WOOD HARVESTING

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EVALUATION OF A DENIS D3000 TELESCOPIC LOG PROCESSOR

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Abstract

This study's objectives were to evaluate the productivity and costs associated with operating a Denis D3000 telescopic processor, and to test the accuracy of its length-measuring device. The Denis D3000 is one of a series of log processors being studied by the Forest Engineering Research Institute of Canada (FERIC).

The processor, employed by Fletcher Challenge Canada Limited in the Southern Interior of British Columbia, was monitored in early 1990. The net stand volume of the study block was 437.8 m^3/ha with an average net stem size of 0.53 m^3. Performance was evaluated under two different operating conditions: while processing roadside decks piled by a grapple yarder, and while processing hand-felled right-of-way wood.

Introduction

In recent years, mechanized delimbing and processing have improved the safety and efficiency of harvesting operations in the Interior of British Columbia. Interior operations are well suited to mechanical processing because the timber is generally less than 60 cm in diameter at the butt, and less than 30 m in length. One log processor that is designed to operate in timber of this size, as well as in timber with butt diameters up to 66 cm, is the Denis D3000 telescopic boom processor. In early 1990, the Forest Engineering Research Institute of Canada (FERIC) studied the productivity and costs associated with operating a Denis D3000 telescopic processor, and tested the accuracy of its length-measuring device.

The Denis D3000, manufactured by Équipements Denis Inc. in St. Hyacinthe, Quebec (with a branch office in Kamloops, British Columbia), is capable of delimbing, bucking, measuring, stacking, and sorting logs in a roadside or landing situation.

Study Method

The evaluation of the Denis D3000 included two methods of collecting timing data. For the shift-level study, a DSR Servis recorder was mounted on the processor to monitor machine activities. The operator was asked to place a recording chart in the recorder prior to every shift, tally the number of merchantable stems processed, and note all delays longer than 10 minutes. The total volume of logs produced from the block was determined from millyard weigh-scale returns. From this compiled information, figures on machine availability, utilization, production, and costs were calculated.

A FERIC researcher used a hand-held data logger to collect timing data, with accuracies to one-hundredth of a minute (Appendix I). Data concerning butt classes, species, long-butting,[1] and number of logs per stem were also recorded.

The butt classes were divided into 10-cm increments (Table 1). These increments made volume estimates more accurate than if overall volume estimates were made using one average stem volume for all the trees in the stand. By measuring a sample of stems

[1] Long-butting is a term that refers to cutting off the butt end of the stem to eliminate defect (e.g. rot, flare, pistol grip, undercut notches, stump pull, etc.) before processing commences.

Keywords: Delimbing, Slashing, Processors, Stroke delimbers, Machine evaluation, Productivity, Costs, Denis D3000 Processor.

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Table 1. Butt Measurements

Butt-diameter class, at mid-point (cm)	Butt-diameter range (cm)
10	≤14.9
20	15.0 - 24.9
30	25.0 - 34.9
40	35.0 - 44.9
50	45.0 - 54.9
60	≥55.0

in each diameter class, down to a 10-cm top, FERIC was able to derive the average volume per stem for each diameter range. However, these volumes apply only to areas where the detailed timing occurred, and not to the entire block.

Also, the processor's length-measuring device was evaluated for accuracy. The operator processed and measured a number of logs, then set them aside for manual measurement before placing them in the log deck. The manual measurements were then compared to the machine's target lengths.

Site and System Description

The study area was located approximately 50 km east of Kelowna, British Columbia. The block had a westerly aspect with an average slope of 45% and a stocking mix of lodgepole pine (attacked by mountain pine beetle), Engelmann spruce, sub-alpine fir, western red cedar, Douglas-fir, and western larch. The timber cruise compilation for the block identified a net stand volume of 437.8 m^3/ha. Also, a sample scale carried out by FERIC during the detailed-timing study showed the average stem volume was 0.53 m^3.

Harvesting on the study block was done by Armitage Contracting Limited of Armstrong, British Columbia for Fletcher Challenge Canada Limited. The operation utilized a Washington 108 grapple yarder, a Caterpillar D8 mobile backspar, an International TD20 tailhold for the yarder guylines, and the Denis D3000 telescopic processor mounted on a Komatsu PC220LC carrier (Figure 1). Loading and hauling functions were performed by two independent self-loading logging trucks. This system produced approximately 200 m^3/shift.

