III. Studies on Logging Techniques

Photo 1. Campos do Jordão State Forest

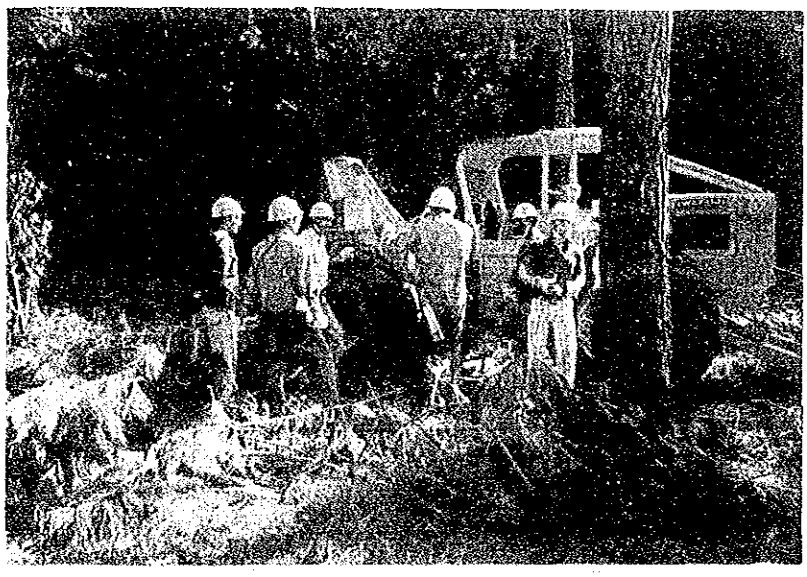


Photo 2. Exercise on tractor logging operation

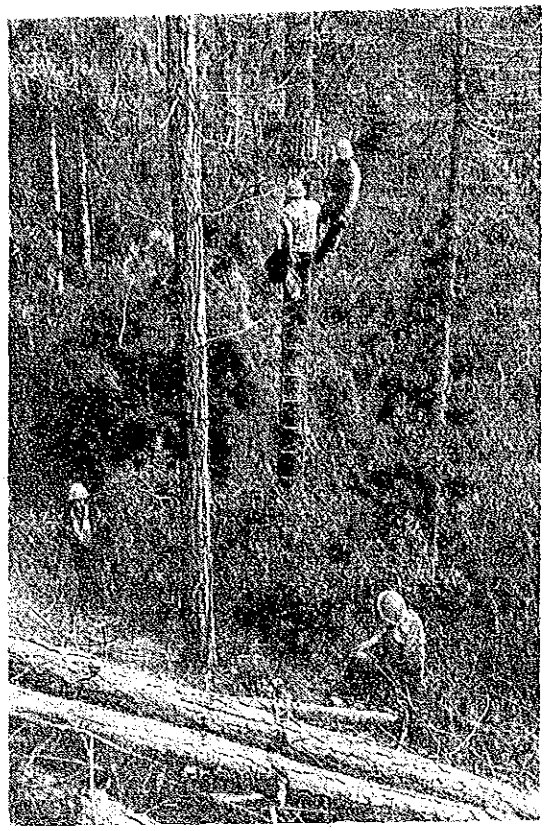


Photo 3. Setting-up work of mono-cable system

Photo 4. Hooking operation in mono-cable yarding operation

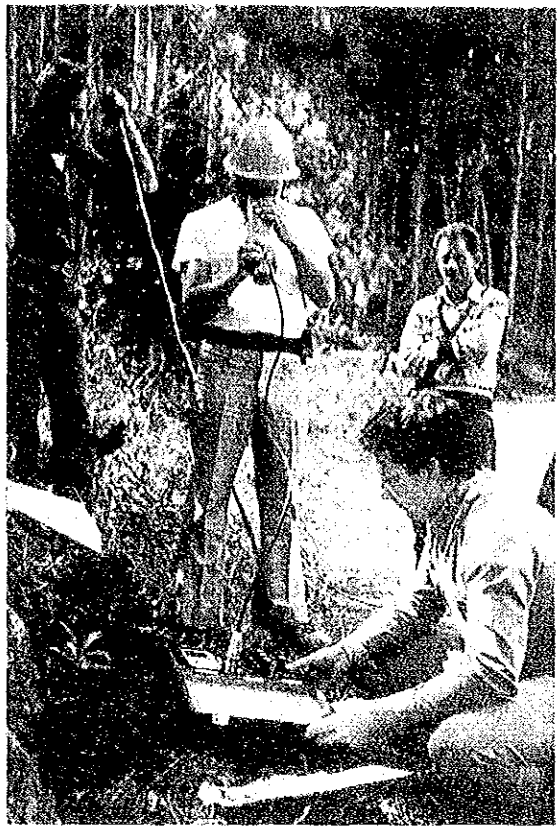


Photo 5. Investigation of work load by flicker value measuring unit

Photo 6. Stump holding power test for work safety

III. Studies on Logging Techniques

III-1 Outline of Research Cooperation on Logging Techniques

III-1-1 Content of Cooperation Project

The research cooperation in the field of mechanized logging can roughly be divided into two fields, transfer of techniques and research cooperation in a narrow sense. The transfer of techniques is indispensable for execution of the research cooperation in this field, and it was carried out ahead of the research cooperation.

The techniques taken up as subject of transfer of techniques, in compliance with the request of the authorities of the São Paulo State, were those of the logging systems for thinning; and they are widely adopted in non-clear cutting system in Japan as techniques of high managing efficiency and productivity for watershed control in mountainous region. Varieties of methods are resorted to for the purpose such as monocable system, slackline system, running skyline system, other cable logging systems, and logging systems by means of skidder, forwarder, monorail and chute.

As objectives of research, performance of machine, operational efficiency, work load, work safety, and operating cost, were taken up order toimprove the productivity, ensure the work safety, and lighten and work safety, and lighten the work intensity.

III-1-2 Proceedings of Research Cooperation

Machines and instruments necessary for the transfer of logging techniques and research cooperation were provided with starting in 1979, the first year of the project; and the research cooperation was started in 1981 in the stateowned forest in Campos do Jordão, located on Serra da Mantiqueira in the east of São Paulo.

A mechanical logging crew was organized to be accompanied by a counterpart in charge of technology, and transfer of techniques was started. Compartments 105 and 106 of the state forest were selected as the first exercise field, and thinning and collection of logs from the pine forest were operated with the workers using skidder T-50 and monocable system. Before setting up the monocable system, handling techniques of wire rope, that is splicing and securing by aluminum ferrule, were transferred. They made good progress in the tractor logging techniques

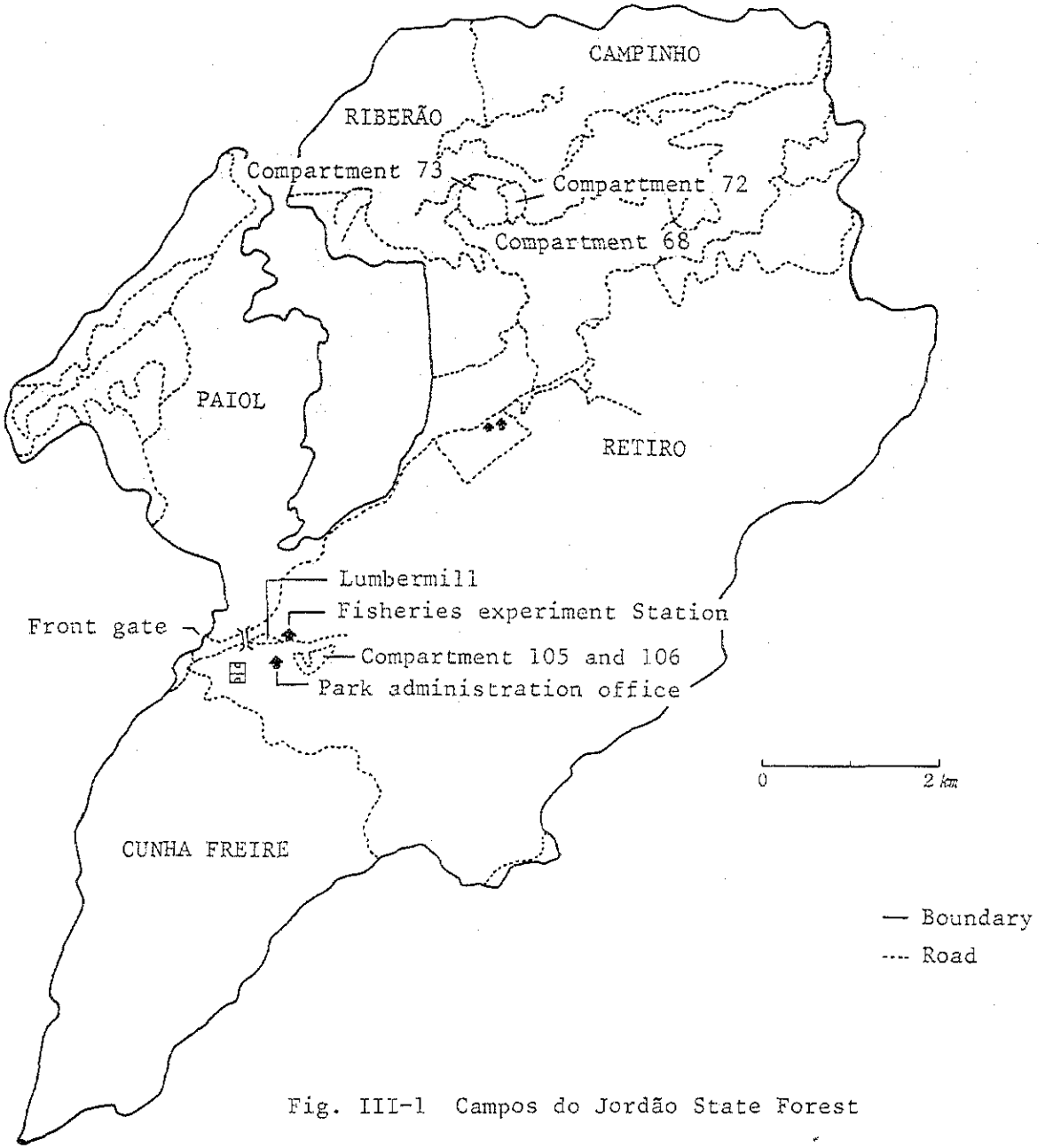


Fig. III-1 Campos do Jordão State Forest

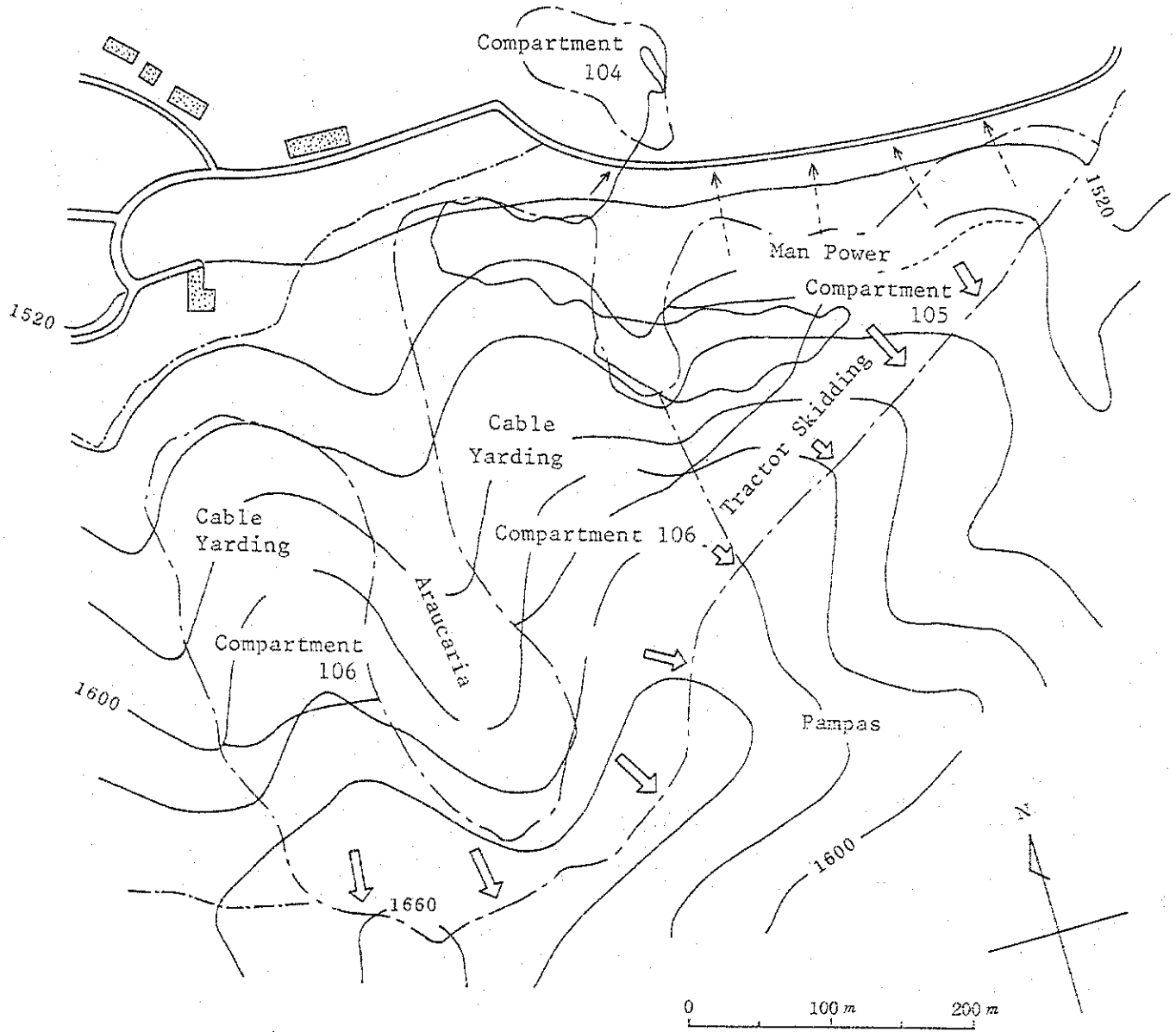


Fig. III-2 Park area

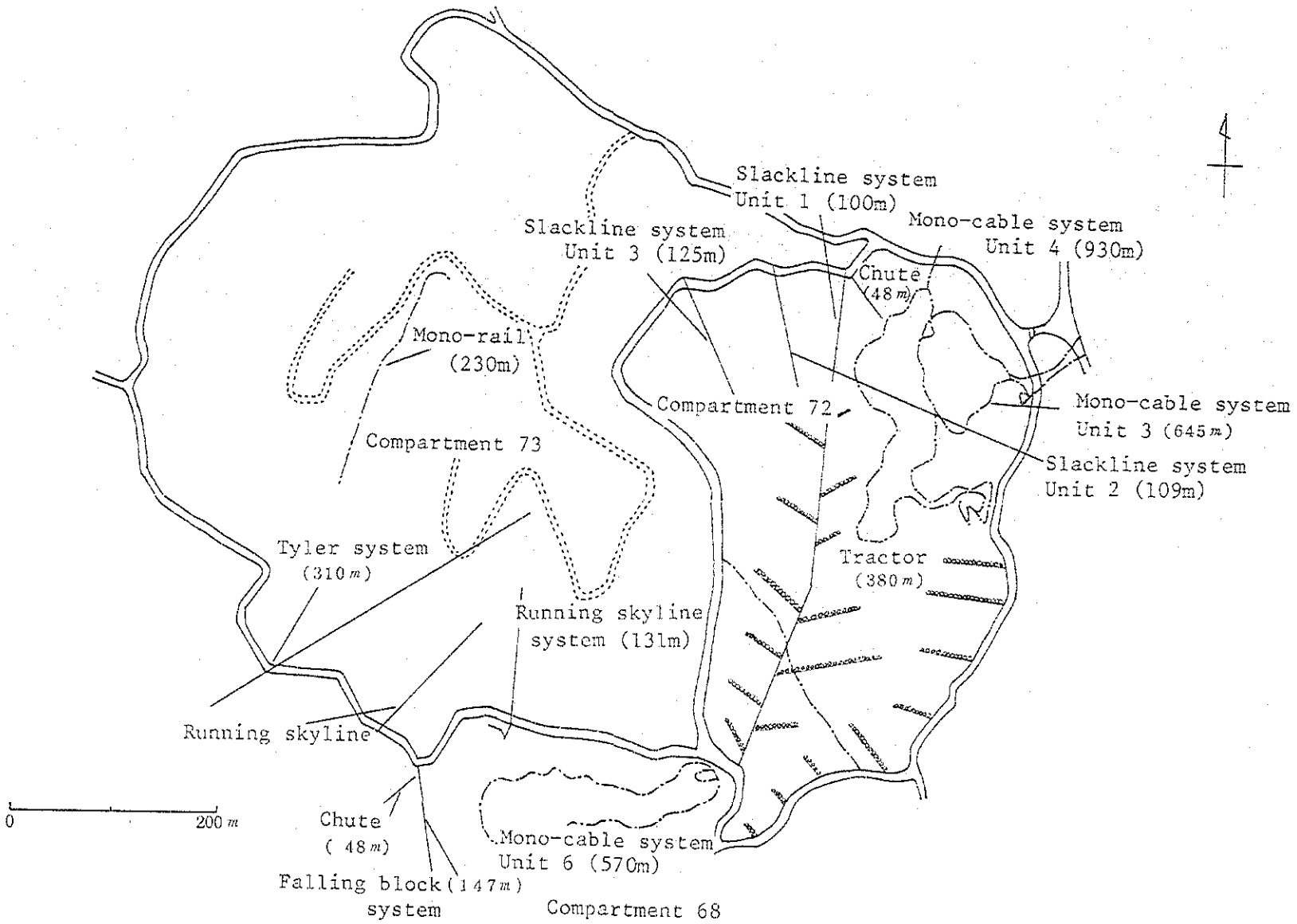


Fig. III-3 Ribeirão Area

before long and favorably carried out tree length skidding in thinning forest. A new Brazilian counterpart joined the group in September, 1981, and research cooperation mainly on investigation of performances of machines was started.

The new exercise field was prepared in Ribeirão area of the state forest, and the techniques for cable logging system by slack line were transferred in addition to the above techniques. In 1982, High-lead system and Endless Tyler system were installed in addition to Delpis forwarder, monorail transportaion unit and remote control winchs for training the logging crew.

After the transferred techniques almost took root in 1983, the research cooperation turned very active. The research objects of the Instituto Florestal do São Paulo was gradually clear, and emphasis was laid on the operation research rather than the mechanical one. Studies on operational efficiency was carried out along with appraisal of fixing of transferred techniques. Studies on the method of measuring labor intensity using respiratory analyzer and flicker value measuring instrument were carried out. On the other hand, in the field of transfer of techniques, running skyline system, aluminum chute, and order methods of collecting logs were introduced. Various techniques for thinning and logging operation transferred were repeatedly exercised until they were planned, installed, and operated by the Brazilian workers alone.

In the extended period of 1984 and onward, the research cooperation was focused on work study and safety, while the techniques on safety control and production control in the logging operation were presented, so that the techniques would take root in the state forest. In 1984 dtailed time study for improvement of operating methods, heart rate measuring method using heart rate memory, and testing method for the holding power of stumps as a part of safety study were taken up. The subject trees of stump test were Taeda pine.

In 1985, that is the final year, the research cooperation were undertaken for various tests such as the method of time study and analysis for various logging operations, work load measurement by means of heart rate investigation and flicker value test, measurement of line tensions of cable logging systems and the holding power of stumps of Elliotti pine as a review lesson of what had been transferred. In the field of technical cooperation, safety control and production control were taken up, and a record of no accident and no damage was established

for the whole period of the cooperation.

III-2 Result of research cooperation

III-2-1 Testing method for performance of forestry machine

(1) Aim of study

The principal objectives of mechanizing forestry operation lies in improving operating efficiency and productivity, reduction of working intensity, security of safety, and so on. In employing a new type of machine in a system of operation or switching into a new system of operation, the performance of new machine must fully be displayed, but is is also important to avoid occurrence of accident and disaster as far as possible. Therefore, it is necessary to investigate the performance of the machines correctly and select those that are suitable for the object of the operation. The operation beyond the proper performance of the machine must be avoided.

(2) Testing method and result

Items of tests vary depending on the kind of machines and the object of use. As common items, dimension of the main body, total weight, engine performance, braking performance, and other data of measurement can be enumerated, while, for vehicles, running performance, turning performance, and climbing performance shall be tested. Other important performances such as winch performance, tractive performance, and further noise and vibration emitted from the machine should be measured in some cases. Testing methods and results of testing are shown for each of the items, for main machines provided with in this project as follows:

① Measurement of engine speed

Measurement of engine speed is one of the fundamental tests of machine equipped with an engine. Machines of a type of larger vehicle is equpped with an indicator for engine speed, but in the case of chain saw, brush cutter, yarder,and mono-rail, engine tachometer is used. The engine tachometer consists of a sensor, amplifier, digital indicator, and battery in the case of HT-331 and of sensor and analog indicator with supply of AC power in the case of AR-721. The former tachometer is convenient in

inspection and adjustment of the engine in the field. Turn on the power switch, adjust the selection switch to the numbers of cylinders and cycles of the engine to be measured, bring the sensor closer to the top near the high voltage plug of the engine, and find the position where the engine speed is indicated on the digital indicator correctly. If the tachometer is not in the proper position, abnormal number is indicated. Take care not to change the position during measurement. Indicator of AR-721 is of an analog type and quick response, and it is suitable for more accurate measurement for a long time. The sensor is of a type of magnetic field induction, being connected by a cable, and the measurement in nallow space is possible even if the indicator itself cannot be brought in. For measurement, bring the sensor similarly to the case of HT-331 above, and switch the range of engine speed to meet the number of cylinders. DC voltage and current terminals for recording on data recorder (DTR-200) or electromagnetic oscillograph are located on the back.

② Measuring fuel consumption

Fuel consumption can be measured by a simple method of finding actual consumption by a certain work, starting from the full charge of fuel in the tank and finding the remainder of fuel; but for a correct measurement of performance test, the fuel consumption meter DG-100E is used. The instrument can be used either for gasoline or light oil; but the arrangement must be changed depending on the kind of fuel. In the case of a diesel engine, it is arranged generally between the filter and the injection pump as shown in Fig. III-4. If it is placed apart from the fuel pump because of the piping, an electric pump is used as shown in Fig. III-5

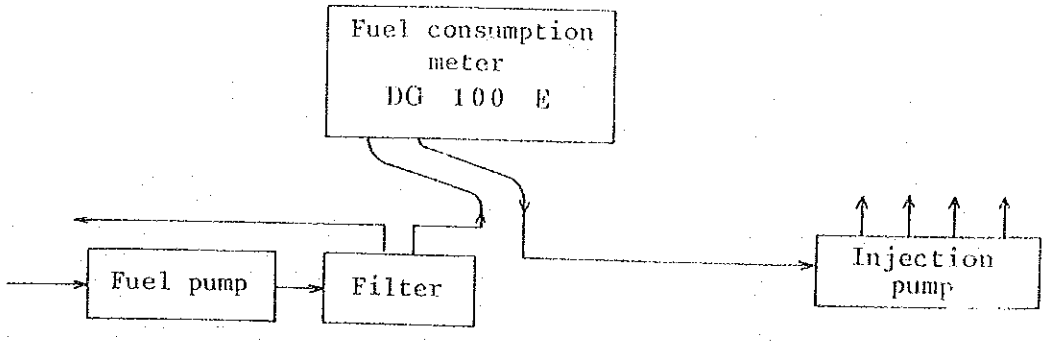


Fig. III-4 Diagram of measurement of fuel consumption of Diesel engine (1)

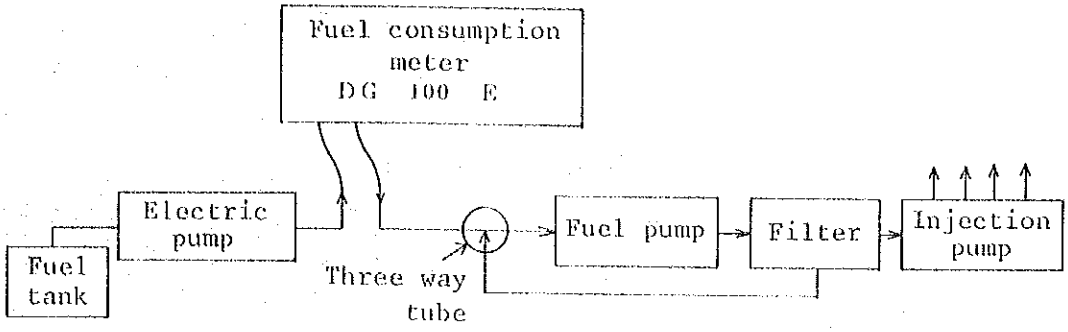


Fig. III-5 Diagram of measurement of fuel consumption of Diesel engine (II)

In the case of gasoline engine, the meter is arranged before the carburetor if the fuel pump pressure is 0.1 atm. or higher, as shown in Fig.III-6. In the case of fuel pump pressure being lower than 0.1 atm. or piping being in the manners of Fig. III-6, it is arranged as shown in Fig. III-7 along with electric pump and others.

