LOGGING INDUSTRY RESEARCH ASSOCIATION

NEW ZEALAND

PROJECT REPORT

"ERGONOMICS — A SCIENCE TO IMPROVE THE SAFETY AND PRODUCTIVITY OF LOGGING WORKERS"

P.R.30 1986

N.Z. LOGGING INDUSTRY RESEARCH ASSOCIATION (INC.)

P.O. Box 147 Rotorua New Zealand

New Zealand Logging Industry Research
Association (Inc.)
P.O. Box 147
Rotorua
NEW ZEALAND

"ERGONOMICS - A SCIENCE TO IMPROVE THE SAFETY AND PRODUCTIVITY OF LOGGING WORKERS"

P.R. 30 1986

Prepared By :

J. Gaskin
N.Z. Logging Industry Research
Association (Inc.)

November 1986

For information address the N.Z. Logging Industry Research Association (Inc.), P.O. Box 147, Rotorua, New Zealand.

SUMMARY

During 1985 the author spent five months working with Arbetarskyddsstryelsen, (The Swedish Board of Occupational Safety and Health) in Stockholm, Sweden. The broad objective of that study period was to investigate ergonomic research currently being practiced by that organisation, with particular reference to logging, with the view to draughting a programme of such research suitable to the New Zealand logging industry. The following report summarises that work.

The report is divided into three parts.

Part I introduces the subject of Ergonomics and its relevance to the logging industry. The theory is illustrated by examples taken from the Swedish and New Zealand logging industries.

The major points to emerge are that Ergonomic applications, as indicated by the Swedish experience, increase the effectiveness and efficiency of the logging industry.

Part II examines some of the Ergonomics research that has been carried out in New Zealand so far. It is pointed out that we have not done as much in the field of Ergonomics as other countries. A major reason may be the fact that other countries, especially in Europe, have incorporated the use of Ergonomics in their legislation. In addition New Zealand is one of a few countries that has yet to ratify the Occupational Hygiene and Safety Convention 1981 (ILO Convention 155) that stresses the application of Ergonomic principles.

Part III contains a proposal for Ergonomics research. The proposal assumes that the N.Z. logging industry cannot fund Ergonomics research at the level seen in Sweden. Nonetheless, given these limitations, the proposals if implemented will go a long way towards increasing production in the industry and provide a healthier and safer environment for the workers.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

PART I

ERGONOMICS

INTRODUCTION

Ergonomics is the scientific study of the relationship between man and his working environment. Environment in this sense includes tools and materials, methods of work, organisation of work, as well as the ambient environment, either as an individual or within a working group. A number of scientific disciplines and technologies contribute to ergonomics.

Anatomy and Physiology - structure and function of the body
Biomechanics - body size, how man moves
Experimental psychology - information processing, decision making
Occupational psychology -man's relation with his fellow workers, supervisors etc
Engineering - design of machines, layouts, work station designs

As well as those disciplines, occupational psychology plays an important part in solving some problems in ergonomics, man's relations with his fellow workers, supervisors, management and his personal life. The use of behavioural science techniques for example has been most effectively used in encouraging the use of techniques and equipment.

Ergonomics then should increase the efficiency of human activity by providing data which will enable informed decisions to be made. It should enable the cost to the individual to be minimised, in particular by removing those features of design which are likely in the long term to cause inefficiency or physical disability. By its activities it should create an awareness in industry of the importance of considering human factors when planning work.

As part of a proposed "Handbook in Ergonomics for Forestry and Forest Industries in Developing Countries", L. Bostrand has developed a structured model for Ergonomic Problems in Forestry Work.

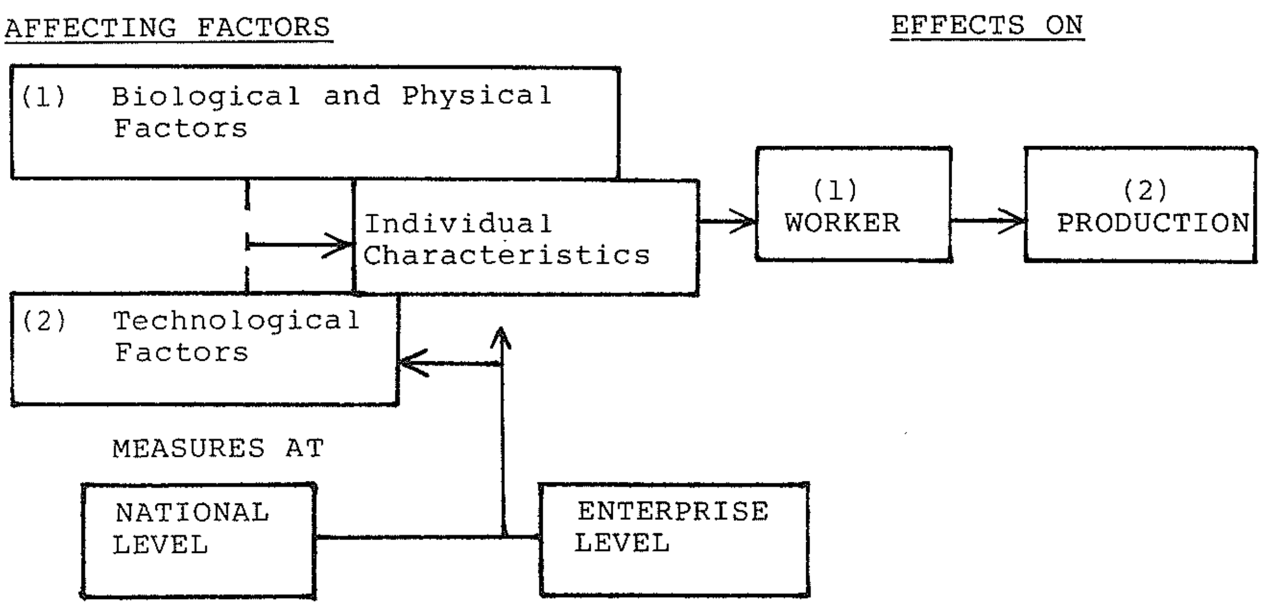


Figure 1 - Structured model for Ergonomic problems in forestry work. (After Bostrand 1985 in press.)

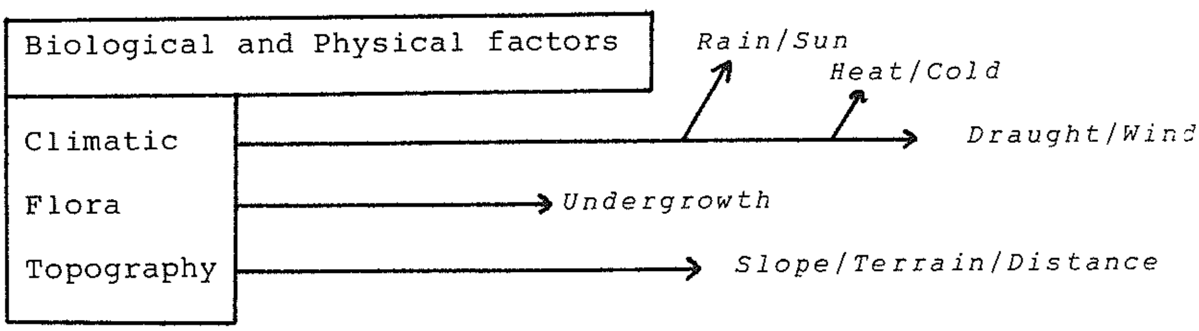
The first section of this report uses that model to describe the basics of ergonomics. Wherever possible examples given are for New Zealand conditions. The objective of this overview of ergonomics is simplicity, so therefore, much of the technical detail has been omitted and descriptions are kept as brief as possible. Although the model was designed for all aspects of forestry work, only forest harvesting operations have been considered.

AFFECTING FACTORS

1. Biological and Physical Factors

The biological and physical factors which exist within forest harvesting operations are as follows :

TABLE 1 : Biological and Physical Factors



They all have in common the fact that man can do little to directly influence or change them.

1.1 **Climatic** - All those employed in logging are to some extent exposed to the elements. Such things as rain, cold, direct sunlight, and wind all effect the loggers' ability to perform. Excesses of heat or cold can have a physiological effect on the worker as well as being uncomfortable. The other factors mentioned mainly effect morale and motivation of workers.

1.2 **Flora** - A factor not often thought of as something that could affect the working environment, but working in high blackberry or heavy gorse undergrowth is hardly conducive to the best levels of efficiency. Heavy undergrowth could also effect the dispersion of exhaust emissions of chainsaws, and could lead to the operators being subjected to dangerously high levels of carbon monoxide and/or formaldehyde.

1.3 **Topography** - Adverse slope places heavy strain on loggers by increasing the work load involved in whatever task they are performing. The risk of slipping and falling is also increased with increased slope.

Although it has been stated that little can be done to directly change these factors, much can be done to reduce the effect of them. Examples are: providing good rainwear, shelter from direct sunlight, crushing the undergrowth in stands prior to the commencement of logging and providing good footwear to reduce slippage in the case of people working on steep country. It is important that managers of logging operations are aware of these factors and that they will affect the efficiency of their workers.

2. Technological Factors

These include items such as machines, tools, materials, methods, techniques, organisation and management (Table 2). All these factors have in common the fact that they are man-made and can therefore be more easily changed when found defective or in need of improvement. They perform many different functions and produce numerous damaging effects. Considerable research and development has already taken place to improve or reduce the damage they may have on man. Types of effects and means of studying these effects are presented in this section.

TABLE 2 : Technological Factors

Technological Factors	⟹	
Machines		Noise, vibration
Tools		Gas, smoke, dust
Equipment		Visibility, lighting
Materials		Ventilation, draught
Methods		Design, function
Techniques		Workload, work place
Organisation		Rest periods, schedules
Management		Supervision

2.1.1 Noise

All those employed in forest harvesting operations are exposed to noise levels which are considered damaging. Some, such as chainsaw operators and in some cases machine operators, are exposed to levels which far exceed the International Standard of 85 dB.

Damage to hearing results from strong and repeated stimulation from noise. That damage is only temporary at first but after being "deafened" repeatedly, some permanent damage may occur. This is called noise deafness and is brought about by a slow but progressive degeneration of the sound sensitive cells of the inner ear. The louder the noise and the more often it is repeated the greater the damage to hearing.

Numerous pieces of equipment are available to reduce the noise to an acceptable level, i.e. helmets equipped with integral earmuffs, separate earmuffs, or ear plugs. The problem in the past has been how workers can be convinced to use hearing protection. Because hearing loss is such a slow process and irreversible, it's difficult to convince people at an early stage that they should be wearing such equipment. Two options to achieve this are; (1) the use of feedback to operators concerning damage being done to themselves, and (2) the use of legislation that makes it compulsory for workers, in a high risk area, to wear such equipment. The use of legislation, while often being the more concrete method, can result in a resentment by the worker to his immediate superior. The first technique, information feedback, encourages the operator to change because he wants to. Zoher et al (1980) compared these two techniques; figure 2 illustrates their findings. The study was conducted in a metal fabrication plant.

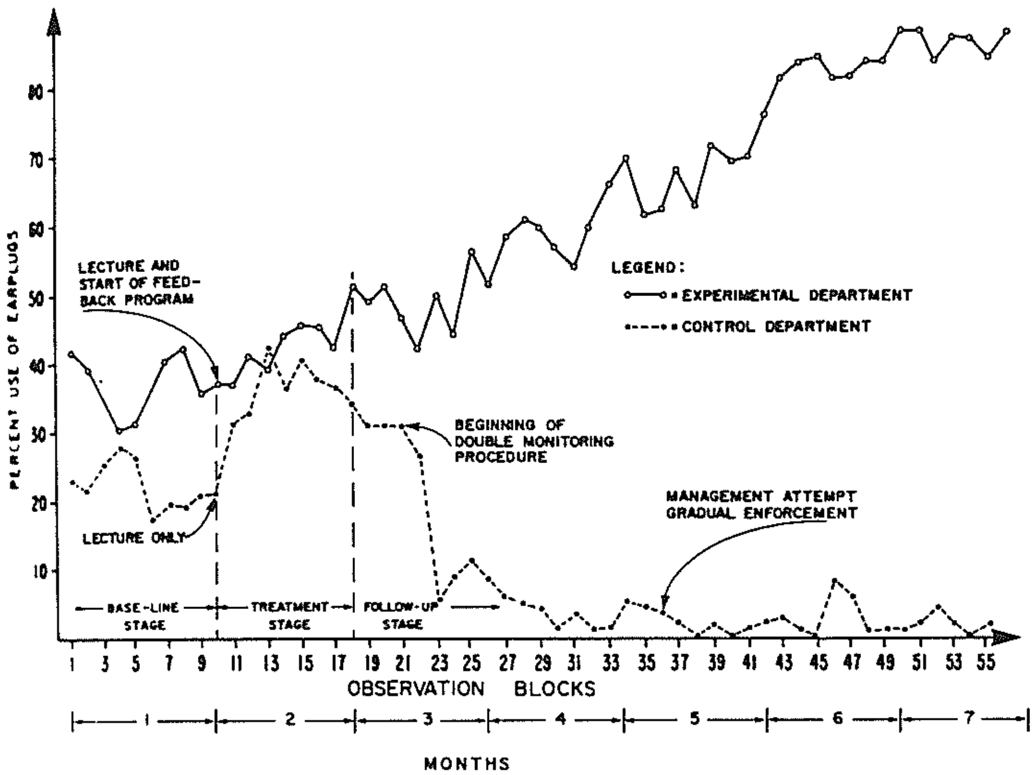


Figure 2 - Percentages of workers observed to be wearing earplugs in the experimental and control department during the baseline, treatment (feedback), and follow-up states of the study. Each plotted percentage point represents the average of three samples tours conducted on three consecutive days. (After Zoher et al 1980)

2.1.2 Vibration

In the logging industry there are two types of damaging vibration; hand/arm and whole body. Hand/arm vibration is that experienced by chainsaw operators, which can result in the disease commonly called "white finger". Whole body vibration effects machine operators. Less is known of the prolonged medical effects of the whole body vibration. Griffin, compiled a list of symptoms caused by whole body vibration. He paid no attention to the quality of the studies and concerned himself only with the conclusions reached. The following list is what resulted :

Back problems - degeneration of spinal vertebrae
- herniated disc
- osteoarthritis etc

Abdominal pain
Digestive problems
Urinary frequency
Prostatitis
Hermorrhoids
Balance
Vision
Headaches
Sleepiness

He reasoned that if many complaints were experienced often (over fifty epidemilogical studies concerned with health and whole body vibration), the phenomenon must be causing some damage.

Hand/Arm Vibration

The severity of hand transmitted vibration in working conditions is influenced by many factors :

(a) the frequency spectrum of vibration
(b) the magnitude of vibration
(c) the duration of exposure per working day and the total exposure time
(d) the temporal exposure pattern and working method (length and frequency of work and rest spells)
(e) the magnitude and direction of forces applied by the operator through his hands
(f) the posture of the hand, arm and body positions during exposure
(g) the type and condition of vibrating machinery
(h) the area and location of the parts of the hands which are exposed to vibration

The severity of biological effects of hand transmitted vibration in working conditions may be influenced by :

(a) the direction of the vibration transmitted to the hand
(b) the method of working and the operators skill
(c) any predisposing factors in the individuals health

The following factors may specifically affect the circulation changes caused by hand/arm vibration :

(a) climatic conditions
(b) diseases which affect the circulation
(c) agents affecting the peripheral circulation, such as smoking
(d) noise

Measurement of Hand/Arm Vibration

Hand/arm vibration measuring equipment generally consists of a transducer, an amplifying device and amplitude indicator or recorder. Measurements are taken for three axis; X, Y, Z. The directions of these three are illustrated in the adjacent figure.

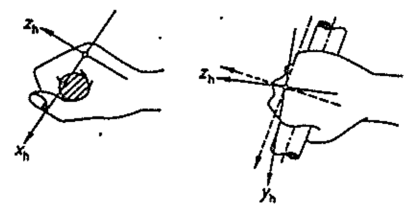


Figure 3 - X,Y,Z, axis directions for measurement of hand/arm vibration

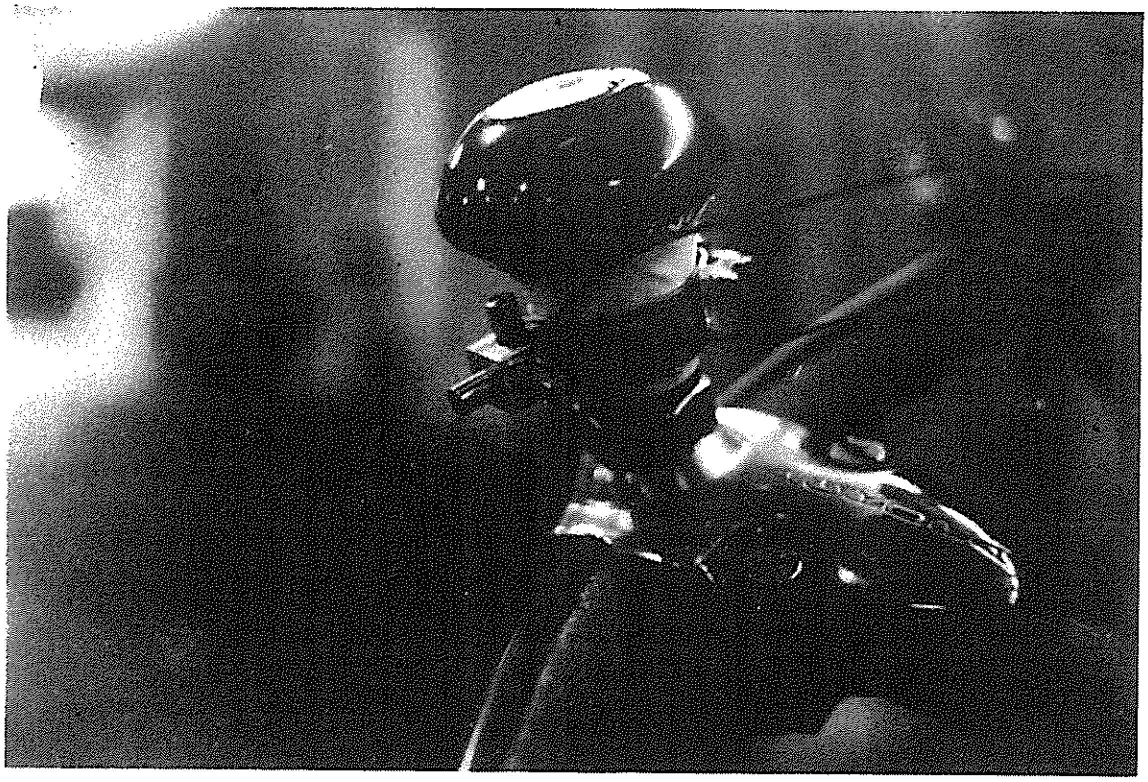


Figure 4 - Accelerometers (transducers) attached to steering knob on a forklift truck to measure hand/arm vibration transmitted through steering knob

If more accurate spectrum analysis is required then the signal must be recorded through an amplifier onto FM tape. Subsequent analysis of such a signal is quite complicated and requires sophisticated expensive equipment.

Examples of data sheets and data analysis from hand/arm vibration studies are presented in Appendix 1(a), hand/arm vibration calculation forms.

Whole Body Vibration

As previously stated less is known about the effects of whole body vibration and, although there is an international standard (Appendix 1(b)), there is still considerable debate about the maximum levels attained. (Kjellberg & Wikstrom, 1983).

Considerable research has been undertaken on measuring whole body vibration. The above mentioned authors suggested the five following variables as being of major importance when evaluating whole body vibration :

(1) intensity
(2) variation with time
(3) frequency
(4) direction
(5) duration

Measurement of Whole Body Vibration

The basic equipment requirements are similar to those of hand/arm vibration measurement. The accelerometer type used for whole body vibration measurement of forestry equipment, say a skidder, is typically a triaxial seat accelerometer. This has been specially designed for whole body vibration and is intended to be positioned under the buttocks of a seated person.

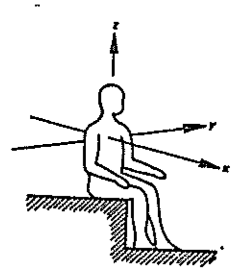


Figure 5 - X,Y,Z axis directions for measurement of whole body vibration

It contains a triaxial pickup, able to detect vibration in three mutually perpendicular directions, that is, vertically (Z axis) buttocks to head, transerve (Y axis) right to left, and (X axis) back to chest.

Figure 6 - Whole body vibration recording equipment. Consists of two triaxle seat accelerometer, FM 4 channel tape recorder, B & K whole body vibration recorder.

In studies of truck drivers, the Y axis is of little interest. However in forest machinery operation, the Y axis becomes very interesting because there is often considerable sideways movement during the operation.

2.2 GAS

Those employed in the harvesting industry are all exposed to exhaust fumes to some extent, be it from chainsaws or logging machines. The two worst situations are (1) operating a chainsaw in heavy undergrowth in still conditions, and (2) operating a machine that has a faulty exhaust system, say a leak at the manifold. The gases given off which are particularly dangerous are Carbon-monoxide and Formaldehyde. Carbon-monoxide causes a person to feel ill and thereby, can severely limit their working effectiveness. Formaldehyde is irritating to the eyes and therefore will cause varying degrees of discomfort.

Limits of carbon-monoxide and formaldehyde have been set in Sweden (Hansson and Pettersson, 1980), at 35 parts per million (PPM), mean value over an eight hour working day for carbon-monoxide, and 1 part per million (PPM) time - averaged limited, (i.e. maximum permissible mean concentration over a 15 minute period), for formaldehyde.

