METSÄTEHON katsaus

Metsäteho Review 9 A/1979

BRUUNETT MINI 578 F FORWARDER

By Esko Mikkonen and Veikko Ylä-Hemmilä

The Bruunett mini is a forwarder designed for timber harvesting in thinnings. It represents the most modern forwarder technology. In its performance values the Bruunett mini is nearly similar to medium heavy forwarders. It handles well and probably does not damage the forest to the same extent as the forwarders in use today. The Bruunett mini meets current ergonomic requirements.

GENERAL

The Bruunett mini represents new forwarder technology and ranks in size between light and medium heavy forwarders. Special attention has been paid in its design to ergonomic demands and output requirements, including the demands imposed by the forest working environment,particularly thinnings.

One of the assumptions in planning the Bruunett mini was that it would be used as a basic machine for the mechanisation of harvesting thinnings. Additional devices for the preparation of timber, e.g. a processor part that can be fitted to the machine, are under construction.

The Bruunett mini differs in the following respects from conventional forwarders: It has bogies both front and rear, the power transmission is hydrostatic-mechanical, with the body joint in the middle of the axle base both front and rear wheels move along the same track and the loader grapple is unusually large for the loader size.

By May 18, 1979, approx. 100 Bruunett mini forwarders had been manufactured. About 65 units have been sold to Sweden, 11 to Finland and about 10 elsewhere.

Fig. 1. The Bruunett mini 578 F forwarder. Photo by Formacomp Oy

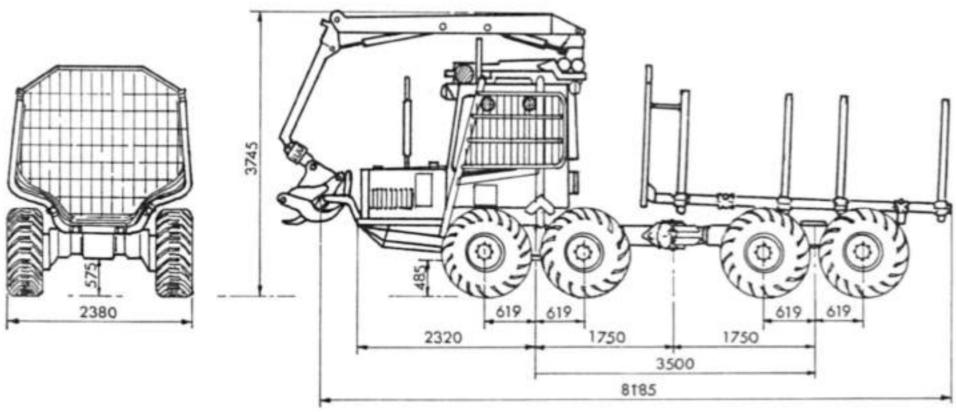

Fig. 2. The Bruunett mini 578 F forwarder. Dimension sketch (measurements in mm)

The Bruunett mini is made by Bruun System AB, the subsidiary in Sweden of Sponsor Oy, and by M. Laine Oy, its subsidiary in Rauma, Finland. The machines are marketed in Finland by Sponsor Oy's subsidiary Formacomp Oy which is also responsible for their servicing.

The machine carries a 6-month or 1,000-hour guarantee. It is allowed to pull a trailer and to move on public roads without any special limitations. It has been type certificated in Finland. Vakola, the Finnish Research Institute of Engineering in Agriculture and Forestry, has carried out an ergonomic inspection. The National Board of Work Safety has accepted the forwarder for use in forest operations.

EXAMINATION

Metsäteho studied the Bruunett mini forwarder in December 1978 in Lammi and in January 1979 in Hausjärvi at the work sites of Puulaaki Oy. A time study was made on the machine while transporting timber after manual thinning and clear cutting and after the Pika 52 processor. In addition, routine measurements were performed in conjunction with tests.

	Thinning		Clear-cutting			
	After manual cutting		After manual cutting		After the Pika 52 processor	
	2-m spruce pulpwood	pre-bunched softwood logs	2-m pine pulpwood	softwood logs	3...6-m softwood pulpwood	softwood logs
Loads, units	13	12	4	20	4	14
Timber, m^3	76.2	119.4	19.7	157.9	24.3	136.3
Average terrain class in hauling	2.0	1.7	2.0	2.0	1.0	1.0

The time study comprised 67 loads, 533.8 solid m^3 in all.

The results of the study conducted by the Swedish Forskningsstiftelsen Skogsarbeten were used in drawing conclusions.

