A handbook produced by ErgoWood, a project co-financed by the EUROPEAN COMMISSION

European ergonomic and safety guidelines for forest machines 2006

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Foreword

Throughout the years there have been different ergonomic guidelines for forest machines in different countries in Europe. In 2006 they became European as result of a by EU co-financed project titled *Ergoefficient mechanised logging operations (ErgoWood)*. Partners from France, Germany, Norway, Poland, Sweden, and United Kingdom have been involved. Reference groups in each country and in Finland have given contributions. The reference groups were made up of machine operators, machine owners, trade unions, contractor associations, forest owners and forest companies, machine manufacturers, health and safety authorities, and researchers.

The 2006 version of *Ergonomic and safety guidelines for forest machines* is based on the Nordic *Ergonomic guidelines for forest machines* (Gellerstedt et al., 1999), the Swedish *Ergonomic checklist for forest machinery* (Löfroth et al., 2003) and the German *Checklist for purpose built forest machines* (KWF, 2003). Compared to previous versions, this one is more directed to manufacturers, testing institutes, and larger companies using forest machines. A short ergonomic checklist aimed mainly for the users is also available as a separate booklet.

These guidelines have no legal binding, otherwise than its lowest levels, which are based on the safety requirements in the EU directives and mandated EN standards.

Contents

Introduction

The purpose of *European ergonomic and safety guidelines for forest machines* is to provide guidance on ergonomic matters for manufacturers, buyers, and users of forest machines. The guidance will encourage the development of safe forest machines that are easy to use and maintain. This, in turn, offers the machine operators a good chance to preserve their health and well-being, and to secure a good income. The guidance is based on scientific knowledge, standards, and established practices of people using forest machines.

The *Ergonomic and safety guidelines* cover all cab-equipped off-road machines that are used in forestry, which means that excavators and farm tractors are also included. The guidelines specify the functional criteria to be met by the design of the operator's workstation, the operation of the machine and its equipment, as well as maintenance procedures.

Machines manufactured after January 1, 1995 shall carry a CE-mark, and are presumed to meet the requirements in the Machinery Directive, 98/37/EC, EMC-directive 89/336/EEC, pressure vessels 87/404/EEC, etc. To verify the compliance, technical documentation of manufacturing must be provided. Such documentation is composed of drawings, calculations, test results, technical reports, manuals, and risk assessments. The *Ergonomic and safety guidelines* do not identify all safety risks on the machines. Complementary risks are to be found in the manufacturers risk assessments.

A machine manufacturer can use the *Ergonomic and safety guidelines* to find out what criteria a forest machine must meet. Buyers and users can find out if a machine can be efficiently operated and not causing operator health problems. The *Ergonomic and safety guidelines* can be used for determining a machine's ergonomic profile.

Accommodating variations in individuals

The handbook uses ISO standard 3411 (Human physical dimensions of operators and minimum operator space envelope), which states that 90% of a large sample of machine operators from all over the world are between 155 and 190 cm tall (well-built, dressed in winter clothing but not wearing a hard hat) and weigh between 55 and 109 kg. The machine should also allow all, except the weakest 5% in that population, and operators with minor disabilities (e.g. visual capacity due to age or the 10% of men that are colour-blind) to operate the machine.

Seat reference point

The seat index point (SIP) according to ISO 5353 is used as the fixed point in the cab. 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. Due to practical reasons the seat reference point (SRP) (SS 2863) is used when checking the machine. SRP is located in the middle of the seat, on the intersection between the seat and the backrest. A horizontal load might be applied to the lower part of the backrest to help to find the point. SIP is located 97 mm above and 130 mm forward of the SRP (see Figure 1). The SRP is used since it is easier to determine.

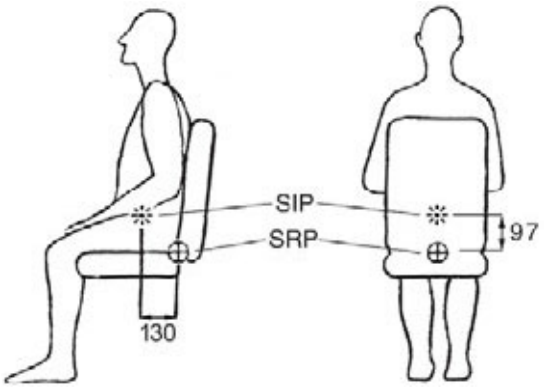


Figure 1. Comparison between the seat reference point (SRP) and the seat index point (SIP). Measurements are given in millimetres (mm).

Division into five classes

The constructor of the machine has to decide which ergonomic profile the particular machine will meet. The *Ergonomic and safety guidelines* gives guidance how to design the functions of the machine that influence the operator's working conditions. The guidance is based on what kind of work (its difficulty) the machine is supposed to do, at which tempo, and the duration of time (day/week per operator) the machine is supposed to be operated. For each item (e.g. seat, noise), the classes are defined by the suitability of the machine for operation in the specified conditions.

The machine shall be designed in conjunction with the ergonomic principles stated in EN 14386 Safety of machinery: Ergonomic design principles for the operability of mobile machinery, in EN 614 Safety of machinery: Ergonomic design principles; Part 1: Terminology and general principles; Part 2: Interactions between the design of machinery and work tasks, and in ISO 10075 Ergonomic principles related to mental workload; Part 1: General terms and definitions; Part 2: Design principles.

A machine supposed to be used year around in shift work and in many different conditions needs an ergonomic profile with many tested sections in the better classes. For a forestry equipped farm tractor, utilised a hundred hours per year, it is sufficient to have most items in lower classes. The principle is that the impact of the machine on the operator's health and comfort should be the same, regardless of the class to which the assessed item has been assigned. This presupposes that the machine is used for the purpose for which it was designed.

The machine is designed for:

Class A: Year around highly productive work in all types of terrain and forestry conditions. High level of 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 (e.g. easier terrain and forestry and climate conditions, lower tempo and/or shorter duration of time). Same high level of safety but, otherwise, not of the same high standard as in class A.

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

Class D: Easier conditions and/or lower tempo/shorter duration than in class C. Not of the same standard as in class C, but good level of safety.

Class E: The machine does not satisfy the statutory safety requirements (EU directives on machines and national regulations) 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).

Ergonomic profile

In order to gain an overview of a machine's characteristics, it is appropriate to compile an ergonomic profile. When assessing a machine's functions, standardised methods should be used, both for measuring and interpreting the results. Apart from familiarity with the machine operations, some knowledge of ergonomics is required to make a sound assessment.

Section	Class				
	A	B	C	D	E
Cab access	☐	☐	☐	☐	☐
Cab	☐	☐	☐	☐	☐
Visibility	☐	☐	☐	☐	☐
Operator's seat and armrests	☐	☐	☐	☐	☐
Controls	☐	☐	☐	☐	☐
Operating the machine	☐	☐	☐	☐	☐
Information from the machine	☐	☐	☐	☐	☐
Working posture	☐	☐	☐	☐	☐
Winch	☐	☐	☐	☐	☐
Noise	☐	☐	☐	☐	☐
Vibration	☐	☐	☐	☐	☐
Climate control	☐	☐	☐	☐	☐
Gases and particulates	☐	☐	☐	☐	☐
Lighting	☐	☐	☐	☐	☐
Manuals and instructions	☐	☐	☐	☐	☐
Maintenance	☐	☐	☐	☐	☐
Maintenance index	☐	☐	☐	☐	☐

Any item rated as unacceptable safety turns the whole section into Class E.

The point system

Each chapter has a set of questions (see e.g. the chapter on Cab access). The answers to these questions are classified into the 5 levels with an increasing number of penalty points.

Level	Points	Comments
1	0	Some items about safety only have Level 1 and 5.
2	1	
3	3	Items may have Level 2, 3, or 4 as the lowest possible.
4	7	
5	15	**If an assessment of an item falls into a grey marked area in the assessment tables the item is rated unacceptable safety, which turns the whole section into Class E.**
5	-	**Some items rated unacceptable safety (grey marked area) may not be given any points at all. Unacceptable safety of an item anyway turns the whole section into Class E.**

In order to mark the importance of the different questions, the points awarded for a particular level are multiplied with a weight factor.

Weight factor for the questions to obtain penalty points		
Has to be fulfilled	-	If the item has an unacceptable safety, the whole section is rated Class E.
Very important	4	
Important	2	
Less important	1	

The penalty points for each item are added to obtain the total points for the particular section. The ergonomic profile table is then used to classify the section, where A signifies the highest evaluation. The threshold values between classes A and B is set at 3%, between classes B and C at 10%, etc. (see the table below).

	Class	Min. points	Max. points
Threshold values between the classes making up the ergonomic profile	A	0 %	3 %
	B	>3 %	10 %
	C	>10 %	25 %
	D	>25 %	50 %
	E	>50 %	100 %

In the case of Cab access, the maximum possible score is 607 points. The corresponding evaluation table looks like this:

Ergonomic profile			
Class	**Min. Points**	**Max. points**	
A	0	18	The maximum number of points used for calculating the ergonomic profile table is the sum of all attainable penalty points for the section.
B	19	60	
C	61	151	
D	152	303	
E	304	607	

An example: In many instances the threshold between Level 4 and 5 is determined by a standard, which shall not be exceeded. For example, EN ISO 2867 states that the maximum height of the first step of the cab access may not exceed 700 mm. If this value is exceeded, the item First step is assigned to Level 5, and the whole section classified as Class E, as the safety hazard is so great. However, a height in excess of 550 mm is already too high for the first step and is classified as Level 5 and given 15 points.

Machine data

The machine data is primarily used to identify the machine itself before the ergonomic assessment and is required for a correctly and comparable assessment. Most of the specifications are possible to measure or note down at the assessment but some of the technical data must be supplied by the manufacturer before the assessment.

Many of the machine parts or options affects a lot of parameters in the assessment and it is most important that all the technical data are noted down if applicable.

Section A contains information to identify the machine and its essential machine parts and tools. This is important information when comparing assessments.

Section B contains specifications needed to perform the assessment and makes it possible to compare similar assessments.

Section C contains information from the manufacturer that helps to evaluate the overall ergonomics and safety of the machine.

Technical specification of the machine

A. Machine identification information

Type of machine: _____

Make/brand: _____

Model: _____

Year of manufacture: _____

Serial No. (VIN): _____

Total operating hours (meter reading): _____

Engine; make and model: _____

Crane; make and type: _____

Rotator; make and type: _____

Grapple; make and type: _____

Harvester head; make and type: _____

Winch; make and type: _____

Seat; make and type: _____

Armrest; make and type: _____

Controls; make and type: _____

B. The following data must be noted down at the assessment

Tyres; make and dimensions, front: _____

Tyres; make and dimensions, rear: _____

Number of wheels front and rear: _____

Front axle type (bogie or rigid): _____

Rear axle type (bogie or rigid): _____

Axle configuration: _____

Steering system (Ackermann or articulated): _____

Wheelbase (bogie-bogie/axle-axle/bogie-axle): _____

Maximum length of the machine (without boom, if applicable): _____

Maximum width of the machine (without boom, if applicable): _____

Length and width of tracks: _____

Number of tracks: _____

Crane; reach: _____

Winch; cable length and diameter: _____

Other tools: _____

Load bunk; width and height: _____

Number of bunks: _____

Levelling equipment: _____

Type of lighting: _____

Number of lamps: _____

Additional equipment (e.g. remote control): _____

Tool kit; contents: _____

Fire extinguishing equipment: _____

Instruction handbook (edition): _____

Interactive software (version): _____

Miscellaneous: _____

C. The following data/information must be supplied by the manufacturer

Engine power: _____

Engine displacement: _____

Gross machine weight: _____

Maximum permitted load on front axle/rear axle: _____

Specify test standard for the information below

Roll over protective structure (ROPS): _____

Falling object protective structure (FOPS): _____

Operator protective structure (OPS): _____

Brakes: _____

EMC: _____

Machine safety: _____

Cab access

Many accidents among forest machine operators occur when they are mounting or alighting the machine. Such accidents are usually caused by the operators missing their 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 may also constitute a hindrance to older operators working on the machine. As a consequence, operators may be deterred from leaving the cab to take a break or to do work out of the cab, e.g. changing a saw chain that needs sharpening.

Guidelines

Operators of different stature 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 Figure 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.

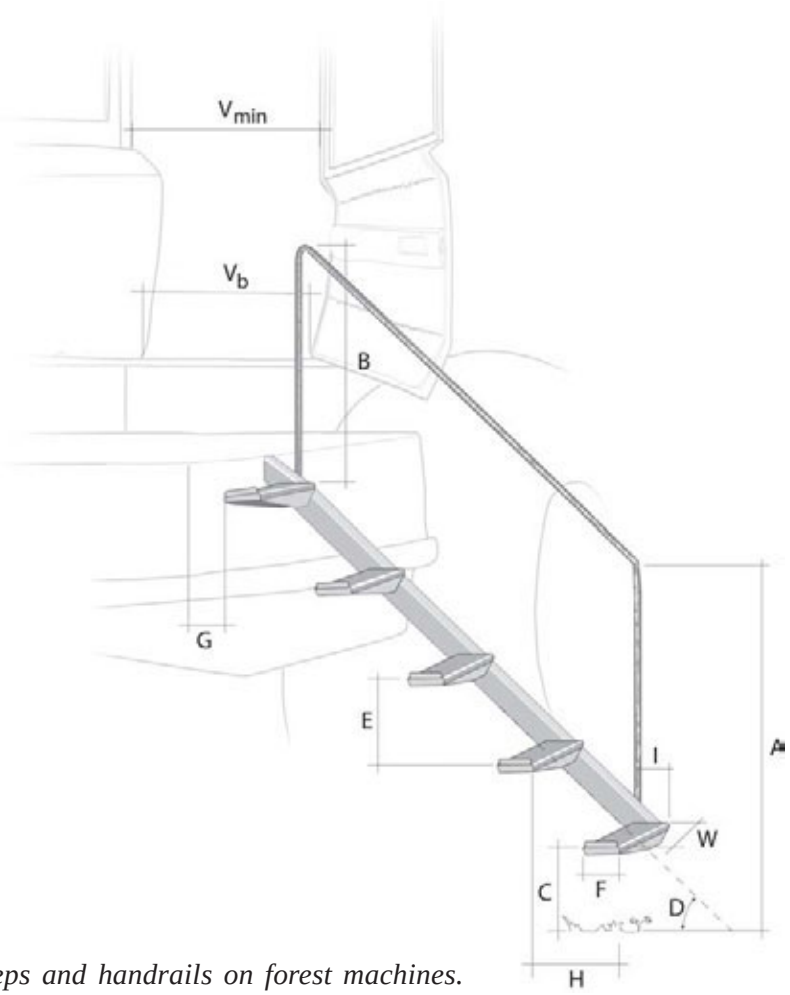


Figure 2. Design of steps and handrails on forest machines.

Measuring technique

For assessment of cab access, the machine should be standing on level ground. Parking mode, according to the manual, shall be used. 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.

Assessment

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

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Level 5 Unacceptable	Penalty points
1. Ground to first step (C) [1], mm	_____	4	<350 mm	351 - 400 mm	401 - 450 mm	451 - 550 mm	>550 mm or steps lacking	>700 (EN ISO 2867)	
2. Maximum pitch (D), [2), 3)], °	_____	4	<45° variation <2	46 - 50° variation <2	51 - 60° variation <5	61 - 80° variation >5	>80 or steps lacking		
3. Step width (W), mm	_____	2	>390 mm	321 - 390 mm	251 - 320 mm	160 - 250 mm	<160 mm		
4. Step depth (F), mm	_____	2	≥240 mm	151 - 239 mm	101 - 150 mm	51 - 100 mm	≤50 mm	Ø <19 or >60 □ <6	
5. Stride distance (H), mm	_____	2	≥240 mm	≥200 mm	≥160 mm	≥130 mm	<130 mm		
6. Rise (E) [4)], mm	_____	2	221 - 250 mm Variation = 0 mm	201 - 300 mm Variation ≤10	180 - 350 mm Variation ≤20 mm	180 - 400 mm Variation >20 mm	<180 mm or >400 mm Variation >20 mm		
7. Horizontal clearance (G) [5)], mm	_____	2	>150 mm		101 - 150 mm	50 - 100 mm	<50 mm		

8.	Ground to handrail or handle (A), mm Step to handrail or handle (B), mm Maximum horizontal distance to handrail or handle (l), mm	A: _____ B_{max}: _____ B_{min}: _____ l_{max}: _____	4	A 850 - 960 mm B_{max} ≤1000 mm B_{min} ≥850 mm l_{max} ≤630 mm Handrail sufficient to allow mounting/alighting forwards.	A 800 - 1100 mm B_{max} ≤1000 mm B_{min} ≥850 mm l_{max} ≤630 mm Handrails and 3-point support, mount/alight backwards.	A 800 - 1400 mm B_{max} ≤1500 mm B_{min} ≥800 mm l_{max} ≤630 mm Handle and/or Handrail 3-point support. Handle length >150 mm		A 800 - 1600 mm B_{max} >1500 mm B_{min} <800 mm l_{max} >630 mm Only 2-point support. Handle length <150 mm	A >1600 mm or <800 mm	
9.	Handrail/handle diameter, mm	_____	1	Ø 22 - 30 mm		Ø 15 - 35 mm		<15 mm or >35 mm		
10.	Hand clearance behind handrail or handle, mm	_____	1	>70 mm		50 - 70 mm	<50 mm	Handrail or handle missing.		
11.	Enter cab from ladder or stairways.	_____ _____	2	Direct access to the cab or to a platform >300 mm broad levelled ±10 mm to the cab bottom. Handles available.	Enter the cab over platforms/catwalks >300 mm broad across steps until 250 mm. Handles available.	Enter the cab over platforms/catwalks <300 mm broad or across steps >250 mm. Handles available.	One step only onto wheel/track required or cab has to be in a special position for safe alighting. Handles available.	Wheel or track used for mounting and alighting or handrail or handle lacking.		
12.	Risk of slipping.		2	Self cleaning steps and platforms with a good grip. They do not collect snow and ice. The construction minimise the risk of slipping sidewise.	Self cleaning steps platforms and catwalk provide good grip, easy to clean (not mounted over surfaces). Construction minimise risk of slipping sidewise.	Steps, platforms and catwalks provide good grip, not easy to clean. The construction minimise the risk of slipping sidewise.	Difficult to clean. Simple slip protection, e.g. "sandpaper". provide good grip,	Very difficult to keep clean or slip protection lacking.		