2.3 VISIBILITY AND LIGHTING

Because very few operations in New Zealand are double shifted, or for that matter are often in a situation where lighting is required, only a brief treatment will be given to this subject. Visibility, on the other hand, is one aspect which is very important to any machine operator. In fact it should be one of the essential factors in deciding on what machinery to purchase. Both of these aspects can have an effect on efficiency, safety, fatigue, work postures etc.

2.3.1 Visibility

Poor visibility increases the likelihood of the operator being forced to adopt uncomfortable and tiring positions. Take the example of a skidder operator trying to blade the extraction track, often he has to lean to one side or the other or even partially stand to adequately see what he is doing. That results in extremely poor working posture, which, is often made worse if he hits a stump during this activity and is thrown with some force back into the seat. Such an occurrence could well result in serious damage to the spine. Another example is when the loader driver is manoeuvring on the skids. Frequently he operates the machine at some speed. While reversing he either has to twist in his seat (poor posture), or trust that others on the skid know what he is going to do (not a safe technique).

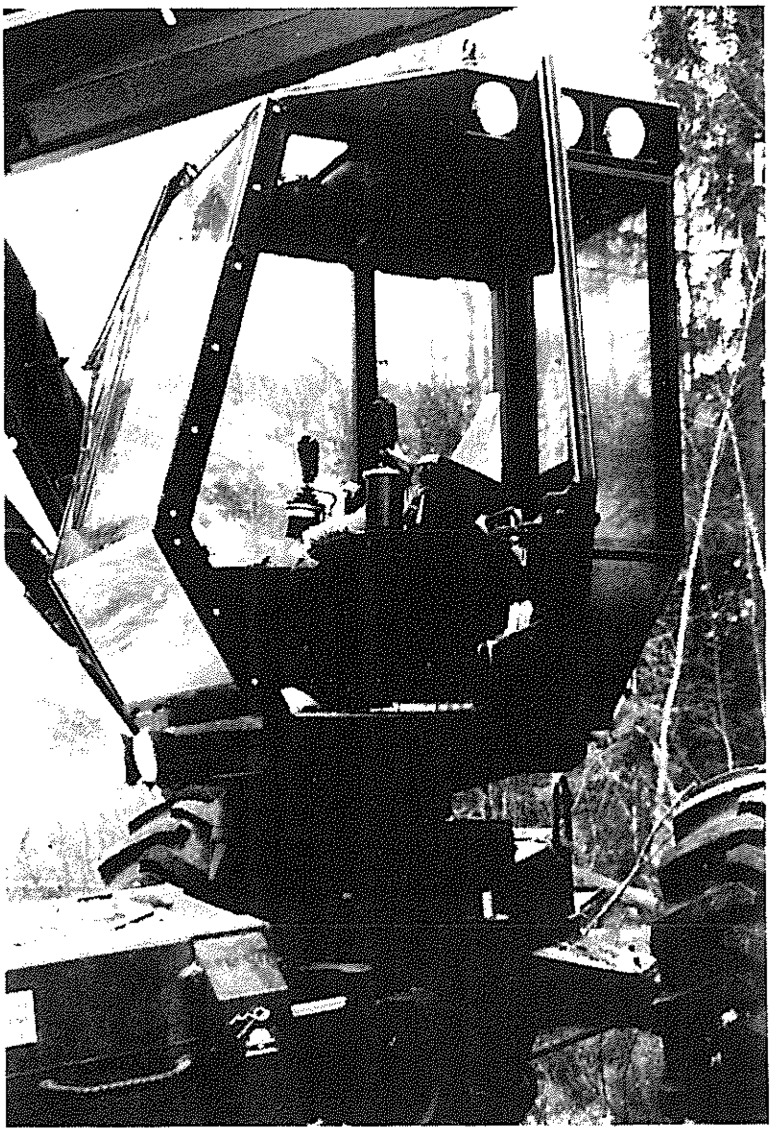


Fig. 7 - Valmet one grip harvester, excellent visibility and lighting built into machine

Visibility should be judged from the point of view of the operator when seated comfortably in his seat. Unfortunately not all operators are the same size so it is essential to take this into consideration. The operator's view of the ground should be assessed and his field of vision should be assessed in relation to the operation to be carried out. An easy way to do this is to have the operator seated and then move around the machine with him telling you when he can see your feet. It is recommended, (Hansson and Pettersson, 1980), that there should be a clear all-round view of the ground starting no further than 5 metres from the seated position. In skidders oneof the worst areas is visibility to the rear, essential while winching in a drag. To achieve any sort of visibility the operator is forced to adopt an extremely bad twisted posture.

2.3.2 Lighting

J-E. Hansson and B. Pettersson (1980), suggest that the lighting provided should be sufficient for the operator to clearly see all that he needs to without difficulty. In other words the appropriate lighting should provide sufficient and relatively even lumination throughout the field of vision. This can usually be achieved through a good lighting system that is sufficiently powerful and evenly distributed over the operating area. If a skidder was used at night then the two areas of concern for illumination would be: forward of the machine, for travel in and out of the forest, and to the rear, for manoeuvring in the bush and also at the skids. On the other hand, if a self loading truck was used at night then the illumination would need to be 360° as the crane is often operating through such a field.

2.4 VENTILATION AND DRAUGHT

In section 2.2 (Gas), the problem of gases and the effects they have on a worker was briefly discussed. That problem is greatly reduced in conditions where there is some breeze. Fortunately most work places in New Zealand logging industry have good air ventilation. If and when however we start using machines with fully enclosed cabs then there are some pertinent points that should be assessed. If the machine has a climate control system, the air should be evenly circulated through the cab. Air, be it hot or cold, should not be directed onto the operator, but rather the air vents should be moveable so that air can be directed away from the operator.

Ventilation in most forest machines in New Zealand is currently regulated by two things: (1) the speed at which the machine travels and (2) wind speed (i.e. "through flow ventilation"). One of the worst examples which can be found was a conversion of a skidder to a forwarder (figure 8). In that particular machine the hydraulic valve bank and most of the hydraulic hoses were inside the cab with the operator. Apart from the interior of the cab resembling a sauna during summer, the operator

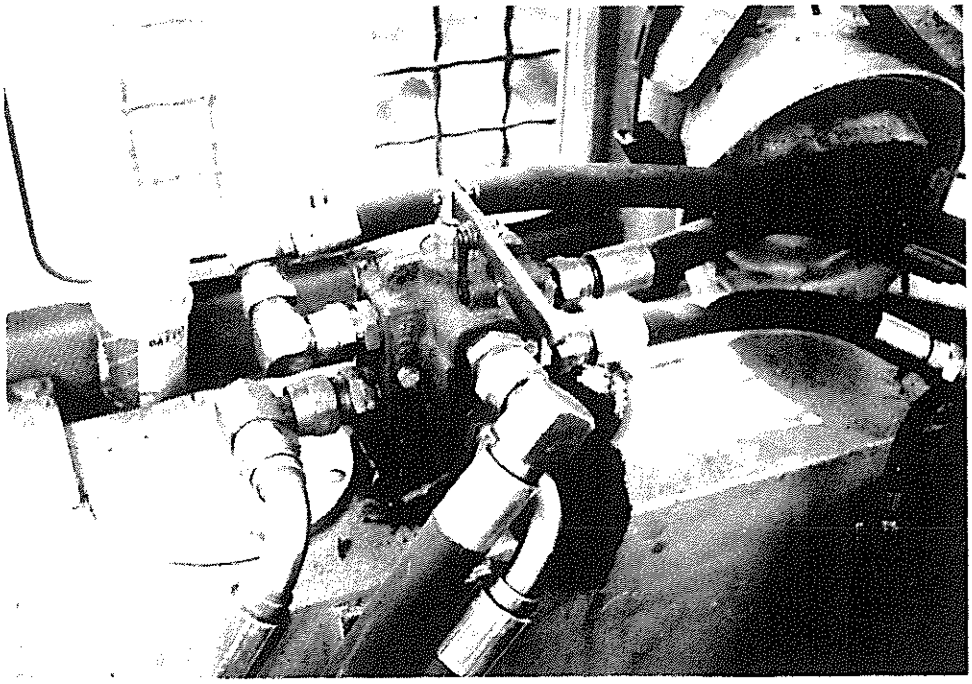


Fig 8 - Forwarder conversion, hydraulic hoses and valve bank inside cab, little consideration given to operators cab micro climate.

was placed at considerable risk if one of the hoses burst.

Much could be done to improve the environment within the operating area of the machines used for harvesting in New Zealand. Such improvements would result in increased productivity while lowering the risk of injury.

2.5 DESIGN AND FUNCTION

Considerable research effort has been concentrated on the design and functions of tools, machines, and even the workplace itself. That research has been based on well founded studies and designed to improve the efficiency, health and therefore productivity of the logger. In logging there are basically three main areas where this research has been directed: improving the chainsaw, improving machinery, and better design of safety clothing.

2.5.1 Chainsaws

The chainsaws in use today are much improved over those used 20 or 30 years ago. Some of the improvements which are now standard on many of the better designed professional saws are :

(a) Better overall design of the body of the saw to give better balance and easier use. Examples of this are the use of plastics in components to reduce weight, saw bodies designed so they can be easily manoeuvred during felling and delimbing operations, and smooth surfaces (no protrusions to catch on clothing or other obstacles during operation).

(b) Vast improvements to vibration damping. As mentioned in section 2.1.2, vibration is the main contributor to white finger. The Swedish manufactured chainsaws for example are well tested for vibration levels before production of a saw model commences. Improvements to vibration levels have been made through good isolation of the motor unit from the handles via rubber mounts, (more recently this aspect has been further improved through using springs), increasing the R.P.M. of the motor which helps to reduce vibration severity, and the introduction of heated handles. While the latter does nothing to reduce vibration, it keeps the operators hands warm and improves circulation. Even in New Zealand, heated handles, especially those controlled by the operator, are a good idea. We may not have snow but try working in an 8°C frost first thing in the morning.

(c) Improved and more numerous safety factors. Most of the better saws now include as standard a chainbrake of some description which stops the chain's rotation in the event of a kickback. Work is still continuing on these and the latest is the inertia chainbrake which, it is claimed, never needs servicing. Chain catchers prevent or reduce the risk of the operator being cut if the chain is thrown. Throttle locks mean the saw cannot be operated unless held correctly.

(d) Reduction in noise levels. Although these exceed the current ISO standard of 85 dB, the level is much lower than it was.

It is most important that these features are maintained in the same condition as when purchased new. For example there is little use having vibration isolating facilities if the rubber mounts, important to that feature, aren't repaired immediately when they become defective.

As well as the preproduction testing carried out in the factory, numerous other groups also test chainsaws. Examples of two such testing organisations are shown in Appendices 2(a) and 2(b). The organisations are; one from New Zealand - N.Z.F.S., (results published as LIRA reports), and Statens Maskingprovningar, Sweden.

Numerous international standards exist which cover chainsaws. Two already mentioned are for vibration levels and noise levels. Two others are a standard for kickback risk, which covers a general test method, and chainsaw design standard, which is a minimum standard required in the design of chainsaws. A point worth noting is that many countries have their own standards which might vary from the international standard only slightly. This means that chainsaw manufacturers have to conform to all these standards as well. The international standard is drawn up by a committee with representatives from most Western countries and should be sufficient without each country making their own standard.

2.5.2 Forest Machines

Considerable improvements again have been made in the design and function of forest harvesting machinery. The world leaders in this field, Sweden, build machinery which is now extremely well designed to ensure operator comfort and therefore efficient operation. Unfortunately other machinery manufacturers have been slower to adapt many of the concepts currently standard in Swedish logging machinery. For example, buyers will sacrifice operator comfort in the belief that they will save money. In the short term this is no doubt true, but what is the use of spending time and money training a machine operator and then putting that investment at risk by giving him machinery to operate which is not the best. For example, how much will it cost in terms of production loss when he is ill for weeks with a spinal injury induced by the buyer opting for a cheaper option.

Hansson and Pattersson (1980) list the following features that should be considered when purchasing a machine. These considerations had been written specifically for Swedish forestry machines which include forwarders, harvesters, etc. Some liberty has been taken in modifying their recommendations to be more applicable to machines used in New Zealand, namely skidders.

(a) Mounting and alighting - a convenient and safe means of access to and from the cab, is especially important in jobs where the operator is on and off the machine frequently - such as a skidder operator who does his own breaking out. Adequate handholds should also be in place. The maximum height that the step should be above the ground is 40 cm.

(b) Operators working position - to avoid undue strain on the operator the design of the cab must allow the operator to work in a comfortable position, i.e. the use of limbs and muscles should not cause any discomfort. Positions, such as where the operator has to twist around, must be avoided. Think of how often a skidder operator is twisted and consider the load being placed on his spine. The operator should be able to change his position from time to time. Operators of varying shapes and sizes should be able to be comfortably accommodated, therefore movement up and down, and back and forwards, of the seat is essential.

(c) Operator's cab - the operator's cab should be large enough for a well built operator to attain a comfortable working position. There should be no protruding parts that could injure the operator or hinder his entry or exit, especially the latter, in an emergency. To meet such requirements the cab should be at least 90 cm wide for machines that are operated in one direction, such as skidders. If the machine is operated from both directions for say an equal amount of time then the cab must provide sufficent room for the operator to rotate the seat comfortably, say a minimum width of 100 cm. Note - increased width of cab size will have an effect on visibility; discussed in Section 2.3.1.

(d) Operator's seat - most of the operator's day is spent in the seat. For skidders travel empty and travel loaded can account for as much as 60% of the time, and yet in many machines it is the part that least attention has been paid to. Some prerequisites of a good seating arrangement are that the seat should be securely anchored, the height and depth of the seat should be easy to adjust, it should be possible to adjust the seat cushion and backrest independently, and it should have some suspension and damping which can be adjusted to suit different body weights.

(e) Controls - those that are used frequently, such as steering, winch, gear shift and blade, or which effect safety, such as emergency stop, brake and parking brake, should be positioned well within the convenient working areas. No part of the range of lever movement should fall outside the area of convenient hand movement.

The design of controls should be such that the operator can obtain a secure grip on them. Their arrangement and coding should eliminate the risk of confusion and the wrong control being operated inadvertently, i.e. don't have them so close together that the largest handed operator wearing gloves operates two at once.

(f) Instrumentation - instrumentation and acoustic signals should provide the operator with all necessary information, but not unnecessary information. Design and arrangement should enable all the important ones to be monitored at a glance.

Preferably the dial should have light figures on a dark background and graduations should be in two or five unit increments.

(g) Maintenance - the machine illustrated in figure 9 shows an ideal or very good system for "exposing" the machine for maintenance. The engine cover is balanced so that it can be pulled back easily, the cab is tilted by a hydraulic jack and the jack handle is used to raise the spring loaded belly pan.

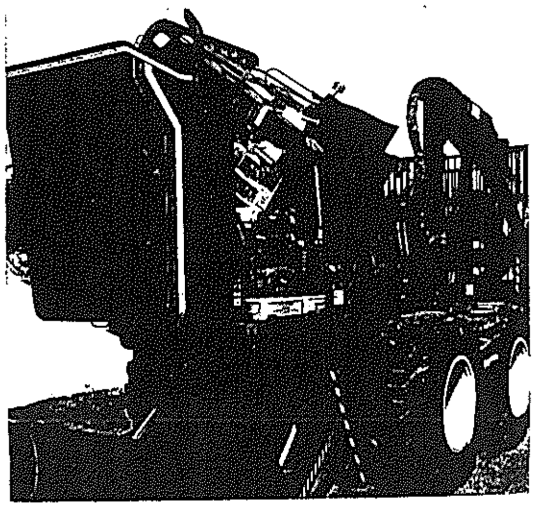


Fig 9 - Example of thought given by machinery manufacturer to maintenance access.

Other important features are where daily greasing has to be done, access to grease points should be easy and if, for any reason, the operator has to stand on the machine to reach any of these, non slip surfaces should be placed there to prevent possible accidents.

2.5.3 Safety Equipment or Personal Equipment

This section can further be divided into two separate categories; personal safety equipment and accessories to make the work easier. Developments in these areas have been mainly aimed at motor manual operations :

"Is this a dangerous tool?" (referring to chainsaw). "Maybe so. The chain is completely uncovered, still the

> faller carries the chainsaw around in an environment where ordinary people can hardly walk without falling. Suggest another industry where that would be allowed!"

2.4.3.1 Protective Clothing

From a statement like the above then it is not surprising that suitable personal productive equipment has been and is being developed. It is important to remember that this equipment doesn't necessarily stop the accident but may reduce the severity. The types of safety equipment commonly available are helmet, earmuffs or ear protectors, visors, either as separate pieces or as a combination, (the requirements of ear protectors has already been explained in 2.1.1), the need for a helmet is self-explanatory. Trousers or chaps with built in cut resistant material are now readily available. Of the two options, trousers are by far the best.

Many other examples of clothing exist, such as gloves to reduce the damage done to the hands. Boots are now being made lighter and more durable. An example of this is the use of wood in the bottom of a popular brand of boot in Europe which results in better shape being retained longer. Signal blouses or high visibility jerkins serve the purpose of making it easier for the faller to be seen and for fallers to be able to see where their mate might be working.

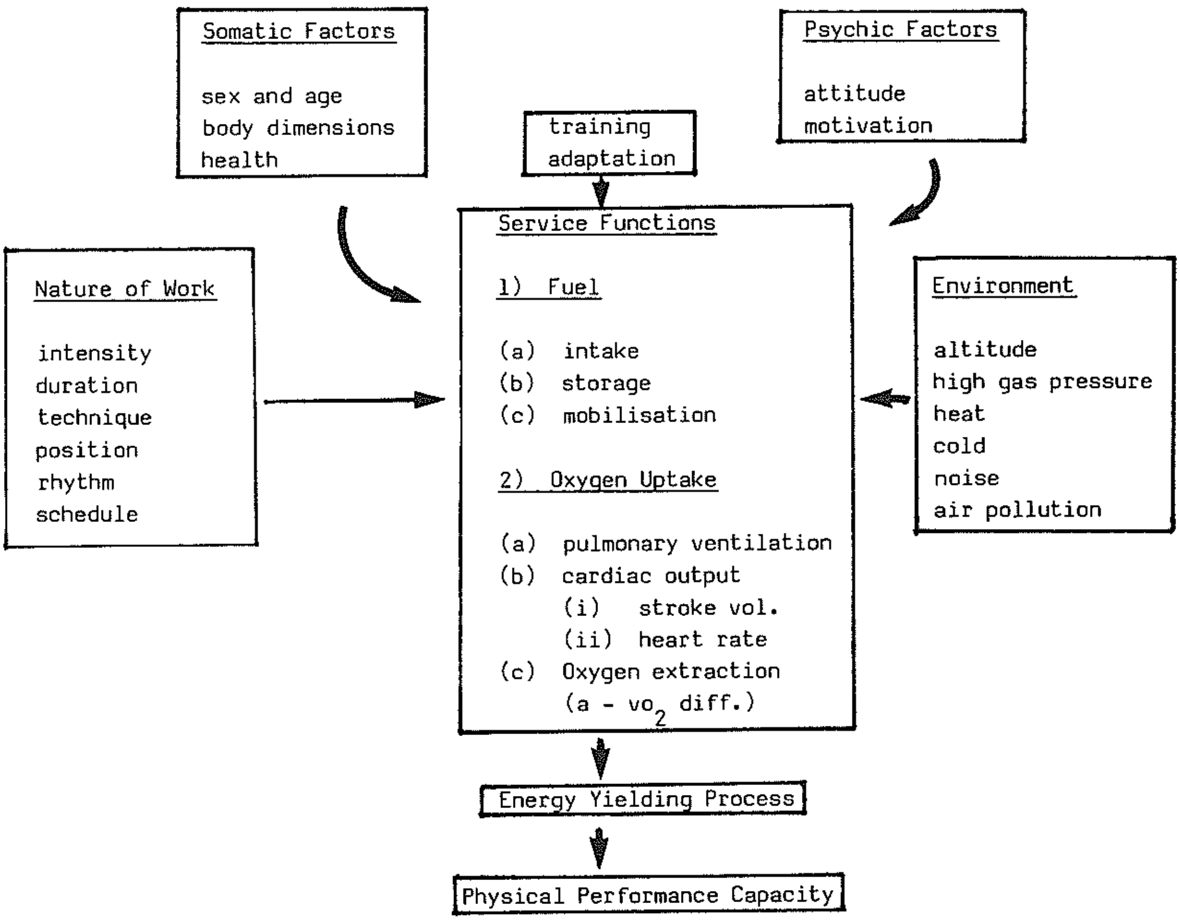
2.5.3.2 Personal Equipment

This equipment has been designed to make the physical aspects of logging easier to carry out. The felling lever is designed to reduce strain to the faller's back when using on trees leaning slightly in the wrong direction. The felling bench was designed to allow easier trimming by getting the tree to rest at a more ideal height, and to improve subsequent manoeuvring of the tree. The effects that such aids have is often difficult to quantify. A discussion of a technique which can be used to quantify effects of such equipment is in the following section.

2.6 WORKLOAD - WORKPLACE

Many factors affect the capacity for physical performance or workload. The figure below illustrates these factors.

Figure 10 - Factors Affecting Workload



(From Astrand, et. al. 1977)

The workload is a function of workplace and vice versa. For example, workloading of forestry work such as felling and trimming with a chainsaw is very high. (Astrand and Roadhl, 1977.) In fact there are few other types of work where workload is heavier, e.g. working with an axe, tending the heating furnace in a heavy steel mill, playing squash or skiing.