TECHNICAL DATA

Most of the technical data were supplied by the manufacturer.

Main Dimensions

Length	8,185 mm
Width	2,380 mm
Height	3,745 mm
Track gauge	1,880 mm
Axle base	3,500 mm
Ground clearance, front	485 mm
" " middle and rear	575 mm
Cross section of loading space	2.7 m^2
Length of loading space	3,800 mm

Weights

The tare weight is 8,010 kg, 6,550 kg on the front and 1,460 kg on the rear axle. Carrying capacity is 7,000 kg and total loaded weight 15,010 kg.

Engine

Make and type	International Harvester D-246, 4-cylinder, 4-stroke direct injection diesel
Cylinder volume	4.031 dm^3
Maximum output	55 kW 40 r/s (DIN)
Maximum torque	245 Nm 27 r/s (SAE)
Fuel tank volume	90 dm^3

Power Transmission

The Bruunett mini is an 8-wheel drive vehicle. The transmission is hydrostatic and the power is mechanically transmitted to the wheels. The transmission comprises both a hydrostatic and a mechanical part. Either the slow or fast speed range is selected with the mechanical gear and the speed is governed by the hydrostatic transmission. The r/s of the engine is kept at a constant 29 r/s during driving. The driving speed is regulated with the steering rod of the hydraulic transmission. Speed regulation forward and reverse is stepless. The speed range of the slow gear is 0...10 km/h and of the fast 0...27 km/h. The hydrostatic transmission gives very effective motor braking.

Power is transmitted from the gearbox to the front bogie wheels through the differential, traction shafts and gears and to the rear bogies through the cardan shaft, differential, shafts and gears. All the bogies are similar and the transmission to all the wheels is the same. Both the front and rear axles have a pedal-driven hydraulically operated differential lock.

The forwarder is easy to drive because of its hydrostatic transmission.

Wheels

The wheels have low-pressure tyres, 500 x 22.5", 8 ply. The tractor *cannot* be equipped with tracks. Chains are used on the rear wheels of both bogies in snow conditions. Chains are generally not necessary unless the soil is frozen.

Steering

The Bruunett mini has hydraulic articulated steering. The forwarder is steered with steering rods which are installed on both sides of the seat and turn with the seat. The steering link is midway between the front and rear axles. The steering angle is $\pm 40^{\circ}$.

Brakes

The driving brakes are single-circuit, hydraulically operated, oil-immersed disc brakes that work on the traction shafts of the front axles. Driving brakes are seldom needed because the hydrostatic transmission constitute an effective braking system. The parking brake is a hydraulically operated disc brake which locks all the wheels. It is also an emergency brake.

Hydraulic System

The loader and the articulated steering are operated by a gear pump with an output of 55 dm^3/min when the engine speed is 29 r/s. The pressure in this open circuit is 15 MPa.

The hydraulic system of the power transmission consists of three circuits: the driving circuit, the servo circuit and the feeding and cooling circuit.

The driving circuit is closed and consists of an axial piston-type driving pump and driving motor. The displacement/r of both the pump and the motor is variable by tilting the swash plate of the pump and motor. In the free position the pump swash plate is at zero and the motor swash plate in the extreme position. When the vehicle begins to move the pump swash plate is tilted first and when it is in the extreme position and if a higher speed is desired the tilting of the motor swash plate is decreased. This gives a stepless driving speed.

The servo circuit is needed for tilting the swash plate of the driving pump and driving motor.

In the feeding and cooling circuit the infeed pump fills the driving pump and the excess oil circulates through the oil cooler.

The oil volume of the hydraulic system is 65 dm^3. The system comrises the hydrostatic transmission, loader hydraulics and the driving wheels of the front axles.

Electric System

The voltage of the electric system is 12 V, battery (1 unit) 128 Ah. The AC charger (Bosch) effect is 1.26 kW and the starter motor effect is 3.7 kW.

There are eight halogen lights for working. They are in the upper part of the operator's cab, two on each side. There are two driving lights.

The battery capacity could be greater.

Loader

The loader is a Cranab 4115. It is mounted above the operator's cab on a pylon fixed to the forwarder frame. The pylon is separate from the operator's cab and the movements of the loader are therefore not felt fully in the cab. The loader is controlled by five-lever steering. The levers are fixed to the sides of the seat and turn with the seat.

