-end diameter.
  - SHIFT C: Corresponds to entering small-end diameter instead of large-end diameter. This function also gives the computed large-end diameter.
  - D: Computes the turn volume in cubic feet after user key "A" and user keys "C" or SHIFT "C" have been executed.
  - SHIFT D: Computes the turn volume in board feet after user keys "A" and "C" or SHIFT "C" have been.
  - E: Computes turn weight in pounds from data entered in functions A and C or SHIFT C.
  - SHIFT E: Computes the difference between the user's desired (design) payload (user key "B") and the computed turn weight (user key "E"). This tells the users if they are overloaded (negative) or underloaded (positive). Design payload (user key "B") must be entered before this function can be executed.
6. "PAYLOAD=?": Prompt for the desired (design) payload in pounds for the harvest system.
7. "L-END DIA.=?": Prompt for the large-end diameter in inches of the log(s) (input).
8. "L-END DIA=": Shows large-end diameter in inches (output).

9. "SM-END DIA=?": Prompt for the small-end diameter in inches of the log(s) (input).
10. "SM-END DIA=": Shows small-end diameter in inches (output).
11. "TURN VOL=X.XX CF.": Shows turn volume in cubic feet (output).
12. "TURN VOL=X.XX BF.": Shows computed turn volume in board feet (output).
13. "TURN WT.=": Shows computed turn weight in pounds (output).
14. WT. LEFT=": Shows the difference between the design payload and computed turn weight (output).

B. Step-by-Step Example

Given: Number of logs: 1  
 Taper: 8 ft/inch taper  
 Density: 46 lbs/ft<sup>3</sup>  
 Log Length: 34 ft  
 Large-end diameter: 38.0 inches  
 Design payload: 15,000 lbs

Determine: Small-end diameter  
 Turn weight  
 Turn volume in cubic feet  
 Turn volume in board feet  
 System overload with respect to design payload or under loaded

Solution: Small-end diameter = 33.67 inches  
 Turn weight = 11,169.00 lbs  
 Turn volume = 242.80 cubic feet  
 Turn volume = 1755.11 board feet  
 The system has an extra 3831 lbs of available payload (system under loaded)

Program Execution: Access program by XEQ ALPHA LOGWT ALPHA.

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"TAPER=?" (stem taper in feet per inch)	8	<u>R/S</u>

"NO. LOGS=?" (number of logs in turn)	1	<u>R/S</u>
"DENSITY=?" (wood density in lbs./ft. <sup>3</sup> )	46	<u>R/S</u>
"LENGTH=?" (log length in feet)	34	<u>R/S</u>
"A B C D E" (program menu)	No Response	<u>B</u> (prompts and stores design payload)
"PAYLOAD=?" (design payload in lbs.)	15,000	<u>R/S</u>
"A B C D E" (program menu)	No Response	<u>C</u> (prompts and stores large-end diameter and calculates small-end diameter)
"L-END DIA.=?" (large-end diameter in inches)	38	<u>R/S</u>
"L-END DIA = 38.00" (views large-end diameter in inches)	No Response	<u>R/S</u>
"SM-END DIA = 33.67" (views calculated small-end diameter in inches)	No Response	<u>R/S</u>
"A B C D E" (program menu)	No Response	<u>E</u> (computes and outputs turn weight)
"TURN WT = 11,169.00" (views calculated turn weight in pounds)	No Response	<u>R/S</u>
"A B C D E"	No Response	<u>D</u>
"TURN VOL = 242.80 CF" (views turn volume in cubic feet)	No Response	<u>R/S</u>
"A B C D E"	No Response	<u>SHIFT D</u> (computes turn volume in board feet)

"TURN VOL = 1,755.11 BF"      No Response  
(views turn volume in board feet)

R/S

"A B C D E"

SHIFT E  
(computes difference  
between design payload  
and computed turn  
weight)

"WT. LEFT = 3,831.00"      No Response  
(difference between design payload  
and computed payload in pounds)

R/S

"A B C D E"

At this point all answers for this example problem have been found. If users desire, they can go back and change any input data by pressing the corresponding user key (if users desire to determine board foot volume, all data must be re-entered through user keys "A" and "C" or SHIFT "C").

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

Knout's rule is used to calculate Scribner board-foot volume. This is less accurate for small-diameter classes.

