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INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

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Evaluation of Bombardier B-15 Choker Arch Skidder and Comparison with FMC 210CA Skidder

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FOREWORD

This Technical Note presents the results of a study of the Bombardier B-15 skidder operating in British Columbia. The work was prompted by the need for factual information comparing the performance of Bombardier B-15 and FMC choker arch skidders. The comparison was necessary to see if the Bombardier B-15 was a reasonable equivalent to the FMC 200CA or 210CA, and to answer questions related to the import duty on the FMC skidders.

Short-term studies such as this one cannot explore the long-term productive potential of machines that may later work under a broad range of conditions. Moreover, the ultimate success of a new machine will depend not only on its productivity, but also on its mechanical availability and the cost of the wood it produces. FERIC does not plan further studies at this time because there is only one Bombardier B-15 operating in B. C.

Grateful appreciation for cooperation in arranging this study is extended to the following companies:

West Fraser Mills Ltd., Quesnel, B. C.
Amboy Logging Ltd., Quesnel, B. C.
Industrial Division, Bombardier Ltd., Valcourt, Quebec
and Alpine Distributors Ltd., Vernon, B. C.

The authors also wish to acknowledge the help of Eric Phillips and Paul Tse of FERIC during field work and data analysis.

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SUMMARY

The Bombardier B-15 choker arch skidder has been considered as an alternative to the FMC 210CA skidder. It is similar in many aspects but has close to twice the track width and bearing surface as the FMC, and thus much lower ground pressure. The Bombardier B-15 studied was the first used for skidding logs in British Columbia. It was operated with an FMC skidder on the same area, near Wells, B. C. during July, August and September, 1977. During that time FERIC made a brief comparison of the performance of the two machines. Some mechanical problems causing downtime for both machines are described. The productivity per 8-hour shift (assumed: 6.4 hours of productive machine time) and for comparable skidding distances was estimated as follows:

Terrain Type	Bombardier B-15	FMC 210CA
STEEP		
Average skidding distance, feet (m)	350 (107)	350 (107)
Volume per shift, cunits (m^3)	68 (191)	73 (207)
SWAMPY		
Average skidding distance, feet (m)	980 (299)	980 (299)
Volume per shift, cunits (m^3)	50 (142)	60 (169)

Since the Bombardier costs less to purchase than the FMC the differential in productivity may be offset to some extent. The short study provided little basis for predicting long-term availability of the Bombardier or for estimating the life of its tracks. Both these factors are important in determining whether or not the Bombardier is a valid alternative to the FMC under British Columbia conditions.

TECHNICAL DESCRIPTION

The Bombardier choker arch skidder is a tracked vehicle with low ground pressure (Figure A). It has a box-type frame enclosing all transmission components. The tracks are driven by front sprockets and the rear idlers also have sprockets to help keep the tracks in place. Three supporting wheels on each side are sprung by rubber elements and trailing arms. All wheels are 6 inches (15.2 cm) wide, and all sprockets and wheels have solid rubber tires on steel. (Rubber is used to give the vehicle a softer ride.)

The tracks have channel-shaped steel cross-members on two steel wire-reinforced rubber belts. The track is 41 inches wide (104 cm) and the rubber belt is 0.75-inch (1.9 cm) thick and 16.5 inches (41.9 cm) wide. Unladen, the machine has a ground pressure of about 3 psi (20.7 kPa). Wide tracks give excellent flotation but do not dig into the ground enough for good traction and they have a tendency to come off on rough ground. The crowned shape of the cross-members tends to cause the vehicle to slide sideways. To increase the machine's capability for travelling on rough terrain and slopes, the tracks could be made narrower without sacrificing too much flotation. The rubber belts might become too narrow to stand up under the traction forces, however.

Present track design is more suitable for swamps and minimizing ecological damage than for slopes and rough ground. Track tension is adjusted hydraulically.

The engine is a GM 6V-53 diesel, developing 195 hp (145 kW) at 2800 rpm. The transmission is Clark with torque converter and 3-speed power shift forward or reverse. The steering differential has hydraulically operated band brakes. The service brake is the caliper-disc type and the parking brake is the drum type on the transmission. Both are power-assisted.

The machine has a hydraulically-operated dozer blade which covers almost the full track width. A Gearmatic winch is mounted behind the cab. A combined arch and log platform which can be tilted hydraulically is mounted in the rear. The tilt cylinders are small but will be exchanged for heavier ones.

General dimensions:

length	20.3 ft (6.19 m)
width	10.9 ft (3.32 m)
height (cab)	9.7 ft (2.96 m)
ground clearance	19 in. (48.3 cm)
weight	34,000 lb (15.4 tonnes)
ground pressure	3.0 psi (20.7 kPa)

Figure B shows the Bombardier B-15 and FMC 210CA working together in the study area.

ERGONOMIC CHARACTERISTICS

The machine was evaluated using the Swedish Ergonomic Checklist as a reference (see Appendix I). The ergonomics of the machine are typical of North American skidders, including the FMC 210CA.

Mounting and alighting: Very difficult and a serious problem for a choker skidder. The track is 34 inches (86 cm) above the ground and so wide that the operator cannot grasp the hand-holds when standing on the ground. The tracks are often slippery. The door opening is narrow and low.

Working position: Generally comfortable but some of the frequently used controls are out of the optimum working area, e.g., throttle pedal, blade and arch control, and gear shift levers.

Operator's seat: Fairly comfortable, but the upholstery is vinyl, which gets very hot in summer and cold in winter. The seat height is not adjustable.

Operator's cab: Not enclosed. Height and length are somewhat less than reference data.

Visibility: Fairly good.

Controls and instrumentation: Generally acceptable.

Noise level: Too high, about 100 dBA. Ear protectors should be used.

Maintenance: Typical for logging machines. Engine compartment doors are bolted rather than hinged.