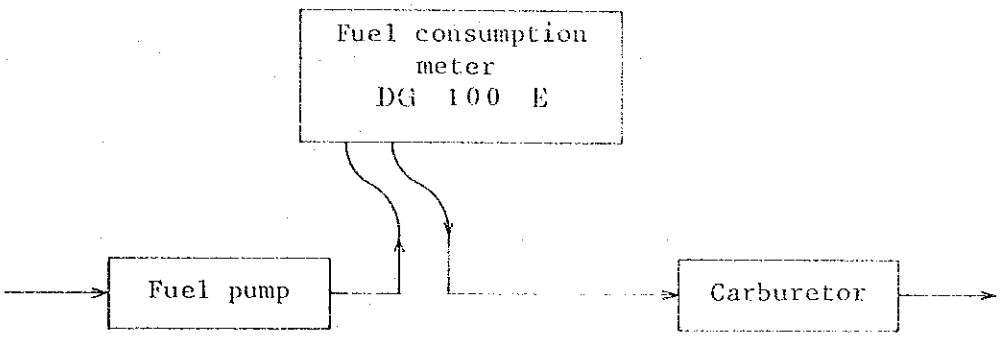


Fig. III-6 Diagram of measurement of fuel consumption of gasolin engine (Pump pressure is higher than 0.1 atmospheric pressure)

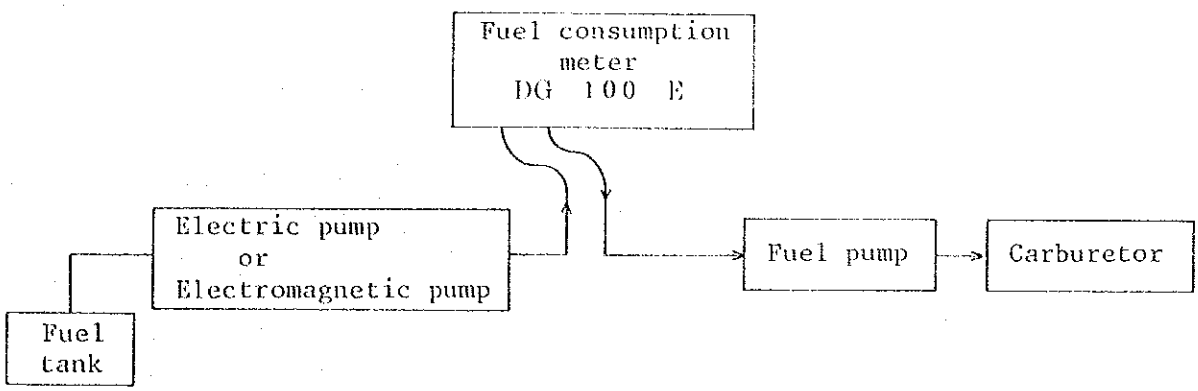


Fig. III-7 Diagram of measurement of fuel consumption of gasoline engine (Pump pressure is 0.1 atmospheric pressure or less)

After the arrangement is completed, the power cord is connected to 12-V battery, making sure of the polarity, and the switch is turned on. The engine is started, and the air inside fuel consumption meter and pipe to the carburetor is eliminated. This is achieved by connecting the attached vinyl tube on the de-airing valve at the exit of the meter and by loosening the screw. After all of the air is eliminated, fuel begins to come out and de-airing is completed, the valve is closed. The counter on the meter is adjusted to zero and the measurement is started. The amount of fuel passing is integrated and indicated to be read. The maximum of reading is 999.995 liter and the minimum 0.005 liter (5 cc). Fig. III-8 shows the result of a test for the relationship between fuel consumption and engine speed of chain saw. In measurement for a chain saw, an electric pump shall be used in place of the fuel pump in the arrangement shown in Fig. III-7.

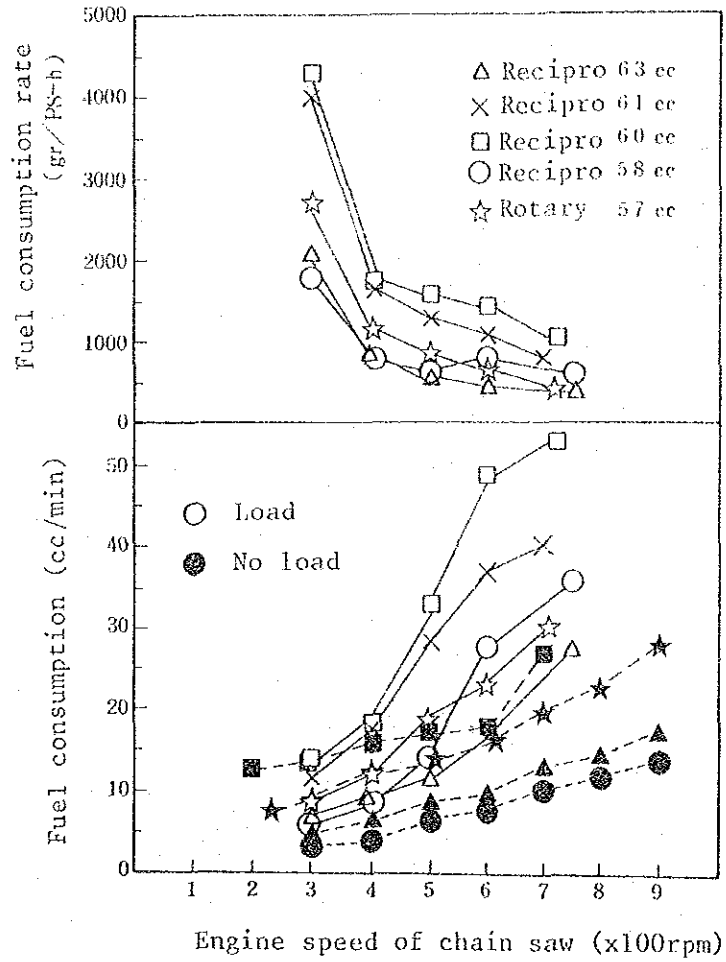


Fig. III-8 Relation between fuel consumption and engine speed of chain saws

Table III-1 Running speed of Forwarder DP-100

(1) On a flat paved road of 50 m length carrying trailer on the back

Transmission	1st test	2nd test	3rd test	4th test	Average	Speed
	sec	sec	sec	sec	sec	km/h
Forward 1st	19.6	18.9	18.9	18.1	18.88	9.5
2nd	12.8	11.9	11.7	11.0	11.85	15.2
3rd	8.0	8.0	7.9	7.4	7.83	23.0
Backward	24.0	23.9	24.2	24.0	24.03	7.5

(2) On a flat paved road of 1 km length, carrying logs on trailer

No. of test	Time measured	Speed	Load	Remarks
		km/h	kg	
1	4'50"	12.41	1,889	Three-wheel drive
2	4 20	13.85	1,880	(Forward 3rd)
3	5 00	12.00	1,779	
4	5 00	12.00	1,863	
5	4 30	13.33	1,813	
Average		12.72	1,845	
1	4 50	12.41	1,575	Two-wheel drive
2	4 20	13.85	1,651	(Forward 3rd)
3	5 00	12.00	1,601	
4	5 00	12.00	1,613	
5	4 30	13.33	1,660	
Average		12.72	1,620	

③ Measuring running speed, minimum turning radius, and climbing performances

Running performances of forest vehicles can be measured by simple instruments such as surveyer's compass, measuring rope, stop watch; but it is important to make initialization and readings correctly.

The running speed of forest vehicle of wheel type is measured on a flat paved road, and that of a crawler type on a flat ground after cutting grass on, by selecting a straight course of 50 m or longer. During the test, acceleration rate is kept constant, and gear change, clutch operation and braking shall not be made. Three or more tests shall be made according to a sign by someone other than the driver under the same conditions, using a stop watch; and a mean value is obtained. Table III-1 shows the result for the forwarder DP-100.

Minimum turning radius is generally measured similarly on a flat paved road in the case of wheel type vehicle, and on a flat ground after cutting grass in the case of crawler type one. An area sufficient for turning of the vehicle shall be secured. The test shall be made without load on the vehicle. The running speed shall be about 2 km/h. The minimum turning radius is measured by the track of the center of outside front wheel in the case of wheel type vehicle and by the track of the outer edge of caterpillar in the case of crawler type vehicle. Table III-2 shows the result of test for DP-100. "A" in the table

Table III-2 Minimum turning radius of DP-100

	1-st	2-nd	3-rd	Average
A	0.90	0.94	0.94	0.93
B	1.10	1.15	1.16	1.14
C	2.85	2.85	2.85	2.85
C	3.36	3.36	3.36	3.36

shows the turning radius of the center of left wheel of trailer, "B" that of the center of left rear wheel of the tricicle, "C" that of the center of front wheel, and "C" that of the rightside end of steering handle (cf. Fig.III-9). B-A gives the difference in turning radius between inner wheels of tricicle and trailer but the difference is small so that the trailer wheels almost tread on the trail of the rear wheels of the tricicle.

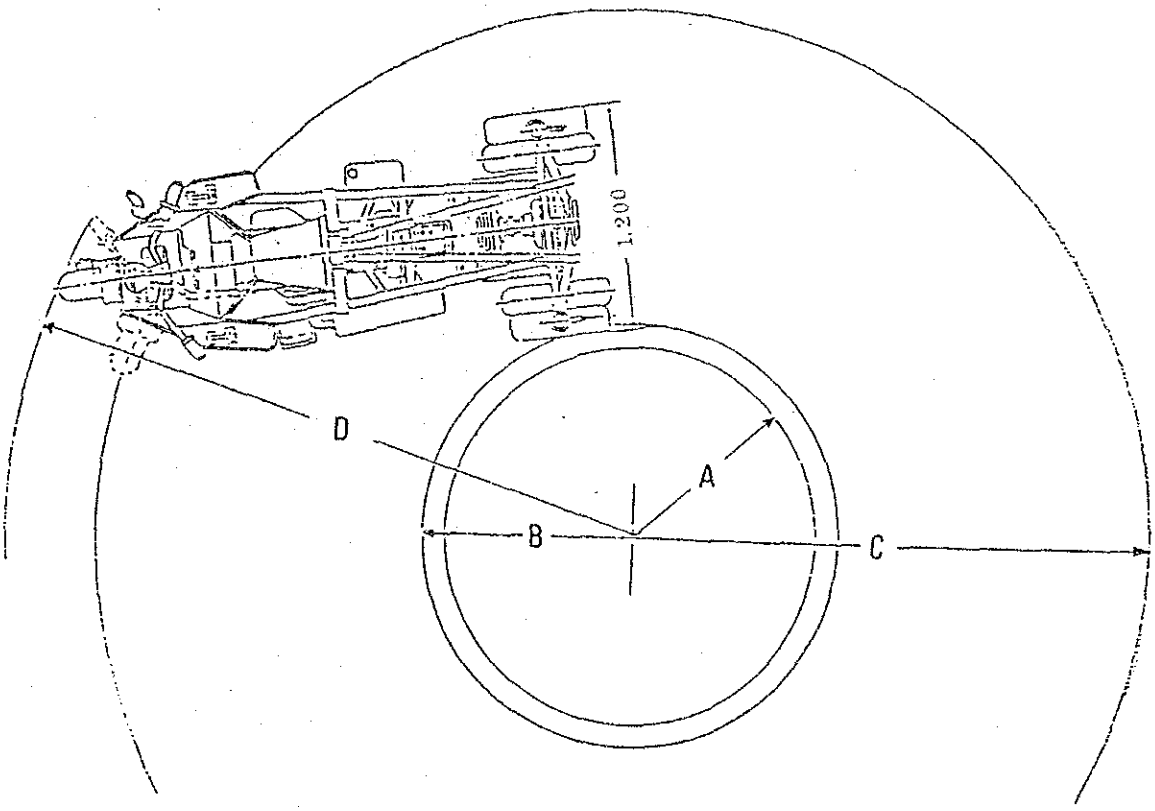


Fig. III-9 Turning radius of DP-100

Climbing performance of a vehicle is affected more by the conditions of road than by the output power of the engine, and tests must be carried out under grasping of road conditions correctly. A simple measurement of climbing performance is made by running the vehicle in a straight course of 30 m or longer length with a constant slope. Values for loaded and unloaded conditons shall be taken. The vehicle is run under each of the gear ratios, avoiding slipping of wheels as far as possible. The accelerator shall be opened full as required. Three or more

tests shall be made in the same course, and test is stopped when the road conditions change. Table III-3 shows the results on DP-100. Moisture content can affect the running performance, even if the same road is used.

Table III-3 Climbing performance of DP-100

(1) Grave road, 18° inclination 40 m testing distance, carrying trailer

1st speed	Possible
2nd speed	Possible
3rd speed	Impossible (stop halfway)

(2) Soft earth road, 20° inclination, 40 m testing distance, carrying trailer

1st speed	Possible
2nd speed	Possible
3rd speed	Impossible (stop halfway)

(3) Gravel road

1st speed, 11° inclination, climbable upto 800kg load Possible

1st speed, 16° inclination, climbable upto 600kg load Possible

(4) Gravel road, 25° inclination, 40 m testing distance, carrying trailer

1st speed	Possible
2nd speed	50% possible (twice success, twice stop halfway)
3rd speed	Impossible

④ Performance of winch

Winch is one of the most important machines in logging operation in combination with the cable. The same thing applies to yarder, skidder, remote control winch and forwarder. The performance test for a winch consists of measurement of cable tension and winding speed. For measurement of tension, load cells, dynamic strain meter, and photoelectric recorder are used.

The operation for these instruments are explained in Paragraph III-2-4, 'Study on Operation Safety'. For the measurement of cable winding speed, calculation is possible from the rotational frequency of the engine, gear reduction ratio, drum diameter, and number of layers of rope on the drum; but actual measuring and finding relationship between load conditions and especially obtaining slip rate on an endless drum are among the items of fundamental testing.

⑤ Tractive Performance

An accurate determination of tractive force of a tractor is generally carried out by means of an exclusive breaking car. However, a simple method for measuring tractive performances of skidder and forwarder will be explained here. Testing road is arranged on a strip road in a forest by measuring the slope and interval distance in advance. The tractor is fully loaded with logs and allowed to run. The speed of running shall be within the range where the driver feels no danger or apprehension. The time required for running is measured for each of the intervals, and relationship between the inclination and speed is obtained. The maximum amount of traction and speed vary with the conditions of the ground surface, whether it is on a road or forest ground. Fig. III-10 shows the relationship between the inclination of skid road and tractive performance of T-20 and DP-100. In the traction test logs of Patula pine are dragged on the ground. The distance of dragging was 10 - 30 m, the ground was of dry soil, and the weather was fine.

⑥ Measuring vibration and noise of chain saw

Measurement and analysis of vibration acceleration and noise level of a chain saw can effectively be carried out by the system shown in Fig. III-11. For measurement of vibration acceleration, a triaxial pickup (PV-93) is fixed on the grips of front and rear handles by means of steel band. Then the sensitivity of vibrometer (VM-23) is set in the range for indication without overscaling. Reading of the indicator can be done in the field, but the data-recorder (DTR-200) shall be connected so that frequency analysis can be made later and that

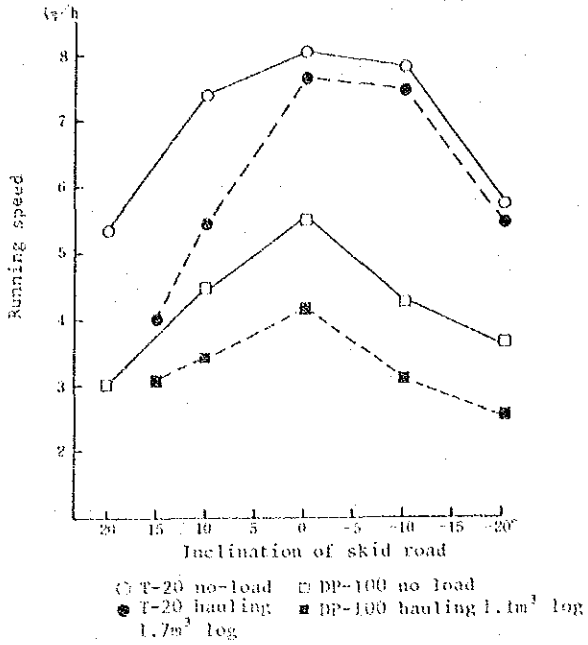


Fig. III-10 Relationship between road inclination and running speed of T-20 and DP-100

the output of the engine tachometer (AR-721) and the noise level meter (NA-61) are recorded simultaneously. Measurement of noise level is carried out by fixing the microphone (VC-26) on the helmet near the right ear of the operator. For frequency analysis, each of the signals is taken out of the data-recorder to be charged on the frequency analyzer (1/3 octave filter unit NX-02A) connected, the rotational frequency of engine recorded simultaneously being checked, and the data during stable rotational frequency are adopted. Inspection of the meter before and after measurement by means of a vibration calibrator (VP-23) and piston phone (NC-72) and assuming a constant operator posture during measurement as shown in Fig. III-12 contribute to reliability and reproducibility of the data obtained and to proper appraisal of the machines tested.

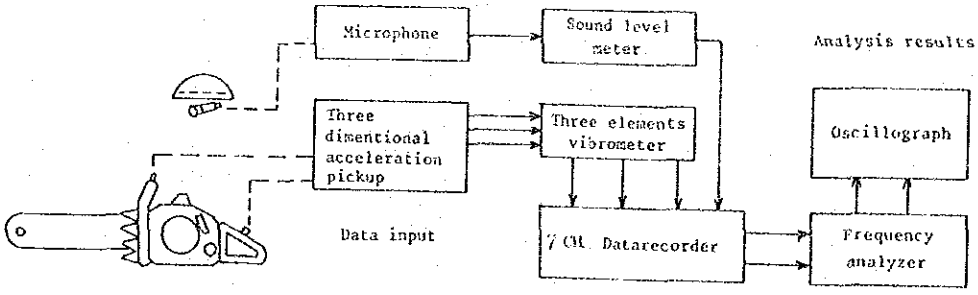


Fig. III-11 Flow sheet of measurement and analysis of vibration and noise

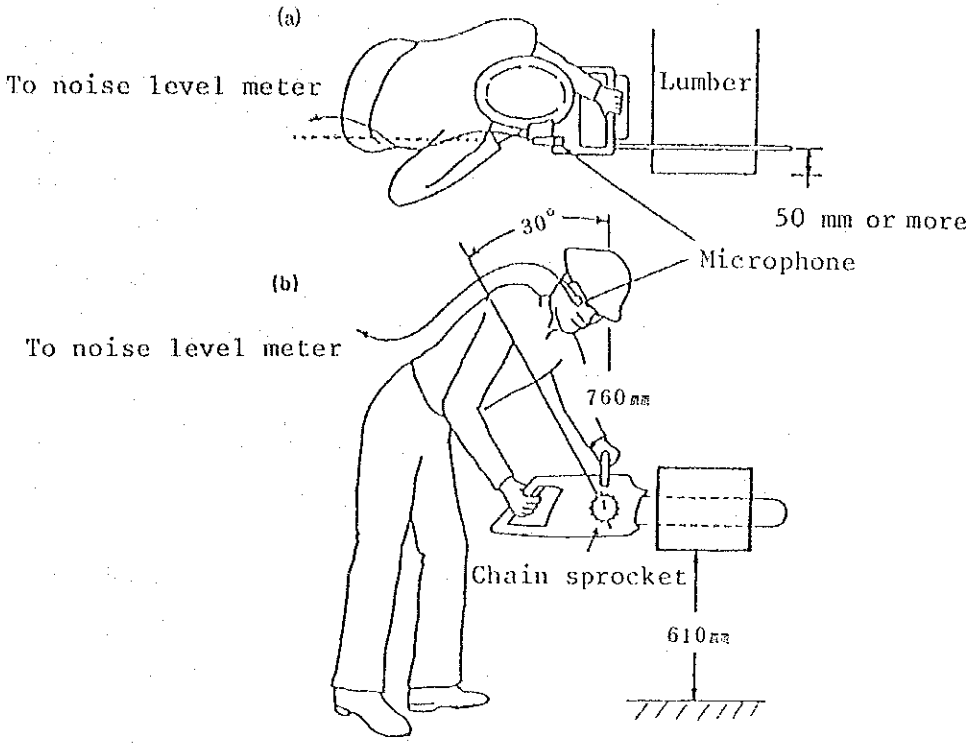


Fig. III-12 Posture at the measurement of the noise by sawing

III-2-2 Studies on investigation of operation efficiency and improvement of operation scheme

(1) Target of study

Work study consists of method study and work measurement. Method study is a methodology for optimizing working method, and work measurement can be called a theory for measuring the time and resources (raw material, production means, labor, and energy) needed for a work. The region of work study overlaps with that of work science and human engineering in the awareness of problem to find out how to work safely and with less fatigue.

The direct objective of work study lies in improving and designing working method and operation system, standardization of working method, training of workers for a working method, work control, providing data for planning and controlling departments, measuring productivity, and so on. In order to understand the

problem of work as the subject of study correctly, it is necessary to investigate and analyze the actual state where the problem is fostered, along with pursuing the object and function of the work. For this purpose, the means of investigation of operational efficiency provides with an effective clue. It can elucidate the factors for bringing about the problem, not to speak of finding the point of problem in the existing conditions. It can also allow us to grasp the possibility of another problem being fostered in the future in the case of the existing conditions being left uncorrected, and this is effective in improving the operation system.

Transfer of techniques of mechanized logging was undertaken with an object of selecting logging methods suitable for thinning of mountain forest and of letting the methods take root in the land. Therefore, it is necessary to evaluate the degree of taking root, as working techniques in transportation of thinning logs, from the aspect of operational efficiency, by quantitative understanding and comparison of the results of transfer of techniques in terms of forestry production techniques. By comparison of operational efficiency, the productivity data that are the basis of operation plan or production plan are obtained. Further, the effectiveness of time study in improvement of working method is shown. Therefore, the work measurement is taken up for study in the present paragraph. It would be superfluous to say that the classification into method study and work measurement is made by the object, and many of the techniques actually applied are in common.

(2) Method of investigation

① Investigation of working conditions

Factors affecting productivity in mechanized logging operation are investigated. First factors concerning operation system, that must be decided in the stage of working plan or execution of operation, are taken up, such as machines used, organization of logging crew, working methods, linking with the working steps ahead or behind. Social conditions and environmental conditions affect mainly working hours, and they must be understood. Employment relationship, labor conditions, traffic condition and climate are some of the examples.

As the factors related to forest and logging material that is the subject of work, the following factors can be enumerated in addition to the method of treatment (clear cutting, selective cutting, thinning, etc.). Tree species, stand age, growing stock (m^3/ha), stand density (number of trees/ha), size of standing tree (DBH: cm, tree height: m), size of logs (diameter: cm, length: m), production or output (m^3), and so on.

As the factors related to the logging site, relationship of forest road and strip road with the cutting area, size, shape, topography, surface conditions of the forest ground (inclination, irregularity, soil, vegetation, etc.) of the cutting area, skidding direction, and yarding distance can be enumerated.

② Time study

For time study, the workers of average skill are desirable as observation subjects. It is also desirable that workers, who can work in their normal pace under observation, are selected.

It is by no means pleasant for them to be observed and measured during work. Therefore, it is necessary to explain the objective and method of investigation in advance and ask them not to mind the observation and to work in their normal place.

Instruments such as stop watch, time study board, writing materials, and measuring instruments are necessary. A stop watch of digital type is easier to handle. The study board of a size larger than that of observation sheet with hanging tape is desirable for less fatigue. Holders of stop watch and sheet holder attached to the board are also convenient. For recording working conditions, measuring instrument (compass, measuring tape, poles), calipers, hypsometer, and a scale are arranged. The data processing after observation, an electronic calculator shall be arranged.

The first thing that the observer should consider is to place him in a safe place and not to disturb the operation. Observation is made usually from the side or obliquely in front of the worker. The observer should keep standing so that he can respond quickly to the action of the worker and record it.

The degree of dividing the work into elements depends on the characteristics of the work and on the object of investigation. Detail is not necessary for planning, but for an improvement of working method, the structural content of working hours shall be divided into those of main work and subsidiary work with clearly divided allowances. General method for dividing works into elements is as follows: (a) The work is divided into elements so that they are clearly distinguished with one another. (b) Working hours are divided into those by mechanical work and manual work. (c) Works of the nearly constant pace and those of varying pace depending on the size or weight of materials are separated. (d) Works of cyclic nature and these of small frequency or of non-cyclic nature are separated. (e) Elements shall be of short working time as far as possible in the range of observer's skill.

③ Procedure of time study

The following is the procedure for actual time study.

