FERIC FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA
INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

TN #
40

Evaluation of the Finning Swing Hydraulic Yarder

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SUMMARY

This Technical Note reports the results of an Interior B.C. study of a new prototype swing yarder, the Finning SY235. The SY235 has a Caterpillar 235 undercarriage with raised cab, an interlocking hydraulically-driven three-drum winch set, and a 12-metre boom. It was designed for rapid set-ups, simplicity of operation, swing capability and capability for grapple or choker yarding with the running skyline system.

During this Interior study, the prototype operated as a grapple yarder with mobile tailspar, and averaged 277 pieces per shift over 44 shifts worked. Average shift length was 8.8 hours. Downtime was not excessive for a new machine, but wear on lines and winch components are areas of concern being investigated further.

INTRODUCTION

Finning Tractor and Equipment Company, Caterpillar Tractor Co. and Lantec Industries collaborated to build an all-hydraulic yarder similar to the PeeWee yarder developed by the USDA Forest Service and Lantec for thinning coastal stands.

The Finning 235 Swing Yarder (SY235) utilizes a Caterpillar 235 excavator undercarriage. Lantec Industries designed and built the winch set, boom, and gantry. Finning assembled the yarder and provided technical advice.

After successful tests at the University of British Columbia Research Forest at Haney, the prototype yarder was moved to Jacobson Brothers Forest Products Limited for an operational test. Jacobson Brothers have operated a Skagit GT-3 Grapple Yarder since 1974 in Interior stands of large timber (Cottell et al, 1976). They agreed to compare the prototype of the Finning yarder with their Skagit. The yarder was given a complete trial. It yarded uphill, downhill, on cleanup operations and as a full production machine.

This Technical Note presents the results of early tests of the prototype of the Finning SY235 Yarder and a comparison with the Skagit GT-3.

DESCRIPTION OF THE MACHINE

The prototype of the Finning 235 Swing Yarder (Figure A) has a Caterpillar 235 undercarriage with raised cab, fully interlocking three-drum winch set, and a 12-metre boom. Actual specifications for the Yarder are given in Appendix I. The winch set is driven by hydraulic motors and utilizes an interlock system. The winch set is an unique feature of the machine and more information about it can be obtained from Lantec Industries or from publications on interlock systems and the PeeWee Yarder (Carson, 1974 and Mann, 1978).

Positive features of the Finning SY235 prototype are:

1) The walking guyline sheaves on the gantry swivel independently, reducing road change times.
2) Its good slackpulling ability is useful for lateral yarding.
3) Its ease of operation reduces training time and increases the number of potential operators.
4) The interlocking system partially suspends the loads to reduce hangups and snagging.
5) A swing of 220 degrees allows logs to be windrowed or landed with precision.
6) Parts and service are available through Finning Tractor's network of dealerships. Many parts are standard on other Caterpillar equipment.
7) Its mobility allows the operator to take advantage of yarding opportunities.
8) The yarder's versatility permits it to be used as a grapple or choker machine. It can be converted to an excavator, log loader or feller-buncher with appropriate attachments. Conversions are costly however, and should not be done on a short-term basis.
9) It is ergonomically sound.
10) The hydraulic winches operate smoothly with excellent speed and power control.
11) The interlock system has lower power requirements than a non-interlock system as power is transferred to useful work rather than lost as brake heat.

Possible negative features of the Finning SY235 prototype are:

1) The line pulls and speeds are lower than those of similar mechanical yarders. (However, this may result in less wear on the machine and less breakage of logs during yarding. Also, the lower line pulls reduce the pull on tailblocks thus reducing the chances of pulling out tailholds or pulling tailhold Cats over).
2) Facilities, parts and mechanics for maintaining hydraulic equipment must be made available at a considerable investment. The manufacturer feels, however, that maintenance of the yarder could be less costly than for mechanical yarders in the long run, once this investment is made.
3) The winch drums are not free-spooling and the machine cannot be used for gravity slacklining (shotgun yarding) as can some of its competitors. The yarder was not designed for gravity operations.
4) It is more expensive than similar mechanical machines.
5) The performance of the hydraulic winches in the winter, line wear and the wear on winch components were considered areas for study before the winch set could be proven operationally.

The Finning SY235 operated as a grapple yarder, utilizing the running skyline system (Figure B). A D7 Cat with blade and a fabricated A-frame mounted on the C-frame was used as a backspar. The grapple used was a standard (normal weight) model like the one used with the Skagit GT-3.