Figure A. Bombardier B-15 Skidder

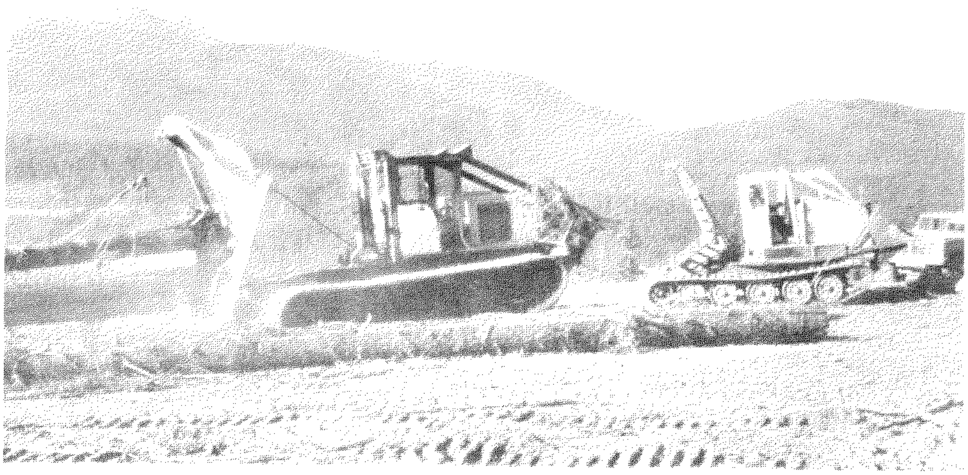

Figure B. Bombardier B-15 and FMC 210CA Skidders at the Landing

Lighting, working climate and vibration: Not studied.

Overall impression: (See last item on checklist, Appendix I.) The Bombardier B-15 was described as "fairly good" with respect to panel instruments and visibility. Mounting/alighting and noise levels were rated "very poor."

BRIEF DESCRIPTION OF THE STUDY AREAS

All areas were northeast of Wells, B. C. near Bowron Lakes Provincial Park, and comprised a convex-sloped moraine across a generally flat-bottomed valley.

The steep terrain had an average slope of 33%. Most of the timber was chainsaw-felled, but lesser amounts of blowdown timber occurred on the flatter ground. It was more difficult to assemble turns in the blowdown timber, but this task was shared equally by the two machines. Timber type was spruce (*Picea engelmannii* Parry), and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.). The ground was firm, dry and relatively stable.

The swampy areas were two basic types: 1) concave swampy ground near the top of the moraine, and 2) convex swampy ground located mid-slope between two benches. These had been left as seed blocks of spruce but were blown down two years ago in a major windstorm. Ground bearing capacity of blowdown areas was classed as soft,* but the skid trails were located on relatively firm and stable ground. Traction conditions were probably not severe enough to tax the full flotation capability of the Bombardier.

Table 1 compares the average conditions and operating factors for the two machines on both types of terrain.

*Based on Bennett, W. D. 1970. Identification and measurement of key environmental and operating factors on logging operations. Woodlands Report WR/30, Pulp Pap. Res. Inst. Can., Montreal. 10 pp. plus Appendix.

Table 1. Average Conditions and Operating Factors

	Bombardier			F M C		
	Mean	S.D.*	Range	Mean	S.D.*	Range
STEEP (HARD) TERRAIN						
Av. Skidding Distance, ft	290	159	95 to 675	480	128	355 to 700
(m)	(88)	(48)	(29 to 206)	(146)	(39)	(108 to 213)
Slope, %**	-18	3.1	-12 to -24	-14	1.3	-12 to -16
Number of Turns	28	-	-	12	-	-
Number of Operators	1	-	-	1	-	-
Load Size, ft^3	265	59	155 to 334	300	61	212 to 410
(m^3)	(7.5)	(1.7)	(4.4 to 9.5)	(8.5)	(1.7)	(6.0 to 11.6)
Av. No. of Logs per Turn	6.5	0.9	4 to 8	7.2	0.7	6 to 8
Av. Log Size, ft^3	40	32	3.7 to 262	42	23	4 to 118
(m^3)	(1.1)	(0.9)	(0.1 to 7.4)	(1.2)	(0.7)	(0.1 to 3.3)
SWAMPY (SOFT) TERRAIN						
Av. Skidding Distance, ft	640	80	475 to 765	1100	276	700 to 1590
(m)	(195)	(24)	(145 to 233)	(335)	(84)	(213 to 485)
Slope, %**	+5	0.9	+3 to +6	+8	4.4	-7 to +13
Number of Turns	16	-	-	45	-	-
Number of Operators	1	-	-	2	-	-
Load Size, ft^3	359	141	92 to 626	326	109	109 to 587
(m^3)	(10.2)	(4.0)	(2.6 to 17.7)	(9.2)	(3.1)	(3.1 to 16.6)
Av. No. of Logs per Turn	5.5	1.3	1 to 7	6.0	1.5	1 to 8
Av. Log Size, ft^3	65	39	2 to 190	54	41	3 to 232
(m^3)	(1.8)	(1.1)	(0.1 to 5.4)	(1.5)	(1.2)	(0.1 to 6.6)

*Standard Deviation
**Favourable -
Adverse +

OBSERVED DOWNTIME

The study period was too brief to provide a pattern of downtime, but the following mechanical problems involving major lost time were noted.

Bombardier

--Failure of main hydraulic pump due to cavitation on steep slope

--Damaged hydraulic cylinders on dozer blade (corrected by remounting blade at better angle)

--Lost track

FMC

--Winch breakdown

Track life for the Bombardier is an area of particular interest to potential users but could not be assessed over the short study period.

In addition to mechanical downtime, each of the machines was sometimes shut down for lack of wood to skid (Appendix II).

PRODUCTIVITY RESULTS

The following section on productivity is based on productive time, disregarding mechanical downtime mentioned above.