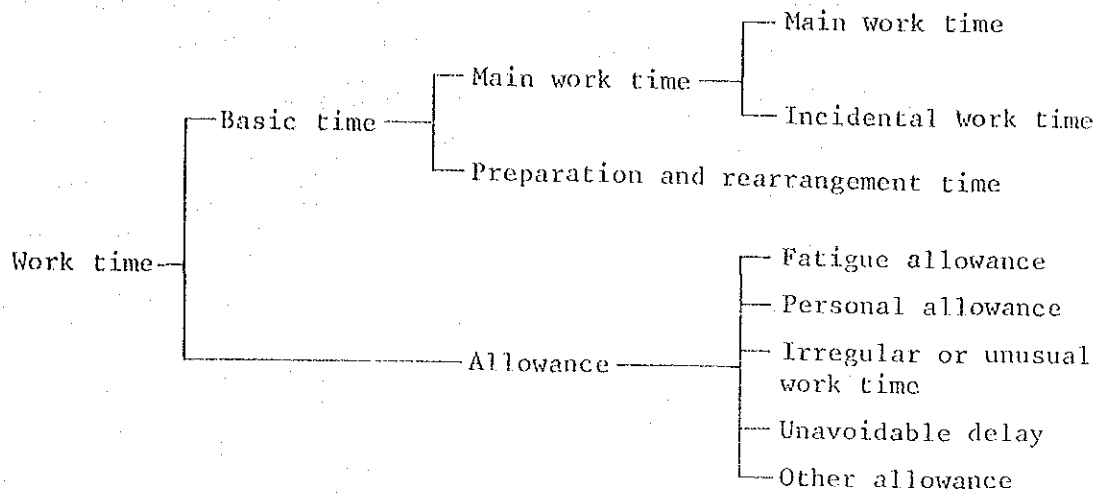
(a) Deciding the object and subject of observation, planning for execution.
(b) Selection as subject of observation.
(c) Explanation to the foremen and workers.
(d) Investigation of operational conditions.
(e) Investigation of working process.
(f) Making a list of elements of work.
(g) Presentation of elements to the observers. Training of observers if necessary.
(h) Time observation.
(i) Investigation of products.
(j) Putting the results of observation together.

④ Putting time study data together

For putting data of time study together, the main work time, preparation and rearrangement time, and allowance shall be treated separately.

The main work time is the time spent for the working object direct, and in a repeated work, some elements appear in every cycle, while some others appear once in several cycles.

Table III-4 Work Time



Those appearing in a small frequency and requiring a short time are treated as allowance. Preparation and rearrangement are meant for a smooth operation of the main work, and they appear before and after the morning work and afternoon work. Allowance consists of fatigue allowance, personal allowance, irregular elements, and unavoidable delay. Fatigue allowance is a resting time for recovery from fatigue so that the work is continued. Personal allowance are inevitable interruption of work by the needs of worker, such as those for easing the nature, drinking water or wiping sweat. Irregular elements include those of irregular occurrence and small frequency of short time and of a nature originally to be included in the main work time or subordinate work time. Unavoidable delay means interruption of work by unavoidable or unexpected happening such as trouble in the machine.

(3) Operational efficiency investigation

① Investigation for understanding productivity

(a) Work as subject of investigation

As the subject of investigation, extraction work of logs in

thinning site was selected, for a sufficient time had elapsed since the techniques were transferred and the logging crew had already mastered them. More concretely, Mono-cable system and Slackline system were taken up among cable logging systems. Tyler system was formerly installed for exhibition in a meeting of Brazilian forestry society and it is not necessarily suitable for transportation of thinned logs, but investigation was carried out after some period of training. Among tractor logging systems, the work by T-20 skidder was taken up.

Table III-5 Outline of mechanized logging system

Logging system	Number of workers	Crew member				Span	Inclination between upper and lower supports (degree)	Machine used		Pull capacity	Cable diameter
		Choker setter	Chaser	Landing worker	Machine operator			Type	Output		
Mono-cable	5	2	1	1	1	*5.2~22.8 13.7 m	5.0~25.00 12.40	Y-252E	67ps 3200 rpm	3000 kg	12 mm
Slackline	4	1	2		1	125 m	15°	KK-1	12ps 2200 rpm	1000 kg	12 mm
Tyler	4	1	1	1	1	340 m	12.5°	Y-252E	67ps 3200 rpm	3000 kg	14 mm
Skidder	2	1			1	200~300 m		T-20			

* Total length of endless cable: 420 m

Collection of logs by conventional method was also investigated for comparison in order to obtain data for the mannual work operated before introduction of the mechanized logging operation.

(b) Thinning site

Manpower collection of logs and mono-cable logging were carried out in Retiro area, compartment 38 of Campos do Jordão state forest. In Ribeirão area, compartment 72 Slackline system was applied, in compartment 73 Tyler system, and in

compartment 68 tractor logging.

The tree species was Taeda pine in compartments 38, 68, and 72, and Elliottii Pine in compartment 72. All of the trees were planted in 1962 - 1963, and the age was 21 - 22. The standing density was 1638 - 2600 trees/ha, average diameter at breast height 17 - 19 cm, average tree height 17.5 - 19.5 m, and growing stock 491 - 629 m^3/ha. The thinning rate was 58 - 64% in the number of trees and 37 - 45% in the volume.

The inclination of the ground is 13 - 33°, and about 25° is the most frequent inclination. The average inclination of land for tractor skidding is 15°. The forest floor was covered with defoliated pine leaves in 10 - 15 cm thickness, but the humus layer was not very thick. No vegetation was noticeable on the forest floor except small number of herbs and shrubs.

The soil is red yellow latosol, and practically no rocks and gravels are contained. Therefore, forest roads can be constructed easily, and they have been arranged in a density of about 40 m/ha. However, gravel for covering the road is hardly available, and passage in rainy season is difficult and the road surface can be damaged by heavy vehicles.

(c) Outline of operation

The selection of trees for thinning was made by a specified worker for all of the thinning site at 60%. The standard of selection is similar to the low thinning method.

Felling of thinning tree was operated by two workers using a chain saw. The branches were removed by a sickle, and chain saw was rarely used. Cross-cutting was operated on the landing in the case of tree length logging by skidder, but in the forest otherwise. Cross-cutting was operated by two workers as a team by means of a chain saw, one in charge of measuring and the other cutting. Cross cutting into 4 m was normal, except cutting into 2 m for large diameter logs that cannot be logged in the case of manpower logging.

Manpower logging was operated by means of wire or nylo rope of about 2-m length with a wooden handle of about 30 cm attached to one end and skidding the logs on the ground. The longest

Fig. III-13 Man-power skidding

distance of dragging was 80 m. In the case of difficult skidding of large log by one worker, two or three workers skidded in cooperation.

Log hauling was carried out with the mono-cable crew using a portable single-drum winch, and logs were collected for a distance of 20 m to the cable. It was operated by two workers as a team, one operating the winch and the other hooking operation, taking turn occasionally.

Monocable system was operated on the continuous transport system by two-point suspension method. The circulating cable was stopped every time of loading and unloading, but no loosening or stretching of circulating cable was made. The tension of cable was held constant from the start to the end of operation for a day.

Slackline system was set up so that the hooking and unhooking can be recognized by the operator as the span is as short as 125 m. The main cable had an inclination of 15°, and the suspended load run down by its own weight when the cable was

tightened.

In the Tyler system, the operating procedure and guiding of carrage in lateral yarding on thinning site were difficult, and the system was not accepted by the workers. Therefore, lateral yarding was not done and logs collected under the skyline alone were swung. The span length was 340 m and the inclination between upper and lower supports was 12.5°.

Tractor logging was operated by tree length logging, and the yarding distance was 250 ~ 300 m. The choker setter arranged in the forest for the next turn after his choker setting was over. The logs were cross-cut in the landing outside forest after skidding.

(d) Result of investigation and discussion

Table III-6 shows the results of operational efficiency investigation. The amount of logs collected by man power by one ground skidding was as small as 0.045 m^3/turn on average, but the number of turns can be larger, and average logging of 2.848 m^3/man-day was given as a result by 5 workers, which lies in a medium position among several means of logging. Forest land has a suitable inclination for skidding, and it is one of the effective means of logging when the distance is short and the logs are of a small size. The mono-cable logging showed a small variation in operational efficiency by log diameter and yarding distance. (cf. Fig. III-14 and Fig. III-15) This is considered to be an effect of continuous transport. The operational efficiency was as low as 1.796 m^3/man-day, being limited by the loading operation, that had to depend on man power, and the running speed of circulating cable at 0.6 m/sec; but a stable efficiency was shown. Slackline system showed a small variation of 3.147 - 3.521 m^3/man-day owing to the small span of 125 m, that caused small variation in yarding distance and number of turns. The system is expected to give stable production if it can be installed so that the turn of logs will not collide with the ground and that a sufficient inclination between the spar trees can be arranged for transportation by gravity. Tyler system showed a yarding volume as large as 0.492 m^3 at a time on average, but the daily opera-

Table III-6 Result of operational efficiency investigation

Logging system	Working hours	number of turns	Total pieces	Total production		Yarding production m^3/man-day		Yarding distance	Remarks
				Mean diameter method	Top diameter square method	Mean diameter method	Top diameter square method		
Man power	6 hr. 10 min	365	493	17.382	15.805	3.476	3.161	~ 50	Five workers
	6 23	280	390	12.464	11.818	2.493	2.364	~ 65	
	5 32	218	318	10.458	9.279	2.092	1.856	~ 75	Suspended in the afternoon by rain
	6 20	339	536	19.283	16.996	3.857	3.399	~ 70	
	3 10	225	399	12.370	10.173	(2.474)	(2.035)	~ 73	In the morning only
Mono-cable	6 54	101	194	11.103	10.738	2.221	2.148	65 ~ 81	
	6 58	99	188	9.309	8.917	1.862	1.783	68 ~ 100	
	7 00	105	172	9.219	8.993	1.844	1.799	93 ~ 122	
	5 51	85	127	7.787	7.528	1.557	1.506	113 ~ 133	Suspended in the afternoon by rain
	6 58	97	141	9.705	9.370	1.941	1.874	160 ~ 188	
	6 59	87	122	8.294	7.998	1.659	1.600	187 ~ 197	
	6 33	96	120	9.805	9.324	1.961	1.865	194 ~ 240	
Slackline	6 26	83	269	12.486	12.586	3.121	3.147	65 ~ 84	
	6 17	88	290	13.315	13.067	3.329	3.267	80 ~ 110	
	6 38	83	227	14.718	14.082	3.680	3.521	37 ~ 95	
Tyler	6 16	39	136	17.101	17.982	4.275	4.500	140 ~ 151	
	6 32	50	198	24.917	27.063	6.229	6.766	55 ~ 150	
	6 06	37	252	21.459	22.071	5.365	5.518	129 ~ 150	
	6 11	43	202	19.088	20.092	4.772	5.023	85 ~ 151	
	2 57	25	77	7.839	8.189	(1.960)	(2.047)	~ 85	In the morning only
Skidder	4 33	12	48		8.68		4.34	250	Many obstacle trees treated
	5 28	17	110		20.66		10.33	270	
	5 29	16	108		16.64		8.32	300	

tional efficiency showed a large fluctuation owing to variable number of times per day caused by efficiency in choker setting operation. The Tyler system cannot be regarded as a suitable system at the moment because a high skill is required for installation and removal. Tractor system showed 4.34 m^3/man-day even on a day when much time was spent for treatment of obstacle trees. In a favorable case, the operational efficiency as large as 10.33 m^3/man day was shown.

Comparison of operational efficiency based on one by man power hauling (2.848 m^3/man day) gives similar value by the Slackline system (3.312 m^3/man day) on average, and smaller efficiency by the Mono-cable system (1.796 m^3/man day). There was not very large difference in times of yarding and size of logs extracted between the Slackline system and the Mono-cable system, but the amount of logs loaded per turn was larger in the Mono-cable system (0.156 m^3 on average) than in the Slackline system (0.094 m^3 on average); and this resulted in the difference in daily efficiency. Although the operational efficiency in the Mono-cable system is lower than those of other systems, the feature of the system of "mechanized yarding without damaging the forest ground" should be appraised; for the logs are carried under complete suspension. The operational efficiency of tractor skidding is as large as 7.663 m^3/man-day, which is larger than one by the Tyler system, the largest of the cable systems (5.300 m^3/man day). Besides, no auxiliary works such as installation and removal is necessary; and the overall productivity is higher. However, it can be a problem that the remaining trees are damaged and the forest ground is disturbed.

The degree of the techniques transferred by the present project taking root as those of the Instituto Florestal was measured by comparison of the operational efficiency between the same works in Brazil and Japan. The operational efficiency of tractor skidding is largely affected by the conditions of remaining trees as obstacles. This is clearly shown by the fact that the efficiency can be half as large as one in normal days when removal of many obstacle trees is necessary. Comparison of tractor logging systems was not possible due to lack of examples in Japan, where intensive thinning of 60%

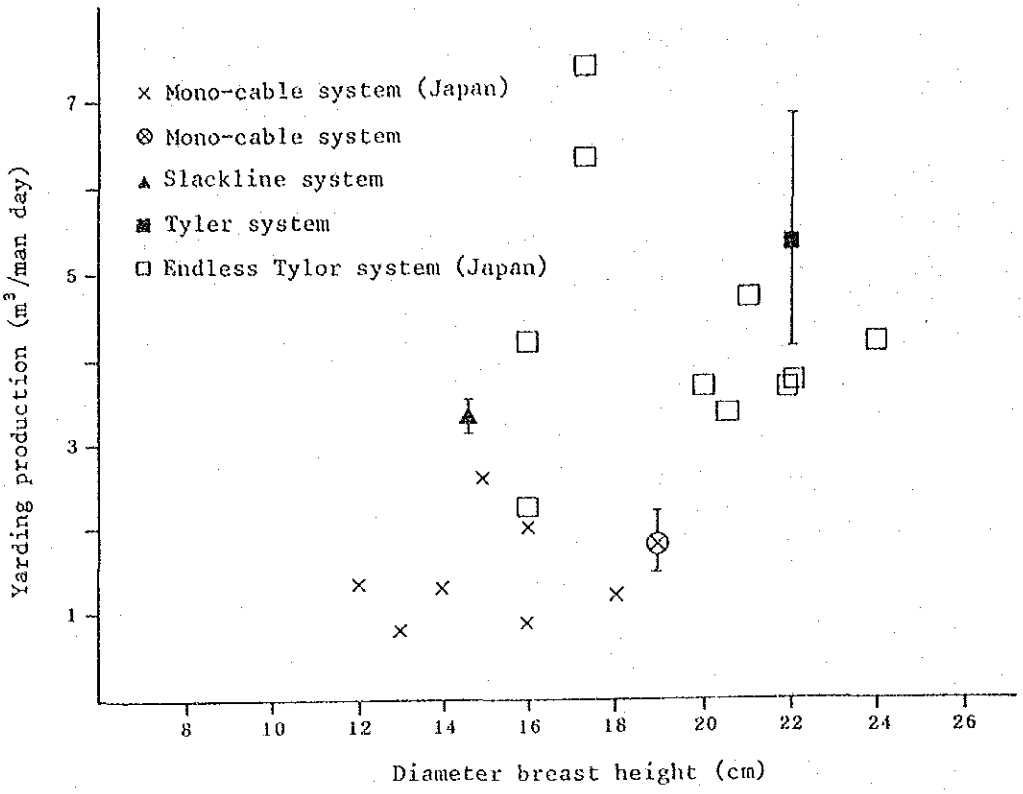


Fig. III-14 Yarding production per man-day versus average diameter breast height

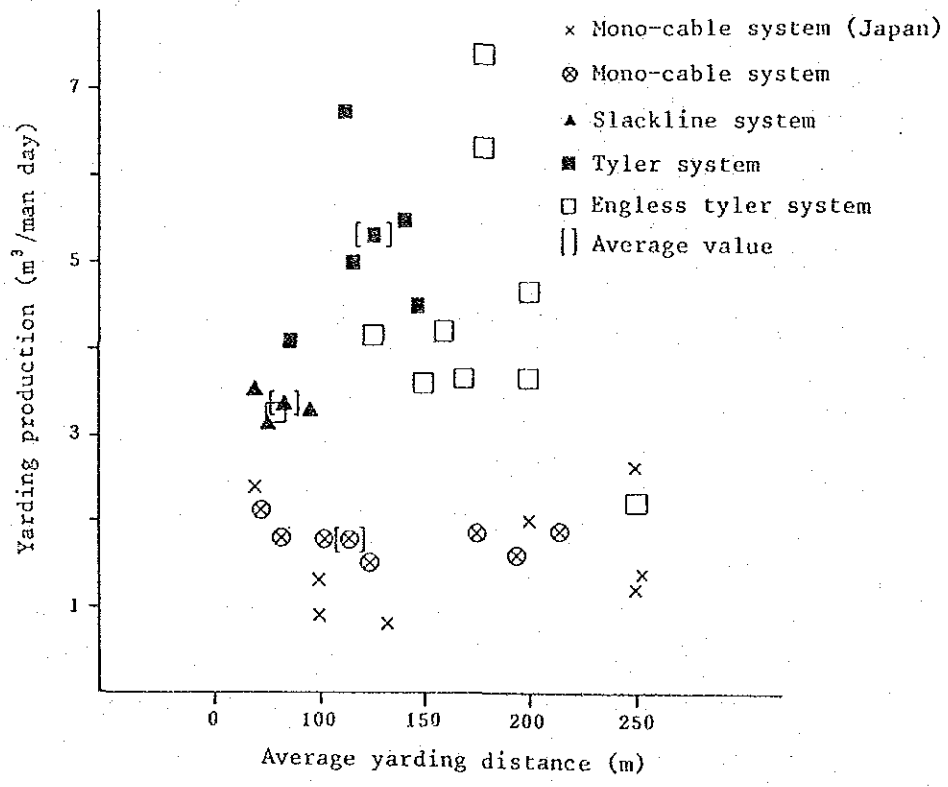


Fig. III-15 Yarding production per man-day versus average yarding distance

in the number of trees and tree length yarding by tractor are not carried out; and the comparison was made only for cable logging system.

Examples in Japan were extracted that are similar to the conditions in Campos do Jordão state forest; namely thinning and logging operation in a coniferous man-made forest with groung inclination of 15 - 30° with trees of mean diameter breast height of 25 cm or smaller, and collecting bucked logs for a distance of 250 m or shorter. No example of Slackline system being applied was found, and no case of Tyler system satisfying the said conditions was found either. However, there are many cases of endless Tyler system being applied to the thinning operation in Japan, as shown in Fig. III-14 and Fig. III-15. Comparison of these data with those of Campos do Jordão reveals that the operational efficiency in the latter case reaches the medium level in Japan.

Operation techniques in tractor logging is discussed in the next paragraph in detail, and the technical level at the moment of the present investigation is not necessarily sufficient. However, the efficiency was the highest of all systems. This may mean that Brazilian workers are accustomed to driving vehicles and they can acquire tractor logging techniques more easily.

From the facts described above, it is clearly that the mechanized logging techniques as introduced by the present project have taken root as those of Instituto Florestal do São Paulo.

② Time study for improvement of operation method

(a) Aims of investigation

Vehicles running on land routes occupy the leading position of traffic and transportation systems in Brazil, a continental country. Workers in Brazil are familiar with machines of vehicle type, and the techniques of tractor logging is the most welcome of all, probably being well suited to the national character. The tractors for forestry use have been developing recently in Brazil among difficult condition to produce forestry machines. Diversion of agricultural tractors to

forestry is another fact that makes us assume that the most dependable techniques in the future is tractor logging.

Based on these assumptions we would like to provide some guide lines for understanding the operational efficiency in the introducing stage and improving the operating methods, so that the tractor logging techniques may take root as logging techniques in mountain forests. We tried to improve the operation methods first, followed by investigation of the effect of improvement to prove the appropriateness of the improvement plan.

(b) Result of investigation and operation improvement plan

In order to examine the degree of newly introduced techniques taking root after introduction and to find out the points of improvement in operation method, a detailed time study for the works is necessary. Here every work element consistuting the work must be recorded for a detailed time study, and every wasteful motion and repetition in the work must be found out. Outline of the forest conditions in the detailed time study (whole day time study) of the tractor logging operation carried out in Taeda pine forest in compartment 68 of Campos do Jordão state forest using the skidder T-20 is shown in Table III-7. The number of standing trees and thinned trees was counted for two sample plots 20 m x 20 m size. The investigation was carried out for four days, but the result was arranged in Tables III-8 to III-14 for whole of the three days, omitting one in the first day when the operation method by choker setter was different.

Table III-7 Subject thinning forest for tractor logging for Tractor logging

Forest	Campos do Jordão state forest, Compartment 68
Tree species	Taeda pine (man-made forest)
Stand age	22 years
Stand density	1,575/ha
Growing stock	(Unknown because of volume table not prepared)
Thinning rate	57.9% by number of trees
	38.8% by volume
Inclination	about 15° (5° - 25°)

Table III-8 Summary of logging operation of thinned logs by skidder T-20

(1984)

Thinning site	Campos do Jordão state forest, compartment 68			Remarks
Forest condition	Taeda pine man-made forest, 21-22 years of age Thinning rate: (volume) 38.8%, (number) 57.9%		Stand density: 1,575/ha Growing stock: Unknown, because of volume table not prepared yet.	
Topography	Inclination: about 15° (5° - 25°)			
Date of investigation	14/11/84	21/11/84	22/11/84	
Yarding distance	250 m : 200 m skid road 50 m in forest	270 m : 200 m skid road 70 m in forest	300 m : 200 m skid road 100 m in forest	cf. Fig. III-16
Crew member	2 (choker setter and operator)	2 (ditto)	2 (ditto)	
Log type	Tree length log	Tree length log	Tree length log	
Daily production	8.68 m^3 (48 trees)/day	20.66 m^3 (110 trees)/day	16.64 m^3 (108 trees)/day	
Number of turns	12	17	16	
Tern volume	0.723 m^3 (4 trees)	1.215 m^3 (6.5 trees)	1.040 m^3 (6.8 trees)	
Working hours	Operator 16,087 sec. Choker setter 16,358 sec.	Operator 19,702 sec Choker setter 18,660 sec	Operator 19,346 sec Choker setter 18,787 sec	Less preparation time, rearrangement time, and excludable time.
Characteristics of work	Choker setter prepares for the next turn in mountain.	ditto	ditto	

Table III-9 Work time analysis of skidder operator (1) Date: November 14, 1984

Operation: Tractor skidding of tree length in thinning forest Time: 7:50:01 ~ 15:04:00

Skidder : Iwafuji T-20

sec.

Elements / Turn No.	Basic Work Time																						Allowance							Cycle time	Preparations and Rearrangement						Exception						Observed time
	Drive skidder to logging site	Unwind winch line	Stop skidder engine	Step off skidder	Wear gloves	Take down chokers from skidder	Walk at logging site	Hand stop stick to choker setter	Pull winch line off drum	Carry chokers	Help choker setter with his work	Remove obstacle	Obviate winch line trouble	Ride in skidder	Start skidder engine and turn it up	Wind winch line	Check choker set	Reset chokers	Skid turn to landing	Operate skidder winch at landing	Drive skidder at landing	Pile logs by skidder	Sub-total	Talk with choker setter at logging site	Wait and see at logging site	Talk with choker setter at landing	Wait and see at landing	Personal needs	Have a rest	Sub-total		Make preparations or rearrangement	Start skidder engine and turn it up	Drive skidder from garage to landing	Move from one working place to another	Others	Sub-total	Take noon recess	Have a chat	Be set with heart rate memory, or taken it off	Others	Sub-total	
Morning Preparation																															221	190	635	217	Have a coffee 145	1,408	-	58	3,826	-	3,884	5,292
1	47	-	-	-	-	-	55	-	131 (83)	-	-	-	-	-	-	49 (20)	-	-	317 (142)		173	64	836 (245)	90	153 (95)	-	-	-	-	243 (95)	1,079 (340)												1,079
2	277	-	-	-	-	-	6	-	22	-	59	-	-	-	-	141	-	-	148		108	48	809	-	193	-	22	-	-	215	1,024												1,024
3	186	-	-	-	-	-	118	-	119	-	10	-	-	-	-	21	-	-	236		106	33	829	49	58	-	18	-	-	125	954												954
4	133	-	-	-	-	-	108 (56)	-	12	-	174 (174)	-	-	-	-	35	-	-	278		52	39	831 (230)	57 (21)	851 (448)	-	-	-	-	908 (469)	1,739 (699)												1,739
5	156	-	-	-	-	-	111	-	182 (40)	-	10	-	37	-	-	167 (132)	-	-	195		115	50	1,023 (172)	15	302 (52)	-	-	-	-	317 (52)	1,340 (224)												1,340
Noon																																					3,390	-	-	Help Jeep 382	3,772	3,772
6	116	-	-	-	-	-	231	-	9	9	80	-	-	-	-	92 (14)	-	-	180		86	30	833 (14)	66 (6)	91 (27)	-	-	-	-	157 (33)	990 (47)												990
7	178	-	-	-	-	-	-	-	149 (56)	-	213 (170)	-	-	-	-	238 (110)	-	-	184		79	48	1,089 (336)	76	133 (33)	-	-	-	57	266 (33)	1,355 (369)							-	85	-	-	85	1,440
8	175	-	-	-	-	-	-	-	19	-	45	-	-	-	-	21	-	-	146		63	43	512	20	50	-	-	-	-	70	582												582
9	196	-	-	-	-	-	296 (91)	-	220 (65)	-	137 (67)	-	-	-	-	134 (17)	-	-	240 (26)		71	89	1,383 (266)	77 (34)	141 (20)	-	-	-	-	218 (54)	1,601 (320)												1,601
10	444 (120)	-	-	-	-	-	465	-	117	-	144 (87)	-	-	-	-	61	-	-	354		63	66	1,714 (207)	354 (23)	356 (50)	-	-	-	-	710 (73)	2,424 (280)							-	22	-	-	22	2,446
11	195 (10)	-	-	-	-	-	120 (35)	-	208 (138)	-	263 (19)	-	-	-	-	232 (114)	-	-	248 (25)		113	88	1,467 (332)	133 (23)	184 (112)	-	-	-	25	342 (135)	1,809 (467)							-	-	-	702	702	2,511
12	196	-	-	-	-	-	82 (74)	74	35	-	40 (10)	-				197 (8)	-	-	310		75	46	935 (92)	133 (63)	122 (25)	-	-	-	-	255 (88)	1,190 (180)												1,190
Rearrangement																															-	17	-	-	-	17	-	-	62	-	62	79
Total	2,299	-	-	-	-	-	1,592	74	1,223	9	1,145	-	37	-	-	1,298	-	-	2,836	-	1,104	644	12,261	1,070	2,634	-	40	-	82	3,826	16,087	221	207	635	217	145	1,425	3,390	165	3,888	1,084	8,527	26,039
Productive Time	2,169	-	-	-	-	-	1,336	74	841	9	627	-	37	-	-	883	-	-	2,643	-	1,104	644	10,367	900	1,772	-	40	-	82	2,794	13,161												
Non-productive time	130	-	-	-	-	-	256	0	382	0	518	-	0	-	-	415	-	-	193	-	0	0	1,894	170	862	-	0	-	0	1,032	2,926												

Note: Figures between brackets indicate the non-productive time included.