Wood density is usually the "weak link" in calculations of log weight. Possible procedures for determining wood density:

Obtain a sample chunk of wood, with an axe or chainsaw, figure the cubic-foot volume, and weigh it.

Weigh an entire log, or load of logs, and calculate their cubic-foot volume.

Use the increment-core hydrometer method developed by Gary Bergstrom of the Rogue River National Forest. This method has several attractive features: apparatus is lightweight and portable, standing trees can be sampled, and results are immediate and accurate.

Use typical values for log densities. Note, however, that wood density can vary widely, with log position in tree, time of year, position of tree on slope, growth rate, and numerous other factors. Typical values are: (pcf = pounds per cubic foot).

Douglas-fir (old growth)	
butt logs	47 pcf
top logs	40 pcf
Douglas-fir (second growth)	
butt logs	49 pcf
top logs	42 pcf
Western redcedar	36-40 pcf
Western hemlock	50-57 pcf
Ponderosa pine	50-55 pcf
Sitka spruce	38-43 pcf

Many people use the rule-of-thumb that one board foot equals 10 pounds (this program doesn't). In the example, the rule-of-thumb would have overestimated the turn weight by 57%. This program is more accurate because it uses density.

If the number "2" is entered into the program for the number of logs, the program will assume that the two logs are exactly the same. If users desire to use two different logs, they will have to run each log through the program and add values outside of the program.

Knout's rule, used to compute board feet in this program, is an estimate based on the equation. This is not recommended for determining scaled volumes.

# Critical Tensions for Uphill Jack Passage (JACK)

USFS NO. 353

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## I. BACKGROUND INFORMATION

### A. General Assumptions

The boundary conditions that describe critical conditions at the jack for uphill carriage passage occur when forces at the jack are in static equilibrium and  $\theta$  equals  $90^\circ$  (see Figure 30).

The y distance in Figure 30 is negligible.

Tailhold is assumed to be at the left.

### B. References: Brantigan, 1978.

### C. Figures and Formulas:

Figure 30. Typical Skyline System with Intermediate Support  
Figure 31. Variables and Conventions for JACK

$$\Delta S = (h^2 + [2m \sinh (L/2m)]^2)^{1/2}$$

$$V = [Hh - w \Delta S(L-e)]/L$$

$$e = L/2 + mh/\Delta S [L/2m \coth (L/2m) - 1]$$

## II. CONVENTIONS AND MEMORY

### A. Conventions

"H1": Measured as negative if the left anchor is lower than the support jack and positive if the left anchor is higher than the support jack.

"H3": Measured as positive if the headspar is higher than the support jack and negative if the headspar is lower than the support jack.

