INTERNATIONAL STANDARD

ISO 6395

Second edition
2008-03-15

Earth-moving machinery — Determination of sound power level — Dynamic test conditions

Engins de terrassement — Détermination du niveau de puissance acoustique — Conditions d'essai dynamique

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 6395 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors* in collaboration with Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 6395:1988), which has been technically revised. It also incorporates the Amendment ISO 6395:1988/Amd. 1:1996.

Introduction

This International Standard is a specific test code for earth-moving machinery as defined in ISO 6165.

A simulated dynamic test condition, rather than an actual work cycle, is used. Simulated dynamic test conditions provide noise emission data which are repeatable and representative. Actual work cycle tests are complex and repeatability can be a problem.

Specific procedures are described in this International Standard to enable the sound power emission in dynamic test conditions to be determined in a manner which is repeatable. Attachments (bucket, dozer, etc.) for the manufacturer's production version are intended to be fitted since this is the configuration most likely to exist when the machine is in actual use.

This International Standard enables compliance with noise limits to be determined, if applicable. It can also be used for evaluation purposes in noise reduction investigations.

A complementary test code is given in ISO 6396. This other specific test code is intended to be used to determine the noise emitted by earth-moving machinery, measured at the operator's position in terms of the A-weighted sound pressure level with the machine under dynamic test conditions.

Corresponding measurements of noise emitted to the environment and noise at the operator's position under stationary test conditions are described in ISO 6393 and ISO 6394, respectively.

Earth-moving machinery — Determination of sound power level — Dynamic test conditions

1 Scope

This International Standard specifies a method for determining the noise emitted to the environment by earth-moving machinery, measured in terms of the A-weighted sound power level while the machine is operating under dynamic test conditions.

It is applicable to earth-moving machinery as specified in Annex A and as defined in ISO 6165.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3744:—[1)], *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering method for an essentially free field over a reflecting plane*

ISO 6165, *Earth-moving machinery — Basic types — Identification and terms and definitions*

ISO 6393:2008, *Earth-moving machinery — Determination of sound power level — Stationary test conditions*

ISO 9249, *Earth-moving machinery — Engine test code — Net power*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3744, ISO 6165 and the following apply.

3.1
time-averaged A-weighted sound pressure level
$L_{pA,T}$
A-weighted sound pressure level averaged on an energy basis over the whole measurement period, T

3.2
A-weighted sound power level
L_{WA}
quantity obtained from the time-averaged A-weighted sound pressure levels averaged over the measurement surface on an energy basis

1) To be published. (Revision of ISO 3744:1994.)

3.3
basic length
l
length used to define the radius of the measurement hemisphere

NOTE The dimension of the basic length, *l*, is determined in Annex A.

3.4 Machine centre point

3.4.1
machine centre point
⟨all machines, except those with slewing upper structure⟩ midpoint of the basic length, *l*, at the machine longitudinal centre line

3.4.2
machine centre point
⟨machines with slewing upper structure⟩ centre of rotation of the upper structure

3.5 Fan speed

3.5.1
maximum working speed of the fan
fan speed at which the fan provides maximum cooling performance for the machine under the most severe operating conditions

3.5.2
fan drive with continuous variable fan speed
fan drive that varies the fan speed continuously throughout a variable range to minimize its speed for the needed cooling performance in relation to the heat load

4 Instrumentation

The instrumentation shall be capable of carrying out the measurements according to Clause 8. The preferred instrumentation system for acquiring the data is an integrating-averaging sound level meter complying with the requirements of IEC 61672-1 for a class 1 instrument.

5 Test environment

5.1 General

For the purposes of this International Standard, the test environment specified in ISO 3744:—, Clause 4 and Annex A, apply. Additional requirements are given in 5.2 to 5.5.

Humidity, air temperature, barometric pressure, vibration and stray magnetic fields shall be within the limits specified by the manufacturer of the instrumentation.

5.2 Test site and environmental correction, K_{2A}

For test-site measurement ground surfaces consisting of a hard reflecting plane — such as concrete or non-porous asphalt [(5.3.1 a) and b)] — and having negligible sound-reflecting obstacles within a distance from the source equal to three times the measurement hemisphere radius, it may be assumed that the absolute value of environmental correction, K_{2A}, is less than or equal to 0,5 dB, and can therefore be disregarded. In this case, K_{2A} shall be equal to 0 dB.

For the all-sand test site [5.3.1 c)], the value of environmental correction, K_{2A}, shall be determined and used in the sound power calculation.

5.3 Test site

5.3.1 General

The following three types of test-site measurement ground surface, described in 5.3.2, 5.3.3 and 5.3.4, are allowed:

a) hard reflecting plane (concrete or non-porous asphalt);

b) combination of hard reflecting plane and sand;

c) all-sand plane.

The hard reflecting plane, as described in 5.3.2, shall be used for testing the following:

— rubber-tyred machines, all modes of operation;

— excavators, all modes of operation;

— crawler loaders, stationary hydraulic mode of operation;

— rollers, all modes of operation.

The combination of hard reflecting plane and sand, as described in 5.3.3, may be used for rollers with raised pads and landfill compactors.

The combination of hard reflecting plane and sand, as described in 5.3.3, or the all-sand plane, as described in 5.3.4, shall be used for crawler-type machines (e.g. crawler dozers, crawler loaders, crawler dumpers, etc.) in travel and stationary hydraulic modes, provided that

— the environmental correction, K_{2A}, determined in accordance with ISO 3744:—, Annex A, is less than 2,0 dB, and

— for the all-sand plane, as described in 5.3.4, and where K_{2A} is greater than 0,5 dB, the correction is accounted for in the calculation of the sound power level.

5.3.2 Hard reflecting plane

The test area bordered by the vertical projection of the microphones to the ground shall consist of concrete or non-porous asphalt.

5.3.3 Combination of hard reflecting plane and sand

The travel path of the machine shall consist of humid sand of grain size up to 2 mm. The minimum depth of the sand shall be 0,3 m. If 0,3 m is not deep enough for track penetration, the depth shall be increased accordingly. The ground surface between the machine and the microphones shall be a hard reflecting plane, as described in 5.3.2.

It is possible to use a combination site of minimum size comprising only a single reflecting plane with a sand path along the side. In this case, the machine shall be operated in a forward travel mode twice, each time in the opposite direction, for each of the three microphone positions. The reverse travel mode shall be carried out in the same manner.

5.3.4 All-sand plane

The sand shall be as specified in 5.3.3.