Technical data

Maximum reach	5.0 m
Net lifting capacity	30.0 kNm
Lifting capacity at max. reach	6.0 kN
Torque	11.0 kNm
Turning radius of the loader	380°
Turning radius of the grapple	unlimited
Cross section area of the grapple	0.35 m^2
Loader weight	about 1,000 kg

The speed of the loader movements when the engine speed is 25 r/s is as follows according to Metsäteho measurements.

Turning of the loader	$37^{o}/s$
Raising the lifting boom	$10^{o}/s$(0.9 m/s)
Lowering the lifting boom	$19^{o}/s$(1.6 m/s)
Turning the grapple	$55^{o}/s$
Opening and closing the grapple	3.0 s

The movements of the loader are fairly slow and its effect is not sufficient at maximum reach for several concurrent movements. The loader reach at the ground surface level is small and if the machine tilts the loader does not in its extreme position reach the ground.

The loader is fairly handy to use thanks to its positioning and is fairly efficient for the size of the forwarder, mainly because of its large grapple. The slow speeds of the loader movements are probably due to the small hydraulic pump.

PROPERTIES AND EVALUATION RESULTS

Terrain Capability

Effect of Softness of the Soil

Ground pressures illustrate the tendency of the machine to sink in soft soils. The ground pressures shown in the schedule were calculated in the way described in Metsätehon katsaus — Metsäteho Review 9/1975.

Theoretical ground pressures

	Tyre size	Ground pressure, kPa		
		empty	with a 6-ton load	with a 7-ton load (= max. carrying capacity)
Front	500 x 22.5	55	55	55
Rear	500 x 22.5	12	62	71

The ground pressures given in the schedule are not fully comparable with the ground pressures of other forwarders. The calculation formula used by Metsäteho does not take into account the special features of the Bruunett's tyres. They differ in size and construction from the tyres in general use. When ground pressures are calculated according to the Metsäteho formula it is assumed that the tyre sinks by 15 % of its outer diameter and spreads 3 % under loading. Thus, a 17.6 cm sinkage was used in the calculation of the ground pressures of the Bruunett, whereas 24.8 cm was applied for the commonly used 18.4 x 34" tyre. This means in theory that if the formula gives the Bruunett the same ground pressure as a forwarder with a 18.4 x 34" tyre, Bruunett leaves on softer soil a track that is approx. 7 cm shallower. Nor does the formula take into consideration the fact that the low-pressure tyre used in the Bruunett spreads more than a conventional tyre under loading and thus enlarges the contact area.

Whatever the deficiencies of the method of calculation, the ground pressures presented are smaller than those of other forwarders and the machine is therefore usable also on fairly soft soils. Thanks to the small ground pressures and absence of tracks the Bruunett mini probably does not damage the soil as much as larger units do.

The weight distribution is such that the ground pressure of the front part is the same empty and loaded. If there is long timber in the load, the centre of gravity of the load is behind the rear axle and the load tends to lighten the weight on the front part.

Effect of the Slope of the Ground

The work sites were of terrain class 1...3 in gradient. The steepest slope was 30 % and the Bruunett mini managed it fairly easily both empty and loaded during the snowless period. The gradient may limit the load size in certain cases. For instance, if the trees are slippery because of ice they do not keep in the load when the vehicle goes up a steep slope. This is partly because the load space is short, partly because it has a slight backward tilt.

The Bruunett mini does not on the whole differ in lateral stability from other forwarders. With long logs on board the load tends to become back-heavy because of the position of the load space and the steering link; especially if the logs are loaded buttends to the rear. This lightens the front part of the machine and impairs the lateral stability when the steering links are turned into the extreme position while driving downhill or, correspondingly, the vehicle is reversed uphill. On account of this, back-heavy loads should be avoided as far as possible in sloping terrain.

There is no stop in the steering link to limit twisting between the front and rear frame.

Effect of Roughness of the Ground and of Snow

As the Bruunett mini has a bogie both front and rear it moves relatively smoothly even in difficult terrain. The bogies both ease the movements of the machine and reduce swaying caused by the terrain.

The snow depth varied from 20 to 50 cm at the test work sites. Snow cover smaller than the ground clearance of the machine (48.5 cm) does not affect its movements to any appreciable extent. In winter 1979, when the snow was soft and frosty, the Bruunett mini was driven in about 60 cm deep snow which slowed it down but did not prevent its movement. A thick layer of snow weakens mainly its capacity for climbing slopes. Reversing in thick snow was considerably more difficult than moving forward because the machine had chains only on the rearmost wheels of the bogies.