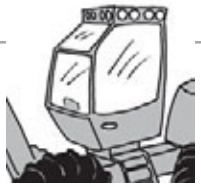
13.	Main door opening dimensions: Height (J) [6], mm Minimum width (V_{min}) measured between 460 mm and 1250 mm high [6], mm Width at bottom (V_b) [6], mm	J: _____ V_{min}: _____ V_b: _____	4	J ≥1700 mm V_{min} ≥ 650 mm V_b ≥ 450 mm No threshold.	J = 1600 - 1699 mm V_{min} = 600 - 649 mm V_b = 350 - 449 mm No threshold.	J = 1500 - 1599 mm V_{min} = 550 - 599 mm V_b = 250 - 349 mm Threshold <30 mm	J = 1300 - 1499 mm V_{min} = 450 - 549 mm V_b = 250 - 349 mm Threshold ≥30 mm	J <1300 mm V_{min} <450 mm V_b <250 mm	
14.	Emergency exit provided (apart from main access).	_____	2	Two emergency exits; Round diameter >650 mm, Square [7] >600 · 600 mm, or Rectangular [7] >470 · 650 mm	One emergency exit; Round diameter >650 mm, Square [7] >600 · 600 mm, or Rectangular [7] >470 · 650 mm	One emergency exit; Round diameter <650 mm, Square [7] <600 · 600 mm, or Rectangular [7] <470 · 650 mm		No functional emergency exit provided or measurements less than level 3.	
15.	Cab door stays open when machine tilted or in wind. There is no risk that the operator is pinched.		1	Automatic construction withstanding 15° machine tilt. No risk being pinched.	Device 15° withstanding machine tilt. No risk being pinched.	Device with mechanical lock. No risk being pinched.	Device that not withstanding 15° machine tilt. Little risk being pinched.	Device missing. Obvious risk being pinched.	
16.	Cab door opens and closes (moment required for closing door, Nm)	_____	1	Door opens and closes automatically.	<35 Nm	36 - 75 Nm	76 - 150 Nm	>150 Nm	

17.	There is no risk that the operator becomes caught in or pinched by means of access.	_____	1	No risk. No objects protrude into door opening, staircase, or handrail. Foot space between door and seat on the cab ground at least 240 · 300 mm.		Some risk. Opening size limited by protruding objects. Foot space between seat and door is >240 · 300 mm.	Door opening restricted by protruding objects and seat. Safe entrance requires care or foot space between seat and door is <240 · 300 mm.	Door opening severely restricted by protruding objects and seat. Major risk of clothes being caught. Entrance requires contortions and utmost care.	
18.	The door is possible to open from the outside without movements of the person.		1	No movement is needed.		A step backwards on the same platform/step is needed.		Must step backwards to a lower level.	
19.	Means of access protected against damage.		2	No risk of damage.		Small risk of damage or automatic function with minor shortcomings.	Steps and catwalks can be let down in one simple manual operation or some risk of damage.	Steps and catwalks can be let down, deep knee-bending or major force required, or large risk of damage.	
20.	Cab door, steps and ground under steps well lighted. [8)]		1	All parts of the access are well lighted by specially arranged lamps.	Access is well lighted by working lights.	Access is not well lighted. Some parts, esp. the ground, are in the dark.	Lighting is lacking.		
								SUM	

[1)] Parking mode, according to the manual, shall be used in the assessment.
[2)] If the pitch can be altered the measuring should be carried out with steps in a horizontal position.
[3)] If the pitch is less than 45° mounting and alighting forwards is possible.
[4)] Including the distance step to first catwalk.
[5)] Measure from front edge to the nearest point behind step or to the point where the vertical clearance is less than 100 mm.
[6)] Any objects protruding into the door opening must be taken into account when measuring door dimensions. Measured from edge to edge or to any object protruding into door opening.

[7] Rounded edges are possible.
[8] E.g. Lighting turns on when head switch is activated.

	Class	Min. points	Max. points
Ergonomic profile	**A**	0	18
	B	19	60
	C	61	151
	D	152	303
	E	304	607



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, who should be able standing in the cab while entering it. If a person 1 900 mm tall is wearing winter boots and head gears, a clearance of a least 50 mm is required in the cab of a still standing machine. This gives the minimum required head room of 2 000 mm.

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 levelling devices. Although the cab width is not usually critical, a wide cab does reduce visibility on either side.

Dimension (mm)		Guideline
A	2000	Headroom
B	630 [1)]	Seat in rear position
C	1150	Seat in rear position, measured at toes
D	880 [2)]	Seat in forward position and at mid-height
E	700	Seat in forward and highest position
F	1200 [3), 4)]	Cab width measured at armrest height

[1)] 700 mm 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, 650 mm of clearance from the SRP is needed for rotation of a conventional seat when occupied.
[4)] A cab not equipped with levelling may be fitted with a laterally tiltable seat requiring greater cab width.

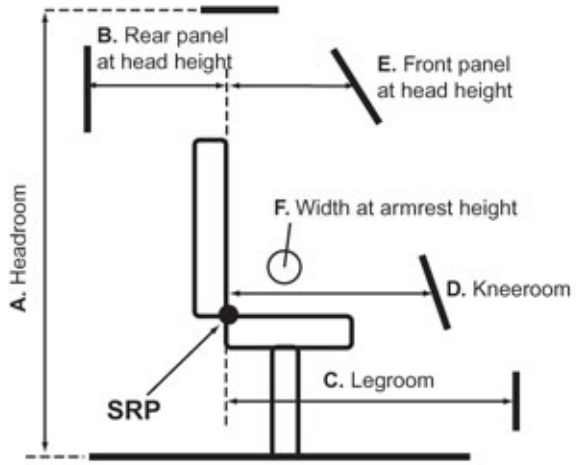


Figure 3. Inside cab dimensions.

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 be positioned at least 300 mm from sources of cold drafts. Space is 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 levelled, there should be room for levelling 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 labelled stowage place for a first aid kit.

Measuring technique

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

Assessment

When measuring the dimensions of the cab, the seat should be positioned at the centre of its possible horizontal range. SRP should be 450 mm above the floor.

In machines with a separate driving and working direction or with two working directions, all relevant measurements (such as legroom) should be measured in both directions. The evaluation is then based on the worst measurement.

All measurements are in mm.

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1. Headroom (A), mm (area 250 · 250 mm above SRP)	_____	4	≥2000	1801 - 1999	1651 - 1800	1510 - 1650	<1510	
2. Rear panel at head height (B) [1], mm (with tiltable seat)	_____	2	≥630 (≥700)	591 - 629 (631 - 699)	541 - 590 (561 - 630)	440 - 540 (491 - 560)	<440	
3. Legroom; driving and working position (C), mm	_____	4	≥1150	971 - 1099	861 - 970	600 - 860	<600	
4. Knee room (D) [2], mm	_____	2	≥880	831 - 879	781 - 830	730 - 780	<730	
5. <u>If two working directions:</u> Knee and foot room at turning of the seat [2], mm	_____	2	≥700	651 - 699	601 - 650	570 - 600	<570	
6. <u>If two working directions:</u> Clearance between seat and fixed objects at turning of seat [3], mm	_____	2	≥25	10 - 24		<10		
7. Front panel at head height (E), mm	_____	2	≥700	651 - 699	601 - 650	550 - 600	<550	
8. Width at armrest height (F) [4], mm	_____	2	≥1200	1101 - 1999	1001 - 1100	920 - 1000	<920	
9. Stowage space for first aid kit.		1	Big enough			To small or lacking		

10.	Stowage place for personal items, e.g. hook for outdoor garments, compartments for small items.		1	Cool box present	Yes	Shortcomings	
11.	Cab easy to keep clean. Door extends all the way down to the floor.		1	Yes	Minor shortcomings	Moderate shortcomings	
12.	The machine does not have sharp corners or sharp edges.		2	No	Not fully compliant but can be used in certain conditions.	Falls well short of requirement.	
						SUM	

[1] For a seat tiltable in forward/backward direction 700 mm is required.
[2] From SRP to inside limit (wall, steering wheel, computer screen, etc.).
[3] Horizontal adjustment in rearmost position. Clearance between armrests and backrest and fixed objects in the cab.
[4] A cab not equipped with levelling may be fitted with a laterally tiltable seat requiring greater cab width (+60 mm).

	Class	One working direction		Two working directions	
		Min. points	Max. points	Min. points	Max. points
Ergonomic profile	A	0	8	0	9
	B	9	28	10	32
	C	29	70	33	81
	D	71	141	82	163
	E	142	283	164	327

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 in many forest machines.

The need of good visibility often conflicts with suitable placing 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 Figure 12). However, it is not detrimental to occasionally turn the head sharply or to bend forward.

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 Figure 4). Measurements are made in the dark with the machine standing on level ground. The boom, if there is a 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, i.e. 1 300 mm above the floor and 130 mm forward of the SRP in the working direction (e.g. 800 mm above the SRP with the seat 500 mm 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, e.g. 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 harvester operator's view should extend 25 m upwards at a horizontal distance of 10 m is usually met at an angle of about 65°.

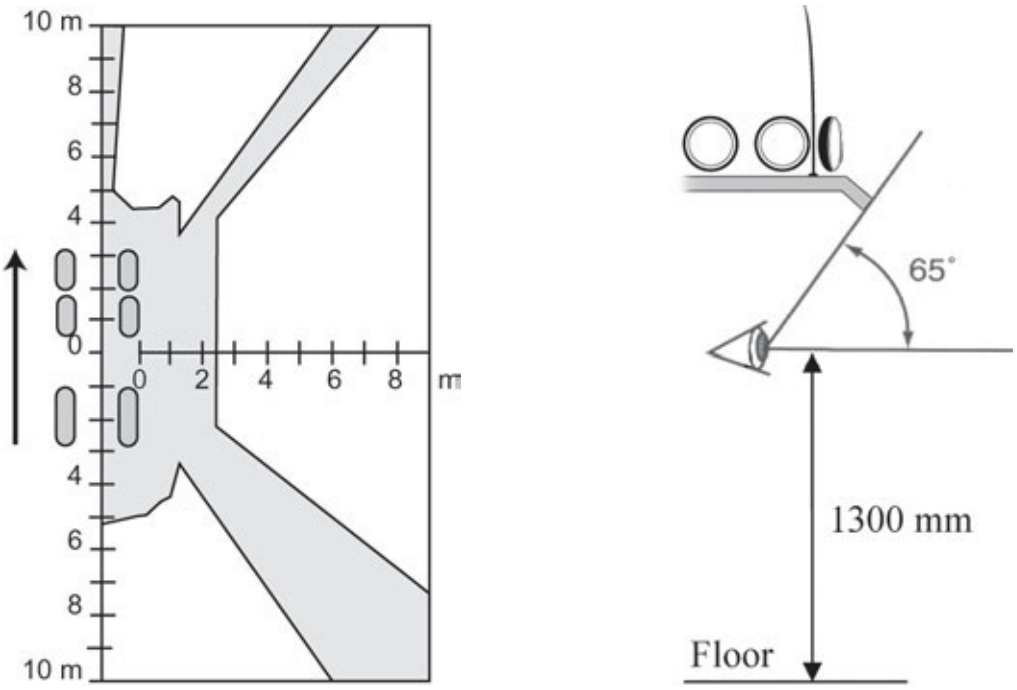


Figure 4. An example of a ground plan of the area and angle of the field of view from a harvester forward, to the side, to the rear of the machine, and upward from the operator's seat. The shading denotes the areas in which the operator's vision is obscured.

Assessment

Vertical angle of view: _____°

Eye should be positioned 1 300 mm above floor. The seat should be vertical and in central position (middle position of legroom adjustment range).

Evaluation of vertical angle of view upwards

	Harvester	Forwarder and skidder
Level 1	≥65	≥50
Level 2	≥60	≥45
Level 3	≥50	≥40
Level 4	≥40	≥30

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1A. <u>Harvester and forwarder:</u> In the working envelope of the boom, the operator can see the ground less than 2 m from the side of the machine (incl. wheels or tracks). Swivelling cabs may rotate about 90°.	_____	4	Side ≤2 m	Side 2 - 3 m	Side 3 - 4 m	Side 4 - 5 m	>5 m to side of machine	
1B. <u>Skidder:</u> The operator can see the ground less than 2 m from the side of the machine (incl. wheels or tracks).	_____	2	Side ≤2 m	Side 2 - 3 m	Side 3 - 4 m	>5 m to side of machine		
2. In driving direction the ground can be seen within 5 m from SRP.	_____	2	Forwards <5 m	Forwards 5 - 7 m	Forwards 7 - 10 m	Forwards 7 - 10 m	>10 m in front of machine	
3A. <u>Harvester:</u> Vertical angle of view (in working position) ≥65°	_____	4	≥65°	60° - 64°	50° - 59°	40° - 49°	<40°	
3B. <u>Forwarder:</u> Vertical angle of view (in working position) ≥50°	_____	4	≥50°	45° - 49°	40° - 44°	30° - 39°	<30°	
3C. <u>Skidder:</u> Vertical angle of view (in working position) ≥50°	_____	2	≥50°	45° - 49°	40° - 44°	30° - 39°	<30°	
4. When driving forward, the operator can see the front wheels and ground between the front wheels.		2	Yes	Operator must twist/contort his body slightly to see.		Operator has to stand up.	The ground cannot be seen.	

5.	The windows in all work directions are equipped with a window wipe-wash system. The wiped surface is >75% of the window area.		2	Yes	Wiped area limited, 50 - 75% of the window area.	No window wash system.	Wipers missing in one working direction.	
6.	Two or more de-icing nozzles per window.		2	Yes	De-icing with minor shortcomings.	De-icing with major shortcomings.	De-icing system missing.	
7A.	Harvester: Free view to the rear and front is not obstructed by boom posts, cab stays and equipment. Operator must not shift his sitting position to obtain view of working area.	_____	2	Cab stays <120 mm Rear view camera from the working position.	Cab stays <120 mm	Cab stays >120 mm View partially obstructed by boom post.	Cab stays >120 mm View obstructed by boom post.	
7B.	Forwarder: Free view to the rear and front is not obstructed by boom posts, cab stays, and equipment. Operator must not shift his sitting position to obtain view of working area. The rear view with load is limited.	_____	2	Cab stays <120 mm Rear view camera both in the working and driving position.	Cab stays <120 mm Rear view camera in one direction.	Cab stays >120 mm View partially obstructed by grille or boom post.	Cab stays >120 mm View obstructed by grille or boom post.	
7C.	Skidder: Free view to the rear and front is not obstructed by boom posts, cab stays and equipment. Operator must not shift his sitting position to obtain view of working area.	_____	2	Cab stays <120 mm		Cab stays >120 mm View obstructed by boom post.		
8.	Machine parts that can cause glare is painted with dark and dull colour. Sun blinds installed.		2	Yes	As for level 1; no sun blinds.	As for level 2; limited protection against glare.	Only in driving direction.	Not provided
							SUM	

Ergonomic profile	Class	Harvester and forwarder		Skidder	
		Min. points	Max. points	Min. points	Max. points
	A	0	8	0	6
	B	9	28	7	20
	C	29	71	21	50
	D	72	142	51	100
	E	143	284	101	200

Operator's seat and armrests

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 of time. It is therefore important that the operator is 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 Figure 5 and Figure 6). The larger angle between trunk and thigh also reduces the strain on the lower back. It is vital that good lumbar support is achieved.

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 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 30-50 mm 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 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 or machine cannot be levelled and swivelled 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.

A rotating seat must be provided in machines that can be operated in both directions.

Adjusting the seat and armrests shall be simple and shall not require tools. It must be easy to readjust the settings again.

Measuring technique

Measuring tape and a protractor/digital water level.

Assessment

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

New ☐ Second hand ☐

Additional equipment etc.: _____

Repairs/overhauls carried out: _____

Establish the Seat Reference Point (SRP). The SRP is situated in the centre of the seat in the intersection between the seat cushion and the backrest from which the measurements are taken. The SRP is 97 mm below and 130 mm behind the Seat Index Point (SIP) (see ISO 5353).

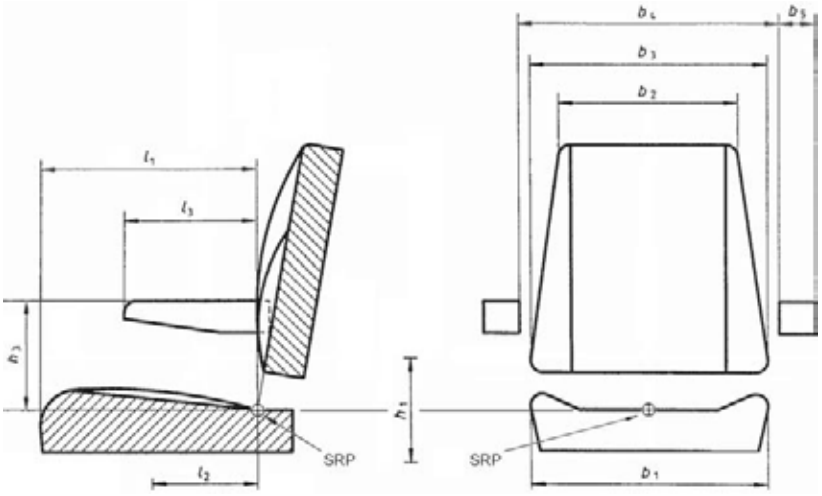


Figure 5. Measurement points on operator's seat and armrests.