Tables 1 and 2 present the results of detailed timing studies for both machines on the two types of terrain. Table 2 reports averages for distance, travel speed, production per productive machine hour (PMH) and production per shift. The productivity averages are based on 80% utilization, or 6.4 PMH per 8-hour shift. Table 3 reports corresponding averages of time-per-turn by time elements. Minor delays (less than 10 minutes per delay occurrence) are itemized in Appendix II.

As Table 2 indicates, average skidding distances were shorter for the Bombardier in each type of terrain. Direct comparisons of time and productivity based on these averages

Table 2. Skidder Productivity (from detailed timing results)

	Bombardier		F M C	
<u>STEEP TERRAIN</u>				
Average Distance, ft (m)	289	(88)	483	(147)
Travel Speed--empty & loaded ft/min (m/min)	165	(50)	331	(67)
Productivity,* cunits/PMH (m^3/PMH)	10.5	(29.7)	10.9	(30.9)
cunits/shift (m^3/shift)	67.2	(190.3)	69.8	(197.7)
<u>SWAMPY TERRAIN</u>				
Average Distance, ft (m)	637	(194)	1,099	(335)
Travel Speed--empty & loaded ft/min (m/min)	185	(56)	313	(95)
Productivity,* cunits/PMH (m^3/PMH)	9.7	(27.5)	9.1	(25.8)
cunits/shift (m^3/shift)	62.1	(175.8)	58.2	(164.8)

*Assuming 80% utilization

Table 3. Summary of Average Times per Turn in Minutes

	Bombardier			F M C		
	Mean	S.D.	Range	Mean	S.D.	Range
STEEP TERRAIN						
Travel Empty	2.04	1.13	.84- 4.18	2.72	.66	1.74- 3.93
Maneuver	.34	.33	0- 1.51	.85	.76	.17- 2.18
Loading	5.19	.99	3.41- 6.99	5.33	.51	4.46- 6.05
Move During Load	.83	.62	0- 2.11	1.58	.64	.73- 2.55
Travel Loaded	1.48	.44	.79- 2.49	1.65	.54	1.07- 2.80
Unload	1.32	.34	.51- 2.03	1.31	.44	.81- 2.11
Align/Deck/Limb	1.23	1.40	0- 7.52	.83	.97	0- 3.54
Delays	2.30	2.26	0-10.00	2.26	1.88	0- 5.21
Total Turn Times	14.73	3.39	9.67-26.43	16.53	2.26	12.59-19.50
SWAMPY TERRAIN						
Travel Empty	3.29	1.37	1.87- 7.37	3.24	.84	1.95- 5.18
Maneuver	.55	1.16	0- 4.77	.45	.85	0- 5.64
Loading	6.91	1.81	3.31- 9.70	6.68	2.03	2.31-11.52
Move During Load	.79	.39	.20- 1.41	1.58	1.45	0- 7.37
Travel Loaded	3.57	.76	2.40- 4.82	3.78	1.34	1.09- 6.89
Unload	1.30	.46	.83- 2.31	1.40	.41	.74- 2.08
Align/Deck/Limb	1.04	1.20	0- 5.36	.60	.49	0- 3.04
Delays	4.21	4.18	.83-14.50	3.29	3.05	0-13.39
Total Turn Times	21.66	7.97	13.42-38.85	21.02	5.05	9.89-31.16

would thus be biased in favour of the Bombardier. To remove the effect of different skidding distances, a series of regressions was run, relating travel time with distance. The results appear in Table 4. These relationships, of the form:

$$Y = \text{Travel time} = a + b \times \text{distance}$$

were significant for three of the four machine/terrain combinations. Values of r^2 (coefficient of determination, indicating the approximate proportion of variation in travel time associated with distance) ranged from 0.41 to 0.55. For the fourth combination, the FMC on swampy terrain, an r^2 value of only 0.01 was obtained, indicating that the regression was virtually no improvement over the simple mean of all travel times, regardless of distance. This result was derived from 45 turns, ranging from 700 to 1,590 feet (213 to 485 m) in distance. In the absence of a firm relationship, the mean travel time, 7.02 minutes, was used throughout the range of observed distances for the FMC on swampy ground.

Table 4 also shows average terminal time and delay time for each case so that an estimate of total turn time can be made.

Table 5 shows estimates of total turn time for varying distances derived from Table 4, with corresponding productivity in cunits (m^3) per PMH based on the load sizes shown in Table 1.

Figure C illustrates these same results graphically (productivity plotted over skidding distance). The FMC shows somewhat higher productivity than the Bombardier for all combinations except at distances below 700 feet (213 m) on swampy terrain. Even here, the difference is inferred rather than proven, since no FMC turns shorter than 700 feet were observed. On steep terrain, where the regression equations established fair relationships between travel time and distance for both machines, the FMC showed a superiority in the order of 0.6 cunits (1.7 m^3) per PMH at the longer distances shown, increasing to 1.0 cunits (2.8 m^3) per PMH at short distances.

The weighted average skidding distance on steep terrain for both machines was 350 feet (107 m). On swampy terrain it was 980 feet (299 m). Table 6 is a comparison of productivity based on these distances and using the time and average load relationships already derived.

Table 4. Summary of Time Estimates for Productivity Comparison

STEEP TERRAIN

Time in Minutes	Bombardier	F M C
Terminal Time	8.91	9.90
Delay Time	2.30	2.26
Travel Time	Y = 2.03 + 0.0051 x distance* $r^2 = .41$	Y = 1.62 + 0.0057 x distance* $r^2 = .54$
Total Time per Turn	= 11.21 + Y	= 12.16 + Y

SWAMPY TERRAIN

Time in Minutes	Bombardier	F M C
Terminal Time	10.54	10.71
Delay Time	4.21	3.29
Travel Time	Y = -3.69 + 0.0166 x distance* $r^2 = .55$	7.02
Total Time per Turn	= 14.75 + Y	= 21.02