Because the cutblock was felled by hand rather than by a feller-buncher, the grapple yarder could not produce sufficient volumes to keep the processor fully occupied. Consequently, the D3000 was used to daylight-process[2] the right-of-way stems in the cutblock before the subsequent felling and yarding phases commenced. This not only kept the processor busy, but also assisted the yarding phase by cleaning up the decking area. Timber one tree length from the road was directionally felled towards the road, thus enabling the processor to reach all felled stems. The stems were then processed (butt first), loaded, and hauled before the remaining trees were felled and yarded. Using the D3000 to yard and process this wood reduced the overall system cost because the yarder did not handle the wood.

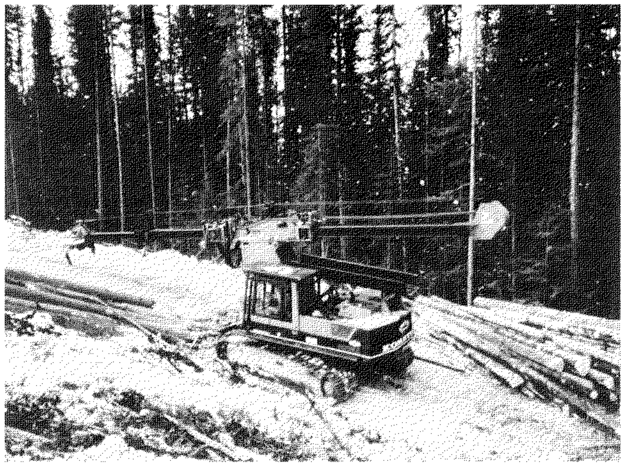

Figure 1. Denis D3000 telescopic boom processor.

The Denis D3000 has a unique telescopic boom feature. The main boom tube is powered through the boom pedestal by a feed chain and drive sprocket mechanism while a smaller tube section telescopes inside the main boom by means of double cables and pulleys. Both boom sections are stroked simultaneously for rapid processing speed. The processing head is attached to the end of the smaller boom tube and includes a set of grapple arms with integral delimbing knives, and fixed front and rear delimbing knives. A chain saw for bucking and topping completes the set-up. The rear assembly is fixed to the boom pedestal and includes a larger set of holding arms; a butt plate; a second, larger, bucking chain saw (on the 81-cm funnel model); and an Entek length-measuring system. Figure 2 shows the Denis D3000 at work in the grapple-yarded wood.

Operation of the Denis D3000 is similar to that of other stroke delimbers. The front grapple arms secure a stem approximately three metres from the butt then pull it away from the deck towards the rear assembly. After the stem passes by the elec-

[2] Daylight-process is defined as delimbing, bucking, and decking unyarded stems felled one tree length from the road.

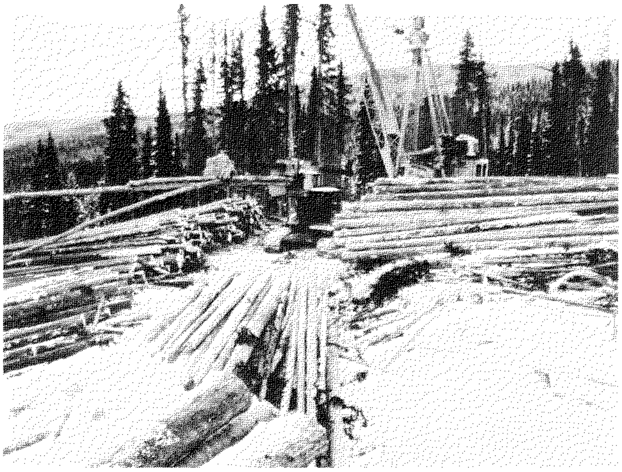

Figure 2. Denis D3000 decking wood for grapple yarder.