Table III-10 Work time analysis of skidder operator (2) Date: November 21, 1984 Time: 7:51:00 - 14:58:00

Operation: Tractor skidding of tree length in thinning forest

Skidder : Iwafuji T-20

sec.

Elements / Turn No.	Basic Work Time																						Allowance							Cycle time	Preparations and Rearrangement						Exception					Observed time
	Drive skidder to logging site	Unwind winch line	Stop skidder engine	Step off skidder	Wear gloves	Take down chokers from skidder	Walk at logging site	Hand stop stick to choker setter	Pull winch line off drum	Carry chokers	Help choker setter with his work	Remove obstacle	Obviate winch line trouble	Ride in skidder	Start skidder engine and turn it up	Wind winch line	Check choker set	Reset chokers	Skid turn to landing	Operate skidder winch at landing	Drive skidder at landing	Pile logs by skidder	Sub-total	Talk with choker setter at logging site	Wait and see at logging site	Talk with choker setter at landing	Wait and see at landing	Personal needs	Have a rest	Sub-total		Make preparations or rearrangement	Start skidder engine and turn it up	Drive skidder from garage to landing	Move from one working place to another	Others	Sub-total	Take noon recess	Have a chat	Be set with heart rate memory or taken it off	Others	Sub-total	
Morning Preparation																															80	120	846	673	211 Make a pause	1,930	–	–	590	–	590	2,520
1	86	–	–	–	21	29	60	28	–	–	–	–	–	–	4	35	–	–	158	–	65	12	498	18	59	–	34	–	–	111	609												609
2	227	25	–	–	6	29	–	–	–	–	–	–	–	–	20	87 (40)	–	–	156	–	53	70	673 (40)	11	214 (144)	–	40	–	–	265 (144)	938 (184)												938
3	220	–	–	10	13	63	–	5	–	–	–	–	–	–	17	44	–	–	150	–	46	9	577	–	9	–	42	–	–	51	628							–	4	–	–	4	632
4	205	–	–	–	–	19	10	12	58	–	–	–	–	8	–	55	–	–	155	–	65	30	617	–	12	–	28	–	–	40	657												657
5	253	–	–	8	7	25	36 (8)	6	–	–	–	–	–	7 (7)	7 (4)	99 (12)	32 (24)	160 (160)	192	–	60	33	925 (215)	2	45	–	56	–	–	103	1,028 (215)							–	23	81	–	104	1,132
6	241	3	–	13	–	11	27	4	–	–	–	–	–	14	–	134	6	–	182	–	39	61	735	11	467 (146)	–	34	–	–	512 (146)	1,247 (146)							–	17	111	–	128	1,375
7	327	–	–	17	–	27	17	4	–	–	–	–	–	9	6	68	–	–	186	–	80	39	780	–	222	–	88	–	–	310	1,090												1,090
8	403	8	–	6	–	33	15	28	–	–	–	–	–	10	17 (3)	139 (8)	–	–	178	–	62	39	938 (11)	27	231	–	41	–	–	299	1,237 (11)												1,237
9	417 (113)	–	–	14 (8)	–	13	33	10	29	–	27	52 (52)	–	27	–	87	12	–	251	–	46	165	1,186 (173)	137 (71)	240 (76)	–	108	–	15	500 (147)	1,686 (320)							6	–	–	6	1,692
Noon																															–	–	–	94	–	94	2,838	–	–	62 Make a	2,900	2,994
10	358 (12)	4 (4)	8 (8)	18	–	13	39 (7)	17	9	–	–	–	–	16 (10)	24	60 (18)	56 (47)	–	202 (35)	–	54	75	953 (141)	52 (5)	386 (320)	–	65	–	–	503 (325)	1,456 (466)												1,456
11	317	–	24 (9)	14 (10)	5	34	34 (21)	4	48 (48)	–	50 (50)	–	–	12 (7)	7	77 (45)		70 (70)	190 (5)	–	66	60	1,012 (265)		17	–	39	–	–	56	1,068 (265)												1,068
12	284	–	–	8	21	43	12	–	–	–	–	–	–	9	–	45	13		188	–	73	76	772	6	57	–	92	–	–	155	927												927
13	233	–	10	10	11	18	45	–	–	–	143	–	119	5	–	75	37	197 (180)	235	–	67	22	1,227 (180)	16	87	–	67	–	10	180	1,407 (180)							–	25	–	–	25	1,432
14	244	–	4	19 (9)	27	19	98 (51)	7 (7)	38 (38)	–	–	–	–	20 (8)	9	118 (69)	55 (40)	218 (218)	218	–	82	66	1,242 (440)	11 (11)	148	–	76	–	34	269 (11)	1,511 (451)												1,511
15	431	–	4	24	27	19	95	12	51	–	–	–	–	15 (5)	7	115 (11)	77 (55)	35	178	–	65	51	1,206 (71)	54 (42)	77	–	94	–	365	590 (42)	1,796 (113)							–	40	–	–	40	1,836
16	350	13	3	8	–	35	55	12	71	–	–	11	–	11	4	114	25	–	201	–	59	119	1,088	90	55	–	142	–	7	294	1,382							–	23	–	–	23	1,405
17	264	–	–	13	–	–	56	8	22	–	–	–	–	3	–	91	26	43	224	–	47	44	841	33	53	–	31	–	77	194	1,035							–	14	–	–	14	1,049
Rearrangement																															–	–	–	60	–	60						60
Total	4,860	53	53	182	138	430	632	157	326	–	220	66	119	166	122	1,443	339	723	3,250	–	1,020	971	15,270	468	2,379		1,077	–	508	4,432	19,702	80	120	846	827	211	2,084	2,838	152	782	62	3,834	25,620
Productive Time	4,735	49	36	155	138	430	545	150	240	–	170	14	119	129	115	1,240	173	95	3,210	–	1,020	971	13,734	339	1,693		1,077	–	508	3,617	17,351												
Non-productive time	125	4	17	27	0	0	87	7	86	–	50	52	0	37	7	203	166	628	40	–	0	0	1,536	129	686		0	–	0	815	2,351												

Note: Figures between brackets indicate the non-productive time included.

Table III-11 Work time analysis of skidder operator (3)

Date : November 22, 1984
Operation: Tractor skidding of tree length in thinning forest
Skidder : Iwafuji T-20

Time: 7:56:40 - 15:00:38

Sec.

Elements / Turn No.	Basic Work Time																						Allowance							Cycle time	Preparations and Rearrangement						Exception					Observed time
	Drive skidder to logging site	Unwind winch line	Stop skidder engine	Step off skidder	Wear groves	Take down chokers from skidder	Walk at logging site	Hand stop stick to choker setter	Pull winch line off drum	Carry chokers	Help choker setter with his work	Remove obstacle	Obviate winch line trouble	Ride in skidder	Start skidder engine and turn it up	Wind winch line	Check choker set	Reset chokers	Skid turn to landing	Operate skidder winch at landing	Drive skidder at landing	Pile logs by skidder	Sub-total	Talk with choker setter at logging site	Wait and see at logging site	Talk with choker setter at landing	Wait and see at landing	Personal needs	Have a rest	Sub-total		Make preparations or rearrangement	Start skidder engine and turn it up	Drive skidder from garage to landing	Move from one working place to another	Others	Sub-total	Take noon recess	Have a chat	Se set with heart rate memory or taken it off	Others	Sub-total	
Morning Preparation																															1,190	-	172	-	Pile logs 123	1,485						1,485
1	265	-	-	11	-	-	55	-	-	31	84	-	-	13	-	52	-	-	202	9	82	58	862	53	69	-	41	-	-	163	1,025											1,025
2	242	-	-	17	-	-	20	-	31	17	-	16	-	11	-	41	-	-	191	14	38	55	693	68	50	-	34	-	-	152	845											845
3	321	-	-	18	-	-	18	31	-	22	-	-	-	11	-	61	-	-	223	-	93	59	857	-	33	-	69	-	-	102	959											959
4	212 (20)	-	-	24 (9)	-	-	59 (22)	-	81	52	118 (97)	40	-	3 (3)	-	132 (80)	-	-	203	-	36	40	1,000 (231)	39 (16)	191 (118)	-	56	-	-	286 (134)	1,286 (365)											1,286
5	449 (81)	-	-	20 (6)	-	-	82 (39)	-	32 (10)	36	139 (52)	117	-	16	-	183 (102)	-	-	219	-	52	46	1,391 (290)	83 (31)	82 (48)	-	122	-	-	287 (79)	1,678 (369)											1,678
6	298	-	-	12	-	-	32	-	41	74	-	-	-	6	-	52	-	-	242	-	54	54	865	19	76	-	36	-	-	131	996											996
7	561	-	-	14	-	-	47	-	23	28	50	60	-	13	-	169	-	-	236	-	89	44	1,324	62	132	35	43	-	-	272	1,596							-	-	-	110 Prepare lunch	110	1,706
8	276	-	-	7	-	-	35	-	29	13	-	-	-	8	-	62	-	-	253	-	74	54	811	-	60	-	28	-	-	88	899											899
Noon																															-	21	-	116	-	137	3,803	-	-	132 Arrangement	3,935	4,072
9	841	-	-	18	-	-	86	-	41	49	60	30	-	15	-	49	-	-	171	-	28	28	1,416	-	39	-	44	-	-	83	1,499											1,499
10	322	-	-	11	-	-	53	-	-	-	-	-	-	6	-	32 (3)	-	-	267	-	53	57	801 (3)	-	109 (55)	-	193	-	-	302 (55)	1,103 (58)											1,103
11	247	-	-	9	-	-	46	-	22	24	-	-	-	7	-	48	-	-	201	-	59	37	700	-	70	-	117	-	-	187	887											887
12	464 (108)	-	-	35 (20)	-	-	63 (46)	-	90 (67)	25	130 (130)	-	-	32 (18)	-	399 (223)	-	15	187	-	32	30	1,492 (612)	43 (39)	511 (315)	-	44	-	-	628 (354)	2,120 (966)											2,120
13	288	-	-	14 (6)	-	-	40 (14)	-	98 (72)	22	75 (75)	-	-	19 (14)	-	137 (63)	-	-	207	-	63	45	1,018 (214)	11 (11)	209 (31)	-	162	-	-	382 (42)	1,400 (286)											1,400
14	317	-	-	7	-	-	5	-	-	29	-	-	-	10	-	136	-	-	190	-	92	63	849	-	176	-	99	-	-	275	1,124											1,124
15	340	-	-	28	-	-	10	-	-	12	-	-	-	10	-	106 (72)	-	-	162	-	54	48	770 (72)	-	90 (38)	-	76	-	-	166 (38)	936 (110)											936
16	364 (57)	-	-	10	-	-	50	-	49	52	16	66	-	8	-	165 (72)	-	-	209	-	44	20	1,053 (129)	15	255 (204)	-	70	-	-	340 (204)	1,393 (333)											1,393
Rearrangement																															-	-	-	25	-	25						25
Total	5,807	-	-	255	-	-	701	31	537	496	672	329	-	188	-	1,824	-	15	3,353	23	943	728	15,902	393	2,182	35	1,234	-	-	3,844	19,746	1,190	21	172	141	123	1,647	3,803	-	-	242	4,045	25,438
Productive Time	5,541	-	-	214	-	-	580	31	388	496	318	329	-	153	-	1,209	-	15	3,353	23	943	728	14,321	296	1,373	35	1,234	-	-	2,938	17,259											
Non-productive time	266	-	-	41	-	-	121	0	149	0	354	0	-	35	-	615	-	0	0	0	0	0	1,581	97	809	0	0	-	-	906	2,487											

Note: Figures between brackets indicate the non-productive time include.

Table III-12 Work time analysis of choker setter (1) November 14, 1984 Time: 7:50:00 - 15:03:00

sec.

Elements / Turn No.	Basic work time																			Allowance					Cycle time	Preparations & Rearrangement			Exception					Observed time
	Pick up chokers	Choose logs that will make up a turn	Carry chokers	Remove obstacle	Bunch logs	Walk on logging site	Set chokers	Pull winch line off drum	Put winch line through chokers' eyes	Direct skidder	Be apart from skidder being operated for safety	Set chokers again	Straighten working clothes or wear groves	Carry chainsaw or axe	Crosscut obstacle timber	Remove obstacle for skidder	Throw slight of winch line over a stump to change direction of pull	Cut off stumps	Others	Sub-total	Talk with skidder operator	Wait and see at logging site	Personal needs	Have a rest	Sub-total		Make preparations or rearrangement	Move from one working place to another	Sub-total	Take noon recess	Have a Chat	Be set with heart rate memory or taken it off	Others	Sub-total	
Morning preparation																										33	91	124	-	8	4,908	Make a pause 20	4,936	5,060
1	-	63	102 (39)	-	-	107 (47)	135 (76)	121 (60)	-	-	139 (71)	-	-	-	-	-	-	-	-	667 (293)	204 (26)	143 (15)	-	12	359 (41)	1,026 (334)				-	9	-	-	9	1,035
2	-	-	48	-	-	288 (37)	91 (21)	42	24	97 (97)	80 (44)	29	-	-	-	-	-	-	-	699 (199)	88 (69)	63	-	21	172 (69)	871 (268)				-	164	-	-	164	1,035
3	-	10	103	-	-	207 (93)	134	68	29	58	12	12	-	81 (81)	47 (47)	-	-	-	-	761 (221)	62	-	-	55	117	878 (221)									878
4	-	16	70	5	-	254 (76)	60	137	41	31	72	-	7	82 (82)	124 (124)	-	-	660 (660)	-	1,559 (942)	58 (21)	135	-	18	211 (21)	1,770 (963)									1,770
5	-	18	198	25	-	250 (34)	225	225 (40)	17 (10)	10	137 (95)	45 (45)	-	-	-	-	-	-	-	1,150 (224)	41 (4)	124	-	4	169 (4)	1,319 (228)				-	9	-	-	9	1,328
6	-	34	121	-	-	249 (24)	61	221	48 (26)	123	56 (36)	6	-	-	43 (43)	-	-	-	-	962 (129)	61 (4)	39	-	37	137 (4)	1,099 (133)				-	4	-	-	4	1,103
Noon																										-	164	164	3,504	11	-	63 Make a pause	3,578	3,742
7	-	-	122 (17)	-	-	258 (106)	147 (31)	121 (18)	59	146	204 (141)	104 (44)	15 (15)	19 (19)	83 (83)	5	-	-	-	1,283 (474)	24	79 (36)	-	29	132 (36)	1,415 (510)									1,415
8	-	18	19	34	-	76 (10)	130	41	-	12	60	10	-	39 (39)	168 (168)	-	-	-	-	607 (217)	41	-	-	-	41	648 (217)									648
9	-	26	180	35	-	187 (110)	165 (75)	163	-	102 (42)	49 (31)	83 (83)	-	68 (68)	376 (376)	-	-	-	-	1,434 (785)	23	22 (18)	-	-	45 (18)	1,479 (803)				-	-	222	-	222	1,701
10	-	52	145	-	-	428 (294)	178	158	34	-	82	-	-	15 (15)	249 (249)	-	-	-	-	1,341 (558)	278 (149)	117	-	269	664 (149)	2,005 (707)									2,005
11	-	-	78	55	-	164 (102)	315 (231)	144 (44)	-	32	212 (152)	-	-	18 (18)	594 (594)	-	-	-	-	1,612 (1,141)	143 (45)	128	-	680	951 (45)	2,563 (1,186)				-	-	107	-	107	2,670
12	-	28	42	-	-	210	129	97	34	124	240	51	-	-	-	-	125	-	-	1,080	51	92	33	29	205	1,285				-	120	-	-	120	1,405
Rearrangement																										83	102	185						185
Total	-	265	1,228	154	-	2,678	1,770	1,538	286	735	1,343	340	22	322	1,684	5	125	660	-	13,155	1,074	942	33	1,154	3,203	16,358	116	357	473	3,504	325	5,237	83	9,149	25,980
Productive Time	-	265	1,172	154	-	1,745	1,336	1,376	250	596	773	168	7	0	0	5	125	0	-	7,972	756	873	33	1,154	2,816	10,788									
Non-productive time	-	0	56	0	-	933	434	162	36	139	570	172	15	322	1,684	0	0	660	-	5,183	318	69	0	0	387	5,570									

Note: Figures between brackets indicate the non-productive time included.

Table III-13 Work time analysis of Choker setter (2) November 21, 1984 Time: 7:57:00 - 15:00:00

sec.

Elements / Turn No.	Basic work time																				Talk with skidder operator	Allowance				Preparations & Rearrangement				Exception					Observed time
	Pick up chokers	Choose logs that will make up a turn	Carry chokers	Remove obstacle	Bunch logs	Walk on logging site	Set chokers	Pull winch line off drum	Put winch line through chokers' eyes	Direct skidder	Be apart from skidder being operated for safety	Set chokers again	Straighten working clothes or wear gloves	Carry chainsaw or axe	Crossout obstacle timber	Remove obstacle for skidder	Throw bight of winch line over a stump to change direction of pull	Cut off stumps	Others	Sub-total		Wait and see at logging site	Personal needs	Have a rest	Sub-total	Cycle time	Make preparations or rearrangement	Move from one working place to another	Sub-total	Take noon recess	Have a chart	Be set with heart rate memory or taken it off	Others	Sub-total	
Morning preparation																											386	637	1,023	-	130	652	-	782	1,805
1	-	35	78	-	89	286	175	23	-	22	12	-	-	-	-	-	-	-	-	720	-	286	-	-	286	1,006				-	-	40	-	40	1,046
2	-	-	20	-	26	103 (26)	167 (135)	114 (20)	-	-	-	-	-	-	-	-	-	-	-	430 (181)	-	199 (23)	-	-	199 (23)	629 (204)				-	-	13	-	13	642
3	-	9	62	20	63	92	134	88	-	31	18	-	-	-	-	-	-	-	-	517	13	137	-	-	150	667									667
4	-	-	12	-	44	156	137	106	-	-	11	-	-	-	-	-	-	-	-	466	-	84	-	-	84	550									550
5	-	20	70	28	81	129	146	55	-	22	28	-	-	-	-	-	-	-	-	579	-	193	-	-	193	772				-	-	18	-	18	790
6	-	54	64	-	250	116 (18)	513 (374)	77	-	23	67 (27)	-	-	-	-	-	-	-	-	1,164 (419)	83	349 (11)	-	-	432 (11)	1,596 (430)				-	-	127	-	127	1,723
7	-	61	85	-	81	91	197	50	-	-	-	-	-	-	-	-	-	-	-	565	-	39	-	-	39	604				-	-	293	-	293	897
8	-	32	30	15	52	263 (27)	200 (43)	47	-	-	15	75	-	-	-	-	-	-	-	729 (70)	279	381 (71)	-	-	660 (71)	1,389 (141)									1,389
9	-	-	83	36	129 (120)	254 (46)	282	48	-	45	-	12 (12)	-	-	88 (88)	-	-	-	-	977 (266)	22	415 (66)	-	-	437 (66)	1,414 (332)				-	-	67	-	67	1,481
Noon																											-	268	268	3,452	-	80	-	3,532	3,800
10	-	-	24	-	84	85	117	92	-	-	-	23	-	-	-	-	-	-	-	425	-	45	-	-	45	470									470
11	-	29	39	59	148	233	177	32	-	81	-	-	-	-	-	-	-	-	-	798	93	228	-	-	321	1,119									1,119
12	-	-	-	26	144	302	142	92	-	96	9	-	-	-	-	-	-	-	-	811	55	194	-	-	249	1,060				-	-	50	-	50	1,110
13	-	58	95	-	45	148	283	92	-	-	19	-	-	-	-	-	20	-	-	760	38	349	-	-	387	1,147				-	-	4	-	4	1,151
14	-	-	127 (48)	388 (81)	18	435 (118)	256 (114)	103 (65)	-	61	35 (16)	63	-	-	-	-	-	-	-	1,486 (442)	116 (15)	339 (50)	-	-	455 (65)	1,941 (507)				-	-	15	-	15	1,956
15	-	-	51	184	-	443 (49)	175 (15)	173 (73)	-	22	-	-	-	-	-	-	-	-	-	1,048 (137)	47 (17)	664 (434)	-	-	711 (451)	1,759 (588)				-	-	5	-	5	1,764
16	-	-	-	245	36	284	239	71	-	-	20	24	-	-	-	-	-	-	-	919	64	259	-	-	323	1,242				-	-	10	-	10	1,252
17	-	-	52	287	12	277 (46)	212 (37)	135 (75)	-	14	12	23	-	-	-	-	-	-	-	1,024 (158)	-	271 (110)	-	-	271 (110)	1,295 (268)				-	-	3	-	3	1,298
Rearrangement																											43	407	450	-	-	20	-	20	470
Total	-	298	892	1,288	1,302	3,697	3,552	1,398	-	417	246	220	-	-	88	-	20	-	-	13,418	810	4,432	-	-	5,242	18,660	429	1,312	1,741	3,452	130	1,397	-	4,979	25,380
Productive Time	-	298	844	1,207	1,182	3,367	2,834	1,165	-	417	203	208	-	-	-	-	20	-	-	11,745	778	3,667	-	-	4,445	16,190									
Non-productive time	-	-	48	81	120	330	718	233	-	-	43	12	-	-	88	-	-	-	-	1,673	32	765	-	-	797	2,470									

Note: Figures between brackets indicate the non-productive time included.

Table III-14 Work time analysis of choker setter (3) November 22, 1984 Time: 7:55:00 - 15:00:00

sec.

Elements / Turn No.	Basic work time																				Allowance				Cycle time	Preparations & Rearrangement			Exception					Observed time
	Pick up choker	Choose logs that will make up a turn	Carry chokers	Remove obstacle	Bunch logs	Walk on logging site	Set chokers	Pull winch line off drum	Put winch line through chokers' eyes	Direct skidder	Be apart from skidder being operated for safety	Set chokers again	Straighten working clothes or wear groves	Carry chainsaw or axe	Crosscut obstacle timber	Remove obstacle for skidder	Throw bight of winch line over a stump to change direction of pull	Cut off stumps	Others	Sub-total	Talk with skidder operator	Wait and see at logging site	Personal needs	Have a rest	Sub-total		Make preparations or rearrangement	Move from one working place to another	Sub-total	Take noon recess	Have a chart	Be set with heart rate memory or taken it off	Others	Sub-total	
Morning preparation																										163	339	502	-	-	1,007	-	1,007	1,509
1	-	70	92	-	56	101	117	71	40	12	7	9	-	-	-	-	-	-	-	575	29	33	-	-	62	637								637
2	13	17	46	43	-	129	79	28	33	71	19	-	9	-	-	239 (239)	-	-	-	726 (239)	30	44	-	43	117	843 (239)				-	22	107	-	129	972
3	13	62	87	30	49	134	164	57	54	99	15	-	25	-	-	15 (15)	-	-	-	804 (15)	14	51	-	13	78	882 (15)									882
4	33	36	75	58	82	227 (28)	155	253 (132)	6	53 (26)	119 (94)	96 (96)	-	-	-	-	-	-	-	1,193 (376)	55	130 (52)	-	-	185 (52)	1,378 (428)				-	27	-	-	27	1,405
5	13	62	100 (11)	29 (5)	-	93 (31)	156	159 (58)	71	23	169 (110)	45 (19)	17	-	-	276 (276)	94 (65)	-	-	1,307 (575)	44 (21)	207 (49)	-	-	251 (70)	1,558 (645)									1,558
6	9	23	71	40	53	63	169	26	40	16	110	-	-	-	-	238 (238)	-	-	-	858 (238)	20	155	-	44	219	1,077 (238)									1,077
7	23	84	54	27	23	105	287	103	40	68	147	-	89	-	-	-	33	-	100 Repair skid trail	1,183	81	151	-	-	232	1,415				-	15	-	-	15	1,430
8	12	96	105	18	-	61	108	83	26	21	6	-	30	-	-	240 (240)	-	-	-	809 (240)	1	219	-	-	223	1,032 (240)				-	27	-	-	27	1,059
Noon																										90	712	802	3,660	9	240	-	3,909	4,711
9	44	52	31	77	72	172	122	90	32	8	39	-	13	-	-	59 (59)	-	-	-	811 (59)	54	140	-	-	194	1,005 (59)									1,005
10	4	66	24	6	102	154 (13)	88	51	30	35 (12)	49 (42)	47 (47)	-	-	-	-	-	-	-	656 (114)	20	162	-	87	269	925 (114)									925
11	7	71	16	78	-	162	141	97	52	43	52	9	-	-	-	-	-	-	-	728	-	120	-	139	259	987									987
12	23	50	81	-	90	159 (69)	254 (19)	324 (211)	51	162 (109)	234 (179)	406 (220)	41	-	-	22 (22)	89 (54)	-	-	1,986 (883)	74 (24)	127 (78)	-	14	215 (102)	2,201 (985)					34	-	-	34	2,235
13	32	94	122 (19)	-	80	124 (17)	200 (70)	160 (29)	38	91 (9)	85 (42)	180 (96)	-	-	-	-	-	-	-	1,206 (282)	-	-	-	-	-	1,206 (282)									1,206
14	16	73	4	40	63	236	80	58	19	104	57	21	26	-	-	12 (12)	41	-	-	850 (12)	79	59	-	166	304	1,154 (12)									1,154
15	9	35	126	16	78	44 (23)	152	60	29	133 (58)	62 (32)	34 (9)	-	-	-	20 (20)	-	-	-	798 (142)	-	150	-	66	216	1,014 (142)									1,014
16	10	53	58	40	11	85 (20)	186	119	38	118	55 (55)	164 (158)	11 (11)	-	-	36 (36)	-	-	-	984 (280)	33 (15)	383 (94)	-	73	489 (109)	1,473 (389)									1,473
Rearrangement																										48	173	221	-	-	40	-	40	261
Total	261	944	1,092	502	759	2,052	2,458	1,739	599	1,057	1,225	1,011	261	-	-	1,157	257	-	100	15,474	537	2,131	-	645	3,313	18,787	301	1,224	1,525	3,660	134	1,394	-	5,188	25,500
Productive Time	261	944	1,062	497	759	1,851	2,369	1,309	599	843	671	366	250	-	-	0	138	-	100	12,019	477	1,858	-	645	2,980	14,999									
Non-productive time	0	0	30	5	0	201	89	430	0	214	554	645	11	-	-	1,157	119	-	0	3,455	60	273	-	0	333	3,788									

Note: Figures between brackets indicate the non-productive time included.

