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Comparison of Shotgun with Highlead Yarding

(With Supplemental Note on Operating and Safety Factors by J.M. Ewart)

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FOREWORD

This Technical Note describes a cable-logging system which can be readily adapted from existing highlead equipment and used to advantage in uphill yarding.

FERIC was given an ideal opportunity to evaluate this system--and to compare it with adjacent highlead operations --by the Squamish Logging Division of MacMillan Bloedel Limited. The cooperation of division personnel, and particularly that of its general foreman, Frank Bonar, is gratefully acknowledged.

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SUMMARY

A conventional two-drum highlead yarder can be converted to the gravity slackline configuration and it can be done with few special attachments and little time loss. Once converted, the machine can yard uphill only, but will operate over greater distances. It can readily revert to highlead for horizontal or downhill yarding.

During a brief field comparison of the two systems conducted on the same area, the gravity slackline out-produced the highlead by a factor of 1.08 (based on shift-level studies), even though it operated over a greater external yarding distance. Crew size and timber characteristics were identical. Delays and downtime were similar over the brief study period.

Operational factors peculiar to the gravity slackline system were examined, including potential line wear, general safety considerations, and the need for additional care in positioning guylines.

With proper planning, the gravity slackline system can be an inexpensive and productive supplement to the highlead system. Its capability for yarding longer distances should create opportunities to reduce the costs and environmental effects of road development.

INTRODUCTION

The "Shotgun" or "Bullet" system is the simplest skyline system available for logging steep slopes uphill. Although these names are commonly used, the name "Gravity Slackline" is more descriptive, since the system employs gravity for the outhaul and performs somewhat like a slackline on the inhaul (see Figure 1).

SYSTEM AND STUDY AREA DESCRIPTION

The yarder used was a Madill two-line (mainline and haulback) yarder. The specifications are given in Table 1.

Table 1. Machine Specifications.

Tower height	90 ft (27 m)
Engine size	535 hp (398 kW)
Number of winches	2 plus strawline
Type of undercarriage	tracked (tank)

The machine originally designed for highlead was modified by the addition of a three-inch snub brake to the main drum for use in the gravity slackline system. In the gravity configuration, the mainline is used as a live skyline and the haulback line as the skidding line. In order to lead the skidding line under the skyline, a dutchman block is attached to one of the guylines by a butt-rigging three-point swivel and two shackles. This block prevents the haulback from rubbing on the skyline and permits the

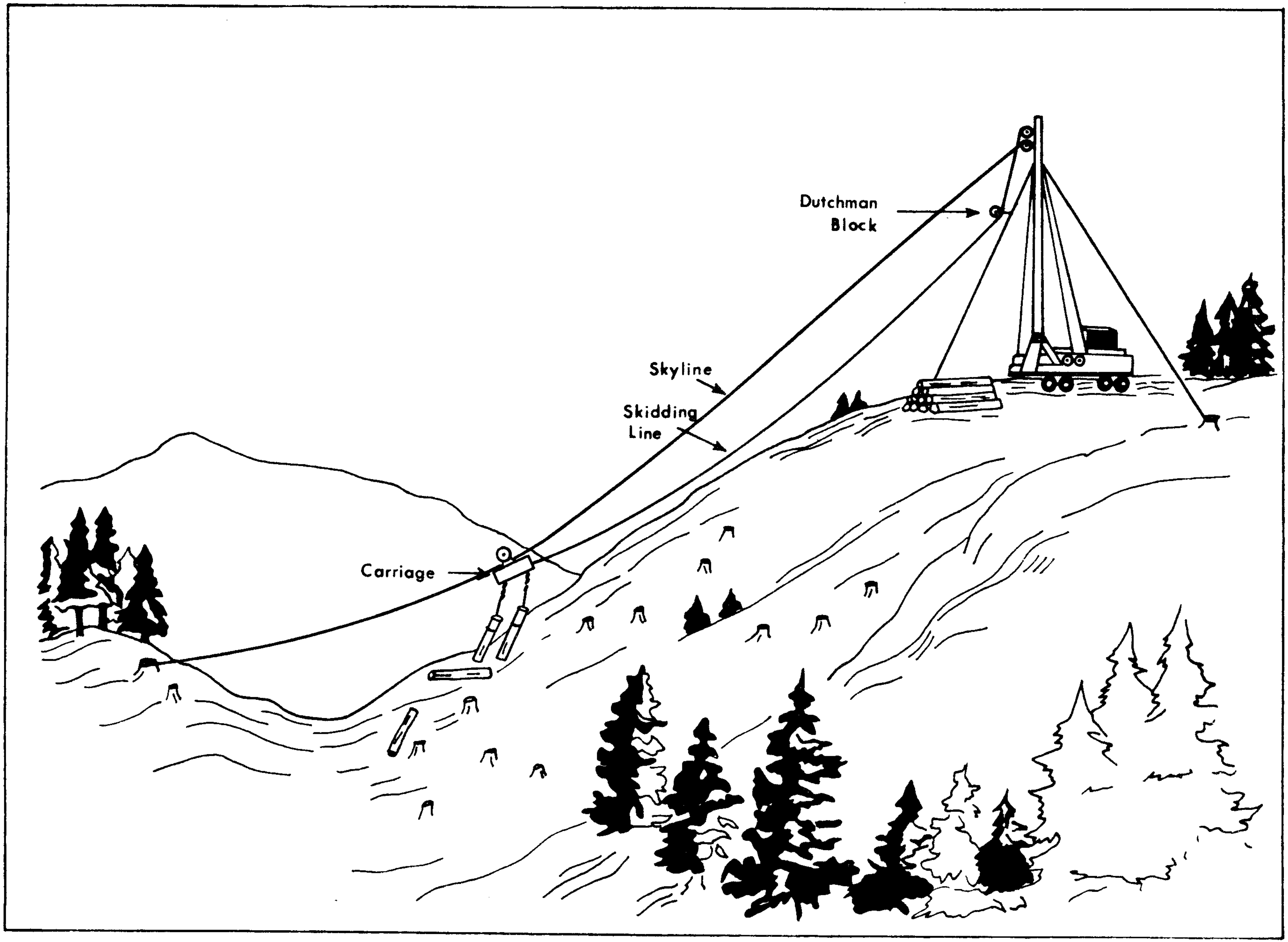


FIGURE 1. GRAVITY SLACKLINE OR "SHOTGUN" SYSTEM FOR UPHILL YARDING.

operator to pull the incoming logs closer to the base of the spar without tangling the lines.