Operator's seat

Legroom ± 240	Height 400-650 [1]	Damping	Backrest angle - 5-30°	Seat pitch Up 8° Down15°	Lumbar-support convexity > 80
Lumbar-support height 150-230	Seat depth 370-480	Fore-and-aft tilt [2] > ± 20°	Lateral tilt [2] ±10-15°	Seat swivel [3] 220°/270°	Seat width 460-510	Backrest width b_2: 310-360 b_3: 430-510

[1] The height of the seat cushion above the floor should be measured with a load of 750 N on the seat.
[2] Depending on whether the operator's seat or cab can be levelled.
[3] Depending on whether the cab is rotateable.

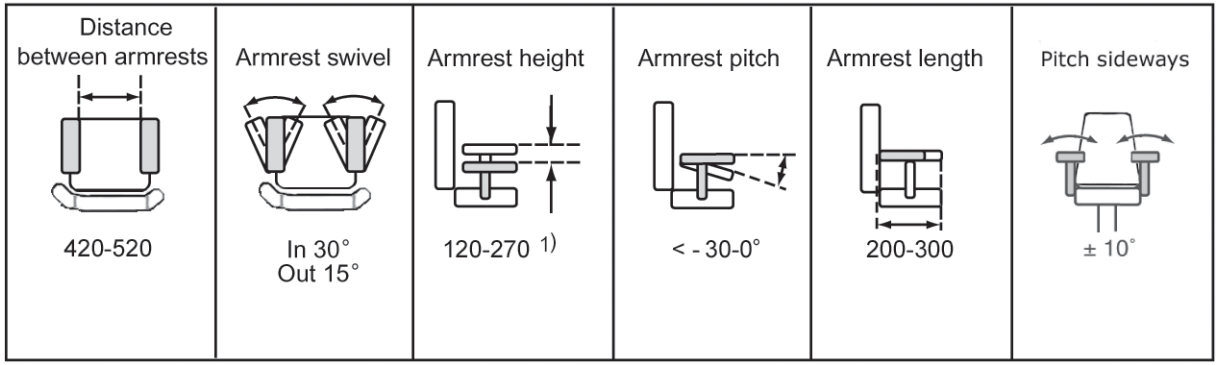
Figure 6. Range of seat adjustments (mm or °).

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1. Legroom adjustment (l_2) [1], mm	_____	4	>240 mm	>180 mm	>140 mm	≥100 mm	<100 mm	
2. Lowest height SRP [2], mm	_____	4	≤400 mm	401 - 450 mm	451 - 500 mm	501 - 550 mm	>550 mm	
3. Height range (h_1) [3], mm	_____	4	>250 mm	151 - 250 mm	75 - 150 mm	<75 mm	Fixed	
4. Spring suspension and damping.		4	Good damping vertically and horizontally protecting from vibrations as well as jolts and shocks.	Good vertical damping. Minor shortcoming; jolts; moderate horizontal damping.	Good vertical damping; horizontal damping is lacking.	Poor damping for light or heavy persons or at extreme altitudes.	Poor damping for persons weighing 70 - 100 kg.	
5. Backrest angle, °	_____	1	-5 - +30°; adjustable	0 - +20°; adjustable		+5 - +15°; adjustable	Fixed or less than Level 4.	
6. Seat pitch, °	_____	1	-15 - +8°; adjustable	-5 - +10°; adjustable	0 - +10°; adjustable	+5 - +10°; adjustable	Fixed or less than Level 4.	
7. Lumbar support convexity, mm	_____	1	>80 mm	≥50 mm - 80 mm	<50 mm	Lacking		
8. Lumbar support height, mm	_____	1	150 - 230 mm	Two fixed points; adjustable	One fixed point; adjustable	Lacking		
9. Seat depth (l_1), mm	_____	2	370 - 480 mm; adjustable	370 - 450 mm; adjustable	Fixed 400 - 450 mm	Fixed 450 - 480 mm	Fixed >480 mm	
10. Fore and aft tilt (seat or cab) [4], °	_____	1	> ±20°	±15 - 20°	±10 - 15°	< ±10	Fixed	
11. Lateral tilt (seat or cab) [4], °	_____	2	±10 - 15°	< ±10°	Missing			
12A. Harvester: Seat or cab swivel, °	_____	2	≥220°; continuously variable	190 - <220°; continuously variable	≥180 - <190°; continuously variable	<180°	Missing	
12B. Forwarder and grapple skidder: Seat or cab swivel, °	_____	2	≥270°; continuously variable	>180 - <270°; continuously variable		180°; two point	Missing	

13. Seat and backrest width (b_1, b_2, b_3), mm	b_1: _____ b_2: _____ b_3: _____	2	b_1 ≥460 - ≤510 mm b_2 ≥310 - ≤360 mm b_3 ≥430 - ≤510 mm	b_1 >430 - ≤550 mm b_2 >360 mm b_3 >400 - ≤550 mm	b_1 <430 mm b_2 <310 mm or >400 mm b_3 <400 mm	
14. Backrest height, mm	_____	1	>580 mm	≥280 mm	<280 mm or >700 mm	

[1] There must be at least 25 mm clearance between the back rest inclined at 5° and the nearest fixed object behind the seat
[2] Seat damping must be provided in the upper and the lower settings.
[3] The height of the seat cushion above the floor should be measured with a load of 750 N on the seat.
[4] Question not included in this assessment if machine has levelling system other than the seat and the cab. See the section on Working Posture.

Armrests



[1] Measured with horizontal armrests from SRP.

Figure 7. Range of armrest adjustments (mm or °).

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
15. Distance between armrests (b_4) [5], mm	_____	2	Adjustable 420 - 520 mm	Adjustable 450 - 500 mm	≥470 mm, not adjustable	<470 mm, not adjustable	Armrests not provided.	
16. Armrest swivel, °	In:_____ Out: ____	1	In >30° Out >15°	In 20 - 30° Out 10 - 15°	In 10 - 19° Out 0 - 9°	0 - 9°		
17. Armrest height (h_3) [6], mm	_____	4	Adjustable 120 - 270 mm	Adjustable 150 - 250 mm	Fixed 180 - 250 mm	Fixed <180 mm or >250	Armrests not provided.	
18. Armrest pitch lengthways, °	_____	2	< -30 - 0°; adjustable	-30 - 0°; adjustable	-20 - 0°; adjustable	-15 - 0°; Fixed	Not adjustable	
19. Armrest length (l_3), mm	_____	2	200 - 300 mm	301 - 350 mm		<200 mm or >350 mm	Armrests not provided.	
20. Armrest pitch sideways, °	_____	1	±10°	±5°	Can not be pitched or only possible to pitch in one direction.			
21. Armrest width (b_5), mm	_____	2	≥140 mm	≥120 mm	≥100 mm	<100 mm		
22. Individual settings of seat and armrests can be programmed and quickly reset automatically. [7]		4	Seat with memory of more than four functions.	Seat with memory of up to four functions.	Seat with memory of two to three functions or manual adjustment with graded scales for seat and armrest.	Manual adjustment quick and easy without graded scales.	Tools needed.	
23. Armrests follow seat movements automatically.		4	Yes			Can be readily adjusted manually.	Major shortcomings	
24. Feet have room under front of seat when legs are being bent as far back as an angle of 60° or smaller.	_____	4	Yes	60 - 80°	No room for feet under the seat (>80°).			

25.	Seat cushion and backrest equipped with thermostatic heating, ventilation, and washable loose covers.		2	Yes	One feature missing.	Two or more features missing.		
26.	Stable seat (i.e. well sited and anchored) and easy to maintain.		4	Yes		Minor shortcomings	Major shortcomings	
27.	Suitable means of restraint provided (e.g. seat belt).		2	3-point seat belt	Inertia-reel seat belt around the waist.		Fixed belt	Belt not provided
								SUM

[5] Measured with parallel armrests.
[6] Measured with horizontal armrests from SRP.
[7] Automatic adoption of operator settings for legroom, backrest, seat height, damping force, seat depth, lumbar support convexity, lumbar support height, distance between armrests, armrest height, armrest pitch, armrest length, or armrest swivel.

	Class	Harvester, forwarder and grapple skidder		Cable skidder	
		Min. points	Max. points	Min. points	Max. points
Ergonomic profile	A	0	22	0	21
	B	23	75	22	72
	C	76	189	73	181
	D	190	378	182	363
	E	379	756	364	726

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.

The decision between hand-and-finger-operated controls (e.g. 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, e.g. to be able to steer with either a lever or a steering wheel (steering wheel desirable 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, e.g. changing the menu on a display or making a phone call.

Remote controls are usually used in forestry for operating winches and moving skidders. These controls are exposed to all weather conditions and must have a degree of protection provided by the enclosure (IP code) for normal outdoor conditions. The size of the buttons and switches and distance between them must be sufficiently large. There has to be an emergency stop switch.

Guidelines

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.

Controls with too small actuating force maybe affected by e.g. vibrations, thus rendering work more difficult. A too high actuating force may cause problems and be detrimental to both precision and speed. To introduce some variation and choice, some functions may have dual controls, e.g. steering and bucking. Infrequently used controls may 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 in such a way that when pressing the button the thumb will move into 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.

Measuring technique

Establish the Seat Reference Point (SRP) (see page 6). 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 Figure 11).

Assessment

NB: According to EN ISO 6682, the reference point for the spatial arrangement of the controls is the SIP but in this assessment the SRP is used.

Two separate measurements are required in the case of swivelling seats (driving and working position). The evaluation is then based on the worst results.

According to EN ISO 6682, primary controls are those controls that are frequently or constantly used by the operator such as:

- Machine controls (transmission, brakes, steering, engine speed, etc.)
- Equipment controls (boom, grapple, harvester head, processor, etc.)
- Safety controls (emergency stop)

According to EN ISO 6682, secondary controls are those controls that are used infrequently by the operator such as switches for the lamps, wipe-wash system, lighting, starter, heating unit, air-conditioning, etc.

NB: If a remote control system is provided to operate the machine and equipment control functions it shall be included in the assessment.

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1. Primary controls within the zone of comfort or the zone of reach (EN ISO 6682).		4	All controls within zone of comfort.		One or two controls outside zone of comfort.	All controls within zone of reach.	Not within zone of reach.	
2. Secondary controls within the zone of comfort or the zone of reach (EN ISO 6682).		4	One or two controls outside zone of comfort.	All controls in zone of reach.			Not within zone of reach.	
3. Actuating forces according to Table 1 (incl. the remote control).	_____	4	0 - 9 points	10 - 30 points	31 - 75 points	76 - 150 points	>150 points	
4. The minimum distance between controls reflects the actuating forces.		4	Yes	Secondary controls deviate slightly.		Primary controls deviate slightly.	Major deviation	
5. Control function clearly labelled; controls cannot be mixed up with one another or accidentally actuated.		2	Yes			Minor shortcomings	Missing	

6.	Lever control functions in accordance with Figure 8 and Figure 9 [1)]		–	Yes			No	
7.	Controls have a neutral position.		2	Yes		Not all secondary controls.		
8.	Accidental activation of controls when leaving or entering cab is prevented.		4	Yes			No	
9.	Distance between pedals is adequate. Pedals are of suitable shape and size and have an anti-slip surface.		2	Yes		Partially	Major deviations	
10.	Brake and throttle pedal position corresponds to road vehicle.		2	Yes		Minor shortcomings, e.g. numerous pedals.	Major shortcomings	
11.	The most frequent controls are positioned for operation primarily by thumb or index finger.		2	Yes		Operating by the middle finger and/or hand.	Major shortcomings	
12.	All pushbuttons give a clear acknowledgement when pressed.		2	Yes	Primary controls acknowledge action.	Some controls acknowledge action.	No acknowledgement	
13.	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. If throttle is frequently used it should be possible to operate it by hand control as well.		2	Yes		Minor shortcomings, e.g. more than two foot controls.	Major shortcomings	
14.	The position of levers and control panels are readily adjustable to suit different operators.		4	Yes, automatically	Yes, manually; simply; scales provided.	Moderate shortcomings	Major shortcomings	Not possible

15.	Remote control only: Remote control has an emergency stop switch and machine function returns to neutral when the machine looses the contact with the remote control.		4	Yes		Has emergency stop but machine functions does not return to neutral.	Emergency stop missing.
16.	Remote control only: The degree of protection provided by enclosure of the remote control transmitter (IP code) is at least IP 54. [2]		2	Yes, >IP 54	Yes, IP 54		No, <IP 54
17.	Remote control only: The degree of protection provided by enclosure of the remote control receiver (IP code) is at least IP 65. [2]		2	Yes, >IP 65	Yes, IP 65		No, <IP 65
18.	Remote control only: Carrying method.		2	On the belt or the chest		At waist	By hand
19.	Remote control only: Transmitter weight, g	_____	2	<1000 g		≤2000 g	>2000 g
20.	Remote control only: System.		2	Radio control		Cable control	
21.	Remote control only: Hamming distance, HD [3]	_____	2	≥2		<2	
							SUM

[1] In accordance with ISO 15078. [2] In accordance with EN 60529. [3] Information from manufacturer.

	Class	Without remote control		With remote control	
		Min. points	Max. points	Min. points	Max. points
Ergonomic profile	**A**	0	13	0	19
	B	14	45	20	65
	C	46	112	66	164
	D	113	225	165	329
	E	226	450	330	658

Table 1. Actuation forces. Compare the measured values with Table 2

Control	Measured value, N	Penalty points
Throttle		
Brakes		
Clutch		
Steering		
Pushbuttons		
Equipment [1], finger		
Equipment [1], hand		
Remote control		
	SUM	

[1] Boom, grapple, harvester head, etc.

Table 2. Recommended actuating forces for each type of control

Item	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points
Fingertip-operated pushbuttons	1.5 - 2.5 N	>2.5 N		>3.5 N or <1.5 N	>5 N
Fingertip-operated controls	2 - 5 N	>5 N		>15 N or <2 N	>40 N
Hand-operated lever (Forward/Backward)	5 - 15 N	15 - 50 N		>50 N or <5 N	>140 N
Hand-operated lever (Left/Right)	5 - 15 N	15 - 30 N		>30 N or <5 N	>60 N
Steering wheel	5 - 20 N	>20 N		>100 N or <5 N	>230 N
Leg-operated controls (clutch)	45 - 60 N	>60 N	>90 N	>120 N	>250 N
Leg-operated controls (brakes)	60 – 100 N	>100 N	>250 N	>450 N	>600 N
Toe-operated controls (throttle)	20 - 30 N	>30 N		>40 N	>60 N

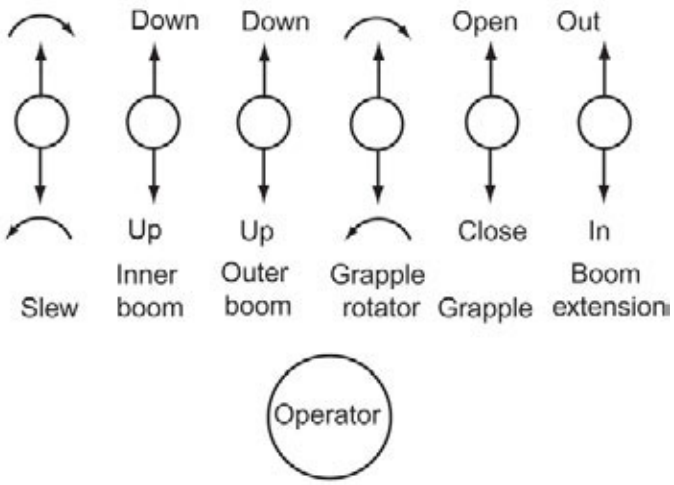


Figure 8. Lever sequence and function controls for booms, primarily log loaders, that are manoeuvred with six hand levers (RTG 6907).