5.4 Background noise correction, K_{1A}

The requirements for background noise, as specified in ISO 3744, shall be fulfilled. Corrections for background noise shall be made as specified in ISO 3744:—, 8.3.2.

5.5 Climatic conditions

Measurements shall not be carried out under the following conditions:

a) when there is precipitation, i.e. rain, snow or hail;

b) when the ground surface is covered with snow;

c) when the temperature is below −10 °C or above +35 °C;

d) when the wind speed exceeds 8 m/s; for wind speeds in excess of 1 m/s, a microphone windscreen shall be used and appropriate compensation for the effect of its use allowed for when calibrating.

6 Measurement of time-averaged A-weighted sound pressure levels

6.1 Size of measurement surface

The measurement surface to be used for the test shall be a hemisphere. The radius of the hemisphere shall be determined by the basic length, l, of the machine as specified in Annex A.

The radius shall be

— 4 m when the basic length, l, of the machine to be tested is less than 1,5 m,

— 10 m when the basic length, l, of the machine to be tested is greater than or equal to 1,5 m but less than 4 m,

— 16 m when the basic length, l, of the machine to be tested is greater than or equal to 4 m but less than 8 m, and

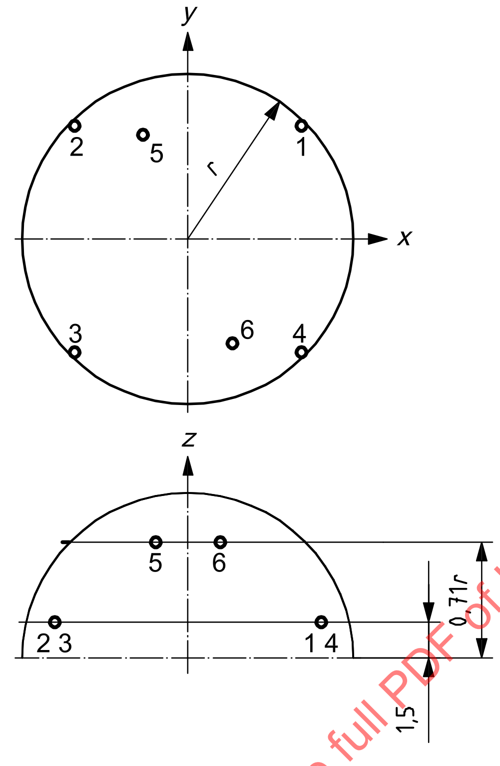
— the smallest radius of the sequence, 16 m, 18 m, 20 m... when the basic length, l, of the machine to be tested is greater than 8 m and the hemisphere radius exceeds twice the characteristic length, d_0, of the machine to be tested.

NOTE Characteristic length, d_0, is as defined in ISO 3744, with the machine length, l, equal to l_1.

6.2 Microphone positions on the hemispherical measurement surface

Six measuring positions shall be used. Microphone positions and their coordinates shall be as shown in Figure 1 and as given in Table 1.

Dimensions in metres



Key

1 to 6 microphone positions

r hemisphere radius

Figure 1 — Microphone array on the hemisphere

Table 1 — Co-ordinates of microphone positions

Microphone position	x/r	y/r	z
1	0,7	0,7	1,5 m
2	–0,7	0,7	1,5 m
3	–0,7	–0,7	1,5 m
4	0,7	–0,7	1,5 m
5	–0,27	0,65	0,71 r
6	0,27	–0,65	0,71 r

6.3 Positioning the machine

Depending on the type of machine, measurements are made in

— travel mode,

— stationary work cycle mode, or

— a combination of the two.

The operation and positioning of the machine is specified in Annexes B to L.

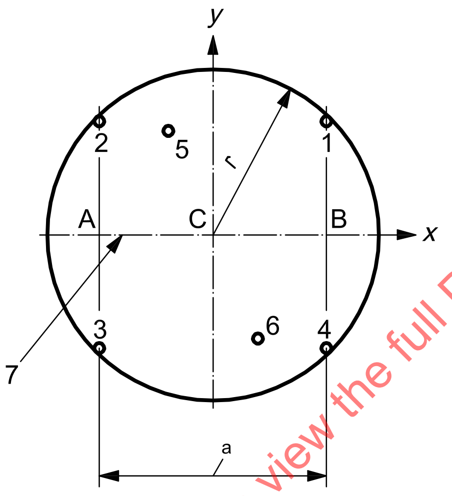
6.3.1 Travel mode

The travel path of the machine is shown in Figure 2. The centre line of the machine travel path shall be the x-axis and the longitudinal axis of the machine shall coincide with this axis.

The travel path length shall be A to B, which is equal to 1,4 times the hemisphere radius. The machine forward travel mode shall be from A to B and the reverse travel mode shall be from B to A.

6.3.2 Stationary work cycle mode

The longitudinal axis of the machine shall coincide with the x-axis and the front of the machine shall face direction B. The machine centre point shall be approximately vertical above the centre of the hemisphere, C, given in Figure 2. The operation and positioning of the machine are specified in Annexes B to L.



Key

1 to 6 microphone positions
7 centre line of travel path
A, B and C points on the travel path
r hemisphere radius

a Noise measurement zone = 1,4 r.

Figure 2 — Machine travel path

7 Set-up and operation of machine

7.1 General

7.1.1 Safety and operation

All relevant safety precautions and the manufacturer's operating instructions shall be followed during the test.

No signal devices, such as forward warning horn or back-up alarm, shall be activated during the test.

7.1.2 Machine set-up

The machine shall be equipped with the equipment and attachment(s) specified by the machine manufacturer. The engine and hydraulic system shall be warmed to normal operating conditions as specified by the machine manufacturer.

All liquid systems shall be filled within the range specified by the manufacturer.

7.2 Engine speed

The engine rotational speed shall be set at the maximum value with no load, as specified by the machine manufacturer.

