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Skidder Load Capacity and Fuel Consumption HP-41C Program

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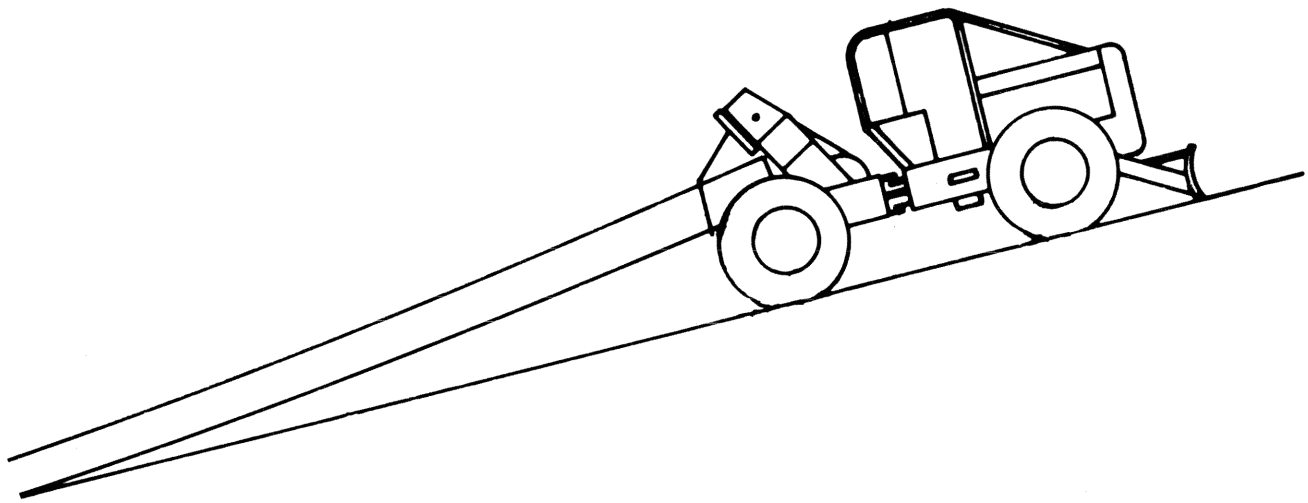

The Author

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Abstract

This program gives the log weight that the skidder can move and gives fuel consumption either in liters or gallons per turn. Slope of the skid trail, skidder weight, and skid distance must be entered into the program.

Introduction

Loggers work for profit and therefore seek improved efficiency to increase profits. Increasing costs constantly face logging operators. Efficiently loading a skidder will help reduce costs per unit of wood skidded, and we have developed a program for doing this. The Hewlett-Packard-41C[1] hand-held calculator program can be used as a tool to quickly compare loads and fuel used by wheeled skidders under different skidding conditions. Although a great number of variables influence skidding, only the major ones were used to simplify this hand-held calculator program and to give the operator items of input that can be readily determined. Iff and others (1982) incorporated 39 variables pertaining to skidder capacity in a Fortran program to obtain the skidder load. The program presented here will not compare to the highly sophisticated program. The trade-offs gained are simplicity of use and the low-priced, highly portable equipment that can be used almost anywhere.

The computer program described in this publication is available on request with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program. For information, please write: Engineering Research, Northeastern Forest Experiment Station, 180 Canfield Street, Morgantown, WV 26505. If you want to obtain the program, send three blank Hewlett-Packard magnetic cards. Features of the HP-41C are presented in Appendix A. A program list is provided in Appendix B.

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

Program Characteristics

The program gives not only a load that the skidder will pull but also the fuel per turn. Input items for load are skidder weight and slope for the loaded skidder. Distance of skid is added to calculate fuel used per turn. When slope and skidder weight are entered into the program, the maximum log weight for the load appears. Values of traction, rolling resistance, and sliding friction used in the program limit the maximum weight of the load. The selected values for these variables should give an accurate answer in the majority of situations; however, extra soft soil or overly rocky conditions could readily change the practical value of the maximum load.

Prompts

After starting the program, the first prompt "SLOPE?" appears. Percentage of slope for the average skidding distance should be entered as a whole number. Use positive slope for uphill skidding and negative slope for downhill skidding. If vast variations in slope exist over the skidding distance, various sections of the skidding distance could be treated independently and then combined. Press the R/S (run/start) key after entering slope and the next prompt "SKIDDER WT?" appears.