2.6.1 Measurement of Workload

Physical workload can be measured using a number of techniques. The most often used are: two measuring oxygen uptake during the actual work or by measuring pulse rate.

2.6.1.1 <u>Measurement of Oxygen Uptake</u>

Typically this is done by collecting the expired air in Douglas bags carried by the operator. The operator breaths into the bag through a valve system that allows him to breath in normally and expired air to be directed into the bag. The air is usually collected for about seven minutes. Air volume is subsequently measured in a gasometer, and proportions of oxygen and carbon dioxide are determined by analysis.

A disadvantage of the Douglas Bag method is that in logging operations it can hamper the movement of the subject and it requires expensive and specialised analysis equipment. Even with these limitations numerous studies have been conducted in forest harvesting operations using the Douglas Bag technique. It is the most accurate method still today to measure energy expenditure.

2.6.1.2 <u>Measurement by Pulse Rate</u>

It has been established through research that in a given person there is generally a linear relationship between oxygen uptake and heart rate. Therefore the heart rate, under certain standardised conditions (same temperature, same person etc) can be used to estimate work load. The prerequisite for such a technique is that the work load - heart rate relationship has been established for a known work load and that the person to be studied will be using the same large group of muscles that they were using while doing the control test. Conditions such as temperature and emotional stress should also be kept the same. Figure 11 shows how the linear relationship can be used for estimating work load from heart rate (E. Wigaeus and A-S. Ljungberg, 1982).

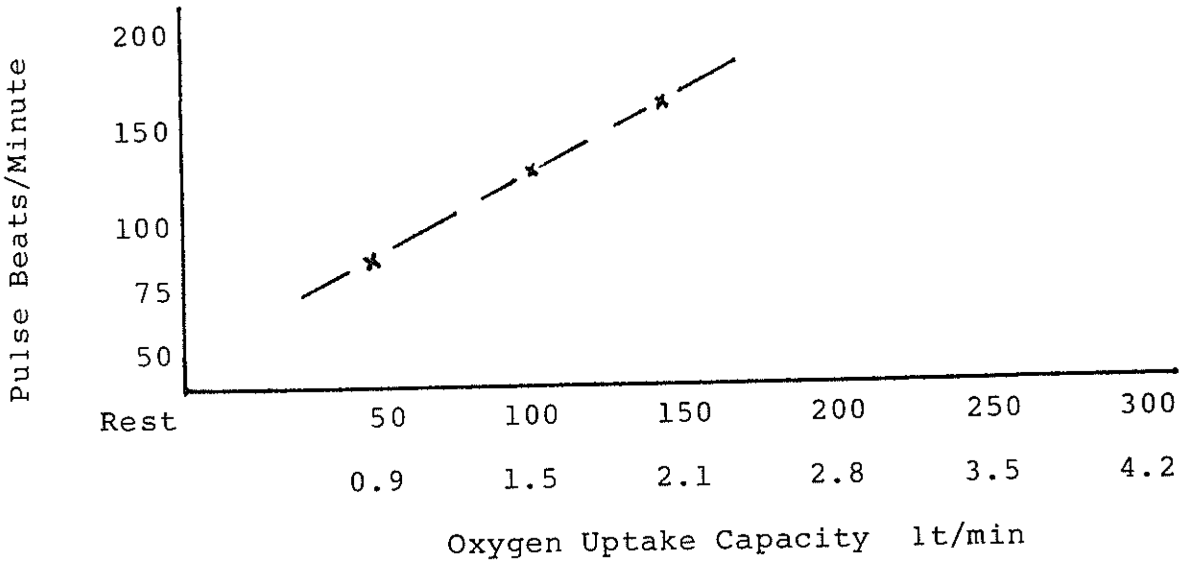


Figure 11 - Linear relationship between pulse rate and workload

Numerous methods of measuring the pulse rate while the operator is working can be and are used. First however a pulse rate at given work loads must be established; normally 50, 100 and 150 watts. Typically this is done using a bicycle ergometer. Depending on the age of the person and their physical condition a thorough medical check may be necessary. Some basic "rules" regarding such tests are included in Appendix 3. To conduct a test the following equipment is required :

(a) Bicycle ergometer - these come in a variety of shapes and sizes and can be either mechanically or electrically braked to simulate predetermined work loads. The choice of cycle ergometer is a function of how sophisticated the study should be. An excellent such unit is the Monark Ergometer 868. It has a moderate level of sophistication but is mechanically braked and not dependent on a supply of electricity, therefore being very portable. This type of unit has been seen in use in the forest (inside gang hut).

(b) A metronome, which is set at 100 beats per minute, (the setting should be checked against a stop watch).

(c) A conventional stop watch for measuring work time.

(d) A special stop watch for measurement of pulse rate.

There are several points of caution and preferably such testing should be done with a nurse in attendance. The table below, (Wigaeus and Ljungberg, 1982), gives the pulse rate that should not be exceeded with test persons of various ages.

TABLE 3 : Maximum Pulse Rate For Age (after Wigaeus and Ljungberg, 1982)

AGE :	20-29	30-39	40-49	50-59	60-69
PULSE :	170	160	150	140	130

TESTING SHOULD NEVER BE A COMPETITION!!!

As mentioned earlier, numerous techniques can be used to collect pulse rate during work. These include :

(a) Physically taking the pulse of the operator, say 10 beats, using the special pulse rate watch, at predetermined times. This technique requires that the person recording the pulse rate is very experienced at pulse measurement.

(b) Using electrodes placed on the body to transmit a signal to a tape recorder carried on a belt by the operator, Medilog 4.24 Oxford Electronics Industries Ltd, (Wigaeus Hjelm and Frisk, 1985). The recorded EMG signals can then be subsequently analysed using a Medilog playback unit (PB-2) and small computer (ABC-80) for example. The disadvantage of such a system is that the analysis of the tape requires rather specialised equipment.

(c) A third technique, and possibly best for logging activities, has recently been developed by the University of Forestry, Garpenberg, (Tegmyr, 1985). Equipment within this system include, (1) ECG electrodes attached to the operator and hooked up to a transmitter worn around the operator's neck, (2) a receiver unit with an oscilloscope to enable the signal to be visually monitored, (3) an anolog/digital signal converter which converts the analog signal from the receiver to digital for the computer, (4) a Husky Hunter microcomputer, (5) an FM tape recorder (optional) and (6) a power supply, typically a motorcycle battery, to allow portability. The photo below shows the system in operation.

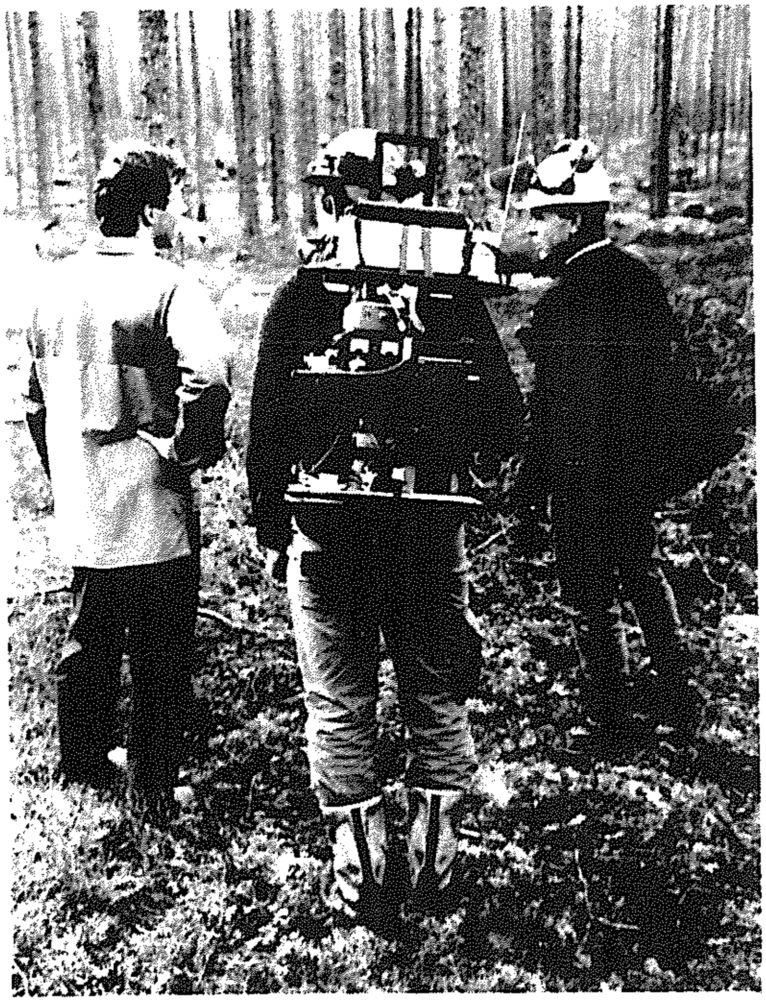


Figure 12 - Husky Hunter micro-computer for collecting data on workloading via electrodes on worker's chest. The worker is the one on the left.

A sample printout of the information collected is in Appendix 4. What makes this system better than others is that it is relatively simple to use. Also results and simple analysis can be readily obtained by interfacing with another computer. It is portable and allows information to be collected while the researcher does not put himself or the operator/worker at risk. The range is 50 m. As can be seen in figure 12, it can be easily carried as a backpack. The most expensive part of the set up, the Husky Hunter, is a very robust unit which has been selected as the best microcomputer for application to work study data collection and analysis in the forest industry.

2.6.1.3 Electromyography as a Means of Measuring Muscle Loading

By the use of electromyography (EMG) it is possible not only to estimate the load on individual muscles but also to study the development of muscle fatigue. EMG is the recording of electric activity of muscles. To develop tension in a muscle, motor units have to be activated. When a motor unit is activated, the movement of ions along the muscle fibre membrane results in an action potential. A recording electrode close to the muscle fibres will detect the potential. During an increased voluntary effort of the muscle, the electrical activity increases due to activation of more motor units and higher discharge frequency in the motor neurons. Thus there is a relation between myoelectric activity and muscular performance (M. Hagberg, 1981). Electromyography involves the accurate positioning of electrodes on the muscle centre and connecting each electrode to an amplifier. The signal is run through an oscilloscope to check for electrical interference and correctness and is then taped on an FM tape system (normally multi channelled tape recorder).

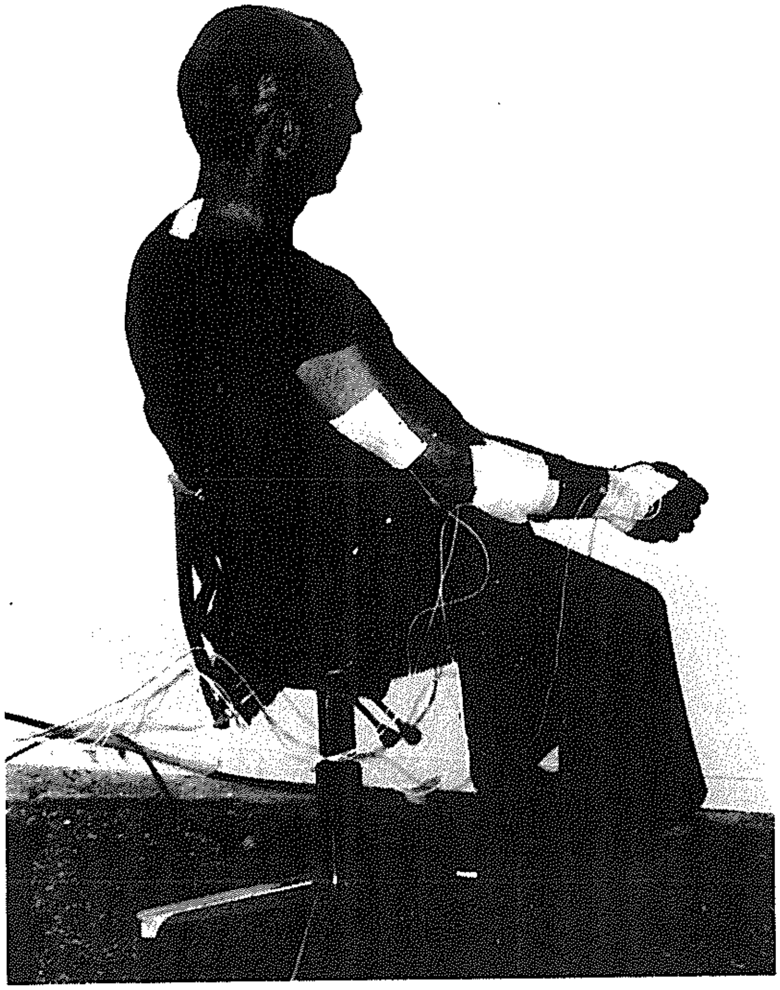


Figure 13 : Electrodes attached to various muscles of a test person to measure the effects of working with an orbital sander.

In the opinion of the author, EMG studies are far too sophisticated and expensive to be considered in the New Zealand logging industry within the foreseeable future. The technique is however being used extensively in Sweden to measure muscle loading in the neck/ shoulder region on harvester and forwarder operators who have complained of considerable discomfort in that part of their anatomy.

2.6.1.4 <u>Work Posture</u>

Work posture not only has a significant effect on the possibility of the operator incurring an injury but it also has significant effect on work load. A simple example of this effect has been taken from Grandjean (1980) where a table is presented of work done by Malhotra and Sangupta (1965). *"These authors showed* *that schoolchildren who carried their satchel in one hand needed twice as much energy as when they carried the satchel on their backs".* No specific reference is made to the posture of the children but when considering the lines drawn to show the different carrying techniques on the spine, it is reasonable to assume posture has more than a little effect on the energy requirements.

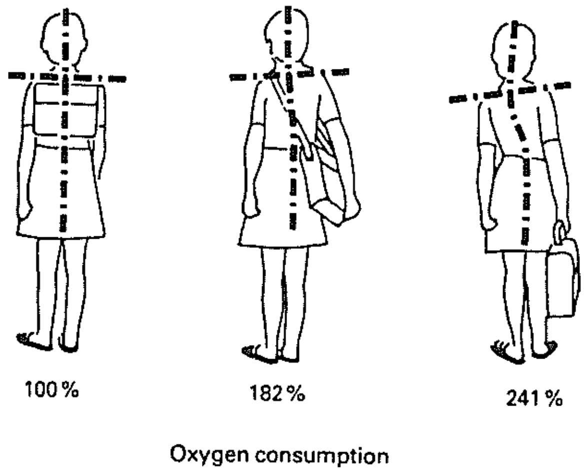


Figure 14 : Effect of Static Effort on Energy Consumption (measured by oxygen consumption) for three ways of carrying a school satchel. (After Malhotra and Sengupta, 1965)

Consider the examples of trimming, as depicted in figure 15, or the example of the strain being placed on the ankles, knees

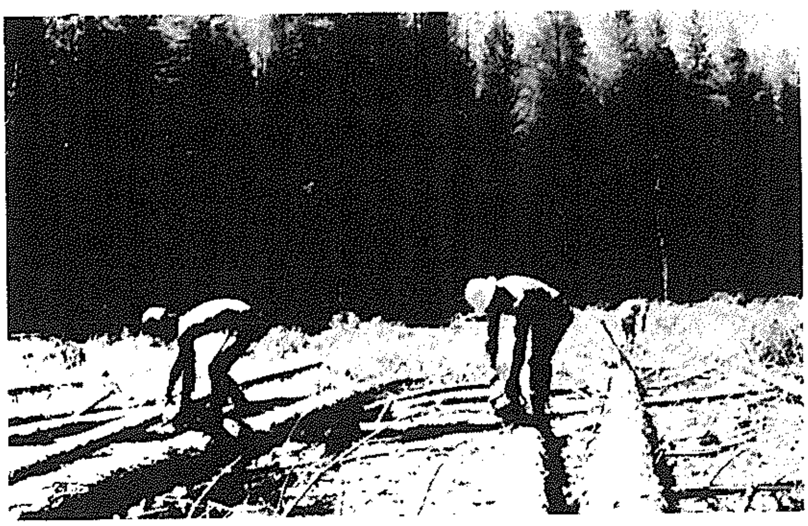


Figure 15 : Example of commonly seen posture amongst trimmers; that posture places severe strain on operators back.

and back of the operator who jumps off his machine without using the steps provided. Unfortunately examples of poor work posture are numerous in the logging industry. At best they will result in fatigue and at worst, serious-permanent injury.

Techniques to measure posture are mainly based on direct observation, for example using video filming techniques. One example of such a technique is VIRA, (Kilbom, Persson and Johnsson 1985), developed to provide a simple method for evaluating working postures and movements in sitting, repetitive work. The worker is informed of recording aims and the necessity of working normally. Pieces of coloured tape are fixed in key places in order to facilitate subsequent analysis; the person is filmed from rear and side position. The positioning would of course depend on the task being carried out. The analysis relies on simple bio-mechanical principles.

The analysis, as well as giving the percentage of time that the body is subjected to different postures, can also give analysis of variance for different positions. This is an important technique for improving work place design.

Another example of a technique to record posture uses the Husky Hunter micro-computer, (Tegmyr, 1985) and predetermined numeric codes for different postures. From that, the percentage of time spent in different postures can be calculated. Using bio-mechanical formulae, the potential loading can also be calculated for each posture. For example in studying a skidder operator the following postures and numeric values might be assigned :

1 = driving facing forward
2 = driving body twisted so as to see to the rear
3 = winching in body twisted to see rear
4 = manually pulling winch rope
5 = bending over to attach strops
6 = jumping from machine

If used in the work study mode then a maximum of nine numerical values can be used. If, however, a work study is also required then a separate group of five numeric codes could be used for work postures. These can be recorded at a time interval chosen by the person conducting the study. In effect this system is a type of activity sampling technique.

2.6.2 Work Place

Many aspects of work place have already been covered in earlier sections of this report, such as 1.2 (Flora), 1.3 (Topography), 2.5.2 (Forest Machines), etc. In the previous sections, various techniques for measuring work load were discussed. Those measurements could then be used to improve the work place and thus reduce work load. An example of such an attempt being made in New Zealand to improve work place design is in the work done on Organised Felling for thinning extraction by a hauler unit (Gaskin 1984, Liley 1984). It was considered that by clearing the branches from the extraction corridor that the work place was significantly improved for the faller, the person doing the setting up of lines, and for the breakerout.

Unfortunately, at that time, the stated improvements to the working environment were unable to be tested. Now however, using the techniques mentioned in the previous section for measurement of pulse rate, work place improvements with organised felling could have easily been tested.

2.7 REST PERIODS AND SCHEDULES

Studies have shown that changes in the length of day worked often result in a higher output for a shorter day, and actually lower output for a longer day. Therefore in heavy work load areas such as logging, rest is important. Because functions of the human body are a rhythmical balance between energy consumption and energy replacement, rest pauses are essential as a physiological requirement if performance and efficiency are to be maintained. There are basically four types of rest :

(a) Spontaneous pauses - obvious pauses that workers take on their own initiative - say at the end of walking back from trimming a tree. These are not normally very long.

(b) Disguised pauses - where the worker occupies himself with some easier task, in the case of the faller going for a walk to check the next 10 trees to be felled, or in the case of a skidder operator going for a drive to see how much wood he still has to pull from an area.

(c) Work-conditioned pauses - these arise from organisation of the work or operation of the machine; for example the skidder or chainsaw operator refueling his machine.

(d) Prescribed pauses - breaks that are laid down by the management, e.g. smokos and lunch breaks.

Two good examples of the effect of pauses on productivity or work output are to be found in Grandjean (1980).

Figures 16 and 17 show the effect of short breaks on the net working time.

