Ergonomic guidelines for forest machines

Swedish National Institute for Working Life
SkogForsk (the Forestry Research Institute of Sweden)
The Swedish University of Agricultural Sciences

SkogForsk
– The Forestry Research Institute of Sweden

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This handbook has been produced jointly by SkogForsk (the Forestry Research Institute), the National Institute for Working Life and the Swedish University of Agricultural Sciences. The editorial team included **Sten Gellerstedt**, **Rolf Almqvist**, **Monica Attebrant**, **Dag Myhrman**, **Bengt-Olov Wikström**, and **Jørgen Winkel**.

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Foreword

Ergonomic guidelines for forest machines is a revised version of *An Ergonomic Checklist for Forestry Machinery,* which has been used in Swedish forestry since 1969 and revised several times. Representatives of forestry and research in Denmark, Finland, Norway and Sweden agreed in 1995 to compile and publish a set of ergonomic guidelines for forest machines.

Sten Gellerstedt of the Swedish University of Agricultural Sciences and Dag Myhrman of SkogForsk were appointed as project leaders, and Sten Gellerstedt and Rolf Almqvist of Garpenberg Utveckling AB were chiefly responsible for providing the text and graphic support for the publication. Monica Attebrant, Bengt-Olov Wikström and Jørgen Winkel at the National Insitute for Working Life were members of the working group and also compiled the scientific information for the revision.

Tore Vik of the Norwegian Forest Research Institute, Hannu Tapola of the Ministry for Social Affairs and Health in Finland, and Ebbe Bøllehus of the Danish Forest and Landscape Research Institute were members of a Scandinavian working group and also coordinated the work on the ergonomic guidelines in their respective countries. Reference groups in Scandinavia, consisting of manufacturers, buyers, and users of forest machinery, offered views and contributed from their experience. The work was monitored by the IUFRO (International Union of Forest Research Organizations) ergonomics group.

One of the objectives of the project was that the *Ergonomic Guidelines* handbook should find widespread acceptance and that the manufacturers would follow the guidelines when building new machines. However, the agreement of buyers, sellers and users to follow the recommendations in this document is on a purely voluntary basis.

The project was financed by the National Institute for Working Life in Sweden, the Swedish Agricultural Accident Insurance Fund, SkogForsk and the Swedish University of Agricultural Sciences (SLU). The Norwegian Development Fund for Forestry financed the scientific input to the section on lighting. Participation in the Scandinavian group and the reference groups was financed by the participating organizations.

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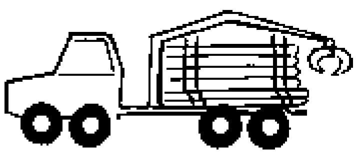
Introduction

The purpose of *Ergonomic guidelines for forest machines* is to provide guidance on ergonomic matters for manufacturers, buyers and users of forest machines in the hope that it will encourage the development of safe forest machines that are easy to use and maintain. This, in turn, offers the machine operators a better chance to preserve their health and general wellbeing, and also to secure a good income. The advice given is based on sound knowledge and experience of the physiological, psychological and social aptitude of people for using and maintaining off-road machines.

Ergonomic Guidelines covers all cab-equipped off-road machines that weigh more than two tonnes and are used in forestry—which means that such machines as excavators and farm tractors are also included. The guidelines largely specify the functional criteria to be met by the design of the operator's workstation, the control and operation of the machine and its equipment, and maintenance procedures.

A machine manufacturer can use the *Ergonomic Guidelines* handbook to find guidance on the sort of criteria that a forest machine must meet, based on the operator's needs when working in different conditions and environments. Similarly, a user can assess a machine to find out how, where and by whom it can be used or in order to determine which aspects should be given priority in an overhaul of the machine.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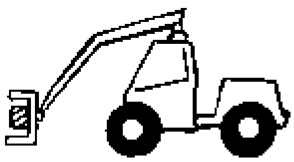
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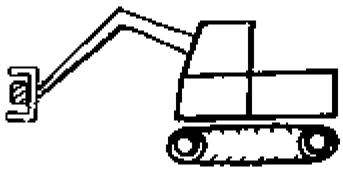
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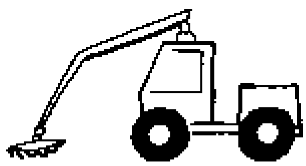
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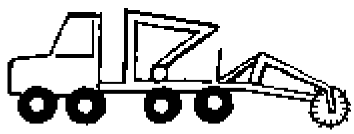
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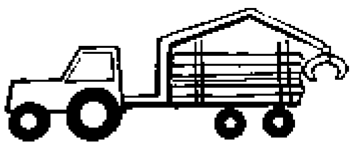
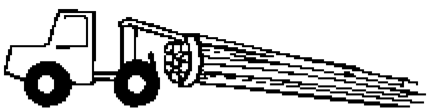

Agricultural tractor for forest work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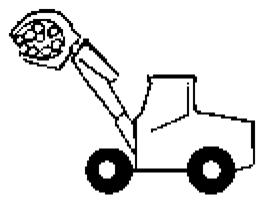

Loader

Scientific base

The *Ergonomic Guidelines* handbook is based on a comprehensive review of the science and experience in the field. For each section, researchers have compiled the information available on safety, health, wellbeing, ergonomic guidelines and measuring technique. Summaries of these have been published in *ARBETE och HÄLSA* 1998:10, where references to research reports may also be found. Most of the references given in the handbook are to standards. For general information, the reader should refer to the summaries in the aforementioned publications.

In this handbook, a broader overview is given of how the operator uses the machine than in the superseded publication, *An Ergonomic Checklist for Forestry Machinery.* There is also a greater emphasis on the mental work done by the operator, particularly in the section on operation of the controls and boom manipulation, and the enlarged section on operator information. Sections on safety requirements and maintenance procedures have also been added. It is assumed that the latest machines meet both the European Union (EU) directives on machines and also the national safety regulations applying in the individual countries.

Accommodating variations in individuals

The design of the machine should be such that it can accommodate operators taken from 90% of the working population aged between 18 and 65. This means that all but the shortest and/or weakest 5% and the tallest 5% of all individuals should be able to operate the machine. Minor disabilities, eg, reading difficulties, and the 10% of men that are color-blind should also be taken into account. The handbook uses ISO standard 3411, which states that 90% of a large sample of operators in the world are between 155 and 190 cm tall (assumed to be well-built, dressed in winter clothing but not wearing a hard hat) and weigh between 55 and 109 kg. (See also Appendix 1—Body measurements.)

Seat reference point

The seat reference point (SRP), as per SS standard 2863, is used as a datum point in the cab. It is located in the middle of the seat, on the intersection between the seat and the backrest, when a load of 550 N is applied to the seat (see Fig. 1). Another standardized point used in seat design is the seat index point (SIP) as per ISO 5353. The SIP is located at a point above the seat, midway between the hip joints when the operator's back is in contact with the backrest. It is 9.7 cm above and 13.0 cm forward of the SRP. The reason that we recommend the SRP is that it is easier to determine. This can be done best with the aid of a simple measuring jig, although a simple measuring tape will also suffice.

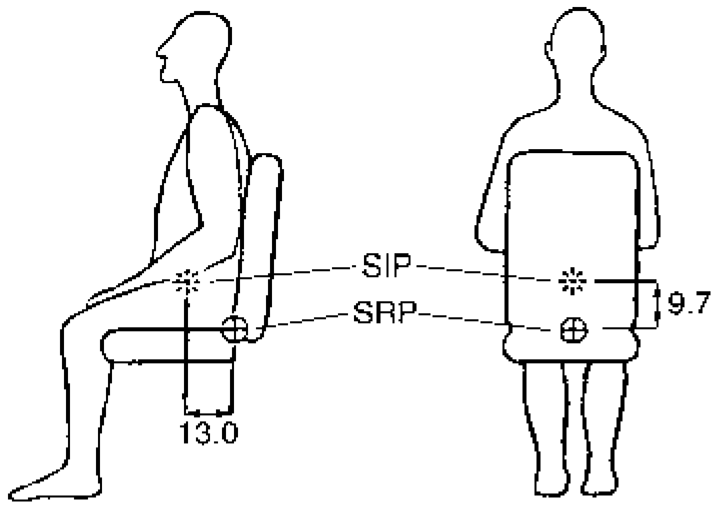


Figure 1.
A comparison between the seat reference point (SRP) and the seat index point (SIP). Measurements are given in centimeters (cm).

Division into classes

A new feature in this handbook is that the elements of the machine's design and function that influence the operator's working conditions, eg, the cab and maintenance procedures, are divided into five predefined classes. In the past, assessment was made on a five-point scale, ranging from "Very good" to "Very poor". The reasoning behind the new classification system is explained under "Classes" below.

Each item that is assessed in the different sections is assigned to one of the five classes. This calls for a measure of subjective judgement, as it is impossible to define the classes definitively. This applies above all to how important a particular item is to the overall assessment of the section. Apart from familiarity with the machine operations, some knowledge of ergonomics is therefore also required to make a sound assessment. Both technical and subjective assessment criteria are given for each class. The aim is that the assessment will be the same, regardless of who is doing it. That is why standardized methods should be used whenever possible both for measuring and interpreting the results.

Classes

The classification principle is that the impact of the machine on the health and wellbeing of the operator should be the same, regardless of the class (A, B, C or D) to which the assessed item has been assigned. This presupposes that the machine is used for the purpose for which it was designed and that consideration is given to the duration, tempo and difficulty of the work.

For each item to be assessed (eg, seat height, noise level), the classes are defined by the suitability of the machine for operation in the specified conditions.

Class A: Highly productive work in all types of terrain and stands. High level of both active and passive safety. Maintenance work straightforward and safe. Many of the criteria in this class will not be met for a few years yet.

Class B: Highly productive work but under somewhat easier conditions than in class A (eg, lower tempo, less-demanding work, and easier terrain, stand and climate conditions). Same high level of active and passive safety but, otherwise, not of the same high standard as in class A.

Class C: Easier conditions and/or shorter duration than in class B. Same high level of active and passive safety but, otherwise, not of the same high standard as in class B.

Class D: Easier conditions and/or shorter duration than in class C. Same high level of active and passive safety but, otherwise, not of the same high standard as in class C.

Class 0: The machine does not satisfy the statutory safety requirements and/or has such serious defects that the operator runs a high risk of injury. The machine must not be used until the defects have been rectified and it meets the criteria specified in one of the other classes (A–D).

Guidelines

The guidelines are written with reference to class A and therefore describe the strictest requirements. In some sections, which require the use of measuring equipment that is not always readily available, the guidelines have been divided into two sections, one optional, based on measurements, and the other mandatory, based on subjective assessment. In other words, a subjective assessment must be carried out in either case.

In the tables under the guidelines, some classes have been omitted for some items (denoted by a dash"—").

Ergonomic profile

In order to gain an overview of a machine's characteristics, it is appropriate to compile an ergonomic profile. This profile is an aid to deciding the type of work, terrain, etc., for which the machine is suited. It also gives support to determining the length of suitable work spells and to selecting personnel who are competent to operate the machine.

Section	Class A	B	C	D	0
Cab access (mounting and alighting)	☐	☐	☐	☐	☐
Working posture	☐	☐	☐	☐	☐
Cab	☐	☐	☐	☐	☐
Visibility	☐	☐	☐	☐	☐
Operator's seat	☐	☐	☐	☐	☐
Controls	☐	☐	☐	☐	☐
Operating the machine	☐	☐	☐	☐	☐
Information	☐	☐	☐	☐	☐
Noise	☐	☐	☐	☐	☐
Vibration	☐	☐	☐	☐	☐
Climate control in the cab	☐	☐	☐	☐	☐
Gases and particulates	☐	☐	☐	☐	☐
Lighting	☐	☐	☐	☐	☐
Instructions and training	☐	☐	☐	☐	☐
Maintenance	☐	☐	☐	☐	☐
Brakes and operator safety	☐	☐	☐	☐	☐

How a machine meets the recommendations in the sections on working posture and vibration is of the highest importance to operator health. If a machine receives serious criticism in these sections, the operator should be assigned shorter spells at the controls. For example, if any item assessed in the Working posture section is rated as class D, the operator should not spend more than a total of two hours at the controls in any one day. This applies when the machine operates in difficult conditions and for most of the year. The alternative is to modify the machine or acquire one of a higher class.

Even operators on the best forest machines built in the early 1990s are exposed to health risks. There are a variety of ways in which these risks can be reduced, the main one of which is simply to reduce the time the operator spends in the cab. High-intensity work, such as operating a thinning harvester, should not exceed six hours a day other than in exceptional circumstances. Another option is to use the machine occasionally for lighter work or to reduce the working tempo. A general recommendation is that the operator should take at least one five-minute break every hour. The operator should also take regular breaks from the controls and, ideally, rotate the work with other tasks during the day.

Productivity and health

After many years in the job, many forest-machine operators are no longer able to maintain a high level of productivity. They may be suffering from chronic fatigue or other illness or have lost their motivation, resulting in an inability to sustain a normal working tempo. This phenomenon is partly attributable to work in a machine cab being unnatural for us. The human body is not naturally disposed for sitting still in a vibrating cab and performing repetitive arm and head movements. Few operators today can cope with this day after day, year after year. Even the best machines are wearing on the operator. Human beings are predisposed for physically active and mentally varied work.

Machine work, and hence the health and wellbeing of the operator, is affected by the entire production system and how it changes. Forestry work is subject to constant rationalization, and the operator therefore has to reassess his situation continually. It is a matter of striking a balance between productivity demands and the effort they require. Machine users need to be aware of the implications of rationalization for working conditions. These may involve an increase in the intensity and complexity of the work, longer spells in the cab, working nights, weekends and on public holidays, and also poor posture and inadequate breaks. A change in the work load can potentially lead to health problems, but it is also an opportunity for the operator to change and develop his way of working—which presupposes not only that the operator is able to influence the work but also that he has the support of the management, and his co-workers and family.

Accidents and occupational diseases

Most accidents in mechanized forestry work in Scandinavia that give rise to sick leave occur during maintenance. Impact injuries, cuts, body parts being trapped or crushed, and back injury are the most common causes, with unexpected machine movements and physical straining or overexertion resulting in the longest periods of sick leave—55 and 64 days respectively (median values). Statistics also show that maintenance of harvesters is riskier than other maintenance work. In Finland, about 70% of operators reported that in an average year they slip or stumble on more than one occasion when mounting and alighting. In Sweden, such accidents account for 20% of operator sick leave.

Operating forest machinery also incurs health problems, particularly aches and pains in the neck and shoulder regions. More than half of all machine operators who have been active in Sweden in the 1980s and 1990s have suffered from such problems to a greater or lesser extent. Problems with the joints, above all elbows and knees, and the lumbar region are also prevalent. Operators who continue to work in spite of these ailments are often diagnosed as having occupational disorders and put on long sick leave. Health problems constitute the main reason that operators leave their jobs. One finding is that health problems in harvester operators occur earlier in thinning work than in final felling and that operating a forwarder is less of a strain than operating a harvester.

High tempo and few natural breaks

There are many causes of the problems experienced by operators in the neck and shoulder region: operators perform the same precise, quick and repetitive movements of the head, arms and hands day in and day out. Harvester work also lacks natural breaks. Another reason is that operators have to remain constantly alert, looking around all the time. Working on a machine that is shaking and often tilted also causes operators to tense their muscles unconsciously. Combined with pressure to sustain a high level of productivity, having to do shiftwork, working in darkness and having to deal with interruptions, these factors can also lead to gastric disorders, headaches and irritability—all of which can be compounded by long working hours, long journeys to work and employment uncertainty.

The causes of problems in the lumbar region include long periods of sitting in the same position, twisting of the body and awkward posture, jolting and whole-body vibration. Operators have expressed the wish to be given better seats and more spacious cabs that offer greater scope for varying their posture when sitting. Levelling of the cab or seat is also much appreciated by the operators and has been shown to reduce strain in the lower back.

Alternating between sitting and standing is also beneficial: the angle of the joints changes, sets of muscles that were under tension before are relaxed and the body weight is redistributed between the buttocks and the feet. This, in turn, enables good circulation to be restored to the muscles and the blood to flush the system, and ligaments and tendons to be lubricated. Operators can work standing up in difficult terrain, for instance, as this allows them to use their legs to absorb the bumps, jolts and rolling of the machine. It also offers better visibility close-up to the machine and an opportunity for them to stretch their legs. However, operating the machine safely when standing up requires the provision of support for the buttocks, together with grab handles with integral controls, so that the operator can steady himself. Nevertheless, operating the machine from a standing position is not recommended yet as there is insufficient practical experience of this at present.

The opinion of operators on mechanized forestry work is that they are fairly independent and that the work should not give rise to repetitive strain injury (RSI). RSI is only a risk when adverse factors and high-intensity work occur together for prolonged periods. It is therefore essential that operators have the opportunity to vary their posture and movements when in the cab. It should be easy, for instance, to adjust the seat height, to set boom movements to different speeds and to take both long and “micro” breaks at regular intervals. Greater automation of the machine functions can result in natural micro breaks in the process, which allow the blood to flow through the muscle tissue and transport the waste products away.

Other factors that have been shown to contribute towards ill health at work include having little opportunity to influence the work, a poor psychosocial environment, little recognition for work performed, low self-esteem, smoking, advanced age, inexperience of the work, poor physical fitness, and a previous history of muscular and joint disorders. Such problems can largely be overcome through the provision of education and training, and reorganization of the work. Good general fitness benefits both physical and mental wellbeing, and relaxation exercises give valuable rest.

Work organization

The harsh conditions prevailing in forestry require both machine and organization to be adapted to the needs of the operator and the work team. The employer, machine owner and operator must organize the work together and ensure that the pressure on the operator remains at an acceptable level. The machine owner then gains not only operators that are experienced and fit but also a stable business. There is then every chance of having an alert and skillful operator in the cab on every shift.

The tempo and/or quality of the work often tends to decline towards the end of a shift, especially when work is being carried out in the dark. The work must therefore be planned and organized so that the operators can utilize the machine efficiently throughout the shift. Working eight hours a day, day in and day out, is not recommended even on the best forest machines. That’s because no forest machine offers enough scope for the majority of operators to avoid health problems by varying their posture and the stresses imposed on their bodies.

The following should be taken into account in attempts to develop profitable organization of the work:

- Productivity targets and the financial status of the machine owner
- The type of work for which the machine will be used (intensity, decision-making, monotony, terrain, stand, climate, etc.)

- The design of the machine and the functions (physical design, operator control over the functions, short breaks, mental effort required, etc.)
- How the work is organized (schedule, breaks, journey routes, lone working, support and help)
- Operator profile (family life, motivation, age, health, etc.)

An effective strategy for preventing muscular and joint problems is to adjust the spell in the cab to suit the individual operator. This can be done through the team's drawing-up its own shift and job-rotation schedules. Job-rotation schemes must take all types of work into account—which involves more than simply drawing up a schedule for work. Operator training for other tasks must also be included. Flexible work teams better equip a business to cope with change.

Important goals of work organization

- Physically, mentally and socially varying work assignments
- Acceptable working intensity that allows the operator to vary his working tempo
- A machine that is suitable fo the prevailing conditions
- To tailor spells in the cab, the working tempo, etc., to the ergonomic profile of the machine
- Adequate short, micro and long breaks to obviate cumulative fatigue over time
- A positive social climate, with opportunities for information, help and support from others
- Influence in drawing-up shiftwork schedules and over choice of machine and the organization and planning of work
- Periodic training and opportunities to advance in career

Machine design—always a compromise

The manufacturer determines the ergonomic class of the machine as early as in the drawing-board phase of its development. The designer has to deal with a host of conflicting requirements—ergonomic considerations on the one hand and such factors as the need for machine mobility and performance on the other. The need for ample ground clearance to enable the machine to negotiate rough terrain, for instance, makes mounting and alighting more difficult. Similarly, fast feeding of the stems necessitates greater concentration on the part of the operator and, when the machine is driven at a higher speed, the level of vibration and jolting will also be increased. Again, the need to provide suitable working lights for older operators has to be weighed against the capacity of the alternator, while positioning the boom post to achieve the greatest stability can obstruct the operator's view. A slewing cab offers good visibility but makes the provision of access steps for the operator more difficult.

Conversely, in other aspects of the design work the ergonomic requirements are in concert with operational characteristics. Functions for smooth starting and stopping of the hydraulic flow, for instance, also make for both simpler boom control and less wear on the hydraulic system. Accumulators that absorb shock waves in the hydraulic system benefit both operator and machine components. Similarly, leveling of the whole machine improves the operator's environment, facilitates boom work on slopes and reduces the risk of the machine rolling over.

But conflicts even arise between ergonomic requirements. Leveling the cab enhances operator comfort but diminishes his view when the machine is on a slope and also increases the difficulty of configuring the lights for suitable illumination of the working zone. A large cab offers more room for the operator but necessitates a larger area of window glass for good visibility; this, in turn, results in greater heat loss and/or radiated heat in the cab and hence the need for a higher-capacity climate-control system. To stop quickly the log feed through the processing unit, the operator must keep a finger on the feed button, which constitutes a sound safety precaution. Automatic feeding, on the other hand, gives the operator much needed micro breaks.

The designer therefore has to strike a delicate balance between the conflicting requirements. Moreover, he also has to create an optimum working environment for a wide range of operators.

Common obstacles to effective utilization of forest machines

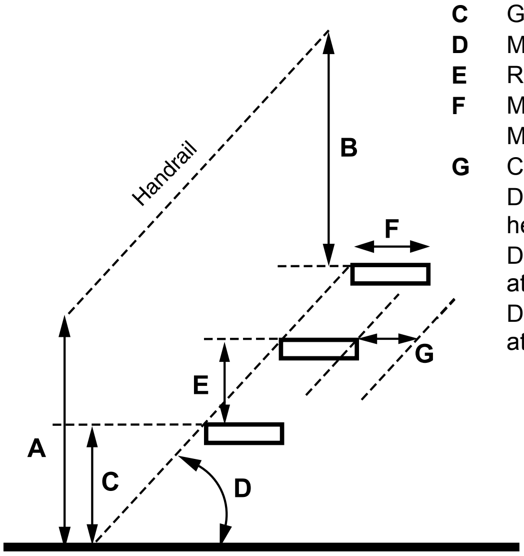
Common obstacles that prevent optimum utilization of the machine by the operator are associated with posture, manipulation of the controls, vibration, mounting and alighting, and maintenance work. The following are examples of problems encountered in different forestry operations:

Scarification	Vibration and jolting, particularly in difficult terrain. Need to twist body to look behind. High temperatures in summer.
Cleaning	Requires higher level of concentration and exertion than in thinning and final felling. Highly intensive and repetitive boom operation.
Thinning	The most complicated operation in forestry. Needs excellent visibility from the cab. Problems with pushbutton panel, controls and high intensity of the work.
Final felling	Determining bucking break for optimum yield whilst working at high tempo. Problems with pushbutton panel, controls and high intensity of the work.
Forwarding	Vibration and jolting. Danger of machine rolling over.
Chipping	Repetitive operation of controls. Noise, dust and high temperature in summer.
Agricultural tractor	Cab—poor access and cramped, poor visibility, awkward operator posture, operation of boom controls difficult.