7.3 Fan speed

If the engine of the machine or its hydraulic system is fitted with fan(s), they shall operate during the test. The fan speed shall be in accordance with one of the following conditions, stated and set by the manufacturer of the machine.

a) Fan drive directly connected to the engine

If the fan drive is directly connected to the engine and/or hydraulic equipment (e.g. by belt drive), it shall operate during the test.

b) Fan drive with several distinct speeds

If the fan can work at several distinct speeds, the test shall be carried out

— either at the maximum working speed of the fan, or

— in a first test with the fan set at zero speed and in a second test with the fan set at maximum working speed; the resulting time-averaged A-weighted sound pressure level, $L_{pA,T}$, shall then be calculated by combining both test results using Equation (1):

$$L_{pA,T} = 10\ \lg\left(0{,}3 \times 10^{0{,}1 L_{pA,0\%}} + 0{,}7 \times 10^{0{,}1 L_{pA,100\%}}\right)\ \text{dB} \tag{1}$$

where

$L_{pA,0\%}$ is the time-averaged A-weighted sound pressure level determined with the fan set at zero speed;

$L_{pA,100\%}$ is the time-averaged A-weighted sound pressure level determined with the fan set at maximum speed.

c) Fan drive with continuously variable speed

If the fan can work at continuous variable speed, the test shall be carried out either in accordance with 7.3 b) or with the fan speed set by the manufacturer at no less than 70 % of the maximum working speed.

d) Machine equipped with more than one fan

All fans shall run at the conditions specified in a), b) or c).

7.4 Travel mode operation of machine

The travel path of the machine shall be as specified in 6.3.1 and as shown in Figure 2. For crawler machines, the travel path shall be sand and, for rubber-tyred wheeled machines, a hard reflecting plane as specified in 5.3.2. The machine operation shall be in accordance with Annexes B to L.

The machine shall be operated with the equipment or attachment(s) in a lowered carry position (300 ± 50) mm above the travel path, and at maximum governed engine speed (high idle) in a constant forward and reverse travel velocity. For ride-on machines, the forward travel velocity shall be close to, but not exceeding, 4 km/h for crawler and steel-wheeled machines, and 8 km/h for rubber-tyred wheeled machines. The matching gear ratio shall be used in the reverse travel mode, regardless of the velocity. For the majority of machines, this will be first forward and first reverse. Hydrostatic drive machines may use a range of 3,5 km/h to 4 km/h for crawler or steel-wheeled machines, and 7 km/h to 8 km/h for rubber-tyred machines, owing to the difficulty of setting ground speed controls for exact travel speeds.

For pedestrian-controlled machines, the forward travel velocity shall not exceed 6 km/h and the reverse travel velocity shall not exceed 2,5 km/h.

These modes of operation shall be used non-stop across the hemisphere in both directions, without movement of the equipment or attachment(s), unless otherwise specified. If the lowest gear results in a velocity higher than the specified velocity, it shall be used with the engine operating at maximum governed speed (high idle). For hydrostatic drive machines with the engine at maximum governed engine speed (high idle), the ground speed control shall be set to match the stated above specified velocities. The sound pressure level shall be measured only while the machine mid-point is operating on the travel path between positions A and B in Figure 2.

The operator should make steering corrections as the machine moves through the test course in order to maintain the machine travel path over the test course centre line.

Three separate forward and reverse cycles shall be carried out in accordance with 8.1.

8 Determination of A-weighted sound power level

8.1 Measurement procedure

The A-weighted sound power level shall be determined in accordance with ISO 3744.

For each mode of operation, as defined in Annexes B to L for each particular machine family, the time-averaged A-weighted sound pressure level shall be measured at all microphone positions (preferably simultaneously) at least three times.

From these measurements, sound power levels (at least three) are calculated in accordance with 8.2 for the combined work cycle (see Annexes B to L) of the particular machine family.

In order to meet the requirements of 8.3, measurements of additional work cycles may be necessary. Guidelines for carrying out the noise measurements are given in Annex M.

8.2 Calculation of A-weighted sound power level

The A-weighted sound power level, $L_{W\text{A}}$, in decibels, of the machinery shall be calculated using Equation (2):

$$L_{W\text{A}} = \overline{L_{p\text{A},T}} - K_{1\text{A}} - K_{2\text{A}} + 10 \lg\left(\frac{S}{S_0}\right) \text{ dB} \tag{2}$$

where

$\overline{L_{p\text{A},T}}$ is the energy average of the time-averaged A-weighted sound pressure levels on the measurement surface, in decibels (reference: 20 µPa), with

$$\overline{L_{p\text{A},T}} = 10 \lg\left(\frac{1}{N}\sum_{i=1}^{N} 10^{0,1 L_{p\text{A},i}}\right) \text{ dB} \tag{3}$$

where

$L_{p\text{A},i}$ is the time-averaged A-weighted sound pressure level resulting from the microphone position i, in decibels (reference: 20 µPa);

N is the total number of microphone positions (N = 6);

K_{1A} is the background noise correction (see 5.4);

K_{2A} is the environmental correction (see 5.2 and 5.3.1);

S is the area of the hemispherical measurement surface, in square metres, i.e. $S = 2\pi r^2$;

$S_0 = 1\ \text{m}^2$;

$10\lg\left(\frac{S}{S_0}\right)$ = 20,0 dB for 4 m radius, 28,0 dB for 10 m radius and 32,1 dB for 16 m radius.

All intermediate results, such as sound pressure levels and area calculation, shall be expressed to one decimal place.

8.3 Determination of measurement result

Calculate the three A-weighted values of the sound power level from the three sets of data obtained at each microphone position (see 8.1).

If two of the three values so obtained do not differ by more than 1 dB, further measurements are unnecessary. If this is not the case, continue taking measurements until two values within 1 dB of one another are obtained. The A-weighted sound power level to be reported is the arithmetic mean of the two highest values that are within a 1 dB range of each other.

9 Information to be recorded

The following information, as applicable, shall be compiled and recorded for all measurements made in accordance with this International Standard.

a) Machinery under test:

- machine manufacturer;
- machine model number;
- machine serial number;
- type of fan-drive system(s), test method(s) used, as specified in 7.3 a), b) or c), including corresponding system maximum fan speed and fan speed(s) used during the test for each fan;
- machine arrangement, including major equipment and attachments, engine speed at maximum governor position (high idle), fan speed and gear ratios or control settings;
- engine net power, in kilowatts, at corresponding speed, as defined in ISO 9249.

b) Acoustic environment:

- description of test site and type of test-site measurement surface(s) used, including a sketch showing the position of the machine;
- air temperature, barometric pressure, relative humidity and wind velocity at the test site.

c) Instrumentation:

- instrumentation used for the acoustical measurements, including name, type, serial number and manufacturer;

— method used to calibrate the instrumentation system;

— date and place of calibration of the instrumentation system.

d) **Acoustical data:**

— location of the microphones;

— time-averaged A-weighted sound pressure level at each microphone position for each measurement carried out in accordance with 8.1;

— A-weighted sound pressure level of the background noise at each microphone position;

— time-averaged A-weighted sound pressure level averaged over the measurement surface, calculated in accordance with 8.2 for each work cycle mode, is defined in the Annexes B to L;

— final value of the A-weighted sound power level calculated in accordance with 8.2 and determined in accordance with 8.3.