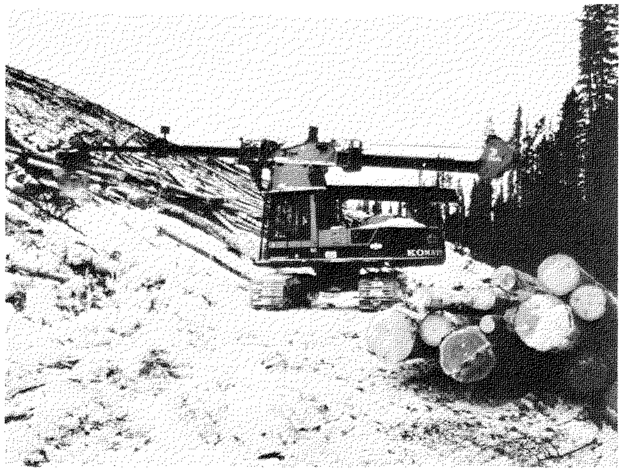

Figure 3. Denis D3000 long-butting a stem.

tronic photo-eye of the length-measuring device (located between the rear holding arms and the butt plate), the rear holding arms secure it. The processor head is then powered along the stem removing branches at speeds up to three metres per second until the minimum top diameter, or a pre-determined length, is reached. The top portion (waste) is bucked and dropped in the slash pile. After topping is completed, the machine's front grapples are opened slightly and the boom is retracted. The front grapples then grasp the log again as it is released by the rear holding arms, and position it over the deck where it is finally released.

Longer stems, comprising two logs, were pushed partially into the funnel, or tray. The funnel is located directly behind the rear assembly and prevents the stem from dropping onto the carrier shrouding. The same topping process as described earlier occurs, except the boom retracts to a pre-determined length. The topping saw then cuts and drops the short log into the log deck. Finally, the butt log is retrieved from the funnel and decked. Occasionally, the delimber handled very large stems by processing and decking the butt log independently of the remaining log.

Long-butting is done with the topping saw, or with the chain saw mounted on the rear assembly. The operator preferred not to use the rear bucking saw because it was more efficient to retrieve the top after each long-butting cut than to use the rear chain saw and drop waste near the road and the machine (Figure 3).

Results and Discussion

The contractor operated the processor eight hours per shift, five shifts per week. A total of 38 shifts were recorded during the study period from February 5 to March 29, 1990; 14 232 stems were processed, or approximately 8728 m^3 of wood. The total ownership and operating cost was \$91.76/h. (Costs were derived by FERIC and are not the actual costs incurred by the contractor, see Appendix III).

Shift-Level Study

The Denis D3000 was monitored for 38 productive shifts over a period of 53 days. The 15 non-productive shifts were weekends (operator off). Right-of-way and yarded wood could not be separated in the shift-level study; therefore, production figures are lower and costs are higher than if only yarded wood had been processed. Discussion with the operator revealed that relatively short move times from the yarded decks to right-of-way processing were also not recorded. Table 2 shows the shift-level results.

Average hourly production for processing the combination of yarded and right-of-way wood was 47.8 stems/h, or 29.3 m^3/h (total time). The total processing cost for all the wood in the study block was determined to be \$3.13/m^3, or \$1.92/stem, when using the hourly machine costs derived in Appendix III. In addition, machine utilization for the processor was determined to be 81.7% with an availability of 92.2%. A summary of delays in the shift-level study is provided in Appendix II.

Detailed-Timing Study

Almost 39 h of detailed timing were done randomly during the shift-level monitoring period. All productive time and delays less than 10 min were considered part of the detailed-timing study. The processing of grapple-yarded wood and right-of-way wood were timed separately and summarized (Table 3).

Table 2. Shift-Level Study: Summary

Elements	Results
Productive machine hours (PMH)	
Yarded wood (h)	176.00
Right-of-way wood (h)	67.00
Mechanical delay hours (MDH)	
Repairs (h)	13.20
Service (h)	10.00
Subtotal (h)	23.20
Nonmechanical delay hours (NDH)	
Operational (h)	18.20
Organizational (h)	13.20
Subtotal (h)	31.40
Total: All delays (h)	54.60
Total machine hours (TMH) (h)	297.60
Utilization (PMH/TMH) (%)	81.7
Mechanical availability [(TMH-MDH)/TMH] (%)	92.2
Total stems processed (no.)	14 232
Volume produced (m^3) [a]	8 728
Shifts with production (no.)	38
Piece production	
Stems/PMH (no.)	58.6
Stems/TMH (no.)	47.8
Volume production	
m^3/PMH	35.9
m^3/TMH	29.3
Production/8-h shift	
Stems (no.)	382.4
Volume (m^3)	234.4

[a] Volumes from millyard weigh-scale.