Cab access —mounting and alighting

In this section, steps are used as an example of the means of access to the cab but this obviously does not preclude the use of other means, such as a platform lift, for example. What is important is that access to the cab is easy, safe and with a minimal risk of the operator straining himself. Access involves the operator climbing onto the machine with the aid of individual steps or a flight of steps, a handrail or grab handles, etc., sometimes moving along the machine, and then entering the cab and sitting down in the seat.

One-fifth of all accidents sustained by forest-machine operators occur when they are mounting or alighting from the machine. Such accidents are usually caused by the operator missing his footing, falling, slipping or jumping down from the machine. Climbing onto a wheel or track incurs an additional risk of slipping. If the means of access is inconvenient, the operators are tempted to jump down, which in time can result in damaged hips, knees or feet. Badly designed access can also constitute a hindrance to older operators working on the machine. In consequence, operators may be deterred from leaving the cab to take a break or to do work out of the cab, eg, changing a saw chain that needs sharpening.



Dimensions in cm or degrees (°)		**Class A**	**Class B**
A	Ground to handrail	120	Unspecified
B	Step to handrail	85	Unspecified
C	Ground to first step (min	35	40
D	Maximum pitch	45°	70°
E	Rise	20–25	20–30
F	Minimum tread (step) depth	20	10
	Minimum step width	30	30
G	Clearance behind step	≥15	≥15
	Door opening, minimum height	160	160
	Door opening, minimum width at shoulder heigh	60	60
	Door opening, minimum width at bottom	35	35

Figure 2.
Design of steps on class A and B forest machines.

Guidelines

Operators of different stature (see Appendix 1) should be able to mount and alight from the machine without being forced to twist their upper body. There should be convenient direct access from the ground via steps onto a platform outside the cab door, even when the machine is standing on a slope. In machines with a rotating cab, there should always be at least one position in which the guidelines are met. The operator must also be able to mount and alight from the machine safely, whatever the position of the cab.

The operator should be able to climb down from the machine forwards, which means that the machine must be equipped with a safe flight of steps. The steps must have an amply sized tread that will accommodate most of the foot (see Fig. 2). At least one handrail that provides support all the way must be provided. The operator should not have to climb or step onto a wheel or track nor be forced to negotiate any obstacles in order to reach the cab. The door opening should be big enough to allow the operator to pass through it comfortably when wearing winter clothing.

Class A	Class B	Class C	Class D	Class 0
1. Steps as per Fig. 2. Platform outside cab door.	Steps as per Fig. 2. Platform provided.	Minor shortcomings	Major shortcomings	Unsafe
2. If no direct access to cab, sturdy, safe catwalk with handrail provided.	Yes but some minor shortcomings (not posing a safety hazard)	As for class B	One step only onto wheel or track required. Suitable handrail provided.	Wheel/track used for mounting/ alighting. Suitable handrail lacking.
3. Handrail and steps provide good grip and do not collect snow and ice. Easy to keep clean and minimal risk of slipping.	As for class A	As for class A	As for class A	Handrail and steps unsafe.
4. Door opening measures at least 160 cm H, 60 cm W at shoulder height an 35 cm W at bottom.	As for class A	Minor discrepancies	Major discrepancies	—
5. At least one functioning emergency exit provided.	As for class A	As for class A	As for class A	No!
6. Cab door opens wid enough and stays open in wind and when machine tilted.	Minor shortcomings	Moderate shortcomings	Major shortcomings	—
7. Cab door opens & closes easily even when machine tilted.	As for class A	Minor shortcomings	Major shortcomings	—
8. Means of access presents no risk of operator becoming caught up or trapped by it.	Minor shortcomings	Moderate shortcomings	Major shortcomings	—
9. Means of access protected against damage	Minor shortcomings	Moderate shortcomings	Major shortcomings	—
10. Cab door, steps and ground under steps well lighted.	Minor shortcomings	Major shortcomings	No lighting	—

Measuring technique

For assessment of cab access, the machine should be standing on level ground. Check whether mounting or alighting is affected when the machine is tilted. Convenient aids are a measuring tape and a simple protractor. The width of the door opening is measured at right angles to the natural entry angle, at shoulder height and at the bottom.

Working posture

The collective guidelines for body posture and operator movements in the cab are influenced by the design of the cab, seat and controls, and by visibility and manipulation of the controls. These factors should be assessed first, before an overall assessment is made of the working posture. Posture is also affected by machine vibration and jolting.

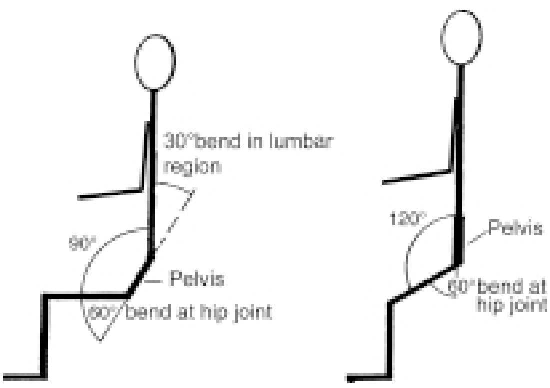
A relaxed sitting posture

The joints of the operator's body should generally be in a "neutral" position when he is seated working in the cab, ie, the joints should be at a comfortable angle and not fully straightened. Accordingly, the shoulders should be relaxed, the upper arms either parallel to the body or slightly forward, and the forearms at an angle of 105–120° to the upper arms. Nor should the joints be subjected to heavy extraneous loading, such as that imposed by heavy shocks. The operator should be able to shift his position freely from this basic posture, being able to straighten the body and stretch the legs. He should also be able to bend his knees and place his feet under the seat, and to vary his position, eg, by increasing the angle between trunk and legs (see Fig. 3), which reduces the static load placed on the lumbar region.

A level seat is conducive to a relaxed posture, in contrast to one that is tilted, which is very tiring. Ideally, the entire machine should be leveled; second best is a leveling function for the cab and, failing that, leveling of the seat. If leveling can only be provided in one direction, priority should be given to lateral leveling.

Operator movements

Backward bending of the head should be avoided, especially when combined with forward movement of the neck, as injuries can occur in this position, particularly if the operator is subjected to jolting by the machine. The operator should not have to turn his head frequently or for long periods in a way that necessitates use of the shoulder muscles, as this part of the operator's body is already subjected to stress from operating the machine. The operator's workstation (ie, the seat, armrests, footrests, controls, push-button panel, instruments and field of vision) shall be capable of swiveling freely within the working envelope and independently of the boom, so that the operator can enjoy good visibility with a minimum of twisting or turning of the body and head.



Basic posture

Trunk–upper arm	0–15°
Elbow	105–120°
Trunk–thigh	105–120°
Knee joint	105–120°
Ankle joint	90–100°

Figure 3.
Examples of low and high sitting positions.

Guidelines

Class A	Class B	Class C	Class D	Class 0
1. Operators of different stature can assume a relaxed basic posture in which the controls are within optimum reach and good visibility is afforded.	As for class A	Some difficulty for operators of above or below-average posture	Many shortcomings	Ergonomically unacceptable
2. The operator can easily shift between low and high sitting postures, straighten his body and stretch his legs.	More-limited height adjustment. Operator still able to stretch legs.	More-limited height adjustment. Somewhat cramped.	Little scope for varying posture.	Ergonomically unacceptable
3. Seat, armrests, controls and orientation of instruments all readily adjustable to suit different operators.	As for class A	A few shortcomings	Many shortcomings	Ergonomically unacceptable
4. The machine/cab can be tilted through 15° both laterally and longitudinally for leveling.	Through 7° laterally and longitudinally or 15° in one direction only	Seat can be leveled	No leveling function	—
5. The operator's station can be swiveled independently of the boom in any direction within the working envelope.	Operator's station follows boom movement	Seat swivels and can be locked in any position	Rigid workstation and non-swivelling seat	—
6. Boom and grapple/harvester head easily manipulated with few movements by operator.	A few shortcomings	Moderate level of shortcomings	Many shortcomings	—
7. Control work allows relief of static load in shoulders and neck during each boom cycle.	Frequent relief afforded	Occasional relief afforded	Relief seldom afforded	—

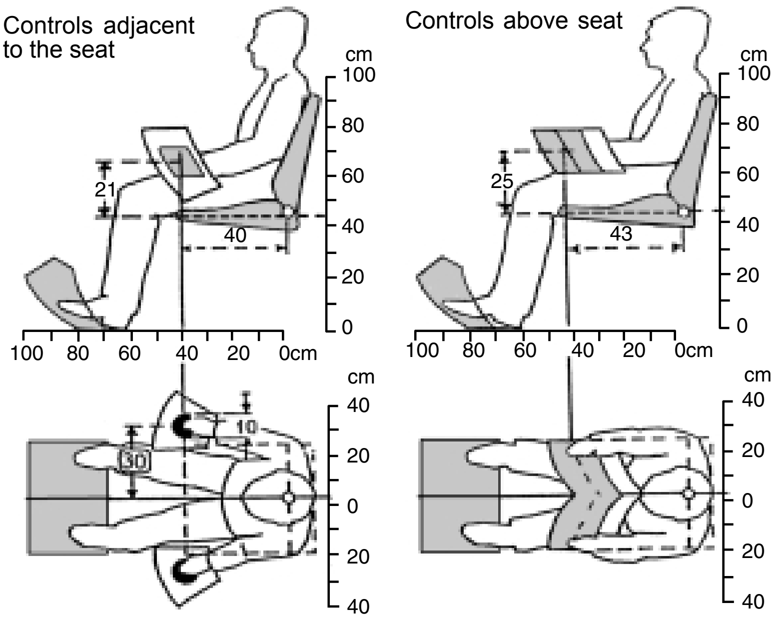


Figure 4. Optimum working envelopes for hands and feet. Normal sitting posture. Measured with seat occupied.

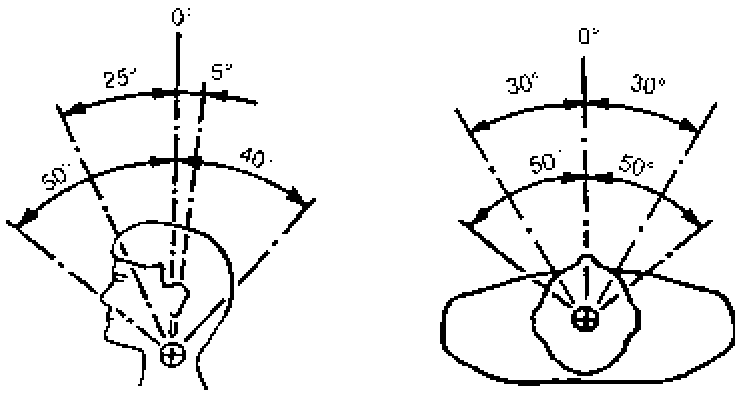


Figure 5.
Optimum and maximum ranges of movement for the head and neck. Maximum range should be used only for short periods on isolated occasions during a work cycle.

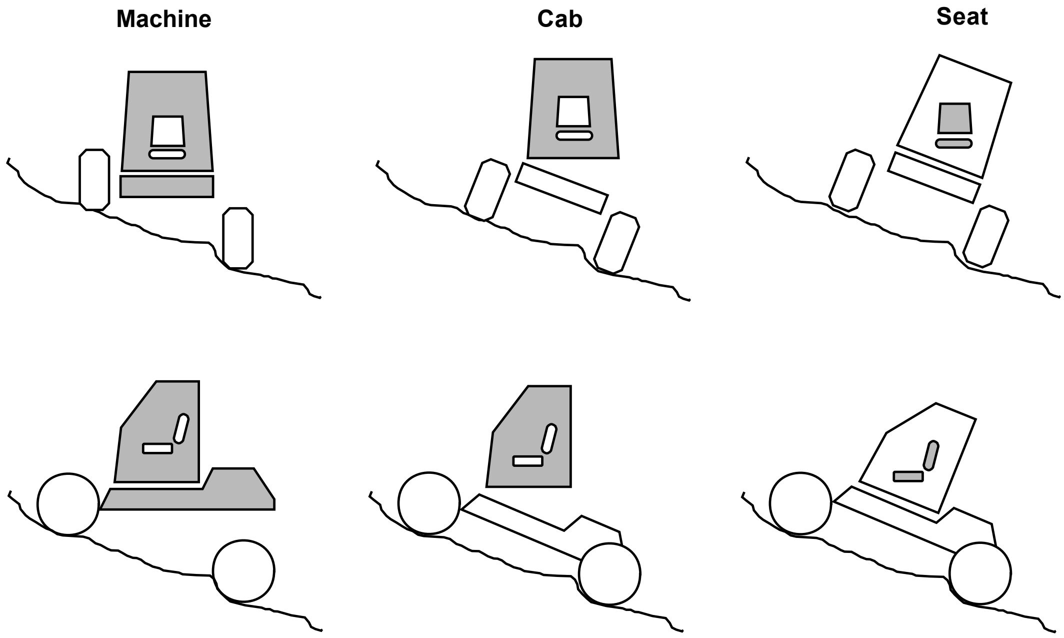


Figure 6.
Some principles of leveling of the operator's workstation.

Measuring technique

The manufacturer's measurements and description are used for assessing machines already in operation. If a dimension is missing, it may be necessary to measure the operator's workstation more accurately. The same applies if any dimensions have been altered, such as when new equipment has been fitted. In this case, the first task is to determine the seat reference point (SRP) (see page 7). Thereafter, the assessment is made using a measuring tape and a simple protractor, and through interviews with the machine operators.

It is recommended that a CAD program, together with an ergonomic dummy (the size of which should be variable in accordance with ISO 3411), be used to simulate operators of different stature and with varying reach in the design or modification of a machine, cab, seat or controls. In this way, space, visibility, the location of instruments and controls, operator movements and actuating forces can be assessed. The same program should be capable of determining the SRP.

Cab

The size and design of the cab have a critical influence on whether the operator can work efficiently. A cramped or poorly designed cab forces the operator to work in a fixed posture that is both tiring and, in time, detrimental to health. The volume of the cab must also be adequate for a satisfactory climate to be achieved.

The headroom in the cab is determined by the tallest operator. For a person 190 cm tall, the distance between the floor and the top of the head in the higher sitting position is about 165 cm. To this must be added additional clearance, both to obviate the operator's head from hitting the roof of the cab when the machine is operating in rough terrain and also to enable the operator to raise himself from the seat. The additional clearance required is at least 15 cm, giving a minimum required headroom in the cab of 180 cm.

The length of the cab is determined by the legroom needed for the operator to be able to straighten his body and stretch his legs. But, of course, the length of the cab also influences the overall length of the machine—and the longer the machine, the greater the difficulty in turning. The width of the cab is determined by the space needed to accommodate the armrests and controls, and whether the seat is to be equipped with swivel and leveling devices. Although the cab width is not usually critical, a wide cab does reduce visibility on either side.

Dimension (cm)		Guideline
A	180	Headroom
B	55[1)]	Seat in rear position
C	115	Seat in rear position, measured at toes
D	70[2)]	Seat in forward position and at mid-height
E	50	Seat in forward and highest position
F	100[3), 4)]	Cab width measured at armrest height

[1)] 70 cm is needed for a seat that tilts forwards and backwards.

[2)] Measurement from SRP to inside limit (wall, steering wheel, computer screen, etc.).

[3)] With both forward and reverse machine operation, 65 cm of clearance from the SRP is needed for rotation of a conventional seat when occupied.

[4)] A cab not equipped with leveling may be fitted with a laterally tiltable seat requiring greater cab width.

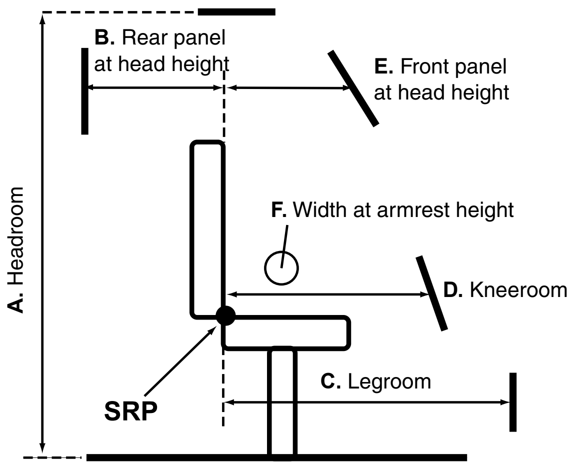


Figure 7.
Inside cab dimensions.

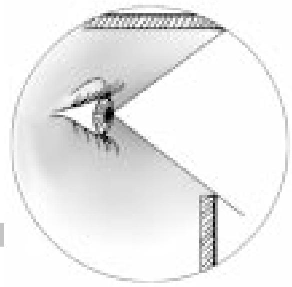
Guidelines

The operator should be able to assume a comfortable position that affords good visibility and from which the controls are within convenient reach. Operators of differing stature should readily be able to operate the machine and adopt different postures. There should be ample room for armrests, controls and the operator's knees and feet so that they do not make contact with the cab interior or other equipment. The steering wheel, pedals, etc., should be positioned such that they do not impinge on the operator's freedom of movement—the same applying to retrofitted equipment. A certain width is required to obviate the operator knocking against objects when the machine lurches. The operator should also be positioned at least 30 cm from sources of cold drafts. Space is also needed to give the operator access to the seat for adjustment. On a machine operating both forwards and in reverse, there should be room to rotate the seat. If the machine or cab cannot be leveled, there should be room for leveling of the seat. When seated, the operator should be able to extend the angle between trunk and thighs to at least 135° and to stretch the legs out straight. There should be a readily accessible and clearly labeled stowage place for a first-aid kit.

Class A	Class B	Class C	Class D	Class 0
1. Dimensions in Fig. 7 are met.	Minor deviations in headroom and length dimensions	Moderate deviations	Major deviations	Ergonomically unacceptable
2. Armrests and controls do not foul walls, interior objects etc.	As for class A	Not entirely true	Serious shortcomings	—
3. With forward & reverse operation, there is ample room in both directions. The seat can be rotated freely to any position	Not fully adequate	Moderate shortcomings	Serious shortcomings	—
4. Stowage space for first-aid kit, instruction manuals and personal items.	As for class A	Not fully adequate	Moderate shortcomings	No provision for first-aid kit
5. Cab easy to keep clean. Door extends all the way down to the floor.	Minor shortcomings	Moderate shortcomings	—	—
6. No equipment in cab that can leak oil nor protruding objects that could cause injury.	As for class A	As for class A	Some shortcomings	Ergonomically unacceptable

Measuring technique

Measuring tape used for dimensions; simple protractor for body angles.



Visibility

Good visibility from the cab is vital if the operator is to maintain a high level of productivity and, at the same time, safeguard his health and the equipment. Poor visibility increases the risk of accidents, reduces productivity and forces the operator to assume poor posture—it is detrimental, for instance, if he is forced to hold his head turned or his neck bent backwards for other than brief periods. The problem of poor visibility is aggravated if the operator has to follow the boom movement from a fixed cab. Bear in mind that people who wear spectacles must turn the head more to be able to see clearly. In certain cases, a mirror or video camera can be used to obtain a better view. Reflections from window glass and dazzle from the sun are a problem on many forest machines.

The need for good visibility often conflicts with suitable siting of the boom, thick cab pillars, sturdy rollover protection (ROPS), and protective grilles. A large, spacious cab affords the operator a poorer view of the ground.

Guidelines

The operator should have a free view of the operating zone without having to adjust his posture. This means, for instance, that the head should not be turned more than 30° to the side nor tilted more than 5° up or 25° down (see Fig. 5). However, it is not detrimental to occasionally turn the head sharply or to bend forward.

Class A	Class B	Class C	Class D	Class 0
1. The operator can see the ground to within 3.5 m of the side of the machine in the working envelope of the boom and to within 5 m of the machine in the direction of travel (measured from the SRP).	Some shortcomings	Moderate shortcomings	Major shortcomings	Unsafe
2. The operator can see at least up to a height of 25 m above the ground at a distance of 10 m from the machine.	Visibility up to height of 20 m. On a forwarder, operator can see the whole length of the boom in the boom-operating zone	Visibility up to height of 15 m. On a forwarder, operator can see the top of the cab guard	Major shortcomings. On forwarder, as for class C	Unsafe
3. The operator can see the front wheels when driving ahead.	May have to bend/stretch a little	Moderate shortcomings	Major shortcomings	—
4. Easy to clean rain, snow, mist, dirt, etc., from windows.	Minor problems	Major problems	Seriously inadequate	—
5. Boom, pillars and equipment do not obstruct operator's view or force him to adjust his posture to be able to see into the working zone.	Visibility slightly obstructed, eg, by the boom	Visibility obstructed in several ways	Visibility seriously obstructed	—

Reflections from the window glass should be avoided and any dazzle from working lights, reflections from the machine or strong contrasts of light on the machine are unacceptable. The window glass should be easy to keep clean and be equipped with wipers and washers that cover the entire area of the glass. Protective grilles must not constitute a hindrance to keeping the windows clean. Provision must be made to ensure that windows are kept free from mist and ice.

Measuring technique

A ground plan of the field of view is sketched (see Fig. 8). Measurements are made in the dark with the machine standing on level ground. The boom is positioned at an angle of 45° to the centre line of the machine and is extended to half its reach. A lamp is placed at the operator's eye level, ie, 130 cm above the floor and 13 cm forward of the SRP (eg, 80 cm above the SRP with the seat 50 cm above the floor). The seat should be in the mid-position longitudinally. The edges of the shadows can be measured after grid lines have been marked out on the ground. The method can also be used in daylight: this is done by attaching a mirror to a staff at an angle of about 45°. The staff with the mirror is moved along the ground up to the point at which the light from the lamp is obscured. This point is then marked on the plan.

The angle of the upward field of view can be measured, eg, by means of a protractor and a plumb line that intersects the point at which the lamp (representing the position of the operator's eyes—see above) is positioned. The angle described by the horizontal plane at eye level and the line at which the field of view is cut off by the cab roof (or sun blind) is now noted. The height above ground of the measuring point should be measured, after which the height above ground (tree height) to which the field of view extends at a distance of 10 m can be calculated from the equation:

$X = 10 \tan A + B$ (where X = tree height, A = view angle and B = height of measuring point above the ground). The criterion that the operator's view should extend 25 m upwards at a horizontal distance of 10 m is usually met at an angle of about 65°.