10 Information to be reported

10.1 Information

The following information shall be reported:

a) machine manufacturer, model number, serial number, engine net power (in kilowatts at rated speed, as defined in ISO 9249) machine arrangement, including major attachments, and the type of test-site measurement ground surface used;

b) A-weighted sound power level, determined in accordance with 8.3, rounded to the nearest whole number (use the lower number for values $< 0,5$; use the higher number for values $\geqslant 0,5$);

c) engine speed at maximum no-load governor control position (high idle), with the machine stationary and transmission in neutral;

d) type of fan-drive system(s), test method(s) used as specified in 7.3 a), b) or c), including corresponding system maximum fan speed and fan speed(s) used during the test for each fan;

e) level of the fuel tank and, if applicable, level of the sprinkler water tank(s) and ballast compartment(s).

10.2 Declaration of sound emission data and uncertainty

In some markets, the additional requirements listed in the normative Annex N apply. The declaration of sound emission data and uncertainty shall be made in accordance with Annex N, if relevant.

Annex A
(normative)

Basic length, l, and additional machine specifications

A.1 Dozer

A.1.1 Crawler dozer

See Figure A.1.

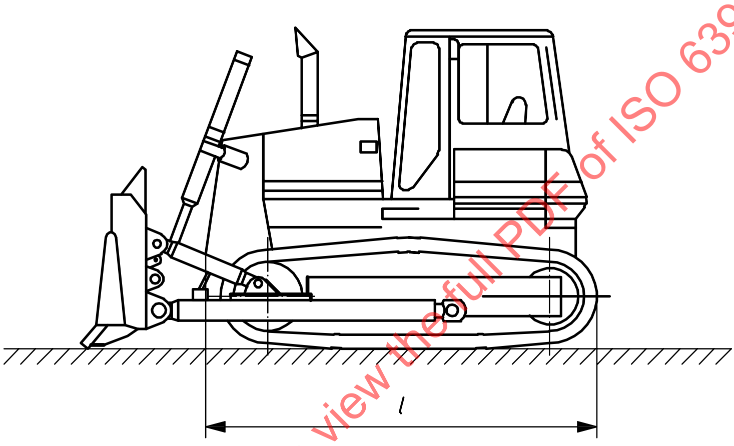


Figure A.1

A.1.2 Wheeled dozer

See Figure A.2.

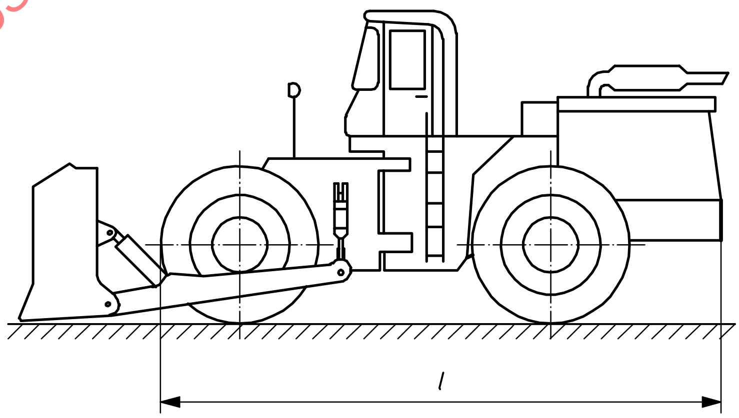


Figure A.2

A.2 Loader

A.2.1 Wheeled loader

Wheeled loader with an operating mass > 4 500 kg. See Figure A.3.

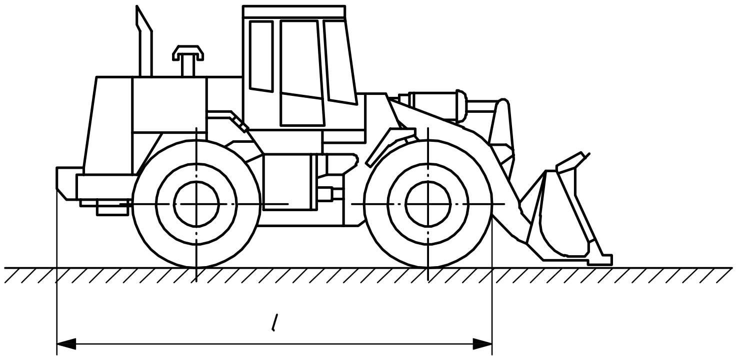


Figure A.3

A.2.2 Compact loader, wheeled

Wheeled loader with an operating mass ⩽ 4 500 kg. See Figure A.4.

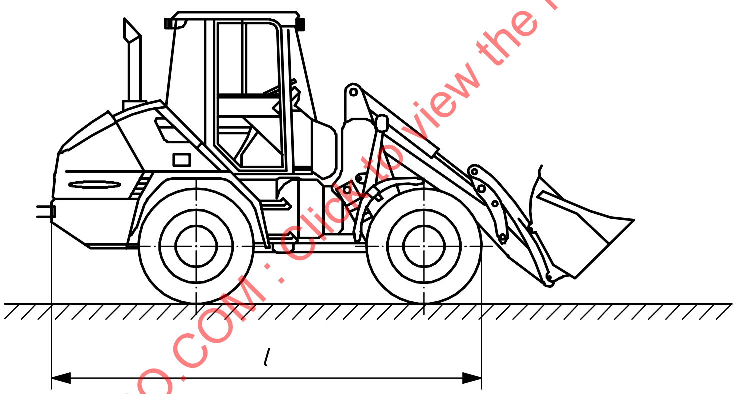


Figure A.4

A.2.3 Crawler loader

See Figure A.5.

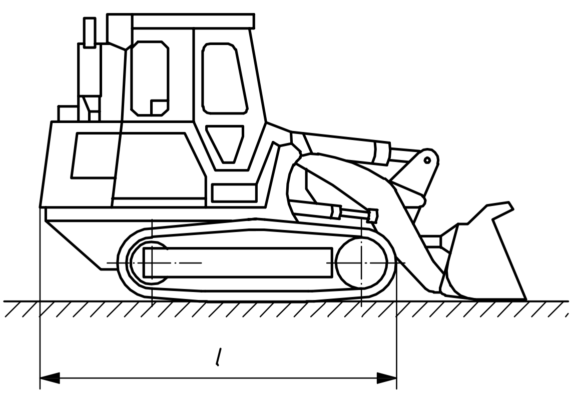


Figure A.5

A.2.4 Skid steer loader

See Figure A.6.