*Skidding distance in feet

Table 5. Summary of Turn Time and Productivity

STEEP TERRAIN	Bombardier Av. 2.65 cunits (7.5 m^3)/turn			F M C Av. 3.00 cunits (8.5 m^3)/turn		
Distance	Total Turn Time minutes	Productivity		Total Turn Time minutes	Productivity	
		cunits /PMH	(m^3 /PMH)		cunits /PMH	(m^3 /PMH)
100	13.75	11.6	(32.8)			
200	14.26	11.1	(31.4)	14.92	12.1	(34.2)
300	14.77	10.8	(30.6)	15.49	11.6	(32.8)
400	15.28	10.4	(29.4)	16.06	11.2	(31.7)
500	15.79	10.1	(28.6)	16.63	10.8	(30.6)
600	16.30	9.7	(27.5)	17.20	10.5	(29.7)
700	16.81	9.5	(26.9)	17.77	10.1	(28.6)
800	17.32	9.2	(26.0)	18.34	9.8	(27.7)

SWAMPY TERRAIN	Bombardier Av. 3.59 cunits (10.2 m^3)/turn			F M C Av. 3.26 cunits (9.2 m^3)/turn		
Distance	Total Turn Time minutes	Productivity		Total Turn Time minutes	Productivity	
		cunits /PMH	(m^3 /PMH)		cunits /PMH	(m^3 /PMH)
300	16.04	13.4	(37.9)			
400	17.70	12.2	(34.5)			
500	19.36	11.1	(31.4)			
600	21.02	10.2	(28.9)			
700	22.68	9.5	(26.9)			
800	24.34	8.8	(24.9)			
900	26.00	8.3	(23.5)			
1,000	27.66	7.8	(22.1)			
1,100				21.02	9.3	(26.3)

FIGURE C. SKIDDING PRODUCTIVITY VERSUS SKIDDING DISTANCE

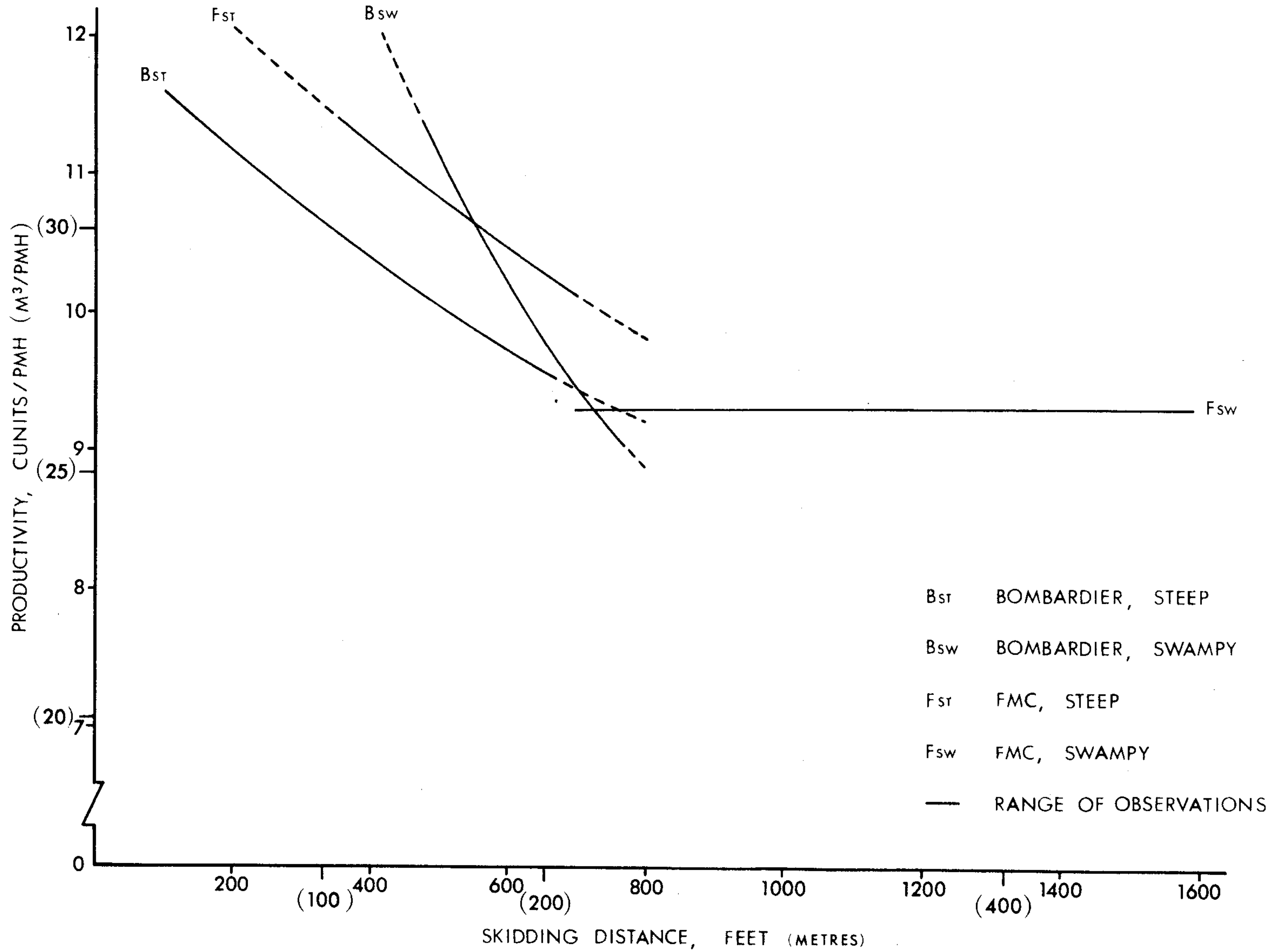

Table 6. Comparative (Projected) Productivity per Shift, Based on Weighted Mean Skidding Distance for Steep and Swampy Terrain

Terrain Type	Weighted Average Skidding Distance ft (m^3)	Measure of Productivity	Bombardier	F M C
STEEP	350 (107)	Min/turn Turns/shift* Cunits/turn Volume/shift cunits (m^3)	15.03 25.5 2.65 67.6 (191.4)	15.77 24.3 3.00 73.0 (206.7)
SWAMPY	980 (299)	Min/turn Turns/shift* Cunits/turn Volume/shift cunits (m^3)	27.33 14.0 3.59 50.3 (142.4)	21.02 18.27 3.26 59.6 (168.8)

*Assumption: 1 shift = 8 scheduled machine hours at 80% utilization
= 6.4 productive machine hours

The Bombardier's productivity per shift was lower than that for the FMC by the volumes shown. On steep terrain the lower ground pressure of the Bombardier tracks appeared to limit traction, maneuverability, and allowable payload in comparison with the FMC. On swampy terrain the FMC was still more productive than the Bombardier for the mean observed distance, but the Bombardier showed good results on shorter distances and should perform better whenever low ground pressure is a critical need.