Manoeuvrability and Travelling Width

Fig. 3 shows the turning radii of the Bruunett mini. The turning radii measured by Metsäteho in the terrain when driving without a load were approx. 1 metre greater. The difference between the theoretical and measured values is caused primarily by the tendency of the light-weight rear end of the Bruunett mini to slide sideways when the machine is turned in the terrain, preventing achievement of the smallest possible turning radius. The rear end holds the ground better when the vehicle is driving loaded.

The turning radius of the machine is small and as the rear wheels follow the front wheels exactly the turning radius is the same as the machine width, 2.4 m. The small turning width and the side poles tilted inwards permit the unit's use on strip roads that are slightly narrower, about 3.5 m, than usual. The strip road cannot be narrower than this, especially if it is winding and the load contains timber that is longer (over 3.8 m) than the load space. Long timber tends to "mark" the trees along the strip road when the forwarder bends.

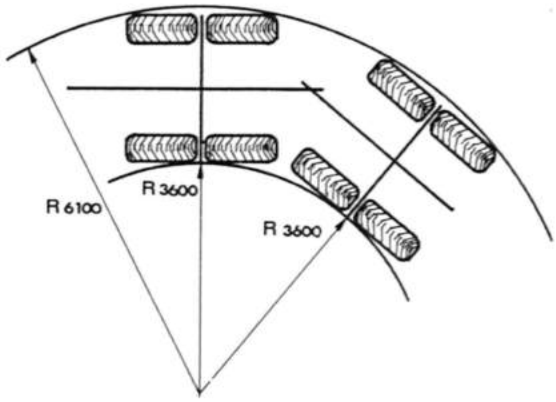

Fig. 3. The turning radii and travelling width of the Bruunett mini 578 F forwarder (measurements in mm)

Driving Speeds

The average terrain class for driving ranged from 1 to 2. There were occasional places belonging to terrain class 3, especially as regards gradient.

Driving speeds increased in the course of the study. This was because before beginning the study the driver had only about a month's experience driving the Bruunett mini forwarder. He learnt during the study to make better use of the terrain driving properties of the machine and it is probably therefore that the driving speeds in the Pika 52 work sites which were studied last are higher although they were corrected for the effect of better terrain.

The driving speeds in the present study were slightly lower than those in the study by Skogsarbeten in Sweden (Sondell 1978, unpublished typescript). Caution must be observed in drawing conclusions about the driving speeds of the schedule, for the terrain driving speeds varied considerably with the conditions. For instance the range was from 40 to 62 m/min when driving empty in the transport of pulpwood in thinnings and from 31 to 58 m/min when driving loaded;

Average driving speeds by investigation targets

	Thinning		Clear-cutting			
	After manual cutting		After manual cutting		After the Pika 52 processor	
	2-m spruce pulpwood	pre-bunched softwood logs	2-m pine pulpwood	softwood logs	3...6-m softwood pulpwood	softwood logs
	m/min					
Driving empty						
– in terrain	37	45	63	50	94	79
– on the forest road	75	44	102	78	63	62
Hauling loaded						
– in terrain	35	40	65	48	65	71
– on the forest road	98	59	115	96	80	72
Loading-hauling	22	23	19	15	24	19
Terrain class of driving	2	2	2	2	1	1
Average forest hauling distance, m	140	120	120	110	110	165
Average road driving distance, m	90	20	85	75	65	35

TABLE 1 Average per-load composition of time expenditure by investigation targets

Work phase	Thinning		Clear-cutting				
	After manual cutting					After the Pika 52 processor	
	2-m spruce pulpwood	pre-bunched softwood logs	2-m pine pulpwood	pine logs	spruce logs	3...6-m softwood pulpwood	softwood logs
	Share, %						
Driving empty	16	12	8	10	9	6	10
Loading	31	39	27	35	36	33	35
Loading-hauling	17	13	28	15	13	11	9
Driving with load	10	8	8	5	9	7	9
Unloading	19	20	17	25	27	29	29
Arrangements and preparations	7	8	12	10	6	14	8
EFFECTIVE TIME	100	100	100	100	100	100	100
Average driving distance, m							
— empty	270	175	200	210	180	170	215
— loaded	180	100	215	155	205	170	180
— loading	135	90	180	80	65	90	47

and in the transport of logs it was from 23 to 46 m/min when driving empty and from 26 to 47 m/min when driving loaded. The corresponding range of variation after the Pika 52 was 24...80 m/min when loaded with logs and 25...120 m/min when driving empty. It was thus possible to achieve fairly high terrain driving speeds with the machine.