FIGURE 30. TYPICAL SKYLINE SYSTEM WITH INTERMEDIATE SUPPORT

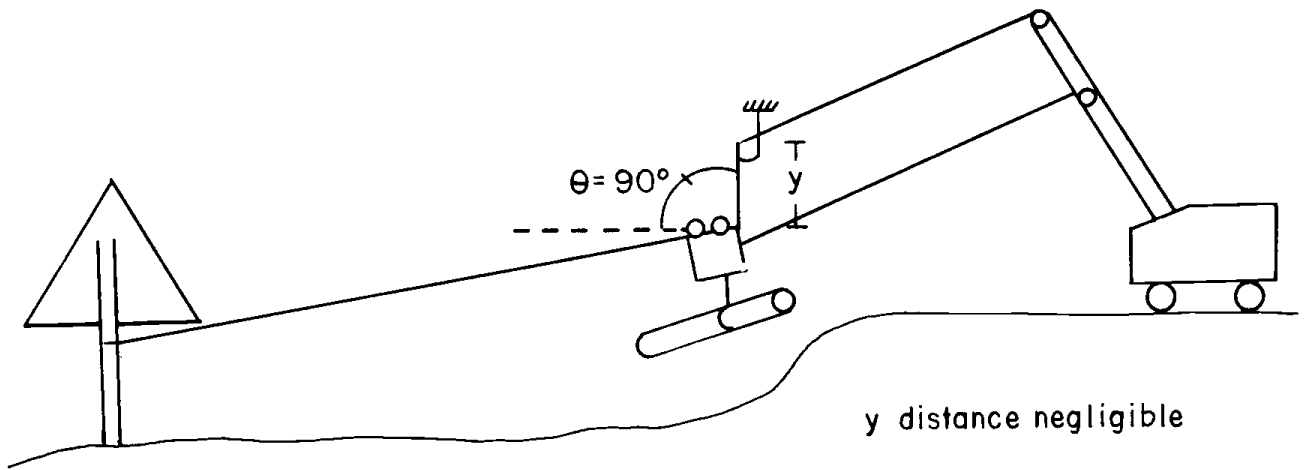
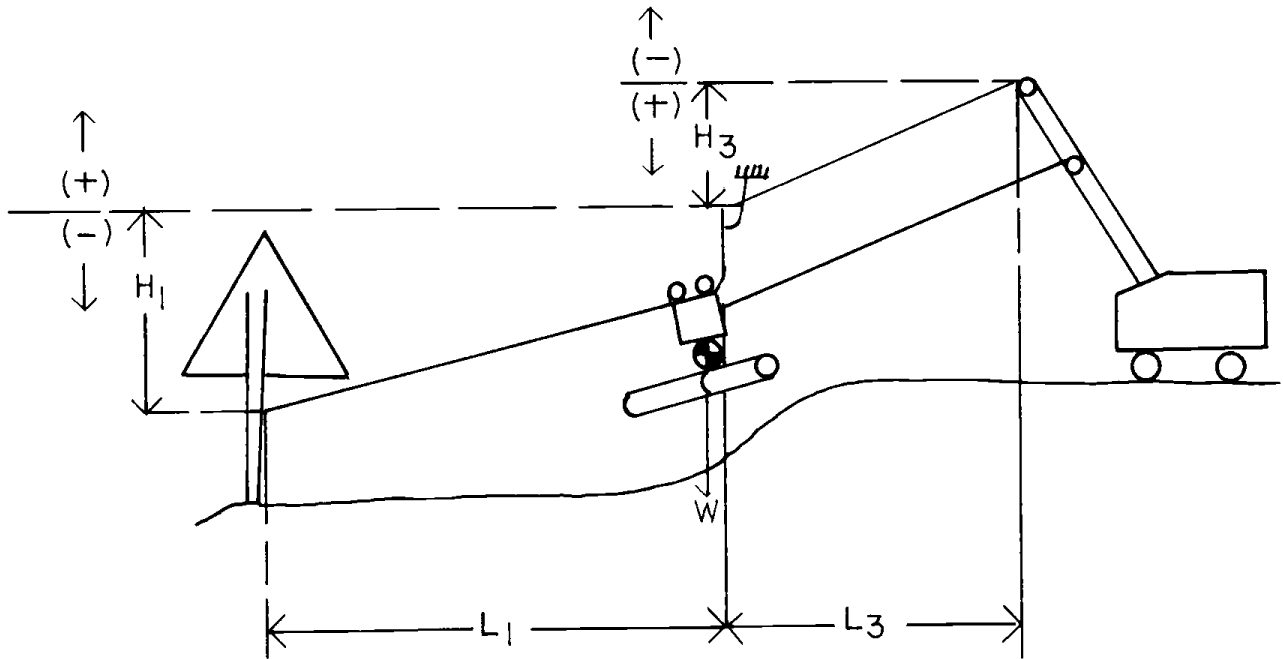




FIGURE 31. VARIABLES AND CONVENTIONS FOR JACK



B. Size and Capacity

The calculator must be sized to 022. The program uses 57 storage registers. Total calculator capacity must be 79 registers. The program consists of 183 steps.

III. EXAMPLE OF PROGRAM USE

A. Information Needed

1. "W1=?": Prompt for weight per unit length of skyline in pounds per foot (input).
2. "W3=?": Prompt for weight per unit length of mainline in pounds per foot (input).
3. "H1=?": Prompt for difference in elevation in feet between the support jack and downhill anchor (input).
4. "H3=?": Prompt for difference in elevation in feet between the support jack and headspar (input).
5. "L1=?": Prompt for length in feet of downhill span from support jack to anchor point (input).
6. "L3=?": Prompt for length in feet of uphill span from support jack to headspar (input).
7. "W=?": Prompt for gross flying payload in pounds (input).
8. "TS=": Shows critical skyline tension in pounds (output).
9. "TM1=": Shows critical mainline tension in pounds (output).