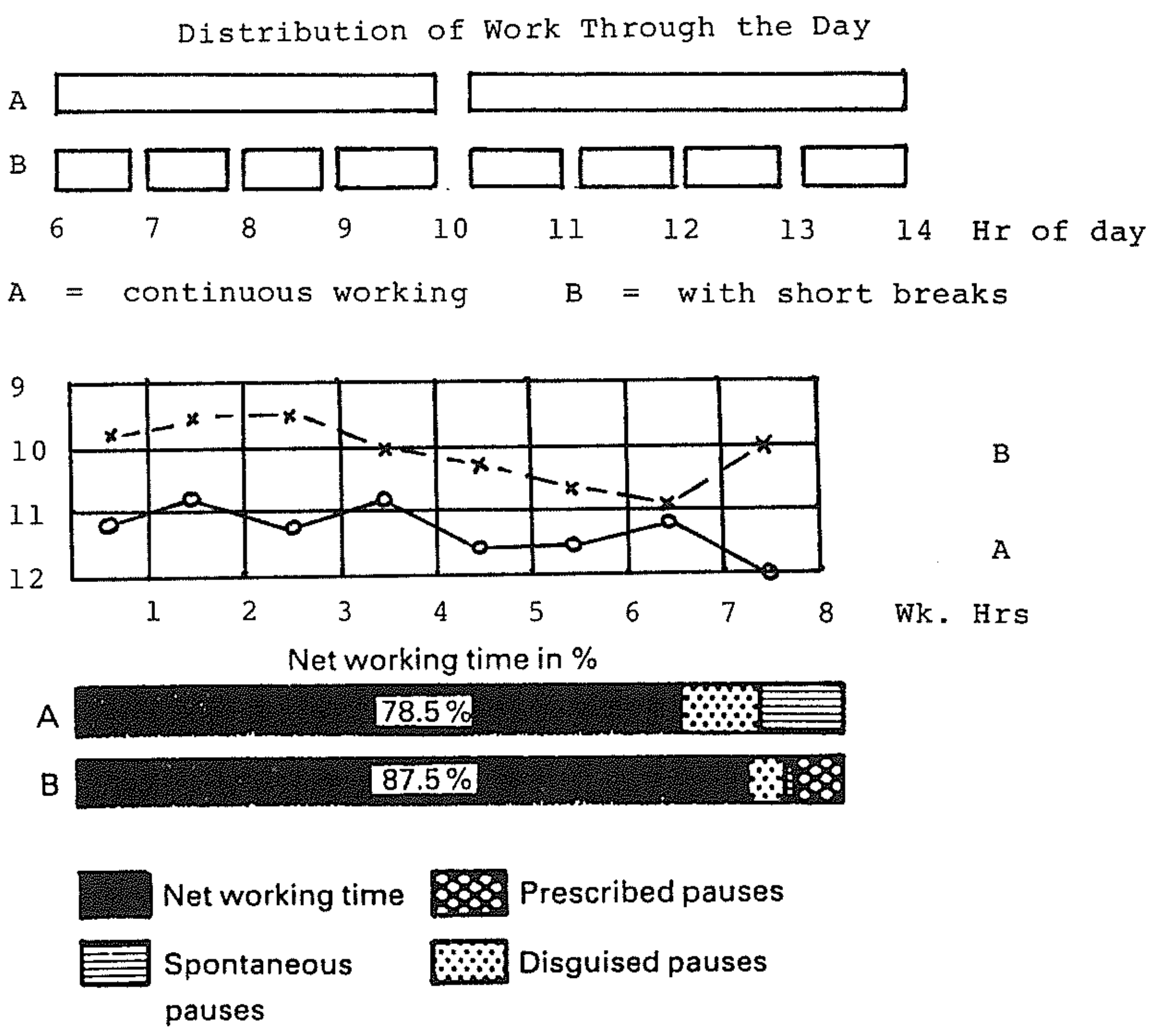


Figure 16 : The effect of short breaks (B) on the net working time, on secondary tasks (disguised pauses) and on spontaneous pauses. (After Graf, 1954)

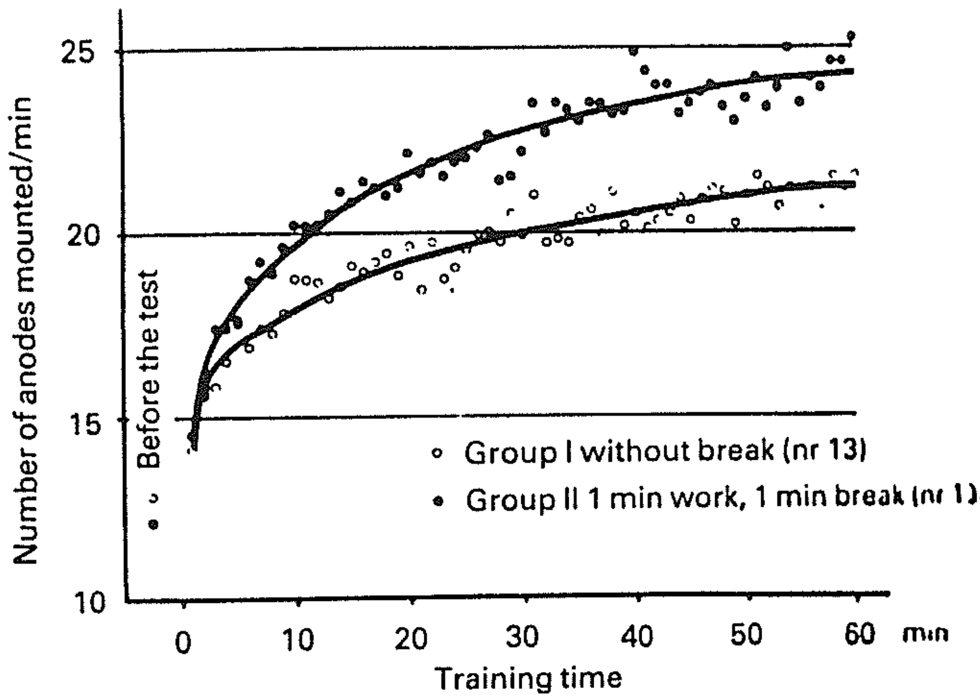


Figure 17 : The effect of rest pauses on the learning of a skilled operator (after Iskander, 1968)

2.8 SUPERVISOR

This person has the potential of being a significant affecting factor because often he is the person from "outside the bushman's environment" that the logging gang members have the most contact. The supervisor can affect gang motivation, gang willingness to adopt new techniques and equipment (behavioural changes), and he can also have either a positive or negative affect on the quality of the job being done. This group will be dealt with more fully in a subsequent section.

3. INDIVIDUAL CHARACTERISTICS

The third group of affecting factors is that of the individual worker's characteristics. Table 4 below sets out the various facets of these characteristics.

TABLE 4 : Individual Characteristics

Age
Sex
Health
Physical Fitness
Education
Cultural Background
Attitudes
Socioeconomic Situation
Employment Conditions
Payment System

3.1 AGE

Already the effect of age on pulse rate has indicated that reduction in heart rate has an adverse effect on maximal oxygen uptake and therefore physical work capacity (Table 1, Section 2.6.1.2). Astrand and Rodahl (1970), noted that the maximal oxygen uptake increased with age up to twenty years old. After that there was a gradual decline, to the extent that a sixty year old person only achieves 70% of the maximum at twenty-five years. The level of training, and or physical activity, however, has a very positive effect on maximal oxygen uptake. This will be discussed in Section 3.5 (Physical Fitness).

Other factors that change with age and could have a detrimental effect on a person's ability to work in a job that places severe demands on their physique are :

- muscle strength, studies have shown a 20% decrease in muscle strength from twenty-five years old to sixty-five years old;

- weight, there is an increase of about 10% in body weight over the same period;

- height, a slight decrease in body height occurs with age. For example, an American survey (Grandjean, 1980), showed that people in the 45 to 65 years age group had changed stature by -4 cm when compared to the twenty year old age group.

3.2 SEX

This doesn't refer to how often, but rather male or female and the differences to be expected between the two groups. In recent years, although not seen to any extent in New Zealand, there has been an increasing number of women employed in the once male domain of logging. In countries such as Sweden women are now working as chainsaw operators in the forest. In New Zealand to date most women seen in forestry have been employed in the management sphere, however the time will undoubtedly come when they will be employed as chainsaw operators.

There are some basic physiological differences between the two sexes. Grandjean (1980) stated that it could reasonably be assumed that the average woman will only be about two thirds as powerful as the average man. The figure below illustrates this difference.

Figure 18 - Muscle power in relation to age and sex. (After Hettinger, 1960)

There is also a similar reduction in oxygen uptake between male and female. Astrand, etc, noted that before puberty there is no significant difference between the sexes and both sexes appear to peak between 18 and 20 years. However after puberty the aerobic power of women is on average 25 to 30% less than that of males. Both sexes however follow the same decline pattern.

Figure 19 shows maximum oxygen uptake for men and women.

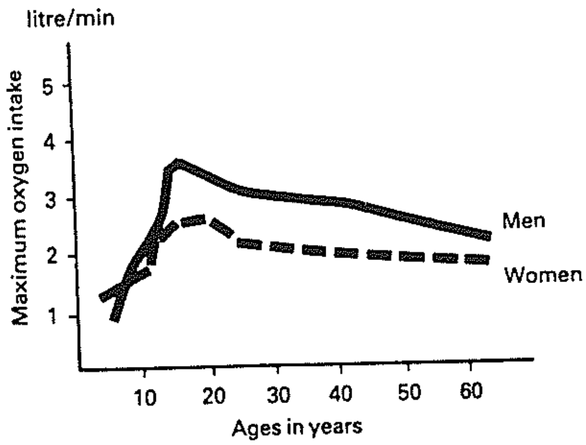


Figure 19 - Maximum oxygen uptake for men and women. (After Astrand 1952 and Astrand 1960)

Another major difference between the two sexes is to be found in size or stature. This factor is of particular importance in machine design. Some examples of size difference are given below, from Diffrient et. al. 1974. The groups being compared are from the 97.5 percentile; the sample group is from the U.S.A.

TABLE 5 : Difference in Body Size Between Sexes

Measurement	Male	Female	Difference	%
Height, cm	187.96	173.99	-13.97	8
Half span - body centre to finger tips, cm	97.54	90.17	- 7.37	8
Shoulder Width, cm	49.28	44.96	- 4.32	10
Sitting Hip Width, cm	40.13	44.96	+ 4.83	11
Sitting Sight Line, cm (i.e. from buttocks to standard sight line looking straight ahead)	85.34	79.25	- 6.09	7

From this table it is clear that in designing machinery, for example, these differences must be considered.

3.3 RACE AND SIZE

In the New Zealand logging industry there are two dominant races of people employed - Maori and European. Often you will hear comments made about Japanese built machines being too small both in head room and feet or leg room. From the figure below it is clear that there should be some difference in feet/leg room but the figure indicates the seated Japanese is the same size as the seated white male from the U.S.A. Figure from Diffrient et. al. 1974.

Also from the same source of information Table 6 illustrates the difference in height for the 97.5 percentile for males and, where available, females, from 10 different countries.

Figure 20 - Difference in Body Size Between U.S. Black Male, U.S. White Male and Japanese Male

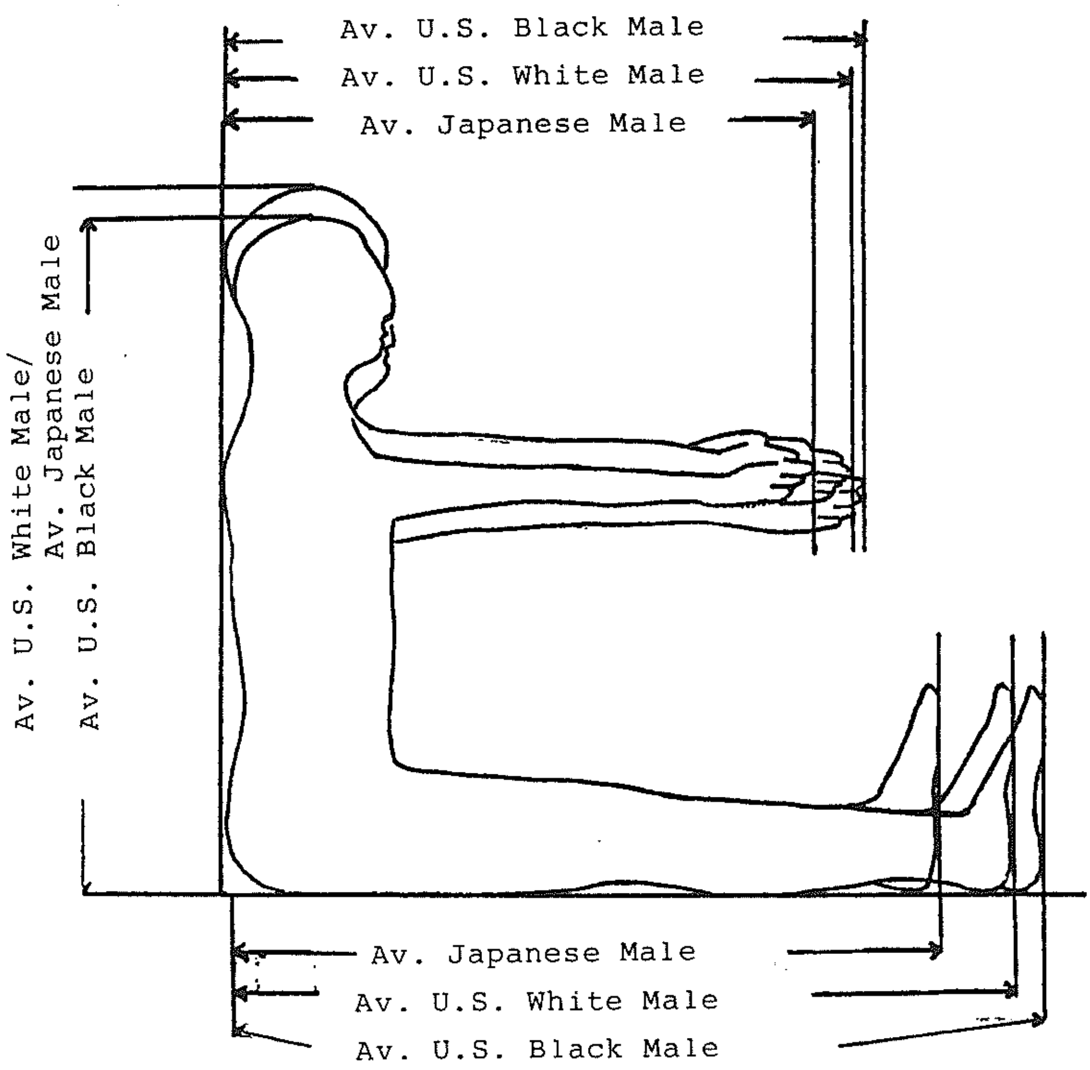


TABLE 6 : Difference in Body Size (Height) Between Various Countries

Country	Male (cm)	Female (cm)
Australia	184.9	N/A
Canada	184.7	169.9
France	185.4	N/A
Germany	181.6	172.0
Great Britain	183.9	173.7
Italy	182.9	N/A
Japan	176.3	163.6
Norway	191.0	N/A
Russia	183.9	N/A
Turkey	180.6	N/A

Source : Diffrient et. al. 1974

Different races also have different values and it is very important that management remember this because it will affect each workers attitude to what he's doing and how he reacts to a given situation. This aspect will be covered in Section 3.10 (Attitudes) and also 3.11 (Socioeconomic).

3.4 HEALTH

Obviously a person with poor health is more likely to be at risk of injury or illness through work than one who is in good health, but how often are loggers asked to have a full medical check up before commencing work? In Appendix 3, which outlines some of the essential rules of work load testing, the importance of checking a person's health is stated and if there are any problems, such as a fever, then the test should not be carried out. A person suffering from poor health at work is a danger to himself. More often than not he will be feeling so sorry for himself that he won't be concentrating on what he's doing.

One other health factor that should again be mentioned is that of cigarette smoking. In two previous sections, Section 2.6.1 and in Section 2.1.2, the effects of smoking on working ability, has been discussed. There is good scientific evidence to suggest that smoking inhibits the circulation and thus increases the risk of operators using vibrating hand tools to suffer from white finger.

3.5 PHYSICAL FITNESS

"In a very broad sense, physical performance or fitness is determined by the individual's capacity for energy output (aerobic and anaerobic processes and oxygen transport), neuromuscular function

(muscle strength, co-ordination and technique), joint mobility, and psycological factors (e.g. motivation and tactics)."

This passage from Astrand and Rodahl (1977) illustrates that the four factors which determine physical performance, capacity for energy and neuromuscular function can be improved by training. The four points mentioned above are all very important to the ability of people employed in logging to perform for six to eight hours without undue risk of damaging themselves. A physically fit person is able to achieve a lower pulse rate when working at a fixed work load than if the person has led a sedentary existance; this can further be improved by training. In working with a chainsaw, a most important aspect is that of using the correct technique. A poor technique results in excess load being placed on the worker thus he will become fatigued much more quickly than if he was using good technique.

3.6 EDUCATION

Within the New Zealand forest harvesting industry, education places most of its emphasis on productivity and how to improve this. Most solutions in New Zealand are seen to lie in changes/ modifications to the machine and/or system in which it works. Little attention has, to date, been placed on the importance of the man. Whatever harvesting system is used still relies heavily on manpower. Those people then who need training in the objectives and basic principals of occupational safety and health are those working in logging, planning or managing others working in logging, and those who in other ways directly affect the working conditions in logging. In other words everyone involved in logging from the logger to manager to, even, machinery suppliers. All these people either influence, or will influence, their own and others' working conditions.

The general aims of such education should be (Bostrand, 1985) :

(a) To encourage the student to develop a positive attitude towards ergonomics, and an interest in and understanding of the concepts of that.

(b) The student should be made aware of what ergonomic problems exist in forestry.

(c) Sufficient knowledge and information should be gained to motivate the student to solve problems they will encounter.

(d) The student should achieve the necessary skills for their particular level, i.e. there is little to be gained by teaching a logger how to convert dB to m/s2 but he should understand the importance of m/s2 in relation to vibration and the damage caused to him from various levels.

Ergonomics is a multidisciplinary applied science, including human anatomy, physiology, sociology, phychology, engineering, management technology, and other related sciences. To be able to adequately educate people on such a wide range of subjects it will obviously be necessary to use outside specialists such as physicians, first aid instructors, physiotherapists, ergonomists etc, to cover many subjects. It must be emphasised though that such outsiders are normally specialists in a rather narrow field so the person responsible for the education must emphasise the necessity of them dealing with parts of their field relevant to the trainee, and, most importantly, at a suitable level of understanding.

3.7 EXPERIENCE

One way of learning is by one's experiences, be they good or bad, something is always learnt. There is a saying which goes "You can have twenty years experience or one year of experience twenty times over", which is very true. The easiest person to influence is one who has very little experience. That person has not yet decided for himself which is the best way to do something. He is therefore more likely to try something new for himself. People who have had some time doing a job will often be those who are more difficult to change (based on personal experience, not quantified). However, using the correct technique such as the example of information feedback quoted in the Section 2.1.1 on noise, even the most experienced person may well change.

Occupational health problems when related to experience can also suggest how long an operator needs to adapt a certain technique to experience some problem. For example, if, in a survey it has shown that 30% of operators suffered from back problems and that in all cases they had been working for say three years at that particular job, then studying what they are doing should assist in revealing the problem.

It should be stressed that most harvesting techniques used in New Zealand are learnt through experience; either an older person who has been doing the job for some time teaching the new person, or the new person learning by trial and error. If it hurts, it's a bad experience, if it doesn't, it's a good experience and therefore one worth repeating.

3.8 CULTURAL BACKGROUND

The harvesting industry in New Zealand involves basically three different cultural groups (the Europeans, the Islanders and the Maoris) and there are vast differences between these three groups. As well as possible differences in skeletal structure already discussed in Section 3.3 (Race and Size), there is also a tendency for Polynesian people to be more heavily built than Europeans. Another very important difference between the groups is the factors that motivate them. Normally the Polynesian attitude is one of having enough money and as few worries as possible, while the European is often conditioned from very early in life to continually try to "better" themselves. Many other differences occur such as living standards, attitudes etc. These comments are subjective and the thoughts of the author, therefore they need to be checked for authenticity. Within the harvesting industry in New Zealand not enough is known about the different races to make any more substantiated remarks about effects of cultural background on occupational safety and health.

3.9 ATTITUDES

Attitudes to occupational safety and health are often a reflection of the management's thoughts on that subject. If management is fully supportive then that attitude has a flow on effect through the supervisors to those actually doing the work.

The attitude of all levels of a logging operation is very important in ensuring a healthy working environment. A positive attitude will result in a good level of morale and therefore higher levels of motivation, productivity and less risk of accidents.

3.10 SOCIOECONOMIC

This refers to the employee/employers financial and social, family and friends, security. If an employee is having a problem in his domestic life then it is very difficult for him not to bring that problem with him to work. That could result in, for example, a faller not having his mind on what he is doing and lead to an accident. It is again a management (employer) responsibility to be aware of the signs that a worker might be having such a difficulty and to give all assistance to sort the problem out.

3.11 EMPLOYMENT CONDITIONS

There are basically three groups of employment conditions. The first group is casual - where someone is employed to fill a temporary vacancy and knows that he will only be there for a short period and is therefore less likely to be concerned with the long term effects of his work. Second is seasonal employment; this type of employment condition doesn't exist very often in logging in New Zealand. An example of such a condition, although it falls between this and the next group, is where numerous contractors are employed for a short term, e.g. during windthrow salvage of 1982/83. The third employment condition is permanent. Most of those employed in logging fall into this category.

3.12 PAYMENT SYSTEM

The effect of payment system on occupational safety and health or accidents is one of the most hotly debated questions. In 1975 a change from piece rate payment system to a flat monthly wage payment in Sweden resulted in a dramatic reduction in accidents. Sundstrom - Frisk, 1984 noted that the change in payment system realised a reduction in the accident frequency and severity rates amongst forest workers. This reduction was attributed to a reduction in stress, fewer human errors, and the benefit associated with risk taking, i.e. more the worker did the more he got paid, which was considered conducive to taking short cuts or risks. The study also noted a reduction in number of sick days per 1000 hours of cutting work - Swedish Forest Service. These two trends are shown in Figures 21 and 22.