Working Times

The share of pulpwood loading-hauling (Table 1) after manual clear cutting is distinctly greater than the other components. This is because the density of this timber assortment was very low; it consisted solely of top pulpwood.

Table 2 shows in addition to the average expenditure of time in the conditions of the study the expenditure of time converted to a 300-m forest haulage distance. The gross effective time shown in the table allows for interruptions of under 15 min. The effective-time expenditure varied considerably with the investigation conditions; the shortest time was 2.91 min/m^3 and the longest 6.89 min/m^3.

The great expenditure of time in the haulage of pine logs after manual cutting compared with other log haulage times is explained by the fact that pine logs at the work site were covered completely by 20...25 cm of snow and had an icy surface. In addition, because of the gradients of the

TABLE 2 Time expenditure and output figures

Specification	Thinning		Clear-cutting				
	After manual cutting					After the Pika 52 processor	
	2-m spruce pulpwood	pre-bunched softwood logs	2-m pine pulpwood	pine logs	spruce logs	3...6-m softwood pulpwood	softwood logs
EXPENDITURE OF EFFECTIVE TIME, E_0, min/m^3							
— in the investigation conditions	6.41	3.21	6.89	5.14	3.94	5.58	2.91
— over a distance of 300 m	7.58	4.00	7.78	5.95	4.45	6.14	3.18
— share of interruptions of under 15 min, %	0.7	1.8	—	—	—	—	—
GROSS EFFECTIVE TIME, E_{15}, min/m^3	6.45	3.27	6.89	5.14	3.94	5.58	2.91
RELATIVE OUTPUT PER EFFECTIVE HOUR	100	198	92	124	161	114	219
Density of assortment, m^3/100 m	4.3	10.9	2.7	9.1	14.9	7.0	20.6
Average driving distance, m	210	140	205	185	190	175	200
Material, m^3	76.2	119.4	19.7	117.8	40.1	24.2	136.3
Loads, units	13	12	4	16	4	4	14
Load size, m^3	5.9	10.0	4.9	7.4	10.0	6.1	9.7
Size of loading bunch, m^3	0.26	0.38	0.24	0.24	0.31	0.41	0.28
Size of unloading bunch, m^3	0.40	0.72	0.42	0.42	0.54	0.59	0.35

work site terrain it was not possible to make the loads quite full as the icy logs would not have kept in position.

Loading and unloading speeds

	Thinning		Clear-cutting				
	After manual cutting		After manual cutting			After the Pika 52 processor	
	2-m spruce pulpwood	pre-bunched softwood logs	2-m pine pulpwood	pine logs	spruce logs	3...6-m softwood pulpwood	softwood logs
				min/m^3			
Loading	1.96	1.24	1.83	1.82	1.44	1.84	1.03
Unloading	1.22	0.66	1.19	1.26	1.08	1.63	0.84

Judging by the loading and unloading speeds, the Bruunett mini gave an impression of efficiency. The loading of pine logs excepted, the loading speeds were greater than those of medium-sized forwarders reported in Kahala's most recent forwarder studies (Metsätehon tiedotus – Metsäteho Report 355). On the other hand, only for the unloading of 2-m pulpwood was the Bruunett mini faster than the machines in Kahala's study.

It is evident that the loader of the Bruunett mini is suited best to handling short pulpwood. The dimensions of the grapple and hoist are not optimal for the loading and especially not for the unloading of logs.

Theoretical load space sizes and load weights by timber assortments. Cross section of load space 2.7 m^2. Green timber

Timber assortment	Size of load space, m^3	Weight of load, Mg
2-m softwood pulpwood (2 bundles)	10.8	5.7
3-m " " (1 bundle)	8.1	4.1
about 5-m " " (1 ")	13.5	6.5
about 6-m " " (1 ")	16.2	7.6
softwood logs (1 ")	13.0	6.2

The carrying capacity of the machine is exceeded according to the calculation only when long, over 6-m pulpwood is transported. Most unfavourable as regards utilization of load space is 3-m pulpwood.

MAINTENANCE

Grading of the location and the ease of servicing of the most important maintenance points

Point	Grading
Location of filling holes	good
Emptying of containers	very good
Location of air cleaner	good
Location of filters	good
Location of battery	very good
Location of fuses	very good
Tightening and changing of V-belts	good
Location of electric wiring	good
Location of the oil pipes of the loader	good
Location of other oil pipes	good
Location of lubrication nipples	good

Daily maintenance is easy and fast.

It is very easy to fill the fuel tank, but a filling funnel is needed for oil.