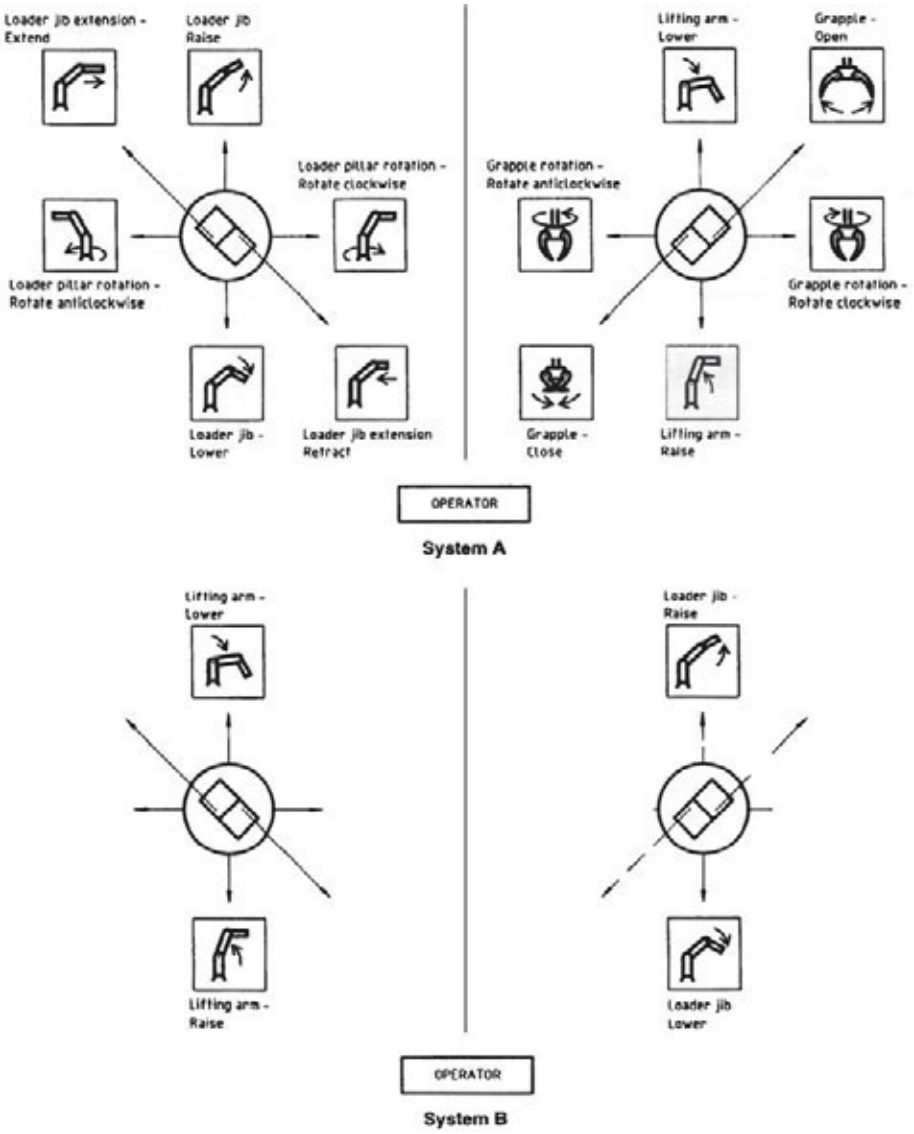


Figure 9. Log loader controls, two lever system operational pattern (from ISO 15078). For system B only the differences from system A are illustrated.

Operating the machine

Functions of a forest machine should be straightforward and sequential, and always behave in the same way. However, many functions on a forest machine, e.g. boom and grapple, are operated manually. When different functions needing high alertness and quick response are performed at once, difficulties arise for the operator. Accordingly, functions that require high attention should not be concurrently with other manually operated functions.

A forest machine operator, and especially the harvester operator, is manipulating the controls most of the time when operating the machine. The operator's repetitive and exact movement of hands, arms and head during the machine work means that the same muscles and joints are being used all the time. This gives high risk for pain and ache in neck, shoulders, and arms. To obviate that risk, control of the boom and its tool needs to involve natural micro-breaks (without the machine work being interrupted, e.g. without stopping a tree being fed) for the operator of at least three seconds. There should be at least one such break during each boom cycle (e.g. one per tree or one per full grapple on loading or unloading). The breaks relieve the operator but also offer the operator an opportunity to plan the work, e.g. examine stems for optimum merchandising.

Measuring technique

Use time studies to measure number of control activations, time, and speed to calculate control movements for effecting typical boom, grapple, or processing head movements. Count the number of control activation to reach a given point above the ground with the boom from a completely different boom position. Let the operator perform the functions that are used in combination and observe their behaviour. Note overlapping functions and state if more than one function has to be actively supervised and controlled by the operator. Describe the work elements (boom out, gripping, positioning, felling, etc.) and assess each element's need of operator involvement. Interview the operator about the operation of the functions.

Assessment

Item	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1. Operator has full control over automated functions and can take over immediately.	-	Yes				No	
2. Automated processes are interrupted automatically when the operator leaves the cab and have to be restarted by the operator.	-	Yes				No	
3. The machine can only be moved if the operator is on the operators' stand. [1)]	-	Yes				No	
4. Can the machine or its components move spontaneously?	-	No				Yes	
5. How is components secured that can move spontaneously?	2	Protective bolting of functions, such as door switch.			Protection can easily be manipulated.	No protection	
6. How is the path correctness during boom work when handling trees/logs sized for the equipment.	4	Follow the path without any need of corrections.	Corrections needed when handling heavy trees on full reach.	Corrections needed during the path when handling heavy trees.	Corrections needed of an empty boom on full reach.	Corrections needed of an empty boom during the path.	
7. Telltale provided to show when a function not in sight of the operator is activated.	4	Always	Not regarding the merchandising (log making) tool.			Not regarding driving.	
8. The brakes are reliable. With footbrake applied, the machine cannot move when an attempt is made to pull away in the lowest gear.	4	Passes static brake test.			Falls short of requirement.		

9.	What is the number of control activations when doing boom out to a given position?	4	Up to three activations	Four activations	More than four activations involved in boom out.		
10.	Can the operator set the speed and starting and stopping times of boom/winch functions that affect working intensity/tempo?	2	Yes, readily when sitting in the seat.		Yes, but has to leave the seat.	Can not set the speed and starting and stopping times.	
11.	How is the speed accuracy of a given lever movement when operating the boom?	2	Produces a proportional response in boom-tip movement throughout its path.		Speed changes occur at start or end of the path that are not able to adjust for in the settings.	Speed changes occur during the path.	
12.	<u>Harvester:</u> What is the number of control activations when operating the harvester head?	2	Process largely automatic, e.g. decide tree species, fit in function, slip control.	Can pre-select tree species with automatic return after a change.	Machine measurement of the stem with automatic processing.	Machine measurement but manual feeding and cross-cut required.	No automation
							SUM

[1)] Except for operation with remote control.

Ergonomic profile	Class	Harvester		Forwarder and skidder	
		Min. points	Max. points	Min. points	Max. points
	A	0	7	0	7
	B	8	26	8	23
	C	27	66	24	58
	D	67	132	59	117
	E	133	264	118	234

Information from the machine

The machine operator receives, processes, and acts on both external information (the stand etc.) and information provided inside the cab. Poor visibility, poor lighting, vibration, and noise make it difficult to receive information. Ill designed and ill presented information cause fatigue and may contribute to pains in the neck and shoulders, stomach ulcers, and head ache.

Guidelines

Most kinds of information when operating the machine are repeated frequently and the operator's response is based on learning by rote. To be most efficient: Fast information should be in form of rather large and clear symbols. Symbols are preferable to text, if they are clear. Seldom changing information need to alter position, level, or shape to be recognised easily. Important and fast information has to be close to the operators' general sensing direction. If boom operation is made very easy, processing of other information is facilitated. As a rule, we handle very few pieces of information at a time when concentration is called for. However, simple decisions can be made in parallel with complicated if the different information is received by different senses.

The information in the cab should be well organised and adapted both in level, rate, and duration to each task. It should be readily discernible, comprehensible, and easy to use (cf. chapter on Manuals and instructions). To make the best use of important information, the operator should be able to determine his own working tempo. The information should be provided at a rate that enables the operator to register it without waiting or rushing for it. The operator must also understand and accept why certain information is presented and know how the machine works. A feed back system that enables personal development is desirable.

- Legibility increases if the text contains lower-case letters.
- Design images, text, and screen placement so that reading glasses are not needed.
- Use few colours for better legibility in poor lighting and since 10% of all men are colour-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 frequencies**	**Low frequencies**	**Always the same**
Bold	20 mm	13 mm	5 mm
Roman	30 mm	17 mm	7 mm

Use a loudspeaker:

- When the message is simple, short, and should be acted on immediately (e.g. warnings).
- When the operator needs to focus on other things and in poor light.
- When it is difficult for the operator to see the display.

The more important the information is, the clearer the acoustic signal should be. A central warning light (flashes at a frequency of 3-10 Hz) combined with some other device that informs the operator of what is wrong is recommended.

Assessment

Item	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1. The operator can under all circumstances hear, see, or feel warning signals for person danger and their respective meaning is clear.	–	Yes				No	
2. Fast and often changing visual information on displays for operator control is close to operator's field of view.	2	Displays within ±15° horizontal view (ahead of SRP).		Displays within ±30° horizontal view.	Displays within ±45° horizontal view.	Displays outside ±45° horizontal view.	
3. Text and symbols on displays and stickers are large enough to be read fast without effort.	2	Yes		Less important text or symbols are to small.		All text and symbols are too small.	
4. Text, symbols, and colours on visual displays are clearly legible in all day-light conditions.	2	Yes		Parts not legible in sunshine.		Whole display not legible in sunshine.	
5. Displays are well illuminated in darkness and with adjustable light intensity (brightness).	2	Yes	Only main display with adjustable light.	Light intensity of the displays not adjustable.	Illuminating missing		
6. Operator controlled alarm horn.	2	Available		Not existing			
7. <u>Cable skidder only:</u> Alarm signals are clearly perceptible from outside the machine.	4	All warnings displayed on the remote control unit.	Central alarm on the remote control unit.		Central acoustic alarm.	Alarm cannot be registered from outside the machine.	
						SUM	

Ergonomic profile	Class	Harvester, forwarder, and grapple skidder		Cable skidder	
		Min. points	Max. points	Min. points	Max. points
	A	0	3	0	5
	B	4	11	6	17
	C	12	27	18	42
	D	28	55	43	85
	E	56	110	86	170

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.

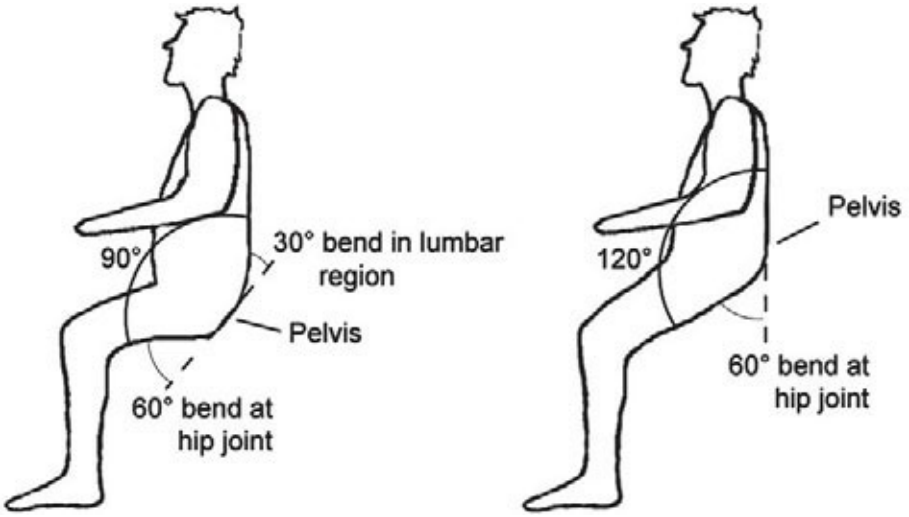
A relaxed sitting posture

The joints of the operator's body when seated in the cab should generally be at a comfortable angle and not fully straightened. Accordingly, the shoulders should be relaxed, the upper arms parallel to the body, and the forearms at an angle of 105° or more 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, e.g. by increasing the angle between trunk and legs (see Figure 10), 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 levelled; second best is a levelling function for the cab and, failing that, levelling of the seat. If levelling can only be provided in one direction, priority should be given to lateral levelling.

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 machine is jolting. 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 (i.e. the seat, armrests, footrests, controls, pushbutton panel, instruments, and field of vision) shall be capable of swivelling 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 Elbow ≥105° Trunk-thigh 105-120° Knee joint 105-120° Ankle joint 90-100°

Figure 10. Examples of low and high sitting positions.

Guidelines

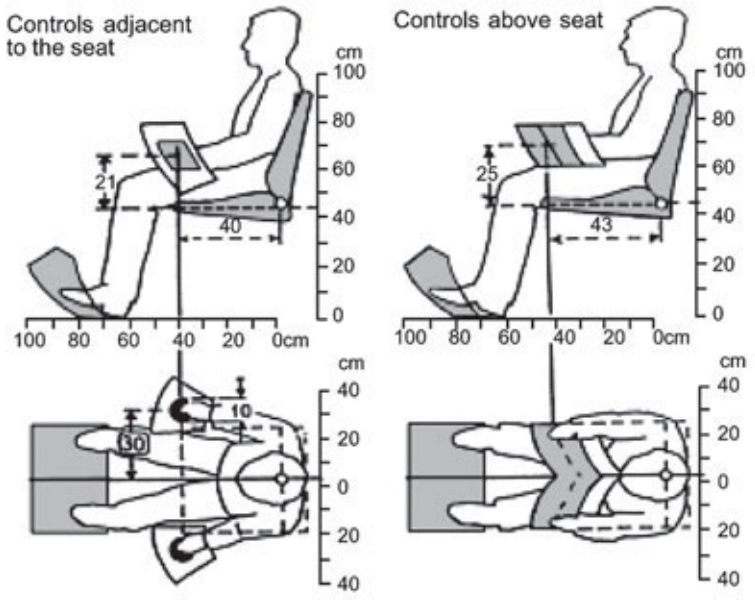


Figure 11. Optimum working envelopes for hands and feet. Normal sitting posture. Measured with seat occupied.

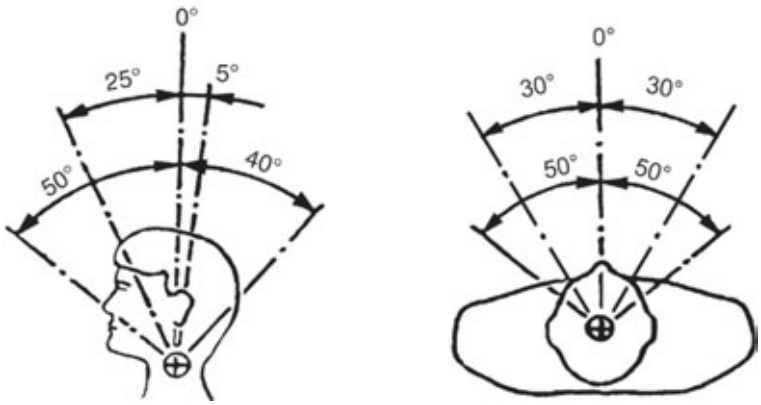


Figure 12. Optimum and maximum ranges of movement for the head and neck. Maximum range should be used only for short periods on isolated occasions during a work cycle.

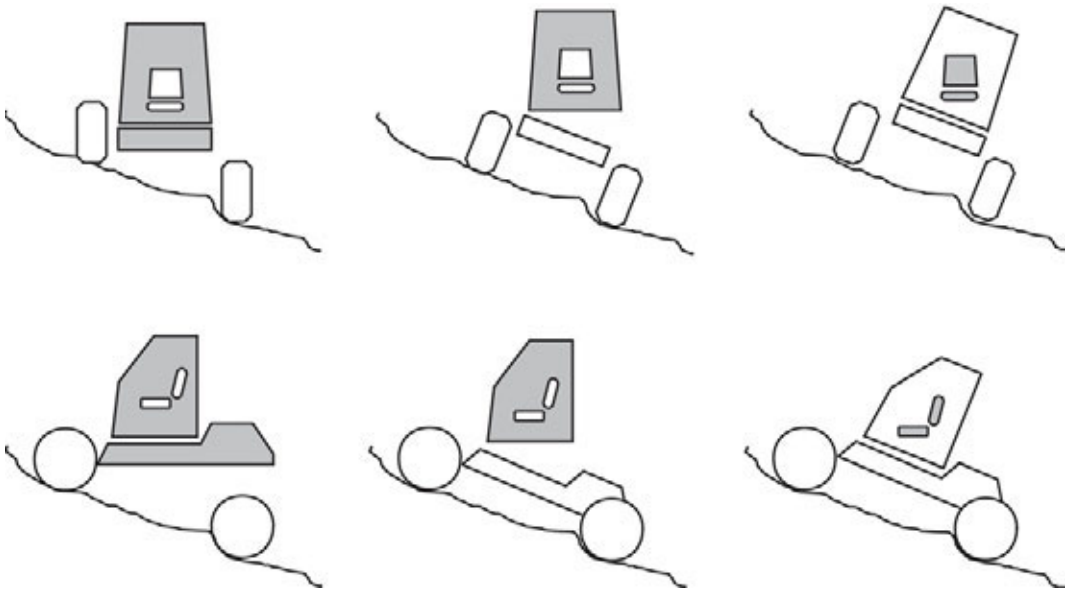


Figure 13. Some principles of levelling of the operator's workstation.

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 6). Thereafter, the assessment is made using a measuring tape and a simple protractor, and through interviews with the machine operators.

It is recommended that computer manikins are used according to ISO 15536 Ergonomics: Computer manikins and body templates, the size of which should be variable in accordance with ISO 3411, in order 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.

Assessment

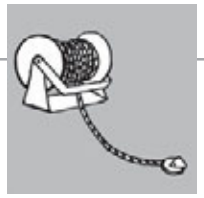
Before the class for this chapter can be determined, the aspects covered by the chapters on Cab, Visibility, Seat, and Controls must be assessed.