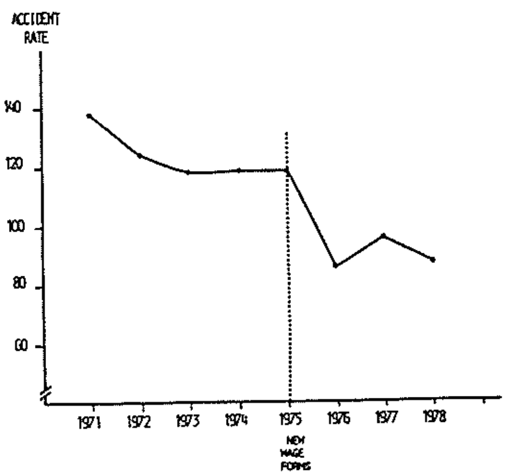


Figure 21 - Number of Accidents per 1 million work hours during cutting operations for the Swedish Forestry Service, 1971-1978 (After C. Sundstrom, 1980)

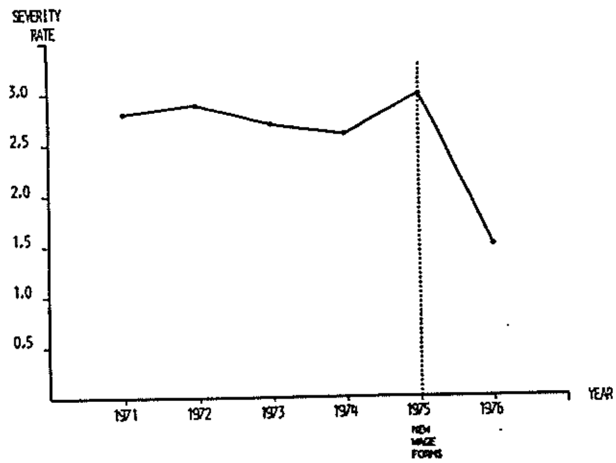


Figure 22 - Number of sick-leave days per 1000 hours of cutting work for Swedish Forestry Service 1971-76 (After C. Sundstrom, 1980)

It is also essential to note that the productivity showed a marked decrease although not so well documented. Estimates appear to be between 25 and 30% reduction. There are, however, numerous examples in New Zealand where highly paid, high producing contract gangs have a low accident rate. The question then is - what makes these crews so safe, yet still able to produce so well?

To try and compare the Swedish example with New Zealand now would be very dangerous as there are many factors which are too different. For example, the reduced productivity, and therefore increased cost of logging, in Sweden was one of the motivating factors in their recent mechanisation.

The preceding sections 1 through 3 of this report have covered all the factors that have an effect on the worker and production. Not one of these factors can be treated strictly in isolation but must be looked at as a total environment. To summarise this, the figure presented at the beginning is represented before continuing with what happens to the worker and productivity.

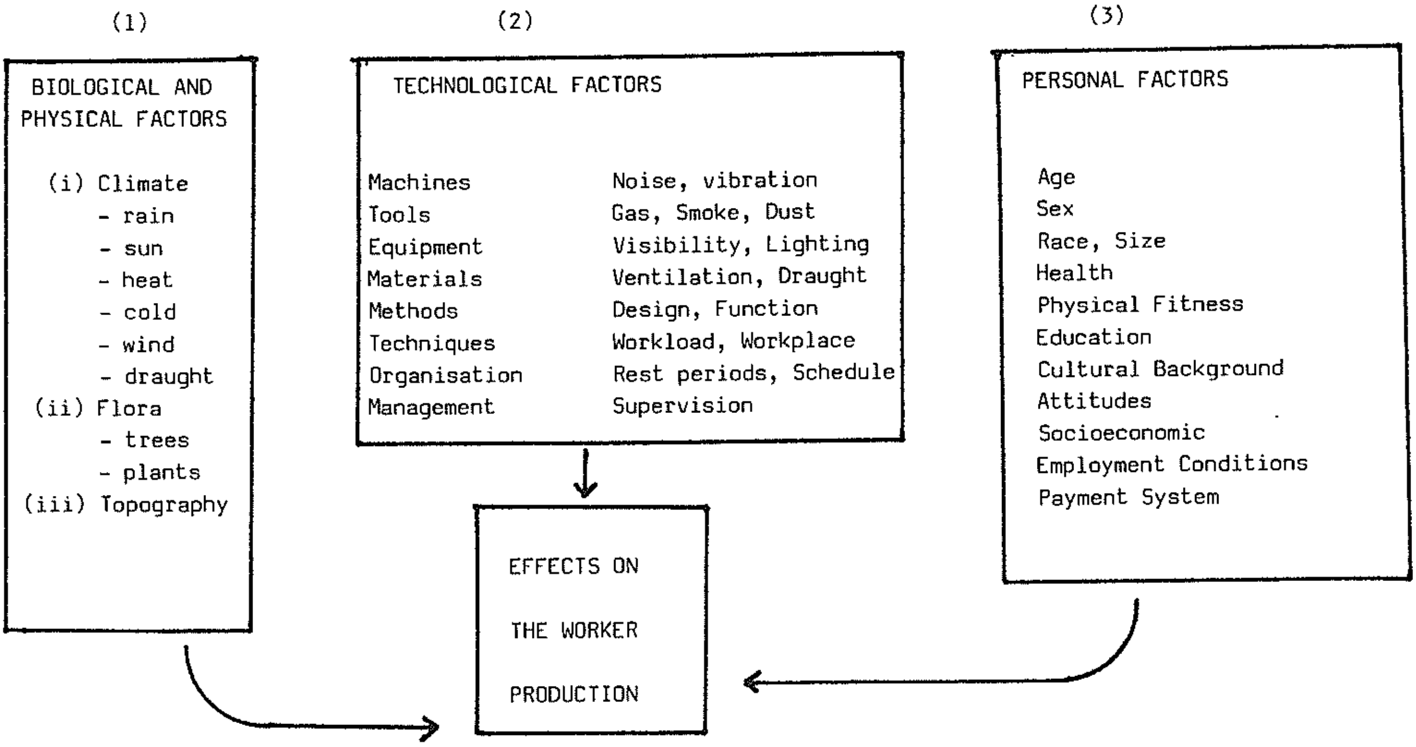


Figure 23 : Factors which affect the worker and production (After L. Bostrand, 1985)

INFLUENCE OF BIOLOGICAL AND PHYSICAL, TECHNOLOGICAL AND PERSONAL FACTORS ON THE WORKER AND PRODUCTIVITY

Those factors all have some influence on the worker and therefore on productivity.

TABLE 7 : Effects on the Worker and Productivity

FACTORS	(4) EFFECTS ON THE WORKER	(5) EFFECT ON PRODUCTION
BIOLOGICAL and PHYSICAL	Occupational injuries	Accidents
	Disease	Absenteeism
	Comfort	Labour Turnover
TECHNOLOGICAL and PERSONAL	Motivation	Efficiency
	Mental Stress	Quality
	Fatigue	Productivity

4. THE WORKER

> *"The main objective of the work physiologist is to make it possible for individuals to accomplish their tasks without undue fatigue so that at the end of the working day they are left with sufficient vigor to enjoy their leisure."* Astrand and Rodahl, 1977.

During the discussion of affecting factors, their influence was briefly discussed. In this section, a full treatment of each of the effects in Table 7 will be covered. The first two effects in that table under "the worker", occupational injuries and diseases, are relatively easy to monitor. However, the remaining effects are often intangible and more reliance must be placed on the worker's own description. For example, measurement of mental stress is not something that's easily done.

4.1 OCCUPATIONAL INJURIES

These are injuries caused by one's occupation, more commonly known as accidents. An accident is an occurrence that causes a person to injure themselves. Many people believe that there is no one single factor that can be isolated as having caused an accident, rather it is a complex pattern of events that are a combination of the interactions between man, machines, production methods, work organisations and environment. Accident severity refers to how severe an accident was, i.e. normally measured by the amount of time a person had to have off work as a result of an accident, from the most severe of being killed, to a near miss.

Most countries maintain some record of accidents in the logging industry, often referred to as accident statistics. This information is essential in studying trends and in helping to direct research and development efforts. A good example of this is the recent development of protective trousers in New Zealand as a direct result of the legs of chainsaw operators being seen, through statistics, as being at considerable risk. With such statistics it is important to study trends and not get caught up with complicated analysis.

One problem with accident statistics is that you only know about an accident after it happens. More emphasis is now being placed, in many countries, on a thorough analysis of the chain of events that led up to an accident. That is normally done through interviews with the person involved in the accident. Such an interview must take place as soon as possible and the interviewer must be very skilled so as not to put the interviewee on the defensive. Many workers in logging operations take what they consider a "calculated risk" during the course of a day's work. In a recent study done in Sweden, Ostberg (1979) found that fallers were well aware of the risks they were taking. This author quotes a rather apt passage from Sass and Butler (1978) : - "It is wrong to ask "Why do accidents happen?", rather we should be asking "What new approaches can be taken to improve workers health and safety?"

Another technique of investigating accidents which is being increasingly used is that of near accident reporting. A near accident is defined as an event producing the experience of imminent injury, (Carter and Menckel, 1985). Near accidents occur more frequently than accidents and it is therefore reasoned that they could provide a larger body of information, on which preventative measures could be based. While there is no doubt that this technique contributes to the information base, the collection of data is very time consuming and requires skilled people to do the interviewing if this technique is to be used. A recent study in New Zealand of near accidents carried out by a student (a complete novice) did provide useful information (Wallace, 1984). In New Zealand's situation though, it would be much better to concentrate on having 100% accident statistics in the short term.

The types of accidents recorded in New Zealand and percentage of the total of each type are shown in Table 8 below. These figures have been taken from the summary of accidents as recorded by the New Zealand Logging Industry Accident Reporting Scheme.

TABLE 8 : Summary of 1985 Accident Statistics From the Logging Industry Accident Reporting Scheme

PART OF OPERATION BY SEVERITY

Part of Operation	Fatal	Loss Time	Minor	Near Miss	Total
01 Felling Preparation	-	11	3	1	15
03 Felling	3	58	16	3	80
05 Felling, Trimming	-	79	13	1	93
07 Breaking Out, Hauling	-	39	13	6	58
09 Crosscutting	-	11	3	-	14
11 Skidwork	1	53	15	1	70
13 Loading Truck	-	4	-	1	5
15 Moving Plant, Rigging	-	4	3	-	7
17 Other	-	24	3	1	28
19 Unknown	-	-	1	-	1
TOTAL	4	283	70	14	371

A record of the number of accidents is not enough. It's equally important to know why the accidents occurred. What causes accidents? It has already been stated that accidents are the result of a chain of events. Seldom can it be attributed to one factor, although it may appear that it was caused by one factor, i.e. the careless use of a chainsaw, but did the operator know the correct technique? Did he have access to adequate safety equipment, which while not necessarily preventing the accident may have reduced its severity? What condition was his saw in? What was the condition of the bush? Had he experienced problems at home? etc, etc. If you refer back to the two tables detailing the affecting factors, an accident then is a combination of all these factors, not just one thing or another.

4.2 OCCUPATIONAL DISEASES

A simple definition of an occupational disease is an illness, which may eventually be incapacitating, which is induced by your occupation. The most well known example of such an occupational disease is that of Raynauds Disease or "white finger". This phenomenon has already been referred to in the earlier Section 2.1.2 (Vibration). It is particularly prevalent amongst chainsaw operators, and usually makes its appearance six months after beginning work at the earliest. Most literature refers to it as being more common in northern countries than in warmer latitudes because it is assumed that cold makes the blood vessels more sensitive to vibration and more liable to vascular cramp. The worst thing an operator can do with a chainsaw to hasten the onset of this disease is to run the saw with faulty vibration damping mounts. For those who feel New Zealand's climate is too warm for this disease to be likely to occur, take a look at how many chainsaw operators suffer from some form of this disease.

Other vibration induced diseases have been discussed in the same Section 2.1.2 where the results of literature surveyed by Griffin showed too many coincidences for it to be taken lightly. Occupational diseases are now beginning to emerge amongst harvester and processor type machine operators in Sweden, in the form of problems with stiffness in neck and shoulder muscles. At present little is known, scientifically, about these problems, but sufficient people are complaining about them for those complaints to be taken seriously. To date much use has been made of physiotherapists to design a set of exercises that operators could do (pers. comm. L. Wessels, 1985). An example of such exercises is shown in figure 24 below. Each machine operator or pair of machine operators is visited by the company physiotherapist

Figure 24 - Company physiotherapist demonstrating exercises to machine operators and supervisors. Such exercises are done to reduce muscle fatigue which results from prolonged use of the same muscles while operating machinery.

and given instruction in how to do the exercises and how often they should be done. (This was the case in one of the biggest companies in Sweden, Stora Skog.) To give some interest to doing the exercises, they have been set to music with a bit of a light-hearted commentary. The photo depicts such a session involving operators of a harvester. In this situation the supervisors were also included in the exercises. Another recommended technique is to not spend all the time (as an operator) on the machine, but to have spells where a different job can be done, i.e. felling and trimming for a couple of hours means you will utilise a completely different set of muscles, thus releasing likely build up of tension in those muscles which are continuously stressed in machine operation.

In most cases of occupational diseases too little is known, and, often it is not known until it is too late. Many diseases don't manifest themselves until as long as five years after the person starts doing what causes it (often it is longer than five years). Thus it becomes very difficult to correctly and accurately attribute the disease. Often it is easier to put it down to a weekend sporting injury and not to consider it has anything to do with work at all.

4.3 FATIGUE

Fatigue is a condition which at some stage or other we have all known. The term usually suggests a loss of efficiency and a lack of desire for any kind of effort but it is not a single, definite state. It is reasonable to draw distinction between two types of fatigue, muscular fatigue and general fatigue. Muscular fatigue arises in overstressed muscles and is localised. It is normally quite painful. General fatigue by contrast is a diffused sensation accompanied by a feeling of lethargy.

4.3.1 Muscle Fatigue

There are currently two theories on muscle fatigue; chemical and CNS. Chemical fatigue sees the loss of performance in muscles as a result of chemical process (consumption of energy-production substances, and accumulation of waste products) with the electrical phenomena in the muscle and nerves playing only a secondary role. The CNS theory sees the chemical process as being merely the releasing stimulus for sensory impulses which travel along the nerves to the brain and cerebal cortex. It is here that muscle fatigue makes itself evident as a sensation of weariness.

Neither of these two theories explain everything. All that can be said certainly is that both CNS phenomena and chemical process in muscles contribute to muscle fatigue.

4.3.2 General Fatigue

A major symptom of this is a feeling of weariness, no desire for either physical or mental activity. This feeling is the body's way of saying it is time for a rest. If a rest is taken then it allows the body time to recuperate and actually stops us from overstraining ourselves. The effect on a person's capacity to produce has been highlighted earlier in Section 2.7 (Rest Periods and Schedule). Causes of general fatigue are complex, all the factors listed below have some effect.

(i) Intensity and duration of physical and mental effort

(ii) Physical problems, responsibilities, worries or conflicts

(iii) Environment: Climate, light, noise

(iv) Pains and illnesses

(v) Circadian rhythm

(vi) Nutrition

The level of fatigue induced then becomes a function of

The amount of Recuperation

At this stage then there is no direct way of measuring fatigue, instead it is measured using a combination of methods. Currently methods used fall into six groups.

(i) Quality and quantity of work performed

(ii) Recording of subjective impressions of fatigue

(iii) Electroencephology (EEG)

(iv) Electromyography (EMG)

(v) Measuring subjective frequency of flicker-fusion of eyes

(vi) Psychmotor tests

(vii) Mental tests

The effect fatigue has on the worker then is obvious from the stated symptom of fatigue, weariness. The worker is less inclined to work and therefore his potential productivity reduces.

4.4 DISCOMFORT

Discomfort is the feeling of "things could be better". Prolonged periods of discomfort may well result in strain and stress to muscles, or the onset of fatigue. Discomfort can be caused from many variables, from merely a piece of sawdust in a chainsaw operator's eye to the situation where a machine operator is forced to adopt a cramped position, i.e. when the cab is too small or he has to twist frequently. Discomfort can also be caused by climatic conditions, heavy rain and cold or direct sunlight. Generally discomfort will result in a feeling of low motivation similar to that experienced from excessive fatigue and will mean a significant reduction in worker productivity.

4.5 LOW MOTIVATION

Some aspects of motivation have already been discussed, Section 2.7 (Rest Periods and Schedules). In that section a table was presented to illustrate the effect of rest pauses on worker productivity. In Section 3.12 (Payment Systems), it was noted that a change of payment system, while having a dramatic effect on accidents, had a similar but detrimental effect on productivity which dropped by 25 - 30%. It would then be reasonable to suggest that financial incentive had been a motivational influencer. However all of the factors mentioned under affecting factors have some influence. If the worker is uncomfortable or unhappy, then he will be less inclined to work, lower motivated and therefore not as productive as he potentially could be.

A means of improving motivation, not already discussed, is that of work organisation. This can be done through such things as job rotation. Many aspects of logging work can be seen as being monotonous. Monotony can be reduced through job rotation, i.e. felling for a month and then having a change for a week or so breaking out or working at the landing. That technique of course presupposes that each worker in the gang has the necessary skill levels to be able to carry out different tasks involved in a logging operation. Management can also have an effect on this by offering different tree species for gangs to work in or even arranging a visit to the local processing plant. The latter may well have an added effect of letting workers see what happens to the timber they produce, and could well have an effect on improving the quality of the product if the need for this can be highlighted during their visit.

4.6 MENTAL STRESS

It is well recognised that people can only maintain a high level of concentration for a relatively short period, dependent on the degree of concentration required. Concentration on what one is doing in the logging industry is very important. A lapse could result in a serious accident. An example of the effect of lapses in concentration is when a machine operator might engage a gear for moving a machine which he is not supposed to, there may even be a large sign displayed prominently which states that he should not do this. By engaging the gear the result might be that the drive system of the machine is destroyed. Who is at fault? The machine operator may have been operating the machine nonstop for three hours. He may have had little sleep the night before. Whatever, the act is basically one of a lack of concentration, i.e. if he was thinking about what he was doing when he did it, the error probably would not have occurred.

Personal discussion with a machine operator in Sweden, who was operating a harvester for eight hours with virtually no breaks, revealed that his productivity during the last one to two hours of the shift was 30 to 40% lower than for the first two hours. He attributed that to the fact that his level of concentration was greatly reduced towards the end of the shift.

It is important to remember that it is often not only one of the influencing factors that effect the worker, but rather all of them to varying degrees. Even within this section of effects on the worker, the same interrelation exists. For example, low motivation may well be caused by the onset of fatigue, discomfort, or mental stress. If you have read this far, the first person to ring LIRA and quote the preceding sentence will be given a free copy of the Costing Handbook. Accidents may well be contributed to by any one of the above conditions as well as poor environment. Many of these factors have been ignored or only given cursory attention in the New Zealand logging industry.

5. EFFECTS ON PRODUCTIVITY

The effect of those influencing factors on the worker generally manifest themselves in less than optimum productivity. Table 9 illustrates ways by which productivity is effected as a result of the influence of biological and physical, technological and personal factors on the worker.

TABLE 9 : Ways by Which Productivity is Effected due to the Influence of Biological and Physical, Technological and Personal Factors on the Worker

Accidents
Absenteeism
Labour Turnover
Inefficiency
Poor Quality
Low Productivity

5.1 Accidents

The effects of accidents on productivity have been divided into two categories - economic and psychological. The economic effect is normally quite obvious and can be felt in the following ways.

How much does an accident cost? A question often asked but seldom, if ever, answered. Considerable work has been done in the past on the cost of accidents in various industries. However only one has addressed that problem in the logging industry. That study was carried out during 1977/78 with the results published by Tempest and Horgan, (1978). In that work three accidents were studied in detail and the financial cost, particularly the employer's indirect costs, were estimated. Those cost estimates were updated for a paper presented to LIRA's 1984 seminar which addressed Human Resources in Logging. One of the case studies examined is reproduced below :

"The accident occurred when a tree was felled by one worker onto another, hitting the latter across the back and shoulders. The following action was taken :

1. The gang stopped work for half an hour to assist the injured worker. The supervisor called a company ambulance which, with a doctor aboard, took the injured man to the hospital where he was X-rayed and discharged. (He returned to work one week later.)

2. The company logging manager and a ranger

visited the site of the accident and made enquiries which involved two witnesses and the gang supervisor for one hour.

3. The logging ranger took a Labour Department bush inspector to the site. The Labour Department prepared a report.

4. Later a general meeting was called for all bush workers, contractors, and staff to discuss the circumstances and causes of the accident.

5. Union delegates and the person who caused the accident had a meeting.

6. Company staff prepared an accident report.

In today's terms (1984), the cost of this accident would be just over $1,700 and the employer's share of this approximately $1,550."

From that "non-serious" accident example it becomes very clear how much such an accident costs and equally important, how many people are involved.

An accident is a very expensive luxury. Many costs or effects on production occur which have not been addressed :

- the effect of employing a replacement
- the effect of that replacement adjusting to the gang's particular way of working
- the cost to society in general of the accident, i.e. hospitalisation, doctors fees, ACC costs etc.

The direct effect of an accident on productivity would be relatively easy to measure yet there are few, if any, documented studies of this nature available in New Zealand. The physchological effects of an accident on productivity would be much more difficult to quantify.

5.2 ABSENTEEISM

A poor working environment results in lower levels of motivation and therefore more likelihood of workers taking days off. From the figure presented in Section 3.12 showing the effects the change in payment system had on absenteeism in one Swedish company, the effects are clearly dramatic. Because the previous payment system placed strain on workers, and thus resulted in a less favourable working environment, they were more tempted to take extra days off work. Reducing the work pressure resulted in a reduction of absenteeism.

The effects of absenteeism on production will vary depending on the size and structure of the logging gang. In the case of a larger clearfelling gang where there is normally a little flexibility in the system, the absence of one worker will go almost unnoticed. However, in a gang where the work organisation is such that each man is an essential part of the operation, such as that typically found in smaller thinning crews, the absence of one man can have a substantial effect on productivity. Thinning operations, such as those found in Lake Taupo Forest, where there are four fallers and one extraction machine working on a drag for drag basis is an example. If one of the fallers is absent then the machine returns to the other three before they have processed a full drag, thus they have extra pressure on them to work harder and the machine is under-utilised.

5.3 LABOUR TURNOVER

Labour turnover in the forestry and logging group in New Zealand is much higher than for most other industrial groups (Wells, 1980) : Forestry and logging 34%, mining and quarrying 18%, and manufacturing 19% for example. A paper presented by Liley (1984) noted there was really little knowledge about turnover in the logging industry.