The operation was carried out by an operator and a choker setter as a team, and Table III-9 to Table III-11 show the results of time study for the operator for each of the days, and Table III-12 to Table III-14 one for the choker setter. Table III-9 shows the result of comparatively rough investigation referred to ① above, while Table III-10 to III-14 that of detailed time study by observing the work elemental as fully as possible. Such detailed time study is indispensable also for obtaining basic data in investigation of the heart rate and respiration.

The present investigation was carried out for the operation du during the whole day from preparation at every starting in the morning to rearrangement after finishing the work, to get the time consumed for each of the elements in every work cycle and to calculate the total time consumption. Particularly, the time of repetition due to failure of operation and the stagnation time due to inappropriate working procedure were recorded in full to be classified as non-productive hour apart from normal productive hour. The figures in the tables of analysis in ( ) show the non-productive hour of the elements, and the total of productive and non-productive hours are shown at the bottom of each table.

The effective working hour in the tables mean the total of basic work time and allowance, the latter including the time spent for arrangement by talking, waiting time, fatigue allowance, and personal allowance. The time spent after work for rearrangement should originally be classified as effective working hour, but it was calculated as a separate account similarly to the case of excluded time; for the starting and finishing times of time study varied from a day to another.

The matters to be noted in particular on working method, before entering into time analysis, are as follows. (i) The direction of felling was not decided in relation to yarding operation and it was at random. This was a large drawback to the following operation. (ii) Logs of a larger size and better quality were collected preferentially and logs of smaller size left uncollected were hindering the yarding operation that followed to lower the yarding efficiency. And, (iii) Logs were cut arbitrary

without reference to the lumbering size in elimination of obstacle timber and this wasted the work time and lowered the value of logs a great deal.

The results of time study carried out with these procedures as the background are as follows: (cf. Tables III-10 to III-14)

1) Average yarding distance was elongated day after day, about 250 m on the first day, about 270 m on the second and about 300 m on the third. (cf. Table III-8 and Fig. III-16)

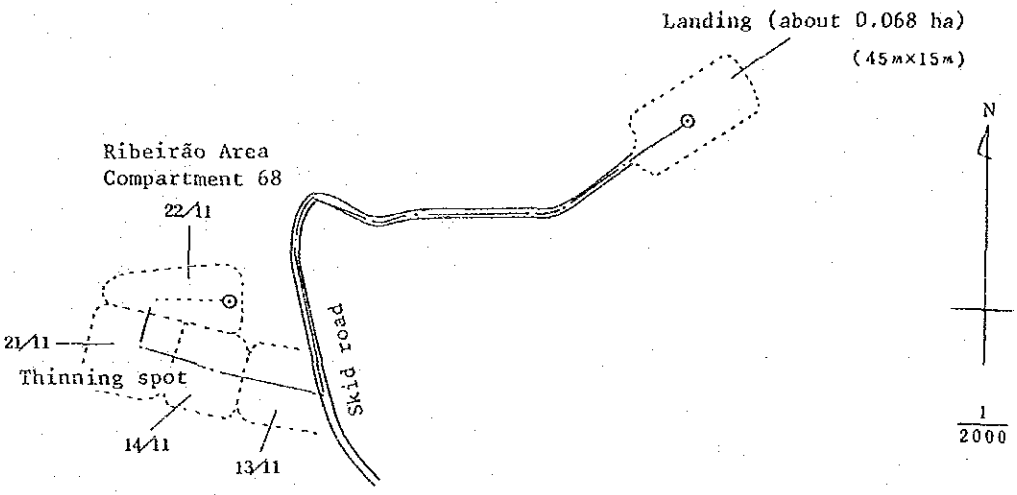


Fig. III-16 Sketch of logging site by skidder T-20

2) Effective working time was the longest on the third day, that of the second day nearly as long and that of the first day the shortest, although this varied by the operator and choker setter to some extent. This was due to more hour spent for fixing and adjusting heart rate memory units.

3) Number of work cycles was 17 on the second day, the largest, followed by 16 on the third and 12 on the first. The amount of collection was 20.66 m^3 on the second day, followed by 16.64 m^3 on the third and 8.68 m^3on the first.

4) A turn volume was 1.215 m^3 on the second day, followed by 1.04 m^3 on the third and 0.723 m^3 on the first. The hourly production based on the effective working hour of operator

was in the same order, 3.775 m^3, 3.034 m^3, and 1.942 m^3 per hour respectively, the largest on the second day and smallest on the first in any of the cases.

5) The total working hour of the choker setter for transportation of chain saw or ax and for cross-cutting of obstructing timber was 2,006 seconds, 12.3 % of the total working hour, on the first day, but it was 88 seconds (0.5 %) on the second and nothing on the third, showing that much time was spent for elimination of obstructing timber.

6) Total of non-productive hour including one for elimination of obstructing timber was 5570 seconds on the first day, 34.1% of the effective working hour, but it was 2,470 seconds (13.2 %) on the second and 3,788 seconds (20.2 %) on the third, showing that non-productive work was the largest on the first day and the least on the second day.

7) The total non-productive hour of the operator was 2,926 seconds (18.2 % of effective working hour) on the first day, 2,351 seconds (11.9 %) on the second and 2,487 seconds (12.6 %) on the third, showing the same tendency as for the choker setter.

8) The waiting time of the choker setter was 942 seconds (5.8 % of the effective working hour) on the first day, 4,432 seconds (23.8 %) on the second and 2,131 seconds (11.3 %) on the third, small on the first day and remarkably large on the second. This shows that the waiting time of the choker setter is larger when the yarding operation is proceeding smoothly, but he is busy, on the contrary, when it is in a bad condition.

9) On the other hand, the waiting time of the operator was 2,182 seconds (11.1 %) on the third day, increasing to 2,879 seconds (12.1 %) on the second and 2,634 seconds (16.4 %) on the third, showing that it is the smaller the more smoothly the operation proceeds, on the contrary.

10) Number of times and hours spent by the operator and choker setter for arrangement by talks were 39 times and 735 seconds on the first day, as a result of analysis of the time study for the choker setter, 28 times and 810 seconds

for the second, and 55 times and 539 seconds on the third, both of the figures being very large on all of the days. This is a result of both of the workers not being familiar with the operation sufficiently, and it shows that the techniques had not taken root well. The average number of times of arrangement talk per turn was 3.3 times on the first day, 1.6 times on the second, and 3.4 times on the third, showing that the number of times was the least on the second day when the operation was the smoothest.

11) The rest hour was 82 seconds for the operator on the first day, 570 seconds on the second and 0 second on the third, and 1,219 seconds, 0 second and 645 seconds for the choker setter respectively, showing that it was extremely small except one for the choker setter on the first day. The choker setter was compelled to take rest on the first day as a result of consumption of his physical strength by cutting obstructing timber by ax.

The improvements of logging operation by T-20 skidder in Campos do Jordão state forest as derived by the time study analysis are as follows:

1) It is necessary in felling of thinning trees to restrict the direction of felling in connection with the yarding operation that follows. The direction of felling shall be indicated for the chain saw man in advance so that the felling operation be carried out correctly and that the tree length logs can be skidded smoothly.

2) Choked logs happened to slip off chokers in many cases. A sure choking operation shall be instructed. Use of chokers of somewhat smaller diameter and/or reduction of the amount of logs per turn should be advised.

3) The unproductive way of yarding logs of better quality first shall be improved so that logs located nearest to skid road are shipped regardless of their quality.

4) The operator and choker setter shall be so trained that they will fully confer in advance on the procedure and that the choker setter can load efficiently.

5) The workers shall take rest appropriately so that their physical strength is maintained.

(c) Effect of operation improvement and new problems

The time study data were analyzed and five items of improvement for the tractor logging were presented. The technical proposal was carried out in the field of technical transfer to improve the operation, and the time study was conducted again in the same method after some period of training for the workers. The investigation was carried out in Ribeirão area, compartment 66 of the state forest, where Elliottii pine trees were planted and grew to 20 - 21 years of age. The topographic conditions were nearly the same as those in compartment 68 where the first investigation was carried out. The residual stand after thinningusually hinders the skidder from traveling and give a large influence on the operational efficiency. The thinning rate stand density and other operating conditions in both of the forests are shown in Table III-15 for comparison. The inclination of forest ground in compartment 66 was larger and the density of remaining trees as obstacle was also higher, as shown in the table, indicating that the operating conditions were less favorable than those in the previous investigation.

Table III-15 Comparison of working conditions

Investigation No.		1	2
Forest compartment		68	66
Tree species Stand age		Taeda pine 22 years	Elliottii pine 21 years
Stand density before thinning		1575 trees/ha	1638 trees/ha
Stand density after thinning		663 trees/ha	801 trees/ha
Thinning rate	Number	57.9 %	51.1 %
	Volume	38.8 %	37.0 %
Inclination of forest ground		15° (5-25°)	17.5° (10-25°)

The effect of the technical proposal on actual operation will be explained based on the data of time study. The most important proposal item was to decide the direction of felling with consideration of the direction of log skidding. The work time for removal of obstacle timber and branches in the second investigation spot was 397, 400, and 231 seconds respectively, and there was no large figure such as 1,684 seconds in the first investigation. This shows that the directions of felling was improved. However, in skidding of tree lengths by choking treetops, there were cases where the logs dropped off the chokers or the treetops were broken off. Therefore, further guidance of workers for their better understanding of the importance of felling direction is necessary. Logs must be choked securely so that they will not drop off during skidding. The method of cross-cutting timber into 8 - 12 m size before skidding, that was tried on the third day of the investigation, was effective in enhancing the operational efficiency. The hour spent for fixing chokers was 2,466 seconds (12.2%) and 2,304 seconds (11.7%) on the first and second days respectively, but it was 3,334 seconds (16.4%) on the third day, indicating that the work intensity of the choker setter was risen by increasing the turn volume. This also increases the work in felling operation. However, on the third day when the operation was carried out by the method, the efficiency was as high as 15.63 m^3/man-day, in spite of the yarding distance being as large as 184 m. This may mean that cutting tree length logs into 8 - 12 m size can be tried in the case of inappropriate direction of felling.

Operational efficiency is a good index for measuring the effect of working method improvement. The forest of the first investigation was in more favorable conditions in terms of tractor traveling and prehauling, but the forest of the second investigation was more favorable in terms of yarding distance. The operational efficiency was 4.34 m^3/man-day, 10.33 m^3/man-day, and 8.32 m^3/man-day respectively in the first investigation while 17.36 m^3/man-day, 9.32 m^3/man-day, and 15.63 m^3/man-day respectively in the second investigation, showing a favorable effect of improvement. The number of turns also increased from 12, 17, and 16 in the first spot to 34, 17, and 22 in the second spot.

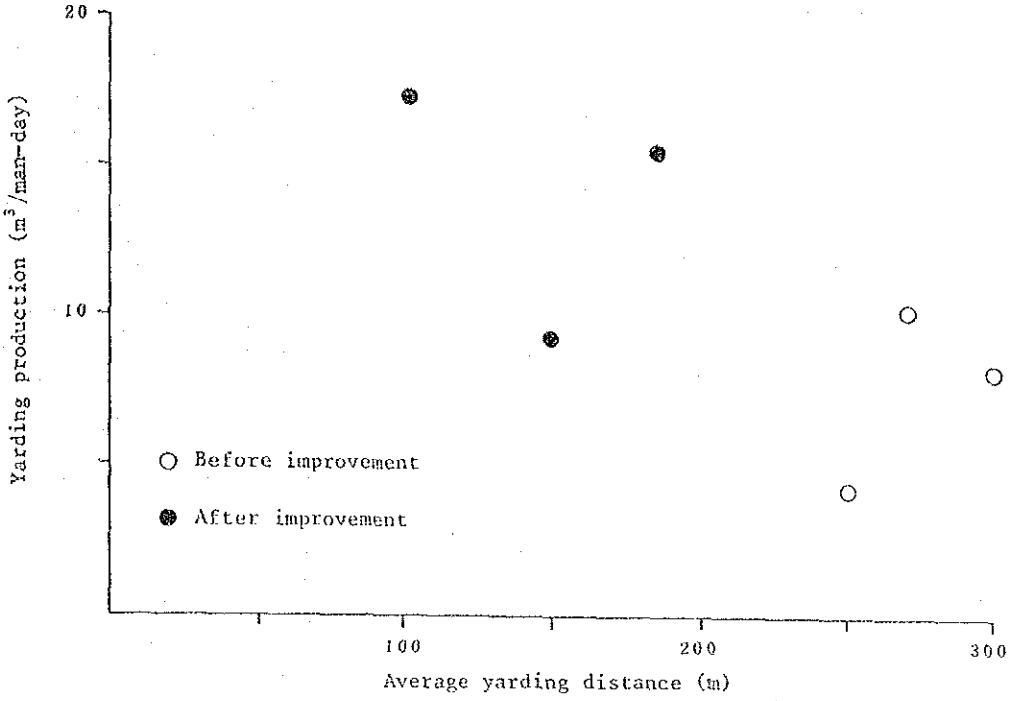


Fig. III-17 Yarding production per man-day versus average yarding distance (Comparison before and after the operation improvement)

A long prehauling distance affects hours for winch extracting operation. Taking an example in the second investigation, 1,606 seconds (8.0 %), 2,064 seconds (10.4 %), and 1,589 seconds (7.8 %) were spent for the operation on the three days respectively, and the long distance in the second day was the cause of the efficiency being as low as 9.32 m^3/man-day. The long prehauling distance also caused an increase in the hour for selecting tree length logs to be yarded to 1,228 seconds (6.2 %). The approaching route of tractor, direction of prehauling and selection method of tree lengths to be yarded largely affect the operational efficiency; and a good cooperation by the tractor operator and choker setter is hoped for. The waiting time occurring during work was 6,221 seconds (30.4 %), 6,692 seconds (34.2 %), and 6,652 seconds (32.6 %) respectively for the operator, all larger than 30 %. The waiting takes place mostly during pre-hauling operation, and the operational efficiency will further be enhanced if the operator help the choker setting operation.

Table III-16 Summary of logging operation of thinned logs by skidder T-20 (1985)

Thinning site Forest conditions Topography	Campos do Jordão state forest, Compartment 66 Elliottii pine man-made forest 20-21 years of age Stand density: 1,638/ha, Growing stock: 629.4m³/ha Thinning rate: 37% (volume) 51.1% (number) Inclination: about 17.5°						Remarks
Date of investigation	September 17, 1985	September 18, 1985	September 19, 1985	September 20, 1985	September 25, 1985	September 26, 1985	
Yarding distance	100.5 m skid road 100.5 m in forest 0 m	67.1 m skid road 67.1 m in forest 0 m	148 m skid road 148 m in forest 0 m	133 m skid road 112 m in forest 21 m	184 m skid road 116 m in forest 68 m	254 m skid road 120 m in forest 134 m	
Crew	4 Operator 1 Choker setter 1 Chain-saw man 1 Scale man 1	ditto	ditto	ditto	ditto	ditto	
Log type	Tree length log	Tree length log	Tree length log	Tree length log	Half stem length logs	Half stem length logs	Half stem length logs mean logs of 8 - 12m length.
Daily production	34.72 m³ (116 trees)	22.4 m³ (96 trees)	18.64 m³ (77 trees)	9.23 m³ (48 trees)	31.26 m³ (141 trees)	24.93 m³ (137 trees)	
Number of turns	34	30	17	11	22	19	
Turn volume	1,021 m³ (3.4 trees)	0.748 m³ (32 trees)	1,096 m³ (4.5 trees)	0.839 m³ (4.4 trees)	1,421 m³ (6.4 trees)	1,312 m³ (7.2 trees)	
Working hours (sec)	Operator 20,480 Choker setter 20,165	Operator 19,512 Choker setter 19,346	Operator 19,575 Choker setter 19,766	Operator 10,182 Choker setter 10,911	Operator 20,413 Choker setter 20,281	Operator 20,530 Choker setter 20,582	Working hours does not include lunch time and preparation time for load tests.
Characteristics of work	Logs felled along a skid road were yarded. Operational condition was very favorable.	Yarding distance was shorter, but the logs were somewhat smaller. Fragile tree top caused logs to come off choker or break.	Pre-hauling distance was a little longer. Some of skidding logs got caught in residual trees or suffered breakage of tree tops.	Half-day work	Tree length operation was difficult due to long tree length and high density of standing trees. Tree length logs were cut off into 8-12m length logs before yarding.	ditto	

Table III-17 Work time analysis of Skidder Operator (1) September 17, 1985 Time: 8:57:00 - 16:18:40

sec.

Elements / Turn No.	Basic work time																Allowance					Cycle time	Preparations and Rearrangement		Exception			Observed time
	Drive skidder to logging site	Skid turn to landing	Unwind winch line	Wind winch line	Drive skidder at landing	Drive skidder at logging site	Step off or ride in skidder	Stop or start Skidder engine	Check chokers set	Helping choker setter	Remove obstacle	Hand stopper stick to choker setter	Walk at logging site	Pile logs by skidder	Others	Sub-total	Talk with choker setter at logging site or at landing	Wait and see at logging site or at landing	Personal needs	Have a rest	Sub-total		Preparations and rearrangement	Sub-total	Take noon recess	Be set with heart rate memory or taken it off Flicker test	Sub-total	
Morning preparation																										1950	1950	1950
1	26	176	21	122	57	–	7	–	–	–	–	–	15	13	–	437	15	251	–	–	266	703	–	–	–	–	–	703
2	23	114	13	73	61	–	–	–	–	–	–	–	–	28	–	312	–	139	–	–	139	451	–	–	–	–	–	451
3	22	107	17	20	57	–	–	–	–	–	–	–	–	25	–	248	–	60	–	–	60	308	–	–	–	–	–	308
4	19	244	37	129	75	27	–	–	–	–	–	–	–	36	–	567	–	71	–	–	71	638	–	–	–	–	–	638
5	29	20	15	80	67	–	–	–	–	–	–	–	–	20	–	231	–	134	–	–	134	365	–	–	–	–	–	365
6	25	109	18	33	78	–	–	–	–	–	–	–	–	24	–	287	–	143	–	–	143	430	–	–	–	–	–	430
7	24	81	28	38	89	–	–	–	–	–	–	–	–	25	–	285	8	122	–	–	130	415	–	–	–	–	–	415
8	29	91	34	54	88	–	–	–	–	–	–	–	–	14	–	310	48	208	–	–	256	566	–	–	–	–	–	566
9	32	73	21	31	83	–	–	–	–	–	–	–	–	24	–	264	–	150	–	–	150	414	–	–	–	–	–	414
10	24	83	54	64	95	–	–	–	–	–	–	–	–	36	–	356	–	154			154	510	–	–	–	–	–	510
11	29	73	52	57	59	–	–	–	–	–	–	–	–	34	–	304	–	176	–	–	176	480	–	–	–	–	–	480
12	46	84	42	–	72	14	–	–	–	–	–	–	–	19	–	277	–	136	–	–	136	413	–	–	–	–	–	413
13	38	94	31	29	59	6	–	–	–	–	–	–	–	17	–	274	–	138	–	–	138	412	–	–	–	–	–	412
14	41	102	41	36	60	39	–	–	–	–	–	–	–	19	–	338	26	99	–	–	125	463	–	–	–	–	–	463
15	50	91	48	26	67	6	–	–	–	–	–	–	–	28	–	316	37	126	–	–	163	479	–	–	–	–	–	479
16	50	87	80	18	48	22	–	–	–	–	–	–	–	20	–	325	–	137	–	–	137	462	–	–	–	–	–	462
17	53	151	24	41	81	34	13	–	–	–	–	–	39	41	–	476	10	435	–	127	572	1048	–	–	–	–	–	1048
18	53	219	15	53	56	13	–	–	–	–	–	–	–	27	–	436	–	206	–	–	206	642	–	–	–	–	–	642
19	57	90	52	61	109	35	5	–	–	–	–	–	–	72	–	481	–	160	–	–	160	641	25	25	–	–	–	666
Noon																							–	–	4070	–	4070	4070
20	69	137	19	33	61	129	–	–	–	–	190	–	–	26	–	664	–	256	–	–	256	920	–	–	–	–	–	920
21	45	159	22	47	88	23	4	–	12	–	–	–	–	35	–	435	28	54	–	–	82	517	–	–	–	–	–	517
22	74	138	20	20	79	4	–	–	–	–	–	–	–	33	–	368	–	113	–	–	113	481	–	–	–	–	–	481
23	59	110	22	25	96	20	–	–	–	–	–	–	–	45	–	377	–	122	–	19	141	518	–	–	–	–	–	518
24	61	127	14	40	95	8	–	–	25	–	–	–	–	28	–	398	–	288	–	–	288	686	–	–	–	–	–	686
25	68	96	50	73	83	52	–	–	–	–	–	–	–	33	–	455	–	188	–	–	188	643	–	–	–	–	–	643
26	71	157	30	30	106	5	–	–	–	–	–	–	–	19	–	418	–	212	–	–	212	630	–	–	–	–	–	630
27	59	130	37	36	34	11	4	–	–	–	–	–	45	–	–	356	18	285	–	668	971	1327	–	–	–	–	–	1327
28	68	142	34	36	124	33	–	–	–	–	–	–	–	31	–	468	9	138	–	–	147	615	–	–	–	–	–	615
29	78	110	34	31	128	9	–	–	–	–	–	–	–	19	–	409	–	196	–	–	196	605	–	–	–	–	–	605
30	78	202	33	45	70	6	–	–	–	–	–	–	–	11	–	445	–	125	–	–	125	570	–	–	–	–	–	570
31	63	134	34	29	68	54	–	–	–	–	–	–	–	16	–	390	23	272	–	–	295	693	–	–	–	–	–	693
32	83	201	26	18	54	11	4	–	–	31	–	–	27	33	–	488	24	232	–	–	256	744	–	–	–	–	–	744
33	102	157	130	88	36	32	–	–	–	9	16	–	27	39	–	636	17	446	–	–	463	1099	–	–	–	–	–	1099
34	95	135	29	16	31	12	–	–	–	–	–	–	–	–	–	318	–	249	–	–	249	567	–	–	–	–	–	567
Rearrange-ment																												
Total	1743	4224	1177	1532	2514	604	37	–	37	40	206	–	153	890	–	13157	263	6221		814	7298	20455	25	25	4070	1950	6020	26500

Table III-18 Work time analysis of skidder operator (2) September 19, 1985 Time: 8:52:00 - 16:17:30

sec.