B. Step-by-Step Example

Given: Skyline weight per foot (W1) = 1.85 lbs/ft  
Mainline weight per foot (W3) = 1.04 lbs/ft  
Change in elevation between support jack and downhill anchor (H1) = -200 ft  
Change in elevation between support jack and headspar (H3) = +400 ft  
Length of downhill span from support jack to the anchor point (L1) = 800 ft  
Length of uphill span from support jack to the headspar (L3) = 1000 ft  
Gross flying payload (W) = 8000 lbs

Determine: Critical Skyline Tension (TS).  
 Critical Mainline Tension (TM1).

Solution: Critical Skyline Tension (TS)= 8,168.24 lbs  
 Critical Mainline Tension (TM1)= 8,133.99 lbs

Program Execution: Access program by XEQ ALPHA JACK ALPHA

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"W1=?" (request skyline weight/ft)	1.85	<u>R/S</u>
"W3=?" (request mainline weight/ft)	1.04	<u>R/S</u>
"H1=?" (request anchor to support jack change in elevation)	200	<u>CHS</u> <u>R/S</u>
"H3=?" (request support jack to headspar change in elevation)	400	<u>R/S</u>
"L1=?" (support jack to anchor point span length)	800	<u>R/S</u>
"L3=?" (support jack to headspar span length)	1000	<u>R/S</u>
"W=?" (request gross flying payload)	8000	<u>R/S</u>
"8,340.43"	} Calculator Iterations	No Response
"7,956.17"		No Response
"8,005.91"		No Response
"7,999.21"		No Response
"TS = 8,168.24 LBS" (computed critical skyline tension)	No Response	<u>R/S</u>
"TM1 = 8,113.99 LBS" (computed critical mainline tension)		

At this point program execution has been completed. The users can start another problem by pressing USER key "A".

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

Field tests showed that the critical mainline tension for carriage passage uphill over an intermediate support jack were actually lower than those predicted by this program in some cases. Use of this program for mainline design may result in a conservative estimate for maximum mainline tension.

After all data has been entered and the program is computing the critical skyline tension (TS) and critical mainline tension (TM1) by iteration, the program will briefly pause after each iteration, flashing a number on the display as shown in the example problem.

TS and TM1 are values at the jack necessary for successful carriage passage.

Check critical tensions against safe working loads in Table 1, page 97.

# Economic Analysis Program (PNV-P)

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## I. BACKGROUND INFORMATION

- A. General Assumptions: Standard cash flow analysis.
- B. References: None given.
- c. Figures and Formulas:

Figure 32. User Keys for PNV-P

Figure 33. Time Line with Five Cash Flows

Figure 34. Alternative No. 1 Cash-Flow Diagram

Figure 35. Cash-Flow Diagram of Equivalent Annual Worth

Single Payment - Compound Amount Factor (F/P, i, n)  
$$F = P(1 + i)^n$$

Single Payment - Present Worth Factor (P/F, i, n)  
$$P = F \left[ \frac{1}{(1 + i)^n} \right]$$

Sinking Fund Factor (A/F, i, n)  
$$A = F \left[ \frac{1}{(1 + i)^n - 1} \right]$$

Capital Recovery Factor (A/P, i, n)  
$$A = P \left[ \frac{i(1 + i)^n}{(1 + i)^n - 1} \right]$$

Uniform Series-Compound Amount Factor (F/A, i, n)  
$$F = A \left[ \frac{(1 + i)^n - 1}{i} \right]$$

Uniform Series-Present Worth Factor (P/A, i, n)  
$$P = A \left[ \frac{(1 + i)^n - 1}{i(1 + i)^n} \right]$$

Where: F = future worth single cash flow  
P = present worth  
i = interest rate  
n = number of discount periods  
A = annual single cash flow (i.e., periodic annual cash flow)