Skidder weight may be entered either in kilograms or in pounds. Readout for log weight of the load will be in the same units as entered for skidder weight. If 10 percent has been entered for slope and 12,000 kilograms or pounds entered for skidder weight, the calculator screen will show "LG WT = 5,610" in the same units used for skidder weight, giving the maximum log weight for the load after pressing the R/S key. Press the R/S key again and the prompt "LG WT?" appears. A value may be entered for load and the R/S key pressed or the R/S key may be pressed with no entry. With no entry, the maximum value of the load will be used for further calculations. By making no load entry and pressing the R/S key with the previous entries, the screen shows "FORCE = 10,071" in the same units used for skidder weight. This force value is the force exerted by the skidder to the soil to move the skidder and the load.

Pressing the R/S key produces "SKID DIST?" on the calculator screen. This asks for skidding distance for a section of skidroad with a relatively constant slope. If kilograms have been used for the skidder weight, the skid distance must be entered in meters. If pounds have been used for the skidder weight, the skid distance must be entered in feet.

Press the R/S key and the screen shows "METRIC?". If kilograms and meters have been used for entries, press number "1" to indicate yes. If pounds and feet have been used for entries, press "0" to indicate no. This permits either system of measure to be used with the same program. If a skid distance of 1,000 feet has been entered and "0" pressed for metric, pressing the R/S key will give an answer of "GAL = 0.355," which would be the gallons of fuel used for one round trip. If a skid distance of 1,000 meters has been entered and "1" pressed for metric, the R/S key produces "LITERS = 9.715," which would be the liters of fuel used for one round trip. The round trip and machine size are both much greater for kilograms and meters than they are for pounds and feet when the same numbers are used.

Input

Best values available should be used for input. Of course, compatible units must be used, either metric or English. The skidder weight given by the manufacturer generally would have greater accuracy than the other inputs. Because the program is for practical use, it does not require extreme precision.

Skidding distance changes with almost every load, thus an accurate estimate may be sufficient. If map measurements or ground measurements are available, an average of the maximum and minimum distance will give a reasonable value if the difference of maximum and minimum is not too great. Where slope changes control a section of skidding distance, a ground measurement would be most accurate. Slope would best be determined with an Abney level, or with a more modern device.

Readout

Some answers appear before making all inputs. This shows in the load which has a readout for maximum load followed by a prompt asking for the load value. Because maximum load generally cannot be obtained with normal operating conditions, this sequence is necessary and a reasonable load may be inserted. Also, the maximum load does not change for downhill or negative slopes.

Fuel consumption per turn includes bringing in the load and making the return trip. Fuel consumption should be considered comparative since this program is greatly simplified from one that considers all of the variables. When a logger works in conditions similar to one where this program has been used, the accuracy of fuel output could be verified, or if necessary, a correction factor could be applied. This situation would permit using fuel output as an absolute value. In any event, a comparison of costs can be made between full and partial loading.

Load

Loading a skidder probably affects efficiency more than any other variable in logging. This program along with production records will demonstrate to the user what additional costs occur from under loading skidders. Consistent loading to skidder capacity is impossible, unless logs are cut to the right size for specific conditions. Loads approaching the maximum can be achieved with experience.

Downhill slopes permit enormous loads to be pulled. However, moving a load considerably larger than the skidder creates a hazard. The program contains a loop for negative or downhill slopes that gives a load that can be pulled on level ground. This maximum load for negative slopes is realistic for two reasons: (1) this gives a safe-size load, and (2) most downhill skidding has at least one level location on the skid trail or landing and the load could not be efficiently changed for this location.

The criteria set up to determine the maximum load were: (1) sliding friction of 85 percent, (2) rolling resistance of 20 percent, and (3) tractive coefficient of 48 percent. Sliding friction of 85 percent is near that measured by Falk and Peters (1979) for west coast cable thinning. They reported 86 percent for an average. The value used also is in the lower range of tests run by Hassan and Gustafson (1981) in North Carolina.

The rolling resistance of 20 percent is suggested by Phillips (1981) for skidders on skidroads. Most of the skidding would be done along a skid trail. The tractive force of the skidder can range to near 85 percent (Iff and others 1982), but slippage would be excessive for any practical use. Nebraska tractor tests (Nebraska Board of Tractor Test Engineers 1980) for farm tractors stop when slippage reaches 20 percent. Burt and others (1982) indicate a range of 45 to 50 percent traction on a relatively firm skid road with 20 percent slip. Thus, 48 percent was selected for the program.

Conditions vary, and loads may be greater than those indicated as maximum. The calculated values should be realistic for most skidding conditions. Where the soil is very firm and traction excellent, tipping of the skidder would be the limiting factor on loading. Loads calculated by the program will not tip a skidder in any reasonable situation.