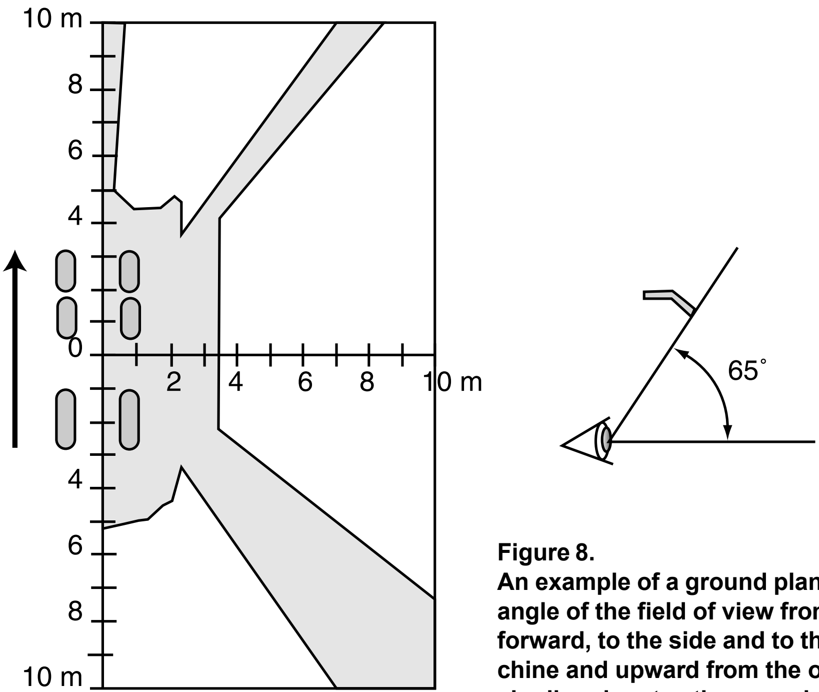


Figure 8.
An example of a ground plan of the area and angle of the field of view from a harvester forward, to the side and to the rear of the machine and upward from the operator's seat. The shading denotes the areas in which the operator's vision is obscured.

Operator’s seat

The operator’s seat on a forest machine should provide adequate support for the legs, buttocks and back, and generally support the body for comfortable and convenient manipulation of the controls. One of the prime causes of back problems is sitting in the same position for long periods. It is therefore important that the operator be able to shift his position during work. The armrests and controls should be positioned conveniently regardless of the operator’s posture.

In the basic sitting posture, the body should be positioned such that the angle between trunk and thighs is 105–120°. The operator should then be able to vary his posture: a relaxed position for the hips is when the trunk-thigh angle is 135°. The best posture for the lower back and pelvis is when the trunk-thigh angle is 120° and the back is in the same position as when the individual is standing upright. This can be achieved with a slightly higher seat whose leading edge is angled slightly downward (see Fig. 3). The larger angle between trunk and thigh also reduces the strain on the lower back—it is vital that good lumbar support is achieved.

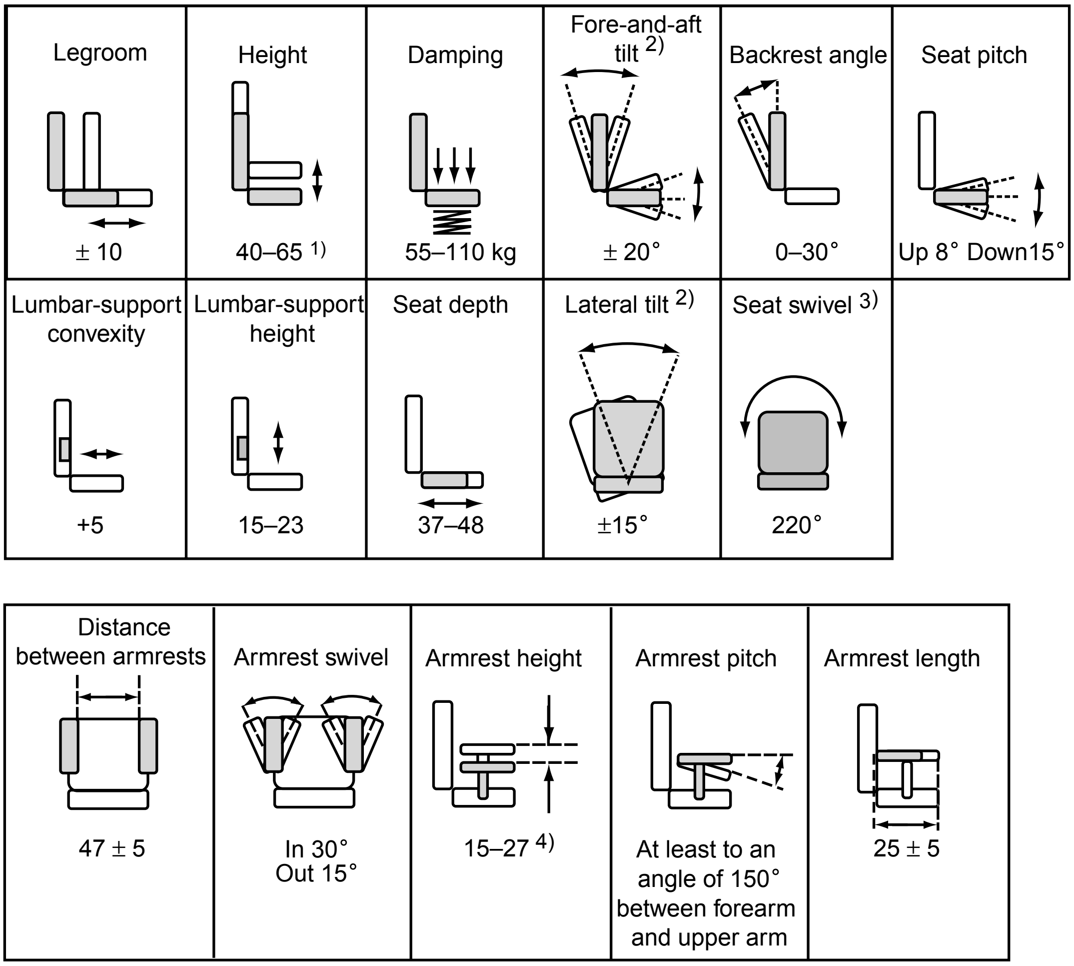
The recommendation for a seat that allows the operator to shift his position from time to time probably means that a new seat for forest-machine operators will have to be designed. What is needed above all is improved adjustability of the height and pitch (forward and down) of the seat cushion.

Guidelines

The seat and armrests should be convenient for operators of differing stature, allow wide variation in sitting posture and be readily adjustable. The seat cushion should be wide enough (at least 46 cm) and slightly cupped to provide good support without impeding the operator’s freedom of movement. The front edge of the seat should be rounded and there should be 3–5 cm of clearance between it and the back of the operator’s knees. The backrest should provide support for the whole of the back but not hinder the operator from turning his trunk or looking behind him. It should also offer proper, adjustable lumbar support.

Well-designed and individually adjustable armrests that provide good support for the forearms reduce the strain on the shoulders and facilitate positive and precise manipulation of the controls. The armrests (at least 10 cm wide) should support the full length of the forearms without hindering movement of the arms. The height of the rear of the armrests should also be adjustable so that operators with long upper arms can work with their shoulders down. There are instances when seats without armrests are desirable, such as when the cab is equipped with six-lever controls.

If the entire cab cannot be leveled and swiveled to face the direction in which the boom is operating, the seat should be able to achieve this. The seat should be able to dampen vibration and shocks in three directions, acting in harmony with the machine’s own suspension system in order to avoid secondary effects. Because of the heavy stresses that the operator’s seat on a forest machine has to withstand, it must be robust with specially reinforced mountings and base. It should also be sited where it allows the operator freedom of movement and optimum visibility.



1) The height of the seat cushion above the floor should be measured with a load of 550 N on the seat.
2) Depending on whether the operator's seat can be leveled.
3) Depending on whether the cab is rotatable.
4) Measured above the SRP; also applies to the back of the armrest. If the armrest does not follow the seat, the measurement should be made with the seat occupied.

Figure 9.
Range of seat and armrest adjustments (cm).

(Table of class criteria on next page.)

Class A	Class B	Class C	Class D	Class 0
1. Seat height readily adjustable between 40 and 65 cm	Readily adjustable 40–55 cm	Less adjustable and less convenient	Inadequate adjustment	Ergonomi cally unaccept-able
2. The seat otherwise meets the specified dimensions and adjustment ranges.	Seat-pitch adjustment only +8°, -7°	Some dimensions more limited	Large deviation from specified dimensions	Ergonomi-cally unaccept-able
3. Armrests offer good support without restricting arm movements and can be adjusted as specified	As for class A	Minor shortcomings	Major shortcomings	Ergonomi-cally unaccept-able
4. Individual settings of seat and armrests can be programmed and quickly reset automatically.	Manual adjustment quick and easy. Scales clearly marked.	Some adjustments awkward.	Major shortcomings	—
5. Armrests follow seat movements automatically.	As for class A	Can be readily adjusted manually	Major shortcomings	Ergonomi-cally unaccept-able
6. Feet have room under front of seat when legs bent as far back as an angle of 60° or smaller.	Legs cannot be bent as far back as in class A.	No room for feet under the seat	—	—
7. The seat has good vibration damping in all height settings.	As for class A	Inferior damping when seat in highest and/or lowest setting.	Major shortcomings	Ergonomi-cally unaccept-able
8. In non-slewing cab, seat rotates far enough and can be locked in any position.	Seat rotates but not infinitely variable.	Major shortcomings	Seat non-rotating	—
9. Seat in non-leveling cab tilts automatically in two directions.	Tilts in one direction automatically or in two manually. Lockable in any position	Limited tilt function.	No tilt function.	—
10. Seat cushion and backrest equipped with thermostatic heating, ventilation and washable loose covers.	Not fully equipped	Major shortcomings	—	—
11. Stable seat—well sited and anchored, and easy to maintain.	As for class A	Some shortcomings	Major shortcomings	Ergonomi-cally unaccept-able
12. Suitable means of restraint provided (eg, seat belt)	As for class A	Minor shortcomings (eg, seat belt)	As for class C	None provided

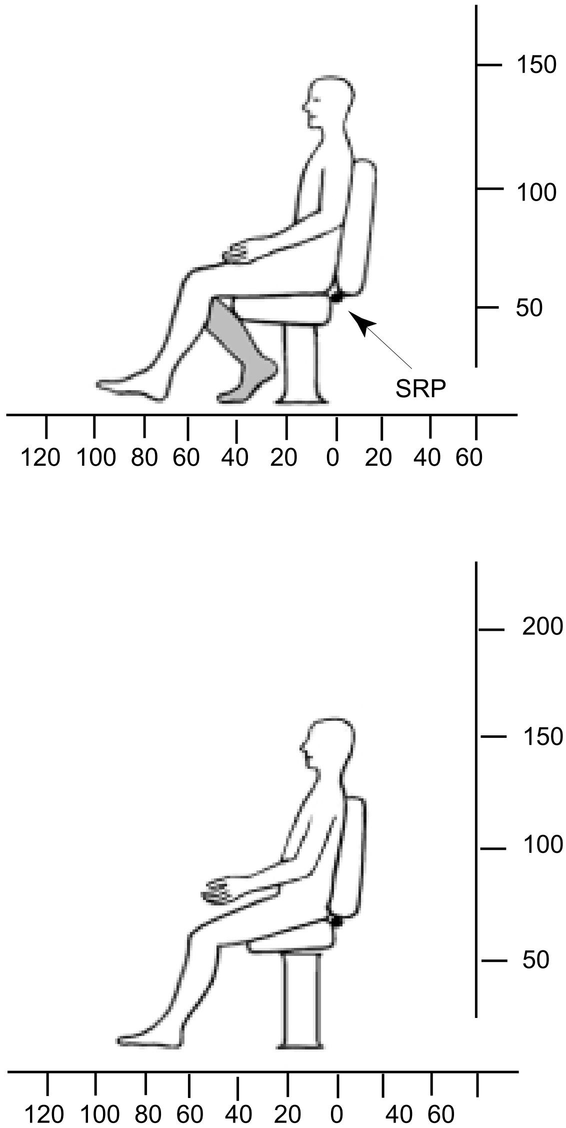
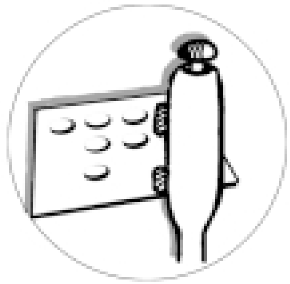


Figure 10.
Different seat settings.
Operator 180 cm tall.

Measuring technique

Measuring tape and simple protractor.



Controls

The choice of controls and pushbuttons together with their location and design has a great bearing on the precision and speed of the work and on the strain imposed on hands, arms, shoulders and neck.

Deciding between hand-and-finger-operated controls (eg, mini levers) for the boom on the one hand and controls operated by movement of the arm on the other is not always easy, as there are pros and cons with both. A control that is operated by hand and fingers is kind to the shoulders, since the forearm is supported by the armrest. Such controls also facilitate greater precision and speed than can be achieved by a lever operated by the hand and arm. However, a drawback with the hand-finger-operated controls is that they are too small to accommodate all the functions needed to control the equipment. In contrast, it is relatively easy to incorporate all the essential functions in a hand-arm-operated control.

It is also advantageous to have a choice between different types of control, eg, to be able to steer with either a lever or a steering wheel (steering wheel disirable on a forwarder). The drawback with a steering wheel, however, is that the space it takes up can restrict the operator's freedom of movement. Another option is to have voice-activated control for certain functions that do not require much speed or precision, eg, changing the menu on a display or making a phone call.

Figure 11. Examples of hand-finger and hand-arm-operated levers equipped with pushbutton panels.

Recommended actuating forces for different types of control	Actuating force, N Optimum[1]	Maximum
Fingertip-operated pushbuttons	2	5
Fingertip-operated controls	2–5	40
Hand-operated lever, Forward/Back	5–15	140
Hand-operated lever, Left/Right	5–15	60
Wheel (tangential force)	5–20	230
Leg-operated controls (clutch and brakes)	45–90	250
Toe-operated controls (eg, throttle)	20–30	

[1] For frequent-usage controls

Guidelines

There should be natural pauses in operating the controls during which the neck and shoulder muscles are relaxed. Both hand controls and control panels with finger-operated joysticks should be designed such that they can be tilted sideways and incorporate a stop to prevent the hand sliding off. It should be possible to change the position of the control with one hand on the control, so that the operator can feel his way to a comfortable position. If a control is used continuously, the operator's arm should be supported by a suitable armrest, which will help to relieve repetitive strain on the shoulder.

If the actuating force is too low, a control may be affected by, eg, vibration, necessitating otherwise unwarranted intervention by the operator. Similarly, if the actuating force is too high, this can be detrimental to both precision and speed of operation. To introduce some variety into the operator's work, some functions may have dual controls—

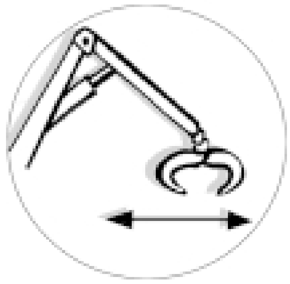
steering and bucking, for example. Controls that are used infrequently can be sited where the operator is forced to stretch to reach them, thus varying his posture.

The design of a control panel with pushbuttons should take into consideration the fact that the hand is primarily an instrument for gripping. Thus, thumb-operated pushbuttons should be placed such that to press the button the thumb will move in towards the hand. The thumb and index finger are best suited for operating buttons that require a quick reaction or are used frequently, and both are capable of being used to operate two buttons each. The middle finger can be assigned to one quick-action button.

Class A	Class B	Class C	Class D	Class 0
1. Levers and pushbuttons that affect safety or are used frequently are located within optimum reach and follow movement of the seat.	As for class A	Some shortcomings	Moderate shortcomings	Unaccept-able
2. The position of levers and control panels is readily adjustable to suit different operators.	As for class A	Moderate shortcomings	Major shortcomings	Ergonomi-cally unaccept-able
3. The relative positions of boom controls and important buttons comply with the guidelines and can readily be adjusted to suit hands of different sizes.	Some difficulty in adjustment	Great difficulty in adjustment	No adjustment possible	—
4. Levers and pushbutton panels (where applicable) offer a comfortable grip and support for the hand.	As for class A	Some shortcomings	Major shortcomings	—
5. Controls for functions requiring a quick response are positioned for operation primarily by thumb or index finger, or failing that, by the middle finger.	Some minor shortcomings	Moderate shortcomings	Major shortcomings	—
6. Grouping and coding of pushbuttons designed to obviate confusion and inadvertent operation.	As for class A	As for class A	Minor shortcomings	Unaccept-able
7. All pushbuttons give a clear acknowledgement when depressed.	Acknowledge-ment of actuation given by important buttons	Acknowledge-ment given by some buttons	No acknowledge-ment given	—
8. Frequently used controls have optimum actuating force.	As for class A	Not all	Many do not	—
9. Pedals are provided only for functions that are normally foot operated in driving (throttle, brakes), that require a strong actuating force or are used infrequently and do not require precision control.	As for class A	Not entirely	Major shortcomings	—

Measuring technique

The SRP (seat reference point) is used as the datum point for determining the position of the controls. A measuring tape (ideally, in combination with a measuring rig) is used to measure the distance of the controls from the SRP, and a dynamometer to measure the actuating force of the controls. (See also Fig. 4.)



Operating the machine

Many functions on a forest machine, eg, boom and grapple, are operated manually, which means that when a function requiring alertness is performed in parallel with other functions, difficulties arise for the operator, especially if quick response and multiple control manipulation are needed. The problem is also compounded if the operator is under pressure. Accordingly, functions that require the oper-ator to make a conscious decision should not be active concurrently with other functions. For optimum control, functions should be straightforward and sequential, and should always behave in the same way. This reduces the pressure and intensity of the work and, hence, is conducive to a high quality of work.

Automation

Forest-machine functions can be automated to varying degrees, such as in control of the transmission and in processing of the tree. Automation is highly advantageous and can relieve the operator of monotonous, complex and simultaneous functions. One of the problems encountered in automating forest-machine functions is the constantly changing conditions in the forest and conflicting safety requirements. This means that the operator must often monitor the automatic processes and intervene to correct what the automated devices cannot do.

It is vital on the introduction of automation that the right functions are assigned to the operator and machine, respectively, so that the capabilities of both are exploited best. For instance, it would be wrong to deprive the operator of tasks that he finds stimulating or which do not put him under any strain. At the same time, there are drawbacks to automation that need to be taken into account: the operator can put too much faith in the technology and fail to intervene when necessary. Conversely, the operator may not trust a particular system and may therefore fail to use it. Some automated processes may also be slower than if the function had been controlled by an experienced operator. A further drawback is that operators can lose interest in the automated processes and therefore fail to become fully conversant with what is happening.

An example of automation is boom control whereby the operator controls the position of the boom tip and a mechanical or electronic system controls the various components of the boom. With sights and computerized boom control, a large proportion of the boom work can be automated, resulting in new ways of working and new types of control.

Machine-controlled breaks

The repetitive and exact movement of hands, arms and head by an operator during logging means that the same muscles and joints are being used all the time—and it is this that gives rise to repetitive strain injury (RSI). To obviate the risk of RSI, control of the boom and felling/processing head needs to be made easier, so that natural breaks occur for the operator during which the muscles can be relaxed from time to time without the machine work being interrupted, eg, without stopping a tree being fed through the processor.

Such machine-controlled breaks should be designed so that the operator has at least three seconds during which no intervention in the process is required of him. There should be at least one such break during each boom cycle (eg, one per tree or one per full grapple on loading or unloading). In this way, it should be possible to reduce the time spent by the operator on actually manipulating the controls to less than 70% of the total time spent in the cab on a harvester. The breaks offer the operator an opportunity to plan the work or to examine stems for optimum merchandising.

Guidelines

Class A	Class B	Class C	Class D	Class 0
1. The machine has enough system power and machine stability for reliable, positive and simple control.	As for class A	Somewhat inadequate	Seriously inadequate	Unaccept-able
2. The controls are logical, with the right number of functions, are conveniently positioned and move as specified in Appendix 2.	Not entirely	Moderate shortcomings	Major shortcomings	Unaccept-able
3. The operator can readily adjust the speed and starting and stopping times of functions that affect safety and working tempo.	Not entirely	Moderate shortcomings	Major shortcomings	—
4. Individual functions are unaffected by the movement of other functions or loads imposed by them.	As for class A	Not entirely	Major shortcomings	—
5. The functions are not affected by external interference, eg, from telephone or power lines.	As for class A	As for class A	As for class A	Not true—therefore unacceptable
6. Automated processes interrupted automatically when operator leaves the cab and have to be restarted by the operator.	As for class A	As for class A	As for class A	Not true—therefore unacceptable
7. Operator has full control over automated functions and can take over immediately	As for class A	As for class A	As for class A	Not true—therefore unacceptable
8. Telltale provided to show when a function not in sight of the operator is activated.	Not always	Moderate shortcomings	Major shortcomings	Unaccept-able
9. Operator gets at least one machine-controlled micro-break of at least 3 s per boom cycle.	During long boom cycle only	No micro-breaks	—	—
10. A given movement of a lever produces a proportional response in boom-tip movement throughout its path.	Moderate shortcomings	Major shortcomings	Seriously deficient	—
11. Processing requires only little manipulation of controls, eg, be-cause process largely automatic.	Moderate shortcomings	Major shortcomings	Seriously deficient	—
12. Control of boom requires only little manipulation of controls, eg, because repeated boom move-ments can be controlled by one lever movement or pushbutton.	Not entirely, eg, a parallel-controlled or telescopic boom	Moderate shortcomings	Major shortcomings	—

Measuring technique

Use time studies to measure time and speed and to calculate control movements for effecting typical boom or processing-head movements. Describe these operations (work elements). Ideally, the time study should be linked to the machine's control system for measuring its signals. Perform the functions that are used in combination and observe their behavior. Note overlapping functions and state whether any of them have to be supervised by the operator. Interview the operator.

Information

The operator of a machine receives, processes and acts on both external information (the stand, team members, etc.) and information provided inside the cab. This handbook is largely concerned with the information available in the cab. Poor visibility, poor lighting, vibration and noise make it difficult for the operator to receive information. Operators who have a stressful personal life also experience problems in making the right decisions based on the information received.