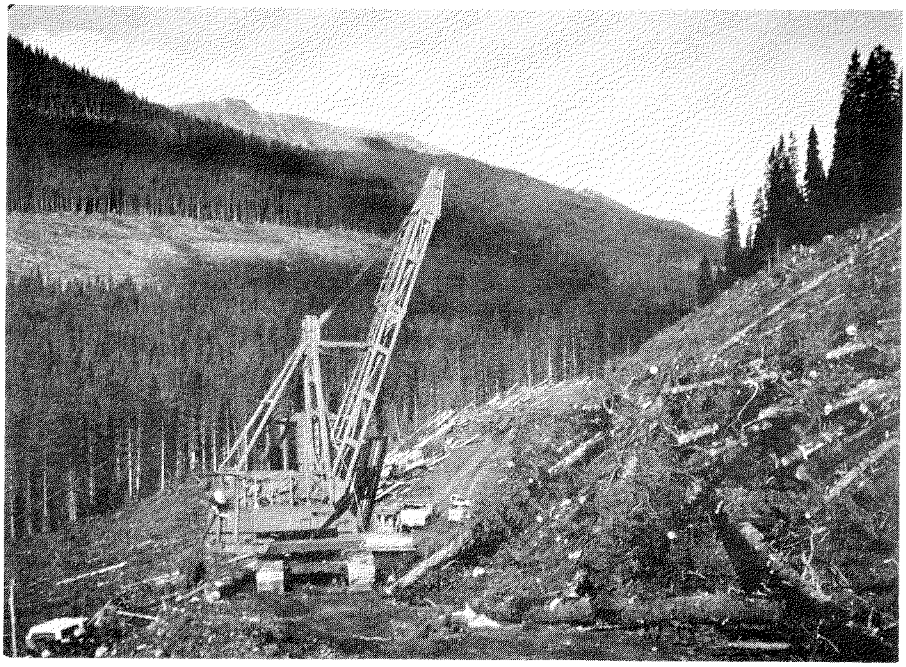


FIGURE A. The prototype of the Finning SY235 Yarder

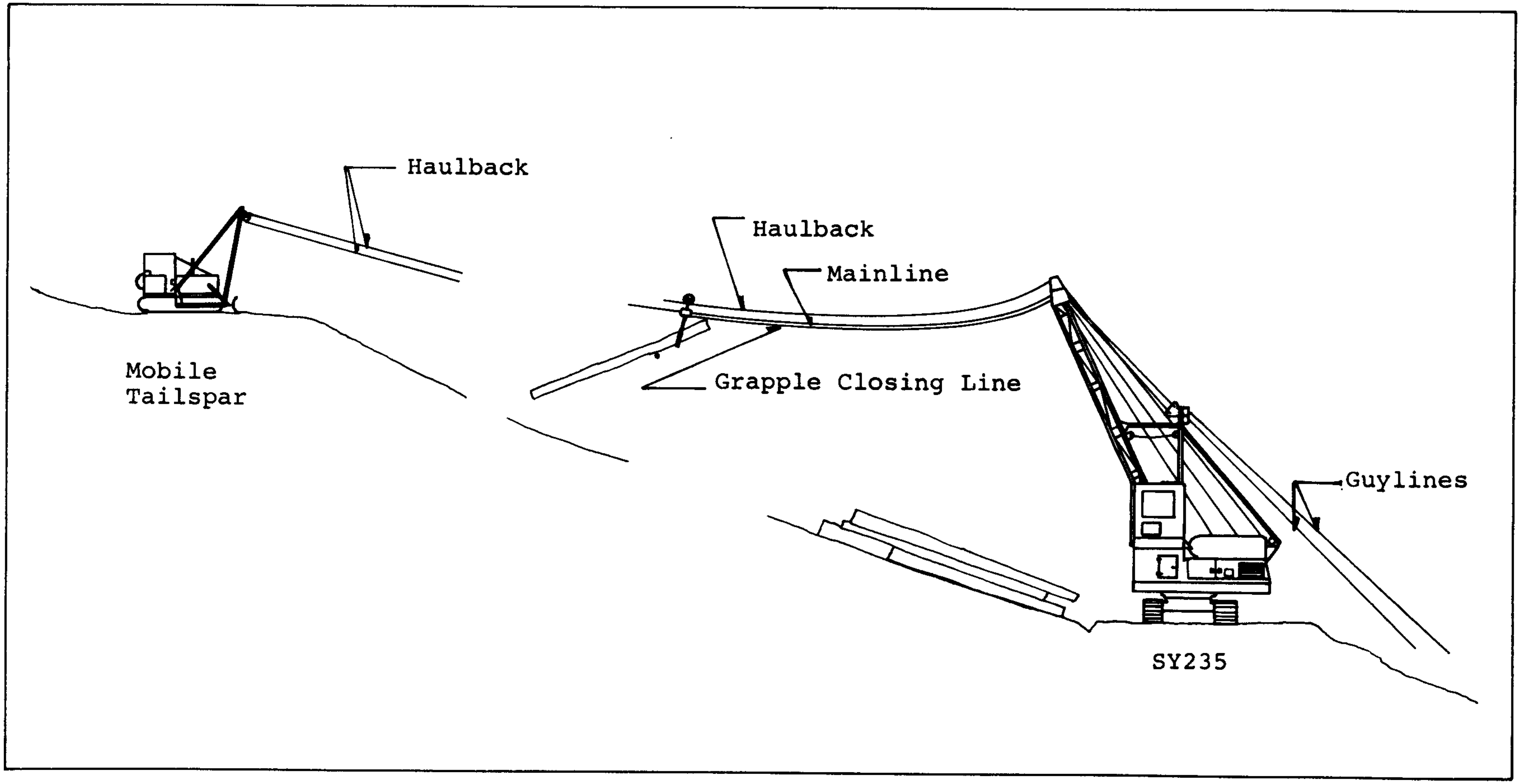


FIGURE B. Finning SY235 in running skyline configuration

THE OPERATION

The SY235 crew consisted of a yarder operator, spotter (also tailspar Cat operator) and a landing man. The crew were experienced in Interior grapple yarding.

The settings were well engineered for grapple yarding. The maximum external yarding distance was 180 metres.

During the trial logs were yarded both uphill and downhill to roadside windrows. The yarder worked its way into a setting, piling logs from one side in windrows beside the road, then out of the setting piling logs from the other side on or beside the road behind the yarder. Later the logs were skidded with a wheeled skidder to a landing where they were sorted, bucked and loaded onto trucks with a front-end loader.

STUDY METHODS

The FERIC study consisted of two parts: a shift-level study and a detailed time study using the work-sampling method.

The operator of the yarder kept a daily log of the number of pieces yarded and any major delays, as well as inserting a new Servis Recorder chart each day for the shift-level study. The charts were read by FERIC personnel and summaries of production and delays were compiled. The shift-level study was conducted for the months of August 1979, January 1980 and February 1980.

The work sample study was conducted from September 10 to September 14, 1979 on the Finning SY235. The Skagit GT-3 was studied from September 17 to September 21, 1979. The work sample study of the machines gives detailed information on delays that occur on the operation, mechanical problems and the routine followed by the operator and crew. It gives an estimate of productivity on a short-term basis. The information gained through the short-term study helped FERIC personnel to read and interpret Servis Recorder charts collected on the long-term study.

SHIFT-LEVEL STUDIES

The results of the shift-level study appear in Tables 1 and 2. Nonproductive time elements are summarized in Table 3 and Appendix II. Table 5 on page 11 gives similar information on nonproductive time elements from the work sample study of the Finning SY235. No cold-weather trouble with the winch hydraulics was noted.

TABLE 1. Summary of Machine Time from Operators' Shift Reports (given in hours per shift)

		Finning SY235	Skagit GT-3