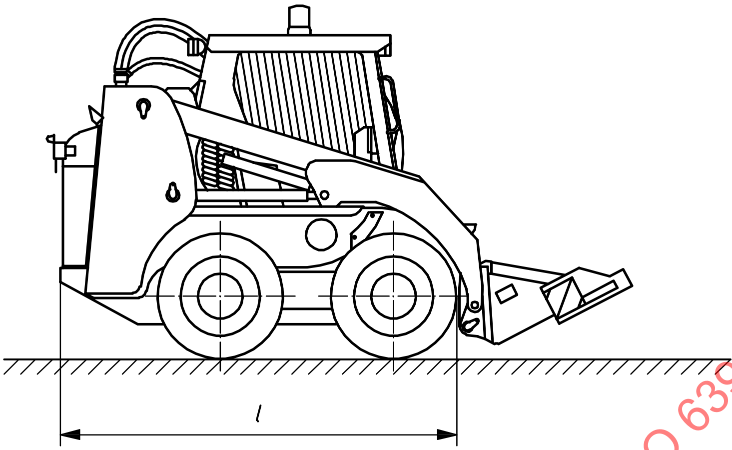


Figure A.6

A.3 Backhoe loader

A.3.1 Wheeled backhoe loader

See Figure A.7.

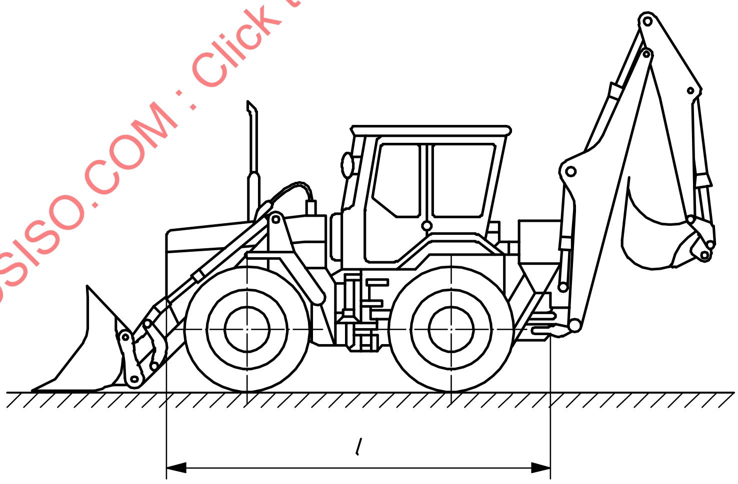


Figure A.7

A.3.2 Crawler backhoe loader

See Figure A.8.

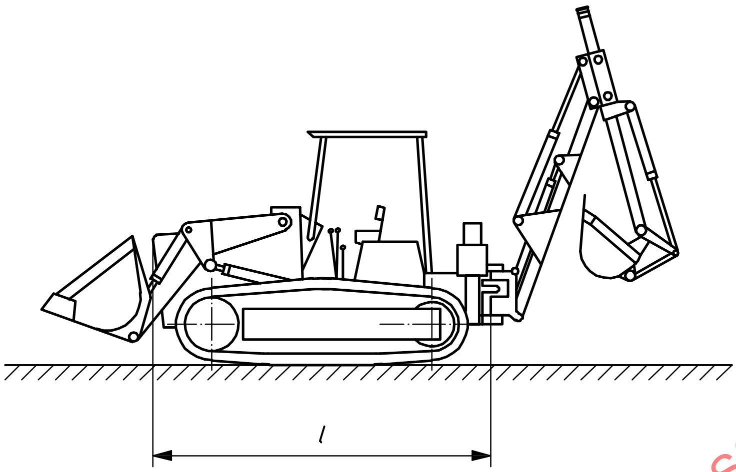


Figure A.8

A.4 Excavators

A.4.1 Wheeled excavator

See Figure A.9.

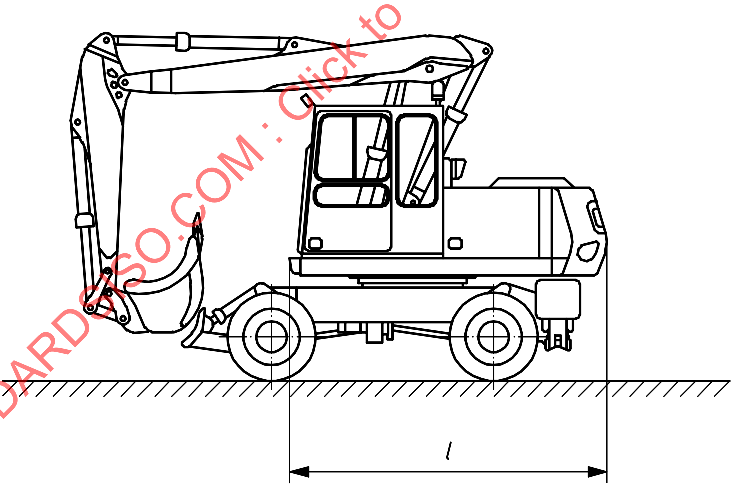


Figure A.9

A.4.2 Crawler excavator

See Figure A.10.

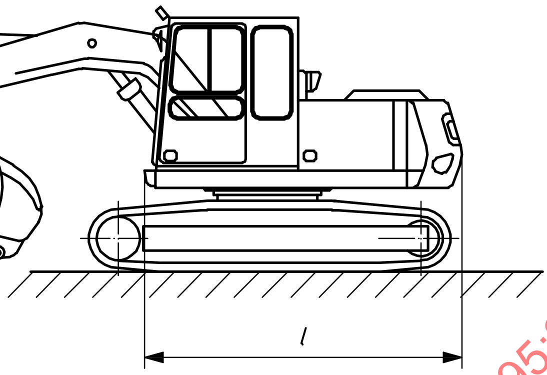
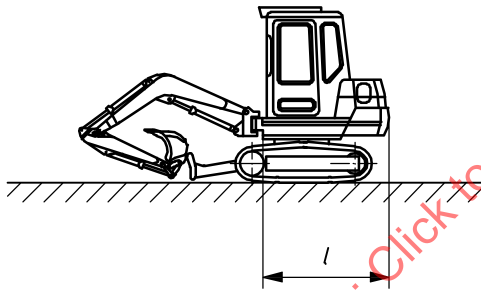


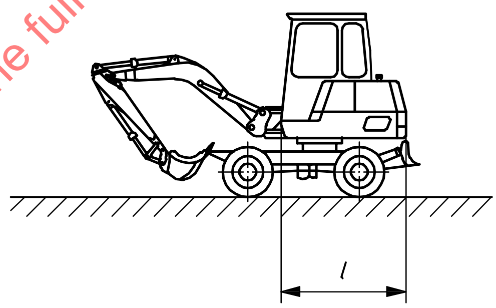
Figure A.10

A.4.3 Compact excavator

Excavator with an operating mass ⩽ 6 000 kg. See Figure A.11.



a) Crawler



b) Wheeled

Figure A.11

A.4.4 Walking excavator

See Figure A.12.