Elements / Turn No.	Basic work time																Allowance						Preparations and Rearrangement		Exception			
	Drive skidder to logging site	Skid turn to landing	Unwind winch line	Wind winch line	Drive skidder at landing	Drive skidder at logging site	Step off or ride in skidder	Stop or start skidder engine	Check chokers set	Helping choker setter	Remove obstacle	Hand stopper stick to choker setter	Walk at logging site	Pile logs by skidder	Others	Sub-total	Talk with choker setter at logging site or at landing	Wait and see at logging site or at landing	Personal needs	Have a rest	Sub-total	Cycle time	Preparations and rearrangement	Sub-total	Take noon recess	Be set with heart rate memory or taken it off Flicker test	Sub-total	Observed time
Morning preparation																										1480		
1	137	222	40	37	167	86	10	8	–	–	–	–	6	44	–	757	19	518	–	–	537	1294	–	–	–	–	–	1294
2	94	171	100	74	191	76	–	–	6	–	–	–	8	69	–	789	12	261	–	–	273	1062	–	–	–	–	–	1062
3	73	147	77	51	85	16	11	–	–	43	94	–	–	23	–	620	28	238	–	–	266	886	–	–	–	–	–	886
4	106	180	258	168	314	71	6	–	13	–	–	–	–	315	–	1431	32	500	–	–	532	1963	–	–	–	–	–	1963
5	70	141	126	136	77	74	18	–	–	184	10	48	–	19	–	903	10	575	–	–	585	1488	–	–	–	–	–	1488
6	71	216	68	68	158	152	–	–	–	–	–	–	–	44	–	777	–	393	–	–	393	1170	–	–	–	–	–	1170
7	93	158	190	74	83	12	–	–	–	8	–	–	14	41	–	673	6	275	–	–	281	954	–	–	–	–	–	954
8	74	144	79	73	105	41	3	10	–	–	–	8	53	30	–	620	30	548	–	–	578	1198	–	–	–	–	–	1198
Noon																										5675		
9	94	351	51	79	179	55	–	3	–	–	–	–	10	82	–	904	–	504	–	–	504	1408	25	–	–	–	–	1433
10	52	187	47	60	82	33	–	–	–	–	–	–	–	32	–	493	–	224	–	–	224	717	–	–	–	–	–	717
11	67	128	66	32	72	5	–	–	–	–	–	–	–	42	–	412	–	310	–	–	310	722	–	–	–	–	–	722
12	56	141	104	83	92	31	–	9	–	–	–	–	–	21	–	537	28	490	–	–	518	1055	–	–	–	–	–	1055
13	62	133	54	47	93	111	–	6	–	–	–	–	–	39	18	563	23	388	–	748	1159	1722	–	–	–	–	–	1722
14	51	103	58	61	68	4	–	–	–	–	–	–	–	18	–	363	–	246	–	–	246	609	–	–	–	–	–	609
15	51	180	57	117	67	69	–	10	–	–	–	–	–	29	15	595	6	333	–	–	339	934	–	–	–	–	–	934
16	76	173	105	93	133	61	–	–	–	–	–	–	–	58	–	699	13	619	–	–	632	1331	–	–	–	–	–	1331
17	40	141	85	64	90	4	–	–	–	–	–	–	–	35	17	476	40	247	–	–	287	763	–	–	–	–	–	763
18	54	39	–	–	–	3	–	29	–	–	–	–	–	–	29	154	22	23	–	–	45	199	75					274
Rearrangement																												
Total	1321	2955	1565	1317	2056	904	48	75	19	235	104	56	91	941	79	11766	269	6692		748	7709	19475	100	100	5675	1480	7155	26730

Table III-19 Work time analysis of Skidder Operator (3) September 25, 1985 Time: 8:55:00 - 16:05:54

sec.

Elements / Turn No.	Basic work time																Allowance					Cycle time	Preparations and Rearrangement		Exception			Observed time
	Drive skidder to logging site	Skid turn to landing	Unwind winch line	Wind winch line	Drive skidder at landing	Drive skidder at logging site	Step off or ride in skidder	Stop or start Skidder engine	Check chokers set	Helping choker setter	Remove obstacle	Hand stopper stick to choker setter	Walk at logging site	Pile logs by skidder	Others	Sub-total	Talk with choker setter at logging site or at landing	Wait and see at logging site or at landing	Personal needs	Have a rest	Sub-total		Preparations and rearrangement	Sub-total	Take noon recess	Be set with heart rate memory or taken it off Flicker test	Sub-total	
																										1568		1568
1	128	147	37	40	60	27	–	6	–	–	–	–	–	21	–	466	23	578	–	–	601		–	–	–	–	–	1067
2	79	131	17	33	50	53	–	–	–	–	–	1	–	31	–	395	4	213	–	–	217		–	–	–	–	–	612
3	79	137	64	39	64	27	–	–	–	–	–	–	–	30	–	440	–	286	–	–	286		–	–	–	–	–	726
4	92	134	55	45	74	144	–	–	–	–	–	–	–	56	18	618	38	275	–	–	313		–	–	–	–	–	931
5	87	155	56	41	74	29	–	–	–	–	–	–	–	41	–	483	–	204	–	–	204		–	–	–	–	–	687
6	86	200	92	42	73	28	2	–	–	–	–	–	27	43	–	593	–	147	–	123	270		–	–	–	–	–	863
7	86	160	91	48	139	37	–	–	–	–	–	–	–	59	–	620	–	340	–	–	340		–	–	–	–	–	960
8	87	137	29	27	55	28	–	–	–	–	–	–	–	31	–	394	–	137	–	–	137		–	–	–	–	–	531
9	89	122	86	49	62	20	3	2	–	–	–	–	64	12	–	509	12	331	50	–	393		–	–	–	–	–	902
10	87	181	29	60	61	34	–	–	–	–	–	–	–	20	–	472	6	307	–	–	313		–	–	–	–	–	785
11	84	124	89	75	75	46	–	1	–	–	–	–	–	36	2	532	15	481	–	–	496		–	–	–	–	–	1028
12	84	163	61	68	122	43	10	–	8	–	–	–	–	35	–	594	–	278	–	–	278		25	–	–	–	–	897
Noon																									3873			3873
13	88	125	75	50	104	74	–	–	15	–	–	–	–	66	–	597	–	371	–	–	371		–	–	–	–	–	968
14	87	126	69	54	79	49	–	–	13	–	–	–	–	40	–	517	–	225	–	–	225		–	–	–	–	–	742
15	75	302	131	170	65	77	–	–	–	–	–	–	–	65	20	905	6	464	–	–	470		–	–	–	–	–	1375
16	92	264	72	157	140	103	–	–	12	–	–	–	–	70	–	910	–	266	–	–	266		–	–	–	–	–	1176
17	91	199	31	60	120	61	–	–	26	–	–	–	–	83	–	671	–	262	–	–	262		–	–	–	–	–	933
18	98	175	43	42	101	49	–	–	–	–	–	–	–	70	–	578	–	267	–	–	267		–	–	–	–	–	845
19	92	181	24	36	94	41	–	16	–	–	–	–	–	51	–	535	19	299	–	530	848		–	–	–	–	–	1383
20	108	214	40	143	161	234	–	–	–	–	–	–	–	69	–	969	12	354	–	–	366		–	–	–	–	–	1335
21	107	214	30	30	85	48	–	–	5	–	–	–	–	30	–	549	–	303	–	–	303		–	–	–	–	–	852
22	91	202	13	61	86	64	–	–	–	–	–	2	–	32	–	551	–	264	–	–	264		–	–	–	–	–	812
Rearrange-ment																												
Total	1997	3793	1234	1370	1944	1316	15	25	79			3	91	991	40	12898	135	6652	50	653	7490	20388	25	25	3873	1568	5441	25854

Table III-20 Work time analysis of choker setter (1) September 17, 1985 Time: 8:57:00 - 16:19:02

sec.

Elements / Turn No.	Basic work time															Allowance				Cycle time	Preparations and rearrangement			Except					Observed time
	Set chokers	Pull winch-line off drum	Put winch-line through choker's eye	Carry chokers	Chose logs that will make up a turn	Remove obstacle	Bunch logs	Direct skidder	Be apart from skidder being operated for safety	Set chokers again	Straighten working clothes or wear gloves	Walk on logging site	Take off chokers from skidder	Others	Sub-total	Wait and see at logging site	Personal needs	Have a rest	Sub-total		Make preparations or rearrangement	Move from one working place to another	Sub-total	Take noon recess	Have a chat	Be set with heart rate memory or take it off flicker test	Others	Sub-total	
Morning preparation																					-	-	-	-	-	1996	-	1996	1996
1	57	49	55	20	-	-	-	-	32	-	-	21	9	-	243	-	-	-	-	243	-	-	-	-	-	-	-	-	243
2	64	18	14	65	94	59	-	22	90	-	-	123	-	36	585	34	-	37	71	656	-	-	-	-	-	-	-	-	656
3	2	11	14	44	-	-	-	-	23	-	-	82	15	19	210	-	-	73	73	283	-	-	-	-	-	-	-	-	283
4	51	44	5	-	25	-	-	-	6	20	-	129	22	-	302	27	-	8	35	337	-	-	-	-	-	-	-	-	337
5	41	23	20	107	37	70	-	14	7	-	-	147	-	34	500	33	-	97	130	630	-	-	-	-	-	-	-	-	630
6	42	24	23	71	20	24	9	15	20	-	-	38	5	27	318	-	-	54	54	372	-	-	-	-	-	-	-	-	372
7	47	45	28	59	10	2	-	70	9	-	-	91	5	19	385	43	-	48	91	476	-	-	-	-	-	-	-	-	476
8	73	67	35	45	-	-	-	41	31	33	-	166	21	17	529	-	-	27	27	556	-	-	-	-	-	-	-	-	556
9	22	30	18	39	42	-	16	125	51	23	-	25	18	35	444	-	-	14	14	458	-	-	-	-	-	-	-	-	458
10	106	66	45	83	11	-	-	22	67	-	-	27	27	6	460	-	-	39	39	499	-	-	-	-	-	-	-	-	499
11	87	44	47	61	22	10	-	12	55	12	-	104	-	-	454	18	-	-	18	472	-	-	-	-	-	-	-	-	472
12	95	54	27	50	-	-	-	4	39	-	-	57	12	57	395	38	-	34	72	467	-	-	-	-	-	-	-	-	467
13	65	28	30	43	39	-	-	-	63	11	-	36	15	10	340	34	-	16	50	390	-	-	-	-	-	-	-	-	390
14	90	46	28	24	41	13	-	11	74	-	-	37	11	-	375	64	-	36	100	475	-	-	-	-	-	-	-	-	475
15	89	28	52	43	10	22	-	-	53	6	-	66	5	-	374	17	-	44	61	435	-	-	-	-	-	-	-	-	435
16	72	28	38	58	-	-	-	-	50	24	-	60	21	8	359	44	-	122	166	525	-	-	-	-	-	-	-	-	525
17	48	36	23	57	-	-	-	-	72	-	-	59	20	5	320	21	-	74	95	415	-	-	-	-	-	-	-	-	415
18	78	45	32	27	10	-	-	-	52	23	-	161	33	21	482	14	-	589	603	1085	-	-	-	-	-	-	-	-	1085
19	73	96	21	42	-	7	35	-	68	12	-	123	19	55	551	124	-	5	129	680	-	-	-	-	-	-	-	-	680
																					70	70	4343					4343	4413
20	93	77	9	-	29	-	-	-	55	5	11	215	26	16	536	135	-	11	146	682	-	-	-	-	-	-	-	-	752
21	53	18	19	9	5	-	-	3	49	22	11	64	17	29	299	36	-	137	173	472	-	-	-	-	-	-	-	-	472
22	52	14	31	29	5	-	-	-	39	-	7	24	12	3	216	29	-	252	281	497	-	-	-	-	-	-	-	-	497
23	60	52	26	36	36	-	-	-	54	-	16	61	17	8	366	-	-	154	154	520	-	-	-	-	-	-	-	-	520
24	100	39	47	13	26	-	-	4	52	119	19	142	21	40	622	29	-	55	84	706	-	-	-	-	-	-	-	-	706
25	130	68	29	40	31	4	-	-	33	37	7	70	30	12	491	19	-	69	88	579	-	-	-	-	-	-	-	-	579
26	112	32	47	49	39	41	-	-	64	7	4	102	21	15	533	18	-	37	55	588	-	-	-	-	-	-	-	-	588
27	115	44	33	46	3	-	45	7	-	31	10	64	23	54	475	14	-	919	933	1408	-	-	-	-	-	-	-	-	1408
28	93	39	33	12	20	27	-	1	50	16	11	107	14	12	435	17	-	78	95	530	-	-	-	-	-	-	-	-	530
29	85	28	44	56	10	-	-	-	44	-	7	19	18	18	329	35	-	241	276	605	-	-	-	-	-	-	-	-	605
30	55	55	28	-	7	-	-	-	59	62	5	54	26	2	353	9	-	277	286	639	-	-	-	-	-	-	-	-	639
31	96	38	23	96	9	51	16	2	39	36	-	120	28	54	608	9	-	-	9	617	-	-	-	-	-	-	-	-	617
32	78	95	32	28	-	46	-	-	52	24	-	268	29	23	675	17	-	22	39	714	-	-	-	-	-	-	-	-	714
33	77	212	97	82	-	21	-	-	116	124	-	87	15	4	835	21	-	232	253	1088	-	-	-	-	-	-	-	-	1088
34	75	13	54	17	-	-	-	-	50	54	-	74	14	-	341	13	-	385	398	739	-	-	-	-	-	-	-	-	739
Rearrangement																					275	275							275
Total	2466	1606	1107	1451	581	397	121	353	1618	701	108	3023	569	639	14740	912		4186	5098	19838		345	345	4343		1996		6339	26522

Table III-21 Work time analysis of choker setter (2) September 19, 1985 Time: 8:52:00 - 16:16:29

sec.

Elements / Turn No.	Basic work time															Allowance				Cycle time	Preparations and rearrangement			Except					Observed time
	Set chokers	Pull winch-line off drum	Put winch-line through choker's eye	Carry chokers	Chose logs that will make up a turn	Remove obstacle	Bunch logs	Direct skidder	Be apart from skidder being operated for safety	Set chokers again	Straighten working clothes or wear groves	Walk on logging site	Take off chokers from skidder	Others	Sub-total	Wait and see at logging site	Personal needs	Have a rest	Sub-total		Make preparations or rearrangement	Move from one working place to another	Sub-total	Take noon recess	Have a chat	Be set with heart rate memory or take it off flicker test	Others	Sub-total	
Morning preparation																					138	–	138	–	–	1470	–	1470	1608
1	106	89	75	48			18		118			109	14	42	619	13			13	632	–	–	–	–	–	–	–	–	632
2	154	95	26	126	202	34			25		8	38	24	21	753	89		33	122	875	–	–	–	–	–	–	–	–	875
3	130	58	38	66	203	15	29	38	95	52	7	161		102	994	98		203	301	1295	–	–	–	–	–	–	–	–	1295
4	61	323	78	177	85	15		6	90	74		88	31		1028	169		112	281	1309	–	–	–	–	11	–	–	11	1320
5	229	104	83	150	68	20	34	12	228	155	11	153	36	16	1299	29		722	751	2050	–	–	–	–	–	–	–	–	2050
6	214	91	28	93	73				148	65		139		36	887	38			38	925	–	–	–	–	–	–	–	–	925
7	192	260	50	110	81				44			97	25		859	53		229	282	1141	–	–	–	–	14	–	–	14	1155
8	209	144	85	80	97			8	86			159	31	97	996	69		44	113	1109	–	–	–	–	11	–	–	11	1120
Noon																					122		122	5311				5311	5433
9	101	70	55	133	32				113		15	274	20	12	825	349		203	552	1377	–	–	–	–	–	–	–	–	1377
10	104	76	23	23	46				79	8		134	35	15	543	47		551	598	1141	–	–	–	–	–	–	–	–	1141
11	130	75	45	75	12		7		94			77	42	2	559	30		137	167	726	–	–	–	–	–	–	–	–	726
12	141	191	44	110	49	46			12			158	20	108	879	49			49	928	–	–	–	–	–	–	–	–	928
13	135	70	70	140	3	24		19	37	18		48		201	765	120		869	989	1754	–	–	–	–	–	–	–	–	1750
14	144	77	34	103	89				132	30		89	15	25	738	35			35	773	–	–	–	–	–	–	–	–	773
15	102	96	48	87	67	32			165	230		90	21	7	945	79		18	97	1042	–	–	–	–	–	–	–	–	1042
16	47	136	41	47	33	62	30		65	51		145	46	54	757	147			147	904	–	–	–	–	–	–	–	–	904
17	105	109	49	73	88	192			82			396	15	281	1390	73		11	84	1474	–	–	–	–	86	–	–	86	1560
Rearrange-ment																					55		55						55
Total	2304	2064	872	1641	1228	440	118	83	1613	683	41	2355	375	922	14836	1487		3128	4615	19451	315		315	5311	122	1470		6903	26669

Table III-22 Work time analysis of choker setter (3) September 25, 1985 Time: 9:00:00 - 16:15:30

sec.

Elements / Turn No.	Basic work time															Allowance					Preparations and rearrangement			Except					
	Set chokers	Pull winch-line off drum	Put winch-line through choker's eye	Carry chokers	Chose logs that will make up a turn	Remove obstacle	Bunch logs	Direct skidder	Be apart from skidder being operated for safety	Set chokers again	Straighten working clothes or wear gooves	Walk on logging site	Take off chokers from skidder	Others	Sub-total	Wait and see at logging site	Personal needs	Have a rest	Sub-total	Cycle time	Make preparations or rearrangement	Move from one working place to another	Sub-total	Take noon recess	Have a chat	Be see with heart rate memory or take it off flicker test	Others	Sub-total	Observed time
Morning preparation																					–	150	150	–	–	1564	–	1564	1714
1	149	59	64	63	24	14	–	–	56	–	6	33	44	66	578	–	–	–	–	578	–	–	–	–	–	–	–	–	578
2	168	29	49	123	24	39	–	36	104	–	–	52	19	6	649	–	–	–	–	649	–	–	–	–	–	–	–	–	649
3	200	70	83	104	25	–	–	21	71	–	–	73	22	20	689	–	–	–	–	689	–	–	–	–	–	–	–	–	689
4	158	65	44	128	25	–	6	52	75	–	–	58	28	41	680	133	–	82	215	895	–	–	–	–	–	–	–	–	895
5	181	67	62	75	13	–	–	37	78	–	–	95	20	13	641	–	–	99	99	740	–	–	–	–	–	–	–	–	740
6	150	87	57	76	–	3	–	19	74	–	–	65	35	–	566	–	–	137	137	703	–	–	–	–	–	–	–	–	703
7	191	129	45	115	45	–	4	21	97	–	–	105	26	–	778	–	–	134	134	912	–	–	–	–	–	–	–	–	912
8	113	23	45	54	24	–	–	–	53	–	4	30	30	–	376	35	–	409	444	820	–	–	–	–	–	–	–	–	820
9	156	101	74	99	55	37	–	–	45	–	–	92	34	37	730	21	–	–	21	751	–	–	–	–	–	–	–	–	751
10	150	48	63	113	41	31	–	–	125	–	–	68	36	20	695	14	–	111	125	820	–	–	–	–	–	–	–	–	820
11	127	62	50	69	45	–	–	20	88	–	–	147	36	257	901	–	–	186	186	1087	–	–	–	–	–	–	–	–	1087
12	184	125	58	107	–	–	–	12	125	–	–	41	26	45	723	–	–	47	47	770	–	–	–	–	–	–	–	–	770
Noon																						222	222	3725				3725	
13	124	54	39	68	–	–	–	–	58	–	15	168	26	8	560	–	–	–	–	560	335	–	335	–	–	–	–	–	895
14	157	104	51	87	44	–	–	–	66	–	–	41	13	–	563	10	–	211	221	784	21	–	21	–	–	–	–	–	805
15	136	157	63	84	68	–	33	–	223	60	–	68	18	99	1009	36	–	137	173	1182	–	–	–	–	–	–	–	–	1182
16	90	72	61	51	–	–	–	–	305	–	4	72	18	15	688	12	–	463	475	1163	–	–	–	–	–	–	–	–	1163
17	134	47	88	43	55	10	–	17	62	–	–	66	20	28	570	–	–	355	355	925	–	–	–	–	–	–	–	–	925
18	193	58	40	34	35	23	–	22	57	–	–	97	20	42	621	–	–	310	310	931	–	–	–	–	–	–	–	–	931
19	141	27	57	46	13	23	–	20	52	–	–	68	24	–	471	–	–	903	903	1374	–	–	–	–	–	–	–	–	1374
20	98	76	26	96	11	20	–	55	304	28	–	31	40	10	795	–	–	392	392	1187	–	–	–	–	–	–	–	–	1187
21	152	61	44	96	–	31	8	20	77	–	–	48	27	8	572	–	–	467	467	1039	–	–	–	–	–	–	–	–	1039
22	182	68	75	66	47				65			36			539			265	265	804	–	–	–	–	–	530	–	530	1334
Rearrangement			0																			190	190						190
Total	3334	1589	1238	1797	594	231	51	352	2260	88	29	1554	562	715	14394	261		4708	4969	19363	356	562	918	3725		2094		5814	26100

Table III-23 Time analysis of thinning operation by T-20: Tractor-operator

		17/09/85			19/09/85			25/09/85		
		sec	hr.min. sec.	%	sec	hr. min. sec.	%	sec	hr.min. sec.	%
Main work	Winding out winch rope	1,177	19′37″	5.8	1,565	26′05″	8.0	1,234	20′34″	6.0
	Winding in winch rope	1,532	25′32″	7.5	1,317	21′57″	6.7	1,370	22′50″	6.7
	Driving to the landing	4,224	1°10′24″	20.6	2,955	49′15″	15.1	3,793	1°03′13″	18.6
	Driving to the mountain	1,743	29′03″	8.5	1,321	22′01″	6.7	1,997	33′17″	9.8
	Driving in the landing	2,514	41′54″	12.3	2,056	34′16″	10.5	1,944	32′24″	9.5
	Driving in the forest	354	5′54″	1.7	751	12′31″	3.8	1,177	19′37″	5.8
	Stop	250	4′10″	1.2	153	2′33″	0.8	139	2′19″	0.7
	Sub-total	11,794	3°16′34″	57.6	10,118	2°48′38″	51.7	11,654	3°14′14″	57.1
Incidental work	Piling logs in the landing	890	14′50″	4.3	941	15′41″	4.8	991	16′31″	4.9
	Gegging on or off the tractor	37	37″	0.2	48	48″	0.2	15	15″	0.1
	Preparing for operating the tractor				75	1′15″	0.4	25	25″	0.1
	Checker setting	37	37″	0.2	19	19″	0.1	79	1′19″	0.4
	Helping choker-man	40	40″	0.2	235	3′55″	1.2			
	Removing obstacles	206	3′26″	1.0	104	1′44″	0.5			
	Carring and landing stoppers				56	56″	0.3	3	3″	0.0
	Waiting	153	2′33″	0.7	91	1′31″	0.5	91	1′31″	0.4
	Others				79	1′19″	0.4	40	40″	0.2
	Sub-total	1,363	22′43″	6.6	1,648	27′28″	8.4	1,244	20′44″	6.1
Allowance	Arranging	263	4′23″	1.3	269	4′29″	1.4	135	2′15″	0.7
	Waiting for the next phase	6,221	1°43′41″	30.4	6,692	1°51′32″	34.2	6,652	1°50′52″	32.6
	Sub-total	6,484	1°48′04″	31.7	6,961	1°56′01″	35.6	6,787	1°53′07″	33.3
	Fatigue and rest allowance	814	13′34″	4.0	748	12′28″	3.8	703	11′43″	3.4
	Sub-total	814	13′34″	4.0	748	12′28″	3.8	703	11′43″	3.4
Preparation	Preparing and settling	25	25″	0.1	100	1′40″	0.5	25	25″	0.1
	Sub-total	25	25″	0.1	100	1′40″	0.5	25	25″	0.1
Exclusive time	Exclusive time	6,020	1°40′20″	—	7,155	1°59′15″	—	5,441	1°30′41″	—
	Sub-total	6,020	1°40′20″	—	7,155	1°59′15″	—	5,441	1°30′41″	—
Total		26,500	7°21′40″	100.0	26,730	7°25′30″	100.0	25,854	7°10′54″	100.0

Table III-24 Time analysis of Thinning operation by T-20: Choker-setter

		17/09/85			19/09/85			25/09/85		
		sec	hr.min. sec.	%	sec	hr.min. sec.	%	sec	hr.min. sec.	%
Main work	Setting slings	2,466	41′ 06″	12.2	2,304	38′ 24″	11.7	3,334	55′ 34″	16.4
	Pulling out the winch rope	1,606	26′ 46″	8.0	2,064	34′ 24″	10.4	1,589	26′ 29″	7.8
	Passing the winch rope through sling-eyes	1,107	18′ 27″	5.5	872	14′ 32″	4.4	1,238	20′ 38″	6.1
	Sub-total	5,179	1° 26′ 19″	25.7	5,240	1° 27′ 20″	26.5	6,161	1° 42′ 41″	30.3
Incidental work	Carring slings	1,451	24′ 11″	7.2	1,641	27′ 21″	8.3	1,797	29′ 57″	8.9
	Chosing the logg to be logged	581	9′ 41″	2.9	1,228	20′ 28″	6.2	594	9′ 54″	2.9
	Removing obstacles	397	6′ 37″	2.0	440	7′ 20″	2.2	231	3′ 51″	1.1
	Pulling logs by hand to set slings	121	2′ 01″	0.6	118	1′ 58″	0.6	51	51″	0.3
	Leading the tractor	353	5′ 53″	1.7	83	1′ 23″	0.4	352	5′ 52″	1.7
	Avoidance and watching being pulled logs	1,618	26′ 58″	8.0	1,613	26′ 53″	8.2	2,260	37′ 40″	11.1
	Resetting slings of the winch rope	701	11′ 41″	3.5	683	11′ 23″	3.5	88	1′ 28″	0.4
	Pulling on or off gloves or others	108	1′ 48″	0.5	41	41″	0.2	29	29″	0.1
	Setting a guide block				97	1′ 37″	0.5	144	2′ 24″	0.7
	Walking	3,368	56′ 08″	16.7	2,532	42′ 12″	12.8	2,116	35′ 16″	10.4
	Taking off chokers from tractor	569	9′ 29″	2.8	375	6′ 15″	1.9	562	9′ 22″	2.8
	Others	639	10′ 39″	3.2	1,060	17′ 40″	5.4	571	9′ 31″	2.8
	Sub-total	9,906	2° 45′ 06″	49.1	9,911	2° 45′ 11″	50.2	8,795	2° 26′ 35″	43.5
Allowance	Waiting for a next phase	912	15′ 12″	4.5	1,487	24′ 47″	7.5	261	4′ 21″	1.3
	Sub-total	912	15′ 12″	4.5	1,487	24′ 47″	7.5	261	4′ 21″	1.3
	Fatigue and rest allowance	4,186	1° 09′ 46″	20.7	3,128	52′ 08″	15.8	4,708	1° 18′ 28″	23.2
	Sub-total	4,186	1° 09′ 46″	20.7	3,128	52′ 08″	15.8	4,708	1° 18′ 28″	23.2
Prepara-tion	Preparing and settling	—		0.0	—		0.0	356	5′ 56″	1.7
	Sub-total							356	5′ 56″	1.7
Exclusive time	Exclusive time	6,339	1° 45′ 39″	—	6,903	1° 55′ 13″	—	5,819	1° 36′ 59″	—
	Sub-total	6,339	1° 45′ 39″	—	6,903	1° 55′ 03″	—	5,819	1° 36′ 59″	—
Total		26,522	7° 22′ 02″	100.0	26,669	7° 24′ 29″	100.0	26,100	7° 15′ 00″	100.0

The proposal of operation improvement were established by the time study, and improvement was actually proved by the second investigation. It was also proved that the time study is effective for improvement of working method. Although the time study revealed that some of the problems were improved and some others being improved, it also picked up some new problems. This reminds us, when we think of the work study being established with improvement of productivity as the major subject, that solution of a problem leads to revealing of another problem that has been hidden behind it. We should understand that working methods have been improved by thus solving various problems. Here we have shown that our effort for solution and improvement of a certain problem provides us with a new clue for stepping over a stage and reaching a higher level of techniques. We have confirmed in the foregoing paragraph that the mechanized logging techniques transferred has already taken root as those of Instituto Florestal do São Paulo, but the detailed examination taking example in tractor logging operation revealed that there is a room for further improvement. Technical matters to be emphasized in training and education of workers can also be found by the work study. Effective utilization of the techniques of work study is hoped for in order that a higher techniques be acquired for a higher safety and higher productivity.