No. of Scheduled Shifts		51	54
Productive Time	Regular yarding cycles	4.8	6.1
	Changing yarding roads	.5	.4
Delay Time	Mechanical	2.5	1.3
	Move (landings)	.4	.2
	Other non-mechanical	.6	.3
Total Hours		8.8	8.3

TABLE 2. Summary of Production from Operators' Shift Records

	Finning SY235	Skagit GT-3
Piece count during study	12 201	14 769
Net volume during study (m^3)	9 448	11 428
Average piece size - net volume (m^3)	0.77	0.77
Number of shifts worked[1]	44	53
Number of scheduled shifts	51	54
Piece count per shift worked	277	279
Net volume per shift worked (m^3)	215	216
Productivity - cubic metres/SMH[2]	21.1	25.6
- cubic metres/PMH[2]	34.9	32.6

[1] Number of shifts during which some production was achieved.

[2] Definitions of machine time taken from Bérard, J.A. et al., "Standard definitions for machine availability and utilization," W.S.I. No. 2428 (B-1), Canadian Pulp and Paper Association, Montreal, 1968.

TABLE 3. Summary of Nonproductive Time Elements for the Periods August 1979, January 1980 and February 1980

Element	Finning SY235		Skagit GT-3	
	Total Hours	% of SMH	Total Hours	% of SMH
Repair	117.2	26	56.4	13
Service	12.3	3	11.7	2
Non-mechanical delays	28.7	6	17.2	4
Landing changes	19.7	4	11.0	2
Total nonproductive time	177.9	39	96.3	21
Total scheduled machine time	448.6	100	446.4	100

WORK SAMPLE STUDY

A work sample study of the Finning SY235 was conducted from September 10 to September 14, 1979. Figure C presents the percentage distribution of scheduled time during the study. Delays are presented in Table 5.

Average production during the study was 340 logs per shift. Based on an average piece size of 1.39 m^3 (gross volume), production averaged 473 m^3/shift.

SITE CONDITIONS--WORK SAMPLE AREA

The Finning SY235 operated on several sites during the operational trial. Stand conditions for the work sample study area are given in Table 4.

TABLE 4. Stand Conditions for Work Sample Study Area

Volume per Hectare (m^3/ha)	280
Species Composition (% by volume)	
Spruce	84
Balsam	14
Cedar	1
Lodgepole Pine	1
Average Butt Diameter (cm)	38
Maximum Butt Diameter (cm)	94
Average Length (m)	17
Average Net Volume per Piece (m^3)	0.97

During the work sample study of the machine the terrain was uniform with sufficient deflection for grapple yarding. Some hangups occurred during uphill yarding when logs were caught in the high log decks. Visibility was generally good.