Forest machines provide information on the status of the engine, transmission and hydraulics. The on-board computer contains programs for merchandising, administration and system monitoring. Telecom systems for both voice and data are used to transmit price lists and log tallies to and from the machine, together with information for special work assignments, such as journeys on-road, and for geographical information systems (GIS) and the Global Positioning System (GPS). There are also functions—particularly automated ones—that are controlled mechanically or electronically and can be difficult to understand.

Impact of information on people

Tasks that require more information than the operator can take in and deal with mentally can give rise to errors being made and the operator's suffering from stress. The problem could be a result of the operator being given too much or too little information, or information that is presented in the wrong form, or from the operator not possessing the necessary skills. The resultant stress can also contribute to pains in the neck and shoulders, heart attacks, stomach ulcers, migraine and asthma.

To make a sound decision, we must have the necessary information. For merchandising decisions, for instance, the operator will need detailed information on the length of the stems, their diameters and other external properties. The operator himself chooses the information he needs. If there is too much information, he will select what he believes to be the most useful. The remaining information he puts out of his mind—which can be risky. We can only store a limited amount of information in our working or short-term memory (the conscious part of the mind) at one time and we use our long-term memory to call on past experience. Certain types of information are repeated frequently and the operator's 's response is based on his learning by rote, which means that he can make a decision and act swiftly, eg, during boom operation. Other situations may be new or difficult, and the operator will then take longer to make a decision, as to do so he will have to concentrate. As a rule, we handle only one piece of information at a time when concentration is called for, although other, simple decisions can be made at the same time, especially if the information is received by more than one of the senses, eg, by both sight and touch.

Guidelines

The information in the cab should be well organized and adapted both in volume and type to each task. It should be readily discernible, comprehensible and easy to use (cf. section headed "Instructions and training"). The operator must also understand and accept why certain information is presented and know how all the machine's systems work, as he will otherwise find it difficult to maintain a good tempo and quality in his work. If the operator is to make the best use of important information, he should be able to determine his own work content and working tempo. The information should be provided at a rate that enables the operator to register it without becoming stressed. The information system should also be designed in a way that is conducive to the personal development of the operator and improvement of the work.

- Legibility increases if the text contains lower-case letters.
- Symbols are preferable to text, if they are unambiguous and clear.
- Design images, text and screen placement so that reading glasses are not needed.
- Use few colors—for better legibility in poor lighting and since 10% of all men are color-blind. Avoid combinations of red-and-blue, red-and-green and blue-and-green.

Recommended height of letters at a reading distance of 70 cm for information occurring at different frequencies:

Type style	High	Low	Always the same
Bold	20 mm	13 mm	5 mm
Roman	30 mm	17 mm	7 mm

The aspect ratio (width-to-height ratio) of vertical character strokes should be 1:6 for bold face and 1:8 for light face; aspect ratio for whole characters should be 3:5.

Use a loudspeaker:

- When the message is simple, short, and should be acted on immediately (eg, warning signals)
- When the operator needs to focus on other things and in poor light
- When it is difficult for the operator to see the display because he is frequently shifting position

The more important the information is, the clearer the acoustic signal should be.
A central warning light combined with some other device that informs the operator of what is wrong is recommended. Use a blinking light that flashes at a frequency of 3–10 Hz and at the same interval, whether it be daylight or dark, to warn of serious danger.

Class A	Class B	Class C	Class D	Class 0
1. The operator can see, hear or sense what is needed for the control and stability of the machine.	As for class A	As for class A	Not entirely	No!
2. The operator can hear or see and comprehend all warning signals in any conditions	As for class A	As for class A	Not entirely	No!
3. Important visual information in the cab is conspicuous and close to operator's field of view. Similar types of Information grouped together.	As for class A	Not entirely	Major shortcomings	—
4. Right medium used to provide information (display, acoustic, etc.)	Not always	Moderate shortcomings	Major shortcomings	Seriously deficienct
5. Displays are clearly legible. Text, symbols and colors are visible in all lighting conditions. Light intensity (brightness) of displays is adjustable.	Not entirely	Moderate shortcomings	Major shortcomings	—
6. Text is large enough, concise, complete and readily comprehensible.	Not entirely	Moderate shortcomings	Major shortcomings	—
7. Coded information (eg, symbols) readily comprehensible. Colors have usual significance.	As for class A	Not entirely	Moderate shortcomings	—
8. Menu structure suitable for context in which it is used. Menus have few levels, are readily comprehensible and can be customized. They follow a standard format and allow short cuts to be used and return to main menu from any level.	Not entirely	Moderate shortcomings	Major shortcomings	—
9. Context-sensitive help available for qualified decision-making.	By and large	Moderate shortcomings	Major shortcomings	—

Noise

The noise level in forest machines is seldom so high that there is a risk of damage to hearing. However, noise can be very irritating and tiring, which can result in lower productivity. Furthermore, even low noise levels can be disruptive to work that requires concentration and alertness on the part of the operator. All in all, forest-machine operators appreciate low noise levels.

Noise on a forest machine is mainly generated by the engine, exhaust system, cooling fans, transmission, hydraulic functions and the work processes. Noise from the transmission, hydraulic pumps and hydraulic valves is transmitted to the cab in the form of structure-borne sound, which means that the noise level is minimized when the engine and cab are on separate sections of the machine, as most of the chassis noise, vibration and resonance is avoided. Since noise from the exhaust system, fans and work processes is transmitted to the cab in the form of airborne sound, the cab should be insulated to prevent the ingress of such noise.

Impact of noise on people

Strong noise in the 200–18,000 Hz frequency range can cause hearing damage. The risk of injury increases with the sound level and the exposure time. Intensive noise can cause temporary hearing impairment and, after prolonged exposure, permanent injury. Noise within a narrow frequency range (the tone) is more damaging than noise in a wide frequency range. It is estimated that long-term exposure to a noise level of 85 dB(A) during an eight-hour working day causes permanent hearing damage in 10% of those affected.

Noise can be irritating, can interfere with speech or acoustic signals, and can cause fatigue and reduce productivity. Speech is disrupted most by sounds in the 1000–3000 Hz frequency range. Noise at a discrete frequency is more disturbing than noise that is evenly spread over several frequencies. It is also more disturbing when concentration and thought are required than during routine manual work. The same applies when the operator needs to use his memory and, at the same time, pay attention to multiple sources of information.

Whether sounds are perceived as disturbing (ie, as noise) is a subjective matter. The degree of disturbance is influenced by such factors as whether the operator's hearing is already impaired, the presence of ringing in the ears (tinnitus), the attitude of the operator toward the source of the noise and whether he is suffering from stress. Many low-frequency sounds (below 22 Hz—infrasound) that are continuous, monotonous and so strong that they are perceptible can reduce alertness and induce fatigue. Conversely, strong, irregular blasts of sound can make a person more alert. It is also harder to become accustomed to low-frequency noise than to high-frequency noise. Variations of 10 dB or more in the sound intensity are most disturbing when low-frequency noise is involved.

Definitions:

dBlin	Unfiltered sound
dB(A)	Sound filtered similar to the ear's own filtering
Equivalent level	Mean value of the sound power level
Impulse sound	Sound blast shorter than one second

Guidelines

A minimal noise level is imperative in cabs in which the operator is required to maintain a high level of attentiveness, to register a wealth of information, to talk on the telephone, to converse with others, to make quick decisions and to exercise precision control of machine functions. According to the European Union's (EU) directive on machines, the sound level should be given in the Operator's manual when the level exceeds 70 dB(A). In certain cases, the peak value of the sound pressure in dB(C) and the sound power level should also be stated.

Class A		Class B	Class C	Class D	Class 0
Test reading					
1. Equivalent sound level, dB(A)	≤ 65	≤ 70	≤ 5	≤ 85	> 85
2. Impulse sound level dB(C)	≤ 80	≤ 85	≤ 90	≤ 140	> 140
Assessment					
3. Noise problem negligible		Noise a minor problem	Noise a problem	Noise a serious problem	Noise unacceptable
4. Single-frequency (tone) noise problem negligible.		Tones a minor problem	Tones a problem	Tones a serious problem	Tones unacceptable
5. Impulse-sound problem negligible.		Impulse sound a minor problem	Impulse sound a problem	Impulse sound a serious problem	Impulse sound unacceptable
6. Infrasound problem negligible		Infrasound minor problem	Infra-sound a problem	Infrasound a serious problem	Infrasound unacceptable
7. Operator has no difficulty in hearing all important signals; does not have to raise his voice to talk on the telephone or to someone in the cab.		Little difficulty in hearing and conversing	Difficulty in hearing and convers-ing	Difficulty in hearing and need to raise voice	Unacceptable difficulty in hearing and forced to shout

Measuring technique

- Measurement of sound and impulse-sound levels should be made with standardized sound-level meters.
- For the measurement of equivalent noise levels over longer periods, eg, a full working day, a noise dosimeter is recommended.
- The microphone should be placed at the operator's ear level, ie, about 80 cm above the SRP. The seat should be in the midway position. Only one person should be in the cab.
- Sound-level measurement should be combined with formulae for perceived disturbance from the sound level, existence of high/low frequencies and tones, white noise and sound fluctuations over time.
- The measurements should be made during normal work and over at least one hour of operation on a harvester or one work cycle on a forwarder. Doors and windows should be closed and fan-speed controls should be set midway. The conditions prevailing at time of measurement should be noted.

Vibration

Vibration and jolting on forest machines are uncomfortable and fatiguing for the operator. In addition, precision work is made more difficult and the operator may have difficulty in keeping his eye on the tree or workpiece being handled. Many years of exposure to vibration on a machine can have a detrimental effect on the health of the operator. The lower back is particularly prone to injury, most often caused by mechanical shocks.

The level of vibration and jolting is affected by driving speed, ground conditions, tires, springs/damping in the chassis, cab and seat, and the operator's working technique. When the machine is stationary, vibration is propagated by movements in the working units, eg, from the force generated by a falling tree. The siting of the cab influences the level of vibration to which the operator is exposed. In this respect, cabs with a high mounting point, eg, suspended cabs, have a theoretical disadvantage. However, these cabs have been found to have a low level of high-frequency vibration. Examples of other solutions that have proved to reduce vibration and jolting include wide tires, central tire inflation, active damping of swing arms or the cab, specially designed oscillating-axle assemblies and the use of bogies front and rear.

Usually, vibration is transmitted to the operator through the seat. The level of vibration is usually higher in harvesters and skidders than in forwarders. To assess the effect of vibration on the operator, measurements need to be made of the intensity (acceleration in m/s^2), frequency (Hz) and direction of the vibration, together with the exposure time. There is still no generally accepted technical method for measuring the effect of jolting on the operator.

Impact of vibration on people

Sensitivity to whole-body vibration is greatest in the 1–2 Hz frequency range in the X- and Y-axes and in the 4–8 Hz range in the Z-axis. Wear and tear on the joints constitutes the principal health problem, although other parts of the body, such as the gastro-intestinal tract and musculature, can also be damaged. The deleterious effect of vibration is increased by bent, oblique or twisted posture and long periods of sitting without a break. The neck and shoulders are mainly affected when the operator is exposed to vibration when operating the controls. This is because the operator instinctively tenses his shoulder muscles to counter the movement induced by the vibration.

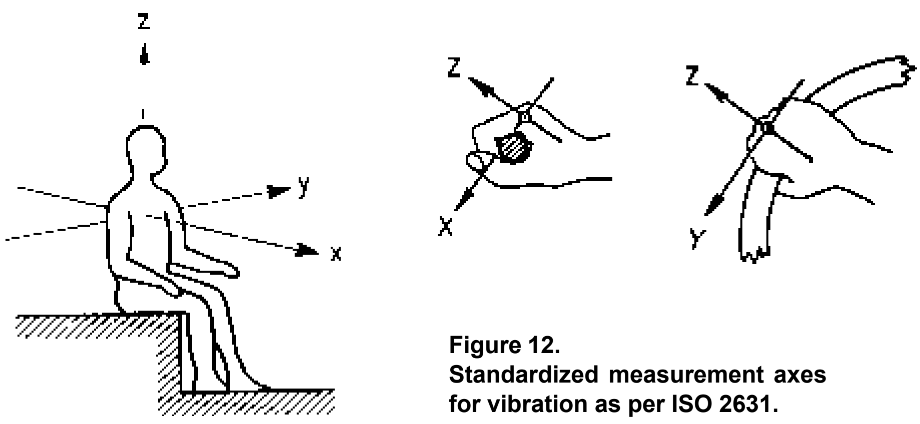


Figure 12.
Standardized measurement axes for vibration as per ISO 2631.

The vibration that is transmitted to the operator through the steering wheel and hand controls is of a higher frequency than that transmitted through the seat. The levels are low, however, and do not give rise to any serious problems on most forest machines. The main effect of vibration is a feeling of discomfort coupled with difficulty in operating the controls—leading to lower productivity in boom work. However, a high level of hand-arm vibration can give rise to circulatory disorders ("white-finger" syndrome), nerve damage and damage to joints and bones in the hands and arms.

Guidelines

Under normal conditions, whole-body vibration should only incur a low risk of injury to the neck and shoulders when the operator is operating the controls and of injury to the lower back. Nor should it give rise to increased fatigue or other than slight discomfort. Reference values for the different classes are denoted by the lower curve on the graph (acceleration · hours = 1.28) in Fig. 13. The upper curve is taken from ISO 2631 and

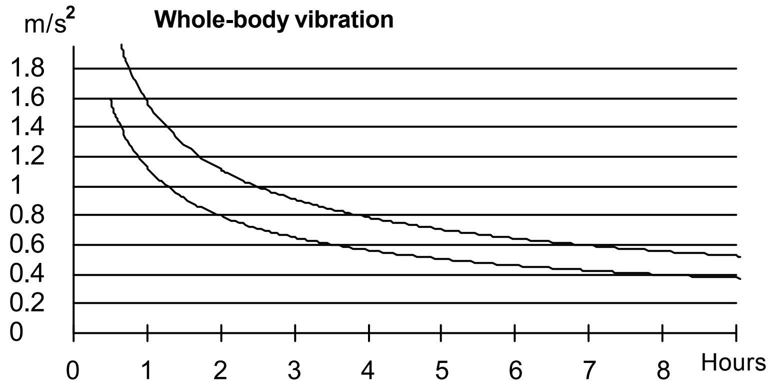


Figure 13.
The lower curve shows the level at which whole-body vibration constitutes only a low risk to health. The upper curve shows the level at which there is a clear risk of injury to the lower back.

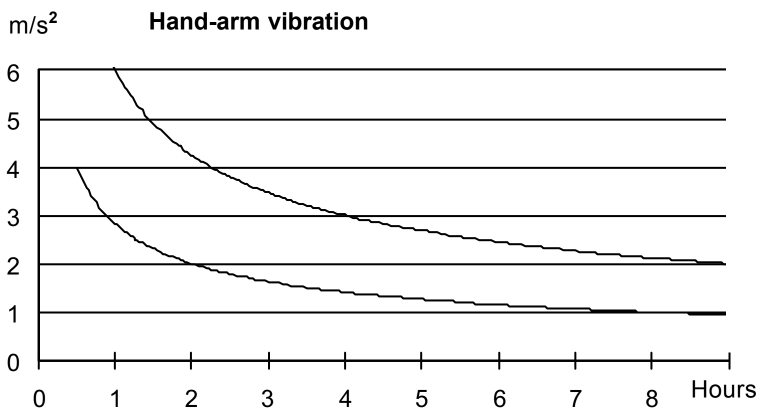


Fig. 14.
The lower curve shows the level at which hand-arm vibration constitutes only a low risk to health. The upper curve shows the level at which 5–10% of a group run a risk of developing circulatory disorder ("white-finger" syndrome).

indicates the level at which there is a clear risk of injury to the lower back under normal working conditions. The machine should also be designed so that the operator is subjected to only minor jolting during normal operation of the machine.

The level of vibration in the hands and arms should not pose a risk of other than minor discomfort. Reference values for the different classes are denoted by the lower curve on the graph (acceleration · hours = 8.0) in Fig. 14. The upper curve is taken from ISO 5349 and indicates the level at which 5–10% of a group run a risk of incurring vibration-induced circulatory injury ("white-finger" syndrome) during normal operation of the machine.

The EU directive on machines prescribes that new machines should be tested for vibration. Documented details of vibration values must accompany machines that have a frequency-weighted value of over 0.5 m/s^2 for whole-body vibration and 2.5 m/s^2 for hand-arm vibration. Standardized test methods are likely to be published during the year 2000. The directive does not yet apply to hand–arm vibration in the machines.

Class A		Class B	Class C	Class D	Class 0
Test reading					
1. Whole-body vibration, m/s^2	≤ 0.40	≤ 0.57	≤ 0.80	≤ 1.1	> 1.1
2. Hand-arm vibration, m/s^2	≤ 1.0	≤ 1.0–1.4	≤ 1.4–2.0	≤ 2.0–2.8	> 2.8
Assessment					
3. Operator subjected to only very slight discomfort from whole-body vibration		Slight discomfort	Moderate discomfort	High discomfort	Extreme discomfort
4. Operator subjected to only very slight discomfort from jolting and shocks		Slight discomfort	Moderate discomfort	High discomfort	Extreme discomfort
5. The machine is designed so that the operator is subjected only to minor jolting and shocks		Somewhat higher level	Moderate level	High level	Extremely high level
6. Operator subjected to only very slight discomfort from hand-arm vibration.		Slight discomfort	Moderate discomfort	High discomfort	Extreme discomfort

Measuring technique

Measuring and assessment of whole-body vibration are based on ISO 2631 (1997). The standard describes the effects in the 0.5–80 Hz frequency range and takes into account the risk to health, reduced comfort and motion sickness. A vibrometer that meets the provisions of ISO 8041 and gives frequency-weighted values along three axes as per ISO 2631 is recommended. The instrument's sensor is fitted inside a plate that is placed on the operator's seat. The total value for the three frequency-weighted axes (see formula below) is used to determine the class to which the machine should be assigned. Values in m/s^2 for the X- and Y-axes should be multiplied by 1.4 (unless the instrument adjusts the readings automatically), since the human body is more sensitive to vibration along these axes than to vibration along the spine—the Z-axis.

$a_v = \sqrt{a_x^2 + a_y^2 + a_z^2}$ (*a* is given in m/s^2 and a_x and a_y are adjusted values)

As there is no standard method for measuring and assessing jolting, a subjective assessment is recommended.

Measurement and assessment of hand-arm vibration is based on ISO 5349 (1986). The standard describes the effects in the 6.3–1250 Hz frequency range and takes into account the risk of vibration-induced circulatory disorder ("white-finger" syndrome). Measurements should be made with the machine operating in normal conditions on snow-free ground over a period of at least 30 minutes to ensure that the readings taken are representative of the work. A vibrometer that meets the provisions of ISO 8041 and gives frequency-weighted values along three axes as per ISO 5349 is recommended. The instrument's sensor, the weight of which should not exceed two grams, should be attached to the control/handle itself. The total value for the three frequency-weighted axes (see formula above) is used to determine the class to which the machine should be assigned. Note that in this case there is no adjustment of the X and Y values.

A subjective assessment should also be made of the machine's ability to absorb shocks and jarring. This mainly concerns the cab suspension and seat springs but other aspects that may be relevant include the siting of the cab and seat, the composition and design of tires and tracks, and the influence that operating units (boom etc.) have on cab movement and the driving characteristics of the machine, eg, the ride and ground-hugging ability of the machine.

Test conditions and assumptions

Whole-body vibration should be measured when the machine is operating in normal conditions on snow-free ground, and with the tires inflated to the pressures specified by the manufacturer. The operator should be experienced and weigh 67–83 kg and the test should take place over a minimum period of 30 minutes. The seat must be securely and rigidly anchored to the cab floor.

Forwarders should be tested in terrain having class 2 ground roughness and class 1 slope (as per SkogForsk publication: *Terrain Classification for Swedish Forestry*). The machine should be driven without a load at a speed of 36–44 m/min and the test performed over one or more operating cycles in which loading and unloading constitute 45–55% of the total cycle time.

Harvesters should be tested in terrain having class 2 ground roughness and class 1 slope. In final felling, the harvester should operate in a stand in which the breast-height diameter (dbh) of the mean stem is 40–50% of the machine's felling-head capacity. In thinning, the mean dbh of the trees felled should be 30–40% of the felling-head capacity. The driving time between set-ups should account for 10–20% of the total test time.

Climate control in the cab

The climate in the confined space of an operator's cab is complex and unstable. Solar radiation and drafts are a serious problem. The operator's sensation of drafts in a cab is often caused by heat from the body being transferred to adjacent cold surfaces or by the flow of air from vents inside the cab. It is therefore difficult to strike a balance between a comfortable level of heat for the whole body and comfort for individual parts of the body. The body usually adjusts its own heat balance naturally but if the climate inside the cab overstresses the body, it will have a detrimental effect on the operator's comfort and performance and, in the longer term, his health as well. A climate-control system therefore has to meet exacting demands if it is to create a comfortable climate for the operator.

It is usually easier to achieve a good climate in a large cab than in a small one. If the operator is seated further away from the window glass, he will be less affected by drafts and the radiated heat from the sun. The climate is also influenced by the interior design of the cab, the level of insulation, the design of the seat, the area and type of window glass and the design of the climate-control system itself. Thus, no single point in the cab can be used as a reference for monitoring or controlling the climate.

Guidelines

The design of the cab and the climate-control system should together provide a climate inside the cab that is acceptable to the vast majority of operators working in the normal conditions prevailing in Scandinavia throughout the year. The climate-control system should have an automatic mode, with individually adjustable settings, and must be able to raise or lower the temperature inside the cab quickly. It must also have an effective defroster function for the windows and be user-friendly. If necessary, the cab should also be equipped with sun blinds.