CONCLUSIONS

Comparing the Bombardier B-15 with the FMC 210CA on steep and swampy ground, we found that the short-term detailed timing study indicated slightly less skidding productivity for the Bombardier B-15.

The June 1978 purchase price of a new Bombardier B-15 is in the order of $108,000 in British Columbia versus about $136,000 for the FMC 210CA (both estimates in Canadian dollars, delivered at interior B. C. points).

The other factor in considering a choice between the two is machine availability and utilization. We believe that the Bombardier B-15 studied is the only specimen which has skidded logs in British Columbia, and that this machine has worked only 26 shifts to date.* In contrast, FERIC has monitored several FMC skidders in several locations, covering a total of 850 shifts. The availability of the FMC during this study averaged 87 percent, and utilization averaged 82 percent, with 22.7 hours of repair and service per 100 productive machine hours. There are no parallel estimates for the Bombardier B-15 in British Columbia, and there will be none unless more machines are brought in, together with spare parts, experienced mechanics, and service facilities. In the important area of long-term availability, the Bombardier, unlike the FMC, is still virtually untried in British Columbia.

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*The machine was idle during the winter of 1977-78 except for two weeks working in a mill yard at Lumby. It has now returned to a new logging operation near Quesnel, and is working satisfactorily although track problems are reported.

APPENDIX I

ERGONOMIC CHECKLIST

for transport and materials handling machinery

Staffan Aminoff
Jan-Erik Hansson
Bo Pettersson

INSPECTION FORM

Machine type ..Choker Arch Skidder..............

Model ...Bombardier B-15........................

Place ....Wells, B.C.................................

Date .....September 29, 1977...................

Inspected by ...Dag Myhrman..........................

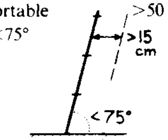
Before the inspection is started, the following points should be checked:

- Field of application of the machine.
- On what type of ground will the machine operate?
- The relative duration of the various work elements (driving, loading, unloading, processing, etc.).
- How often must the operator climb in and out of the cab?
- How long is the machine utilized per shift?
- Is the machine to be used in darkness?

1. Mounting and alighting

Reference data

Height to first step, cm		Gap between steps, cm	
Comfortable	<35	Comfortable	20 – 30
Uncomfortable	35 – 50	Uncomfortable	30 – 40
Very uncomfortable	>50	Very uncomfortable	>40
Angle of steps <75°		Width of step	>30
		Size of door	>62 × 160
		Depth of step (foot-room)	>15



Points to assess

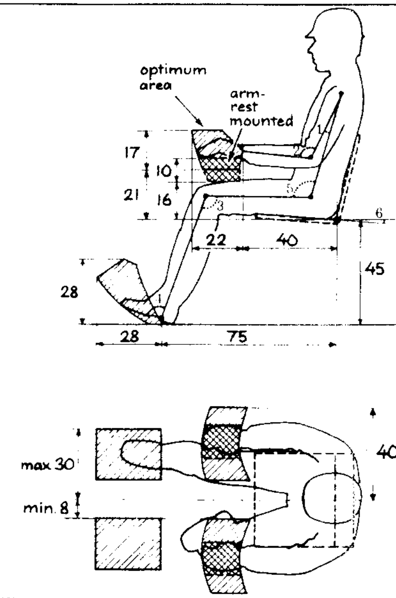
		Yes	No
1.1	Can work be done without risk of slipping (material, design and location of steps, etc.)?	☐	☒
1.2	Can work be done without other accident risks (sharp edges, pointed corners, etc.)	☒	☐
1.3	Is it possible to bale out quickly (roof hatch, location of doors, etc.)?	☒	☐
1.4	Is there a sufficient number of emergency exits?	☐	☐
1.5	Is it possible to mount and alight without undue discomfort (gap between steps, the design, location and functioning of handles, doors, steps, etc.)?	☐	☒
1.6	Other points ______	☐	☐

Remarks: Height to tracks (first step) 34 in (86 cm)
Gap between steps (track to floor) 14 in (36 cm)
No roof hatch
Size of door 20x56 in (50x143 cm)
Tracks are slippery
Front pillar (4x4 in.) are too wide to grasp
Rear handle located too high and is too short.

2. Working position

Reference data

Angles:
1 10 – 15°
2 105 – 115°
3 105 – 120°
4 90 – 100°
5 approx. 100°
6 3 – 7°



Bear in mind that the working place should be comfortable for large and small operators.