The dutchman block also permits landing the logs on the truck road when space is not available for a full-sized landing. The haulback is run over the top tower fairlead, as is normal for highlead, then through the dutchman block and then to the carriage. The simplicity of the dutchman and absence of modification to the tower fairlead results in easy conversion between highlead and shotgun. The effect the dutchman has on guyline tensions will be discussed later.

The carriage (Figure 2) was made locally by the company and weighs approximately 1,000 lb (450 kg). The single block with a 20-in. (50-cm) diameter sheave runs on the skyline. The company plans to put a swivel between the butt rigging and the block to reduce the line wear when the skyline and skidding line are separated by the dutchman block. Two 7/8-in. (22-mm) diameter chokers were suspended from the carriage. Choker length varied from 25 to 50 ft (8 to 15 m).

The carriage was originally designed to carry three 3/4-in. chokers but the mainline drum brake will not support the load. Installation of additional brakes to this drum is being considered.

To gain extra yarding distance, an extension was shackled to the skyline with a flush head narrow-necked shackle. During yarding the carriage travelled over this shackle. The skyline was attached to the tailhold of one or more stumps with a knockout shackle (Figure 3). During the

Figure 2. Locally Made Shotgun Carriage.

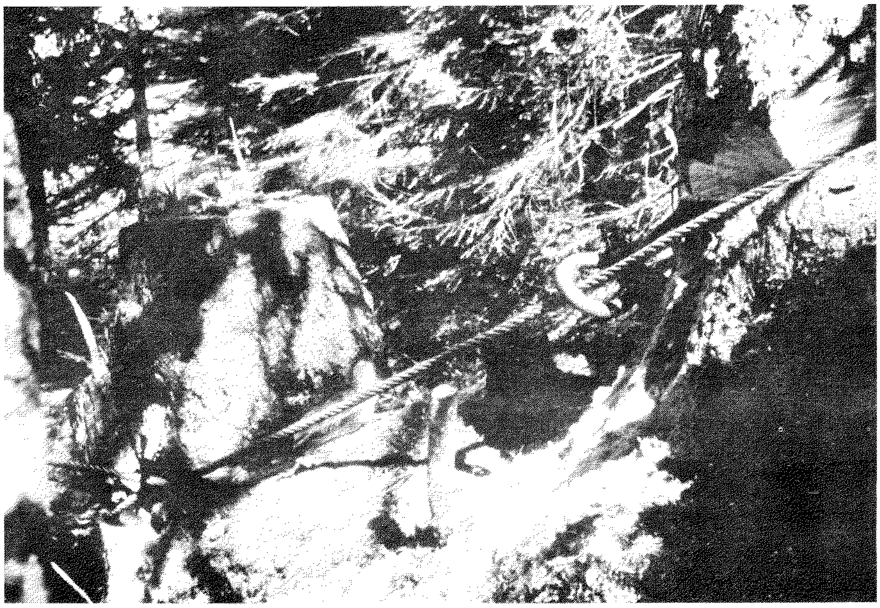


Figure 3. Skyline Tailhold.

study period, the tailhold was located up and across the valley bottom to improve deflection on some yarding roads.

The five-man crew included a hooktender, rigging slinger, chokerman, chaser and yarding engineer. A cable-grapple loader worked with the yarder most of the time.

The study area was located at the company's Squamish operation. Forest stand characteristics are summarized in Table 2.

Table 2. Forest Stand Characteristics.

Volume, cunits/acre (m^3/hectare)	73.1 (511)
Species Composition:	
Hemlock	40%
Balsam	51%
Other (Fir-Cedar-Yellow Cedar)	9%