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1. Operators of different stature can assume a relaxed basic posture in which the controls are within optimum reach and good visibility is afforded.		4	Yes		Some difficulty for operators of above or below average stature.	Difficulty for most operators to assume a good posture.		
2. The operator can easily shift between low and high sitting postures, straighten his body and stretch his legs.		4	Yes	Limited height adjustment; operator still able to stretch legs.	Limited height adjustment; somewhat cramped.		Little scope for varying posture.	
3. Seat, armrests, controls, and orientation of instruments are all readily adjustable to suit different operators. Time for adjustment, s	_____	2	Yes ≤30 s	A few shortcomings (>30 s - 1 min) to adjust posture.	A few shortcomings (>1 - 2 min) to adjust posture.	Major shortcomings (>2 min) to adjust posture.	Difficult to adjust or tools required.	
4A. <u>Harvester:</u> Fore-and-aft tilt machine/cab/seat [1]: The operator's working station can be levelled longitudinally, °	_____	1	Yes, automatic levelling possible > ±20°	Yes, automatic levelling possible ±15 - 20°	Yes, seat can be levelled automatically ±10 - 15°	Manually or limited levelling < ±10	Fixed	
4B. <u>Forwarder and skidder:</u> Fore-and-aft tilt machine/cab/seat [1]: The operator's working station can be levelled longitudinally.		1	Yes		No			

5.	Lateral tilt [1]: The operator's working station can be levelled laterally, °	_____	2	Yes, automatic levelling possible ±10 - 15°	Yes, automatic levelling possible < ±10°	Yes, seat can be levelled automatically ±10 - 15°	Manually or limited levelling < ±10	Fixed	
6.	<u>Harvester:</u> The operator's station can be swivelled independently of the boom in any direction within the working envelope.		2	Yes	Operator's station follows boom movement automatically and imperatively.	Seat swivels and can be locked in any position.	Rigid workstation and non-swivelling seat.		
								SUM	

[1] Operator work station include operator seat, foot pedals, foot rest, primary controls, display, and frequently used secondary controls.

	Class	Harvester		Forwarder and skidder	
		Min. points	Max. points	Min. points	Max. points
Ergonomic profile	A	0	5	0	4
	B	6	17	5	15
	C	18	44	16	37
	D	45	88	38	75
	E	89	177	76	151



Winch

Winches are used in the forestry to pull logs to the skid trail and to the machine. The logs are winched to the skid trails and then skidded out by a skidder or transported with a forwarder to the landing. Winches are also used if the machine gets stuck.

Higher line pulls will have a negative effect on the stability of the machine but reduces the tendency of logs to dig into the ground. This causes psychological stress, as the handling of the machine becomes more difficult, and danger.

Winches with a maximum line pull in excess of 100 kN are only required for extreme tasks.

The highest accident risk when working with a winch occurs when the cable breaks under tension. A snapped cable may kill or severely injure a person. In addition to this, there is a danger of chain links and other parts of the attachments suddenly breaking and being catapulted through the air with extreme force.

The ratio between the barrel diameter and the rope diameter shall not be less than 10 and the diameter of all blocks and pulleys should exceed the rope diameter by a factor of at least 10 to increase the durability of the winch rope (see ISO 19472).

Remote controls are usually used in forestry for operating winches. The skidder operator uses the remote control from a position near the wood to be extracted. The remote control is assessed in the chapter on Controls.

The remote control must be designed to work safely and reliably under the forest canopy.

Guidelines

The diameter of the rope depends on the maximum line pull of the winch. A higher maximum line pull of the winch requires a thicker and therefore heavier rope. Unravelling a heavy rope is an arduous task for the operator. A spool out device can only provide a moderate amount of relief in this task.

Another ergonomically relevant dimension is the winching speed. Too slow and the skidder cannot work effectively; too fast and the operator cannot follow the skidding wood.

Measuring technique

Measuring tape and a dynamometer.

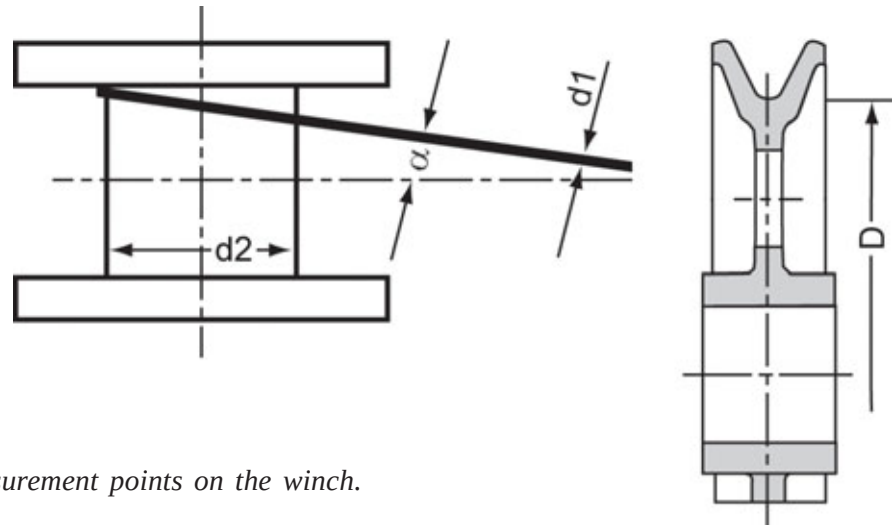


Figure 14. Measurement points on the winch.

	Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1.	Ratio, machine weight/winch line pull [1], kg/kN	_____	4	>2.0 kg/kN	>1.5 - 2.0 kg/kN	≥1.0 - 1.5 kg/kN		<1.0 kg/kN	
2.	Rope breaking safety factor. [2]	_____	4	≥2.5		>2.0 - 2.5	1.4 - 2.0	< 1.4	
3.	Unit rope weight, kg/m	_____	2	<0.50 kg/m	0.51 - 0.75 kg/m	0.76 - 1.25 kg/m	>1.25 kg/m	>2.0 kg/m	
4.	Rope uncoiling force at the drum (full drum), N	_____	2	With spool-out device		40 - 70 N or automatic rope pay out brake.	71 - 100 N	>100 N	
5.	Rope facing device at bare drum (Breakaway force: rated line pull), kN	_____	1	≤0.3 kN				>0.3 kN	
6.	Fleet angle (α), °	_____	2	≤2° or Guided spool device	≤4° or Simple spool device		≤4°	>4°	
7.	Ratio drum/cable (d_2/d_1) and sheave inner diameter/cable (D/d_1).	_____	2	≥10	≥8 - <10		>6 - <8	≤6	
8.	Line speed (m/min) when rated line pull up to 40 kN, up to 60 kN, and over 80 kN	_____ _____ _____	2	2 speeds, level 1: ≥1.0 - ≤1.2 m/min ≥0.9 - ≤1.0 m/min ≥0.8 - ≤1.0 m/min level 2: approx. 30 % higher		1 level ≥1.0 - ≤1.2 m/min ≥0.9 - ≤1.0 m/min ≥0.8 - ≤1.0 m/min	1 level ≥0.9 - ≤1.0 m/min ≥0.85 - ≤0.9 m/min ≥0.7 - ≤0.8 m/min	1 level >1.5 m/min	
9.	Brake system (brake power/line pull).	_____	-	≥1.25				<1.25	
								SUM	

[1] Measured at the first layer on the drum. [2] Safety factor = Minimum rope breaking force / rated line pull.

	Class	Min. points	Max. points
Ergonomic profile	**A**	0	8
	B	9	28
	C	29	71
	D	72	142
	E	143	285

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 minimised 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. Long-term exposure to a noise level of 85 dB(A) during an eight hour working involve a significant risk of getting permanent hearing damage.

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 1 000-3 000 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 (i.e. as noise) is a subjective matter. An experience is that some operators use ear plugs at a noise level about 75 dB(A). The degree of disturbance is influenced by such 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
dB(C)	Sound filtered but not 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.

Measuring technique

To measure inside noise, i.e. at operator's seat, it is recommended to use ISO 6394. NB that the air inlets should be open not directly blowing at the microphone. The noise level should be measured from the position where the operator is working either inside or outside of the cab. Measurements should be made with the machine operating in normal conditions on snow free ground.

Assessment

Test equipment: _____

Fan speed/level: _____

Engine rpm: _____

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1. Equivalent continuous noise level LpAeq at operator ear level.	_____	4	LpAeq ≤65 dB(A)	LpAeq ≤70 dB(A)	LpAeq ≤75 dB(A)	LpAeq ≤85 dB(A)	LpAeq >85 dB(A)	
2. Alarm signal noise exceeds equivalent continuous noise level.	_____	2	Signal >10 dB(A) over LpAeq ≤80 dB(A)	Signal >10 dB(A) over LpAeq ≤90 dB(A)	Signal >10 dB(A) over LpAeq >90 dB(A)	Signal <10 dB(A) over LpAeq	Signal <3 dB(A) over LpAeq	
3. Ventilator equivalent continuous noise level LpAeq (highest level).	_____	2	LpAeq ≤60 dB(A)	LpAeq ≤65 dB(A)	LpAeq ≤70 dB(A)	LpAeq ≤75 dB(A)	LpAeq >75 dB(A)	
4. Skidder with open cab: Equivalent continuous noise level LpAeq at standing operator ear level.	_____	4	LpAeq ≤65 dB(A)	LpAeq ≤70 dB(A)	LpAeq ≤75 dB(A)	LpAeq ≤85 dB(A)	LpAeq >85 dB(A)	
							SUM	

Ergonomic profile	Class	Harvester, forwarder, and skidder with closed cab		Skidder with open cab	
		Min. points	Max. points	Min. points	Max. points
	A	0	3	0	5
	B	4	12	6	18
	C	13	30	19	45
	D	31	60	46	90
	E	61	120	91	180

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 eye on the work piece being handled. Many years of exposure to vibration and shocks on a machine can have a detrimental effect on the health. The lower back is particularly prone to injury caused by shocks. Vibration and shocks also contribute to the development of pain in the neck and shoulders.

The level of vibration and jolting is affected by ground conditions, driving speed, tires and tracks, transmission, springs/damping in the chassis, cab and seat (see chapter on Seat), and the operator's working technique. When the machine is stationary, vibration is propagated by movements in the working units, e.g. from the force generated by a falling tree.

Use of a resilient suspension chain can minimise the transfer of vibration from the contact between the wheels and the ground to the operator. Examples of solutions are wide tires, central tire inflation, especially designed oscillating axle assemblies, damping of swing arms and the use of bogies at front and rear, as well as damping of the cab and the seat. The transmissions ability to smoothly ride a ditch or a rock and the machines ground hugging ability are other aspects influencing vibrations and jolting. The central and low placing of the cab usually facilitate a low vibration exposure of the operator. However, some high mounted suspended cabs have been found to have a low level of vibration. Vibration propagated by movements in the working unit can be reduced by damping of the boom and the cab swivelling.

Impact of vibration on people

Usually, whole-body vibration and shocks in a cab are transmitted to the operator through the seat. 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 constitute the principal health problem, although other parts of the body, such as the gastrointestinal 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. During vibrations the operator tenses the neck and shoulder muscles to counter the movement induced by the vibration, causing strain on these muscles and joints.

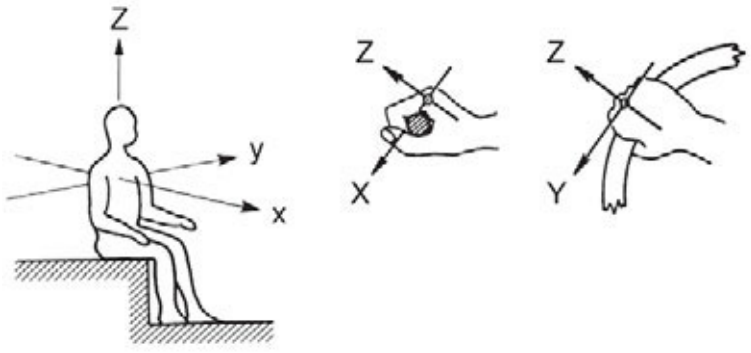


Figure 15. Standardised measurement axes for vibration as per ISO 2631 and ISO 5349.

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 in most forest machines. The main effect of hand-arm 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, shoulders, and 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 Figure 16. The upper curve is taken from ISO 2631 and 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.

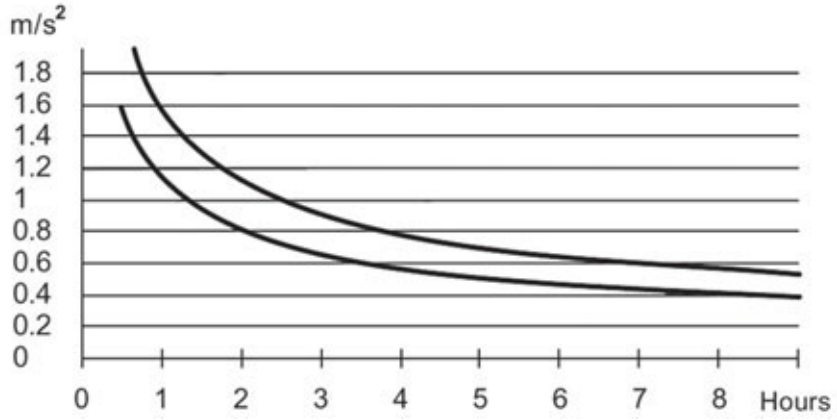


Figure 16. Whole-body vibration. The lower curve shows the level at which whole-body vibration constitutes only a low risk to health. The upper curve shows the level at which there is a clear risk of injury to the lower back.

The standard ISO 2631-5 Methods for assessment of vibration with shocks gives guidance of health assessment of multiple shocks. A daily equivalent static compression dose (S_{ed}) should be calculated and indicates the probability of an adverse health effect. A value below 0.5 MPa indicates a low probability and above 0.8 MPa a high probability of an adverse health effect on the lower spine.

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 Figure 17. The upper curve is taken from ISO 5349 and indicates the level at which 10% of a group run a risk of incurring vibration induced circulatory injury (”white finger” syndrome) during normal operation of the machine.

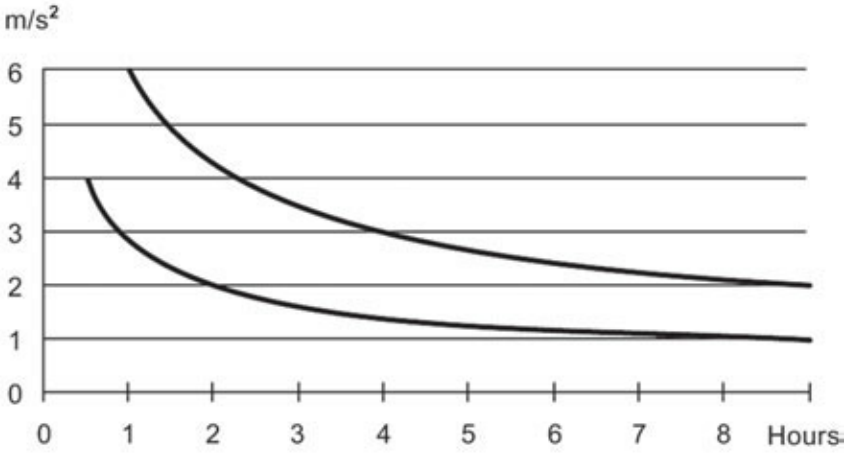


Figure 17. Hand-arm vibration. The lower curve shows the level at which hand-arm vibration constitutes only a low risk to health. The upper curve shows the level at which 10% of a group run a risk of developing circulatory disorder (”white finger” syndrome).

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.

Measuring technique

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. A separate assessment has to be done for shocks.

Measuring and assessment of whole-body vibration are based on ISO 2631. 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. 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). Se also EN 14253 Mechanical vibrations: Measurements and calculations of occupational exposure to whole-body vibration with reference to health: Practical guide.

ISO 2631-5 Methods for assessment of vibration with shocks describes a method for assessing mechanical shocks. A subjective assessment should also be made of the machine's ability to absorb shocks and jolting (see factors affecting vibrations and jolting earlier in this chapter).

Measurement and assessment of hand-arm vibration is based on ISO 5349. The standard describes the effects in the 6.3-1 250 Hz frequency range and takes into account the risk of vibration induced circulatory disorder ("white finger" syndrome). 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.

Test conditions and assumptions

Measurements should be made with the machine operating in normal conditions on snow free ground over a period of time of at least 30 minutes to ensure that the readings taken are representative of the work. Whole-body vibration should be measured when the machine is operating in normal conditions 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 time of 30 minutes. The seat must be securely and rigidly anchored to the cab floor. See also EN 1032 Mechanical vibrations: Testing of mobile machinery in order to determine the vibration emission values.

Forwarders and skidders should be tested in terrain having class 2 ground roughness and class 1 slope (Berg, 1992). 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.

Assessment

Test equipment: _____

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 / Total volume _____

Logging/processing: Number of trees _____

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: _____

Test reading

Type of vibration	Direction of vibration (m/s^2)				A(8)
	X-axis	Y-axis	Z-axis	$a_{w(max)}$	
Whole-body					
Hand-arm					

Item	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Level 5 Unacceptable	Penalty points
1. Whole-body vibration, m/s^2	4	A ≤0.4 m/s^2	A ≤0.6 m/s^2	A ≤0.8 m/s^2	A ≤1.1 m/s^2	A >1.1 m/s^2		
2. Jolts and shock (S_{ed}) [1], MPa	4							
3. Hand-arm vibration, m/s^2	4	A <1.0 m/s^2	A <1.5 m/s^2	A <2.0 m/s^2	A <2.5 m/s^2	A ≥2.5 m/s^2	A ≥5.0 m/s^2	
							SUM	

[1] A value below 0.5 MPa indicates a low probability and above 0.8 MPa a high probability of an adverese health effect on the lower spine. In year 2005, however, there was not much experiences made of this standard in forestry. That is the reason why there are no guideline values given.

	Class	Min. points	Max. points
Ergonomic profile	**A**	0	3
	B	4	12
	C	13	30
	D	31	60
	E	61	120

Climate control

The climate in the confined space of an operator's cab is often complex and unstable. Solar radiation in addition to draught is some of the problems that can occur in a poorly designed operator enclosure environment. The operator's sensation of draught in the cab is sometimes also caused by heat from the body being transferred to adjacent cold surfaces, like the windows and the walls, or by too high airspeed from vents inside the cab. It is thus difficult to achieve a balance between a comfortable level of heat loss for the whole body and at the same time comfort for individual parts of the body. A climate control system consequently has to meet a multitude of demands if it is to create a comfortable climate for the operator.