Formulas

The program was written from derived formulas using slope, rolling resistance, sliding friction, and internal friction of the skidder. The assumptions were made that one-half of the log weight was supported on the skidder, and that the skidder and load were moving on a uniform slope (Fig. 1). Internal friction of the skidder is used for fuel consumption. Twenty-five percent of the skidder weight was used for internal friction. This percentage agrees with a low range of both Matthes

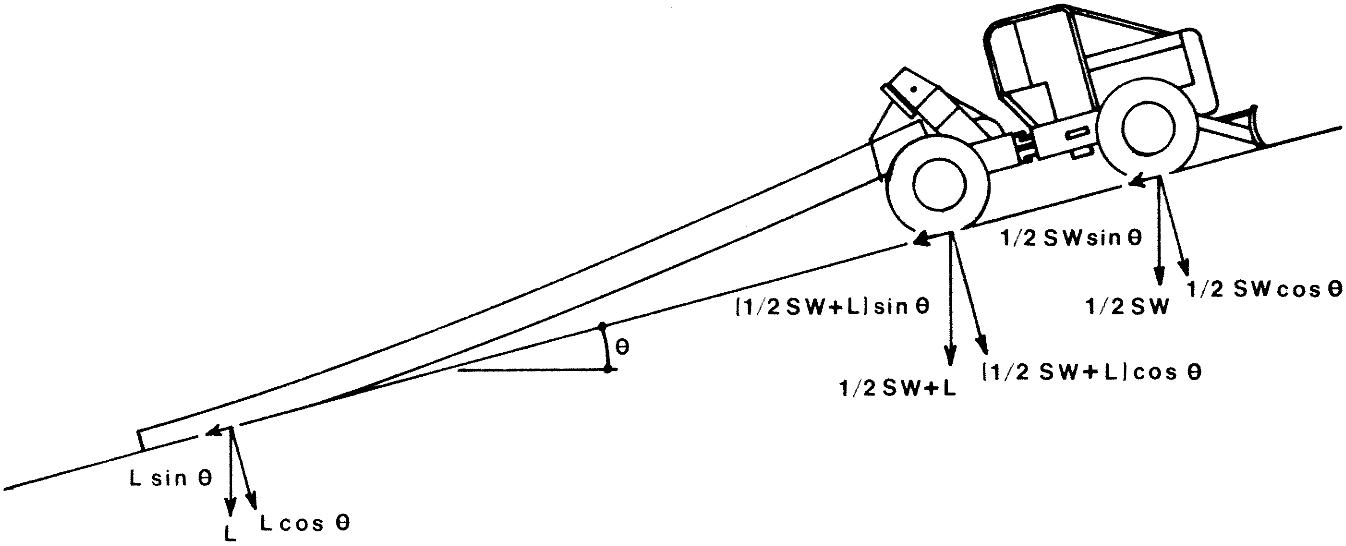

Figure 1.—Force diagram for loaded skidder.

and others (1982) for skidders and Chew (1980) for futuristic trucks.

Values

Slope	$= \theta$
Rolling resistance	= 0.20
Internal friction	= 0.25
Tractive coefficient	= 0.48
Sliding friction	= 0.85
Skidder weight	= SW
One-half log weight	= L
Gravity component normal to slope	$= \cos\theta$
Gravity component along slope	$= \sin\theta$

Tractive force = resistive force

1. $0.48\ SW \cos\theta + 0.48\ L \cos\theta = 0.2\ SW \cos\theta + 0.2\ L \cos\theta + SW \sin\theta + 2\ L \sin\theta + 0.85\ L \cos\theta$

transpose

2. $0.48\ L \cos\theta - 0.2\ L \cos\theta - 2\ L \sin\theta - 0.85\ L \cos\theta = 0.2\ SW \cos\theta + SW \sin\theta - 0.48\ SW \cos\theta$

combine and change signs

3. $2\ L \sin\theta + 0.57\ L \cos\theta = 0.28\ SW \cos\theta - SW \sin\theta$

solve for 2 L = log weight

4. $$2L = SW \frac{0.28 \cos\theta - \sin\theta}{0.285 \cos\theta + \sin\theta}$$

Return to the basic concept of the skidder pulling a log on a uniform slope. The force exerted along the slope is F.