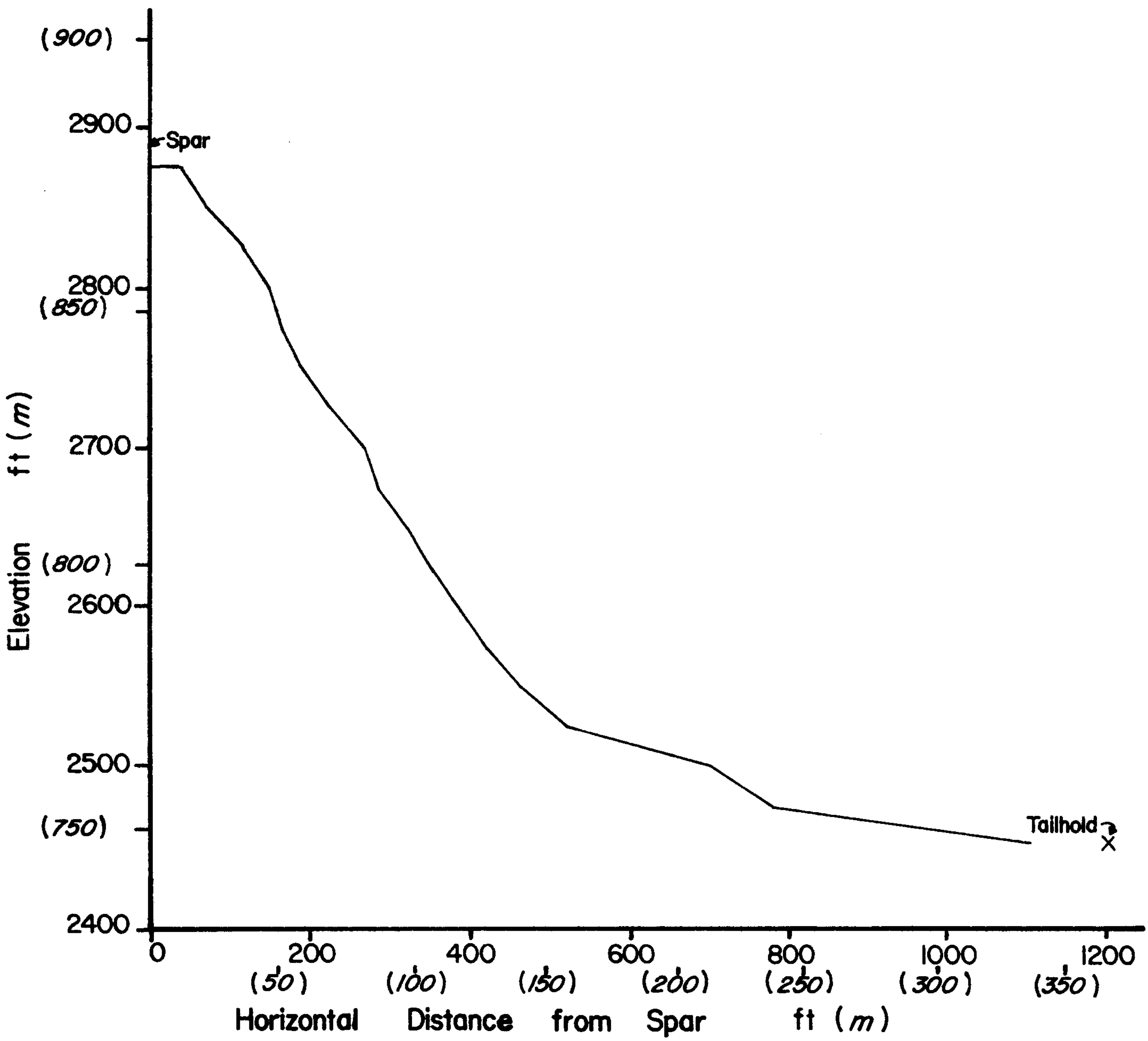
A profile of a typical yarding road is shown in Figure 4. Maximum yarding distance during the study was approximately 1,000 ft (300 m), but the distance to the tailhold exceeded 1,200 ft (370 m).

TIME AND PRODUCTIVITY STUDY

METHOD

Time distribution estimates and volume estimates of pieces yarded were obtained from detailed timing and partial scaling of four separate shifts in August and September

Figure 4. Profile of a Typical Yarding Road.



of 1977. Shift level time and production were developed from reports covering twelve complete shifts. The study techniques were based on methods used primarily for cable yarder evaluation (Cottell et al., 1976).

The yarding cycle was divided into five elements:

Outhaul: Skyline is tightened, carriage moves down the skyline by gravity and stops at the hookup site.

Hookup: The skyline is slacked, and chokers attached.

Inhaul: Skyline is tightened, the skidding line then brings the turn up the hill to the landing.

Decking: Logs are positioned on the landing and the carriage is lowered by slacking the skyline.

Unhook: Chokers are removed from the logs.

Table 3 summarizes the results of the detailed timing for the shotgun system. Figure 5 shows the percent distribution of time for the same period. Table 4 summarizes the major delays by categories from the detailed time study.

Delays of 10 minutes and greater were not considered part of the regular operation and were excluded from the study. These long yarder delays were associated mainly with temporary absences of the loader and resulting lack of landing space for incoming turns. Major yarding hangups occurred infrequently but were difficult to free owing to the lack of haulback on the carriage. Such hangups generally required rechoking of the turn. There were six yarding road changes averaging 1.1 hours reported in the shift level study. The lack of good walking access across the creek made road change times longer than normal.

Table 3. Gravity Slackline: Detailed Time Study Results.

(209 turns)

	Average Turn Time in Minutes	Standard Deviation
Outhaul time	.52	.22
Hookup	3.90	1.91
Inhaul	.76	.33
Decking	.26	.21
Unhook	.73	.39
Road Changes (pro-rated)	.91	--
Subtotal: Productive Time/Turn	7.08	--
Delay Time/Turn (pro-rated)	.93	--
Total Turn Time	8.01	8.06
Number of Pieces/Turn	2.19	.74

Maximum yarding distance: 1,000 ft (300 m)