Guidelines

It is generally easier to achieve a good climate in a larger cab compared to a small one. If the operator is seated further away from the window glass, draughts and the radiated heat from the sun will have less influence. The interior design of the cab, the level of clothing and seat insulation, the area and type of window glass and the design of the climate control system itself all has great influence on the thermal climate. The presence of the operator's body also has an important influence on the climate in the cab. It also has to be considered that the operator's perception of the climate is different at head level compared to the foot level. Consequently, no single point or variable in the cab can successfully be used as a reference for monitoring or controlling the climate. 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. The cab should also be equipped with adequate means for preventing excessive sun load on the operator.

Comprehensive test procedures

Discrete measurements of relevant factors, like air speeds and radiation temperatures, are complicated to relate to human climate perception so some kind of integrative method is needed in order to predict the thermal effects on humans. The best approach is to use a human shaped dummy (manikin). These full size heat flow sensors measures local heat fluxes from defined areas of the surface. The heat losses measured are converted into equivalent temperatures providing a unified, physical measure of the climatic effects on human body heat exchange. The thermal manikin method has been used in different ways for many years. These methods are also subject of International Standardisation work ISO/DIS 14505, Ergonomics of the thermal environment; Thermal environment in vehicles. Assessment of the climate in a modern cab should be done in a climate chamber and with the use of a standardised thermal manikin for measuring the equivalent temperature at several locations over the manikin body. Equivalent temperatures reflect how a person experiences the exchange with the surroundings by air temperature, airspeed, and radiation as a single integrated measure. The situation when thermal comfort conditions cannot be maintained, like in very hot or cold climatic conditions, is regarded to be outside of the scope of these climate control guidelines. The comfort climate control tests are carried out at outdoor or chamber temperature of -20°C (winter) and +27°C (summer). At +27°C, the test is performed with solar radiation at 950 ± 95 W/m^2 at the specified solar altitude. The evaluation is based on the measured equivalent temperature values in terms of anticipated subjective perception of the conditions for the operator. The comfort zone diagrams shown in Figure 18 below refer to summer or winter conditions in agreement with figures D1 and D2 in ISO/DIS 14505 Part 2. The heating and cooling performance and the capacity of the climate-control system can also be determined in accordance with ISO 14269.

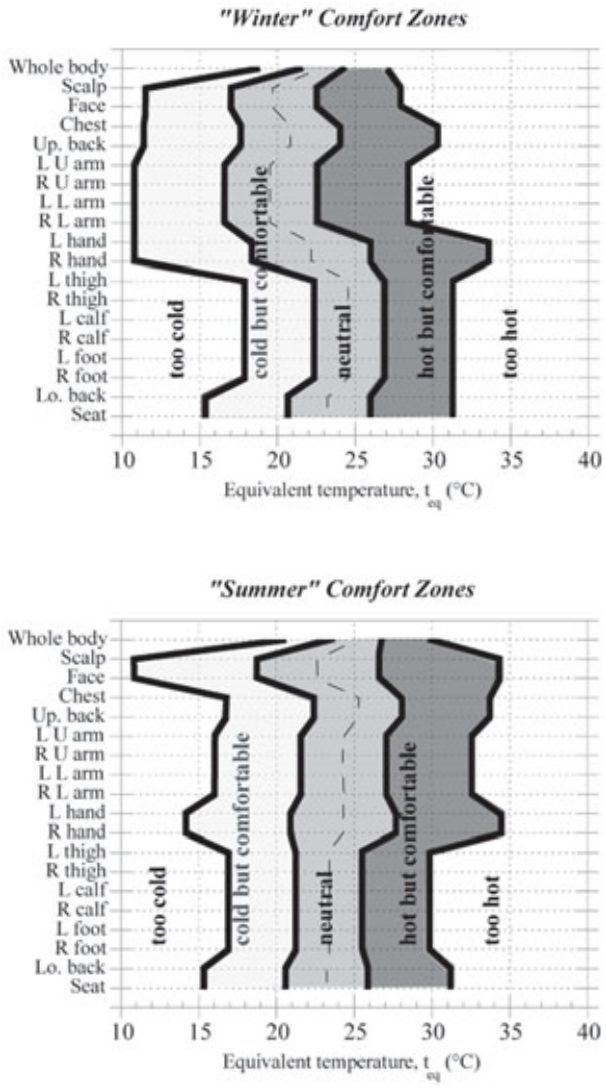


Figure 18. Comfort zone diagrams derived for the summer (Icl = 1.3 clo) and winter (Icl = 1.6 clo) conditions for 16 segments of the body. Abbreviations refer to L = left, R = right, U = upper (ISO/DIS 14505).

Simplified test procedures

For basic testing of the climate in a cab, it is recommended that the equivalent temperature should be measured and calculated at; the feet level in a point 5 cm above the floor (foot in the comfort zone diagram); at the point at which the hands rest on the controls (hand); in front of the chest (chest); and at head level (face). Ordinary air temperature and air speed instruments can be used as well as simple dry heat loss transducers showing the equivalent temperature (t_{eq}) as a single value.

$$t_{eq} = 0.55 \cdot t_a + 0.45 \cdot \bar{t}_r + \frac{0.24 - 0.75 \cdot \sqrt{v_a}}{1 + I_{cl}} (36.5 - t_a)$$

The equation above contains all the important elements affecting the t_{eq} value (SAE J2234). Apart from the air temperature t_a, mean radiant temperature t_r, and air velocity v_a it also shows the influence of clothing (I_{cl}). The equivalent temperature values of these measurements and calculations are used in assessing the heating and cooling performance and the capacity of the climate control system through the comfort zone diagrams above. The tests should be carried out in both hot (ca +27°C) and cold weather (ca -20°C) and should also include a subjective assessment of the performance of the system based on the size of the cab, how well insulated it is, the sun protection equipment, and the position and design of the air inlets (vents). At 27°C, the test is performed with sun at a specified angle.

Assessment

	Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1	Equivalent temperatures from manikin or measurements [1] at an outside temperature of -20°C (cf. Figure 18)		4	All readings comply with the neutral WINTER comfort zone.	More than 90% of the readings comply with the neutral WINTER comfort zone.	More than 80% of the readings comply with the neutral WINTER comfort zone.	More than 90% of the readings comply with the neutral or cold or hot but comfortable WINTER comfort zones.	Less than 80% of the readings comply with the neutral or cold or hot but comfortable WINTER comfort zones.	
2.	Equivalent temperatures from manikin or measurements [1] at an outside temperature of +27°C with sun [2] (cf.Figure 18)		4	All readings comply with the neutral SUMMER comfort zone.	More than 90% of the readings comply with the neutral SUMMER comfort zone.	More than 80% of the readings comply with the neutral SUMMER comfort zone.	More than 90% of the readings comply with the neutral or cold or hot but comfortable SUMMER comfort zones.	Less than 80% of the readings comply with the neutral or cold or hot but comfortable SUMMER comfort zones.	
3.	For a winter cab at an outside temp of -20°C and for a summer cab +27°C with sun, should the inside surface temperature difference be:	_____	2	<4K	<6K	<8K	≤10K	>10K	
4.	Cab temp can be raised from -20°C to 20°C or reduced from +27°C to 20°C within:	_____	2	<10 minutes	<15 minutes	<20 minutes	≤25 minutes	>25 minutes	
5.	Effective means of protection provided against radiation exposure from the sun [2].	_____	2	No sunlight is falling on the operator.	Sunlight is falling on up to 20% of the operator's body surface.	Sunlight is falling on up to 40% of the operator's body surface.		Sunlight is falling on more than 40% of the operator's body surface.	

6.	Functionality of heater and air-conditioning.		2	Automatic climate-control system with adjustable operation.	Manual climate-control system with adjustable operation.	Simple manual control of heating and fan.	Difficult control the heating or fan.	No heating or fan.	
								SUM	

[1)] Measured and/or calculated at; the feet level in a point 5 cm above the floor (foot); at the point at which the hands rest on the controls (hand); in front of the chest (chest); and at head level (face).
[2)] Measured at an incoming solar altitude angle of 45 ± 5°.

	Class	Min. points	Max. points
Ergonomic profile	**A**	0	7
	B	8	24
	C	25	60
	D	61	120
	E	121	240

Gases and particulates

There is not normally much risk of a forest machine operator being exposed to gases, particulates, or oil mist. However, 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 fertilisers 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 sulphur oxides, most of which come from lubricating oil, if the fuel has low sulphur 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 rating 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, i.e. 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.

Guidelines

The operator should not be exposed to exhaust gases, pollen, dust, or oil mist. Exhaust fumes must be directed away from air inlet. The cab must have a pressurised ventilation system with a suitable filter. The filter quality is important and it is preferable that there is a combination of a roughing filter and a fine filter. It must be easy to replace the filters and there should be an indicator indicating when it is time to replace them.

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. To detect if any exhaust fumes are present in the cab, it is possible to use a small toximeter which shows the detected value on a display and has an acoustic alarm when the hygienic limit value is reached. The smell of diesel exhaust fumes is detected long before the level reaches the hygienic limit value. 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 time it takes before dust settles on a clean surface.

Assessment

Item	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1. Air intakes filter system for removal of dust, pollen and soot. (Filter quality in accordance with EN 779.)	4	At least F7.		At least F5.		No filter	
2. Is the filter easy to replace?	4	Yes, easily accessible and done without the use of tools.	Yes, difficult to replace and done without the use of tools.	Yes, easily accessible but tools required.		Difficult to replace and tools required.	
3. Indication when it is time to replace the filter.	4	Yes, both visual and acoustic indication.	Yes, visual indication.	Visual indication at manually actuation.	Indication missing		
4. Is there a possibility of recirculation with an automatic switch off?	2	Yes, with indicator.	Yes, indicator but manual switch off.		No indicator and manually switch off.	No recirculation system.	
5. Exhaust gases not directed towards the cab air inlet.	4	Yes, Exhausts are directed away from the air inlet.			Exhaust gases may be partially sucked into the cab in unfavourable conditions.	Exhaust gases directed towards the cab air inlet.	
6. Emissions are kept as low as possible. (Requirements according to directive 97/68/EC.)	4	Yes, Complies with stage IIIB.	Complies with stage II.			Only complies with stage I.	
						SUM	

Ergonomic profile	Class	Min. points	Max. points
	A	0	8
	B	9	29
	C	30	74
	D	75	149
	E	150	298

Lighting

When operating after dark, many operators unwittingly let the standard of their work fall. One reason is that the lighting on the machine does not provide adequate illumination of difficult situations. 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 boom tip is usually brightly lit, making the surrounding area pitch black. The operator can be 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 colour of the light to achieve optimum illumination is still limited. However, evidence has shown that a white light gives a better illumination than the more yellow one at the same illuminance (lux).

Impact of lighting on people

Too low illuminance gives the operator a severity to see details and will also reduce colour 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 colours.

Uneven lighting can cause headaches and eye fatigue. The reason is that the eye moves 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.

Definitions:

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 blue-green (white) light also should be stated. At the same low lux level, the white light is perceived giving better visibility then the yellow light.
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, i.e. 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.
Colour temperature, Kelvin (K)	Measure of the colour of a light source. A lower temperature means a redder light; a higher temperature a whiter light.

1) $\text{Luminance} = \frac{\text{Illuminance} \cdot \text{reflection factor}}{3.14}$

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 colour 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 Figure 19 and also the requirements specified in the chapter 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 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 or unit, since the operator has to be able to discern any rot in the stem, the kind of branches, 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 type of log, any rot, the lie of the logs, and any possible obstacles. All this he has to take stock of in just a few seconds and regardless of the weather.

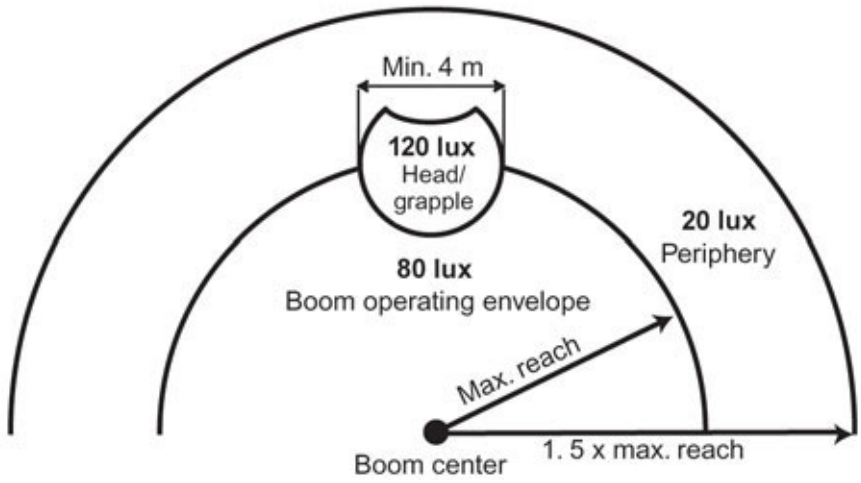


Figure 19. Guidelines for lighting on a forest harvester. The illumination values shown apply to a light source that has a colour temperature over 3 500 K and a high S/P value.

Measuring technique

Testing is usually effected by marking out a grid of two meter squares on the ground.

The origin of the grid is the centre of the boom. The working direction and the SRP should be recorded. 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 centre line of the machine. Grapple (open) or harvester head should be resting on the ground underneath the boom tip.

The illuminance in lux is measured at each intersection on the grid at a point 20 cm above ground level. The sensor is kept strictly horizontally (to avoid reflections from the ground).

Illumination diagram is shown only for half the work area, i.e. within a sector at an angle of 135º to the centre

line of the machine in its travel direction, and the driving lights up to 20 m ahead of the machine. Working lights should be switched on when measuring the driving light. Make sure that the headlights are properly adjusted (where possible), clean, and in good condition. Illuminance around the operating head should be calculated from at least four observations (no shaded spots).

Assessment

Lighting

Working and driving lights: _____

No. of working lamps:_____ Type:_____

No. of driving lamps: _____ Type: _____

Method for measuring illuminance: _____

Test conditions: _____

By lamp manufacturer specified colour temperature	Working lights No _____ Type_____	Lights on the boom No _____ Type _____	Headlights for driving No _____ Type _____	Other lamps: No_____ Type _____
Correlated colour temperature (°K)				

Observations

Illuminance [Lux]	Around grapple or harvester head; radius 2 m	Operating envelope of the boom	Periphery to 1.5 times the boom reach	Ahead of the machine 10 - 20 m
Average				
Max. and min.				
Quotient Max./min.				

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1A. Harvester: Illuminance in the respective (operating) zones, lux	_____	4	>120:80:20 lux Colour temperature >3 500 °K	>100:60:15 lux Colour temperature >3 500 °K	>80:40:10 lux	>60:30:5 lux	>10 lux in operating envelope	
1B. Forwarder and skidder: Illuminance in the respective zones (working envelope and periphery only), lux	_____	4	>80:25 lux Colour temperature >3 500 °K	>60:20 lux Colour temperature >3 500 °K	>40:10 lux	>30:5 lux	>10 lux in operating envelope	
2. Illuminance at driving, lux	_____	1	>10 lux at 20 m in the direction of machine's travel. Colour temperature >3 500 °K	>8 lux	>5 lux	≥2 lux	<2 lux	
3. The light is well distributed. The operator is not dazzled by sharp contrasts and can see the surroundings.		2	Yes	Uneven illumination of nonessential items.	Uneven illumination of operating area.	Very uneven illumination of operating.	Dazzle renders work unsafe.	
4. No distracting reflections from windows or machine parts.		2	No distracting reflections from windows or machine parts.	Minor shortcomings	Moderate shortcomings	Major shortcomings	Dazzle renders work unsafe.	
5. Adequate illuminance for all operations and moving between set-ups. Operator also has upward vision and can see beyond the boom operating envelope.		1	Yes	Not fully adequate in parts of the operating zone.	Inadequate in parts of the operating zone.	Highly inadequate	Inadequate illuminance renders work unsafe.	
6. Colour and quality of the light give good general visibility, do not cause eye strain and reproduce important colours faithfully.		1	Yes	Not entirely	Moderate shortcomings	Major shortcomings		

7A.	Final felling: Lighting can be dimmed when necessary.		1	Yes	Some lights can be switched off individually or as a group.	Not at all	
7B.	Thinning: Lighting can be dimmed when necessary.		2	Yes	All lights can be switched off individually.	Some lights can be switched off individually or as a group.	Not at all
8.	Lamps can be aimed precisely and readily returned to previous setting		2	Yes	Not fully	Somewhat limited	Highly limited
9.	Lighting in the cab is good, can be controlled, and does not cause glare or reflections.		1	Yes	Not entirely	Moderate shortcomings	Major shortcomings
							SUM

Ergonomic profile	Class	Final felling		Thinning	
		Min. points	Max. points	Min. points	Max. points
	A	0	5	0	5
	B	6	18	6	19
	C	19	45	20	48
	D	46	90	49	96
	E	91	181	97	192

Manuals and instructions

This chapter deals with the oral and written instructions, 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 reorganised. 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. The guidelines are publicised by the Swedish Work Environment Authority (www.av.se) as Report 1994:3E Content and design of instruction manuals for mobile machinery (Synwoldt, 1994). The guidelines are based on ISO 3600, ISO 6750, and the EU machine directive 98/37/EC.