Points to assess

		Driving Yes	Driving No	Stationary work Yes	Stationary work No
2.1	Are the pedals and controls conveniently located?	☐	☒	☐	☒
2.2	Can work be done without twisted and awkward postures?	☐	☒	☐	☒
2.3	Is the working position generally comfortable?	☒	☐	☐	☒
2.4	Other points	☐	☐	☐	☐

Remarks: Throttle pedal too far to the right
Gear shift too far to the left and rear
Blade and arch control too far to the right

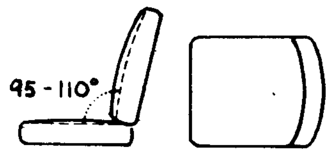
3. Operator's seat

Reference data

Seat
Width >44 cm
Length to reference point 37 – 43 cm
Backward inclination 3 – 7° (adjustable)
Height above floor 45 cm
Height adjustment range ± 5 cm
Length adjustment range ± 8 cm
Cushion thickness 25 – 50 mm, fairly firm and vibration absorbent

Backrest
Width 40 – 50 cm
Height 40 – 50 cm
Seat-backrest angle adjustable between 95 and 110°

Shape:
Slightly convex to the front vertically



Slightly concave to the front horizontally

Points to assess

		Yes	No
3.1	Is the seat properly secured?	☒	☐
3.2	Are the design and inclination of the seat and backrest satisfactory?	☒	☐
3.3	Is the upholstery of the seat and backrest satisfactory (friction, ventilation, etc.)?	☐	☒
3.4	Is the seat well sprung and insulated from shock?	☒	☐
3.5	Has the seat a sufficient adjustment range for both height and length?	☐	☒
3.6	Is the seat easily adjustable?	☒	☐
3.7	Other points: ______	☐	☐

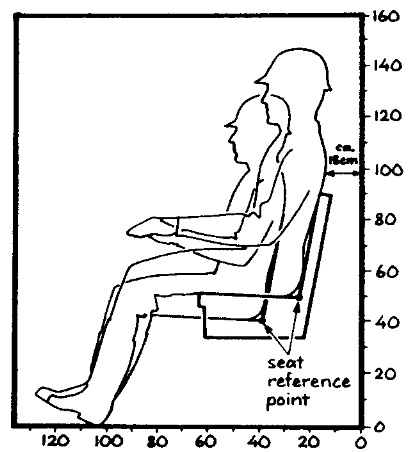
Remarks: Vinyl seat upholstery
Seat height not adjustable

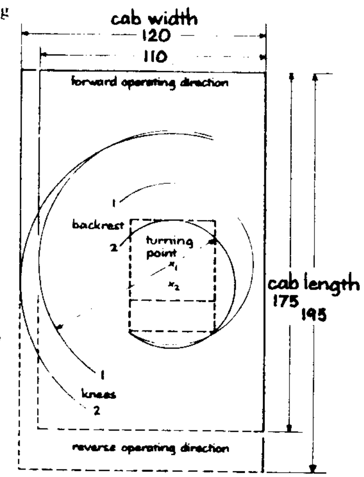
4. Operator's cab

Reference data

Leg and knee-room when seat revolving:
Slewing radius (seat in centre position) >65 cm.

	One operating direction	Two operating directions
Cab width	> 90 cm	>110 cm
Height	>160 cm	>160 cm
Length	>135 cm	>175 cm





Example of the importance of the location of the turning point of the seat in cabs on machines operating in two directions. Two alternative locations of the turning point (x_1 and x_2) are compared.

Points to assess

		Yes	No
4.1	Is the cab large enough?	☐	☒
4.2	Is the cab free from protrusions which may injure the operator?	☒	☐
4.3	Is the cab easy to clean?	☒	☐
4.4	Other points: ______	☐	☐

Remarks: Cab height 56.5 in. (144 cm)
Cab length 50 in. (127 cm)

5. Controls

Reference data

	Actuating force for control, N	
	optimum	**maximum**
Hand-operated	5 – 20	230 steering wheel
		140 lever, operating direction forward – reverse
		60 lever, operating direction sideways
Leg-operated	45 – 90	250 brake, clutch
Foot-operated	20 – 45	

Points to assess

		Steering wheel Yes	Steering wheel No	Pedals Yes	Pedals No	Hand controls Yes	Hand controls No
5.1	Are frequently used controls located within easy reach (see point 2)?	☒	☐	☐	☒	☐	☒
5.2	Is the actuating force below the maximum specified?	☒	☐	☒	☐	☒	☐
5.3	Does the actuating force correspond to the optimum reference data?	☒	☐	☒	☐	☐	☒
5.4	Is the range of movement within the optimum working area?	☒	☐	☐	☒	☐	☒
5.5	Are the controls suited to their functions?			☒	☐	☒	☐
5.6	Is the operation of the control logical and are there a suitable number of operations per control?			☒	☐	☒	☐
5.7	Is the design, grouping and coding of the controls such that a good grip is obtained and that confusion or involuntary actuation of the controls can be avoided?			☒	☐	☐	☒
5.8	Other points ______			☐	☐	☐	☐

Remarks: Blade float position is very hard
Hand controls have no coding

6. Instruments

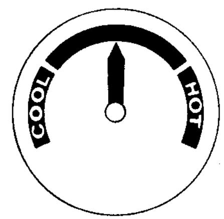
Reference data

The type of instrument should be suitably adapted to the receiving conditions:
Acoustic signals – short, warning signal
Light signals – indicating one of two conditions, e.g. empty – not empty
Dials – most usual for other cases.

Location of instruments – should enable easy surveillance.

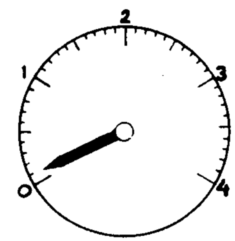
Design of dials

No unnecessary information



Light figures against dark background – if they are to be read under various lighting conditions

The scale should be graduated clockwise and be divided in 2 or 5 divisions or multiples thereof.



Points to assess

		Yes	No
6.1	Are all necessary instruments/signals provided?	☒	☐
6.2	Are all the instruments/signals provided necessary?	☒	☐
6.3	Is critical information communicated in such a way that it is noticed?	☐	☒
6.4	Are the instruments of suitable type?	☒	☐
6.5	Are the instruments well located?	☒	☐
6.6	Are the instruments clearly legible (illumination, size, dial scales, colours, etc.)?	☒	☐
6.7	Other points: ______	☐	☐

Remarks: No warning light or buzzer for dangerous conditions

7. Visibility

Reference data

In driving: A clear view of the ground all round the machine starting at a maximum of 5 m from the operator

In operation when machine is stationary: A clear view of the ground within the working area of the loading equipment (e.g. boom). Unrestricted visibility within the vertical operating area of the loading equipment (forwards, sideways, up and down).