FIGURE 32. USER KEYS FOR PNV-P

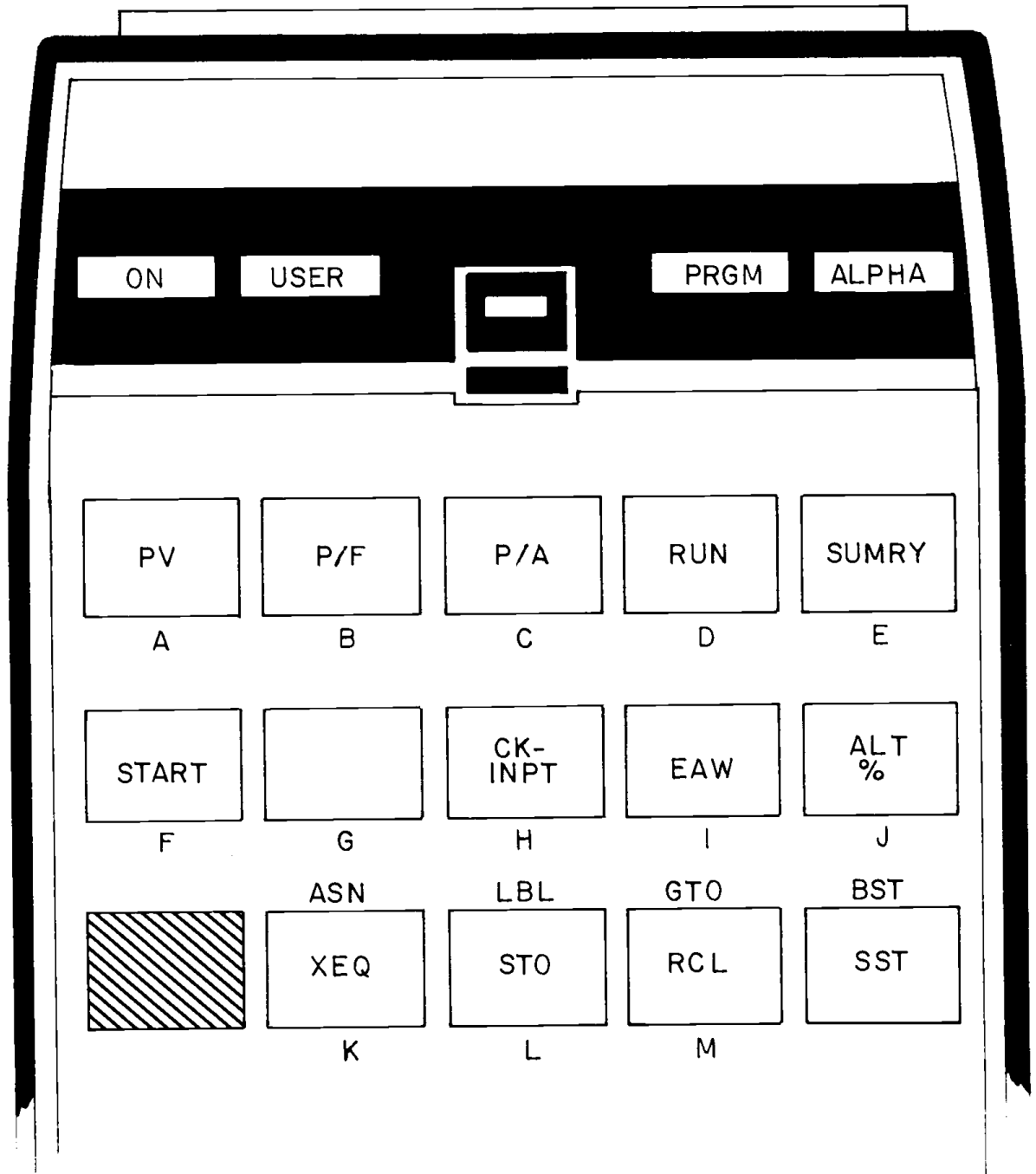
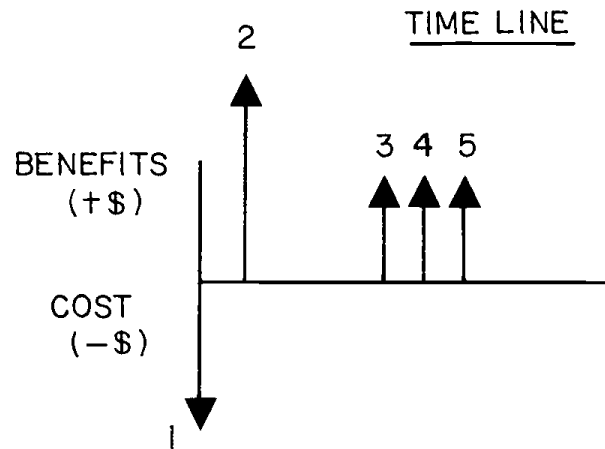


FIGURE 33. TIME LINE WITH FIVE CASH FLOWS



The above time line has a total of five time line cash flow functions.