Contents of the instruction manual

General

It is an advantage for the instruction manual to begin with the following:

- The trademark or name of the machine
- The full address (phone and fax numbers included) of the manufacturer and/or importer
- Whether or not the machine meets the requirements of the EC Directives (CE marking)
- A detailed list of contents
- Initial indication of the type of product, manufacturing year, and serial number (machine number)
- The content and positioning of safety stickers and machine data places
- A short description of the machine
- Information for the user concerning operator training and if the training is compulsory where it is available
- The importance of complying with the safety instructions
- Vibrations, including measuring method, working conditions during measurement, and limit values
- Noise, including measuring method, working conditions during measurement, and limit values

Technical data

This section should preferably contain brief particulars of:

- Principal dimensions, including track gauge and wheel base, together with a sketch
- Net weight of the basic version of the machine, including full fuel tanks, oil tanks, etc.
- Total net weight of the machine with the equipment indicated
- Gross weight of the machine
- Fuel, engine, and hydraulic oil volumes, together with type and grade
- Wheels
    - suspension
    - number of axles and wheels
    - size and types of tyres
    - air pressure

- Caterpillar wheel
  - gauge between tooth wheel shaft and impeller shaft
  - total width across belt
  - number and size of track shoes
  - particulars concerning tooth wheel, rollers, and impeller
- Combustion engine
  - manufacturer's name
  - engine type
  - version
  - serial number
  - number of cylinders, cylinder diameter, stroke, and volume
  - power rating
  - type of fuel filter and lubricant oil filter
  - type of air filter
  - type of injection pump
  - type of generator
  - type of starter device
  - type of cooling system
- Electric motor
  - manufacturer's name
  - type of motor and enclosure class
  - serial number
  - voltage
  - power consumption at full load
  - frequency
  - phase connection
  - output
  - rpm
  - type of rotor
  - start connection
- Transmission
  - type of couplings, drive chains, sprockets, gear wheels, belts, and driving pulleyertype and manufacture of torque converter
  - type of hydraulic pump (rpm, pump capacity, fixed or variable displacement, working pressure and regulation, distribution, and connection pipes)
  - type of cylinder (type, double or single acting, number of telescopic steps, stroke, load, and working pressure)
  - type of hydraulic motor (speed range, output, torque, and working pressure)
- Control system
  - internal and external turning radius
  - sweeping radius
- Hydraulic system, cooling included
  - capacity
  - type and serial number of heat exchanger
- Braking system
  - service brake, including retardation with maximum load
  - parking brake
  - emergency brake
- Compressed air system

  - make, type, capacity, working pressure, and rpm of compressor
  - air valves
  - controls
- Electrical system
  - type of battery and capacity
  - electrical controls and components
- Vibration level, including measuring method, working conditions during measurement, and limit values
- Noise level, including measuring method, working conditions during measurement, and limit values
- Production capacity, e.g.
  - speed
  - performance per hour
  - load capacity
- Working implements usually mounted on the machine, e.g.
  - crane (way of attachment and rotation of the frame, operating system, counterpoise with positioning, attachment to the machine and transit running device, type of arm or boom (principal measurements included), working area of boom extension, buckets etc., lowering device and accessories which can be mounted on an arm or boom, together with measurements, volume, and weight)
  - winch (make, type, serial number, model, maximum speed, and specification of the steel wire)
  - slasher
  - chipper
  - rock blade
- Other equipment

Starting and stopping instructions

Suggested description of starting instructions:

- Before you start, e.g.
  - checking fluid levels
  - inspecting hoses and wires, loose, worn, or missing guards or parts
  - condition and cleaning of belts and shafts
  - checking tyre pressures
  - making sure there is no other person in the danger area
- Adjustment and use of chair, controls, etc., having regard to the risk of local musculoskeletal overstrain, repetitive stress syndrome, and other ergonomic effects
- Starting the engine during normal conditions
  - positions of controls
  - sequence of starting operations (warning signal)
- Starting the engine at different temperatures and in adverse climatic conditions
- Checking instrument readings (oil pressure)
- Warming up the engine
- Starting implements usually mounted on the machine, e.g. crane, winch, felling unit, slasher, chipper, brushing attachment, shovel, rock blade, loader

Suggested description of stopping instructions:

- Sequence of operations for stopping the machine
- Procedure for parking the machine, implements included
- Idling
- Procedure for stopping the engine
- Locking

Running and working instructions

It is proposed that the content of this section describes:

- Positioning of controls and instruments
- Warning devices for the driver's safety
- Function of warning devices
- Functional checks (steering, brakes)
- Moving the machine (changing gear, steering, etc.)
- Road driving equipment
- Driving on public highways
- Off-road driving, including particulars of the machine's stability during various driving or working situations
- Working speeds
- Use of implements, including appropriate safety precautions
- Connection and disconnection of implements, including setting and necessary tool equipment
- Operating techniques, e.g. simple method instructions for harvesters (final felling methods, thinning methods, work methodology)
- Reading list for further instructions on methods

Maintenance and fault diagnosis routines

The following particulars, where applicable, can be included in the description of maintenance work:

- Daily supervision (see also instructions for starting and stopping)
- Regular maintenance checklist, preferably in tabular form, including lubrication chart and suggested procedures for improving the safety and environmental performance of the machine, e.g.
    - oil change and replacement of sparking plugs and cam belt
    - filter change (e.g. air, fuel, engine oil, hydraulic oil filters, and air conditioning filter)
    - checking screw joints, guards, and cracking
    - annual overhaul of fire fighting equipment
    - braking test with accordance to special checklist
    - work with fuel, oils, and greases
    - CFC in the air conditioning system
- Indication of repairs to be done by an authorised workshop
- Particulars of tooling equipment and its storage
- Volumetric data
- Fuel and oil recommendations
- Screw joint torques
- Maintenance of ergonomically important components, e.g.
    - driving seat
    - access routes
    - tyre pressures
    - lighting
- Welding
- Post repair examination of electrical insulation
- Functional description of cab tilting device
- Cleaning and replacement of safety glass
- Worn-out limits for parts which are to be considered as wear parts which can be measured without disassembling the machine (e.g. cutting inserts, teeth, saw chain, guide bar, and sprocket)
- Changing wheels
- Disassembly and assembly instructions for routine preventive maintenance
- Necessary procedure for placing the machine in storage at the end of the season and for starting it up before the new season begins

It is appropriate for the section on fault diagnosis routines to include a description of procedures to be followed, e.g. in the following contingencies:

- Engine will not start
- Starter engine will not rotate
- Engine pulling badly
- Engine overheating
- Engine running, but machine will not move
- Working pressure excessive
- Working pressure insufficient

Safety instructions

Safety instructions are important, e.g. for the following areas:

- General
  - who is allowed to operate the machine
  - starting the machine
  - leaving the machine
  - braking functions
  - emergency stop
  - emergency alarm and/or communication possibilities
  - fire fighting equipment
  - application of stickers – content and positioning
  - danger areas
  - safety grids and safety glasses, including attachment/installation and care
  - risk of overturning, rearing, and crushing
  - no parts to be left lying on the floor, cleanliness (in the cab, on outer footboards and toe holds, places involving fire risks)
  - sensitivity of control and regulating equipment to interference from the communication radio system and suchlike
  - personal protective equipment
  - musculoskeletal injury risks, including various models of job rotation
  - machines used in machinery systems
  - danger to and consideration for fellow workers and the general public
  - unauthorised persons in vicinity to the machine
  - certain particulars of importance for safety, e.g. maximum tree diameter for felling units, chain catching devices
  - safety aspects when connecting implements to the main machine (implements and additional equipment recommended by the manufacturer or importer and marketed for use together with the main machine)
- Off-road driving
  - planning of driving operations in steep or impassable terrain, including particulars of permissible load at a certain gradient
  - safety belt
  - ice covered waters
  - emergency routes
  - tyre pressures
  - treads
  - power line hazards (mounds, crane, jib)
  - particulars of braking effect according to load size and gradient
  - brake inspection

- Driving on public highways
  - checking lighting and slow vehicle sign
  - driving with (a bogey belt)
  - positioning the crane jib
  - trailer transport (lashing, heavy load, extra wide load)
  - traffic regulations for mobile machinery, e.g. classification and manning, vehicle speed, driving licence requirements, driving with dangerous goods
- Maintenance
  - engine turned off
  - pressure relieved
  - machine braked
  - parking the machine
  - towing the machine
  - trestling machine parts
  - use of interlocking systems and locking devices
  - approaching beneath a crane jib
  - checking oil and CFC leakages
  - slipping hazards
  - using a ladder
  - hazards of and protection from contact with oils, greases and motor fuel, and choice of suitable protective equipment
  - choosing the right equipment (power saw chain, caterpillar track)
  - daily inspection
  - regular preventive maintenance, e.g. oil and filter changes, replacement and adjustment of wear parts
- Method of loading and securing the machine for transport by lorry, rail, or other means
- Method of lifting with straps, indicating anchorage points for lifting straps
- Towing procedure

Ergonomic data

It is recommended that this section should include particulars of the machine's compliance with ergonomic requirements. There are ergonomic checklists for trucks and other materials handling machinery, tractors and other agricultural machinery, and forestry machinery.

Particularise the following points of assessment where possible:

- Cab access
- Cab
- Visibility
- Operator's seat and armrests
- Information from the machine
- Winch
- Working posture
- Noise
- Vibration
- Climate control
- Gases and particulates
- Lighting
- Manuals and instructions
- Maintenance

Warranty conditions

This section may include:

- Extent of warranty (including to whom and in what form warranty claims are to be presented)
- Warranty period
- List of authorised workshops

Spares catalogue

The spares catalogue can be included in the instruction manual for less complicated machinery. Otherwise it is best made into an extra book, separate from the instruction manual. It is suggested that the spares catalogue is compiled as follows:

- Exploded drawing
- Item number
- Part number
- Designations of standard parts
- Serial numbers
- Address for ordering

Design of the instruction manual

In order to make the instruction manual as practical as possible, it is recommended that the following points are taken into account when designing.

General

- The manual must be up to date and relevant to the type of machine delivered.
- The manual shall be written in the national language or languages of the country to which the machine is delivered.

Format and durability

- Standard format like A4, A5, or 1/3 A4 is recommended, depending on the amount of text etc. involved.
- The manual should have a permanent, durable binding (with a loose leaf system for service reports and the spares catalogue, if this is an extra book).
- The manual should be made of resilient, waterproof material.

Plainness

- The manual should have a plain, detailed list of contents.
- It should be designed for easy reference using thumb index sections or suchlike.
- It should have a subject index.

Readability

- The manual should be written in plain language with the right terminology and the right international symbols.
- The manual should have marked safety parts or safety sections.
- The manual should strike a good balance between figures and text (extent and mutual positioning).
- Figures should be of good quality and the text in clear, large print.

Assessment

Item	Items lacking	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1. Manuals and instructions are in a language which is fully comprehensive for the reader. The same demands as above for additional or optional equipment.		4	Yes				No	
2. General.	_____	4	All information is in the manual.		1 item missing	2 items missing	>2 items missing	
3. Technical data.	_____	2	All information is in the manual.	2 items missing	3 items missing	4 items missing	>4 items missing	
4. Starting and stopping instructions.	_____	4	All information is in the manual.	1 item missing	2 items missing	3 items missing	>3 items missing	
5. Running and working instructions.	_____	4	All information is in the manual.	1 item missing	2 items missing	3 items missing	>3 items missing	
6. Maintenance and fault diagnosis routines.	_____	2	All information is in the manual.	2 items missing	3 items missing	4 items missing	>4 items missing	
7. Safety instructions; a) general.	_____	4	All information is in the manual.	1 item missing	2 items missing	3 items missing	>3 items missing	
8. Safety instructions; b) off road driving.	_____	4	All information is in the manual.	1 item missing	2 items missing	3 items missing	>3 items missing	

9. Safety instructions; c) driving on public highways.	_____	4	All information is in the manual.	1 item missing	2 items missing	3 items missing	>3 items missing	
10. Safety instructions; d) maintenance.	_____	4	All information is in the manual.	1 item missing	2 items missing	3 items missing	>3 items missing	
11. Ergonomic data.	_____	4	All information is in the manual.	1 item missing	2 items missing	3 items missing	>3 items missing	
12. Warranty conditions and spares catalogue.	_____	2	All information is in the manual.	1 item missing	2 items missing	3 items missing	>3 items missing	
13. Design of the instruction manual.	_____	2	Meets the requirements and is available on data and paper.	1 item missing	2 items missing	3 items missing	>3 items missing	
							SUM	

	Class	Min. points	Max. points
Ergonomic profile	**A**	0	19
	B	20	66
	C	67	165
	D	166	330
	E	331	660

Maintenance

This chapter 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 chapter deal with items of personal safety equipment, hygienic equipment, etc.

Forest machine maintenance in the field is performed outdoors 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, and the handling of slippery, hot and dirty machine parts is all part and parcel of the job. Not surprisingly, therefore, more accidents occur during machine maintenance than in any other type of forest machine work. 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.

Measuring technique

Preventive maintenance is assessed by means of an index for maintainability (maintenance index) in accordance with SAE standard J817/2. The index is based on the periodic maintenance specified in the Operator's manual of 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, e.g. 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.

Assessment

General conditions, e.g. Operator's manual, auxiliary equipment, special tools, etc.: _____

_____

_____

Maintenance index (up to and including monthly maintenance 300h): _____

_____

_____

Access to points of maintenance

Assessment of the access system to points of maintenance if a ladder or stairs must be used. Only the least favourable access system and the least favourable standing area for maintenance will be evaluated. Access to maintenance points must meet the minimum requirements of EN ISO 2867

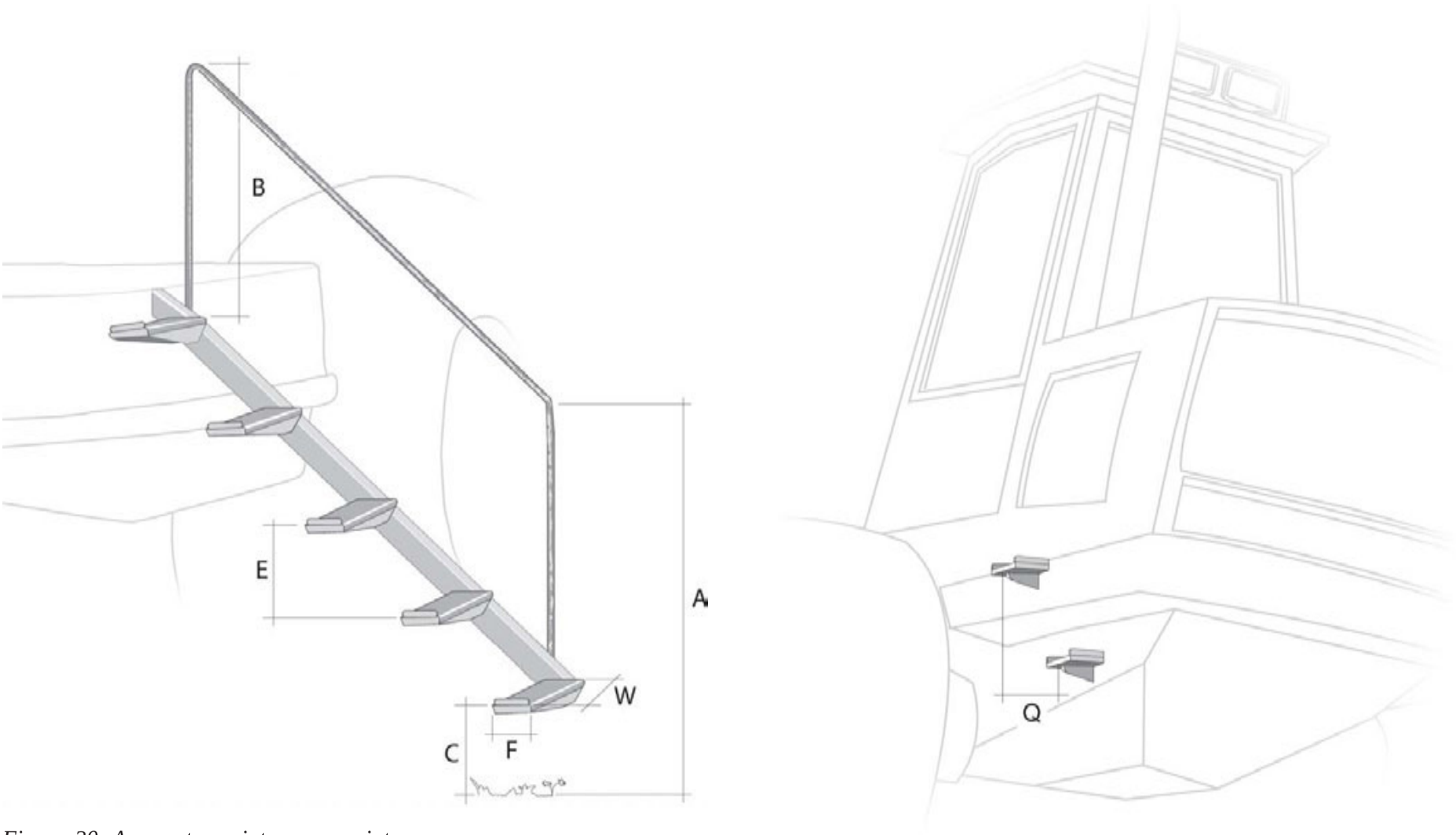


Figure 20. Access to maintenance points.