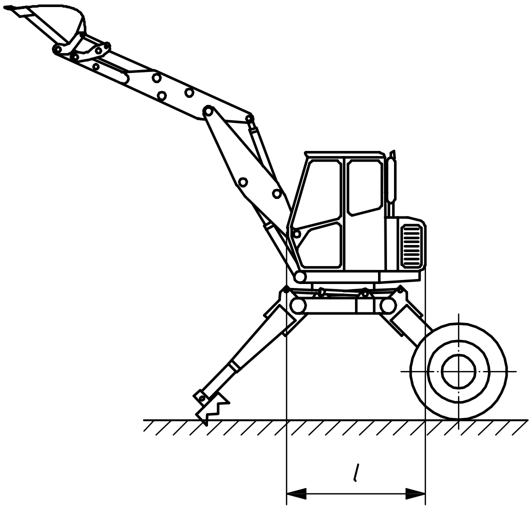


Figure A.12

A.5 Dumper

A.5.1 Wheeled rigid-frame dumper

See Figure A.13.

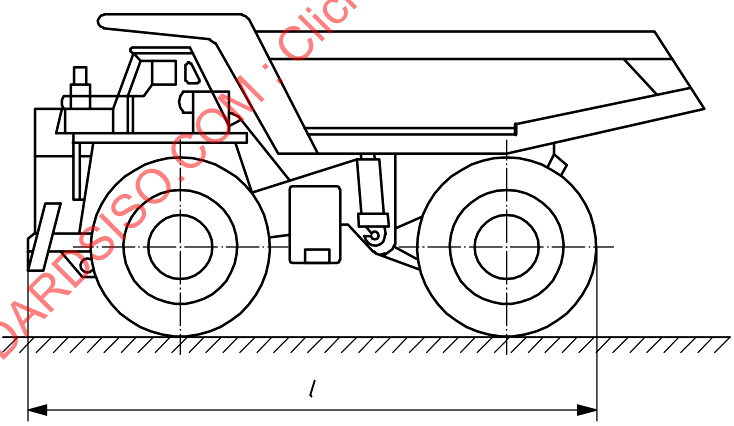


Figure A.13

A.5.2 Articulated-frame dumper

See Figure A.14.

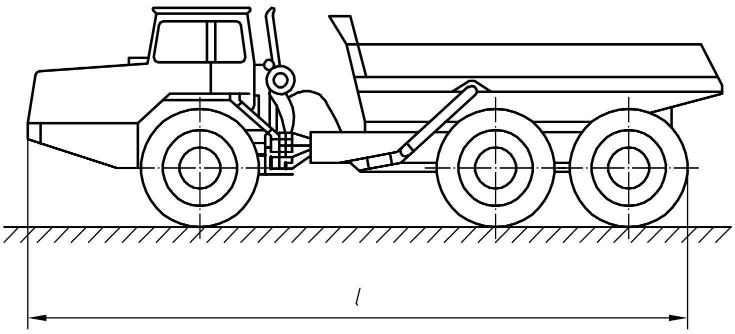


Figure A.14

A.5.3 Crawler dumper

See Figure A.15.

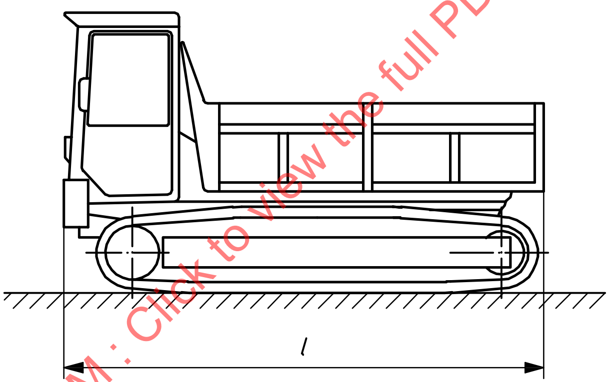


Figure A.15

A.5.4 Compact dumper, wheeled

Wheeled dumper with an operating mass ⩽ 4 500 kg. See Figure A.16.

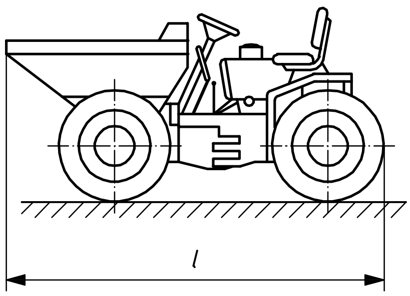


Figure A.16

A.5.5 Compact dumper, crawler

Crawler dumper with an operating mass ⩽ 4 500 kg. See Figure A.17.

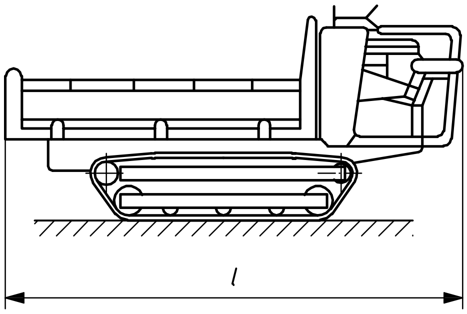


Figure A.17

A.6 Scraper

A.6.1 Scraper with one engine

For scrapers with one engine, the basic length, l, is the length of the machine. See Figure A.18.