It would however be reasonable to assume that labour turnover is a reflection on the working conditions and the general level of satisfaction of employees. The effect that has on productivity is that an employer who has spent time and money training an employee must turn around and repeat the exercise. A new, inexperienced worker will not be as productive in the first instance as the person they replace.

5.4 INEFFICIENCY

Inefficiency is the end result of all, many, or some, of the affecting factors not being of the correct standard. A good example of inefficiency in New Zealand relates to technique. In many thinning operations either another person is employed to work on the landing, mainly to clean up the poor trimming by fallers, or worse, the machine operator does this clean up. The first situation costs an extra person's wages, however the second situation is even worse. The extraction unit, which keeps the operation economic, is stopped and therefore isn't making money.

5.5 POOR QUALITY

A poor working environment, which has resulted from using inadequate techniques, will effect productivity. For example, where the standard of felling is not up to scratch, or if the equipment being used is not good enough, often the situation arises where a tree has to be put the wrong way. Such a situation could have been avoided if suitable aids were available and workers had knowledge of their correct use. Poor quality has a direct effect on daily production as well as the profitability of the company, if the quality is such that it downgrades produce into a lower category.

6. DISCUSSION

Within the first part of this report, the concept of occupational safety and health, or ergonomics, has been introduced in only brief detail, sufficient however for people to understand the many different factors which need to be measured. Many of the examples of measurements and reports quoted are from Sweden, as that country currently is considered to be the world leader in this field. The reason for that reputation became very apparent while working at Arbetarskyddsstyrelsen (the Swedish National Board of Occupational Safety and Health). The size and level of funding of that organisation is very impressive.

That is not however the only organisation involved in such work. Others in Sweden include; the University of Forestry at Garpenberg and the Logging Research Foundation. Forest machinery manufacturers also have heavy commitments to ergonomic research specific to forestry. Because of the length of time spent working in Sweden then this overview has had a heavy Swedish influence.

Ager (1982) suggested that there are three levels of development in ergonomics. These are presented below :

Level I	-	Manual techniques under unfavourable socio-economic and climatic conditions
Level II	-	Moderately mechanised techniques under comparatively favourable socioeconomic and climatic conditions
Level III	-	Highly mechanised techniques under favourable socioeconomic and climatic conditions.

Sweden almost certainly fits into Level III, while New Zealand forest industry, particularly the harvesting section, probably fits between Levels I and II. It would be erroneous and irresponsible to suggest that New Zealand's harvesting industry should achieve the same level as that of

Sweden. Many situations exist in Sweden which the author would suggest are "over the edge". That is, workers are conditioned almost to believe that whatever they are doing will eventually lead to some problem or other within the everyday functions of their daily life. By the same token there is no room for New Zealand to think "She'll be right". IT WON'T BY A LONG WAY!!!

Such conditions exist today in Sweden as the result of many years of recognition of the value of the human resource and substantial research and development into methods of improving the worker's environment. Much of it is controlled by legislation which is administered by the inspectorate group within Arbetarskyddsstyrelsen. People employed in that group are specialists in the area for which they are responsible, i.e. forestry inspectors generally have training in forestry, either Jagmaster or Skogsmaster (equivalent of forester or ranger in New Zealand forest industry).

Much of the research in this field now in Sweden is at a much higher level, technically, than what we are ready for in New Zealand. By the same token, significant achievements have been made in improving methods for the collection of base data required for use as a foundation for further work. An example of this is the method of work rate measurement described using the Husky Hunter computer. Research will continue into data collection techniques which are simple, portable, and accurate. Results of such research should be carefully monitored by New Zealand for possible future application.

Part I of the report has illustrated that ergonomics or occupational safety and health is not just accident statistics or whether or not a chainsaw operator wears protective equipment, but rather understanding the many affecting factors encountered in a harvesting operation and the effects they have on the man and productivity. The affecting factors are easily isolated and it's not too difficult to comment on likely effect, subjectively. What is needed, and in fact has been developed, are methods of measuring the effects. In a harvesting operation anything that effects the human resource will in turn effect productivity. Sometimes that effect can be hidden by the addition of an extra man or machine, but in fact that is only compounding the problem, not solving it. By making use of some of the measurement systems suggested in this part, in conjunction with good information feedback, it would not be unreasonable to expect changes to be made. It is important that these systems of measurement and information, which are to be given to the managers and workers, are kept as simple and as free from scientific jargon as possible. An example of this requirement is the fact that for some years now better techniques have been available for chainsaw operators working in radiata thinning and yet the adoption of these techniques has been very slow. That could be a reflection of the conservative nature of the industry, but it is more likely a reflection of management's interest in improving the environment of the worker or failing to fully recognise the real value of the human resource.

Throughout the first part of the report, wherever possible, examples have been given for New Zealand harvesting conditions. The many examples suggest there is considerable research in this field which needs doing, however before going into detail about what work should be done it is necessary to review what has been done in New Zealand in this field. Part II of this report is then a review of the research and development pertaining to the area of ergonomics or occupational safety and health that has been done to date in New Zealand.

PART II

ERGONOMIC WORK IN NEW ZEALAND LOGGING INDUSTRY TO DATE

A REVIEW

INTRODUCTION

In this section the intention is to review what has been done to date as a lead in to the final section on proposed work. The review is by no means complete but is intended as an indication of the level of research carried out to date.

The New Zealand industry has tended to very much follow, as opposed to lead, with developments in ergonomic research. To a large extent that is a good policy and shouldn't change too much apart from some effort being put in to catch up with the rest of the developed world. Currently most changes in New Zealand logging occur as a spin-off of technological developments in other countries whose products are marketed here. There have, however, been several recent (in the past ten years) developments that have significantly improved our ability to better research the needs of the human resource, and more importantly, implement the results of this research in the field, where it is of most use.

Specifically those developments have been :

- the use of consultants to investigate motor-manual systems
- the formation of the New Zealand Logging Industry Research Association
- the formation of the Logging and Forest Industry Research Board.

It is worth repeating at this stage the objectives of the two above mentioned organisations as they are possibly the most influential in this field in New Zealand.

> "LIRA's objective is to improve the efficiency, productivity, safety and profitability of the logging industry." LIRA Annual Report 1984/85

> "If correct work methods were established and then practised throughout the industry, productivity would be improved and the work injuries reduced." From Training the Loggers for Limited Scale Operations, M.J. Newbold, LIRA Seminar 1985.

The remainder of this section then is a chronological account of specific research and development that has occurred.

1972 NORDFOR CONSULTANTS

In 1972, two Nordfor instructors were employed by N.Z. Forest Products Limited to introduce the Nordfor technique of felling and delimbing. That technique involved a change of saw size and bar length. Jonsered 80's with 20 inch bars replaced the

McCulloch 125cc Super Pro with 26 inch bar. The technique difference was considerable in areas of scarfing and backcutting, as well as trimming. Advantages of the Nordfor technique were said to be; increased safety of the saw operator, increased manhour productivity and reduced fatigue due to the use of the smaller, lighter saws.

Lockie (1974) compared conventional and Nordfor felling. The study was unable to draw any significant statistical conclusion on whether the Nordfor technique was faster, however subjective comment from operators said conventional was much better. The report concludes that in 45 year old clearfell stands, trimming is not necessary, and small saws make felling too slow, but that in 30 year old clearfell stands, small saws may be better. The author did however reduce the rest allowance from 36% to 34% due to the advantage of using small saws.

1978/79 - A SURVEY OF N.Z. LOGGING WORK FORCE

As long ago as eight years it was recognised that knowledge of the logging labour was minimal. To improve that, a pilot study was carried out among the Bay of Plenty logging work (Wells, 1980). The objective of the survey was to obtain information on education and training of loggers, skills, accident records, factors which motivate them and their attitudes to the job. The survey involved 125 men which represented about 10% of the logging work force in the Bay of Plenty.

Results from the survey showed that age distribution was heavily skewed to younger workers, almost 70% under 34 years old. Only approximately 10% of those surveyed had received any formal training, with the majority (75%) being either self taught, or learning from an experienced bushman. The present work force was characterised as being of prime physical fitness, poorly trained for their present job, accident prone, liable to show a high rate of turnover and holding their job in relatively low regard. Conversely the loggers had acquired a wide range of skills, enjoyed the outdoors and their ambient working environment and were motivated by a desire to work as opposed to a necessity to work.

Valuable information was gained from this first survey of the logging work force. However, unfortunately, the impetus the survey built up was not capitalised on and little subsequent work has been done.

1979 - THE FELLING BENCH

That work saving device was firstly reported in New Zealand by an operator who had used one in Australia where it had been developed (Higgins, 1979). The bench was designed to reduce the heavy lifting work necessary to present wood for forwarder extraction. Its application to first thinning of P. radiata (small piece size, less than .20 m^3) stands was recognised and such a unit was made up for evaluation in New Zealand.

The bench proved to be an excellent means of obtaining a good delimbing height for the stem, making the task of delimbing less fatiguing and the quality of the resultant delimbing much higher. Studies failed to show a time saving and, at that stage, a labour work input reduction couldn't be satisfactorily established (relied on operator objective assessment only). Thus the felling bench, although admirable for what it was designed, failed. The main complaint about the bench was not so much in its use, but having to carry it into the felling face at the beginning of the week.

1980 - SWEDFOR CONSULTANCY

With financial assistance from the Accident Compensation Commission, LIRA employed a group of Swedish Consultants, Swedfor Consultancy AB, to investigate safer felling and delimbing techniques for New Zealand conditions, LIRA, 1980. The main objectives of the study were to develop and recommend :

- safe felling and delimbing techniques
- safe equipment
- protective clothing
- a training scheme for the recommended techniques

An industry working group was formed to administer and direct the research project. At the end of the investigation the following recommendations were tabled and endorsed by the working group :

- that the technique for felling and delimbing in radiata thinning and in clearfelling of small size conifers, as developed and tested, be introduced on a broad scale (technique based on smaller saws and shorter bars and an ergonomically improved delimbing technique)

- that the techniques currently used in clearfelling radiata old crop were found to be acceptable, providing that existing safety regulations were followed

- that chainsaw operators have made available to them adequate safety equipment including; helmet with muffs and visors, safety trousers and felling aids

- a centralised training of instructors and introduction of vocational training for loggers be introduced.

From this work two key areas have emerged where considerable research effort has been directed with pleasing results, namely Logging Accident Reporting Scheme and manufacture of protective clothing.

1981 - LOGGING INDUSTRY ACCIDENT REPORTING SCHEME

After an initial 15 month pilot trial that scheme was extended to a national basis at the beginning of 1983 (Prebble, 1984). Input into the reporting scheme is reliant on two types of forms - the monthly summary forms which are designed to collect information from companies who already have good internal accident reporting, and the individual accident report forms intended for contractors or independent crews not covered by comprehensive accident reporting systems. All the incoming information is put on computer for storage and subsequent analysis. The main feature of the individual accident report forms has been their simplicity and anonymity.

These statistics have become invaluable in directing research efforts in the area of accident prevention or accident severity reduction. From Table 10 the high number of accidents associated with the felling and delimbing phase (137, slightly over half) has indicated that this is an area in need of immediate attention. The scheme is now running well but the percentage of industry covered is not known. The scheme is still being administered by LIRA, which involves the compilation and sending out of quarterly news bulletins to keep the industry informed.

TABLE 10 : Summary of 1984 Accident Statistics from the Logging Industry Accident Reporting Scheme

Part of Operation	Fatal	Lost Time	Minor	Near Miss	Total
Felling preparation	0	21	8	2	29
Felling	1	52	15	1	67
Limbing and Trimming	0	64	19	4	83
Breaking out, hauling	0	27	15	3	42
Crosscutting	0	8	2	1	10
Skid work	0	55	18	3	73
Loading Truck	0	0	1	0	1
Moving Plant Rigging	0	3	1	1	4
Other	0	19	10	3	29
Unknown	0	2	0	0	2
TOTAL	1	251	89	18	340

1981 - DEVELOPMENT OF LOCALLY MANUFACTURED PROTECTIVE TROUSERS FOR CHAINSAW OPERATORS

An outline of protective clothing requirements for chainsaw users (Prebble, 1981), which among other things include requirements for safety trousers, was responded to by the clothing industry very positively.

Within that outline it was noted that protective trousers should offer the following features :

- provide full ankle to groin protection to the front of the leg
- be lightweight and pliable so as not to bind or chaff or be too hot to wear
- protection must be sewn into position to stop movement around the leg

- reasonably well cut to avoid snagging, and not loose fitting
- should stand brief contact with hot exhaust
- be easily washed and non-shrinkable.

Now, four years later, suitable safety trousers and safety leggings are available, locally manufactured, and slowly finding acceptance. An unfortunate side to this development has been the emergence of sub-standard protectors. As a means of controlling that, an effort is now being made to draw up a New Zealand minimum standard for such clothing.

1984 - HUMAN RESOURCES IN LOGGING

LIRA's annual seminar in 1984 addressed "Human Resources in Logging" (Prebble, 1984). The seminar covered such topics as :

- the resource, estimating future manpower needs, planning, turnover and training
- accident and safety
- safety codes and standards
- ergonomics
- management and motivation
- industrial relations
- training the industry.

In summing up the seminar, it was noted that the seminar was the first major forum at which the logging industry has talked about its people. The basis for projection of future manpower requirements for the industry are shaky, and there was a need to improve forecasts of requirements. Preliminary work done on turnover within the industry was showing that factor to be quite significant, but again little real base information was available. The Accident Reporting Scheme was providing a good base of information on types of accidents, and thus industry's requirements in the field of development of protective equipment. In the area of ergonomics research it was felt that there were two directions the industry could take :

- simple application of principles already established, e.g. machine cab design and layout or promotion of good work techniques, or
- some basic ergonomic research work within the logging industry in New Zealand.

1984 - SELECTED DEMOGRAPHIC AND SOCIAL CHARACTERISTICS OF THE FORESTRY AND LOGGING WORK FORCES, AND COMMENTS ON THEIR POSSIBLE SOCIAL SIGNIFICANCE

This study was carried out by the University of Auckland, Department of Sociology, under contract to the Forest Research Institute (Crothers and Macpherson, 1984). The study was based on census returns from 1971, 76 and 81. The three objectives of the study were to;

- find out the present geographical distribution of forestry and logging work force at the local authority level of analysis
- identify distribution occupations within the industry and recent changes in those patterns
- establish the main sociodemographic characteristics of forestry and logging work forces.

The study showed that the work force employed in the logging and forestry industry was youthful, rural, high proportion of Maori and unskilled.

The following table has been reproduced from the report. It has been suitably modified to include only figures for the logging industry.

TABLE 11 : Occupational Profile 1981

Occupation	Average Age (yr)	% Male	% Wage Workers	% Unemployed	% Over 65
Logging Managers	35.6	100	78.6	0.0	0.0
Logging Supervisors	39.1	95.7	95.7	0.0	0.0
Logging Planner	32.5	100	100	0.0	0.0
Bushmen	29.5	99.4	83.8	6.1	0.2
Skilled Bushmen	32.6	100	79.0	0.0	0.0
Leading Bushmen	34.3	100	100	0.0	0.0
Logging Contractor	36.9	99.4	24.4	1.7	1.5
Other Loggers	32.5	97.7	88.4	2.3	0.8

Source 1981 Census (After Crothers and Macpherson, 1984)

DISCUSSION

As mentioned in the introduction, the Industry has automatically received the benefits of many technological improvements made to hardware in use. A good example of such evolutionary improvements are to be found in chainsaw developments over the short history of its existence. Amongst the professionally used saws, Husqvarna (or saws made by Electrolux group) and Stihl have attained dominance. Both these manufacturers ensure that saws exported are of the highest possible standard, thus ergonomic improvements automatically reach New Zealand.

The work done by the Swedfor Consulting group during 1980 has also undergone considerable further development, mainly in the form of work undertaken by LIRA on organised felling (Gaskin, 1986). That subsequent development was aimed at improving the environment of the breakerout and/or machine operator, realising definite improvements in productivity and quality and thereby potential to reduce the overall logging cost, especially in small piece size radiata thinning operations.

The Logging and Forest Industry Training Board have gone to some lengths to produce easily read pamphlets which describe the right technique that should be used. The certification scheme also run by the L & FITB takes cognizance of improved technique development.

Many pieces of equipment designed to make the logger's job easier, however, have not been well received. Such things as felling levers, pulp hooks and even retractable loggers tapes, although having been readily available for some time, have found little acceptance. To decide why that is so is very difficult, but part of it could be attributed to the fact that often such equipment is introduced into a system where it obviously will not succeed. Then, following a failure, it is subsequently rubbished as being useless.

PART III

PROPOSED HUMAN RESEARCH PROGRAMME

Throughout Part One of this report, numerous examples of where improvements to the logging work environment could be made, were alluded to. The size and relevant importance (in terms of benefits to improving the efficiency, and therefore profitability of logging) of those problems was varied from an easily solved problem, for example crushing undergrowth prior to logging, to major machine design changes. Similar variation could also be seen in the potential cost of research into many problems mentioned.

In the introduction to Part Two, it was suggested that the New Zealand logging industry has tended to follow, rather than lead, ergonomic research. It should be stressed here that this basic philosophy is reasonably sound. Much spin-off from countries more advanced in this field automatically filters through to New Zealand eventually. In the case of improvements to change in design of chainsaws, the benefit occurs relatively quickly, while improvements in machinery design are less quickly seen. That is perhaps a function of the North American influence. Manufacturers in that area don't have as strong a background in ergonomic design as some of the their counterparts in Scandinavia.

As illustrated in Part Two, much research and development has already taken place and work would continue in those areas. For example, the continued collection and analysis of accident statistics is essential in guiding further development in protective clothing, identifying research needs and assessing progress being made. Much valuable work has already been done in motor-manual technique development. Proposed research will be aimed at improving the extension of that development and better quantification of the effects on the worker of such techniques. Work already being undertaken by the Logging and Forest Industry Training Board should be firmly supported by both research organisations and industry, as the Board forms the vital link between research results and industry implementation. The other two higher education institutions, School of Forestry and Forestry Training Centre, already include some basic ergonomics and man management in their curricula. Given the importance of the human resource in the New Zealand logging industry, i.e. motor-manual based, these three training institutions will play a key role in extension of research findings.

KEY PROPOSED RESEARCH PROJECTS

1. One day seminar on importance of ergonomic research.
2. Survey of logging labour force.
3. Ergonomic evaluation of machines used in logging in New Zealand.
4. Work load measurements of various logging tasks.
5. Develop a stratified training programme for forest workers.

6. Effects of age and condition on hand/arm vibration with chainsaws.
7. Study of work postures and effects of those on the worker.
8. Evaluation of whole body vibration in logging machinery.

1. ONE DAY SEMINAR ON ERGONOMIC RESEARCH

The purpose of such a session would be to bring together all those interested in the subject to explain fully the intentions of the programme and to give them the opportunity to modify the programme to suit their particular short and long term requirements. Such a session ideally would see representatives from logging management, all the various training institutions, Timber Workers' Union and individual contractors. As well as those people, an attempt should be made to encourage interested people from the medical profession (e.g. physiotherapists, doctors) who have already expressed interest in logging related injuries and illnesses. After all, these people are in the best position to explain the results of poor working techniques or attitudes.

The broad objective of this seminar would be two-fold.

(a) To impress upon participants that ergonomics is the improvement of efficiency, and therefore productivity, of the human resource. As a result of that improvement there is often a corresponding reduction in occupational injuries and accidents. Ergonomics is not just accidents and protective equipment, but a complex multi-disciplinary science.

(b) To get those same participants to comment on the proposed programme, and after thorough discussion, to support the programme in all ways possible.

Such a seminar should be timed for the second half of 1987.

2. SURVEY OF THE LOGGING LABOUR FORCE

One of the main findings of the 1978/79 survey (Wells, 1980) was the serious lack of good base information on those employed in the logging industry. Even since then other authors (Liley, 1984; Prebble, 1984; Crothers and McPherson, 1984) have all noted a serious deficit in available information. The earlier survey mentioned above provided an excellent launching pad for subsequent work, however for many reasons that impetus was not capitalised on. That survey was unfortunately constrained by time available and thus could only concentrate on the Bay of Plenty which is recognised as not being truly representative of logging in New Zealand. That time constraint posed the additional problem that the sample size was quite small, less than 5% of the national figure.

During the 1990's, it is expected that New Zealand will have the potential to increase its annual volume harvested from 10 million m3 to 20 million m3. At present between 2,500 and 3,500 people are employed to harvest the 10 million m3 (we are not even sure of the exact figure). It would therefore not be unreasonable to expect that a few more people will be needed to make that increased harvesting programme anywhere near feasible. An additional problem will be that many increases take place in areas without a strong logging tradition.

The objectives of such a survey then would be :

(a) To gain base information about the logging labour force to assist direct future ergonomic research.

(b) To use that information to assist in predicting labour requirements and possible means of recruitment.

(c) To assist the training institutions to determine the potential training requirements.

Possibly the best method to organise and conduct such a survey would be as follows :

(i) Obtain a full list of all logging gangs in New Zealand.
(ii) Select randomly from that list a 20% sample, say every fifth gang. That would solve problems of geographic randomising.
(iii) Draw up a questionnaire with the assistance of sociology departments of universities to be used to collect the information.
(iv) Using that questionnaire, interview each selected gang member individually.
(v) Analysis of data collected and reportage. It would be essential that the reportage was placed in the hands of those in the best position to use it. Analysis must be kept as simple as possible.