5. $F = 0.85\ L \cos\theta + L \sin\theta + 0.2\ L \cos\theta + L \sin\theta + 0.2\ SW \cos\theta + SW \sin\theta$

combine

6. $$F = \frac{1.05}{2}(2L) \cos\theta + 0.2\ SW \cos\theta + (SW + 2L) \sin\theta$$

Internal friction of 0.25 SW is added to the force for determining energy:

7. $$F = \frac{1.05}{2}(2L) \cos\theta + 0.2\ SW \cos\theta + (SW + 2L) \sin\theta + 0.25\ SW$$

Energy consumed bringing the load in is force times distance, and for the return trip, θ is changed to $-\theta$ and a load of 0 is used. Energy per turn is E.

8. $E = F \times D + (0.2\ SW \cos(-\theta) + SW \sin(-\theta) + 0.25\ SW)D$

E may be either in kilogram-meters or in foot-pounds. The conversion factor from kilogram-meters to kilowatt-hours is 1,980,000. The conversion factor from foot-pounds to horsepower-hours is 367,100.

Use 4 kilowatt-hours per liter of fuel oil (Chew 1980, Nebraska Board of Tractor Test Engineers 1980) for a round number near average to convert energy to quantity of fuel. This value converts to 20.3 horsepower-hours per gallon of fuel oil.

9. Fuel = E/1,980,000/4 liters turn.

10. Fuel = E/367,100/20.3 gallons per turn.

These formulas incorporated into the flow chart (Fig. 2) result in the program listed in Appendix B.

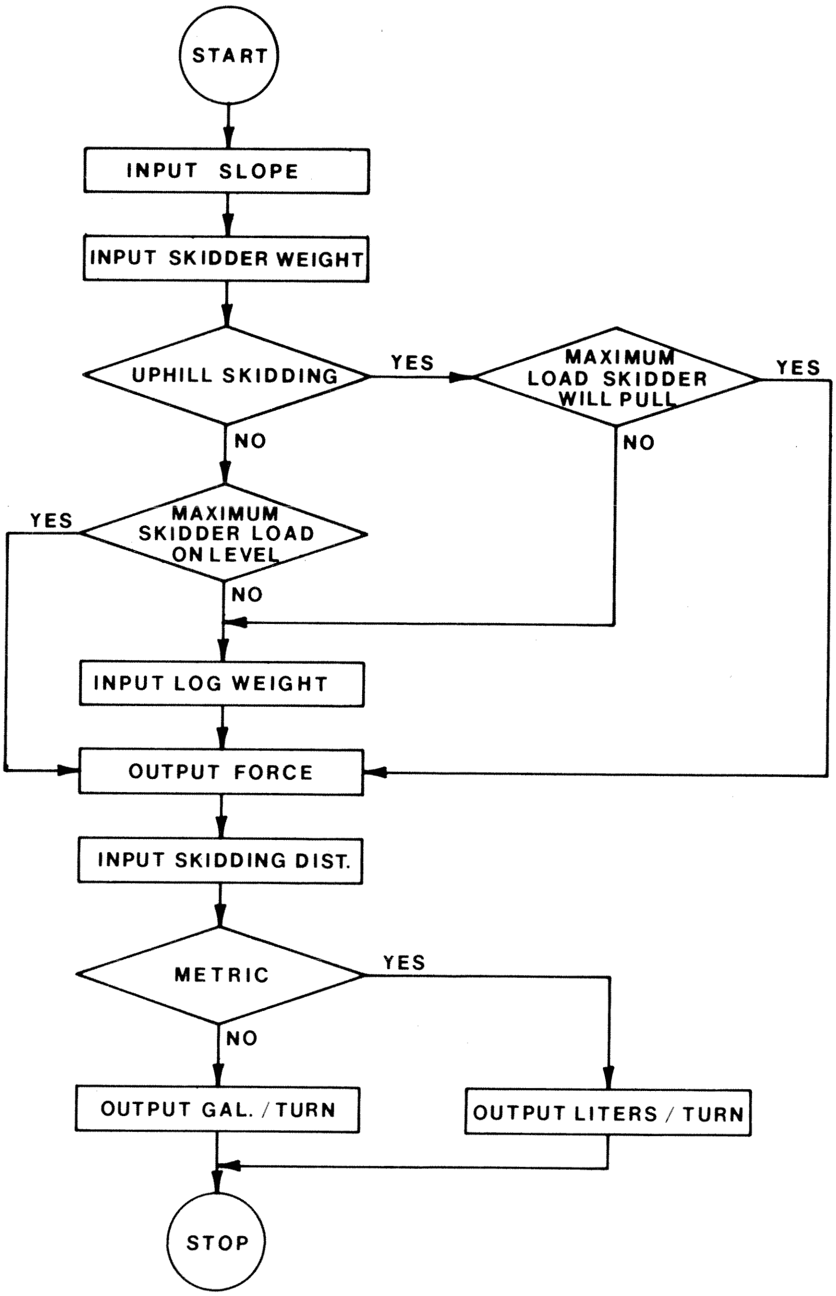

Figure 2.—Flow chart.