Class A	Class B	Class C	Class D	Class 0
Tests				
1. With a standard thermal dummy, all readings comply with the 80% comfort profile.	Hands and buttocks outside the 80% comfort profile.	—	—	—
2. Climate-control system can maintain inside temp of 25°C at an outside temp of -20°C.	As for class A	21°C	Major shortcomings	—
3. Climate-control system can maintain inside temp of 25°C at an outside temp of 27°C and in sunshine.	24°C	Inadequate performance	—	—
4. Cab temp can be raised from -20°C to 20°C within 10 minutes.	Within 15 min.	Within 30 min.	Not at all	—
5. Cab temp can be reduced from 30°C to 25°C within 10 minutes.	Within 30 min.	Inadequate performance	Not at all	—
6. At outside temp of -20°C or +27°C and in sunshine, temp differential between specified measuring points inside cab is < 5°C.	< 6°C	Higher differential	Extremely high differential	—
7. At an outside temp of -20°C and with moisture inside cab, climate-control system can demist and keep window glass clear within 5 min.	At -15°C	At -10°C	Inadequate performance	—

Class A	Class B	Class C	Class D	Class 0
Assessment				
8. In winter, the climate in the cab is acceptable under all weather conditions.	Not at very low outside temperatures	Not at low outside temperatures	Only in fine weather	—
9. In summer, the climate in the cab is acceptable under all weather conditions.	Not at very high outside temperatures and in sunshine	Not in sunshine	Only in fine weather	—
10. Effective means of protection provided against strong heat from the sun.	As for class A	Inadequate protection	No protection provided	—
11. Operator not troubled by cold drafts and fluctuating temperatures.	Minor discomfort	Moderate dis-comfort	Major discomfort	—
12. Cab equipped with automatic climate-control system with individually adjustable settings and user-friendly operation.	Equipped with limited ACC system	Simple manual con-trol of heating and fan	Difficult control of heating and fan	—

Measuring technique

Assessment of the climate in the latest types of cab should be done in a climate chamber and with the use of a standardized thermal dummy for measuring the equivalent temperature at various points between the dummy's feet and head. Equivalent temperatures reflect how a person experiences the body's exchange of heat with the surroundings by air (convection) and radiation. Because equivalent temperatures cannot take sweating into account, the method cannot be used to assess the climate at high temperatures or when the operator is doing hard physical work. The tests are carried out at an outdoor temperature of -20°C and +27°C. At 27°C, the tests are performed both without solar radiation and under solar radiation at 700–800 W/m^2. The comfort profile obtained is compared with the level at which 80% of a group of operators are satisfied with the climate.

The heating and cooling performance and the capacity of the climate-control system are determined in accordance with ISO 6097 and ISO 8953.

Simplified test procedures

For simpler testing of the climate in the cab, it is recommended that the air temperature be measured on both left and right sides of the feet at a point about 5 cm above the floor; at the point at which the hands rest on the controls; in front of the chest; and at head height. An ordinary thermometer that is screened against solar radiation can be used. The average value of these measurements is used in assessing the heating and cooling performance and the capacity of the climate-control system. The tests should be carried out in both hot and cold weather and should also include a subjective assessment of the performance of the system—based on the size of the cab, its size, how well insulated it is (airtightness), the equipment fitted and the position and design of the air inlets (vents).

Gases and particulates

There is not normally much risk of a forest-machine operator being exposed to gases, particulates or oil mist, although there is a danger of diesel fumes getting into the cab—which is highly detrimental to health. Dust from the ground and the trees, and also pollen may be present in the cab. The operator may also be exposed to gases and particulates during the spraying of chemical and biological pesticides, and the spreading of artificial fertilizers or wood ash.

The principal substances in diesel exhausts that are a health hazard are nitrogen oxides, hydrocarbons, carbon monoxide and particulates. Nitrogen oxides are formed from the air during high-temperature combustion, whereas carbon monoxide and hydrocarbons are residues from incomplete combustion of the fuel. The particulates consist mostly of soot and unburned fuel and lubricants. Exhaust gases also contain sulfur oxides, most of which come from lubricating oil, if the fuel has a low sulfur content.

Exhaust emissions from a machine are determined to some extent by the performance and condition of the engine and also by the type and quality of the fuel—the higher the cetane number the lower the concentration of oxides of nitrogen. The production of soot can be reduced by increasing the amount of induction air to the engine, ie, by increasing the charging pressure and providing an intercooler, and filters can be used to reduce soot emissions. If a catalytic converter is fitted to the engine, it must be properly matched to the load on the engine: an improperly matched catalyst can do more harm than good.

Impact of gases and particulates on people

Inhaling exhaust gases can give rise to fatigue, headaches, nausea, irritation of the respiratory tract and mucous membranes and can also affect the lungs. Exhaust gases from diesel engines have a mutagenic effect (affecting genetic material) and also contain carcinogenic substances. Dust and pollen can give rise to lung disorders and allergies.

Hygienic limits for exhaust emissions and particulates, mg/m^3.

Substance	Exposure-level limit values, mg/m^3	Ceiling (C) Short-term value (S)
Formaldehyde[1]	0.6	1.2 (C)
Carbon monoxide (from exhaust gases)[1]	25	120 (S)
Nitrogen dioxide (from exhaust gases)[1]	2	–
Nitrogen oxide [1]	30	60 (S)
Diesel exhaust[2]	0.15	–
Oil mist, including oil smoke[1]	1	3 (S)
Dust, total	10	–
Dust, inhalable	5	–
Dust, organic[3]	5	–

[1] Eight hours exposure per day, as per AFS 1996:2.
[2] Limit values from ACGIH in the USA.
[3] Excluding pollen—no limit values for pollen have been specified in Scandinavia.

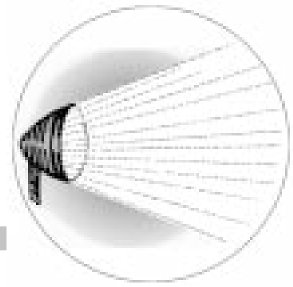
Guidelines

The operator should not be exposed to exhaust gases, pollen, dust or oil mist. If this happens, the situation must be rectified.

Class A	Class B	Class C	Class D	Class 0
1. The operator is not aware of any exhaust fumes, dust or oil mist in the cab even when working in dense stands, dusty conditions or adverse weather.	Aware of exhaust fumes, oil mist or dust in difficult conditions	Discomfort in adverse conditions	Frequent discomfort	Limit value exceeded by at least one substance
2. Engine type/size, rpm, fuel and catalytic converter have been optimized to minimize concentrations of harmful substances.	Minor shortcomings	Moderate shortcomings	Major shortcomings	—
3. The exhaust system is free from leaks and the discharge pipe is positioned well away from the air intake to the cab.	As for class A	As for class A	Minor shortcomings	—
4. Design of cab prevents ingress of fumes into the cab.	As for class A	Minor shortcomings	Major shortcomings	—
5. Filter for removal of dust, pollen, etc., can be fitted to cab air intake when required.	Filtering of dust	Minor shortcomings	No filter available	—
6. There is an indicator that shows when the filter needs changing.	As for class A	Not fully satisfactory	—	—
7. Catalytic converter or particulate filter has certified service life and instructions for care and replacement.	Not fully satisfactory	No!	—	—

Measuring technique

No standard procedure is given for measuring hazardous airborne substances inside the cab. However, the concentrations of these substances should be measured periodically. For field use, there are portable samplers for later analysis in the laboratory. There are also simple reagent tubes through which the cab air can be pumped. However, the smell of diesel-exhaust fumes is detected long before the level reaches the hygienic limit value—so a person's sense of smell is the best way to test for fumes in the cab. Some types of dust are visible in good light when the concentration is higher than 5 mg/m^3. Another method is to see how long it takes before dust settles on a clean surface.



Lighting

When operating after dark, many operators unwittingly let the standard of their work fall. One reason for this is that the lighting on the machine does not provide adequate illumination of difficult trees. Another is that working after dark is more demanding and more tiring than in daylight and makes the operator more prone to making mistakes.

A large problem on forest machines is to provide adequate lighting in all areas of the operating envelope. For instance, the area adjacent to the operating head is usually brightly lit, making the surrounding area pitch black. The operator is often dazzled by reflections in the window glass and from shiny machine parts and illuminated snow. Our knowledge of how to balance illuminance (lux) with the color of the light to achieve optimum illumination is still limited. However, evidence from the use of gas-discharge lamps has shown that the white light they emit illuminates a given area better than yellow light of the same intensity.

Impact of lighting on people

If the lighting is not powerful enough, the illumination provided will not be good enough for the operator to focus on detail and will also reduce his color recognition and rate of perception. An acceptable rate of perception is possible at 50 lux but it will continue to improve up to an illuminance of thousands of lux. In the forest, over 50 lux of white light is needed for a human being to be able to discern colors.

Uneven lighting can cause headaches and eye fatigue. The reason is that the eye and eye muscles move involuntarily to adjust to different levels of luminance. Older people cannot see as well at low luminance values as younger people can: a 40-year-old needs twice as much light as a 20-year-old to achieve the same visual performance. Older people are also more readily dazzled.

Luminous flux, lm	The total light from a light source, usually weighted according to yellow-green light, which gives the highest visual sensitivity in daylight. For outdoor lighting, the proportion of the (white) light source accounted for by blue-green light should be stated. In this light, the eye sees better when the surroundings are dark.
S/P (scotopic/photopic) value	Denotes how the light is weighted according to the sensitivity of the eye to both blue-green and yellow-green light.
Illuminance, lux	The luminous flux incident on unit area of a surface: 1 lux = 1lm/m^2.
Luminous intensity, candela (cd)	The luminous flux in a given direction from a light source, ie, depending on the design of the lamp.
Luminance, cd/m^2	The luminous intensity per unit area in a given direction[1)]; the brightness of the light we see.
Light uniformity	Variation in luminance in a given area. Dazzle is caused when the difference in luminance between adjacent surfaces is greater than 1:20.
Color temperature, Kelvin (K)	Measure of the color of a light source. A lower temperature means a redder light: a higher temperature a whiter light.

[1)] Luminance = Illuminance x reflection factor / 3.14

Guidelines

The lighting on the machine should make it possible for the operator to perform all the tasks that can be done in daylight. The luminous intensity should be high enough and the light directed in such a way that there is no dazzle from contrasts or reflections. Nor should the operator be dazzled by illuminated parts of the machine within his field of view. The color of the light should be conducive to good visibility when the surroundings are dark. Even if these guidelines are met, it is likely that the operator will find work more demanding when he is operating the machine in artificial lighting rather than in daylight.

Uniform general lighting is needed within the working envelope of the boom (see Fig. 15 and also the requirements specified in the section on Visibility). For both safe driving and planning, a certain amount of illumination is also needed in the areas beyond the operating envelope of the boom. For felling, for instance, the operator needs to be able to see where the trees are, their type and size, the appearance of the crown, clearings in the stand, and where the tree tops will strike the ground. In some harvesting operations, the operator needs to be able to see as high as 25 m above the ground at a distance of 10 m from the cab. The best lighting is needed around the operating head/ unit, since the operator has to be able to discern any rot in the stem, the branchiness, crooks and sometimes even any compression wood and obstacles. Remember that the operating head can move rapidly over a fairly large area. The forwarder operator must be able to identify the species etc. of logs and bolts, any rot, the lie of the logs and any possible obstacles—all of which he has to take stock of in just a few seconds and regardless of the weather.

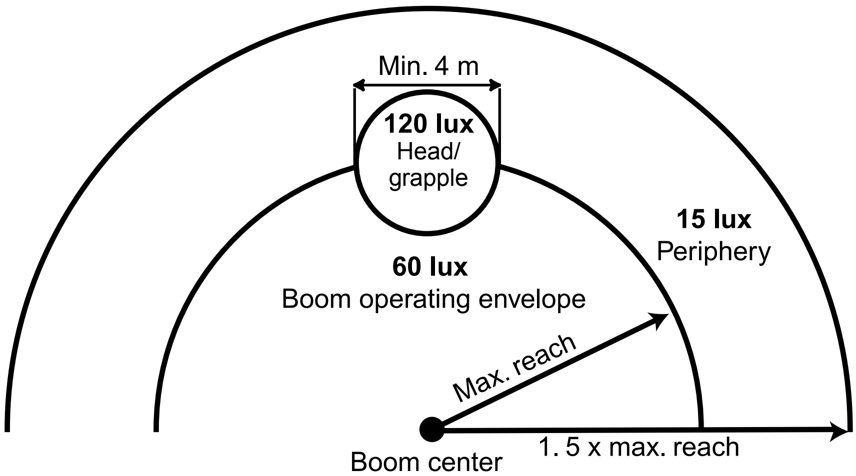


Figure 15.
Guidelines for lighting on forest machines. The illumination values shown apply to a light source that has a color temperature over 4000 K and a high S/P value.

Class A	Class B	Class C	Class D	Class 0
Test reading				
1. The maximum ratio of the highest/lowest lux value between the Zone around the operating head, the Operating envelope of the boom and the Periphery is 10 : 4 : 1.	Maximum of 15 : 5 : 1	Maximum of 12 : 1 : 0.1	Maximum of 20 : 1 : – Periphery not measured	Dazzle renders work unsafe
2. Illuminance in the respective zones is at least 120/ 60/15 lux.	At least 100/40/10	At least 80/30/5	At least 10 lux in operating zone	Inadequate lighting renders work unsafe
3. The illuminance for driving is at least 10 lux at 20 m in the direction of the machine's travel.	At least 8 lux	At least 5 lux	At least 2 lux	Under 2 lux
4. The color temperature of the general lighting is over 4000 K.	At least 3000 K	At least 3000 K	—	—
Assessment				
5. The light is well distributed. The operator is not dazzled by sharp contrasts and can see the surroundings.	Uneven illumination of nonessential items	Uneven illumination of operating area	Very uneven illumination of operating	Dazzle renders work unsafe
6. No distracting reflections from windows or machine parts	Some distraction	Moderate distraction	High level of distraction	Dazzle renders work unsafe
7. Adequate illuminance for all operations and moving between set-ups. Operator also has upward vision and can see beyond the boom operating envelope.	Not fully adequate in parts of the operating zone	Inadequate in parts of the operating zone	Highly inadequate	Inadequate illuminance renders work unsafe
8. Color and quality of the light give good general visibility, do not cause eye strain and reproduce important colors faithfully.	Not entirely	Moderate shortcomings	Major shortcomings	—
9. Lighting can be dimmed when necessary.	Not fully.	Not at all.	—	—
10. Lamps can be aimed precisely and readily returned to previous setting	Not fully.	Somewhat limited.	Highly limited	—
11. Lighting in the cab is good, can be controlled, and does not cause glare or reflections.	Not entirely	Moderate shortcomings	Major shortcomings	—

Measuring technique

Testing is usually effected by marking out a grid of one-meter squares on the ground. The illuminance in lux is measured at each intersection on the grid at a point 20 cm above ground level. The meter should be held horizontally to avoid reflections from the ground. Measurements are made in an area 1.5 times the reach of the boom and up to 20 meters from the machine in its direction of travel. The boom should be extended to its full length in the operating direction of the machine, and at an angle of 45° to the center line of the machine. Particulars of the color spectra (including S/P number), luminance, and the luminous intensity of the lamps, together with the spread of the beam from them, are given by the supplier.

Lamp reflectors and lenses should be intact and clean on examination. Check that the right bulbs are fitted in the lamps and that they have been installed correctly. Check also that the lamps are securely mounted and, if possible, measure the power supply to check that the voltage is correct for the bulb ratings. Poor connections and leads that are not of a high enough rating can reduce the performance of a lamp to below the specified rating. Also check that the alternator voltage is 14 V for 12-V systems and 28 V for 24-V systems. Dazzle and reflections should be measured with a luminance meter, since they are difficult to determine subjectively.

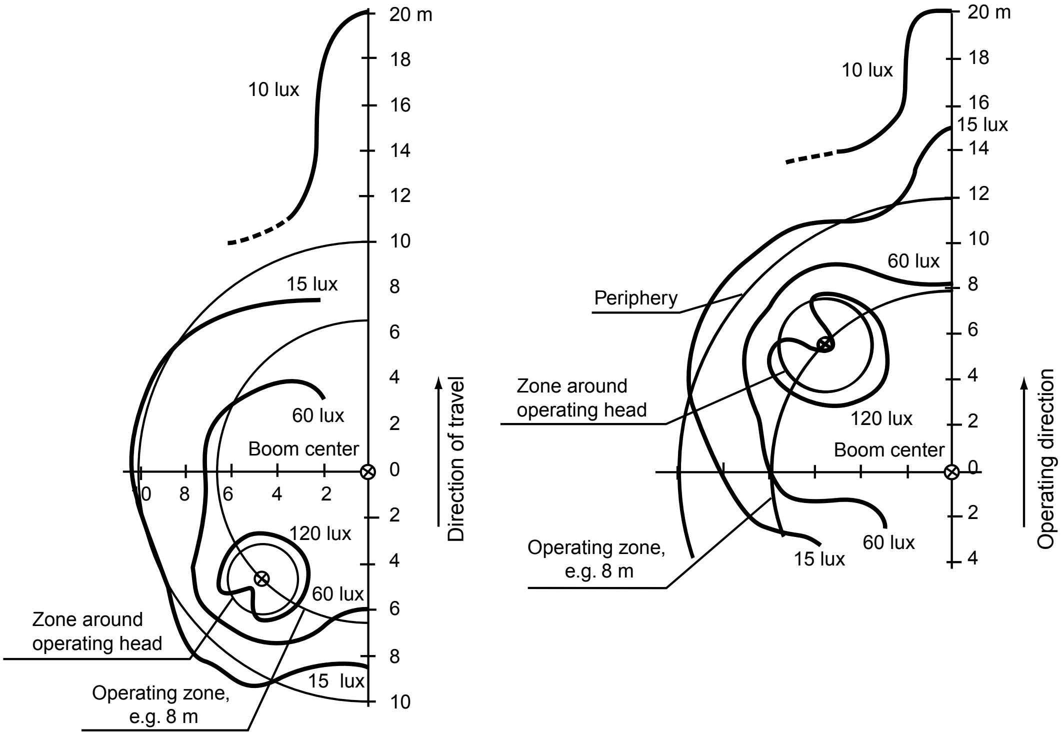


Figure 16.
Example of illumination diagrams for a forwarder and a harvester.

Instructions and training

This section deals with the oral and written instructions, training, manuals and briefing that should be given to the operator, and also the signs and plates that should be displayed on the machine. It is vitally important that the operator use the machine in the right way. Failure to provide the necessary information can result in accidents, severe stress and discomfort for the operator, and low productivity. If the operator is to achieve a sound working technique, he must be properly instructed and given sufficient time for training before the machine is operated at full capacity. Generally, the operator should also be given instruction and training when changing from one machine to another, if the method of working has been changed or if the work has been reorganized. Sound instructions are also vital to prevent the operator from making mistakes that could have disastrous consequences. If the operator is fully familiar with the machine and able to handle it properly, the machine will also need repairing less frequently.

Guidelines

The following guidelines are those regarded as the most important. Examples are also given to show the required extent and scope of the information.

Contents of the Operator's manual

General. Customary particulars of the machine and the implications of the CE markings.

Information on safety labels, operator training, etc.

Technical data. In addition to customary data, also test reports on visibility, lighting, noise and other ergonomic factors. Measuring technique, test conditions and limit values should also be specified.

Technical description. Description of all technical systems on the machine, including the operator's seat, climate-control system, communications and computer systems. Particulars of how well the machine meets the criteria specified in this handbook.

Overview sketch, description of the functions and how they are operated, flow charts, essential diagrams, fitting of accessories and optional equipment, and description of safety precautions and systems.

Instructions for driving and operating the machine. Operation of steering and braking functions; machine stability; instructions for installation and removal of equipment; installation of computer screens; operator's seat; controls.

Instructions on recommended driving and operating technique.

Maintenance. Check list for preventive maintenance; which repairs should be performed by an authorized workshop; maintenance of, eg, operator's seat and lighting; wear limits for consumables (eg, saw chains).

Instructions for replacing components, eg, wheel changing.

Fault-diagnosis routines. Service book.

Safety instructions. Competence required to operate the machine. Emergency alarms; danger zones; personal safety equipment; risk of RSI.

Driving off-road and on slopes; influence of payload on braking capacity and operating on slopes, etc.; seat belt; emergency evacuation; driving on frozen rivers, lakes, etc; overhead power lines.

Driving on public roads; lighting; display of "Slow-moving vehicle" plates; driving with tracks; special traffic regulations; transport of hazardous goods.

Maintenance work when engine is running; how to relieve pressures and to avoid involuntary starting.

Braking the machine; towing; supporting machine on blocks; risk of slipping; use of ladders; hazardous substances, etc.

Spare parts list. Exploded pictures: item, part and VIN/chassis numbers; designation of standard parts; address for ordering.

Other equipment. Separate manuals must be provided for equipment that is fitted on the machine but not covered in the operator's manual. Such manuals should not include instructions that apply to other equipment.

Operator's manual—presentation

The Operator's manual should satisfy the following criteria:

- Applicable to the machine as delivered.
- Suitable for updating and inclusion of supplements.
- Hard-wearing and durable
- Capable of being used outside the cab as well
- Easy to use and understand
- Comprehensive table of contents and index.
- Clearly illustrated
- Easy to read in the local language and uses standard terminology and symbols.

Oral briefing and practical training

Agreements should be concluded for the following:

- Oral briefing and practical training on delivery of a new machine.
- Follow-up after operator has used machine for some time
- Instruction and consultation when necessary.
- Access to authorized mechanic and to spare parts (within a specified time).

Signs

- Signs that should be provided include general warning signs and specific warnings of danger zones in vicinity of moving machine components (eg, booms); hazardous objects handled (eg, falling trees); other hazards (eg, chain breakage).
- Signs should be provided relating to safe operation of machine, eg, maximum RPM, maximum load, whether ear defenders need to be worn, etc.

Class A	Class B	Class C	Class D	Class 0
1. Contents of Operator's manual satisfy the criteria specified in this handbook.	As for class A	Minor deficiencies	Major deficiencies	Unacceptable deficiencies
2. Presentation of Operator's manual satisfies the criteria specified in this handbook.	As for class A	Minor deficiencies	Major deficiencies	—
3. The machine has special provision for storing the Operator's manual and spare-parts list.	Minor deficiencies	Unsuitable provision	No provision made	—
4. Adequate instruction and practical training given in conjunction with delivery.	As for class A	Not fully adequate	Inadequate	Unacceptable
5. Opportunity exists for follow-up, additional training and consultation.	As for class A	Somewhat limited	Very limited	—
6. All essential information and warning signs provided and permanently attached to machine.	As for class A	As for class A	As for class A	No!

Maintenance

This section deals with the scheduled preventive maintenance specified in the Operator's manual and with unscheduled remedial maintenance work (includes fault diagnosis, adjustment, repair and replacement). The guidelines given in this handbook apply to maintenance work that the operator usually performs in the field and are confined to the machine and its equipment. Work involving the use of welding equipment, grinding machines and the like is therefore not included. Nor does this section deal with items of personal-safety equipment, hygienic equipment, etc.