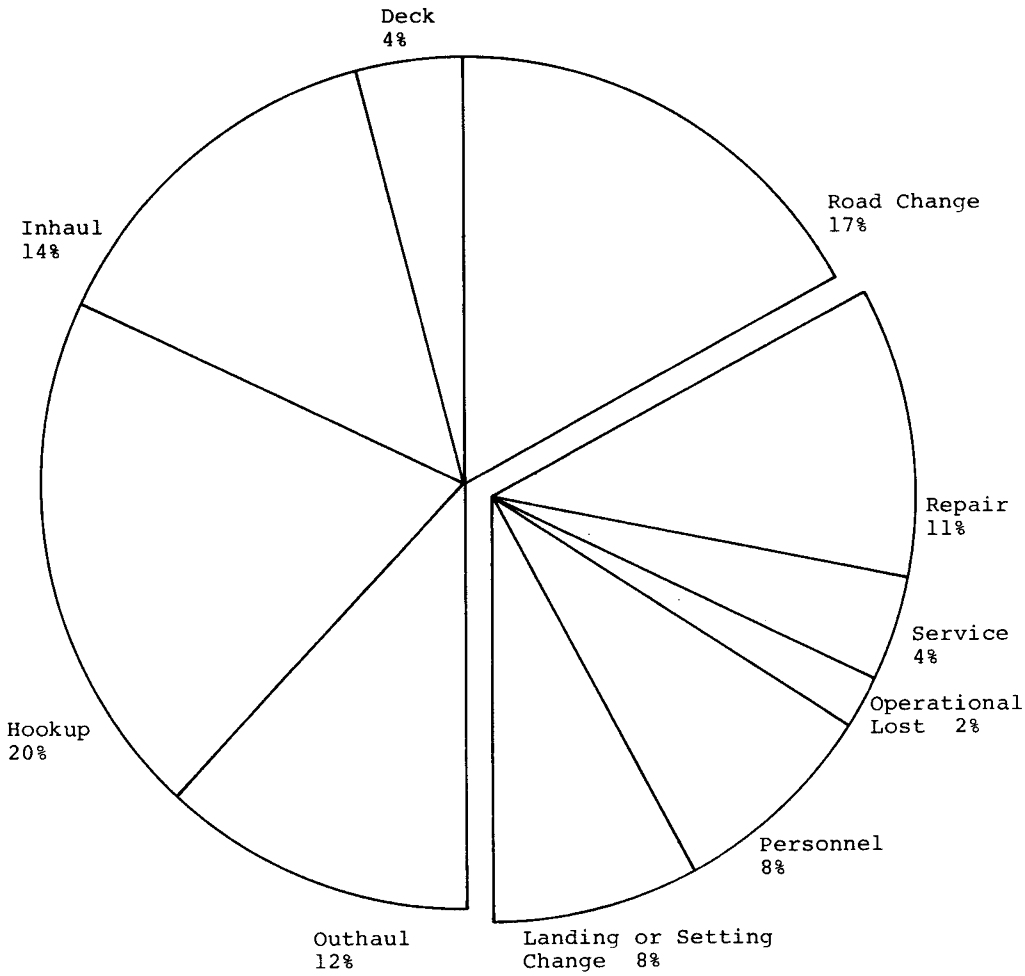


FIGURE C. Percent distribution of scheduled time from the work sample study of the Finning SY235

TABLE 5. Summary of Delays From the Work Sample Study of the Finning SY235. September 10-14, 1979

Repair	
Welding on grapple	4.5%
Broken haulback	2.1%
Lines fouled on drum	1.9%
Grapple wouldn't open	1.2%
Mainline connector broke	1.2%
Other	1.0%
	11.0%
Service	
Fuel machine	1.7%
Grease machine	1.2%
Warmup machine	0.7%
Add motor oil	0.2%
Clean windows	0.2%
	4.0%
Operational Lost	
Grapple caught on lines	0.8%
Hangups during inhaul phase	0.7%
Other	0.5%
	2.0%
Personnel	
Lunches	4.1%
Coffee breaks	3.3%
Crew to bush	0.3%
Other	0.3%
	8.0%

PRODUCTION COMPARISON

Table 6 shows the production of both the prototype Finning Yarder and the Skagit Yarder. The substantial difference between long-term and short-term productivities of the yarders is due primarily to the increased downtime in the long term. For example the repair and service times for the SY235 are 29% of Scheduled Machine Hours for the long-term study and 15% for the short-term study.