Points to assess

	Driving Yes	Driving No	Stationary operation Yes	Stationary operation No
7.1 Does the operator have a generally good view of the ground?	☒	☐	☒	☐
7.2 Does the operator have sufficient upward visibility?	☒	☐	☒	☐
7.3 Is the machine free of components which obstruct visibility (exhaust pipes, safety grille, equipment, etc.)?	☐	☒	☐	☒
7.4 Is it possible to see through windows without the occurrence of confusing reflections?	☐	☐	☐	☐

	Yes	No
7.5 Is the machine fitted with windscreen wipers and windscreen washers in proper working order when these are required?	☐	☐
7.6 Other points: ______________________	☐	☐

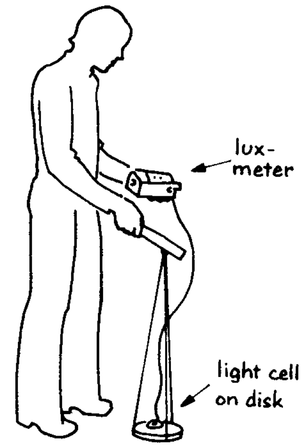
Remarks: ______________________

8. Lighting

Reference data applicable to stationary work

Illuminance in operating area

Satisfactory	>30 lux
Unsatisfactory	15 – 30 lux
Highly unsatisfactory	<15 lux



N.B. To measure illuminance, the light cell should be placed on a horizontal disk just above the ground.

Points to assess

	Driving Yes	Driving No	Stationary operation Yes	Stationary operation No
8.1 Is the illuminance satisfactory?	☐	☐	☐	☐
8.2 Is the illuminated area sufficiently large?	☐	☐	☐	☐
8.3 Is the distribution of light in the field of vision satisfactory (dazzle, etc.)?	☐	☐	☐	☐
8.4 Is maintenance of the lighting equipment straightforward (replacing bulbs, glass, etc.)?			☐	☐
8.5 Other points: ______________________	☐	☐	☐	☐

Remarks: No test made

9. Working climate

Reference data	
– Temperature 18 – 22°C* – Air velocity 0.1 – 0.3 m/s	Maximum value: 32°C 27° SWBGT** 0.4 m/s

Points to assess

		Yes	No
9.1	Is the climate good during summer?	☐	☐
9.2	Is the climate good during winter?	☐	☐
9.3	Is the operator protected from draught?	☐	☐
9.4	Does the interior cooler (if any) operate satisfactorily (adjustibility, reliability and air circulation)?	☐	☐
9.5	Does the defroster work properly (no mist or ice on windows)?	☐	☐
9.6	Other points:		
	______________________________	☐	☐

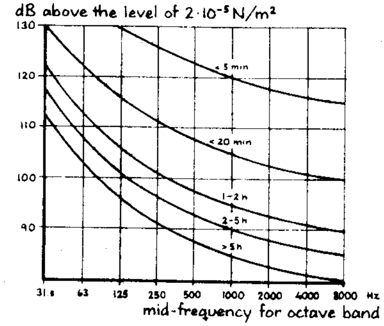
Remarks: Open canopy

* Applies to continual work in the cab.
** See paragraph 9 on page 6.

10. Noise

Reference data

Maximum permissible exposure (mean level) to noise during typical working day (in accordance with SEN 59 01 11).



If the sound level measured exceeds 85 dB(A) a frequency analysis of the noise should be conducted.
From a comfort and communication standpoint the noise should be considerably lower than 85 dB(A).

Points to assess

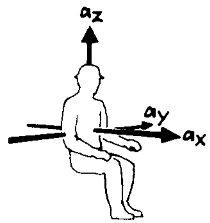
		Yes	No
10.1	Can the operator work without danger of injury to hearing if ear muffs are not used?	☐	☒
10.2	Can the operator work without irritating noise if ear muffs are not used?	☐	☒
10.3	Other points:		
	______________________________	☐	☐

Remarks: Sound levels dBA:
Idle 84
Travel empty 98-100
Maneuver 95-98
Winching max. 101
Travel loaded 99-101

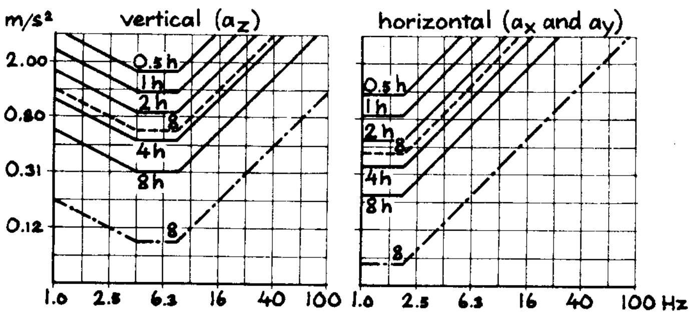
11. Vibration

Reference data

Reference data in accordance with ISO 2631 – 1974.
Limit curves for fatigue and reduced work capacity caused by continuous exposure to vibration. The danger limit levels can be obtained by moving the curves up 1 1/2 squares. In the same way, the limit curves for reduced comfort can be obtained by moving the curves down 2 1/2 squares.



ax, ay, az = acceleration in different directions



Points to assess

		Yes	No
11.1	Is the design of the machine favourable from a vibration viewpoint?	☐	☐
11.2	Can the operator work without danger of injury from vibration?	☐	☐
11.3	Can the operator work without being exposed to vibrations which are fatiguing and which reduce his work capacity?	☐	☐
11.4	Can the operator work without being exposed to vibration which may affect his comfort?	☐	☐
11.5	Other points:		
	____________________	☐	☐

Remarks: No test made

12. Exhaust emission

Reference data, safety limits

Carbon monoxide = 35 ppm (time-weighted mean 8 – hour value)
Formaldehyde = 2 ppm (ceiling value*)
Nitrogen dioxide = 5 ppm (ceiling value*)

Points to assess

		Yes	No
12.1	Do measurements show the gas concentration to be below the reference level?	☐	☐
12.2	Is the cab free from odour of diesel exhaust?	☐	☐
12.3	Is the cab free from odour of oil or petrol?	☐	☐
12.4	Other points:		
	____________________	☐	☐

Remarks: No test made

* ceiling value = maximum time-weighted mean concentration during a 15 – min period.