Forest-machine maintenance in the field is performed outside in all kinds of weather. Working in awkward positions, climbing onto the machine and risking slipping off it, working under the machine, physical exertion, heavy lifting, harmful liquids, the handling of slippery, hot and dirty machine parts—all this is part and parcel of the job. Not surprisingly, therefore, more accidents occur during machine maintenance than in any other type of forest-machine work (see the earlier section entitled, "Productivity and Health"). Most accidents are associated with the operator's slipping or falling, making contact with the saw chain or other sharp objects, being hit by a flying machine part that has come loose, being trapped between moving parts of the machine or coming into contact with escaping steam or hot liquids.

Guidelines

Class A	Class B	Class C	Class D	Class 0
1. Fault-diagnosis chart is clear and comprehensive.	Somewhat flawed	Poor	None provided.	—
2. Facility for quick and safe disengaging/engaging of power sources and discharging of stored energy when working on machine equipment.	As for class A	As for class A	Safe but not as fast	Unsafe
3. If the engine must be running, eg, during fault diagnosis, suitable guards provided to prevent operator from coming into contact with moving parts.	As for class A	As for class A	As for class A	No!
4. Essential tools provided with the machine and can be stored in warm place, but not loose in the cab.	As for class A	Minor shortcomings	Major shortcomings	—
5. Tiltable cab, protective hoods, etc., are securely locked automatically when opened.	As for class A	Secure manual locking	Some shortcomings	Unsafe
6. Essential non-slip steps, handles, ladders, ramps, etc. are fitted or provided with the machine.	As for class A	Minor shortcomings	Major shortcomings	Unsafe
7. Common tasks demand application of force of < 50 N	< 80 N	< 120 N	Far too high	—
8. Common tasks can be effected with a lifting force of < 200 N.	< 300 N	< 400 N	< 500 N	> 500 N
9. Suitable lifting devices and attachment points provided.	Some shortcomings	Major shortcomings	No!	—
10. Movable auxiliary lighting equipment provided.	As for class A	Provided but not fully satisfactory	No!	—
11. The machine can use environmentally friendly fuels, oils and lubricants.	Not exclusively	Only to a limited extent	To a very limited extent	—

Class A	Class B	Class C	Class D	Class 0
Assessment when a maintenance index is available				
12. Maintenance index for monthly maintenance: Harvester: 10,000 Forwarder: ≤ 7,000	≤ 15,000 ≤ 10,000	≤ 20,000 ≤ 15,000	≤ 25,000 ≤ 20,000	> 25,000 > 20,000
Assessment when a maintenance index is not available				
13. Directions given on which tasks can be performed from the same position on the machine.	Incomplete	No!	—	—
14. Normal maintenance can be performed from the ground and in a convenient position	On the machine and in a convenient and safe position	On the machine but need to stretch	Only to a limited extent	Ergonomically unacceptable
15. All important components that need frequent attention are readily accessible and easy to replace.	Not entirely	Only to a limited extent	Only to a limited extent	—
16. Guards, inspection panels, etc., can be opened/raised easily without tools (key acceptable) and remain attached.	Not entirely	Only to a limited extent	Only to a very limited extent	—
17. Handling and filling of fuel, oil and pesticides can be done easily and without spillage.	As for class A	Not entirely	Only to a limited extent	Ergonomically unacceptable

Measuring technique

Preventive maintenance is assessed by means of an index for maintainability (maintenance index) in accordance with SAE standard J817/2 (see Appendix 4). The index is based on the periodic maintenance specified in the Operator's manual for the machine. It will generally suffice to assess maintenance to be carried out monthly or more frequently. The lower the index, the safer, easier and quicker is the maintenance of the machine. The factors to be assessed are service-point location and accessibility, procedure and miscellaneous. A frequency factor is used for the frequency of the task: the higher the frequency the higher the index.

Higher index for potentially hazardous work

- Working up on the machine or underneath it.
- Danger of unexpected machine movement.
- Risk of injury from machine parts that have been detached and are heavy or under a load or pressure, eg, hydraulic-system components, springs etc.
- Awkward working positions.
- When the work requires the application of considerable force.
- Heavy soiling, mud, litter, etc.

It is difficult to assess remedial maintenance (mainly repairs) as the need for repairs cannot be predicted with any certainty. The principle is that suitable instructions for the repair must be provided. The maintenance index can give some guidance for making the assessment.

Brakes and operator safety

This section deals with operator safety in the event of accidents and covers what has not been discussed in previous sections. Safety during mounting and alighting, maintenance work, etc., are dealt with in the respective sections earlier in the handbook. Operator safety is influenced by the design of the machine, how it is used and by such factors as the terrain and stand conditions, the work organization and attitudes towards the work. This section deals only with aspects that are associated with the design of the machine and the equipment. It therefore does not cover safety aspects such as personal items of protective clothing and equipment or the competence and behavior of the operator.

Machine directive of the EU and the EEA agreement

To minimize the safety risks, the machine should be designed in accordance with the EU's machine directive and the special regulations on mobile machines, which address such items as the operator's workstation, the controls and mechanical risks—unexpected movement, failure of a mechanical component during operation, rollovers, falling objects, access routes, power transmission, etc. The most important requirements are as follows:

- A machine should be as safe as is possible given the existing knowledge and technology. This assumes that it is used for its intended purpose and in accordance with the manufacturer's instructions.
- Whenever possible, potential risks should be excluded in the design work and manufacturing.
- The expected useful life and any abnormal use of the machine should be taken into account both during manufacture and the drawing-up of operator instructions.
- Essential tools needed for adjustment and maintenance should accompany the machine.

The CE mark should be affixed to a machine that meets these requirements to enable it to be sold in the EU and countries covered by the European Economic Area (EEA) agreement. As regards forest machines, the CE mark merely indicates that the manufacturer considers that the machine meets the requirements—there is no requirement for official testing. The machine directive specifies a number of measurable requirements but also refers to other standard requirements; the manufacturer should verify that the provisions of the relevant standards have been met. The following are examples of some of the important standards that deal with safety:

- ISO 11850, Safety in forest machines
- ISO 8082, Roll Over Protective Structure (ROPS)
- ISO 8083, Falling Objects Protective Structure (FOPS)
- ISO 8084, Operator Protective Structure (OPS)

Guidelines

Classes A, B and C: Safety assessed as fully satisfactory.

Class D: Acceptable under certain conditions, eg, only to be driven on flat ground; maintenance to be carried out by trained personnel. Alternatively, the risk of injury is deemed to be so minor or to occur so rarely that action can wait until the next service.

Class 0: Fails to meet the requirement or poses risk of injury. The machine must not be used before the defect has been rectified.

The safety assessment is based on the following:

- Risk frequency: ie, how often the risk occurs.

- Probability: ie, the likelihood of injury occurring if the risk arises.
- Severity: ie, the likely severity of the injury if an accident occurs. The number of sick days resulting from the injury as recorded in the accident statistics can give an indication of the severity.

Example 1: The braking system is not powerful enough, which means that there is a risk of an accident occurring every time the machine negotiates a steep slope (high risk frequency). However, even if the machine cannot be brought to a standstill, the risk of injury is still deemed to be fairly low (low probability). If an injury occurs nonetheless, then it is likely to be a serious one (high severity). The machine is therefore assessed and assigned to class 0. If the machine is only used on flat ground, then it can be assigned to class D.

Example 2: There is a sharp edge on the outside of the cab on which the operator could cut himself when entering or leaving the cab. There is thus both a high risk frequency and a high probability of injury, but the severity of the injury is likely to be low. The assessment is therefore class D, but with the proviso that the sharp edge be rectified the next time the machine is serviced.

Class A, B och C	Class D	Class 0
1. The machine has independent controls for the service brake and secondary (emergency) brake.	As for class A	Controls not independent
2. The machine can be stopped on a slope of at least 50% and the brakes can be readily applied in an emergency independently of the power source. The brakes effect a deceleration of at least 4.5 m/s^2 and meet the requirement in ISO 11169 for wheeled machines and ISO 11512 for crawler (track-laying) machines.	Braking performance meets only the requirements of ISO 11169 or 11512	Braking performance does not meet either ISO 11169 or 11512
3. The brakes are reliable. With footbrake applied, the machine cannot move when an attempt is made to pull away in the lowest gear.	Not fully compliant but can be used in certain conditions	Falls well short of requirement.
4. The machine does not have sharp corners or sharp edges.	Not fully compliant but can be used in certain conditions	Falls well short of requirement.
5. Tires, chains and tracks provide good traction.	Somewhat deficient but can be used in certain conditions	Falls well short of requirement.
6. Neither the machine nor its components can move spontaneously.	As for class A	Falls short of requirement.
7. The boom can be immobilized when the machine is parked.	As for class A	Falls short of requirement.
8. All moving parts, transmissions, etc., are fitted with guards.	As for class A	Falls short of requirement.
9. Adequate, reliable and effective fire-extinguishing equipment provided.	As for class A	Falls short of requirement.
10. Battery suitably located and anchored: cannot injure operator, eg, if machine rolls over.	As for class A	Falls short of requirement.
11. Suitable screening of all electronic equipment.	As for class A	Falls short of requirement.
12. An emergency stop button/device, SOS transmitter or other emergency system is provided for when the operator is working outside the cab.	As for class A	Falls short of requirement.

The effectiveness of the brakes should be checked every day in the following manner. The machine is brought to a standstill by means of the footbrake. With the foot still on the brake, the machine should not move when an attempt is made to pull away in the lowest gear. If there is any doubt about how the test should be performed, the manufacturer should be contacted for advice.

Literature cited

Introduction

Winkel J, Atterbrandt M., Wikström B.-O. (eds). 1998. "Konsensusrapporter rörande kunskapsläget om arbertsmiljön i skogsmaskiner" [Consensus reports on current knowledge of the working environment on forest machines]. Arbete och Hälsa 1998:10. Swedish National Institute for Working Life. [In Swedish]

SS 2863. "Lantbruk: lantbrukstraktorer och lantbruksmaskiner – förarstolens referenspunkt" [Agriculture: farm tractors and agricultural machinery—seat reference point (SRP)].

ISO 3411. Earth-moving machinery—Human physical dimensions of operators and minimum operator space envelope.

ISO 5353. Earth-moving machinery—Seat index point.

Noise

ISO 6394. Acoustics: Measurements of airborne noise emitted by earth-moving machinery; Operator's position; Starting test condition.

ISO 5131, Appendix D. Acoustics: Measurements of noise at the operator's workplace on agriculture tractors and field machinery; Survey method.

Vibration

Anon. Terrain Classification System for Forestry Work. SkogForsk, Uppsala, Sweden.

ISO 2631. Mechanical vibration and shock—Evaluation of human exposure to whole-body vibration. Part 1: General requirements.

ISO 5349. Mechanical vibration—Guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration.

ISO 8041. Human-response vibrating measuring instrumentation.

Climate control in the cab

ISO 6097. Tractors and self-propelled machines for agriculture and forestry—test method for performance of air-conditioning systems.

ISO 8953. Tractors and self-propelled machines for agriculture—performance of heat and ventilation system in closed cabs: test method.

Gases and particulates

AFS 1996:2. "Hygieniska gränsvärden" [Hygienic limit values]. Arbetarskyddsstyrelsen [National Board of Occupational Safety and Health], Stockholm, 1996. [In Swedish]

ACGIH. Threshold limit values (TLVs) for chemical substances and physical agents and biological exposure indices (BEIs). ACGIH, 1996.

Brakes and operator safety

ISO 11169. Machinery for Forestry: Wheeled Special Machines; Vocabulary, Performance Test Methods and Criteria for Brake Systems.

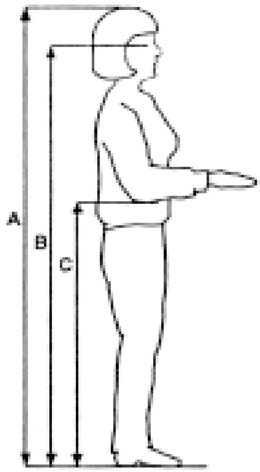
ISO 11512. Machinery for Forestry: Tracked Special Machines; Performance Criteria for Brake Systems.

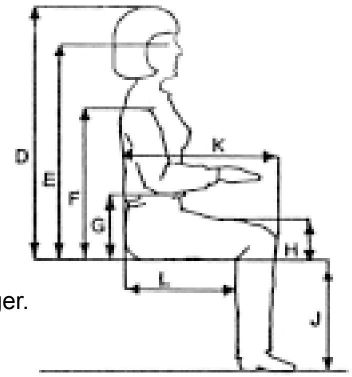
Appendix 1: Body measurements

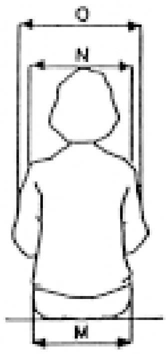
Machine operators' measurements (including shoes) in cm according to ISO 3411.

Body part		Measurement at various percentiles		
		5%	50%	95%[1]
A	Body height	155	172	190
B	Eye height, standing	145	161	176
C	Elbow height, standing	94	107	115
D	Seat–top of head	80	88	99
E	Seat–eye level	69	77	85
F	Seat–shoulder	53	59	70
G	Seat–elbow	20	23	25
H	Seat–thigh	12	15	22
(I)	Forearm length[2]	41	46	51
J	Floor–buttocks	40	45	49
K	Spine–kneecap	53	59	70
L	Spine–back of knee	42	47	52
M	Seat width	32	37	51
N	Shoulder width	38	44	58
O	Elbow width	38	45	64
(P)	Spine–toe tips[3]	67	76	86
	Shoe length	25	29	34

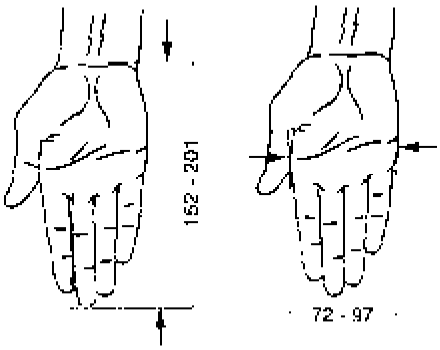
1) Winter clothing, bare-headed and without golves.
2) Forearm length measured from back of elbow to tip of middle finger.
3) With lower legs and thighs at angle of 90°.







Hand measurements, mm



Distance in centimeters between center of fingertips on a medium-sized hand at rest.

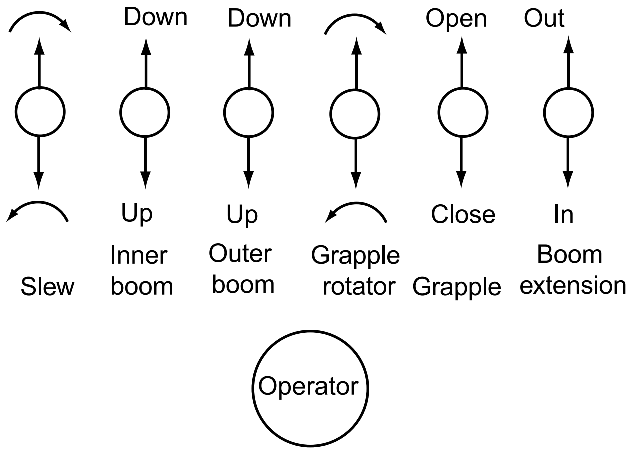
Thumb–index finger: 5.0–8.5
Index finger–middle finger: 2.0–4.0
Middle finger–ring finger: 1.5–2.5
Ring finger–little finger: 3.5–4.5

Appendix 2: Controls on forest machines

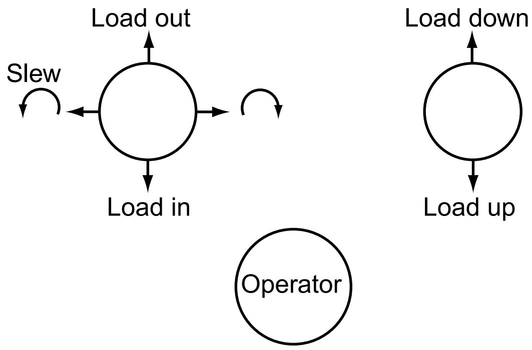
– Extract from the recommendations of SkogForsk's technical advisory group (RTG) concerning controls on forest machines.

The recommendations concern lever sequences and movement for boom controls and the layout of function controls on single-grip harvesters.

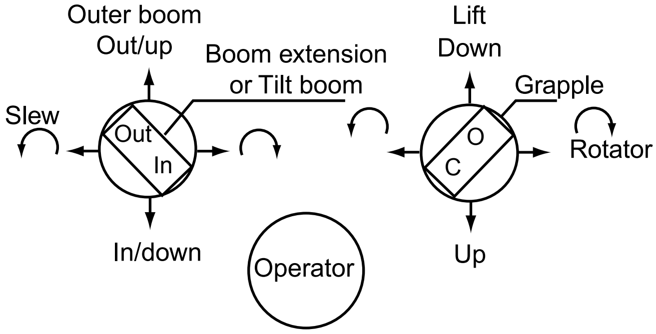
For booms, primarily log loaders, that are maneuvered with six hand levers, the lever sequence and function controls should be according to the diagram below (RTG 6907):



For booms that are maneuvered with combination controls, the main functions— Slew, Lift, Out/In—are arranged as shown below (RTG 7708). The additional function, the grapple, must always be assigned to the right-hand lever.



For grapple (log) loaders with combination controls, the functions should be arranged as shown below (RTG 7708 and ISO 15078, system A).



For single-grip harvesters, the boom functions are arranged in accordance with RTG 7708 above. As regards the many additional functions that a single-grip harvester has, it is recommended that those be assigned to the respecive hands as shown below. The functions have been divided into two groups, one for those that *must* be assigned to the respective hand and one for those that *should* be assigned to the respective hand (RTG 8609).

Functions that *must* be assigned to the respective hand:

Left hand	**Right hand**
Boom slew	Inner boom/Boom
Inner boom/Telescopic boom	Rotator
Boom extension	Grapple (feed rollers, limbing knives)
Felling/Bucking	Pause/Resume
	Lower limit: sawlogs
	Lower limit: pulpwood

The grapple function should be proportional to the control movement.

Functions that *should* be assigned to the respective hand:

Left hand	**Right hand**
Tilt, head	Tree species
(Tilt, float position)	Small-dimension wood
Cab, leveling	Length selection (length step, length preselection)
Tilt, boom post	Pulpwood bolts
Differential lock	Driving (off-road)
Extra clam, feed rollers	Steering (off-road)
Working brake	
Operating rpm	
Zero setting, length sensing	

- High-frequency functions are given priority location.
- The design of the controls should be such that the functions can be identified easily.
- Pedals should only be used for on-road functions, such as accelerator, brake and clutch.

Appendix 3: Electromagnetic fields

Knowledge of the effect of electromagnetic fields on people is scant. The potential health effects discussed are cancer and disorders of the nervous and reproductive systems. However, so far research has failed to find any clear link between exposure and health effects in machine cabs, which is why we have not included a special section on electromagnetic fields in this handbook. Two types of electromagnetic field can be present in machine cabs and these are described as follows:

Extremely low frequency (3–300 Hz) electrical and magnetic fields

There are no certain or strong grounds today to suggest that exposure to these low-frequency magnetic fields, at the levels that are likely to occur in the cab, could have a detrimental effect on health. No exposure limit values have been drawn up in the Scandinavian countries as yet and it is unlikely that any will be introduced in Sweden in the foreseeable future in respect of low-frequency magnetic fields. Some authorities in this field have agreed to adopt a precautionary approach to low-frequency fields, which means that the aim should be to reduce magnetic fields the strength of which deviates widely from those that can be considered normal in the respective environment. Although it is doubtful whether the strength of the electromagnetic fields occurring in the cabs of forestry machines deviates widely enough to come into this category, exposure limits and recommendations have been drawn up in a number of other countries. However, the exposure levels in forestry-machine cabs are not expected to exceed any of these recommendations or limit values.

High-frequency electromagnetic fields around mobile telephones

Some health problems associated with the use of mobile telephones have been reported. Those who spend more than an hour on the phone every day have experienced problems that resemble the symptoms of hypersensitivity to electricity. The National Board of Occupational Safety and Health in Sweden has issued a set of regulations for high-frequency fields (AFS 1987:2), but these do not apply to equipment having a power rating of less than 7 W—which includes mobile phones.

Recommendations

- Fit an external antenna to the vehicle when a mobile telephone is used frequently or for prolonged periods.
- The retrofitting of suitable screening to equipment that emits electromagnetic fields.

Appendix 4: Maintenance index

Extract from SAE J817/2 on maintainability.

SAE J817 ½ gives guidelines on how maintenance work on contractors' and industrial machinery can be studied and evaluated. The extract concerns only scheduled maintenance carried out on machines in the field and it has been adapted by us to make it relevant to forestry machines.

Maintainability

Maintainability is a measure of how easily routine tasks or periodic preventive maintenance can be performed on a given machine. It includes such activities as lubrication, adjustment, preventive maintenance, cleaning and inspection.

Maintainability index (maintenance index)

This system was developed for the assessment of the maintainability of an existing machine or a new machine concept. Each maintenance or service point is given a score based on the following criteria: its location, how easily accessible it is (accessibility), how easy the task is to complete (procedure) and miscellaneous. The total score of all the maintenance points is multiplied by a frequency factor (which is based on how often the maintenance needs to be done) and the resulting figure is the machine's maintenance index. A low number means that maintenance of the machine is easy and safe.

The system

The following limitations apply:

a) The maintenance index is not expressed in time or money.

b) The maintenance index is best suited for comparing earlier and later models of a special machine, machines of different sizes within the same model series or similar types of machine from different manufacturers. It is not advisable to use the maintenance index to compare widely differing machines or machine types.

Procedure

From the maintenance schedule in the Operator's manual for the machine, make a list of the various maintenance points (eg, fluid-level checks, lubrication, cleaning) on the Maintenance-Index Computation Form (see Appendix 5: Assessment forms). Ideally, start by listing the items that need attention most frequently. Each step in a multi-step process should be listed and assigned points. For example, an oil change involves draining the sump (one step) and then filling it with new oil (another step). Both steps should be listed. Similarly, each lubrication point should be listed separately, since the number of steps affects the maintenance index. Refer to the tables below under the headings of Location, Accessibility, Procedure and Miscellaneous. In each table, find which statement applies to (best describes) the maintenance point you are assessing and enter the points in the relevant column on the form. After you have repeated the procedure for each maintenance point, add together and enter (in the "Sum" column) the points total for each row (each maintenance point). Now multiply the figure in the "Sum" column by the frequency factor to obtain the total points for the row. After you have done this for all the rows, add up the figures in the "Total" column to obtain the maintenance index for the machine.