Detailed-timing data were collected for the processing of 1780 stems of grapple-yarded wood (or 943 m^3). Analysis of these data indicates productivity was 84.4 stems/h or 44.8 m^3/h (productive time). In comparison, timing analysis of 1142 stems (or 605 m^3) of right-of-way wood shows productivity was 64.2 stems/h or 34.0 m^3/h (productive time). As a result, costs for the yarded wood were \$2.51/m^3 or \$1.33/stem, while costs for the right-of-way wood were \$3.30/m^3 or \$1.75/stem. All costs associated with detailed timing assume a machine utilization of 81.7% so that a direct comparison can be made with the cost results of the shift-level study.

The data were separated to compare the results of processing yarded wood (decked by the yarder) and right-of-way wood. Productivity was lower for right-of-way processing because extra time was taken to sort and deck the logs along the road. Also, more time was associated with the moving and cleaning elements. Although it cost an extra \$0.79/m^3 to process this wood, it is important to remember there was no yarding cost.

Although the processing of grapple-yarded decks was more productive than processing right-of-way wood, FERIC observed two activities that increased processing time over that which would be expected if the machine was working on a roadside block harvested by a grapple skidder. Before the processor could begin work, those stems with butts directed away from the D3000 had to be turned around, and decks that were too high had to be broken down. Although a quantitative timing comparison was not available, FERIC felt productivity increases could result from consistent butt orientation and lower

Table 3. Detailed-Timing Study: Summary

Elements	Yarded production wood	Right-of-way wood	Total
Total productive time (min)	1 048.79	921.61	1 970.40
Total aborted stems time (min)	53.51	32.86	86.37
Total sum time (min)	114.41	70.82	185.23
Total delays <10 min (min)	48.26	41.86	90.12
Total study time			
Minutes	1 264.97	1 067.15	2 332.12
Hours	21.08	17.79	38.87
Total stems processed (no.)	1 780	1 142	2 922
Total volume processed (m^3)	943.40	605.26	1 548.66
Average volume processed (m^3/stem)	0.53	0.53	0.53
Total stems/hour (no.)	84.4	64.2	75.2
Total volume (m^3/h)	44.8	34.0	39.8

log decks. However, orienting butts towards the road negatively affects the productivity of the yarder, and lower log decks are possible only if more roads are built to shorten the yarding distance.

The productive time is further broken down into separate elements in Table 4. Elements that affect the processing cycle can vary from stem to stem. A description of the elements used during the detailed-timing study are found in Appendix I. Production figures are again broken down to show the influence of different species and diameter classes. A detailed summary is shown in Table 5. Predictably, the number of stems processed per hour decreased and

Table 4. Breakdown of Productive-Timing Elements for All Cycles[a]

Activity	Yarded wood		Right-of-way wood		Total	
	min	%	min	%	min	%
Pick	338.02	30.7	226.48	23.8	564.50	27.4
Process	286.12	26.0	198.83	20.8	484.95	23.6
Process 2	137.98	12.5	75.63	7.9	213.60	10.4
Discharge	225.37	20.4	147.18	15.4	372.55	18.1
Cut	11.13	1.0	10.2	1.1	21.33	1.1
Move	21.15	1.9	44.71	4.7	65.86	3.2
Clean	32.98	3.0	82.06	8.6	115.04	5.6
Deck	49.55	4.5	169.38	17.7	218.93	10.6
Subtotal	1 102.30	100.0	954.47	100.0	2 056.77	100.0
Delay	48.26		41.86		90.12	
Sum Time	114.41		70.82		185.23	
Total	1 264.97		1 067.15		2 332.12	

[a] See Appendix I for definitions of terms.