III-2-3 Work intensity study

(1) Aim of the study

Generally speaking, forestry work mostly belongs to the heavy physical labor. It is especially true in the cases of works where man power or hand tools alone are resorted to, and the work intensity can be lowered by mechanized forest operations. However, this is not very simple when the severe working environment in forests is considered, and various problems are to be solved.

It is, therefore, considered extremely useful in forestry work study to take up the problem of work intensity and understand the methods of applying the basic rules not only for reduction of work intensity but for enhancing labor safety and operational efficiency.

Physical or mental changes always take place during forestry works. By measuring the amount of change physically and

mentally, the degree of load of the work can be found. It is what is usualy called "work load".

Work load varies depending on the worker, even if the amount of work is the same. It varies depending on working environment, experience, age, and other human conditions. Therefore, the work load must be examined with reference to various factors, but it is usual to examine it under ordinary working environment for average worker in age, capacity, and skill.

Physical and mental changes on the workers can be proved by measuring the change of physical and mental functions as a result of the work. Several methods have been resorted to for measuring work load, but here, some of the methods generally used in forestry work study such as (1) heart rate, (2) energy metabolism, and (3) flicker value will be taken up for explanation of the methods, and the result of investigation in the Campos do Jordão forest where the methods were applied to logging operation.

(2) Heat rate measurement

① Significance

Blood transportation to the muscles of worker is increased in order to satisfy the oxygen requirement by the muscles in action as a result of the working. The heart rate of the worker, or the number of times of heart beat per minute, increases accordingly. Proportionality of heart rate with the work load of human being has been demonstrated in the science of labor, and this can be used for measurement of load of dynamic and static physical work and psychological work.

Heart rate can be continuously recorded during work and it is one of the very useful means of measurment as index of work load. However, it must be noted that it is affected also by psychological and neural load.

② Method of measuring

The spike voltage generated on contraction of the heart (called R-wave) in taken out by two electrodes fixed on the breast, and it is recorded continuously after amplification. One of the three electroded is a grounding terminal for safety. The heart

rate is expressed in beat/min by regarding the R-wave as a beat. The wave form of an electrocardiogram is as shown in Fig. III-18 where R-R is a beat. The heart rate is measured by wire or wireless connection, and a digital recorder is used recently for recording it every moment.

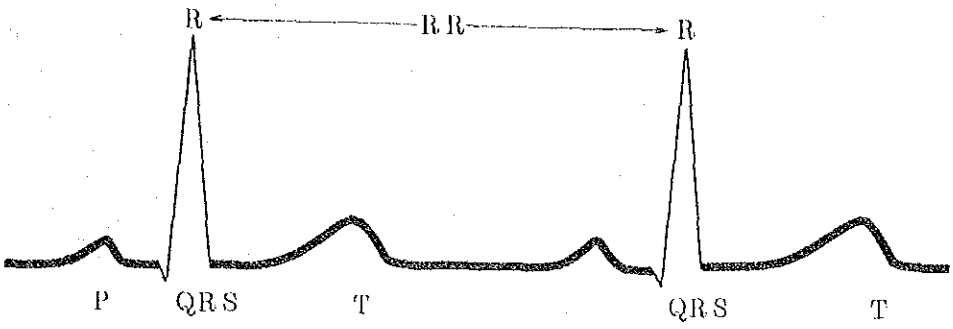


Fig. III-18 Electrocardiogram

(a) Measuring heart rate in telemeter system

An outline of heart rate determination in telemeter system is as follows. For the detail, the operation manual shall be referred to.

1) Block diagram of the telemeter system is shown in Fig. III-19.

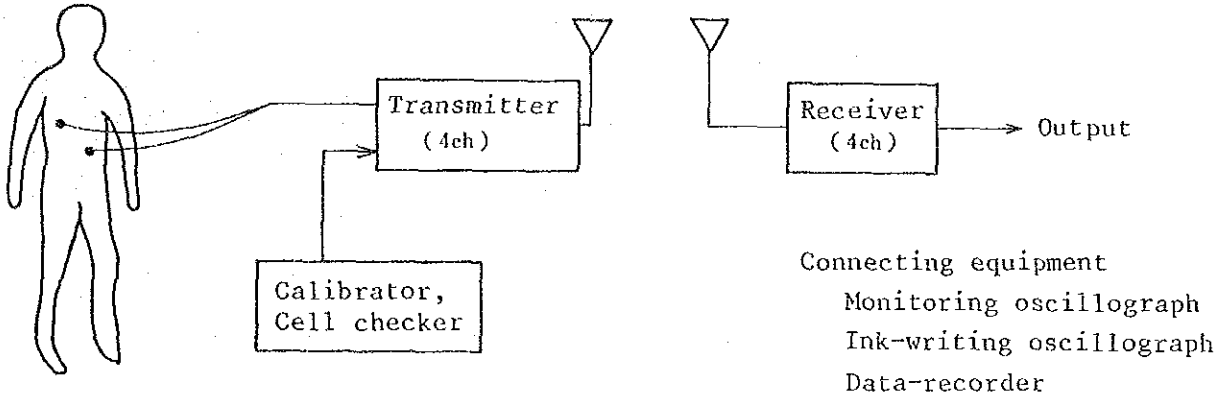


Fig. III-19 Block diagram

2) Principal specifications of a multiple purpose telemeter

ⓐ Receiving distance: About 50 m in a visible place

ⓑ Continuous service time: 48 hours

ⓒ Level calibrator: The voltage of battery built in the transmitter is checked by a meter.

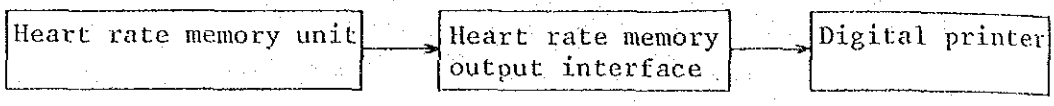
ⓓ Output voltage: ±2 V (5 mA or less)

ⓔ Environment for use, temperature: 10 - 40°C

(b) Digital measurement of heart rate

1) Outline: The unit for heart rate memory is carried by the worker for measurement for many hours, and the result of measurement memorized is digitally printed out through an output interface. It is also possible by switching to record heart rate measured in 10, 30 or 60 seconds within 17 hours continuously.

2) Structure of the heart rate memory unit



3) Principal specifications of heart rate memory unit

ⓐ Interval between countings: 1 minute, 30 seconds, and 10 seconds by switching

ⓑ Duration of measurement: About 17 hours by 1 minute interval, about 8 hours by 30-seconds interval, about 2.8 hours by 10-second interval.

ⓒ Number of memories: 2,047 words

ⓓ Check mark: Red printing in the time of ON

ⓔ Life: About 150 hours

ⓕ Allowable temperature: 10 - 35°C

③ Procedure and criteria

Generally speaking, heart rate increases as work load increases, but the individual variations of heart rate is large. Therefore, it is advisable to obtain heart rate at rest and judge by the increase of heart rate or rate of increase.

Heart rate increase = Heart rate under load - Heart rate at rest

Increasing rate of heart rate = Heart rate increase/Heart rate at rest × 100

Important point to be marked in measurement of heart rate is the method of taking heart rate at rest. It might simply be regarded that value taken at rest without working is sufficient, but the value varies under various conditions at rest.

Heart rate at rest shows a notable daily change, and the effect of daily change can be minimized by measuring it at suitable hours judged from the features of the change. Referring to reports of Japanese studies, it is advisable to avoid the time in the morning before starting work and 1 - 2 hours after lunch and to measure before lunch or after finishing work in the evening.

Even if the said measurement of heart rate at rest under such consideration is difficult, taking a mean value of heart rate at rest before and after work as the standard value is necessary in the case of a large variation of heart rate at rest.

④ Example of investigation

(a) Outline of investigation

ⓐ Date of investigation: September 17 - 26, 1985 (5.5 days net)

ⓑ Loggin site: Campos do Jordão forest, compartment 66

ⓒ Forest conditions: Elliottii Pine, 20 - 21 years of age, Number of trees : 1,638/ha, Thinning rate (number of trees) 51 %

ⓓ Topography: About 15° inclination

ⓔ Subjects: Choker setter C (37 years of age), 3.5 years of experience. Tractor operator W (21 years of age) 3.5 years of experience

ⓕ Skidder used: T-20

ⓖ Method of investigation: Heart rate memory units were fixed on the subjects, and their heart rates were measured continuously from the start of operation to the end. Time study of the two workers was carried out at the same time.

(b) Result of investigation

Change in the work load on the workers was understanded through measurement of heart rate. Besides, the difference in work load between the tractor operator and choker setter and characteristics of their labor were studied.

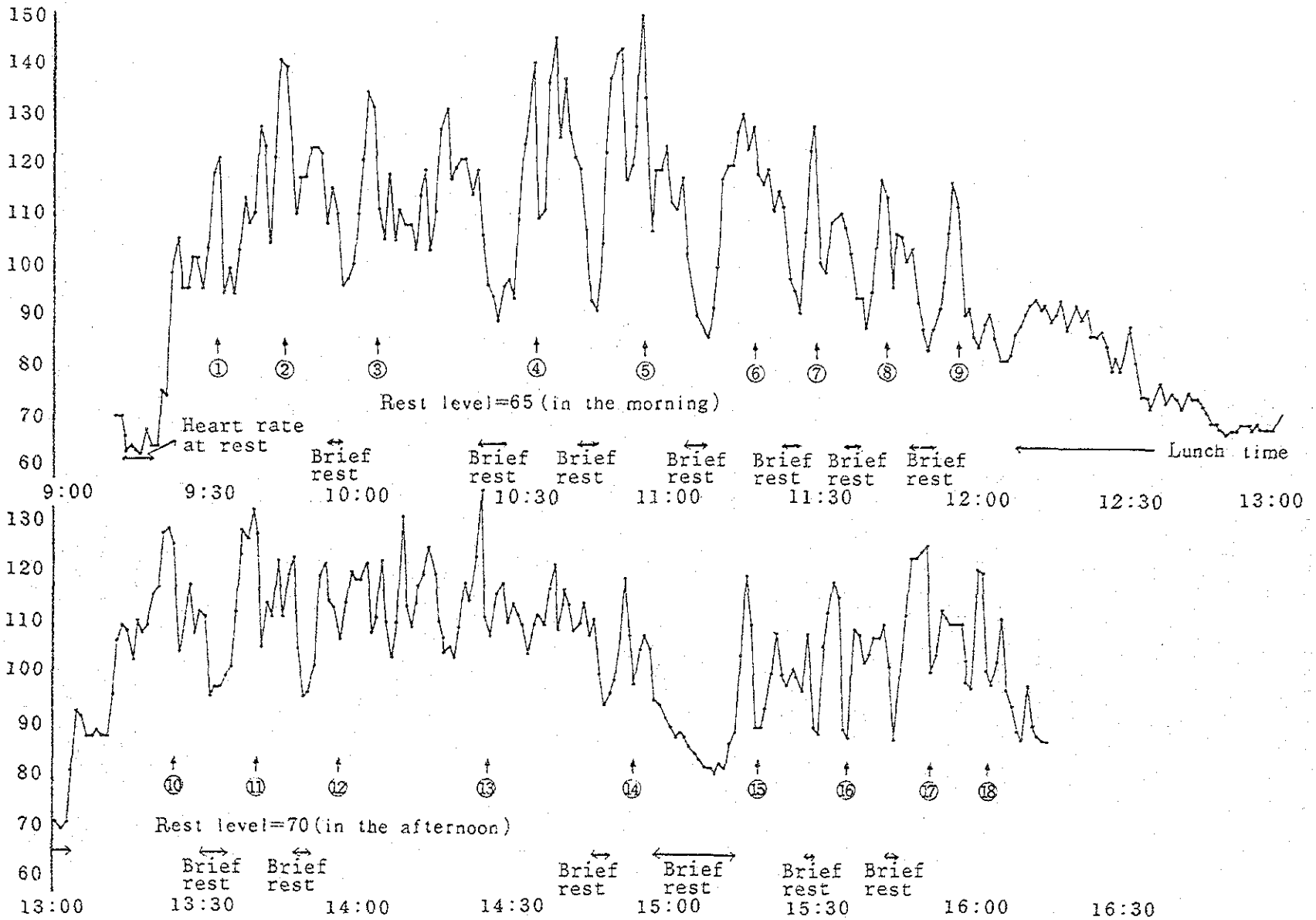


Fig. III-20 Change in the heart rate while working (Choker setter)

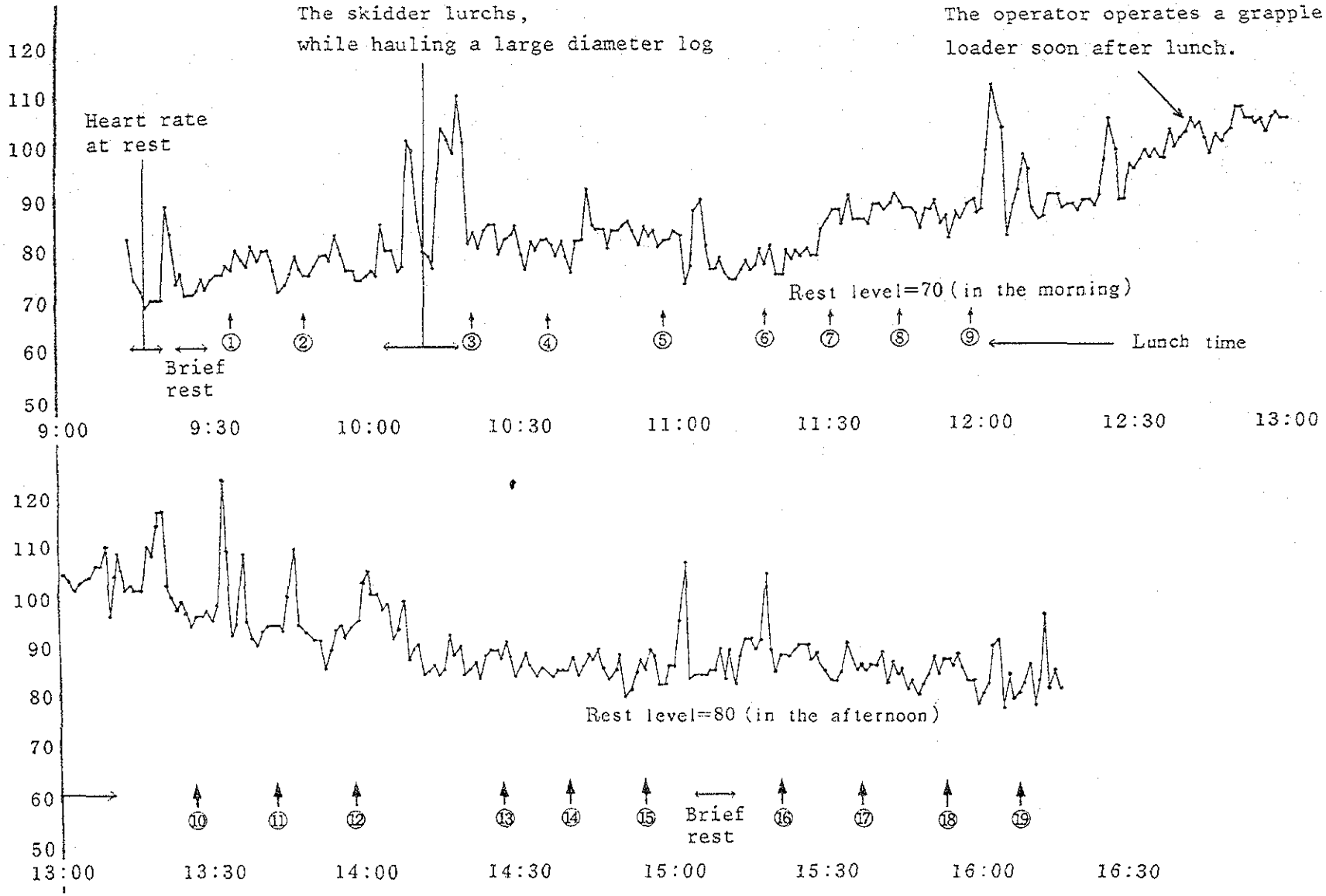


Fig. III-21 Change in the heart rate while working
(Tractor operator)

ⓐ Daily change in work load

Fig. III-20 and Fig. III-21 show the daily change of heart rate during choker setting and tractor operating. The arrows and figures show the number of turns. The characteristics of work load of the works are as follows:

i. Choker setting operation

The heart rate during work was higher than one at rest (65/min in the morning and 70/min in the afternoon), and it varied in the morning within the range of 90 - 140/min, while in the afternoon (to 15:00) in the range of 100 - 130/min with less variation than one in the morning.

Average heart rate during work shown by the figures is about 110/min both in the morning and in the afternoon, and the work load by the choker setting operation is considered to be pretty heavy. Many short rests are noticeable, presumably due to severe labor.

ii. Tractor operation

The heart rate level during work was not very higher than one at rest (70/min in the morning and 80/min in the afternoon) with small fluctuation. However, temporary rises in the heart rate can be noticed. This seems to be due to awaying of the tractor in tugging the tree length by winch when the log was large in diameter or caught by felled trees or standing trees.

ⓑ Examination of work load by the increasing rate of heart rate

Table III-25 and Table III-26 show the increasing rate of heart rate by the content of work.

i. The heart rate and its rate of increase were shown in each of the yarding cycles, taking operations from finished choker setting to the next finish of choker setting as a cycle. Table III-25 shows that average heart rate was about 110/min (93 - 125/min), and that the rate of increase was about 60% (42 - 87 %), meaning that the work is pretty hard. The rate of increase during short rests is about 40 % (31 - 54 %). The heart rate at rest of 67/min, taken between the morning and afternoon, was used. This kind of analysis should be made for every

Table III-25 Heart rate and rate of increase during work
(Choker setting operation during tractor yarding)

Work cycle	Heart rate			Rate of increase		
	Working	Taking short recess	Total	Working	Taking short recess	Total
①	114		114	70.1		70.1
②	117	98	114	74.6	40.3	70.1
③	116	95	112	73.1	41.8	67.2
④	131	99	125	95.5	47.8	86.6
⑤	114	88	109	70.2	31.3	62.7
⑥	113	101	109	68.7	50.8	62.7
⑦	106	81	101	58.2	20.9	50.8
⑧	105	88	99	56.7	31.3	49.8
⑨	98		98	46.3		46.3
⑩	117	98	111	74.6	46.3	65.7
⑪	115	103	112	71.6	53.7	67.2
⑫	115		115	71.6		71.6
⑬	111	99	110	65.7	47.8	64.2
⑭	105	87	93	56.7	29.9	38.8
⑮	102	84	101	52.2	25.4	50.6
⑯	111	92	109	65.7	37.3	62.7
⑰	110		110	64.2		64.2
⑱	95		95	41.8		41.8
Average	111	93	108	65.7	38.8	61.2
Lunch time	79		79	17.9		17.9
At rest			67			

Table III-26 Heart rate and rate of increase during work (Tractor operation)

Work cycle	Heart rate			Rate of increase		
	Working	Taking short recess	Total	Working	Taking short recess	Total
①	76		76	1.3		1.3
②	78	※90	83	4.0	20.0	10.7
③	81		81	8.0		8.0
④	82		82	9.3		9.3
⑤	78		78	4.0		4.0
⑥	80		80	6.7		6.7
⑦	87		87	16.0		16.0
⑧	86		86	14.7		14.7
⑨	102		102	36.0		36.0
⑩	98		98	30.7		30.7
⑪	94		94	25.3		25.3
⑫	90		90	20.0		20.0
⑬	85		85	13.3		13.3
⑭	83		83	10.7		10.7
⑮	89	80	87	18.7	6.7	16.0
⑯	87		87	16.0		16.0
⑰	85		85	13.3		13.3
⑱	83		83	10.7		10.7
⑲	84		84	12.0		2.0
Average	86	85	86	14.7	13.3	14.7
Lunch time	98		98	30.7		30.7
At rest			75			

* Large-sized log (uphill), skidder lurched.

element of work included in the choker setting work for work improvement, but here it was limited to examination for every yarding cycle.

ii. Tractor operation

The heart rate during tractor operation was about 86/min on average (76 - 102/min) with rate of increase at about 15 (1 - 36); and the results show that the work load is smaller than that of choker setting. However, a reckless operation leads to ramping of tractor; and the sense of danger causes an increase in heart rate. Psychological load can be imposed on the operator. This is shown by Fig. III-21 to some extent, but analysis of the increasing rate of heart rate by each of the work elements reveals it more clearly.

(3) Measuring energy metabolism

① *Significance*

Needless to say, workers consume their energy in their work. Forest operation consists of many physical works, and its energy consumption is larger than that of other industry, similarly to the case of agricultural work. However, mechanization of operation is reducing the work intensity also in the field of forest work.

In this regard, work intensity (work load) is often expressed in terms of energy consumption. Energy stored in body is spent for forestry labor, and the transition of energy is called energy metabolism.

The amount of energy metabolism is represented by consumption of oxygen inhaled by respiration, and physical load can be measured by the total consumption of oxygen required for the work.

Energy metabolism is expressed in kcal (kilo-calorie), but energy consumption for a certain amount of work depends on the individual, and elimination of the individual difference is necessary. It is usual in European countries to express the energy consumption in kcal per unit time, and per unit body weight (kcal/hr/kg) or unit body surface area (kcal/hr/m^2).

② Measuring method

Energy metabolism is usually studied by measuring oxygen and carbon dioxide in expired air. Measurement is made in the order of collection of expired air, determination of the amount of expired air, and gas analysis of the expired air.

(a) Collection of expired air

Douglas bag method is usually used in collecting expired air. The method of collection depends on whether a balance is established between the oxygen demand in the body and oxygen supply by respiration during work or not. The state of the balance being maintained is called a steady state.