Assessment rules

Location: This determines the position from which the task must be performed. No attempt has been made to grade how high a person must climb up on the machine; the conditions are usually the same for machines of a similar size and with similar equipment. If more than one task can performed from the same position and the tasks have the same maintenance interval or multiples thereof, the first task is assessed and given a score under "Location", and the remaining tasks are each assigned a score of one point under this heading.

List of designated locations and the points assigned to each:

	Points
(a) Ground level—task performed standing upright and within normal reach	1
(b) Ground level—task requires bending or stretching beyond normal reach	2
(c) Ground level—task requires squatting, kneeling or lying down (excluding lying under the machine)	3
(d) On the machine—within normal reach	10
(e) On the machine—task requires bending, stretching or squatting	15
(f) Any other position (except standing) underneath the machine	25
(g) Climbing necessary but no steps or grab handles provided	50

Accessibility: This refers to ease of access to the service point. If more than one task can be performed from the same position and the tasks have the same maintenance interval or multiples thereof, the first task is assessed and given a score under "Accessibility" and the remaining tasks are each assigned a score of one point under this heading.

	Points
(a) Open access	1
(b) Accessible through an opening	2
(c) Move aside a guard or open a hatch/inspection panel	3
(d) Hatch or hinged cover or panel—no tools needed	4
(e) Hatch or hinged cover or panel—requiring tool for removal of single screw/bolt	10
(f) Hatch or hinged cover or panel—requiring tool for removal of multiple screws/bolts	15
(g) Removal of cover or panel	35
(h) Several covers—requiring tool for removal of multiple screws/bolts	50
(i) Radiator cowling—removal required	50
(j) Raising tilting cab	75
(k) Belly pan/sump guard removal—hinges and screws/bolts	75
(l) Belly pan/sump guard removal—screws/bolts only (not hinged)	100

Procedure: This is the action required to perform the individual maintenance tasks. In the following list of the tasks and the points assigned to each, the tasks have been grouped under different headings to facilitate the assessment.

Fluid levels—check	Points
(a) Visual check	1
(b) Dipstick	3
(c) Screw-on cap—manual removal	4
(d) Multiple screw-on caps—manual removal	6
(e) Screw-on cap or plug—tool required	8
(f) Multiple screw-on caps or plugs—tool required	10
Component checking	
(a) Visual check	1
(b) Manual check of belt tension	2
(c) Non-precision tool required, eg, air-pressure gauge, torque wrench	5
(d) Precision tool required	10
Lubrication	
(a) Grease nipple	1
(b) Grease nipple—requires special adaptor	3
(c) Brush lubrication	5
(d) Lubrication with oil can	5
(e) Grease nipple—requires additional steps, eg, rotating an axle to gain access to nipple	5
(f) Packing with grease by hand (each)	20

Draining

(a) Drain valve—manual	1
(b) Drain valve—requires tool	3
(c) Plug—in the side	6
(d) Plug—underneath	8
(e) Cover plate	10
(f) Multiple plugs or cover plates	15

Filling

(a) Filler cap—manual removal	1
(b) Filler cap or plug—on top, tool required	3
(c) Obstructed access to filler opening or filler opening at awkward angle	8
(d) Plug—in the side and tool required	10
(e) Pump required for filling (eg, under machine)	10
(f) Multiple caps or plugs	15

Cleaning

(a) Use of compressed-air gun	3
(b) Washing in cleaning tank	5
(c) Multiple washes in cleaning tank or washing followed by oiling	10
(d) Cleaning of tank	10

Replacement

(a) Unscrew by hand—opening turned upward (eg, oil filter)	1
(b) Unscrew by hand—opening at angle > 15°	3
(c) Single screw—no tool required	4
(d) Single screw—tool required	5
(e) Multiple screws—no tool required	6
(f) Multiple screws—tool required	7

Adjustment

(a) One step	2
(b) Several steps	4
(c) Several steps and several positions	10

Miscellaneous: The items in this list are those that do not come under any of the above headings and should be avoided whenever possible. Accordingly, points scored under the heading of "Miscellaneous" are penalty points.

	Points
(a) Draining into a container—tube or pipe required	2
(b) Practice J753 (Maintenance intervals different for different components)	2
(c) Bleeding or similar required	3
(d) Use of hand pump or similar required	3
(e) Special tools required	4
(f) Insufficient labeling or information	4
(g) Filler opening too small	5
(h) Sensitive to contaminants	5
(i) Requires machine to be running	5
(j) Torque-tightening required	5
(k) Filter housing requires draining and cleaning	8
(l) Special instructions required	10
(m) Requires machine to be driven or specially positioned	10
(n) No facility for collecting fluids	20
(o) Insufficient room to perform task	20
(p) Requires two persons	40
(q) Requires use of separate ladder (not supplied)	50
(r) Task requires caution	100
(s) Access position requires caution	100

Frequency factor (maintenance interval): This refers to how often lubrication or maintenance should be performed. The factor for each interval is as follows:

Maintenance interval (h)	Frequency factor
(a) 1000 h — Every six months or longer	1
(b) 500 h — Quarterly or as necessary	2
(c) 250 h — Monthly	4
(d) 100 h — Every other week	10
(e) 50 h — Weekly	20
(f) 10 h — Daily	100

The intervals specified in number of hours conform to SAE J753. If the maintenance interval differs from this, use the frequency factor that comes nearest and is typical for the way in which the machine is used.

Each lubrication and service point is assigned just one frequency factor—corresponding to the shortest interval. For example, if the maintenance schedule prescribes that the engine-oil level be checked daily, this task should be noted only once, even if it is also performed in conjunction with a monthly oil change.

Summary

Each item that has a high points score must be examined closely. The high score not only indicates an ideal opportunity for taking action to lower the maintenance index but also draws attention to maintenance tasks that are likely to be deliberately overlooked in practice, owing to the difficulty involved in performing the task. A high points score may also be attributable to the manufacturer's maintenance schedule having an illogical structure, prescribing an unnecessarily high frequency for some maintenance tasks or specifying work that is over-complicated.

Other factors that are not evident from the maintenance index but which should be borne in mind by the machine user include:

a. Least possible number of oil and lubricant types.
b. Use of standard replacement parts.
c. Same location of maintenance points on machines in the same series.

Appendix 5: Assessment forms

This Appendix contains examples of the forms that should be completed in a full ergonomic assessment of a forest machine. The forms are designed for use in conjunction with this handbook—which should therefore be on hand when the assessment is made.

Classification procedure

Each item in the respective section is assessed and assigned to one of the five classes. Although standard methods of assessment should be used whenever possible, a measure of subjective judgement is also called for, as it is impossible to define the classes definitively. To make a sound assessment, some knowledge of ergonomics and also a familiarity with the machine operations are required.

The classification principle is that the impact of the machine on the health and wellbeing of the operator should be the same, regardless of the class (A, B, C or D) to which the assessed item has been assigned. This presupposes that the machine is used for the purpose for which it was designed and that consideration is given to the duration, tempo and difficulty of the work.

For each item to be assessed (eg, seat height, noise level), the classes are defined by the suitability of the machine for operation in the specified conditions.

Class A: Highly productive work in all types of terrain and stands. High level of both active and passive safety. Maintenance work straightforward and safe. Many of the criteria in this class will not be met for a few years yet.

Class B: Highly productive work but under somewhat easier conditions than in class A (eg, lower tempo, less-demanding work, and easier terrain, stand and climate conditions). Same high level of active and passive safety but, otherwise, not of the same high standard as in class A.

Class C: Easier conditions and/or shorter duration than in class B. Same high level of active and passive safety but, otherwise, not of the same high standard as in class B.

Class D: Easier conditions and/or shorter duration than in class C. Same high level of active and passive safety but, otherwise, not of the same high standard as in class C.

Class 0: The machine does not satisfy the statutory safety requirements and/or has such serious defects that the operator runs a high risk of injury. The machine must not be used until the defects have been rectified and it meets the criteria specified in one of the other classes (A–D).

Guidelines

The guidelines are written with reference to class A and therefore describe the strictest requirements. In some sections, which require the use of measuring equipment that is not always readily available, the guidelines have been divided into two sections, one optional, based on measurements, and the other mandatory, based on subjective assessment. In other words, a subjective assessment must be carried out in either case.

In the tables under the guidelines, some classes have been omitted for some items (denoted by a dash"—").

Ergonomic profile

Basic machine/boom/grapple/harvester head:

....

Year of manufacture: .... Serial number (VIN): ....

Total operating hours (meter reading): ....

Section	Class A	B	C	D	0	Remarks:
Cab access (mounting and alighting)	☐	☐	☐	☐	☐	
Working posture	☐	☐	☐	☐	☐	
Cab	☐	☐	☐	☐	☐	
Visibility	☐	☐	☐	☐	☐	
Operator’s seat	☐	☐	☐	☐	☐	
Controls	☐	☐	☐	☐	☐	
Operating the machine	☐	☐	☐	☐	☐	
Information	☐	☐	☐	☐	☐	
Noise	☐	☐	☐	☐	☐	
Vibration	☐	☐	☐	☐	☐	
Climate control in the cab	☐	☐	☐	☐	☐	
Gases and particulates	☐	☐	☐	☐	☐	
Lighting	☐	☐	☐	☐	☐	
Instructions and training	☐	☐	☐	☐	☐	
Maintenance	☐	☐	☐	☐	☐	
Brakes and operator safety	☐	☐	☐	☐	☐	

Enter the lowest class noted in the respective section.

Assessment performed by: ....

Date: ....

Conditions at time of assessment

Participating operator(s):

Name	Age, years	Height, cm	Weight, kg	Years as operator

Assessor: .... Experience: ....

Deviations from the standard machine specification (additional or alternative equipment, modifications, etc.):

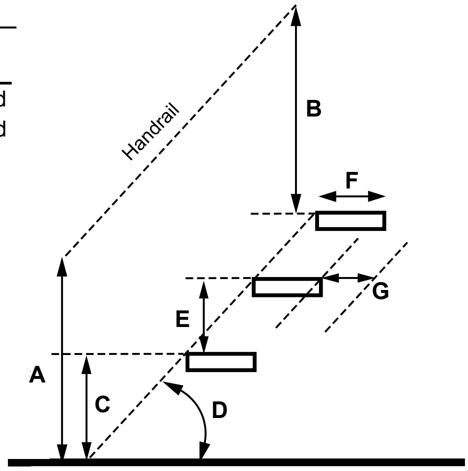
Description of site and other factors that could affect the conditions (stand, type of logging, weather, etc.):

Cab access—mounting and alighting

Date .... Signature ....

Machine standing (slope, terrain, etc.) ....

	Dimensions in cm or degrees (°)	Measured value	Class A	Class B
A	Ground to handrail		120	Unspecified
B	Step to handrail		85	Unspecified
C	Ground to first step (min)		35	40
D	Maximum pitch		45°	70°
E	Rise		20–25	20–30
F	Minimum tread (step) depth		20	10
	Minimum step width		30	30
G	Clearance behind step		≥15	≥15
	Door opening, minimum height		160	160
	Door opening, minimum width at shoulder height		60	60
	Door opening, minimum width at bottom		35	35



Class A	Class B	Class C	Class D	Class 0	Enter class
1. Steps as per Fig. 2. Platform outside cab door.	Steps as per Fig. 2. Platform provided.	Minor shortcomings	Major shortcomings	Unsafe	
2. If no direct access to cab, sturdy, safe catwalk with handrail provided.	Yes but some minor shortcomings (not posing a safety hazard)	As for class B	One step only onto wheel or track required. Suitable handrail provided.	Wheel/track used for mounting/alighting. Suitable handrail lacking.	
3. Handrail and steps provide good grip and do not collect snow and ice. Easy to keep clean and minimal risk of slipping.	As for class A	As for class A	As for class A	Handrail and steps unsafe.	
4. Door opening measures at least 160 cm H, 60 cm W at shoulder height and 35 cm W at bottom.	As for class A	Minor discrepancies	Major discrepancies	—	
5. At least one functioning emergency exit provided.	As for class A	As for class A	As for class A	No!	
6. Cab door opens wide enough and stays open in wind and when machine tilted.	Minor shortcomings	Moderate shortcomings	Major shortcomings	—	
7. Cab door opens & closes easily even when machine tilted.	As for class A	Minor shortcomings	Major shortcomings	—	
8. Means of access presents no risk of operator becoming caught up or trapped by it.	Minor shortcomings	Moderate shortcomings	Major shortcomings	—	
9. Means of access protected against damage	Minor shortcomings	Moderate shortcomings	Major shortcomings	—	
10. Cab door, steps and ground under steps well lighted.	Minor shortcomings	Major shortcomings	No lighting	—	

Working posture

Date .... Signature ....

Before the class for this section can be determined, the aspects covered by the sections on Cab, Visibility, Seat, Controls and Operating the machine must be assessed first, as they can all influence the working posture. The relevant items under those sections are summarized in the following table.

Class A	Class B	Class C	Class D	Class 0	Enter class
1. Operators of different stature can assume a relaxed basic posture in which the controls are within optimum reach and good visibility is afforded.	As for class A	Some difficulty for operators of above or below-average posture	Many shortcomings	Ergonomically unacceptable	
2. The operator can easily shift between low and high sitting postures, straighten his body and stretch his legs.	More-limited height adjustment. Operator still able to stretch legs.	More-limited height adjustment. Somewhat cramped.	Little scope for varying posture.	Ergonomically unacceptable	
3. Seat, armrests, controls and orientation of instruments all readily adjustable to suit different operators.	As for class A	A few shortcomings	Many shortcomings	Ergonomically unacceptable	
4. The machine/cab can be tilted through 15° both laterally and longitudinally for leveling.	Through 7° laterally and longitudinally or 15° in one direction only	Seat can be leveled	No leveling function	—	
5. The operator's station can be swiveled independently of the boom in any direction within the working envelope.	Operator's station follows boom movement	Seat swivels and can be locked in any position	Rigid workstation and non-swivelling seat	—	
6. Boom and grapple/harvester head easily manipulated with few movements by operator.	A few shortcomings	Moderate level of shortcomings	Many shortcomings	—	
7. Control work allows relief of static load in shoulders and neck during each boom cycle.	Frequent relief afforded	Occasional relief afforded	Relief seldom afforded	—	

Basic posture

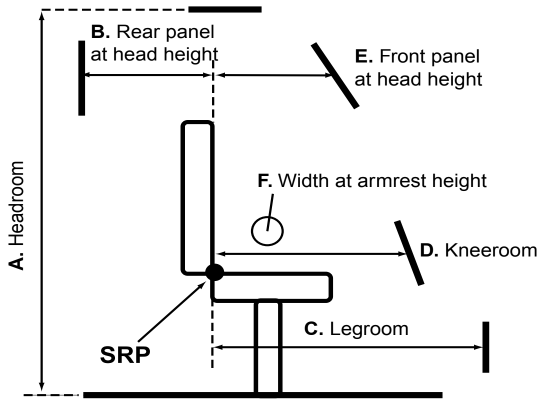
Trunk–upper arm	0–15°
Elbow	105–120°
Trunk–thigh	105–120°
Knee joint	105–120°
Ankle joint	90–100°

Cab

Date .... Signature ....

When seated, the operator should be able to extend the angle between trunk and thighs to at least 135° and to stretch the legs out straight. There should be a readily accessible and clearly labeled stowage place for a first-aid kit.

Dimension (cm)		Guideline
A	180	Headroom
B	55[1)]	Seat in rear position
C	115	Seat in rear position, measured at toes
D	70[2)]	Seat in forward position and at mid-height
E	50	Seat in forward and highest position
F	100[3), 4)]	Cab width measured at armrest height



1) 70 cm is needed for a seat that tilts forwards and backwards.

2) Measurement from SRP to inside limit (wall, steering wheel, computer screen, etc.).

3) With both forward and reverse machine operation, 65 cm of clearance from the SRP is needed for rotation of a conventional seat when occupied.

4) A cab not equipped with leveling may be fitted with a laterally tiltable seat requiring greater cab width.

Class A	Class B	Class C	Class D	Class 0	Enter class
1. Dimensions in Fig. 7 are met.	Minor deviations in headroom and length dimensions	Moderate deviations	Major deviations	Ergonomically unaccept-able	
2. Armrests and controls do not foul walls, interior objects etc.	As for class A	Not entirely true	Serious shortcomings	—	
3. With forward & reverse operation, there is ample room in both directions. The seat can be rotated freely to any position	Not fully adequate	Moderate shortcomings	Serious shortcomings	—	
4. Stowage space for first-aid kit, instruction manuals and personal items.	As for class A	Not fully adequate	Moderate shortcomings	No provision for first-aid kit	
5. Cab easy to keep clean. Door extends all the way down to the floor.	Minor shortcomings	Moderate shortcomings	—	—	
6. No equipment in cab that can leak oil nor protruding objects that could cause injury.	As for class A	As for class A	Some shortcomings	Ergonomi-cally unaccept-able	

Visibility

Date .... Signature ....

To assist this assessment, use the template at the back of Appendix 5 (page 85) to make a ground plan of the field of view.

Upward angle of field of view: ....

Height above ground (tree height)
to which the field of view extends at
a distance of 10 m from machine: ....

Class A	Class B	Class C	Class D	Class 0	Enter Class
1. The operator can see the ground to within 3.5 m of the side of the machine in the working envelope of the boom and to within 5 m of the machine in the direction of travel (measured from the SRP).	Some shortcomings	Moderate shortcomings	Major shortcomings	Unsafe	
2. The operator can see at least up to a height of 25 m above the ground at a distance of 10 m from the machine.	Visibility up to height of 20 m. On a forwarder, operator can see the whole length of the boom in the boom-operating zone	Visibility up to height of 15 m. On a forwarder, operator can see the top of the cab guard	Major shortcomings. On forwarder, as for class C	Unsafe	
3. The operator can see the front wheels when driving ahead.	May have to bend/stretch a little	Moderate shortcomings	Major shortcomings	—	
4. Easy to clean rain, snow, mist, dirt, etc., from windows.	Minor problems	Major problems	Seriously inadequate	—	
5. Boom, pillars and equipment do not obstruct operator's view or force him to adjust his posture to be able to see into the working zone.	Visibility slightly obstructed, eg, by the boom	Visibility obstructed in several ways	Visibility seriously obstructed	—	

Operator's seat

Date .... Signature ....

Make, model and year of manufacture of seat and armrests: ....

Additional equipment etc.: .... How long in use: ....

Repairs/overhaul carried out: ....

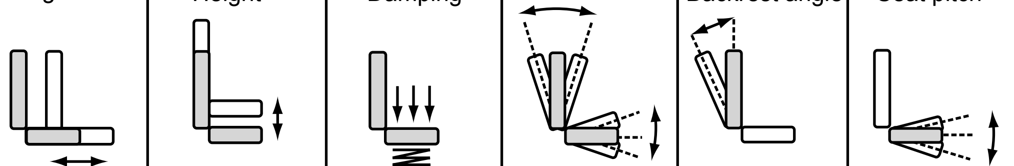
Class A	Class B	Class C	Class D	Class 0	Enter Class
1. Seat height readily adjustable between 40 and 65 cm	Readily adjustable 40–55 cm	Less adjustable and less convenient	Inadequate adjustment	Ergonomically unacceptable	
2. The seat otherwise meets the specified dimensions and adjustment ranges.	Seat-pitch adjustment only +8°, -7°	Some dimensions more limited	Large deviation from specified dimensions	Ergonomically unacceptable	
3. Armrests offer good support without restricting arm movements and can be adjusted as specified	As for class A	Minor shortcomings	Major shortcomings	Ergonomically unacceptable	
4. Individual settings of seat and armrests can be programmed and quickly reset automatically.	Manual adjustment quick and easy. Scales clearly marked.	Some adjustments awkward.	Major shortcomings	—	
5. Armrests follow seat movements automatically.	As for class A	Can be readily adjusted manually	Major shortcomings	Ergonomically unacceptable	
6. Feet have room under front of seat when legs bent as far back as an angle of 60° or smaller.	Legs cannot be bent as far back as in class A.	No room for feet under the seat	—	—	
7. The seat has good vibration damping in all height settings.	As for class A	Inferior damping when seat in highest and/or lowest setting.	Major shortcomings	Ergonomically unacceptable	
8. In non-slewing cab, seat rotates far enough and can be locked in any position.	Seat rotates but not infinitely variable.	Major shortcomings	Seat non-rotating	—	
9. Seat in non-leveling cab tilts automatically in two directions.	Tilts in one direction automatically or in two manually. Lockable in any position	Limited tilt function.	No tilt function.	—	
10. Seat cushion and backrest equipped with thermostatic heating, ventilation and washable loose covers.	Not fully equipped	Major shortcomings	—	—	
11. Stable seat—well sited and anchored, and easy to maintain.	As for class A	Some shortcomings	Major shortcomings	Ergonomically unacceptable	
12. Suitable means of restraint provided (eg, seat belt)	As for class A	Minor shortcomings (eg, seat belt)	As for class C	None provided	

Establish the seat reference point (SRP) from which the measurements are taken.

Describe the method used to calculate the deflection of the seat caused by the application of the specified load in conjunction with measuring of the seat height:

....

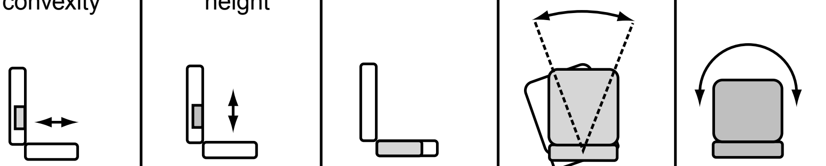
Note down, underneath the respective diagrams, any deviations from the guideline values.



Legroom	Height	Damping	Fore-and-aft tilt 2)	Backrest angle	Seat pitch
± 10	40–65 1)	55–110 kg	± 20°	0–30°	Up 8° Down15°
………...…	………...…	………...…	………...…	………...…	………...…

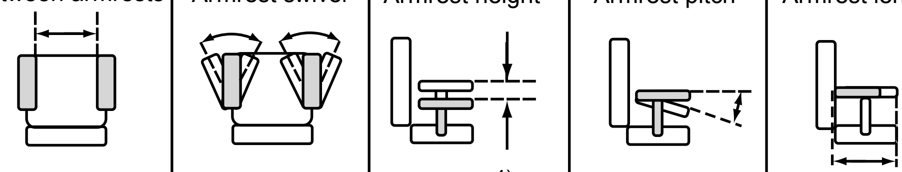
1) The height of the seat cushion above the floor should be measured with a load of 550 N on the seat.

2) Depending on whether the operator's seat can be leveled.



Lumbar-support convexity	Lumbar-support height	Seat depth	Lateral tilt 2)	Seat swivel 3)
+5	15–23	37–48	±15°	220°
………...…	………...…	………...…	………...…	………...…

3) Depending on whether the cab is rotatable.