From such a survey, a better understanding of the following would result; gang/man productivity differences, help in predicting manpower requirements, aspects which motivate loggers, and their reasons for being employed in logging. Knowledge of such factors would assist in recruitment drives. Indications would be shown of what safety equipment is available, what is used and reasons for using/not using it. That would greatly assist manufacturers of such equipment in both development and marketing. Correlations between; accidents and length of service, accidents and payment system, productivity and payment system, accidents and training, productivity and training etc would be able to be drawn and used to highlight areas where more intensive work would be required. For example, if there can be shown a definite reduction in accidents through training, then that is a positive cost benefit of training and would provide those organisations in that field with positive information to support their requirements.

Ideally such a survey should be started as soon as possible in the first half of 1986. (Author's note : this work is already under way.)

3. (a) ERGONOMIC EVALUATION OF MACHINERY USED IN LOGGING IN NEW ZEALAND

Logging machinery used in New Zealand is, almost without exception, imported from North America. Unfortunately little consideration is given to the person who has to operate the machine for up to eight hours per day. Access on and off the machine, seating etc are often very poorly organised. At this stage it is difficult to assess accidents or occupational diseases which these factors directly contribute to. Experience overseas tends to suggest that prolonged operation would lead to severe health problems.

Only one New Zealand study of this nature, concentrating on the design of a logging truck cab, Britton (1981), has been carried out. That study highlighted numerous problems associated with the particular truck studied.

Numerous checklists have been designed for use in evaluating the ergonomics of logging machinery (J.E. Hansson and Pettersson, 1980). A recent survey of rubber tyred skidders in Canada (Webb and Hope, 1983) found that the skidders used were seriously defective in basic operator comfort. The skidder types within that study were similar to those used in New Zealand.

Objectives for Ergonomic Evaluation of Machinery :

(i) To test already developed checklists for use in evaluating logging machinery typically used in New Zealand, and to modify those checklists to a suitable standard where they can be easily applied by machinery purchasers.

(ii) To document the ergonomic standard of logging machinery typical to New Zealand operations.

(iii) To recommend changes to machines/systems to make them more efficient.

In the first instance, the Hansson/Pettersson checklist would be used. A structured format would be developed to work through with each machine type. Things needed to be documented would be :

- machine make and model, machine age,
- description of the system in which it is used,
- modifications which have been made,
- design and layout of controls,
- visibility and seating.

As well as that, each operator should be interviewed, again using a questionnaire approach to find out any changes they would like to see made, any problems they have (injuries) in operating the machine, comments on changing from one machine to another, etc.

From this evaluation it is anticipated that :

(i) A suggested ideal machine would be described. Modifications suggested would then be made to the machine and the effects of those modifications on operator workload and machine productivity would be measured. Such measurement would look at the cost of such design changes.

(ii) Design of an easily used checklist for purchasers of machinery. That checklist would be available to contractors and companies to assist in the evaluation of machines prior to buying.

It is anticipated that this project would be a long term one, lasting for approximately three years and then leading into the next area.

(b) VIBRATION ANALYSIS OF NEW ZEALAND LOGGING MACHINERY

This would commence at the completion of basic machinery design requirements. Although the whole area of damage caused through exposure to whole body vibration is still relatively unknown, it can be reasonably assumed that it is not doing operators any good. More is known about the effects of hand/arm vibration and it is now well recognised that severe damage is caused. Little work has been carried out in New Zealand on such measurements. Again Webb and Hope (1983) examine whole body vibration in this study referred to earlier, and noted very high levels, well in excess of the dose level recommended by the International Standard. These authors made no measurements of hand/arm vibrations.

Research Objective

To document whole body and hand/arm vibration levels on typically used logging machinery in New Zealand. Also to provide detail on factors effecting those levels and recommend means of reducing levels to an acceptable level.

This project would require significant investment in equipment such as vibration measuring gear and signal analysis equipment. It is envisaged that results of such research would be added to the purchasers' handbook.

4. (a) WORK LOAD MEASUREMENTS

The very high work loading associated with motor-manual logging has already been stated. Considerable effort has already been directed into developing techniques to reduce the high loading currently involved in motor-manual felling and delimbing. That work has achieved limited success due to our inability to adequately quantify stated benefits. We have tended to rely on subjective comments from operators, too often research people. It is therefore timely to start looking at a more scientific means of quantifying such benefits and present the results in a way which industry leaders find acceptable.

Research Objectives

(i) To build up a better understanding of workload involved in various jobs in logging, including chainsaw operators, machine operators and breakerouts.

(ii) To use that information to assess the merits of techniques developed.

The structure for such research would be as follows :

(i) Select the operators to participate in the project and thoroughly explain to them the purpose of doing this work.

(ii) Establish the individual operators' linear relationship between pulse rate and workload, using the cycle ergnometer and conversion tables.

(iii) Using telemetry (transmitter/receiver) and data collection unit (Husky Hunter) record work loading of current technique.

(iv) Recommend changes and train operators to competently use the changed technique.

(v) Repeat (iii) above and document changes, if any.

As with the previous project, this area places quite high demands on specialised equipment and trained personnel. Such people are not normally found within the logging industry, so outsiders such as nurses would need to be used for initial pulse rate versus fixed workload measurements. The data collection in the forest, subsequent analysis and reportage/extension could then be done by LIRA research staff.

In terms of convincing people that a particular technique is better for their health, i.e. less fatiguing, this technique would provide invaluable information which could be used in conjunction with productivity information normally collected.

(b) WORK POSTURE MEASUREMENTS

Poor work posture results in unnecessary fatigue at best, severe injury at worse. Little is known about various work postures assumed by operators in New Zealand, but significant work has been done in this area by overseas research organisations. The two areas where work posture is a particular problem in New Zealand are :

(i) The posture assumed during delimbing, especially where the operator trims by walking along the top of the log, and is bent almost double to delimb; and

(ii) The twisted posture adopted by machine operators when winching in a drag of logs, or reversing the machine to pick up a drag.

In both those instances, the operators place themselves at considerable risk of injury from prolonged use of such posture.

<u>Research Objectives</u>

(i) To document types of postures assumed by workers in the logging industry.

(ii) Using bio-mechanics to illustrate loadings on various parts of the body when using those postures, giving examples of the results of prolonged use if possible.

(iii) Develop better techniques to avoid the most damaging postures.

(iv) With aid of physiotherapists, design posters, advertising articles etc to draw attention to the problems.

Research would be structured in the following manner :

(i) Establish which postures have the potential for most damage for the two main employment groups - chainsaw operators and machine operators. That would require the assistance of physiotherapists, or similarly qualified people.

(ii) Having established the worst postures, then study operators to determine the frequency with which they are in that posture.

(iii) Using bio-mechanics, establish the potential for loadings on various parts of the body.

(iv) Documentations and recommendations for improvements.

Two important factors need to be measured - the work posture itself and the frequency with which it is assumed. The first factor, the work posture, can be measured most effectively by placing a grid arrangement behind the operator of a known scale and using still photography to record that. Once scale adjustment has been made, it becomes a relatively simple series of calculations to work out the loading on various parts of the body. The second aspect is much simpler. Once the postures of interest have been established, an activity sample will give percentage of time each posture is assumed. A more accurate picture can be worked out using continuous filming by means of a video camera. A full study could also be done while using the video.

5. THE EFFECT OF AGE AND MAINTENANCE ON CHAINSAW VIBRATION SEVERITY

The best known occupational disease in the logging industry is that of white finger affliction. White finger is caused by vibration, and is thought to be worse in cold climates, but it is common amongst New Zealand chainsaw operators. Considerable research and development into reducing vibration in chainsaws is undertaken by the main manufacturers of professional saws. All the safety factors built into the saw are only as good as the attention they are given after they have been purchased. Many operators still use saws with defective anti-vibration mounts for various reasons.

Research Objectives

To quantify and document the effect of age and maintenance on chainsaw hand/arm vibration severity.

The structure of such a research project would be as follows :

(i) Approach a sample of chainsaw users and explain what is required of them if they participate in the project.

(ii) The user notifies the researcher when he is about to purchase a new saw. The vibration levels on the saw are measured while it is new.

(iii) Vibration levels are then measured at monthly intervals for the life of the chainsaw. At each measurement time notes are made about the condition of the saw, i.e. comments on saw appearance, function of mounts, state of chain and bar etc.

(iv) A form is also retained by the owner/operator on which he details repairs made to the chainsaw during its life.

Information from such a project would be used to explain to operators the potential risks they run in allowing the condition of their chainsaw to become poor. Such a project should increase operator awareness of the potential benefits of good maintenance in reducing the likelihood of them being exposed to high levels of vibration. Such information would also be of direct use to any forest worker training being done.

DISCUSSION

From the attached programme, three areas have been omitted from this detailed comment on each proposed project. Those three are possibly the most important, but will not have such a structured approach as the specific projects.

The first area is that of the one-day seminars. One of these has been scheduled for each year (except 1990 at this stage). The purpose of such seminars is to keep the industry informed about what is happening during the projects, or at the end of the project, when it provides a forum for discussion of results. Those one-day seminars will be critical in assuring the continued support of senior management. They will also give an opportunity to involve some of the specialised outsiders, who will be used in some of the projects, and for them to become more familiar with people from the industry and work being done by the industry. Some of the physiotherapists around Rotorua have already expressed an interest in working alongside the logging industry (Sweetman, 1984). To assist in reducing the risks that operators are exposed to, it would be advisable that their interest is capitalised on while it continues to exist. The seminars also give industry an opportunity to comment on the direction of the human resource research, and to have considerable say in that research.

The second area not covered is that of education. That area would be further divided into two separate groups - management education, and forest worker education. Already some effort has been put into the area of ergonomics or human resource discussions in recognised management education structures (University of Canterbury School of Forestry and Forestry Training Centre, Rotorua). Both these institutions teach basic theories of motivation, and the University also offers an introduction to ergonomics. Much of the research results from these projects could be incorporated into those two courses and provide better New Zealand related information. It is seen that research results would be continually provided to those groups, and the respective people responsible for such education would be automatically invited to the one-day seminars.

Conversely logger education is notable because of its absence. Currently logger education is offered on a very limited scale by the major companies, but that only covers the Bay of Plenty. Most often that education consists of no more than two days to one week of instruction. The Logging and Forest Industry Training Board is slowly starting to make some attempt to cater for education needs outside the Bay of Plenty. To a certain extent however their efforts in the past have been somewhat frustrated by a lack of funds. (Their efforts during the past two years have been divided between "forest skills" and logging.) The proposed harvesting expansion due to start in the mid 1990's, is not far away. Many questions are being asked about labour requirements. Now is the time to start answering these questions. Industry must seriously look at a concept of a centralised logging and silvicultural workers school where companies from all over New Zealand could draw labour. I believe that discussions regarding setting up such a school should be given immediate attention or we will be logging old crop for the rest of our lives.

Research results and documentation then will need to be targetted to these two education levels, as well as for industry itself. That may well result in a certain amount of duplication. However the benefits should be obvious enough for that duplication to be seen as being well worthwhile. The importance of education can't be over-stressed, especially in this field of human resources where so many unknowns exist.

The final area is that of continuing work that has already been started, such as the Accident Reporting Scheme, development of protective equipment, development of techniques etc. Much of that work will inevitably contribute to the direction of the ongoing research, especially the Accident Reporting Scheme. In terms of monitoring overseas developments, it is hoped that at least one digest per year on a relevant overseas project could be produced.

To sum up then, it has already been stated that the New Zealand logging industry has tended to follow rather than lead in the field of human resource research. Given our geographical location, and industry size, it is probably advisable that this concept continues. The research cited in the preceding section is basically all documentation research aimed at giving us the chance to catch up with some of the more developed countries in this research field. A major advantage of this type of research approach is that it allows us to assess the progress being made overseas, and to pick out only the best parts of it, thus avoiding costly mistakes. A further advantage is that pioneer research in this field can be extremely expensive and time consuming. Such research should be avoided if at all possible.

New Zealand has a totally unexploited labour force which by world standards is still relatively cheap. If we are to make the most of this valuable resource then time and effort must be put into it soon. The programme outlined is an ambitious one, but the possible benefits should be clear to industry managers. The potential to improve our efficiency is huge.

BIBLIOGRAPHY

Ager, B. (1982). Improving Health and Safety conditions in Forestry . - Garpenberg, Sweden : Sveriges Lantbruksuniversitet Institutionen for Skogsteknik - Stencil (Sveriges Lantbruksuniversitet Institutionen for Skogstenknik) 151/1982.

Astrand, I. (1960). Aerobic work capacity in men and women with special reference to age. Acta physiol. scand. 49, Suppl. 169.

Astrsand, P.O. (1952). Experimental studies of physical working capacity in relation to sex and age . Munksgaard, Kopenhagen.

Astrand, P.O.; and K. Rodahl (1977). Textbook for Work Physiology : Physiological bases of exercise - 2nd ed. - N.Y. : McGraw-Hill.

Bostrand, Lisbet (1985). Ergonomics in forestry - FAO Advisory Committee on Forestry Education. 13th Session, Mexico City, Mexico, 26-28 June 1985.

Bostrand, Lisbet. Handbook in Ergonomics for forestry and forest industries in developing countries. In prep.

Britton, J.D. (1981). An ergonomic appraisal of a logging truck cab. A research report presented in partial fulfilment of the Diploma of Business and Administration in the Faculty of Business at Massey University, New Zealand.

Carter, Ned; and Ewa Menckel (1985). Near accident reporting; a review of Swedish research - Journal of occupational accidents 7 : 41-64.

Crothers, Charles; and Cluny Macpherson (1984). Selected demographic and social characteristics of the forestry and logging workforces and comments on their possible social significance. - University of Auckland. Dept of Sociology - Working papers in comparative sociology; no. 13.

Diffrient, Niels, Alvin R. Tilley and J.C. Bardagjy; with Henry Dreyfuss Associates : (1974). Humanscale 1/2/3 - Cambridge, Mass : MIT Press.

Evans, R.J. (1984). Chainsaw testing and selection. - Rotorua : LIRA - Technical release (New Zealand Logging Industry Research Association) V.6, no. 11.

Gaskin J.E. (1983). Organised felling for thinning radiata pine. - Rotorua : LIRA. - Report (New Zealand Logging Industry Research Association) V.8, no. 12.

Gaskin, J.E. (1984). Progress in New Zealand. - In Human Resources in Logging (1984 : Rotorua) - Proceedings of a seminar held in Rotorua June 1984. - Rotorua : LIRA. p. 160-164.

Graf, O. (1954). Studien uber Fliessarbeitsprobleme an einer praxisnahen Experimentieranlage. Forschungsbericht d. Wirtschafts-und Verkehrsministerium Nordrhein-Westfalen Nr 114 und Nr 115. - Koln and Opladen : Westdeutscher Verlag.

Grandjean, E. (1980). Fitting the task to the man; an ergonomic approach - London : Taylor and Francis.

Griffin, Michael J. State of art report on whole-body vibration research. - Highfield, Southampton : Institute of Sound and Vibration Research, University of Southampton.

Hagberg, Mats (1981). On evaluation of local muscular load and fatigue by electromyography. - Umea, Sweden : National Board of Occupational Safety and Health. Work Physiology Unit. - Arbete och halsa; 1981:24

Hansson, Jan-Erik; and Bo Pettersson (1980). An ergonomic checklist for transport and materials - handling machinery. - Stockholm National Board of Occupational Safety and Health.

Hansson, Jan-Erik. (1969). Physiological studies aid work measurement. - Industrial Engineering (Sept 1969) : 29-33.

Hettinger, Th. (1960). Muskelkraft bei Mannern und Frauen. Zbl. Arb. Wiss 14, : 79-84.

Higgins, G. (1979). The felling bench. - Rotorua : LIRA. - Technical release (N.Z. Logging Industry Research Association); V.1, no. 5.

Horgan, G.P. (1984). The cost of logging accidents. - In Human Resources in Logging (1984 : Rotorua) - Proceedings of a seminar held in Rotorua June 1984. - Rotorua : LIRA. p. 83-89.

Human Resources in Logging (1984 : Rotorua). Proceedings of a seminar held in Rotorua June 1984 / prepared by R.L. Prebble. - Rotorua : N.Z. Logging Industry Research Association, 1984.

International Organisation for Standardisation. (1984). Acoustics - measurement at the operator's position of airborne noise emitted by chainsaws. - ISO Standard 7182.

International Organisation for Standardisation. (1974). Guide for the evaluation of human exposure to whole-body vibration. - ISO Standard 2631.

International Organisation for Standardisation. (1984). Guildelines for the measurement and the assessment of human exposure to hand-transmitted vibration. - Draft ISO Standard ISO/DIS 5349.2.

Iskander, A. (1968). Ueber den Einfluss Von Pausen auf das Anlernen Sensumotorischer Fertigkeiten. Arbeitswissenschaft und Praxis, Band 6, Beuth-Vertrieb, Verlin Koln Frankfurt/m.

Kilbom, Asa, Jan Persson and Bjorn Jonsson (1985). Risk factors for work related disorders of the neck and shoulder - with special emphasis on working postures and movements. - Solna, Sweden : National Board of Occupational Safety and Health, Work Physiology Unit.

Kjellberg, A; and B.O. Wikstrom (1985). Subjective reactions to whole-body vibration of short duration. - Journal of Sound and Vibration v.99, no.3 : 415-424.

Liley, W.B. (1984). The Igland hauler. - Rotoura : LIRA. - Report (New Zealand Logging Industry Research Association); v. 9, no. 8.

Liley, W.B. (1984). The importance of labour turnover in the logging industry In Human Resources in Logging (1984 : Rotorua) - Proceedings of a seminar held in Rotorua June 1984. - Rotorua : LIRA. p.39-53.

Lockie, I.J. (1974). A comparison between the Nordfor tree felling technique and the conventional tree felling technique used in Kinleith forest. - Christchurch : University of Canterbury. Thesis.

Murrell, Hywel (1965). Ergonomics : man in his working environment. - London : Chapman and Hall.

New Zealand Logging Industry Research Association. Annual Report 1984/85.

New Zealand Logging Industry Research Association and Swedforest Consultancy AB (1980). Development of safe felling and delimbing techniques with chainsaws. - Rotorua : LIRA. - Project report (New Zealand Logging Industry Research Association) 14.

Newbold, M.J. (1983). The Logging and Forest Industry Training Board. In Research and Development in Tree Harvesting and Transportation (1983 : Rotorua) - The proceedings of a seminar held in Rotorua June 1983. - Rotorua : LIRA, 1983. p.245-247.

Nordfor Training : the forest consultant that takes it down to the working man. - Huskvarna, Sweden : Nordfor Training.

Ostberg, Olov (1980). Risk perception and work behaviour in forestry : implications for accident prevention policy. Accid. Anal. & Prev. v.12 : 189-200.

Prebble, R.L. (1981). Criteria for protective clothing for chainsaw operators. - Rotorua : LIRA. - Report (New Zealand Logging Industry Research Association) v.6, no.3.

Prebble, R.L. (1984). A review of logging accident statistics in New Zealand. In Human Resources in Logging (1984 : Rotorua) - Proceedings of a seminar held in Rotorua June 1984. - Rotorua : LIRA. P.65-71.

Sass, R. and R. Butler (1978). The accident proneness theory : a dead horse that won't lie down. - Regina, Canada : Saskatchewan Dept. of Labour, Occupational Health and Safety Branch.

Statens Maskinprovningar (1984). Series testing of chainsaws 1984. - Uppsala, Sweden : Statens Maskinprovningar. - Report (Statens Maskinprovningar) 2924.

Sundstrom-Frisk, Carin (1984). Behavioural control through piece-rate wages. - Journal of occupational accidents v.6 : 49-59.

Sweetman, Karen (1984). The logger's back - a physiotherapist's impression. - Rotorua : LIRA. - Technical Release (New Zealand Logging Industry Research Association): v.6, no.9.

Tegmyr, Mats (1985). Better work study techniques in forest operations. - Garpenberg, Sweden : Swedish University of Agricultural Sciences - College of Forestry.

Wallace, Ian (1984). A preliminary survey of skid accidents in New Zealand. - Christchurch : University of Canterbury. Thesis.

Webb, R.D.G. and P.A. Hope (1983). Ergonomics and skidder operations in Northern Ontario : a preliminary investigation. - Hull, Quebec: Canadian Forest Service, - Information report DPC-X (Canadian Forestry Service); 15.

Wells, G.C. (1980). A survey of the N.Z. logging workforce. - Rotorua : LIRA. - Project report (New Zealand Logging Industry Research Association); 11.

Wessels, L. (1985). Personal communication.

Wigaeus, Eva; and Ann-Sofie Ljungberg (1982). Bestamning av fysisk arbetsformaga - cykelergometertest. - Stockholm : Arbetarskyddsstyrelsen.

Wigaeus - Hjelm, Eva and Claes Frisk (1985). Physical strain on Vietnamese forest workers. - Stockholm : Arbetarskyddsstyrelsen - Undersokningsrapport; 1985:5.

Zohar, Dov,; Alexander Cohen and Naomi Azar (1980). Promoting increased use of ear protectors in noise through information feedback. - Human factors v.22, no.1 : 69-79.

APPENDIX 1(A)

Examples of Vibration Recording Forms

The two forms in this Appendix are examples of a format used in vibration studies to convert dB - a non linear measurement - to m/s^2, and to calculate the maximum permissible time the machinery could be used before the risk of damage occurs. The time limit is based on the ISO standards.

FORM I

This form was developed by the staff of Arbetarskyddsstyelsen and contains normal information one would expect to find on such a recording form, description of equipment being measured, measuring point, accelerometer size used, etc. A correction needs to be made for such things as accelerometer size, measuring time if less than 60s.