13. Maintenance

Points to assess

		Yes	No
13.1	Can work be carried out without the danger of slipping?	☒	☐
13.2	Can work be done without heavy lifting or other physically exerting operations?	☐	☒
13.3	Does the design of the machine allow routine maintenance work to be carried out in a comfortable working position?	☒	☐
13.4	Can the work be carried out without the operator becoming unnecessarily dirty?	☒	☐
13.5	Are the lubrication and service points designed and located so that they are readily found?	☒	☐
13.6	Are suitable storage facilities provided for maintenance equipment?	☐	☒
13.7	Other points: ______	☐	☐

Remarks: Engine compartment side doors are bolted on, requires spanner for opening. Risk of injury to fingers when handling them. Fluid levels can be checked without opening doors.

Overall impression

The checklist contains a large number of points, each of which should be individually assessed. The items are not usually of equal importance. In the final assessment, therefore, the various points should be judged in the light of their ergonomic importance, consideration being given to where, when, how and how often the machine is to be utilized.

Point to assess	Machine design					Ergonomic importance of point to assess		
	1 Very poor	2 Fairly poor	3 Indifferent	4 Fairly good	5 Very good	Less important	Important	Very important
1. Mounting and alighting	X							X
2. Working position			X					X
3. Operator's seat			X					X
4. Cab			X					X
5. Controls		X						X
6. Instruments				X			X	
7. Visibility Driving				X			X	
Stationary				X			X	
8. Lighting								
9. Working climate								
10. Noise	X							X
11. Vibration								
12. Exhaust emission								
13. Maintenance			X				X	

APPENDIX II

MECHANICAL AND NON-MECHANICAL DELAY TIMES RECORDED DURING THE DETAILED TIME STUDY

Note: Delays recorded in the following lists are minor delays only ($<$10 minutes per delay occurrence).

BOMBARDIER--STEEP TERRAIN

Delays Recorded--Detailed Time Study

Category	Number of Occurrences	Description	Total Time (minutes)	% of Total Delay Time
MECHANICAL				
Repair	2	trouble-shooting--blade attachment	2.47	3.83
	1	trouble-shooting--tracks	1.36	2.11
	3		3.83	5.94
NON-MECHANICAL				
Operational Lost	26	push trail	43.07	66.78
	9	planning delay	12.45	19.30
	4	clean trail	3.40	5.27
	1	wait for bucker to finish	1.06	1.64
	1	wait for faller to finish	0.44	0.68
	1	loader in way	0.25	0.39
	42		60.67	94.06
Total	45		64.50	100.00

Average per turn (28 turns) = 2.30 min

FMC--STEEP TERRAIN

Delays Recorded--Detailed Time Study

Category	Number of Occurrences	Description	Total Time (minutes)	% of Total Delay Time
MECHANICAL				
Repair	1	trouble-shooting--mainline	1.31	4.82
	1		1.31	4.82
NON-MECHANICAL				
Operational Lost	10	push trail	19.95	73.34
	3	hang-up	2.84	10.44
	2	wait for other machines to move	0.97	3.57
	1	planning delay	0.74	2.72
	1	fell a snag	0.64	2.35
	1	look for wood	0.49	1.80
	1	clear trail	0.26	0.96
	19		25.89	95.18
Total	20		27.20	100.00

Average per turn (12 turns) = 2.27 min

BOMBARDIER--SWAMPY TERRAIN

Delays Recorded--Detailed Time Study

Category	Number of Occurrences	Description	Total Time (minutes)	% of Total Delay Time
MECHANICAL				
Repair	1	broken mainline	8.12	12.06
	1	leak in blade ram	2.10	3.12
	1	trouble-shooting--radiator	1.28	1.90
	1	trouble-shooting--arch	1.26	1.87
	1	trouble-shooting--tracks	0.55	0.82
	1	trouble-shooting--front end	0.26	0.38
	6		13.57	20.15
Service	1	grease tracks	9.75	14.48
	1		9.75	14.48
NON-MECHANICAL				
Operational Lost	15	push trail	33.97	50.44
	3	planning delay	8.92	13.25
	1	visitors	0.80	1.19
	1	attach choker	0.33	0.49
	20		44.02	65.37
Total	27		67.34	100.00

Average per turn (16 turns) = 4.21 min

FMC--SWAMPY TERRAIN

Delays Recorded--Detailed Time Study

Category	Number of Occurrences	Description	Total Time (minutes)	% of Total Delay Time
MECHANICAL				
Repair	1	trouble-shooting--mainline	1.83	1.24
	1	trouble-shooting--track	0.83	0.56
	2		2.66	1.80
Service	2	fuel up	10.99	7.42
	2		10.99	7.42
NON-MECHANICAL				
Personnel	1	extra lunch	1.55	1.05
	1	water break	1.06	0.72
	1	change shirt	0.90	0.61
	3		3.51	2.38
Operational	42	push trail	115.18	77.79
	7	planning delay	6.68	4.51
	1	rechoke logs	4.33	2.92
	6	other machines in way	2.08	1.40
	1	return sledge hammer	1.13	0.76
	1	look for wood	0.59	0.40
	1	untangle chokers	0.41	0.28
	1	clear debris out of the cab	0.27	0.18
	1	visitors	0.24	0.16
	61		130.91	88.40
Total	68		148.07	100.00

Average per turn (45 turns) = 3.29 min