TABLE 6. Comparison of Net Volume Yarded by the Finning SY235 and the Skagit GT-3. (Based on 8-Hour Shift)

	Finning SY235	Skagit GT-3
Productivity (m^3/shift)		
- short term (work sample study)	300	295
- long term (shift-level study)	195	208
Availability (%)	72	84
Utilization (%)	60	78

It must be noted that the Finning SY235 is a prototype machine and as such was shut down occasionally during scheduled shifts to perform hydraulic pressure checks, to correct minor mechanical and line problems as they occurred. Under normal circumstances many of these minor problems would be checked at the end of the shift, thus not reducing the availability of the machine during the shift.

COST ANALYSIS

Table 7 shows a cost calculation comparing the Finning SY235 with a new Skagit Yarder. The machine costs for the Skagit Yarder are based on the present cost of a new machine, the actual Skagit machine studied was five years old and has a lower owning cost. See Appendix III for a detailed cost breakdown.

The cost figures are based on the actual production and hypothetical machine costs. They are not recorded company costs and should be used for comparative purposes only. There is no allowance for engineering, roads, supervision, employee transportation, overhead or profit.

TABLE 7. Yarding Costs for New Yarders (Based on 8-Hour Shift)

	Finning SY235	Skagit GT-3
Owning Costs ($/shift)		
- yarder	606	520
- backspar	60	60
Operating Cost ($/shift)		
- yarder	657	636
- backspar	102	102
Total yarding cost ($/shift)	1425	1318
Average production based on shifts with production		
- net volume/shift (m^3/shift)	195	208
- pieces/shift	252	269
Yarding cost ($/$m^3$)	7.31	6.34
Falling, limbing and bucking cost ($/$m^3$)	2.23	2.23
Skidding cost ($/$m^3$)	2.24	2.24
Loading cost ($/$m^3$)	1.37	1.37
Total cost of wood on the truck		
- $/$m^3$	13.15	12.18
- $/cunit	37.24	34.49

ERGONOMICS

FERIC conducted an ergonomic check of the prototype Finning SY235 Yarder using the preliminary FERIC checklist (Zerbe, 1979). A summary of the checklist results appears in Appendix IV. The roomy cab, and four-way joystick-type controls of this ergonomically sound machine are of particular interest.

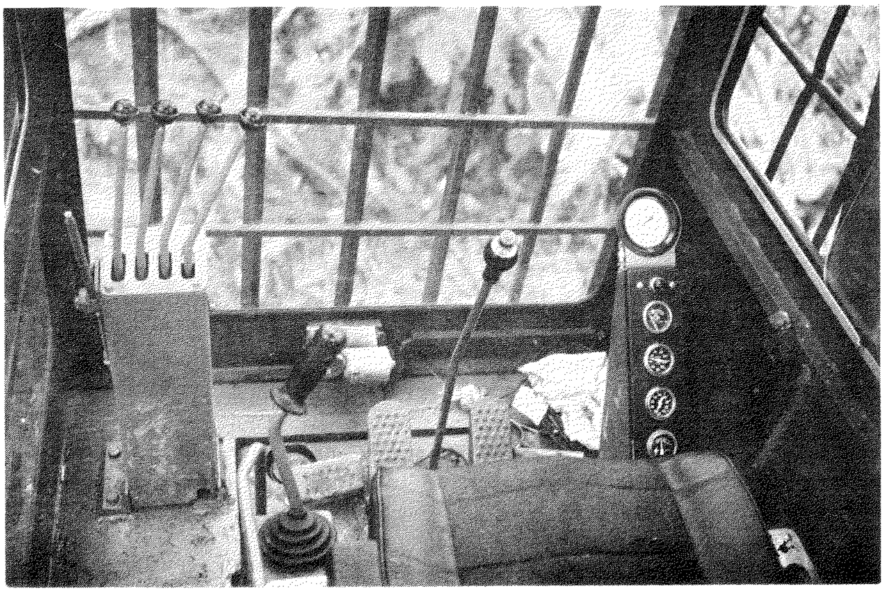


FIGURE D. Controls of Finning SY235

CONCLUSION

The Finning Yarder SY235 is a viable machine for logging steep slopes and environmentally sensitive sites in Interior British Columbia.

The prototype Finning SY235 performed well during its test at Jacobson Brothers' operations at Horsefly, B.C. It yarded uphill and downhill, worked in full production capacity and as a cleanup machine with equal success. Production was sufficient to meet the high ownership cost of this yarder, but costs of wood on the truck were higher than those for the older, depreciated Skagit GT-3. The winch hydraulics performed well in all weather conditions during the test. Line wear and premature wear of winch components are areas of concern and are being investigated by the manufacturer.

REFERENCES

1. Carson, W.W. and J.E. Jorgensen. 1974. Understanding interlock yarders. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Note PNW-221. Portland, Oregon. 13 pp.

2. Cottell, P.L., B.A. McMorland and G.V. Wellburn. 1976. Evaluation of cable logging systems in Interior B.C. and Alberta. FERIC Technical Report No. TR-8. Vancouver. 40 pp. + Appendices.