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Appendix A

Calculator Description

The hand-held Hewlett-Packard 41C contains programmable capabilities and a reasonably extensive storage. The calculator was designed for easy entrance of program storage. The program may be entered by direct programming, which is relatively simple, or through magnetic cards. Magnetic cards offer quick recovery of the program after some interruption such as using another program. The calculator's continuous memory holds the program as long as the storage space is not used for something else and even when the calculator is turned off. The reader will also transfer a program to magnetic cards.

Visual prompting for data shows on the visual display of the calculator so the program can readily be used at logging sites or any other place where a quick answer would be desirable.

The calculator signals for low batteries when BAT appears in the lower left side of the viewscreen. This signal indicates the need for a battery change. Old batteries may cause erratic functions of a program, even before the calculator indicates a need for battery change.

Appendix B

Skidder Load Capacity and Fuel Consumption HP-41C Program List

```
01 LBL "FUEL"
02 FIX Ø
03 "SLOPE?"
04 PROMPT
05 1ØØ
06 /
07 ATAN
08 STO Ø6
09 COS
10 STO Ø2
11 RCL Ø6
12 SIN
13 STO Ø1
14 "SKIDDER WT?"
15 PROMPT
16 STO Ø3
17 RCL Ø2
18 *
19 .28
20 *
21 RCL Ø3
22 RCL Ø1
23 *
24 -
25 RCL Ø1
26 RCL Ø2
27 .285
28 *
29 +
30 /
31 STO Ø4
32 RCL Ø3
33 .9825
34 *
35 RCL Ø4
36 X<>Y
37 X<=Y?
38 GTO Ø9
39 GTO 1Ø
40 LBL 1Ø
41 RCL Ø4
42 "LG WT ="
43 ARCL X
44 PROMPT
45 STO Ø5
46 "LG WT?"
47 PROMPT
48 STO Ø5
49 GTO Ø8
50 LBL Ø9
51 "LG WT ="
52 ARCL X
53 PROMPT
54 STO Ø5
55 "LG WT?"
56 PROMPT
57 STO Ø5
58 LBL Ø8
59 1.Ø5
60 2
61 /
62 *
63 RCL Ø2
64 *
65 RCL Ø3
66 .2
67 *
68 RCL Ø2
69 *
70 +
71 RCL Ø3
72 RCL Ø5
73 +
74 RCL Ø1
75 *
76 +
77 RCL Ø3
78 .25
79 *
80 +
81 "FORCE ="
82 ARCL X
83 PROMPT
84 STO Ø5
85 "SKID DIST.?"
86 PROMPT
87 STO Ø7
88 *
89 STO Ø9
90 RCL Ø6
91 CHS
92 STO Ø6
93 COS
94 RCL Ø3
95 *
96 .2
97 *
98 STO Ø8
99 RCL Ø6
100 SIN
101 RCL Ø3
102 *
103 RCL Ø3
104 .25
105 *
106 +
107 RCL Ø8
108 +
109 RCL Ø7
110 *
111 RCL Ø9
112 +
113 STO Ø1
114 FIX 3
115 "METRIC?"
116 PROMPT
117 X=Ø?
118 GTO Ø6
119 GTO Ø7
120 LBL Ø6
121 RCL Ø1
122 198ØØØØ
123 /
124 2Ø.3
125 /
126 "GAL ="
127 ARCL X
128 PROMPT
129 GTO Ø5
130 LBL Ø7
131 RCL Ø1
132 3671ØØ
133 /
134 4
135 /
136 "LITERS ="
137 ARCL X
138 PROMPT
139 GTO Ø5
140 LBL Ø5
141 "END"
142 PROMPT
143 "RTN"
144 STOP
145 END
```

Phillips, Ross A. **Skidder load capacity and fuel consumption HP-41C program.** Res. Pap. NE-537. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 7 p.

Program gives log weight that the skidder can move and gives fuel consumption either in liters or gallons per turn. Slope of the skid trail, skidder weight, and skid distance must be entered into the program.

ODC 389

Keywords: Skidder, load capacity, logging, computer programs, cost estimating, fuel estimating, skidding forces and distances.

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