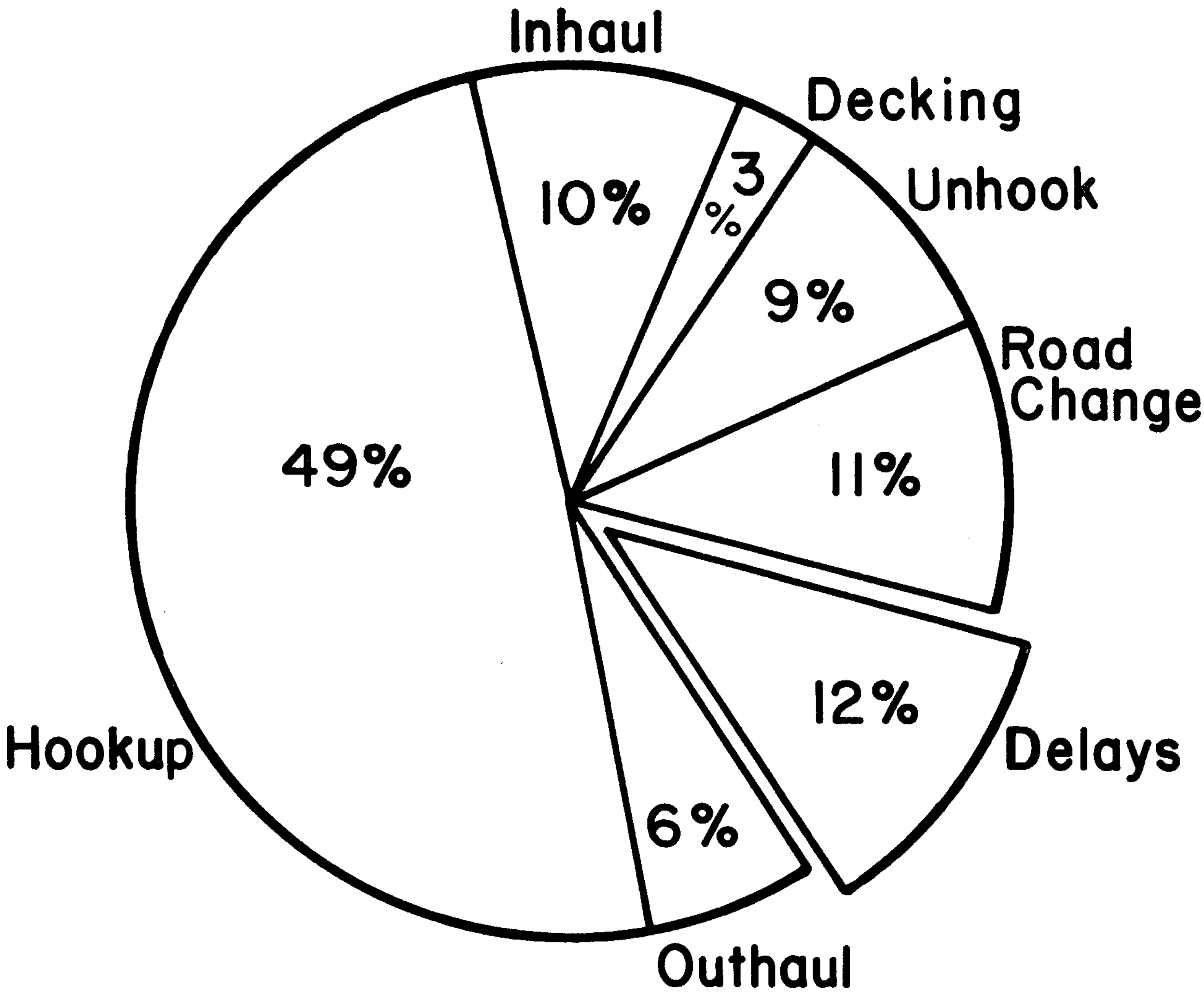


Figure 5. Gravity Slackline: Percent Distribution of Average Turn Time.

Table 4. Gravity Slackline: Summary of Major Delays.

(209 turns)

Delay Category	Description	Number of Occurrences	% of Total Delay Time
Repair	None observed	0	0
Personnel	Crew walking to work site, extra lunch, send lunches to the crew, communications	8	14
Operational	Loader in way	54	49
	Hangups	53	15
	Reset chokers	10	12
	Chokers caught or wrapped about mainline	12	10
	Loader holding logs	1	0
		130	86
Total		138	100

Figure 6 shows piece-size (gross volume) distribution for the study period. Figure 7 shows the percent volume represented by the various volume classes. Note that pieces less than 40 ft^3 (1.1 m^3) volume accounted for over half of the pieces yarded while representing only 15% of the volume.

A number of small chunks were produced by breakage during yarding. Yarding breakage from highlead and the gravity slackline was not compared during the study, but the gravity slackline system with its increased lift should reduce log breakage.

COMPARISON WITH HIGHLEAD

The Squamish study afforded an opportunity to compare the gravity system directly with the highlead system. Detailed timing was carried out on 147 turns and shift level reports were collected for eight shifts, with the same machine rigged for simple highlead. The highlead setting was adjacent to the gravity area with identical piece size and species composition. The gravity system would not work in this area because of lack of adequate tailhold stumps. Maximum yarding distance was 900 ft (275 m). Table 5 summarizes the results of the detailed timing for the highlead system. Figure 8 shows the percent distribution of time for the same period. Table 6 summarizes the major delays by categories from the detailed time study. Three yarding road changes averaging 28 minutes each were reported in the shift level study. During the study, two partial shifts were worked because the crew was being used for slash-burning and reversing the haulback line.

Figure 6. Piece-Size Distribution.