3. Mann, C.N. 1978. The PeeWee Yarder. Skyline Logging Symposium. Oregon State University. 9 pp.

4. Zerbe, W.J. 1979. Preliminary FERIC guide to ergonomic evaluation of logging equipment. FERIC Technical Note No. TN-30. Vancouver. 28 pp. + Appendix.

APPENDIX I

MANUFACTURER'S MACHINE SPECIFICATION SHEET

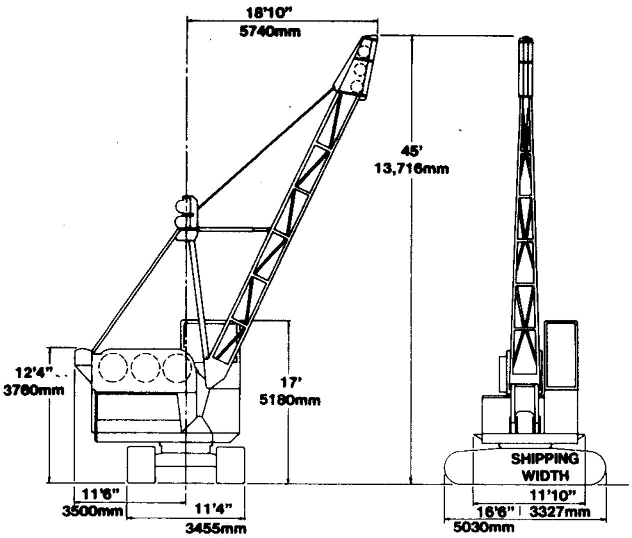
MODEL SY235 RUNNING SKYLINE YARDER

PERFORMANCE - DRUM SIZES - CABLE CAPACITIES

	Main Drum		Slackpulling Drum		Haulback Drum		Strawline Drum	
Barrel Dia.	20.5"	(521 mm)	20.5"	(521 mm)	20.5"	(521 mm)	11"	(280 mm)
Flange Dia.	35.0"	(889 mm)	35.0"	(889 mm)	35.0"	(889 mm)	24"	(610 mm)
Barrel Lengths	24.5"	(622 mm)	24.5"	(622 mm)	24.5"	(622 mm)	13"	(330 mm)
Recommended Cable Sizes	5/8"	(16 mm)	5/8"	(16 mm)	5/8"	(16 mm)	5/16"	(8 mm)
Cable Capacities	2600'	(792 M)	2600'	(792 M)	2600'	(792 M)	3600'	(1097 M)
Recommended Lengths	1400'	(427 M)	1400'	(427 M)	2600'	(792 M)	3600'	(1097 M)
MID - DRUM								
Line Pulls Up To -	12,000 lbs.	(5443 Kg)	5,000 lbs.	(2268 Kg)	10,000 lbs.	(4536 Kg)	2,325 lbs.	(1055 Kg)
Line Speeds Up To -	1,000 F.P.M.	(305 M/M)	1,000 F.P.M.	(305 M/M)	1,000 F.P.M.	(305 M/M)	686 F.P.M.	(209 M/M)
Rigging Speeds -	374 F.P.M.	(114 M/M)	374 F.P.M.	(114 M/M)	1226 F.P.M.	(374 M/M)	686 F.P.M.	(209 M/M)

Maximum Main Line Tension - 17,000 lbs. (7712 Kg)

Lateral Yarding - Drop Line Pull - 13,450 lbs. (6100 Kg)
- Drop Line Speed - 374 F.P.M. (114 M/M)



Caterpillar Engine

Flywheel horsepower @ 2000 RPM 195
Kilowatts 145

(Kilowatts (kW) is the International System of units equivalent of horsepower.)

Caterpillar 4-stroke-cycle 3306 diesel Engine with 6 cylinders, 4.75" (121 mm) bore, 6" (152 mm) stroke and 638 cu. in. (10.5 litres) displacement.

hydraulic system

Two variable displacement piston pumps power the yarder and travel circuits.

Output of each pump @ rated engine RPM and:
1510 psi (104 bar) maximum flow .... 2 x 94 gpm (356 litres/min)
3600 psi (248 bar) minimum flow .... 2 x 28 gpm (106 litres/min)

A double-section gear pump powers the swing and pilot-control circuits.

Output to swing circuit @ rated engine RPM and 1000 psi (69 bar)..... 59 gpm (223 litres/min)
Output to pilot system @ rated engine RPM and 335 psi (23.1 bar) ..... 20 gpm (76 litres/min)

Oil-to-air hydraulic cooler is mounted in front of engine radiator.

Relief valve settings:

Yarder circuits .... 3600 psi (248 bar)
Travel circuits .... 4000 psi (276 bar)
Swing circuit .... 2350 psi (162 bar)
Pilot circuit .... 335 psi (23.1 bar)

drive

Full hydrostatic; each track is driven by an independent hydraulic motor. Two travel pedals: right pedal gives forward movement . . . the left, reverse. Triple-reduction, spur-gear final drive, fully enclosed, splash lubricated. Duo-Cone® Floating Ring Seals on output shaft.