Table 5. Production, by Species and Butt-Diameter Class

Species	Butt-diameter class at midpoint (cm)	Gross merchantable volume (m^3/stem)	Total no. of stems	Average processing time (min/stem)	Projected productivities	
					Stems (no./h)	Volume (m^3/h)
Pine	10	0.073	48	0.34	177.1	12.9
	20	0.368	623	0.55	109.7	40.4
	30	0.847	554	0.81	74.4	63.0
	40	1.505	127	1.01	59.5	89.6
	50	2.504	7	1.21	49.6	124.2
Spruce	10	0.059	113	0.32	187.8	11.1
	20	0.203	218	0.48	124.3	25.2
	30	0.645	95	0.83	72.4	46.7
	40	1.680	58	0.93	64.7	108.6
	50	2.506	21	1.15	52.1	130.5
	60	4.496	7	1.61	37.2	167.3
Balsam	10	0.076	102	0.33	183.8	14.0
	20	0.184	279	0.46	130.2	24.0
	30	0.652	63	0.75	79.8	52.0
	40	1.375	22	0.93	64.9	89.2
	50	2.153	3	1.06	56.6	121.9
All	10	0.069	303	0.33	181.7	12.5
	20	0.286	1230	0.51	117.0	33.5
	30	0.796	745	0.80	74.6	59.4
	40	1.531	231	0.98	61.4	94.0
	50	2.485	37	1.16	51.7	128.5
	60	4.309	9	1.69	35.5	153.0

the volume processed per hour increased as butt diameter increased.

The average time required to process a stem by the Denis D3000 in the study block was 0.67 min (Table 6). Not all stems that were processed had the Process 2 element (see Appendix I); therefore, both a prorated time and an actual time are given. Delay times less than 10 min were included in the detailed-timing study; these are described and summarized in Table 7. Delay times accounted for 3.9% of the total detailed-timing elements.

Table 6. Average Time Required to Process Stems from Roadside Grapple-Yarded Decks

Activity	Time (min)
Pick	.22
Process	.18
Process 2[a]	.12 (.23)
Discharge	.15
Total	.67

[a] This element did not occur on all of the stems, but the value shown is the average applied to all stems. The bracketed number is the average time for the stems that had the occurrence.

Table 7. Delay Time: Summary

Activity	Time (%)
Saw chain	20.5
Personal	18.4
Photo cell	17.2
Discussion	17.8
Unknown	14.0
Clean windows	8.5
Traffic	3.6
	100.0

Length-Measuring Summary

A total of 50 logs were measured by hand to assess the length-measuring accuracy of the D3000. Measurements determined that 92% of the processed logs were within ±7.5 cm of the target length (Table 8).

The four logs that had a high degree of measurement error may have resulted from slippage in the holding arms or from undercut notches on stump pulls left by hand-felling. Such butt irregularities would have caused the computer to start measuring too soon. Occasionally, the operator cut the jagged edge off the butt before processing, thus improving accuracy. At other times, the operator adjusted the log lengths visually if a jagged butt was present; small errors may have occurred from this action.

Table 8. Length-Measuring Accuracy

Description	No.	%
Exact length ± 1 cm	17	34
Long		
By 1-5 cm	8	16
By 5-7.5 cm	3	6
By 7.5-10 cm	1	2
By 12.5-15 cm	1	2
By >15 cm	1	2
Short		
By 1-5 cm	14	28
By 5-7.5 cm	4	8
By >15 cm	1	2
	50	100

Conclusions

In 1990, FERIC evaluated the productivity and costs associated with operating a Denis D3000 processor, and the accuracy of its length-measuring device. The study occurred near Kelowna, British Columbia with cooperation from Fletcher Challenge Canada Limited.

The overall productivity of the Denis D3000 was 29.3 m^3/h; however, this productivity value also reflects the other non-processing activities, e.g. longer moves and decking logs for the yarder. A productivity of 44.8 m^3/h (productive time) was recorded during the detailed timing of the grapple-yarded wood. This figure is significant because it shows that the Denis D3000 is capable of producing approximately 38 m^3/h (with the test site tree size, species mix, and utilization of 81.7%), on a shift-level basis, if only yarded wood is processed. The overall processing cost of \$3.13/m^3 reduces to \$2.51/m^3 when analyzed only against the grapple-yarded wood.

Because the machine worked in conjunction with a grapple yarder, productivity of the D3000 was lower and costs were higher than what would be expected in a conventional roadside system operating in the Interior of British Columbia. The D3000 helps improve productivity and costs associated with operating the yarder by allowing tree-length wood to be brought to roadside. Therefore, the overall system cost is less than using a yarding system without the processor.