Distance between armrests	Armrest swivel	Armrest height	Armrest pitch	Armrest length
47 ± 5	In 30° Out 15°	15–27 4)	At least to an angle of 150° between forearm and upper arm	25 ± 5
………...…	………...…	………...…	………...…	………...…

4) Measured above the SRP; also applies to the back of the armrest. If the armrest does not follow the seat, the measurement should be made with the seat occupied.

Controls

Date .... Signature ....

Type, make and model of controls: ....

Using the SRP as the origin, measure the positions of the controls using a measuring tape and, ideally, a measuring rig. Measure the actuating force for each control by means of a dynamometer. Record any values that deviate from the specified range.

Actuating force, N	Optimum[1]	Maximum
Fingertip-operated pushbuttons	2	5
Fingertip-operated controls	2–5	40
Hand-operated lever, Forward/Back	5–15	140
Hand-operated lever, Left/Right	5–15	60
Wheel (tangential force)	5–20	230
Leg-operated control (clutch and brakes)	45–90	250
Toe-operated controls (eg, throttle)	20–30	

[1] For frequent-usage controls

Control	Distance, cm

Class A	Class B	Class C	Class D	Class 0	Enter class
1. Levers and pushbuttons that affect safety or is used frequently are located within optimum reach and follow movement of the seat.	As for class A	Some shortcomings	Moderate shortcomings	Unacceptable	
2. The position of levers and control panels are readily adjustable to suit different operators.	As for class A	Moderate shortcomings	Major shortcomings	Ergonomically unacceptable	
3. The relative positions of boom controls and important buttons comply with the guidelines and can readily be adjusted to suit hands of different sizes.	Some difficulty in adjustment	Great difficulty in adjustment	No adjustment possible	—	
4. Levers and pushbutton panels (where applicable) offer a comfortable grip and support for the hand.	As for class A	Some shortcomings	Major shortcomings	—	
5. Controls for functions requiring a quick response are positioned for operation primarily by thumb or index finger, or failing that, by the middle finger.	Some minor shortcomings	Moderate shortcomings	Major shortcomings	—	
6. Grouping and coding of pushbuttons designed to obviate confusion and inadvertent operation.	As for class A	As for class A	Minor shortcomings	Unacceptable	
7. All pushbuttons give a clear acknowledgement when depressed.	Acknowledge-ment of actuation given by important buttons	Acknowledgement given by some buttons	No acknowledgement given	—	
8. Frequently used controls have optimum actuating force.	As for class A	Not all	Many do not	—	
9. Pedals are provided only for functions that are normally foot operated in driving (throttle, brakes), that require a strong actuating force or are used infrequently and do not require precision control.	As for class A	Not entirely	Major shortcomings	—	

Operating the machine

Date .... Signature ....

Description of elements in a typical work cycle: ....

....

Number of manipulations per boom cycle (average): ....

Number and duration of micro-pauses per boom cycle: ....

Overlapping functions: ....

Class A	Class B	Class C	Class D	Class 0	Enter class
1. The machine has enough system power and machine stability for reliable, positive and simple control.	As for class A	Somewhat inadequate	Seriously inadequate	Unaccept-able	
2. The controls are logical, with the right number of functions, are conveniently positioned and move as specified in Appendix 2.	Not entirely	Moderate shortcomings	Major shortcomings	Unaccept-able	
3. The operator can readily adjust the speed and starting and stopping times of functions that affect safety and working tempo.	Not entirely	Moderate shortcomings	Major shortcomings	—	
4. Individual functions are unaffected by the movement of other functions or loads imposed by them.	As for class A	Not entirely	Major shortcomings	—	
5. The functions are not affected by external interference, eg, from telephone or power lines.	As for class A	As for class A	As for class A	Not true—therefore unacceptable	
6. Automated processes interrupted automatically when operator leaves the cab and have to be restarted by the operator.	As for class A	As for class A	As for class A	Not true—therefore unacceptable	
7. Operator has full control over automated functions and can take over immediately	As for class A	As for class A	As for class A	Not true—therefore unacceptable	
8. Telltale provided to show when a function not in sight of the operator is activated.	Not always	Moderate shortcomings	Major shortcomings	Unaccept-able	
9. Operator gets at least one machine-controlled micro-break of at least 3 s per boom cycle.	During long boom cycle only	No micro-breaks	—	—	
10. A given movement of a lever produces a proportional response in boom-tip movement throughout its path.	Moderate shortcomings	Major shortcomings	Seriously deficient	—	
11. Processing requires only little manipulation of controls, eg, because process largely automatic.	Moderate shortcomings	Major shortcomings	Seriously deficient	—	
12. Control of boom requires only little manipulation of controls, eg, because repeated boom movements can be controlled by one lever movement or pushbutton.	Not entirely, eg, a parallel-controlled or telescopic boom	Moderate shortcomings	Major shortcomings	—	

Information

Date .... Signature ....

Description of the machine's information systems that constitute the basis for the classification:

....

....

Class A	Class B	Class C	Class D	Class 0	Enter class
1. The operator can see, hear or sense what is needed for the control and stability of the machine.	As for class A	As for class A	Not entirely	No!	
2. The operator can hear or see and comprehend all warning signals in any conditions	As for class A	As for class A	Not entirely	No!	
3. Important visual information in the cab is conspicuous and close to operator's field of view. Similar types of Information grouped together.	As for class A	Not entirely	Major shortcomings	—	
4. Right medium used to provide information (display, acoustic, etc.)	Not always	Moderate shortcomings	Major shortcomings	Seriously deficienct	
5. Displays are clearly legible. Text, symbols and colors are visible in all lighting conditions. Light intensity (brightness) of displays is adjustable.	Not entirely	Moderate shortcomings	Major shortcomings	—	
6. Text is large enough, concise, complete and readily comprehensible.	Not entirely	Moderate shortcomings	Major shortcomings	—	
7. Coded information (eg, symbols) readily comprehensible. Colors have usual significance.	As for class A	Not entirely	Moderate shortcomings	—	
8. Menu structure suitable for context in which it is used. Menus have few levels, are readily comprehensible and can be customized. They follow a standard format and allow short cuts to be used and return to main menu from any level.	Not entirely	Moderate shortcomings	Major shortcomings	—	
9. Context-sensitive help available for qualified decision-making.	By and large	Moderate shortcomings	Major shortcomings	—	

Noise

Date .... Signature ....

Test equipment: ....

Work equipment: ....

Engine rpm: .... Fan speed: ....

Test conditions: Windows closed; radio and phone switched off; only one person in the cab.

	dB(Lin)	DB(A)	DB(A) eq	Impulse sound, dB(C)								Number of sound bursts or impulses per hour
Right ear												
Left ear												
Time (minutes)												

Class A	Class B	Class C	Class D	Class 0	Enter class
Test reading					
1. Equivalent sound level, dB(A) ≤ 65	≤ 70	≤ 5	≤ 85	> 85	
2. Impulse sound level dB(C) ≤ 80	≤ 85	≤ 90	≤140	> 140	
Assessment					
3. Noise problem negligible	Noise a minor problem	Noise a problem	Noise a serious problem	Noise unacceptable	
4. Single-frequency (tone) noise problem negligible.	Tones a minor problem	Tones a problem	Tones a serious problem	Tones unacceptable	
5. Impulse-sound problem negligible.	Impulse sound a minor problem	Impulse sound a problem	Impulse sound a serious problem	Impulse sound unacceptable	
6. Infrasound problem negligible	Infrasound minor problem	Infra-sound a problem	Infrasound a serious problem	Infrasound unacceptable	
7. Operator has no difficulty in hearing all important signals; does not have to raise his voice to talk on the telephone or to someone in the cab.	Little difficulty in hearing and conversing	Difficulty in hearing and convers-ing	Difficulty in hearing and need to raise voice	Unacceptable difficulty in hearing and forced to shout	

Vibration

Date .... Signature ....

Test equipment: ....

Test bodies/measuring points: ....

Work element: ....

Test conditions (recommended values given in brackets):

Tire pressure, front: .... (.......... kPa); rear .... (.......... kPa)

Operator's weight .... (67–83 kg). Condition of seat: ....

Extraction: Number of loads .... Loading/unloading amounting to ....% (45–55%) of driving time. Driving speed (m/min), empty: .... (45–55); loaded: .... (36–44)

Logging/processing: Number of trees .... Time taken moving between setups as percentage of total time .... % (10–20 %). Ratio of tree dbh to maximum diameter at felling point of undercut (notch): in final felling ....% (40–50 %); in thinning ....% (30–40 %)

Terrain conditions: Ground-roughness class .... (2). Slope class .... (1)

Test conditions at time reading taken (eg, engine rpm): ....

Type of vibration	Velocity (m/min)	Direction of vibration (m/s^2)				Total test time (minutes)
		X-axis	Y-axis	Z-axis	Total	
Whole-body						(30)
Hand-arm						(30)

Class A		Class B	Class C	Class D	Class 0	Enter class
Test reading						
1. Whole-body vibration, m/s^2	≤ 0.40	≤ 0.57	≤ 0.80	≤ 1.1	> 1.1	
2. Hand-arm vibration, m/s^2	≤ 1.0	≤ 1.0–1.4	≤ 1.4–2.0	≤ 2.0–2.8	> 2.8	
Assessment						
3. Operator subjected to only very slight discomfort from whole-body vibration		Slight discomfort	Moderate discomfort	High discomfort	Extreme discomfort	
4. Operator subjected to only very slight discomfort from jolting and shocks		Slight discomfort	Moderate discomfort	High discomfort	Extreme discomfort	
5. The machine is designed so that the operator is subjected only to minor jolting and shocks		Somewhat higher level	Moderate level	High level	Extremely high level	
6. Operator subjected to only very slight discomfort from hand-arm vibration.		Slight discomfort	Moderate discomfort	High discomfort	Extreme discomfort	

Climate

Date .... Signature ....

Test conditions: Sun blinds, setting of climate-control unit, sun, wind, precipitation, etc.:

....

....

Temperatures (°C) measured using a radiation-screened thermometer:

Outdoor temp.	At right foot	At left foot	At right hand	At left hand	At chest height	At head	Average temp.

Results of measurements made with thermal dummy in climate chamber: ......% satisfied.

Class A	Class B	Class C	Class D	Class 0	Enter class
Tests					
1. With a standard thermal dummy, all readings comply with the 80% comfort profile.	Hands and buttocks outside the 80% comfort profile.	—	—	—	
2. Climate-control system can maintain inside temp of 25°C at an outside temp of -20°C.	As for class A	21°C	Major shortcomings	—	
3. Climate-control system can maintain inside temp of 25°C at an outside temp of 27°C and in sunshine.	24°C	Inadequate performance	—	—	
4. Cab temp can be raised from -20°C to 20°C within 10 minutes.	Within 15 min.	Within 30 min.	Not at all	—	
5. Cab temp can be reduced from 30°C to 25°C within 10 minutes.	Within 30 min.	Inadequate performance	Not at all	—	
6. At outside temp of -20°C or +27°C and in sunshine, temp differential between specified measuring points inside cab is < 5°C.	< 6°C.	Higher differential	Extremely high differential	—	
7. At an outside temp of -20°C and with moisture inside cab, climate-control system can demist and keep window glass clear within 5 min.	At -15°C	At -10°C	Inadequate performance	—	
Assessment					
8. In winter, the climate in the cab is acceptable under all weather conditions.	Not at very low outside temperatures	Not at low outside temperatures	Only in fine weather	—	
9. In summer, the climate in the cab is acceptable under all weather conditions.	Not at very high outside temperatures and in sunshine	Not in sunshine	Only in fine weather	—	
10. Effective means of protection provided against strong heat from the sun.	As for class A	Inadequate protection	No protection provided	—	
11. Operator not troubled by cold drafts and fluctuating temperatures.	Minor discomfort	Moderate discomfort	Major discomfort	—	
12. Cab equipped with automatic climate-control system with individually adjustable settings and user-friendly operation.	Equipped with limited ACC system	Simple manual control of heating and fan	Difficult control of heating and fan	—	

Gases and particulates

Date .... Signature ....

Weather conditions, work element, etc.: ....

....

Cab design and condition of the fresh-air filter system: ....

....

....

Filter type: ....

Class A	Class B	Class C	Class D	Class 0	Enter class
1. The operator is not aware of any exhaust fumes, dust or oil mist in the cab even when working in dense stands, dusty conditions or adverse weather.	Aware of exhaust fumes, oil mist or dust in difficult conditions	Discomfort in adverse conditions	Frequent discomfort	Limit value exceeded by at least one substance	
2. Engine type/size, rpm, fuel and catalytic converter have been optimized to minimize concentrations of harmful substances.	Minor shortcomings	Moderate shortcomings	Major shortcomings	—	
3. The exhaust system is free from leaks and the discharge pipe is positioned well away from the air intake to the cab.	As for class A	As for class A	Minor shortcomings	—	
4. Design of cab prevents ingress of fumes into the cab.	As for class A	Minor shortcomings	Major shortcomings	—	
5. Filter for removal of dust, pollen, etc., can be fitted to cab air intake when required.	Filtering of dust	Minor shortcomings	No filter available	—	
6. There is an indicator that shows when the filter needs changing.	As for class A	Not fully satisfactory	—	—	
7. Catalytic converter or particulate filter has certified service life and instructions for care and replacement.	Not fully satisfactory	No!	—	—	

Analysis of air in cab—performed when operator is experiencing discomfort from fumes or dust.

Result: ....

Test equipment and analysis method: ....

....

Laboratory analysis performed by: ....

....

Lighting

Date .... Signature ....

Working and driving lights: ....

Method for measuring illuminance: ....

Test conditions: ....

Alternator voltage: ....

Use the template included at the end of Appendix 5 (page 85) to produce an illumination diagram.

Illuminance (lux)	Around operating head	Boom operating envelope	Periphery	20 m in front of the machine	Color temperature ………………… K
Average					S/P number …………………...
Maximum/minimum					
Ratio of maximum to minimum					Voltage …………….……V

Class A	Class B	Class C	Class D	Class 0	Enter class
Test reading					
1. The maximum ratio of the highest/lowest lux value between the Zone around the operating head, the Operating envelope of the boom and the Periphery is 10 : 4 : 1.	Maximum of 15 : 5 : 1	Maximum of 12 : 1 : 0.1	Maximum of 20 : 1 : – Periphery not measured	Dazzle renders work unsafe	
2. Illuminance in the respective zones is at least 120/ 60/15 lux.	At least 100/40/10	At least 80/30/5	At least 10 lux in operating zone	Inadequate lighting renders work unsafe	
3. The illuminance for driving is at least 10 lux at 20 m in the direction of the machine's travel.	At least 8 lux	At least 5 lux	At least 2 lux	Under 2 lux	
4. The color temperature of the general lighting is over 4000 K.	At least 3000 K	At least 3000 K	—	—	
Assessment					
5. The light is well distributed. The operator is not dazzled by sharp contrasts and can see the surroundings.	Uneven illumination of nonessential items	Uneven illumination of operating area	Very uneven illumination of operating	Dazzle renders work unsafe	
6. No distracting reflections from windows or machine parts	Some distraction	Moderate distraction	High level of distraction	Dazzle renders work unsafe	
7. Adequate illuminance for all operations and moving between set-ups. Operator also has upward vision and can see beyond the boom operating envelope.	Not fully adequate in parts of the operating zone	Inadequate in parts of the operating zone	Highly inadequate	Inadequate illuminance renders work unsafe	
8. Color and quality of the light give good general visibility, do not cause eye strain and reproduce important colors faithfully.	Not entirely	Moderate shortcomings	Major shortcomings	—	
9. Lighting can be dimmed when necessary.	Not fully.	Not at all.	—	—	
10. Lamps can be aimed precisely and readily returned to previous setting	Not fully.	Somewhat limited.	Highly limited	—	
11. Lighting in the cab is good, can be controlled, and does not cause glare or reflections.	Not entirely	Moderate shortcomings	Major shortcomings	—	

Instructions and training

Date .... Signature ....

Name of manufacturer's representative contacted: ....

Description of the items assessed: ....

....

....

....

....

Class A	Class B	Class C	Class D	Class 0	Enter class
1. Contents of Operator's manual satisfy the criteria specified in this handbook.	As for class A	Minor deficiencies	Major deficiencies	Unaccept-able de-ficiencies	
2. Presentation of Operator's manual satisfies the criteria specified in this handbook.	As for class A	Minor deficiencies	Major deficiencies	—	
3. The machine has special provision for storing the Operator's manual and spare-parts list.	Minor deficiencies	Unsuitable provision	No provision made	—	
4. Adequate instruction and practical training given in conjunction with delivery.	As for class A	Not fully adequate	Inadequate	Unaccept-able	
5. Opportunity exists for follow-up, additional training and consultation.	As for class A	Somewhat limited	Very limited	—	
6. All essential information and warning signs provided and permanently attached to machine.	As for class A	As for class A	As for class A	No!	

Maintenance

Date .... Signature ....

General conditions, eg, Operator's manual, auxiliary equipment, special tools, etc.:
....

Maintenance index (up to and including monthly maintenance): .... (calculated using the form on page 83).

Class A	Class B	Class C	Class D	Class 0	Enter class
1. Fault-diagnosis chart is clear and comprehensive.	Somewhat flawed	Poor	None provided.	—	
2. Facility for quick and safe disengaging/engaging of power sources and discharging of stored energy when working on machine equipment.	As for class A	As for class A	Safe but not as fast	Unsafe	
3. If the engine must be running, eg, during fault diagnosis, suitable guards provided to prevent operator from coming into contact with moving parts.	As for class A	As for class A	As for class A	No!	
4. Essential tools provided with the machine and can be stored in warm place, but not loose in the cab.	As for class A	Minor shortcomings	Major shortcomings	—	
5. Tiltable cab, protective hoods, etc., are securely locked automatically when opened.	As for class A	Secure manual locking	Some shortcomings	Unsafe	
6. Essential non-slip steps, handles, ladders, ramps, etc. are fitted or provided with the machine.	As for class A	Minor shortcomings	Major shortcomings	Unsafe	
7. Common tasks demand application of force of < 50 N	< 80 N	< 120 N	Far too high	—	
8. Common tasks can be effected with a lifting force of < 200 N.	< 300 N	< 400 N	< 500 N	> 500 N	
9. Suitable lifting devices and attachment points provided.	Some shortcomings	Major shortcomings	No!	—	
10. Movable auxiliary lighting equipment provided.	As for class A	Provided but not fully satisfactory	No!	—	
11. The machine can use environmentally friendly fuels, oils and lubricants.	Not exclusively	Only to a limited extent	To a very limited extent	—	

(Continued on next page.)

Class A	Class B	Class C	Class D	Class 0	Enter class
Assessment when a maintenance index is available					
12. Maintenance index for monthly maintenance: Harvester: 10,000 Forwarder: ≤ 7,000	 ≤ 15,000 ≤ 10,000	 ≤ 20,000 ≤ 15,000	 ≤ 25,000 ≤ 20,000	 > 25,000 > 20,000	
Assessment when a maintenance index is not available					
13. Directions given on which tasks can be performed from the same position on the machine.	Incomplete	No!	—	—	
14. Normal maintenance can be performed from the ground and in a convenient position	On the machine and in a convenient and safe position	On the machine but need to stretch	Only to a limited extent	Ergonomically unacceptable	
15. All important components that need frequent attention are readily accessible and easy to replace.	Not entirely	Only to a limited extent	Only to a limited extent	—	
16. Guards, inspection panels, etc., can be opened/raised easily without tools (key acceptable) and remain attached.	Not entirely	Only to a limited extent	Only to a very limited extent	—	
17. Handling and filling of fuel, oil and pesticides can be done easily and without spillage.	As for class A	Not entirely	Only to a limited extent	Ergonomically unacceptable	

Maintenance-index computation form

Date .... **Signature** ....

Maintenance interval .... (use a separate form for each maintenance interval)

It is recommended that reference be made to Appendix 4 for guidance on this procedure.

Maintenance item (service point)	Task	Loca-tion	Access-ibility	Proced-ure	Miscel-laneous	Sum	Frequency factor	Total	Remarks
Maintenance index									

Brakes and operator safety

Date .... Signature ....

Brake system, functions and controls: ....

....

Brake capacity tested on a slope of ....%.

Nature of ground surface (during braking test and determination of traction): ....

....

Emergency equipment provided (see item 12 in table below): ....

....

Class A, B och C	Class D	Class 0	Enter class
1. The machine has independent controls for the service brake and secondary (emergency) brake.	As for class A	Controls not independent	
2. The machine can be stopped on a slope of at least 50% and the brakes can be readily applied in an emergency independently of the power source. The brakes effect a deceleration of at least 4.5 m/s^2 and meet the requirement in ISO 11169 for wheeled machines and ISO 11512 for crawler (track-laying) machines.	Braking performance meets only the requirements of ISO 11169 or 11512	Braking performance does not meet either ISO 11169 or 11512	
3. The brakes are reliable. With footbrake applied, the machine cannot move when an attempt is made to pull away in the lowest gear.	Not fully compliant but can be used in certain conditions	Falls well short of requirement.	
4. The machine does not have sharp corners or sharp edges.	Not fully compliant but can be used in certain conditions	Falls well short of requirement.	
5. Tires, chains and tracks provide good traction.	Somewhat deficient but can be used in certain conditions	Falls well short of requirement.	
6. Neither the machine nor its components can move spontaneously.	As for class A	Falls short of requirement.	
7. The boom can be immobilized when the machine is parked.	As for class A	Falls short of requirement.	
8. All moving parts, transmissions, etc., are fitted with guards.	As for class A	Falls short of requirement.	
9. Adequate, reliable and effective fire-extinguishing equipment provided.	As for class A	Falls short of requirement.	
10. Battery suitably located and anchored: cannot injure operator, eg, if machine rolls over.	As for class A	Falls short of requirement.	
11. Suitable screening of all electronic equipment.	As for class A	Falls short of requirement.	
12. An emergency stop button/device, SOS transmitter or other emergency system is provided for when the operator is working outside the cab.	As for class A	Falls short of requirement.	

Classes A, B and C: Safety assessed as fully satisfactory.

Class D: Acceptable under certain conditions, eg, only to be driven on flat ground; maintenance to be carried out by trained personnel. Alternatively, the risk of injury is deemed to be so minor or to occur so rarely that action can wait until the next service.

Class 0: Fails to meet the requirements or poses risk of injury. The machine must not be used before defects have been rectified.

Remarks concerning risks, recommended action, etc.: ....

Production of an illumination diagram or lighting curves

Date .... Signature ....

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