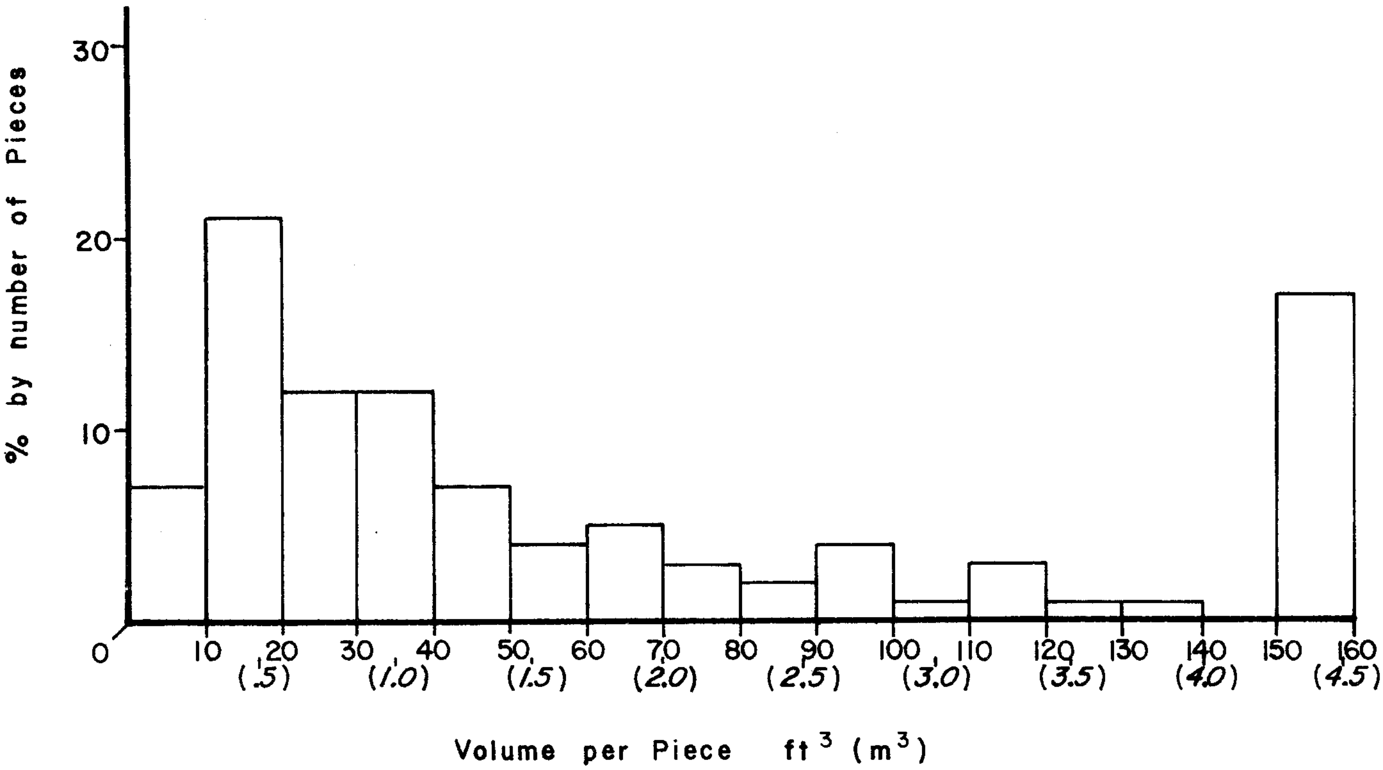


Figure 7. Volume Distribution.

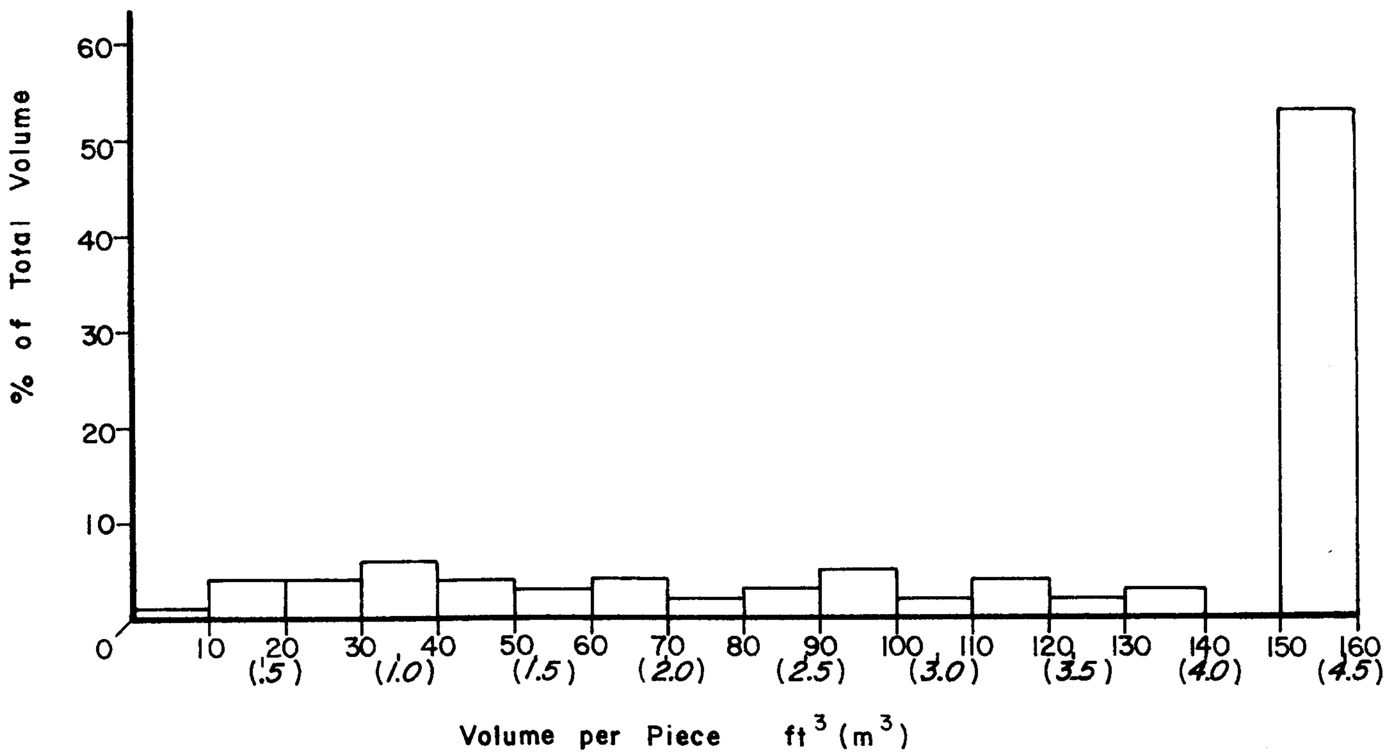


Table 5. Highlead: Detailed Time Study Results.

(147 turns)

	Average Time minutes/turn	Standard Deviation
Outhaul	.60	.21
Hookup	4.24	2.38
Inhaul	.90	.35
Decking	.22	.15
Unhook	.60	.29
Road Changes (pro-rated)	.65	-
Subtotal: Productive Time/Turn	7.21	-
Delay Time/Turn (pro-rated)	1.06	-
Total Turn Time	8.27	4.86
Number of Pieces/Turn	1.9	.51

Maximum yarding distance: 900 ft (275 m)