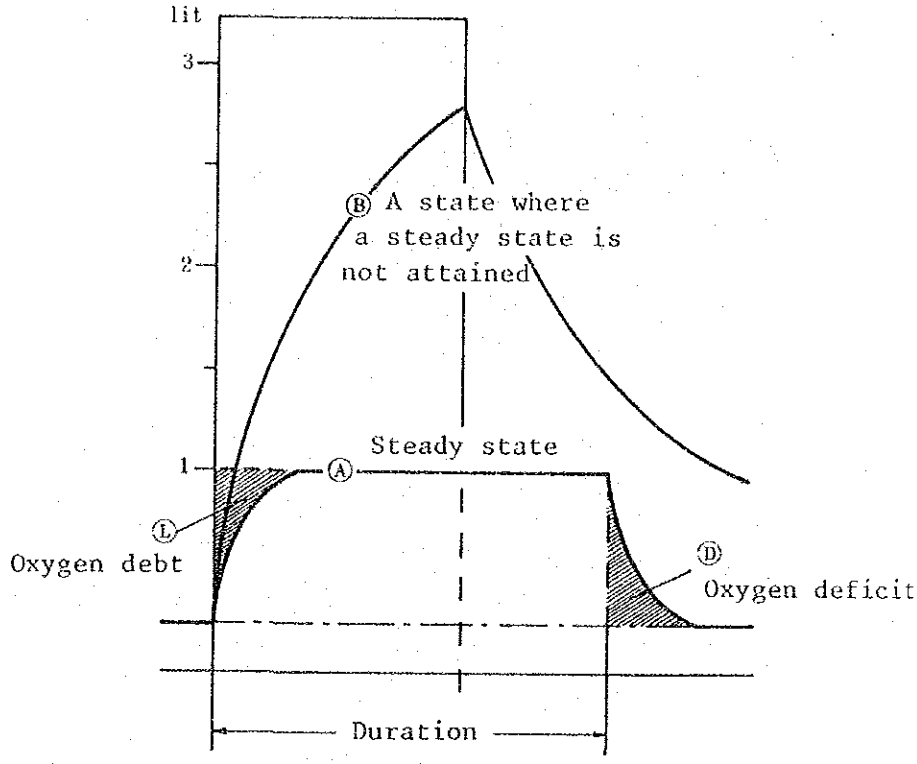


Fig. III-22 Change in the oxygen consumption corresponding to the work amount

A steady state is ually established in a light work, but it is hard to maintain in a hard work. Under a steady state, expired air can be collected at any time 3 - 5 minutes after starting work, and collection in the recovering stage is not necessary. In the case of steady state not established, the gas is collected from the state of the work, along with the expired air in the course of recovery.

(b) Determination the amount of expired air

Gas meter is used for measurement of the amount of expiration. The bag containing expired air collected is connected to the gas meter, and the amount of gas is measured by pressing the bag. Some amount of expired air is taken separately for gas analysis. The amount of gas measured by the gas meter is converted into one under standard conditions by multiplication of the following correction factor.

$$\text{Correction factor} = 273/(273 + t) \times (p - \text{saturated water vapor pressure at } t°C)/760$$

where p: Atmospheric pressure (corrected for t°C)

Refer to Tables III-27 and III-28 for correction of water vapor pressure and atmospheric pressure.

Table III-27 Saturated water vapor pressure for temperature

Temperature	Saturated water vapor pressure	Temperature	Saturated water vapor pressure	Temperature	Saturated water vapor pressure	Temperature	Saturated water vapor pressure	Temperature	Saturated water vapor pressure	Temperature	Saturated water vapor pressure
℃	mm/tg	℃	mm/tg	℃	mm/tg	℃	mm/tg	℃	mm/tg	℃	mm/tg
−20	0.94	−10	2.15	0	4.57	10	9.14	20	17.36	30	31.51
−19	1.03	− 9	2.33	1	4.91	11	9.77	21	18.47	31	33.37
−18	1.12	− 8	2.51	2	5.27	12	10.43	22	18.63	32	35.32
−17	1.22	− 7	2.72	3	5.66	13	11.14	23	20.86	33	37.37
−16	1.32	− 6	2.93	4	6.07	14	11.88	24	22.15	34	39.52
−15	1.44	− 5	3.16	5	6.51	15	12.67	25	23.52	35	41.78
−14	1.56	− 4	3.41	6	6.97	16	13.51	26	24.96	36	44.46
−13	1.69	− 3	3.67	7	7.47	17	14.40	27	26.47	37	46.65
−12	1.84	− 2	3.95	8	7.99	18	15.33	28	28.07	38	49.26
−11	1.99	− 1	4.25	9	8.55	19	16.32	29	29.74	39	52.20

Table III-28 Correction table of atmospheric pressure for temperature

Temperature	Atmospheric pressure			Temperature	Atmospheric pressure			Temperature	Atmospheric pressure		
	750	760	770		750	760	770		750	760	770
1	0.1	0.1	0.1	11	1.3	1.4	1.4	21	2.6	2.6	2.6
2	0.2	0.3	0.3	12	1.5	1.5	1.5	22	2.7	2.7	2.7
3	0.4	0.4	0.4	13	1.6	1.6	1.6	23	2.8	2.8	2.8
4	0.5	0.5	0.5	14	1.7	1.7	1.8	24	2.9	3.0	3.0
5	0.6	0.6	0.6	15	1.8	1.9	1.9	25	3.0	3.1	3.1
6	0.7	0.7	0.8	16	1.9	2.0	2.0	26	3.2	3.2	3.2
7	0.9	0.9	0.9	17	2.1	2.1	2.1	27	3.3	3.3	3.4
8	1.0	1.0	1.0	18	2.2	2.2	2.3	28	3.4	3.5	3.5
9	1.1	1.1	1.1	19	2.3	2.3	2.4	29	3.5	3.6	3.6
10	1.2	1.2	1.2	20	2.4	2.5	2.5	30	3.7	3.7	3.7

(c) Gas analysis for expired air

Concentrations of oxygen and carbon dioxide of expired air can easily be obtained by reading the indicators on the gas analyzer where the expired air collected in the sample gas is transferred. However, the amount of oxygen consumed in the body does not usually agree with the amount of carbon dioxide formed. On this account the concentration of oxygen in the inpired air is corrected referring to the nitrogen concentration in the atmosphere by the following equation:

$$\text{Oxygen concentration of inspired air (\%)} = 20.93 \text{ (atmospheric oxygen content)} \times (N_2\% \text{ in expired air}) / (79.04 (N_2\% \text{ in the atmosphere}))$$

③ Calculation of energy metabolism

The ratio of the amount of carbon dioxide exhausted to the amount of oxygen consumed is called respiratory quotient (R.Q.), and it assumes a certain value depending on the rate of carbohy-

drate, fat, and protein participating in the metabolism. Under usual conditions of metabolism, the ratios between the participating elements are practically unchanged, and a rough calculation of total calories is often made from the oxygen consumption and R.Q. The relationship between R.Q. and calorific value of oxygen consumed per liter is shown in Table III-29.

Table III-29 R.Q. and calorific value of oxygen consumed per liter

R.Q.	Calorific value of oxygen consumed	R.Q.	Calorific value of oxygen consumed
0.71	4.690	0.86	4.875
0.72	4.702	0.87	4.887
0.73	4.714	0.88	4.900
0.74	4.727	0.89	4.911
0.75	4.739	0.90	4.924
0.76	4.751	0.91	4.936
0.77	4.764	0.92	4.948
0.78	4.776	0.93	4.961
0.79	4.789	0.94	4.973
0.80	4.801	0.95	4.985
0.81	4.813	0.96	4.998
0.82	4.825	0.97	5.010
0.83	4.838	0.98	5.022
0.84	4.850	0.99	5.035
0.85	4.862	1.00	5.047

Example of calculation

Test by bicycle ergometer

Weight of subject : 64 kg

Expired air collecting time : 5 minutes

Amount of expired air : 90 liter

Correction factor of expired air : 0.87

CO_2 concentration in expired air : 3.7%

O_2 concentration in expired air : 16.7%

Correction for amount of expired air:

Amount of expired air = 90 ℓ × 0.87 = 78.3 ℓ

O_2 consumption, CO_2 formation

O_2 concentration in inspired air = 20.93 × (100 − (3.7 + 16.7))/79.04 = 21.08

O_2 consumption = (O_2 concentration in inspired air − O_2 concentration in expired air) × amount of expired air = 78.3 ℓ × (21.08 × 16.7)% = 3,430 ℓ

CO_2 formation = 78.3 ℓ × 3.7 % = 2.879 ℓ

R.Q. = 2.897 / 3,430 = 0.84

Table III-29 gives heat formation per liter of oxygen consumed: 4.85 kcal/liter (O_2) as R.Q. is 0.84.

Therefore,

Total heat formed = 4.85 × 3.430 = 16.63 kcal

For elimination of individual difference, the total heat formation is converted into kcal per unit time and expressed in the amount per unit body weight (kcal/hr/kg) or unit body surface area (kcal/hr/m^2) as explained above.

Example of calculation

Total heat formation per unit time per unit body weight in bicycle ergometer test.

$$\frac{\text{Total heat formation} \times \dfrac{60 \text{ minutes}}{\text{Expired air collecting time}}}{\text{Body weight}} =$$

$$\frac{16.63 \times \frac{60}{5}}{64} = 3.12 \text{ (kcal/hr/kg)}$$

(4) Measuring flicker value

① Significance

Light flickers when the source of light is turned on and off at a certain speed. However, the flickering disappears after the speed of on/off increases beyond a certain limit,

and the light looks as if it is lit continuously. This phenomenon is called fusion of flicker, and the frequency of on/off at the started fusion is called flicker value. Flicker value rises under work load, and the rate of rise is used as a measure of fatigue or work load.

② Measuring apparatus

For measurement of flicker value, two kinds of apparatus are used: one that of a sector system where the light from the source is interrupted by a sector and the other neon tube or light modulation tube is excited by an electronic oscillator. The measuring apparatus provided is of the latter type.

③ Measuring method and caution

(a) So-called top-down method is used whereby the measurement is started at an increased frequency of on/off where no flickering is observed and gradually dropping the frequency and find the number of on/off at the started flickering.

(b) The subject should be familiarized with the measurement, and exercise measurements of at least two or three times on the day before real determination are necessary.

(c) Three to five determinations in succession are necessary for every measurement, and average of the figures is obtained by discarding the values very much apart. A quick process of measurement is advisable.

(d) The environmental conditions and the directions to the subject shall be kept constant.

④ Characteristics of flicker value

Flicker value usually rises at the starting period of a certain work, but it begins to drop with time, and finally it takes a lower value at the end of work than one at the start. The extent of rise and drop depends on the amount of work load; a marked rise and drop in case of a heavy

load, and a little rise and drop in case of a light load. This makes us estimate the degree of work load by the change of flicker value. Fig. III-23 shows a schematic representation of such estimate, where a, b, and c are works of different load decreasing in the order.

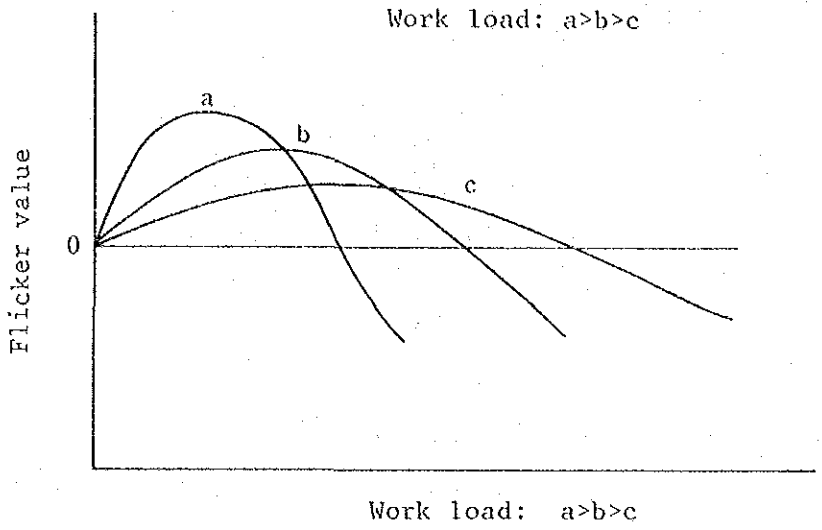


Fig. III-23 Change of flicker value for work load

Fig. III-24 shows flicker values for works in successive days. A, B, and C also show works of different load.

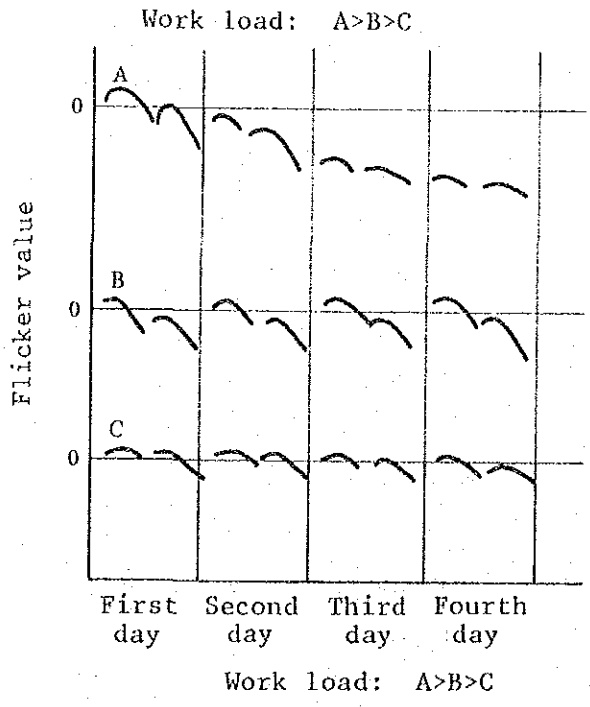


Fig. III-24 Daily change in Flicker values

In the case of work A of the heaviest load, the flicker value of pre-work drops day by day; and this can be regarded as the effect of the previous day when the work load is heavy. In such a case, the degree of load cannot be determined properly by a measurement on a single day.

⑤ Data processing and criteria

Generally speaking, analysis is made for:

(a) Time course variation of the rate of flicker value to pre-work value on the first day or

(b) Rate of variation or daily variation against value before work.

And the results are compared with those in other district or analysed for correlation with other functional examination to estimate the work load.

In addition, average values and mean squares of flicker value changing in time course are compared, and the causative factors for the drop of value are investigated for the case of remarkable drop. Anyway, flicker value shows dispersion by individual difference and others; and standardized values for the whole values of each subject are examined by statistical processing to find out whether the variation is significant or not.

Several patterns of time course change of flicker values during work are noticeable as shown in Fig. III-25.

Pattern A: This pattern appears in muscular or neural operation of a heavy load.

Pattern B: This pattern appears most generally in general operation.

Pattern C: This pattern appears in a monotonous operation.

Pattern A and pattern C are of a problem, because it is feared that an accident is caused by a diminished capacity for doing work.

Table III-30 shows a criteria for flicker value. Drop of the value by 5 % or larger to pre-work value is generally considered undesirable.

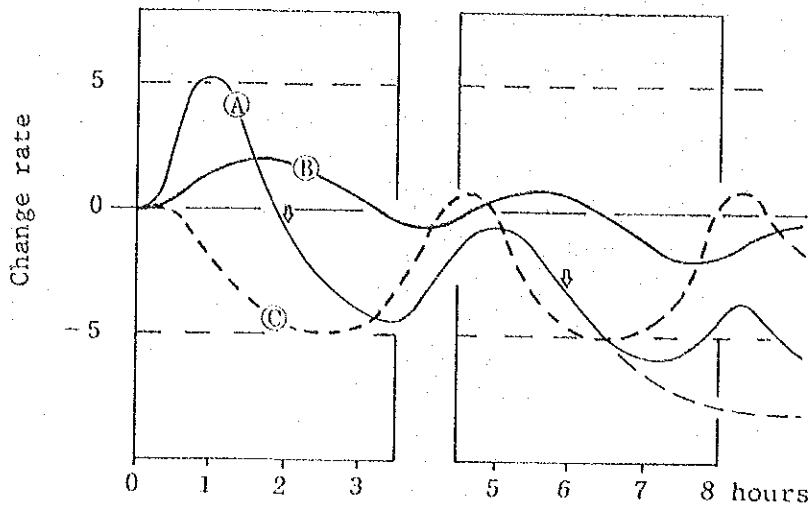


Fig. III-25 Pattern of the time course change in flicker values during work

Table III-30 Criteria for flicker value (Desirable limit of flicker value)

Category of labor	Drop rate of flicker value on first day	Weekly drop rate of pre-work flicker value
Physical labor	- 10 %	- 3 %
Moderate labor	- 7	- 3
Brain work	- 5	- 3

⑥ Example of flicker value investigation

(a) Outline of investigation

The same persons were investigated as subject on the same place of work by the same investigator as in the investigation of heart rate.

ⓐ Method of investigation

Flicker value was measured before starting work (9:00),

before lunch (12:00), after noon recess (13:00), and after work (16:00) for each subject. For observation of change of flicker values, it is necessary to measure every one or two hours; but the measurement was limited as above by operational reasons.

(b) Result of investigation

The results of flicker value measurements are shown in Fig. III-26 and Fig. III-27 for choker setting operation and tractor operation respectively.

ⓐ Choker setting

A drop in flicker value after work is noticeable every day. The drop is especially remarkable on the second day and third day, showing that the degree of fatigue is considerably high. As has been explained, a drop of 10% is considered as the limit of desirable drop. More detailed investigation by measurement every one or two hours is necessary in order to find out the pattern of hourly variation of flicker values. A tendency of daily drop in the pre-work values was not necessarily noticeable on successive days; and the effect of fatigue overnight was not apparent, although the work load was heavy.

ⓑ Tractor operation

The drop in flicker value after finished tractor operation is not very large every day, and this shows that the work load is not very heavy. No remarkable change was recognized either in the pre-work values on succes successive days, showing that there was no problem.

ⓒ Rate of change of flicker values

Flicker values often vary with the individual worker or working day. This is due to a different level of excitement. Therefore, it is necessary for a more strict examination to use practically the rate of variation of flicker values instead of the values themselves.

i) Variation of pre-work values on successive days.

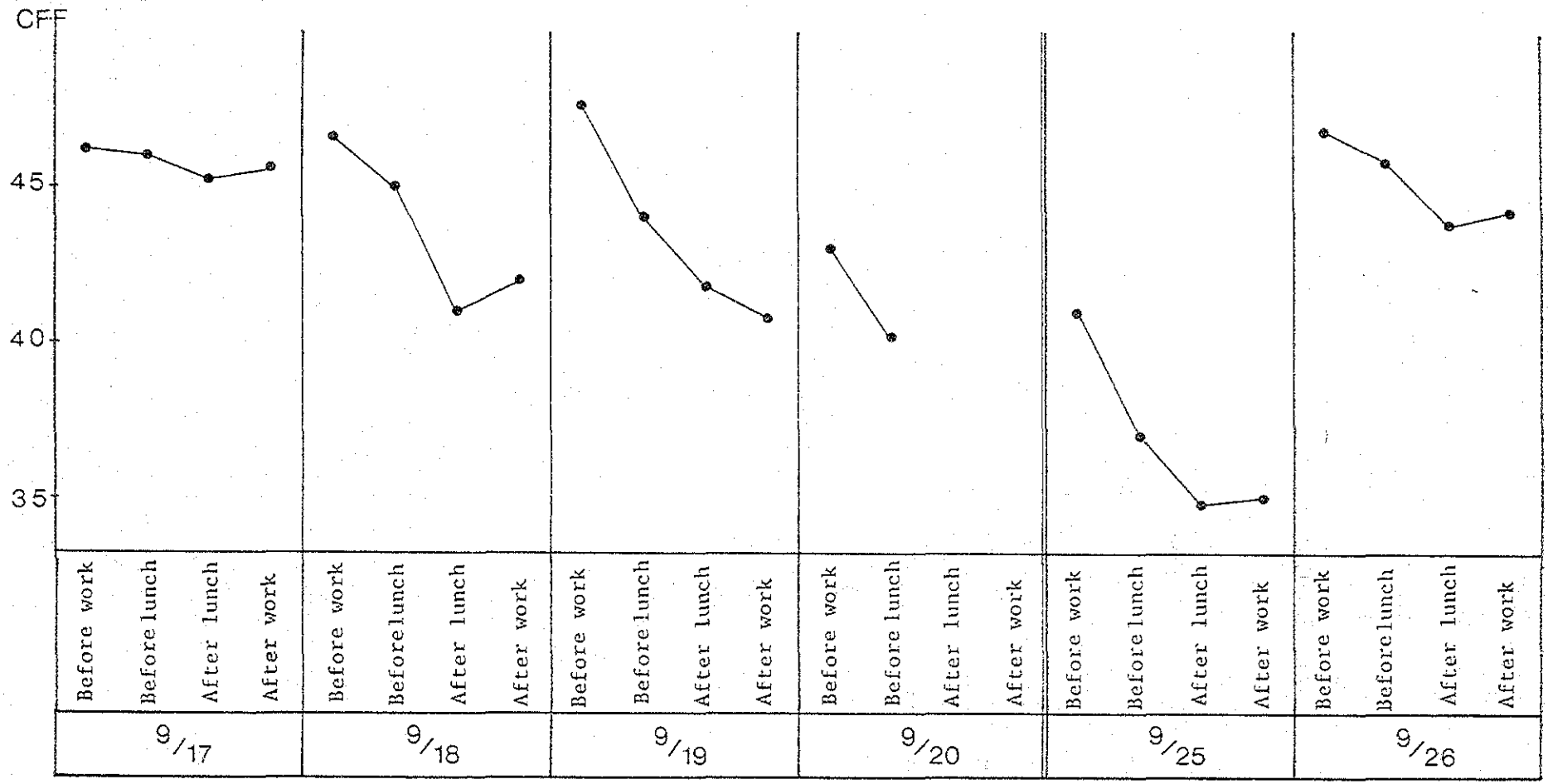


Fig. III-26 Daily change in flicker values due to the work
(Choker setter)

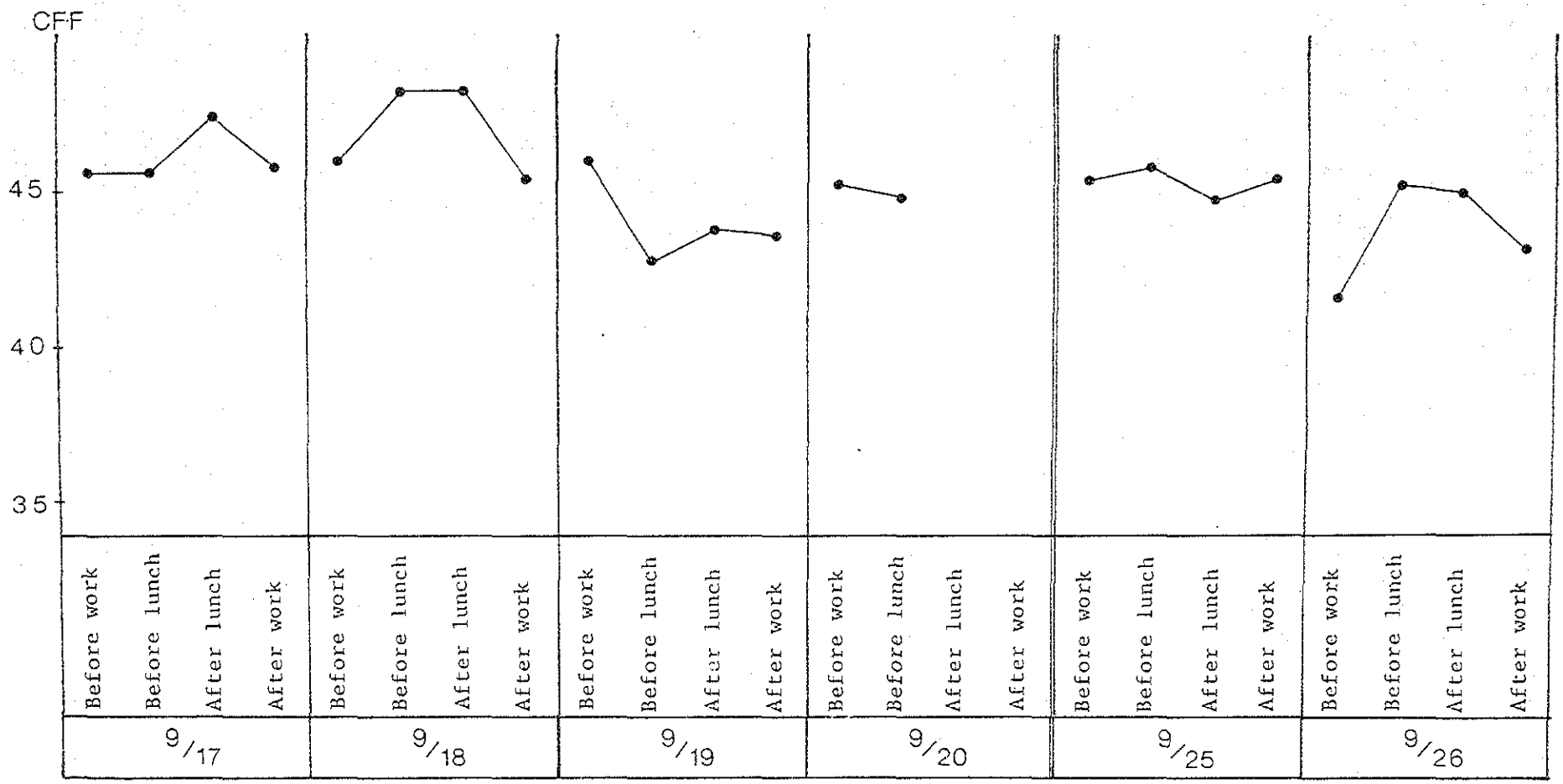


Fig. III-27 Daily change in flicker values due to the work
(Tractor operator)