Evaluation of the length-measuring device determined that 92% of the measurements were within the accepted tolerance of ±7.5 cm of the specified log length. Two main reasons for variation were: slippage of the stem in the holding arms during delimbing, which can be eliminated by adding more tension to the holding arms, and jagged butts associated with hand-felling undercuts.

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Disclaimer

APPENDIX I

Definitions

Timing Elements

pick - Time required from discharge of butt of previous stem to secure butt of next stem.

process - Time required from the point when the stem begins moving in the delimber until first log is manufactured.

process 2 - Time required from the end of cutting the first log to the end of cutting the second log.

discharge - Time required to place the log onto the deck after processing.

cut - Time taken to long-butt (remove defects from) a stem.

move - Time taken by the excavator to move into position to process more stems (tracks are in motion).

clean - Time taken to clean debris around working area.

deck - Time taken to rearrange logs on the log deck.

delay - Time when the delimber was not actively processing stems.

sumtime - Total processing time of a cycle when individual element times were missed.

Timing Events

long-butting - Cutting defects out of the log.

forktop - Stem with a fork or crook in merchantable part.

abort - Unmerchantable stem that is discarded or not processed after it is picked up.

stuck - Processing is halted by stem stuck in the log deck.

stem number - Number of stems processed at one time.

number of logs - Number of logs cut from each stem.

reset - Length-measuring encoder being reset to remeasure a log length.

slip - Stem being processed slips in the holding arms of the delimber.

APPENDIX II

Shift-Level Delays: Summary

Description	Occurrences (no.)	Time (h)
Non-Mechanical Delays		
Operational		
Personal	55	12.2
Planning	9	2.3
Auxiliary equipment	2	1.9
Miscellaneous	3	1.8
Organizational		
Wait for other phase	7	4.9
Move to new area	8	6.6
Miscellaneous	1	1.7
	85	31.4
Mechanical Delays		
Repairs to carrier	3	3.6
Repairs to prime attachment		
Hydraulics	3	0.9
Structural	3	3.8
Saw implement	18	4.9
General service	51	10.0
	78	23.2
Total Delays	163	54.6

APPENDIX III

Machine Costs: Denis D3000 Processor and Komatsu PC220LC Carrier

Ownership Costs	
Processor	
Total price, including measuring device[a] (P) ($)	113 000
Scheduled time (h/y)	2 100
Expected life (H) (h)	12 000
Insurance (Ins) (%)	3
Interest (Int) (%)	14
Salvage value (S) = (P • .25) ($)	28 250
Average investment (AVI) = (P + S)/2 ($)	70 625
Loss in resale (P - S)/H ($/h)	7.06
Insurance cost (Ins/100 • AVI/h) ($/h)	$1.01
Interest cost (I/100 • AVI/h) ($/h)	$4.71
	12.78
Carrier	
Total price, fully rigged for D3000[a] (P) ($)	205 000
Scheduled h/y (h)	2 100
Expected life (H) (h)	12 000
Insurance (Ins) (%)	3
Interest (Int) (%)	14
Salvage value (S) = (P • .25) ($)	51 250
Average investment (AVI) = (P + S)/2 ($)	128 125
Loss in resale (P - S)/H ($/h)	12.81
Insurance cost (Ins/100 • AVI/h) ($/h)	1.83
Interest cost (I/100 • AVI/h) ($/h)	8.54
Total	23.18
Total ownership cost (OC) ($/h)	35.96
Operating Costs	
Annual repairs @ 10% of P (R) ($)	31 800
Fuel (F) (L/h)	15
Fuel cost (f) ($/L)	0.42
Lube & oil (% of F)	15
Wages (W) ($/h)	18.00
Benefits (% of W)	35
Repairs (R/h) ($/h)	15.14
Fuel & lube cost ($/h)	7.25
Wages & benefits W • [1 + (35/100)] ($/h)	24.30
Overtime (2 h/8 h @ 1.5 • W • 1.35) ($/h)	9.11
Total operating cost (OP) ($/scheduled hour)	55.80
Total Ownership & Operating Cost[b] ($/h)	91.76
Production (m^3/h)	29.3
Cost ($/$m^3$)	3.13

[a] Total price does not include taxes.
[b] These figures are based on FERIC's standard accounting formula for determining ownership, repair, and operating costs, and do not account for remote accommodation and machine support expenses. Actual hourly rates may vary.