FIGURE 34. ALTERNATIVE NO. 1 CASH-FLOW DIAGRAM

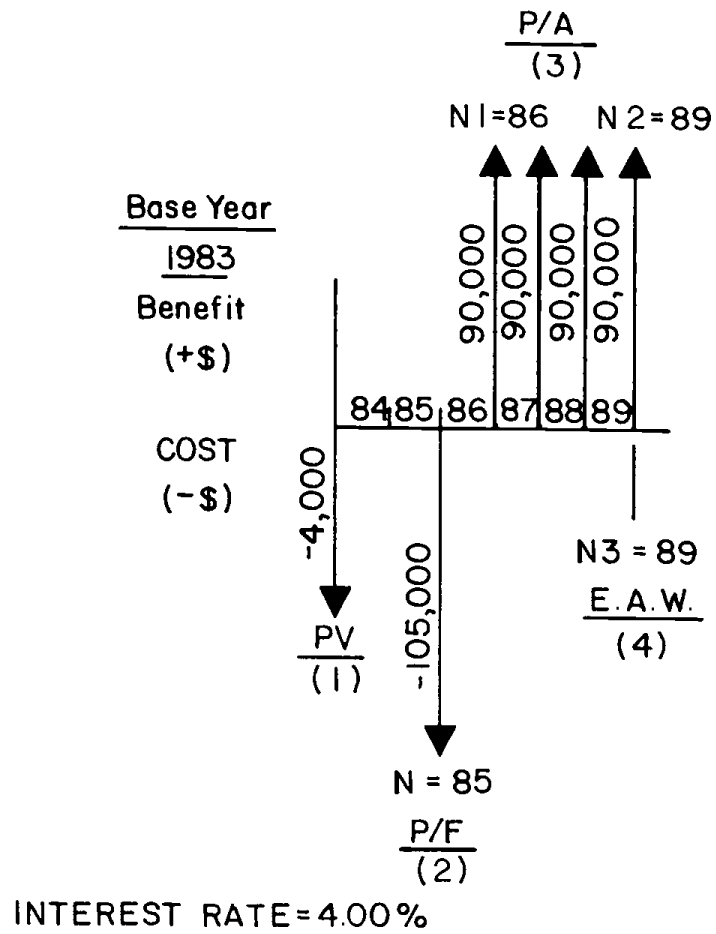
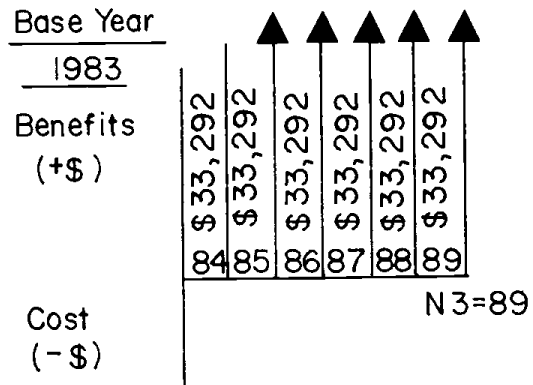




FIGURE 35. CASH-FLOW DIAGRAM OF EQUIVALENT ANNUAL WORTH



INTEREST RATE = 10.00%

## II. CONVENTIONS AND MEMORY

### A. Conventions

For all cash-flow inputs and outputs, a revenue should be entered as a (+) value, costs will be entered and displayed as (-), and benefits will be displayed as (+).

### B. Size and Capacity

The calculator must be sized to 178. The program uses 141 registers. Total calculator capacity must be 319 registers. The program consists of 371 steps.

## III. EXAMPLE OF PROGRAM USE

### A. Information Needed

1. "INT. RATE=%?": Prompt for interest rate for period in percent (input).
2. "BASE YEAR=?": Prompt for any year chosen as beginning of cash flow (the longest year is 999, so for 1985 enter 85).
3. "INPT. KEY?": Prompt to select user key for input (output).
4. "PV=?": Prompt for present value at base year in dollars (input).
5. "N=?": Prompt for the year a future cost or revenue occurs (input).
6. "PW=": Shows present worth at base year in dollars (output).
7. "FV=?": Prompt for future value (i.e., amount cost (-) or revenue (+) at year N (input).
8. "N1=?": Prompt for beginning period for single cash flows (input).
9. "N2=?": Prompt for ending period for single cash flows (input).
10. "AMT=?": Prompt for amount of each single cash flow between and including periods N1 through N2 (input).