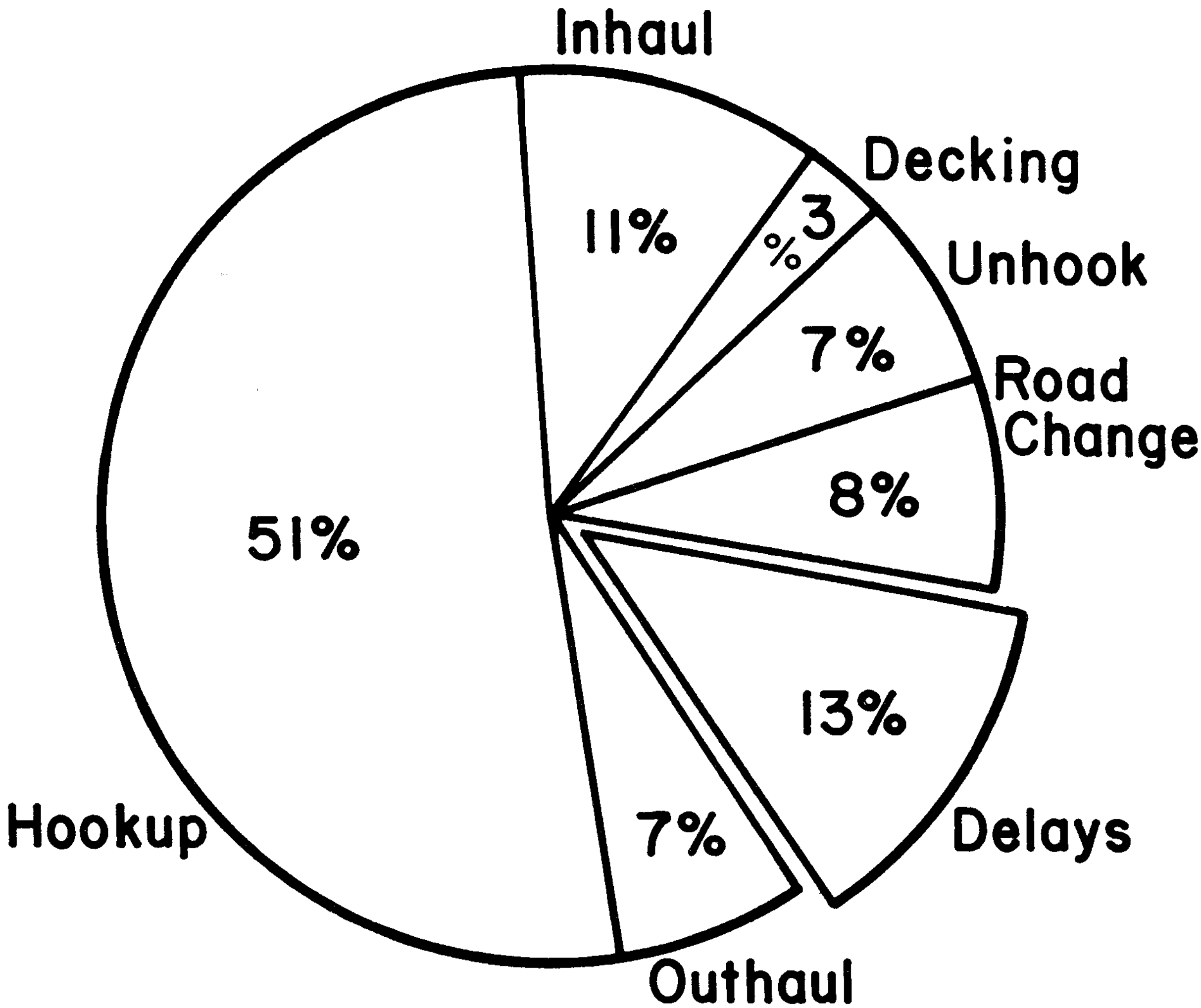


Figure 8. Highlead: Percent Distribution of Average Turn Time.

Table 6. Highlead: Summary of Major Delays.

(147 turns)

Delay Category	Description	Number of Occurrences	% of Total Delay Time
Repair	Butt rigging (tighten or replace shackles)	2	1
Personnel	Crew walking into bush	7	7
	Visitors	1	4
	Other	2	5
		10	16
Operational	Hangup	23	30
	Warmup	4	9
	Chokers buried in deck	10	8
	Decking or redecking at landing	13	7
	Attach or replace chokers	11	7
	Tighten guylines	3	6
	Rechoke turn	7	6
	Other	15	10
		86	83
Total		98	100

Table 7 summarizes time distribution for the gravity and highlead systems on a shift-level basis. Utilization and availability figures are based on a total of 20 shifts combining both gravity and highlead systems. It is felt that the mechanical availability of the machine was essentially the same whether rigged for highlead or gravity yarding.

Table 8 summarizes the production on a shift-level basis for the two systems. Increased production is indicated with the gravity system, even with the longer yarding distances.

GRAVITY SLACKLINE OPERATIONAL ADVANTAGES AND PROBLEMS

The advantages of the gravity system over highlead listed by Studier and Binkley (1974) are reduced fire hazard, safer operation, fewer hangups, faster cycle times, less log breakage and less soil disturbance. The problems include increased line wear; increased strain on the guylines, spar and brakes; and difficulty in finding adequate tailholds. Some of these factors will be discussed later in more detail.

Generally the gravity system is considered safer than highlead for the following reasons:

(a) As the skyline is tightened the logs are lifted by one end and drawn toward the skyline. This eliminates the dangerous tendency of dragged logs to turn end for end.

Table 7. Gravity and Highlead: Time Summary*

	Gravity		Highlead	
	Average hr/shift	Standard Deviation	Average hr/shift	Standard Deviation
Productive Time:				
Yarding	6.4	.6	6.5	1.8
Yarding Road Changes	.5	.7	.2	.3
Delays:				
Mechanical	.3	.6	.0	.1
Non-Mechanical	.8	.5	1.3	1.9
Total: Scheduled Machine Hours	8.0		8.0	
Number of Scheduled Shifts	12		8	
Mechanical Availability (20 shifts)	98%			
Machine Utilization (20 shifts)	85%			

*Table 7 is based on shift data shown in Appendix 1, INCLUDING October 19 when no Pieces Yarded were reported.

Table 8. Gravity and Highlead: Production Summary*

	Gravity	Highlead
Shifts worked	12	7
Average piece, ft^3 (m^3)	73.9 (2.1)	73.9 (2.1)
Piece count per shift worked	103	95
Piece count during study	1232	668
Gross volume per shift worked, cunits (m^3)	76.1 (216)	70.2 (199)
Gross volume during study, cunits (m^3)	910.4 (2579)	493.6 (1398)

*Table 8 is based on shift data shown in Appendix 1, EXCLUDING October 19 when no Pieces Yarded were reported.

(b) Logs have less tendency to hang up and swing around.