The location of the battery is very good for maintenance, but may be too hot for the durability of the battery. There are few lubricating nipples and they are easily accessible except for the nipple of the universal joint.

CONCLUSIONS

The construction of a forwarder suitable for thinnings, which was the aim of the design of the Bruunett mini, has been fairly succesful. The machine is also suitable for use in clear cuttings in which its performance values do not, according to present experience, differ much from those of a conventional medium-sized forwarder. Only a follow-up of longer duration will give an answer to the question of operating reliability and durability of the new forwarder and new technology.

Special attention should be paid in developing the forwarder to the moving speeds and reach of the loader. In addition, the back tilt of the load space should be eliminated and the load space should be lengthened somewhat so that the timber keeps better in the load. The load space is not ideal for the haulage of 3-m timber. The winter conditions made it impossible to study the damage caused to the growing stock. However, root damage to the growing stock will evidently be small because the ground pressures are low, there are no tracks and no chains are needed during the period of unfrozen soil. The narrow strip roads reduce the probable growth losses caused by strip roads in thinnings and the stem damage is probably small as the front and rear part of the machine follow the same track.

Vakola
Forest Group
Kauko Turtiainen

ERGONOMICS AND WORK SAFETY

The Forest Group of Vakola, the Finnish Research Institute of Engineering in Agriculture and Forestry, carried out the inspection of the ergonomics and work safety of the forest machines. Its responsible researcher was Kauko Turtiainen.

Inspection and evaluation of the ergonomics and work safety of the machine was carried out in accordance with a check-list compiled by Vakola. The gradings used were good, satisfactory and poor (Metsäteho reviews have previously used the gradings: very good, good, satisfactory, poor and very poor).

Operator's Cab and Control Equipment

Point	Grading
Operator's cab	
Length	good
Width	satisfactory
Height at seat	good
Access to operator's cab and exit from it	satisfactory
Reserve exits	good
Upholstery	good
Colour	good
Seat	good
Leg room when the seat is revolving	good
Tightness	good
Heater	good
– adjustability	good
Cooler	good
– adjustability	good
Anti-glare protection	satisfactory
Visibility	
– forward	good
– sideways	good
– backward	good
Driving and working lights	satisfactory
Windscreen wipers	good
Control equipment	
Steering rods	good
Pedals	good
Pedal actuating force	good
Gear shift	good
Gauges	good
Light and other switches	good
Light signals and acoustic signals	good
Loader levers	good
Driving and parking brakes	good
Coding of control equipment	good
Other safety	
Fire extinguisher, manual extinguishers (2 units)	good
Safety switch of the starter	good
Main current switch	good
Location of battery	good
Slipping preventers on the forwarder	good
Working levels on the forwarder	good

Vibration

Vibration was measured when the forwarder was idling. The measuring device was Wärtsilä's Vib 2076 c meter which weights the vibration values so that they can be compared directly with ISO's vibration norms (ISO/TC 108/SC 35 N and ISO-2631).

TABLE 3 Vibration, weighted value

Measuring target	Number of revolutions of engine, r/s	Acceleration of vibration, m/s^2
Steering rod	12	0.35
Seat level		
– vertical direction	13	0.10
– lateral direction	13	0.22
Floor level	13	0.40

Noise

The noise level in the operator's cab was measured when driving the vehicle on an even, paved road, at both speed ranges, with the engine at maximum revolutions.

TABLE 4 Noise

Measuring situation	Number of revolutions of engine, r/s	Noise intensity, dB(A)
In gear 1	43	84
" 2	43	85
Idling	43	83
When loading	25	80

The noise level of a forwarder must not exceed 88 dB(A).

Discussion

The air-conditioned operator's cab is good. The control equipment is well-placed. The driving speed of the forwarder can be changed steplessly. Ground pressures are low. The front and rear bogie reduce swaying. The rear wheels follow the tracks of the front wheels. Loading of timber from in front of the forwarder is very possible as the hydraulic grapple loader is mounted in the front part of the forwarder. The forwarder is well suited for timber harvesting in thinnings.

METSÄTEHO
SUOMEN METSÄTEOLLISUUDEN KESKUSLIITTO RY:N METSÄTYÖNTUTKIMUSOSASTO
FOREST WORK STUDY SECTION OF THE CENTRAL ASSOCIATION OF FINNISH FOREST INDUSTRIES
Opastinsilta 8 B · SF –00520 HELSINKI 52 · Finland · Telephone (90) 140 011

ISSN 0357-4326

HELSINKI 1979 PAINOVALMISTE