Maximum travel speed @ rated engine RPM:
Forward and reverse .... 2.4 MPH (3.8 km/h)

swing mechanism

Case-hardened drive gears. Hydraulic motor provides rotational speed of 5.5 RPM. Shoe-type brake on swing gear case, manually applied, holds upper structure steady on side slopes. Smooth, modulated deceleration occurs when swing control lever is released, assuring accurate positioning for next work cycle.

controls

Two joystick hand levers actuate all yarder and swing functions.

Right lever: Move forward and backward to lower and raise interlock (haulback) tension. Left and right to control slackpulling function.

Left lever: Move forward and backward to control speed and direction of yarder primary drive. Left and right to control swing direction.

Oblique movement of either lever operates any two functions simultaneously. Foot pedal combines flow from both piston pumps to increase yarding speeds. Manually applied safety lever on the left console completely neutralizes the control system.

service refill capacities

	U.S. Gallons	(litres)
Fuel tank	105	(397)
Cooling system	11.5	(43.5)
Lubrication:		
Engine oil	7.25	(27.4)
Pump drive	1.75	(6.6)
Swing drive	9	(34.1)
Final drives (each)	14	(53)
Hydraulic system	190	(720)
Hydraulic tank	87	(329)

Refer to Caterpillar 235 Excavator Spec sheet for more detailed data.

APPENDIX II

SUMMARY OF NONPRODUCTIVE TIME ELEMENTS

SUMMARY OF NONPRODUCTIVE TIME ELEMENTS
August 1979, January 1980, February 1980
Finning SY235: Jacobson Brothers

The time distribution for this period shows the following:

	Total hr
Repair	117.2
Service	12.3
Other Non-Mechanical Delays	28.7
Landing Changes	19.7

MECHANICAL DELAYS

No. of Occurrences	Reasons	Total Time (hr)
1	Replace drum shaft	45.0
12	Finning mechanic working on Yarder	20.5
9	Fix haulback or replace with new cable	16.1
1	"Work on Yarder"	6.7
11	Change closing line	5.9
5	Fix grapple or change grapple	5.1
4	Fix carriage or change carriage	4.9
2	Work on tailhold Cat	4.3
1	Put lights on Yarder	4.1
4	Fix mainline	2.4
1	Respool strawline	0.7
1	Broken A-frame on tailhold Cat	0.6
1	Fix exhaust	0.3
1	Work on guylines	0.3
1	Fix broken hydraulic hose	0.3
55	TOTAL	117.2

Service

No. of Occurrences	Reasons	Total Time (hr)
17	Fuel Yarder	5.4
11	Warmup Yarder	3.3
1	Yarder would not start	2.0
2	Grease Yarder	0.7
2	Service	0.4
1	Add water to tailhold Cat	0.4
1	Add hydraulic oil to Yarder	0.1
35	TOTAL	12.3

OTHER NON-MECHANICAL DELAYS

No. of Occurrences	Reasons	Total Time (hr)
1	Operator sick	9.0
30	Coffee breaks	8.3
5	Window frozen shut--no chart in Servis Recorder	7.7
1	Rolled tailhold Cat	1.8
1	Ran out of fuel	1.1
1	Finning visitor	0.4
2	Extra lunch	0.2
1	Tailhold Cat stuck	0.2
42	TOTAL	28.7

SUMMARY OF NONPRODUCTIVE TIME ELEMENTS
August 1979, January 1980, February 1980
Skagit GT-3: Jacobson Brothers

The time distribution for this period shows the following:

	Total hr
Repair	56.4
Service	11.7
Other Non-Mechanical Delays	17.2
Landing Changes	11.0

MECHANICAL DELAYS

No. of Occurrences	Reasons	Total Time (hr)
4	Splice, upend or add haulback	14.2
2	Repairs to tailhold Cat	8.3
1	Broken pendent line	7.4
1	Blew expander tube on haulback	6.5
7	Work on mainline	4.5
11	Replace closingline	3.6
1	Work on haulback brake	3.5
4	Repairs to grapple	1.9
1	Broken compressor line	1.5
1	Change grapple	1.3
2	Broken guyline	1.0
1	Install new window	0.5
1	Problems with fuel system	0.5
1	Fix lights	0.3
1	Work on mainline brake	0.2
1	Respool mainlines	0.2
1	Other small repairs	1.0
41	TOTAL	56.4

Service

1	Frozen airlines	4.5
2	Yarder would not start	3.2
1	Service	1.2
3	Warmup Yarder	1.0
1	Check over Yarder	1.0
1	Fuel Yarder	0.6
1	Grease Yarder	0.2
10	TOTAL	11.7