Information included on the bottom half of the form is :

- Test number (Prov. No.)
- Measuring time in seconds (Mat tid s)
- Average loading dB (av last dB)
- Correction for hand/arm vibration - 20dB
- Correction for damping of the recorder if it occurs - Ki,d
- Correction for accelerometer size (Ka dB)
- Correction for time if other than 60s (Kt dB)
- Corrected values in dB and m/s^2 (Korrigerat varde dB m/s^2)

FORM II

This is the form available from a supplier of hand/arm vibration measuring equipment. As well as information described for the previous form, it also includes :

- Measurement point (Mat Pkt), in this case measurements were taken at two points on the equipment - A1, A2
- Vibration direction (Riktn.), expressed as Z_h
- Time in hours (T h) that the machine could be safely used
- Quick dB - m/s^2 conversion scale (Snabbskala) at the bottom of the page

PROTOKOLL FÖR VIBRATIONSMÄTNINGAR MED B & K 2513 Blad ___

Sign ______ 19__-__-__ kl____

VERKTYG, typ ______________________ Serienr ____________

TILLBEHÖR

1	2	3

MÄTPUNKT/RIKTNING

1	2	3

ACCELEROMETRAR

A	B	C
Cs = 0·122 pC/ms^{-2}	Cs = ____ pC/ms^{-2}	Cs = ____ pC/ms^{-2}
k_a = ____ dB	k_a = ____ dB	k_a = ____ dB

KORREKTIONER / OMRÄKNING

.. för instrumentet vid H/A - mätning	.. om acc känsligheten Cs mätt i pC/ms^{-2} är ≠ 1	.. om mättiden t mätt i sekunder är ≠ 60	.. från acceleration i dB till ms^{-2}
k_i = - 20 dB .. för ev dämpsats k_d = + ____ dB	$k_a = 20 \log \frac{1}{Cs}$ dB	$k_t = 10 \log \frac{60}{t}$ dB	$a_{ms^{-2}} = 10^{(\frac{a_{dB}}{20} - 6)}$

Prov nr	Till be hör	Mät pkt	Acc nr	Fp	Arbete, anm.	Mät tid s	Av läst dB	$k_{i,d}$ dB	k_a dB	k_t dB	Korrigerat värde dB	Korrigerat värde ms^{-2}
#1						60	143	-20	18·3	0	141·3	11·22
						60	143	-20	18·3	0	141·3	11·22
#2						60	121	-20	18·3	0	119·3	0·92
						60	122	-20	18·3	0	120·3	1·00
#3						60	130	-20	18·3	0	128·3	2·60
						60	130	-20	18·3	0	128·3	2·60

Brüel & Kjær

VIBRATIONSMÄTNINGSPROTOKOLL

Vibrationsbedömning av handtag/verktyg

Mätobjekt: .... Serienr: ....

Mätutrustning
2512 ☐ 2513 ☐
Acc Typ: ....
Ser.nr: .... S: .... pC/ms^{-2}

Företag: ....
Avd., Lokal: ....
Mät.datum: .... kl. ....
Mät av: ....

Checklista
Inställningar
etc.:

2513:

Relevanta inställningar vid hand-arm bedömningar

Acc. ☐ 1 km/s² ☐ 100 m/s²
Vel. ☒ 100 mm/s ☒ 10 mm/s

Sev. ☐
☒ H/A ◯ ☐ Lin

RMS ☐ Max ☒ 1 s
Peak ☐ ☒ L_{eq}

—alternativ—

2512:

Hand-Arm
☒ x 1
☐ x 2
☐ x 3
☐ x 4
☐ x 5

Mätområden-utvärdering:

V^{*}(dB) = (A-K) dB
A = avläst dB-värde
K = korrektion
V = 20 log a/10^{-6}

$a = 10^{(\frac{V}{20}-6)}$ m/s²

Beräkning av K: K = ... dB

2512 (gäller dig-display) o. 2513 **utan** laddn. adapt WB 0726

$K = 20 + 20 \log S$ (pC/ms^{-2}) dB

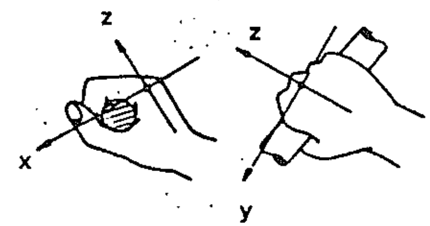
2513 med WB 0726 (2512 analoga instrumentet)

$K = 20 \log S$ (pC/ms^{-2})

MÄTRESULTAT

Mätn. nr.	Mät pkt	Riktn.	Driftsförhållande, varvtal etc.	Mät tid	A dB	K dB	V dB	a m/s²	T h	(Peak dB)
1-1	A_1	Z_h		60	134	10.76	123.2	1.54	14.34	
1-1	B_1	X_h		60	143	10.81	132.2	4.20	1.93	
1	C_1	Y_h		60	139.6	1.73	137.9	7.89	0.55	
1	A_2	Z_h		60	133.5	10.76	122.7	1.41	17.0	
1	B_2	X_h		60	140.4	10.81	129.6	3.08	3.58	
1	C_3	Y_h		60	138.1	1.73	136.4	6.63	0.77	

Definierade riktningar enl. ISO/DIS 5349 samt ASS-förslag



Föreslaget gränsvärde (ASS):

$a = \sqrt{\frac{34}{T}}$ $\left[T = \frac{34}{a^2}\right]$

a = högst av a_y, a_x el. a_z (m/s²)

T = max. daglig exponeringstid (tim)

Snabbskala dB – m/s²

V	90 dB	100 dB	110 dB	120 dB	130 dB	140 (dB re. 10^{-6} ms^{-2})	150 dB	160 dB	170 dB
a	0,0316 · 0,05 ms^{-2}	0,1 · 0,15 · 0,2	0,3 · 0,5 ms^{-2}	1,0 · 1,5 · 2	3 · 4 · 5 ms^{-2}	10 · 15 · 20	30 · 40 · 50 ms^{-2}	100 · 150 · 200	250 · 316

Utv.dat. .... Sign. ....

APPENDIX 1(B)

International Standards Organisation - Standards for Whole Body Vibration

The two tables included in this Appendix are reproduced from the ISO Whole Body Vibration Standard. They give acceleration limits (m/s^2) as a function of freqency, and exposure time, where exposure time is "fatigue decreased proficiency boundary". Considerable debate exists around this standard currently, but it is in force.

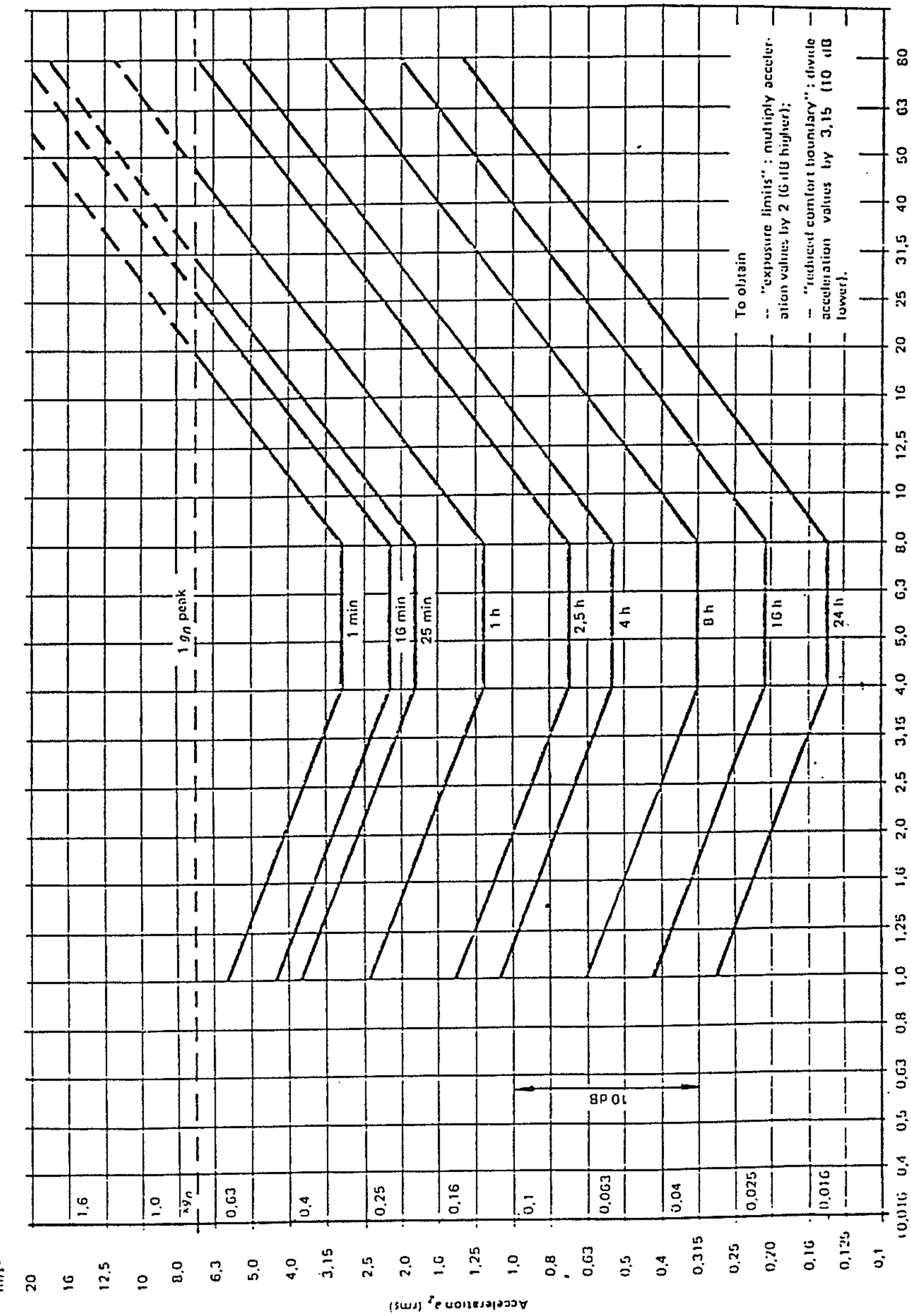


FIGURE 2a – Longitudinal (a_z) acceleration limits as a function of frequency and exposure time; "fatigue-decreased proficiency boundary"

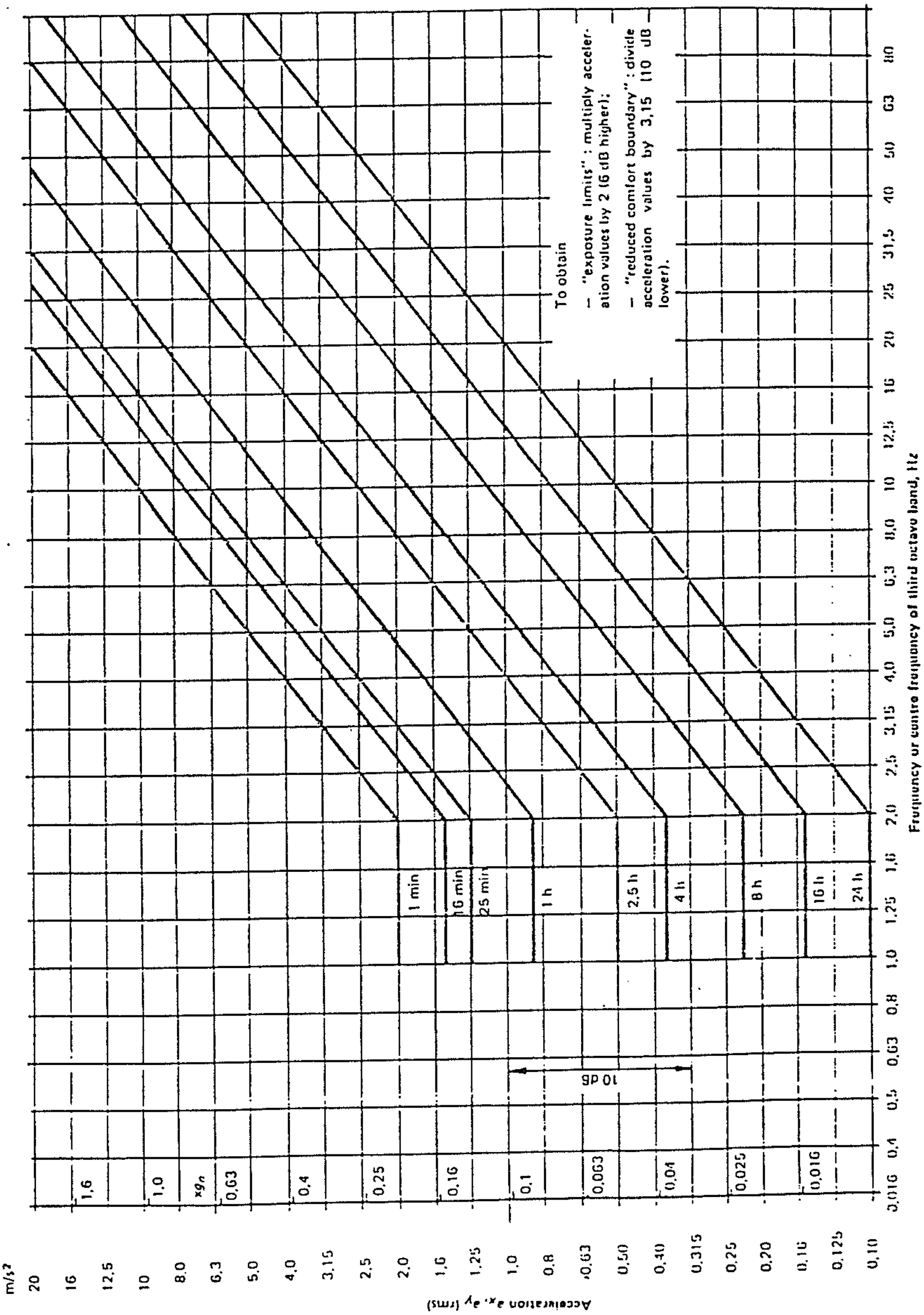


FIGURE 3a — Transverse (a_x, a_y) acceleration limits as a function of frequency and exposure time; "fatigue-decreased proficiency boundary"

APPENDICES 2(A) & 2(B)

Examples of Chainsaw Evaluations

These two appendices are examples of the type of consumer chainsaw testing being carried out by two organisations from two countries. Neither is the full test, but a sample included to give an indication.

APPENDIX 2(A)

Testing as done by the N.Z. Forest Service. Note that the noise level reading under load ("At WOT Cutting") well exceeds the limit of 85 dB as per the ISO standard. Two other important "ergonomic features" are - Muffler Exhaust position and Exhaust direction.

APPENDIX 2(B)

Testing as done by Statens Machingprovningar, Sweden. This test sheet also indicates a chain brake stopping time. It is also interesting to note the different method of expressing vibration - Newtons. Unfortunately there is little uniformity in reporting vibration.

TABLE 2 CHAINSAW TEST RESULTS 1984

CLASS 1B, LIGHT DUTY, 55-69CC, 6-7KG, BARE WEIGHT, 40CM GUIDE BAR

		OLEO-MAC 264	HUSQVARNA 266	JONSEREDS 630	STIHL 038 AVE	ECHO 610 EVL	ECHO 660 EVL	McCULLOCH PRO MAC 655	PIONEER P42
Cylinder Displacement	cc	59.	66.	62.	67	61	64.2	60.	65.
Weight, All up, Fueled	kg	8.65	8.05	7.95	8.88	8.85	8.83	9.05	9.95
Bare, No Bar	kg	6.48	6.06	6.04	6.65	6.98	6.92	7.14	7.59
Bar Clear Length	cm	46.	38.	38.	43.	36.	36.	38.	46.
Sprocket No. of Teeth		7.	7.	7.	7.	7.	7.	7.	8.
Fuel Capacity	Litres	0.69	0.74	0.78	0.69	0.65	0.65	0.45	0.81
Peak Power									
Power	kW	2.47	2.90	2.73	2.74	2.39	2.31	2.07	3.32
At RPM		8000	8500	8000	9000	8000	7500	7000	8600
Fuel per hour	Litres	1.92	1.87	1.76	2.26	1.93	1.93	2.55	2.49
Tank run time	Mins	21.56	23.74	26.59	18.32	20.21	20.21	10.59	19.52
At 8500 RPM									
Power	kW	2.38	2.88	2.70	2.67	2.39	2.17	1.73	3.32
Fuel per hour	Litres	2.00	1.87	2.15	2.32	2.12	1.93	2.89	2.49
Tank run time	Mins	20.66	23.72	21.73	17.88	18.36	20.19	9.36	19.52
At 9500 RPM									
Power	kW	2.17	2.75	2.34	2.56	2.00	2.00	1.31	2.91
Fuel per hour	Litres	2.14	2.07	2.35	2.34	2.43	2.00	2.86	2.92
Tank run time	Mins	19.33	21.42	19.90	17.71	16.05	19.52	9.43	16.67
Noise Level									
At WOT Cutting	dBA	108.3	106.7	103.7	105.6	105.3	110.3	113.7	106.3
At Idle	dBA	82	84	80.3	80	91	83	95	87
Muffler Exhaust									
Volume	cc	396	350	408	432	195	254	-	405
Position		Front	Front	Front	Front	U/side	U/side	-	Side rear
Exhaust Direction									
Horizontal (Bar at 0°)		0	45RT	45RT	90RT	90RT	130rt	-	45RT
Vertical (Hor at 0°)		45	0	0	0	45	0	-	0

Table 4. Noise level, [illegible] vibration forces, chain brake [illegible] time [illegible]
is given those values measured in the earlier type testing.

Saw	Noise level dBA		Vibration before operational testing, N		Chain brake time (longest 1/100 s)			Kick back
m/s²)	cross cutting	racing (full throttle)	front handle	back handle	before op-test	after op-test	type test	
			I-II	I-II				
Echo 360 EVL	104 (104)	105 (103)	8-10 (8-9)	8 (7-10)	6-7	5-8	(5-9)	32
Echo 440 EVL/EVLH	103.5 (104)	103.5 (104)	20-22 (17-21)	14-15 (8-13)	5-9	6-7	(3-7)	22
Husqvarna 50 Rancher	100 (98-99)	101-104 (100)	11-13 (10-12)	6-10 (13-15)	5	8-10	(3)	30
Husqvarna 238 SG/SE	101.5 (101.5)	100.5 (101.5)	10-11 (10-11)	4-6 (4-6)	4-6	6	(4-6)	14
Husqvarna 154 SG/SE	104 (102-104)	106 (105)	12-14 (6-8)	11 (5-10)	4	11	(3-4)	24
Jonsered 420	102-106 (102)	105 (102-105)	17-19 (10-17)	6-8 (5-13)	4-8	8-9	(3-8)	1[illegible]
Jonsered 520 SP	107.5 (100-102)	104.5 (101-102)	17-22 (11-17)	19-23 (16-19)	3-4	5	(4-5)	26
Jonsered 490	108 (104)	103 (101-102)	13 (14-16)	11-13 (18-21)	7	11-14	(4-7)	3[illegible]
Jonsered 630	102 (102)	105 (105)	15-16 (9)	14-15 (8)	7-10	10-13	(9)	2[illegible]
Partner 400	97.5 (97)	102 (100-102)	6 (6-7)	6-7 (7-8)	5	8-10	(4-5)	1[illegible]
Partner 500	105 (101-103)	104 (100-101)	13-18 (13-15)	13-16 (9-22)	8-9	7-14	(6)	3[illegible]
Partner 5000 Plus	107 (104-105)	103 5 (102-103)	12-14 (10-13)	11-16 (11-13)	7-8	6	(6)	3[illegible]
Stihl 024 Plus	103 (101-102)	102 (100-101)	12-13 (13-15)	12-16 (12-13)	4	10	(3-4)	7

*) Total tests (of 40) where the saw reaches into the protection zone with a rotating chain.

F = m · a
wtm = kg.

APPEN
2(B)

APPENDIX 3

Basic Rules for Workload Testing

1. No heavy physical activity the day of, or hours before, the test.

2. Leave at least one hour after a meal or 3-4 hours after heavy activity before starting the test.

3. No smoking for one hour before the test. Coffee will also effect the pulse rate so should be avoided.

4. Do not attempt to test anyone with fever, infection, or heart disease.

5. Make sure the test person is wearing light clothing, that the air temperature is 18°C, and make use of a fan for some breeze.

6. Test the same person at the same time of the day under similar conditions.

7. Do not stress the test person, ensure a quiet environment. Only the test person and the person monitoring the test in the same room.

8. Make sure that the test person understands what is to be done and ensure that they are put at ease.

APPENDIX 4

Example of Heart Rate Recorded During Felling and Delimbing

Sample printout of Husky Hunter system of measuring workload. Only ten lines of data are included as it is only for an indication of the type of information available with this system.

NR	AC	PR
61	6	123
62	6	118
63	3	113
64	5	152
65	7	99
66	7	108
67	5	129
68	5	139
69	6	92
70	1	92

KEY : NR = line number
AC = activity
PR = pulse rate
1 = walk
2 = clear butt
3 = fell
4 = push
5 = trim
6 = bunch
7 = refuel
8 = rest

During this recording of workload an activity sample was also done so the various heart rates could be related to tasks being performed at the time of measurement, that is summarised below :

ID CODE	OCC.	%	HEART RATE	HEART RATE STD
1	12	17	121	16
2	0	0	0	0
3	11	15	114	35
4	0	0	0	0
5	24	34	105	24
6	20	28	126	11
7	2	3	125	37
8	2	3	68	5