(c) The haulback and associated bight hazard is eliminated.

(d) The skyline gives better control of the logs approaching the landing.

Crew members must be aware of the live skyline's motion and stand well in the clear when the lines are moving.

There is more line wear with the gravity system than with highlead. Although the dutchman block separates the lines, some rubbing still takes place and the carriage causes wear on the skyline. In addition, the fixed length of the skyline on each road concentrates the wear at the fairlead and on the mainline drum. The line wear on the drum can be excessive if the line on the drum is not properly spooled and tensioned. When changing from a long road to a shorter road or from gravity to highlead, care should be taken to tension the mainline with the strawline rather than allowing it to spool loosely on the drum.

All loggers using the gravity system must appreciate that it is like a slackline system, capable of exerting heavy tensions on guylines. Guyline placement is, therefore, more critical than for highlead.

In a recent report for FERIC titled "Effective Use of Guylines on Logging Spars," J. M. Ewart makes the following recommendations which are applicable to all spar installations, including the gravity system:

"1. <u>Inspection and service</u>

It is very seldom that maximum conditions of tension in all operating lines occur simultaneously with the worst allowable placement of the lines. Safe line-tension and spar-stress level has been limited to 70 percent of yield. In spite of this, failure is a certainty unless equipment is properly inspected and serviced. Although not included in the scope of this report, anchor-stump selection is obviously important. Guylines should be replaced when damaged. Guyline blocks should be inspected and lubricated each time the spar is lowered. Guyline shackles should be replaced at regular intervals or whenever there is a sign of bending or distortion. Guyline rings should be examined periodically and replaced when distorted or cracked. Guyline block safety straps must be used on all spars. Spars should be examined for dents and cracks. Repairs must be carried out immediately, according to the manufacturer's specifications.

"2. <u>Guyline placement</u>

(a) <u>Angle between guylines (see Figure 9)</u>--Avoid large angle spacing between load-sharing guylines. This angle must not exceed 90 degrees on six-guyline machines or 60 degrees on eight-guyline machines. At the same time, little is achieved by placing guylines closer than 30 degrees to one another. Doing so will jeopardize proper spacing of guylines elsewhere around the spar.

(b) Guyline angle (see Figure 10)--Avoid steep guyline angles. Load-carrying guylines must never be less than 45 degrees from the spar.

(c) Guyline length--Avoid excessive differences in guyline lengths (shock loads tend to fall more heavily on shorter guylines).

(d) Dutchman block--The same guyline system can be used safely for highlead and gravity slackline provided that a dutchman block is not attached to a load-sharing guyline. (Editor's note--when the guylines are rearranged around the spar so that three are opposing the pull the dutchman can be placed on one of these. However, care must be taken to avoid large angles between other guylines and to relocate guylines when the gravity logging is discontinued.)

(e) Pre-tensioning--All guylines should be pre-tensioned equally.

"3. Yarding angle (see Figure 2)

Since guyline reactions increase as the yarding angle approaches the horizontal, the yarding angle should be as far away from the horizontal as possible.

Figure 9

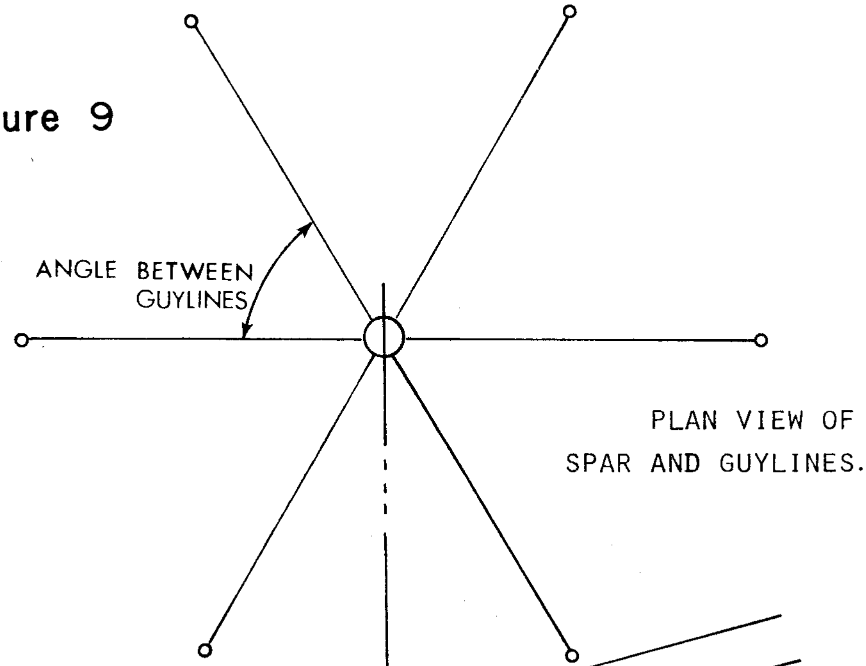
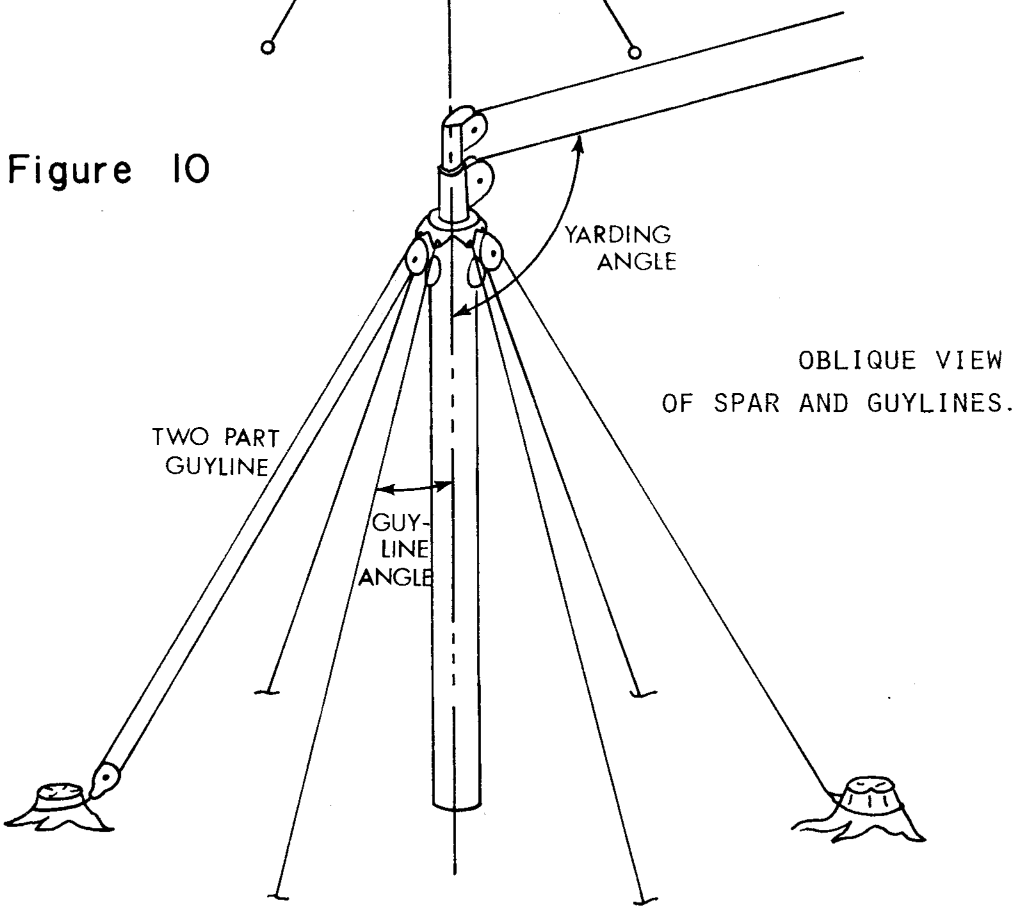