OTHER NON-MECHANICAL DELAYS

No. of Occurrences	Reasons	Total Time (hr)
1	Work on forest fire	7.0
3	Tailhold Cat stuck	3.8
9	Coffee breaks	2.6
1	Wait for fallers	1.3
3	Radios went dead	1.2
1	Tailhold Cat flipped over	1.0
3	Extra lunch	0.3
21	TOTAL	17.2

APPENDIX III

COST COMPARISON WORK SHEETS FOR

FINNING SY235 AND SKAGIT GT-3

APPENDIX III

Ownership Costs	Finning SY235	Skagit[1] GT-3
Purchase price ($)	487,760	418,733
Residual value ($)	97,552	83,747
Depreciable value ($)	390,208	334,986
Annual Utilization (hr/yr)	1600	1600
Equipment depreciation ($/year, 5 year period)	78,042	66,997
Interest ($/year)	33,168	28,474
Taxes, license, insurance and storage ($/year)	9,950	8,542
Annual ownership cost ($/year)	121,160	104,013
Ownership cost per hour ($/hour)	75.73	65.01

Operating Costs	Finning SY235	Skagit[1] GT-3
Repair and maintenance ($/hour)	24.39	20.94
Fuel and lube ($/hour)	7.48	9.51
Lines and rigging ($/hour)	8.46	7.21
Crew ($/hour)	41.81	41.81
Operating cost ($/hour)	82.14	79.47
Machine rate ($/hour)	157.87	144.48

Note:
- Purchase Price : 1980 new price, $C.
- Depreciation : straight line, 5-year life with a 20% residual, 200 operating days per year.
- Interest : 13.6% of half the purchase price per year.
- Repairs and Maintenance : 8% of the purchase price per year.

[1]Hypothetical new Skagit GT-3 in 1980. Purchase price is inflated from original 1975 price.

APPENDIX IV

ERGONOMIC EVALUATION

FINNING SY235 YARDER (PROTOTYPE)

APPENDIX IV

Ergonomic Evaluation
FINNING SY235 YARDER (PROTOTYPE)

The ergonomic checklist proposed by Zerbe in FERIC Technical Note No. TN-30 (1979) was used to evaluate the Finning Yarder. The unit examined was a prototype. Several modifications have been proposed and carried out since the check was completed in September, 1979.

	Category	Comments
1.	Climbing On and Off:	The distance from the ground to the first step (on top of the tracks) is high. The placement of a mid step on the undercarriage and a handhold would assist in climbing on and off. Guard rails are well placed. Ladders and walkups were satisfactory.
2.	Operator's Cab:	The cab is roomy, quiet and comfortable. There is room for a second person to stand comfortably behind the operator's seat. This would facilitate training of new operators. Fire extinguishers could be activated quickly and an automatic system (activated from the cab) protects the engine compartment.
3.	Operator's Seat:	The seat offers good support. Wider armrests are comfortable. The seat fabric would be comfortable in summer or winter.
4.	Locations of Controls and Control-Actuating Forces:	The controls are well placed to allow comfortable yarder operation (See Figure D).

Category	Comments
	The main controls are two joysticks; one to control swing (left-right) and line direction (forward-back), the other to control line tension (forward-back) and the grapple opening or closing (left-right). A transmission shift switch (Hi-Lo) was later changed from a floor control to a button switch on one joystick. It is suggested the guyline control panel be moved to a position behind the seat (located at present in the front left of cab), where the guyline winches can be observed. Forces needed to actuate controls were within the Zerbe's guidelines.
5. Instruments and Trouble Signals:	Satisfactory. Automatic outside "beeper" to warn bystanders when machine is in travel mode.
6. Visibility:	For Yarding: Forward visibility is good, sweeping through 50^{o} front left to right. Seat position is far back requiring the operator to bend forward to see up steep sidehills. Left side visibility is good. Right side visibility of the winch is somewhat restricted by the gantry and cab frame. For Moving: The machine can be swung to any direction to give good visibility.
7. Lights:	No lights: Machine was not used at night.

Category	Comments
8. Cab Climate:	The heater has since been replaced to provide adequate warmth for winter operation. Windows were opened to allow fresh air to circulate in warm weather.
9. Air Quality:	No evidence of fumes were detected in the cab.
10. Noise and Vibration:	Noise levels in the cab were within U.S. Department of Labor, Occupational Safety and Health Administration dB-A limits, with windows open. The winch set tended to "whine", but this would not affect an operator wearing radio earphones. Vibration occurred on inhauls. However, the seat prevented any discomfort.
11. Machine Maintenance:	The yarder is easy to service and maintain. Panels can be removed around the engine to provide good accessibility. A service chart and diagram are mounted on the machine and space is provided for tool storage underneath the operator's cab. The winch set is readily serviced and most parts are of a modular design that allows for quick replacement.

12. Changes Recommended:

a) Installation of a step and hand-hold to assist the operator when mounting the yarder.

b) Relocation of the guyline control levers so the operator can easily see the guylines while operating the winches.