11. "PVB=": Shows present value benefits (total revenues at present worth in dollars) (output).
12. "PVC=": Shows present value costs (total present worth costs over entire cash flow period in dollars) (output).
13. "PNV=": Shows present net value (PVB-PVC) in dollars (output).
14. "B/C": Shows benefit to cost ratio, PVB/PVC (output).
15. "NEW I=%?": Prompt for new desired interest rate in percent (input).
16. "N3=?": Prompt for the ending year for computation of equivalent annual worth (input).
17. "E.A.W.=": Shows equivalent annual worth of computed net present value distributed equally through (N3-Base Year) time periods (output).
18. Cash Flow Functions: (Figure 34).
  - 19(1). PV = Present value at base year.
  - 19(2). P/F= Present value of a single discounted future value.
  - 19(3). P/A = Present value of a series of equal future cash flows.
  - 19(4). E.A.W.=The Equivalent Annual Value of a computed Net Present Value distributed equally through (N3-Base Year) periods.

#### B. Step-by-Step Example

Problem is illustrated in Figure 34 (except at one point of the program execution the interest rate is changed from 4.00% to 10.00%).

Figure 35 illustrates E.A.W. output from the net present worth where  $i = 10\%$ .

Given: Interest Rate = 4% (Case 1)  
 Base Year = 83 (1983)  
 Present Value = \$40,000  
 N = 85 (year \$105,000 cost is incurred)  
 Future Value = -\$105,000  
 Future Revenues: 1986: \$90,000  
                   1987: \$90,000  
                   1988: \$90,000  
                   1989: \$90,000  
 So, N1 = 86, and N2 = 89  
 E.A.W. needs to be computed to year 1989 (N3 = 89)

Solutions: For i = 4% Summary:  
 PWB = \$302,044.00  
 PWC = \$-101,078.00  
 NPW = \$200,966.00  
 B/C = 2.99

For i = 10% Summary and E.A.W.:  
 PWB = \$235,775.00  
 PWC = \$-90,777.00  
 NPW = \$144,998.00  
 B/C = 2.60  
 EAW = \$ 33,293.00

Program Execution: Access the program by pressing XEQ ALPHA  
PNV-P ALPHA. Make sure the computer is in "USER" mode when  
 reading the program into the computer memory. (SHIFT MINUS  
 keys give hyphen)

<u>Prompt</u>	<u>Response</u>	<u>Keystroke</u>
"PNV-PGM"		
"INT RATE=%?"	4	<u>R/S</u>
"BASE YEAR=%?"	83	<u>R/S</u>
"INPT. KEY?"	Select input for PV	<u>A</u>
"PV-INPT"	No Response	No Keystroke
"PV=%" (present value)	4,000	<u>CHS</u> <u>R/S</u>

"1."	No Response Select P/F computation	<u>B</u>
"P/F-INPT" (future cost or revenue, discounted to present)	No Response	No Keystroke
"N=?" (year of occurrence)	85	<u>R/S</u>
"F=?" (future value)	105,000	<u>CHS</u> <u>R/S</u>
"1."	No Response Select P/A computation	<u>C</u>
"P/A-INPT" (present value of stream of like revenues or costs)	No Response	No Keystroke
"N1=?" (first year of occurrence)	86	<u>R/S</u>
"N2=?" (final year of occurrence)	89	<u>R/S</u>
"AMT=?" (amount of each revenue or cost)	90,000	<u>R/S</u>
"1."	No Response Select option to check input	<u>H</u>
"CK INPT R/S"		<u>R/S</u>
"REG NO = 25."		<u>R/S</u>
"DATA = -4,000.0000"		<u>R/S</u>
"REG NO 26."		<u>R/S</u>
"DATA = -105,000.0020"	F of 105,000 and 2 discount periods in Reg. No. 26	<u>R/S</u>
"REG NO 27."		<u>R/S</u>