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
1. Ground to first step (C) [1], mm	_____	2	≤400 mm	≤500 mm	≤600 mm	≤700 mm	>700 mm or missing	
2. Step width (W), mm	_____	2	For two feet ≥320 mm One foot ≥160 mm				<320 mm <160 mm	

3.	Step depth (F), mm for a ladder or single rectangular steps and for a stair.	_____	1	50 ±5 mm 300 ±20 mm	≥6 [2] mm or if round steps are used 240 ≤ F ≤ 400 mm	<6 mm >400 mm or <240 mm	
4.	Rise (E) [3], mm for a ladder or single steps and	_____	1	300 ±20 mm 180 ±20 mm	>320 mm or <280 mm or if round steps are used	>400 mm [4] or <230 mm	
	for a stair.				>200 or <160 mm	>250 mm (for stairs 600 ≤ G + 2 B ≤ 660 mm must be true)	
5.	Horizontal distance from the uppermost step to the maintenance platform, mm	_____	1	0 ±20 mm	≤100 mm	>300 mm	
6.	Maximum permitted backlash of a single step (Q), mm	_____	1	0 ±5 mm	5 < Q < 10 mm	>10 mm	
7.	Handrail distance: Ground to handrail or handle(A) and step to handrail or handle (B) [5] (select the less favourable case), mm	A: _____ B: _____	2	900 ±20 mm 900 ±20 mm	A ≤1600 mm 850 ≤ B ≤ 960 mm	A >1600 mm B > 960 mm or B < 850 mm	
8.	Handrail / handle diameter, mm for a ladder or single steps and for a stair.	_____	1	Ø 25 ±5 mm 50 ±5 mm across flats (af)	15 [5] ≤ Ø ≤ 38 mm 16 ≤ af ≤ 80 mm	Ø <15 mm [6] or >38 mm <16 mm or >38 mm	
9.	Length between the bending radiuses of the handrail (usable length), mm	_____	1	>250 mm	150 ≤ length ≤ 250 mm	<150 mm	
10.	Hand clearance behind handrail or handle, mm	_____	1	≥75 mm	50 ≤ clearance <75 mm	Clearance <50 mm or handrail/handle missing	

11.	Width between parallel handrails, mm for a ladder or single steps and for a stair	_____	1	400 [7] ±20 mm 700 ±20 mm	≤600 [8] mm ≥460 mm	>600 mm <460 mm	
12.	Depth of standing areas, mm	_____	2	>600 mm	≥230 mm	<230 mm	
13.	Width of standing areas, mm	_____	2	>600 mm	≥230 mm	<230 mm	
14.	Dimension of openings for hand access, mm	_____	1	Round ≥ Ø 150 mm Rectangular ≥100 · 150 mm	Round ≥ Ø 110 mm Rectangular ≥65 · 110 mm	Round Ø < 110 mm Rectangular <65 · 110 mm	
15.	The construction of maintenance platforms and stands minimise the risk of slipping.		-	Yes		No	
16.	Neither the machine nor its components can move spontaneously.		2	Protective bolting of functions, such as door switch.	Protection can easily be manipulated.	No protection	

[1] Parking mode, as in the manual, shall be used at the assessment.
[2] If steps are consisting of several parts, the minimum width must be 3 mm; round steps are permitted with a diameter between 19 to 60 mm.
[3] Including the distance step to first catwalk.
[4] If the step is incorporated in a track or wheel system 500 mm from the track/wheel step to the catwalk are permitted, the minimum rise from the uppermost step to the catwalk is 150 mm.
[5] Measure from front edge to the nearest point behind step or to the point where the vertical clearance is less than 100 mm.
[6] 19 mm if the handrail is vertical or is situated more than 3 m above the ground.
[7] 600 mm if clearance for hips is necessary.
[8] Up to a maximum of 950 mm.

Assessment of the maintenance points

Maintenance and inspection points must be made according to the EU machine directive 98/37/EC, to EN 14861 on safety requirements of forestry machinery, and if applicable according to EN 1553 on safety requirements of agricultural machinery.

Item	Measure-ment	Weight factor	Level 1 0 points	Level 2 1 point	Level 3 3 points	Level 4 7 points	Level 5 15 points	Penalty points
17. Fault diagnosis chart is clear and comprehensive.		2	Yes, both in the onboard computer and in the service handbook.	Yes, but only in the service handbook.	Difficult to understand for the operator.	Some service charts are missing.	None provided.	
18. Facility for quick and safe disengaging/engaging of power sources.		4	Yes			Safe, but not quick.	Shortcomings	
19. Facility for discharging of stored energy when working on machine equipment.		4	Yes			Safe, but not quick.	Shortcomings	
20. If the engine must be running, e.g. during fault diagnosis, adequate advice must be given in the operator's manual on how to perform this work safely.		2	All service and maintenance work can be performed without the engine running.		Minor shortcoming in the advice, not causing danger to the operator.	Shortcomings in the advice leading to possibly dangerous situations.	No advice	
21. Essential tools provided with the machine and can be stored in warm place.		1	Yes	Yes, but no warm place for storage.	A few tools are lacking.	Several tools are lacking.	No tools provided.	
22. Tiltable cab, protective hoods, heavy guards, etc., are securely locked automatically when opened.		4	Yes	Cab or hood secured automatically, the other secured manually.	All manually secured.	Lock unsafe. Minor risk of injury.	Lock missing. Risk of severe injury.	
23. Protective hoods, covers etc. can be opened and closed by one person.	_____	2	Yes, force max. 135 N		Yes, force max. 250 N		Force >250N	
24. All mechanical power transmissions are protected by safety devices.		-	Yes				No	

25.	Sufficient support for parts of the machine which must remain in an uplifted position is provided.		-	Yes			No	
26.	Battery suitably located and anchored: Cannot injure operator, e.g. if machine rolls over. The positive pole of the battery is protected against short circuits.		2	Battery located separately in ventilated space. Protected terminals. Easily accessed outside the cab. Positive pole protected.	Battery located separately in ventilated space. Protected terminals. Accessed with difficulty. Outside the cab. Positive pole protected.	Outside the cab. Protected location. Access very difficult. Positive pole protected.	Outside the cab. Unprotected location. Positive pole protected.	Battery inside the cab. Positive pole not protected.	
27.	The boom and other uplifted machinery parts can be immobilised when the machine is parked, if necessary.		2	Yes, simple to set locked position of the boom.	Somewhat difficult to set locked position of the boom.	Special tools required.		Not possible	
28.	Windows are easy to clean.		1	Yes, no grilles.	Yes, some platforms and handrail missing. No grilles.	Yes, some platforms and handrail missing and/or grilles that is easy to disassemble without tools.	Platforms, handrail and handles missing.	Platforms, handrail and handles missing and/or difficult to disassemble grilles.	
29.	If due to a failure machine parts remain in an uplifted position due to hydraulic pressure it is possible to lower these parts in a safe and controlled way to the ground or to a safe rest according to the indications in the user instructions.		2	Yes, all necessary information is given in the user manuals.	Yes, but the information in the manuals is incomplete.		Yes, but only with special precautions or special devices.	No	
30.	Common tasks can be effected using a grip force of <50 N.	_____	2	Yes	<80 N	<120 N	No		

31.	Suitable lifting devices and attachment points provided.		2	Yes or not needed	Some shortcomings	Major shortcomings	No	
32.	Movable auxiliary lighting equipment provided.		1	Yes		A power outlet for an auxiliary light is provided.	No	
33.	The machine is equipped with a main power switch.		-	Yes			No	
							SUM	

	Class	Min. points	Max. points
Ergonomic profile	**A**	0	22
	B	23	74
	C	75	185
	D	186	370
	E	371	740

Maintenance index

Item	Index points	Class A	Class B	Class C	Class D	Class E
1A. Harvester: Maintenance index	_____	≤10 000	≤15 000	≤20 000	≤25 000	>25 000
1B. Forwarder and skidder: Maintenance index	_____	≤7 000	≤10 000	≤15 000	≤20 000	>20 000

Maintainability index (maintenance index)

SAE J817/2 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 in order to make it relevant to forestry machines.

Definition: 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.

Index system

The maintenance index 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 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 (e.g. fluid level checks, lubrication, cleaning) on the Maintenance Index Computation Form (see below). 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 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 "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 – working upright, within normal reach	1
(b) Ground level – bending or stretching outside normal reach	2
(c) Ground level – squatting, kneeling, or lying (except under the machine)	3

(d) Mount machine – normal reach 10
(e) Mount machine – bending, stretching, or squatting 15
(f) Any position (other than upright) under or within the confines of the machine 25
(g) Requires climbing into position without handrails and/or steps/platforms being 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.

Consideration of accessibility and the points assigned to each situation:

Points

(a) Exposed 1
(b) Exposed – through an opening 2
(c) Flip up cover or flap 3
(d) Door or cover; hand operated 4
(e) Door or cover; single facer 10
(f) Door or cover; multiple facers 15
(g) Hood removal 35
(h) Multiple covers – multiple facers 50
(i) Radiator guard removal 50
(j) Tilt cab 75
(k) Crankcase/drive train guard removal – hinged and bolted 75
– bolted only 100

Operation considerations and their respective point values

Operation refers to the action required to perform the servicing of the listed items. The operation considerations and their respective point values are grouped into categories of similar actions for easy reference. If the operation cannot be performed on the ground or at one single location, adjustment points have to be added to the operation points. The respective points and the adjustment points are shown below:

Compartment checking (Liquid)

(a) Visual check 1
(b) Dipstick 3
(c) Screw cap – hand removable 4
(d) Multiple screw cap – hand removable 6
(e) Screw cap or plug requiring tool 8
(f) Multiple screw cap or plug requiring tool 10

Component Checking

(a) Visual check 1
(b) Hand check of belt tension 2
(c) No precision tool (includes tire pressure check or torque wrench) 5
(d) Precision tool 10

Lubricating

(a) Fitting (or bank of fittings) 1
(b) Fitting requiring special adapter 3

(c) Brush on lube 5
(d) Oil can lube 5
(e) Fitting requiring secondary action, such as hand rotating shaft to get fitting to accessible location 5
(f) Hand packing (each) 20

Draining

(a) Drain valve – hand operable 1
(b) Drain valve – tool required 3
(c) Horizontal plug 6
(d) Vertical plug 8
(e) Cover plate 10
(f) Multiple plugs or covers 15

Filling

(a) Hand removed cap 1
(b) Tool removed cap or plug – vertical 3
(c) Awkward access to filler because of interfering parts or excessive slope of filler tube 8
(d) Tool removed plug – horizontal 10
(e) Requires pump to fill (i.e. differential under machine) 10
(f) Multiple caps or plugs 15

Cleaning

(a) Blow with air 3
(b) Single bath wash 5
(c) Multiple bath wash or wash and oil 10
(d) Clean reservoir by solvent spray or similar technique 10

Filter replacement

(a) Spin on (vertical base up) 1
(b) Spin on (base up inclined more than 15 degrees) 3
(c) Single facer not requiring tool 4
(d) Single facer requiring tool 5
(e) Multiple facer not requiring tool 6
(f) Multiple facer requiring tool 7

Adjustment

(a) Single step 2
(b) Multiple step 4
(c) Multiple location multiple step 10

Miscellaneous

Items in this list cannot be categorised under the headings in the table on Operation. These requirements are generally considered undesirable and as such should be avoided if possible. In effect, the point values listed for miscellaneous items are punitive points. The requirements for caution can be established by the manufacturer's maintenance instructions, by warnings and cautions affixed to the machine, or by the judgment of the auditor. The miscellaneous considerations are shown below.

Miscellaneous considerations and their respective point values

(a) Drainage indirectly collectible into container (requires hose or pipe) 2
(b) Interval not in conformance with SAE Recommended Practice J753 2
(c) Bleeding required 3
(d) Priming required 3
(e) Special tool 4
(f) Inadequately identified 4
(g) Filler size inadequate 5
(h) Vulnerable to contamination 5
(i) Need to start engine 5
(j) Torquing required (per facer) 5
(k) Drain and wash filter housing 8
(l) Need for special instruction 10
(m) Need to operate or position machine (includes warm-up) 10
(n) Unable to collect fluid 20
(o) Inadequate clearance for required operation 20
(p) Two persons required 40
(q) Requires use of ladder separate from machine 50
(r) Operation requiring caution 100
(s) Position requiring caution 100

Quantity factor

Any item occurring more than once must by multiplied by the number of occurrences (e.g. air pressure check by the number of tyres)

Frequency factor (Maintenance interval)

Maintenance interval refers to the frequency of performing a lubrication or maintenance item. Requirements for one-time-only, scheduled retightening or lubricant changes for new machines with less than 100 h on them will not be considered in determining maintenance index points. The frequency multipliers are assigned as shown below.

Frequency (maintenance interval) consideration and the respective point values

(a) 1000 h – semi-annually, or greater 1
(b) 500 h – quarterly, or as required 2
(c) 250 h – monthly 4
(d) 100 h – semi-monthly 10
(e) 50 h – weekly 20
(f) 10 h – daily 50

The hour intervals listed conform to SAE Recommended Practice J753. If intervals other than those shown are used, apply the frequency multiplier of the nearest SAE Recommended Practice interval plus a miscellaneous penalty of two points. Each lubrication and maintenance item is assigned a frequency multiplier once (i.e. the most frequent interval performed). E.g., a schedule that stipulates that the engine oil level must be checked daily would be recorded on the form only once. This item would not enter the count again, even though it may be performed during 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 too complicated.

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

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

Examples on using maintenance index

SAE J817/2 gives guidelines on how the maintenance work can be studied and evaluated. The extract concerns only the scheduled maintenance mentioned in the instruction handbook for maintenance up to 250 h – monthly.

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)
- Undesirable miscellaneous

Location

This determines the position from which the task must be performed. 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 Location, and the remaining tasks are each assigned a score of one point under this heading.

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.

Operation

Operation refers to the action required to perform the servicing of the listed items.

Miscellaneous

Items in this list cannot be categorised under the headings in the table operation.

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.

Example No. 1

Frequency: Daily maintenance
Item: Engine oil level
Task: Check
Location: Must climb up on the machine and then it is possible to reach the dipstick within normal reach.
Accessibility: Open a flip-up hood
Operation: Dipstick
Miscellaneous: - -

Service point	Task	Location	Accessibility	Operation	Miscellaneous	Subtotal	Frequency factor	Total	Remark
DAILY MAINTENANCE									
Engine oil Level	Check	10	3	3	0	16	50	800	

Example No. 2

Frequency: Weekly maintenance
Item: Lift cylinder
Task: Lubrication
Location: Standing on the ground with two lubricant nipples within normal reach and both are accessible from the same ocation.
Accessibility: Exposed
Operation: Lubrication nipple
Miscellaneous: - -

Service point	Task	Location	Accessibility	Operation	Miscellaneous	Subtotal	Frequency factor	Total	Remark
WEEKLY MAINTENANCE									
Lift cylinder	Lubrication	1	2 · 1	2 · 1	0	5	20	100	

Maintenance index computation form

Date_____ **Signature** _____ Maintenance interval _____ (use a separate form for each maintenance interval). It is recommended that reference be made to SAE J 817/2 for guidance on this procedure.

Maintenance item (service point)	Task	Location	Accessibility	Operation	Miscellaneous	Subtotal	Quantity multiplier	Frequency factor	Total	Remarks
								Sum index		

Date_____ **Signature** _____ Maintenance interval _____ (use a separate form for each maintenance interval). It is recommended that reference be made to SAE J 817/2 for guidance on this procedure.

Maintenance item (service point)	Task	Location	Accessibility	Operation	Miscellaneous	Subtotal	Quantity multiplier	Frequency factor	Total	Remarks
								Sum index		

Date_____ **Signature** _____ Maintenance interval _____ (use a separate form for each maintenance interval). It is recommended that reference be made to SAE J 817/2 for guidance on this procedure.

Maintenance item (service point)	Task	Location	Accessibility	Operation	Miscellaneous	Subtotal	Quantity multiplier	Frequency factor	Total	Remarks
								Sum index		

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EU Directive 98/37/EC. Approximation of the laws of the Member states relating to machinery.

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EN 779. Particulate air filters for general ventilation: Determination of the filtration performance.

EN 1032. Mechanical vibrations: Testing of mobile machinery in order to determine the vibration emission values.

EN 1553. Agricultural machinery: Agricultural self-propelled, mounted, semi-mounted and trailed machines: Common safety requirements.

ISO 2631. Mechanical vibration and shock: Evaluation of human exposure to whole-body vibration; Part 1: General requirements; Part 5: Method for evaluation of vibration containing multiple shocks.

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Recommendations

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European ergonomic and safety guidelines for forest machines 2006

These European guidelines specify ergonomic and safety requirements on forestry machinery. The guidelines are mostly directed to manufacturers, testing institutes, and larger companies using forest machines. A short ergonomic checklist aimed mainly for the users is also available as a separate booklet. The guidelines have no legal binding, except for the lowest levels, which are based on the safety requirements in the EU directives and mandated EN standards.

The *Ergonomic Guidelines* lead you step by step through the most relevant ergonomic and safety features of a machine. Each chapter ends with specified requirements that should be met. These requirements are levelled making it possible to calculate assessment points and to compile an ergonomic profile of the machine.

This handbook is based on international standards, research, and established practice from people using forest machines. Machine operators, machine owners, machine manufacturers, contractor associations, and forest companies, as well as health and safety authorities and testing institutes in six European countries have contributed with their knowledge and experience.

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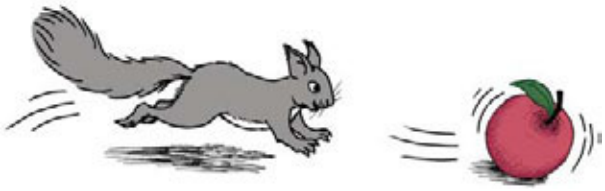

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