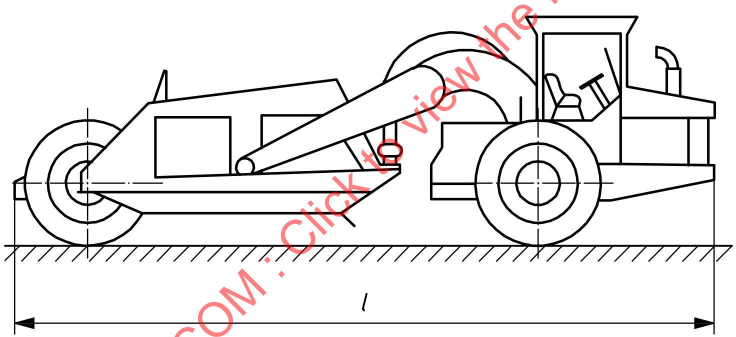


Figure A.18

A.6.2 Scraper with two engines

For scrapers with two engines, the basic length, l, is the length of the machine. See Figure A.19.

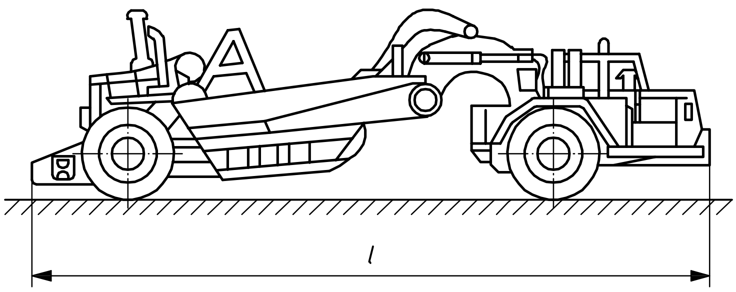


Figure A.19

A.6.3 Crawler scraper

See Figure A.20.

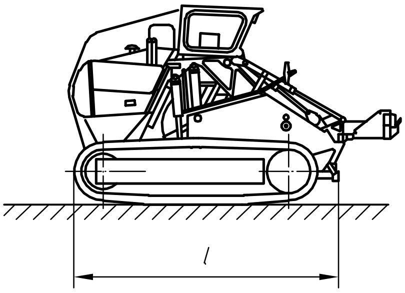


Figure A.20

A.7 Grader

See Figure A.21.

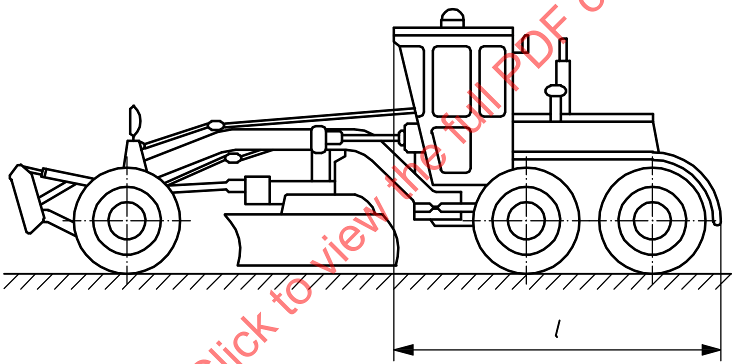


Figure A.21

A.8 Pipelayer

See Figure A.22.

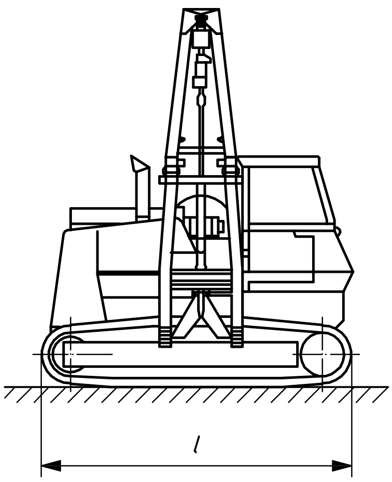


Figure A.22

A.9 Trencher

A.9.1 Wheeled ride-on trencher

See Figure A.23.

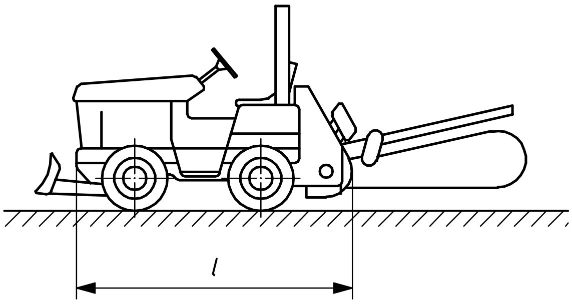


Figure A.23

A.9.2 Crawler ride-on trencher

See Figure A.24.

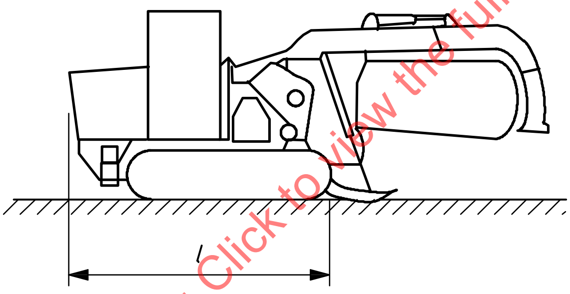


Figure A.24

A.9.3 Walk-behind trencher

See Figure A.25.

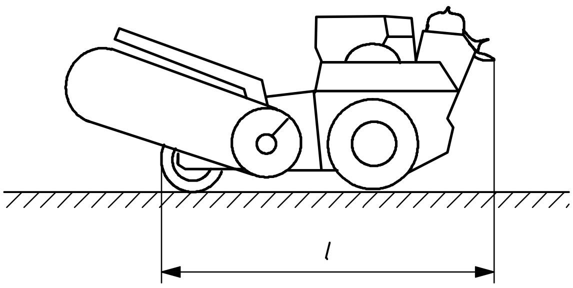


Figure A.25

A.9.4 Disk trencher

See Figure A.26.

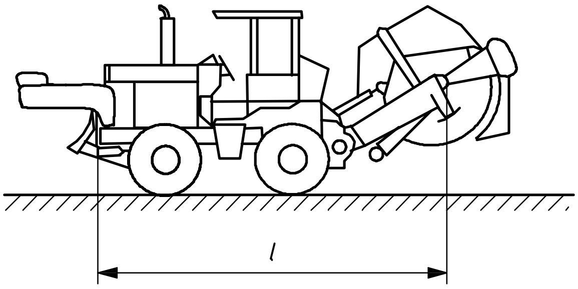


Figure A.26

A.10 Landfill compactors

A.10.1 Landfill compactor with loading equipment

See Figure A.27.