"DATA = 0.0030"	First cash flow period of the P/A computation stored in Reg. No. 27	<u>R/S</u>
-----------------	---	------------

"REG NO. 28."		<u>R/S</u>
---------------	--	------------

"DATA = 0.0060"	Last cash flow period of the P/A computation stored in Reg. No. 28	<u>R/S</u>
-----------------	--	------------

"REG NO. 29."		<u>R/S</u>
---------------	--	------------

"DATA = 90,000.0000"	The periodic flow of the P/A computation	<u>R/S</u>
----------------------	---	------------

"END DATA"		<u>R/S</u>
------------	--	------------

To change data after checking it, view the display and then key in the data in the correct format and store it in the proper register. For example reenter the correct value in Reg. No. 26 after viewing it:

"REG NO. 26."		<u>R/S</u>
---------------	--	------------

"DATA = -105,000.0020"	This is value is correct but it will be reentered	Key in 105,000.0020
------------------------	---	------------------------

CHS STO

"STO _ _"	Where should new data be stored?	Key in 26
-----------	-------------------------------------	-----------

If errors had been present, they could be corrected by examining storage registers.

"END DATA"	No Response	<u>R/S</u>
------------	-------------	------------

"SUM DATA R/S"	Data Analysis Output	<u>R/S</u>
----------------	----------------------	------------

"% I = 4.00"	Interest Rate	<u>R/S</u>
--------------	---------------	------------

"BASE YR = 83"	Base Year or Period Cash Flow	<u>R/S</u>
----------------	----------------------------------	------------

"PVB = \$302,044"	Present Value of Benefits	<u>R/S</u>
-------------------	---------------------------	------------

"PVC = \$101,078"	Present Value of Costs	<u>R/S</u>
-------------------	------------------------	------------

"PNV = \$200,965"	Net Present Value	<u>R/S</u>
-------------------	-------------------	------------

"B/C = 2.99"	Benefit to Cost Ratio	<u>J</u>
	Then try alternative interest rate	
"ALT% = ?"	10	<u>R/S</u>
"SUM DATA R/S"	View new values as above with 10% interest rate. Same output as above.	<u>R/S</u>
"SUM DATA R/S"	Compute EAW	<u>I</u>
"N3 = ?"	89	<u>R/S</u>
"EAW = \$33,293"	Equivalent Annual Worth at 10% interest	

At this point users may choose to start another run, or alter the interest rate again.

#### IV. CAUTIONS, LIMITATIONS, AND COMMENTS

Initial computations are made to the nearest \$1.01, and subsequent calculations are rounded to the nearest \$1.00; thus, slight variations of equivalent results may occur.

The maximum single cash flow that can be entered is  $\pm$  \$9,999,999.00.

The largest year is 999. For example, the year 2000 equals 100 and current year 85 equals 1985.

To store cash flows greater than  $\pm$  \$9,999,999.00, round all cash flows to the nearest \$1,000. For example, the value \$13,501,600 would be rounded to 13,502.00, and the multiples would be documented outside the parameters of the program.

Calculator generally must be in "USER" mode for key assignments to work properly.

To start another alternative with different cash flows, the user must go back to the beginning of the program by pressing "F".

In order to adequately utilize this program, users should have a working knowledge of the following:

- Present value (PV)
- Future values brought back to present values (P/F)
- Annual single cash flows brought back to present values (P/A)
- Benefit-cost ratios
- Present net worth (PNW)
- Equivalent annual worth (EAW)
- Periodic interest rates
- Cash flows and cash-flow diagrams

Users may wish to iterate over some interest rates to find the internal rate of return (IRR). IRR is determined when the  $PNV = 0$  and the  $B/C = 1$ . These values are determined when the  $PVC = PVB$ . Once a PNV is determined with an initial interest rate such as 10%, the B/C can be analyzed. In this example the  $B/C = 2.6$ . As the B/C is greater than one, try a higher interest rate. At 50% interest rate, the  $B/C = 1.27$ , still greater than one. At 70% the  $B/C = 0.97$ , which indicates the interest rate is now too large as the B/C is less than one. An interest rate of 68% provides  $B/C = 1.00$ . The  $PNV = \$-195$ . The interest rate of 68% is very close to the true IRR and would be considered adequate for most cash flow analysis. The true value of the IRR is 67.62%.



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