Figure 10



"4. Braking

On skyline machines including gravity slackline, never increase braking capacity without the permission of the manufacturer. Never dog the skyline drum. The brakes must allow the drum to slip under a heavy pull.

"5. Line size

Always conform to the manufacturer's specifications for line size.

"6. Regulations

Be familiar with and observe local safety codes."

ENGINEERING REQUIREMENTS

The two basic engineering requirements for the gravity slackline system are adequate slope and deflection. A slope of 30% between the spar and tailhold is required to ensure efficient operation. Deflection requirements are similar to those for other skyline systems. A minimum of 8% (80-foot clearance on a 1000-foot span) is desirable to reduce the strain on the skyline, tailhold and skyline brake. Deflection can be increased by placing the tailhold across the creek when logging in canyons but this will reduce the skyline slope. (It can also be increased by placing the spar on the outside edge of the road but this reduces the landing space.)

When the dutchman is used, less space is required for the gravity slackline than for highlead and in many cases the truck road is sufficient with no additional landing.

The gravity slackline requires adequate guyline stumps, especially against the direction of pull. It also requires strong tailhold stumps for securing the skyline on each yarding road.

Because the gravity slackline provides more lift than high-lead, hangups are reduced and yarding distances can be increased to 1,200 feet or more where deflection permits.

CONCLUSION

The gravity slackline system is a simple skyline system applicable to many uphill yarding situations on steep coastal terrain. Standard highlead yarders can be used with little modification provided the operator and hook-tender are aware of the special operational problems. The gravity system can be operated as safely as highlead but more care must be taken in the placement of guylines. Where slopes permit, yarding distances can be increased beyond the highlead maximum. Settings must be carefully chosen and engineered to assure that skyline deflection is adequate to prevent unsafe line tensions.

The gravity slackline system is not as widely applicable as highlead and can be used only for steep uphill yarding. The time study comparison of both systems on similar areas showed that the gravity system will increase production even when operating at longer yarding distances. Coastal operators should therefore encourage their highlead yarding crews to use the gravity system whenever ground conditions permit, in order to increase production and lower logging costs.

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APPENDIX 1. Summary of Shift Level Data.

Date	Scheduled Machine Hr (SMH)	Road Change	Delay Hours		Total	Productive Machine Hr (PMH)	Pieces Yarded
			Repairs	Other, Non Mechanical			
Shotgun System (12 shifts)							
Aug 24	8	-	-	1.4	1.4	6.6	90
25	8	-	2.0	.5	2.5	5.5	50
26	8	.8	-	1.1	1.9	6.1	76
30	8	1.4	.4	.3	2.1	5.9	112
31	8	.9	.2	.6	1.7	6.3	116
Sept 1	8	-	-	1.1	1.1	6.9	106
2	8	-	.5	.4	.9	7.1	132
6	8	-	-	2.2	2.2	5.8	108
12	8	2.0	-	.7	2.7	5.3	84
13	8	-	-	1.0	1.0	7.0	141
14	8	.7	-	.7	1.4	6.6	90
17	8	.6	-	.3	.9	7.1	127
Total	96	6.4	3.1	10.3	19.8	76.2	1232
Mean	8.00	0.53	0.26	0.86	1.65	6.35	102.67
S.D.	0.00	0.66	0.58	0.55	0.63	0.63	25.90
Highlead System (8 shifts)							
Sept 29	8	.9	.3	.2	1.4	6.6	93
30	8	-	-	5.5	5.5	2.5	36
Oct 3	8	.5	-	.1	.6	7.4	114
7	8	-	-	2.5	2.5	5.5	72
17	8	-	-	.7	.7	7.3	117
19	8	-	-	.3	.3	7.7	-
20	8	-	-	1.2	1.2	6.8	145
21	8	-	-	.1	.1	7.9	91
Total	64	1.4	0.3	10.6	12.3	51.7	668
Mean	8.00	0.18	0.04	1.32	1.54	6.46	95.43
S.D.	0.00	0.34	0.11	1.87	1.77	1.77	35.06

Combined Machine Availability = (SMH - Repair Hours)/SMH = 0.98
Combined Machine Utilization = (PMH + Road Change Hours)/SMH = 0.85