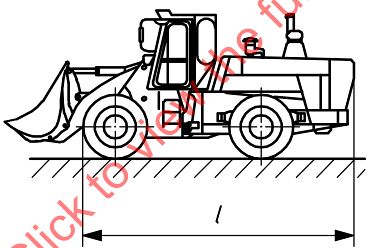


Figure A.27

A.10.2 Landfill compactor with dozing equipment

See Figure A.28.

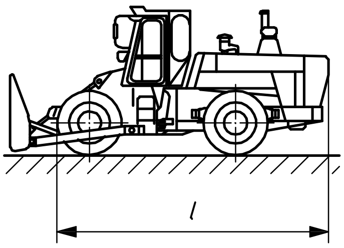
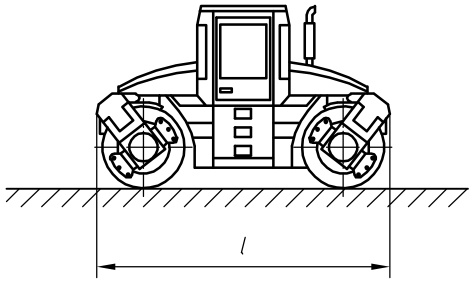


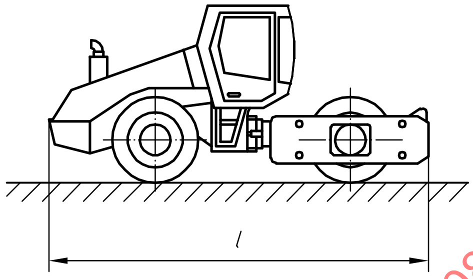
Figure A.28

A.11 Rollers

See Figure A.29.



a) Two drums



b) One drum

Figure A.29

Annex B
(normative)

Excavators (hydraulic or cable-operated)

B.1 Definition

The definition of excavator given in ISO 6165 applies.

B.2 Measuring surface and machine positioning

The machine shall be positioned as specified in 6.3.2. The machine centre point of the excavator is the centre of the rotation of the upper structure.

The measuring surface shall be as specified in 5.3.2.

B.3 Machine set-up

The machine set-up shall be as specified in Clause 7. All actuating movement shall be carried out at maximum velocity but without activating relief valves or contacting the end of travel barriers.

B.4 Machine operation

B.4.1 Basic machine cycle

The dynamic cycle, without moving material, as described in B.4.2 to B.4.5, comprises three 90° swings to the left of the operator and back again, with the machine positioned as specified in 6.3.2.

Each swing shall be from the x-axis to the y-axis, and back to the x-axis. A single cycle consists of three continuous 90° swings to the left and back again, while moving the front end attachment through a complete sequence for each 90° swing and return.

B.4.2 Hoe attachment

The aim of the dynamic cycle is to simulate trench excavation and dumping the material adjacent to the trench. At the beginning of the cycle, the boom and arm shall be adjusted so as to place the bucket at 75 % of the maximum reach with the bucket as close as possible to the ground surface, but not touching the ground. The cutting edge of the bucket in the rolled forward position shall be at an angle of 60° to the test-site measurement surface.

First, raise the boom and simultaneously retract the arm so that the bucket follows the ground surface for 50 % of the remaining boom and arm travel distance. Then, roll back or curl the bucket. Lift the bucket by raising the boom and continue to retract the arm to simulate the adequate clearance (30 % of maximum bucket lift height) needed to swing across the edge of the trench. Execute a 90° swing to the left of the operator. Raise the boom during the swing and extend the arm until the bucket has reached 60 % of maximum boom lift height. Then uncurl the arm until it is 75 % extended. Roll forward or uncurl the bucket until the cutting edge is vertical. Execute a return swing to the starting position, with the boom being lowered and the bucket curled.

Repeat the above sequence of actions two more consecutive times, in order to complete a single dynamic cycle.

B.4.3 Shovel attachment

The aim of the work cycle is to simulate excavation at the height of a high wall. At the beginning of the cycle, with the bucket cutting edge parallel to the ground, the bucket shall be 0,5 m above the test site in the 75 % retracted position.

First, extend the bucket to 75 % of travel while maintaining the original bucket orientation. Then, roll back or curl the bucket, and raise it to 75 % of maximum lift height and 75 % of dipper arm extension. Execute a 90° swing to the left of the operator and, at the end of the swing, actuate the bucket dump mechanism. Execute a return swing to the starting position with the bucket 0,5 m above the test site in the 75 % retracted position.

Repeat the above sequence of actions two more times consecutively, in order to complete a single dynamic cycle.

B.4.4 Grab-type attachment

The aim of the work cycle is to simulate excavation of a pit. At the beginning of the cycle, the grab shall be open and 0,5 m above the test site.

First, close the grab. Then, raise the grab to half of the maximum lift height. Execute a 90° swing to the left of the operator. Open the grab. Execute a return swing while lowering the attachment to the starting position.

Repeat the above sequence of actions two more consecutive times, in order to complete a single dynamic cycle.

For compact excavators, the grab height may be as close as possible to the ground but not touching the ground.

B.4.5 Dragline attachment

The aim of the work cycle is to simulate excavation of a layer in a trench and dumping of the material adjacent to the trench. For the duration of the cycle, the boom shall be positioned at an angle of 40°. The bucket shall hang vertically under the end of the boom and 0,5 m above the test site, without the drag chains touching the ground.

First, retract the bucket to bring it as close as possible to the machine while maintaining the distance of 0,5 m above the test site. When the bucket has been retracted, execute a 90° swing to the left of the operator. Simultaneously, actuate the bucket dump and retract the bucket to the starting position.

Repeat the above sequence of actions two more consecutive times, in order to complete a single dynamic cycle.

Annex C
(normative)

Dozers

C.1 Definition

The definition of dozer given in ISO 6165 applies.

C.2 Measuring surface and machine positioning

The machine shall be positioned as specified in 6.3.1.

The measuring surface shall be as specified in 5.3.2 for wheeled dozers, and in 5.3.3 or 5.3.4 for crawler dozers.

C.3 Machine set-up

The machine set-up shall be as specified in Clause 7.

C.4 Machine operation

C.4.1 Operation mode

The mode of operation of the machine shall be as specified in Clause 7.

C.4.2 Calculation for combined forward and reverse travel mode cycles

Since forward and reverse modes are two distinct modes of operation, both the time and sound pressure levels shall be measured as separate entities for each travel direction. Calculate the time-averaged A-weighted sound pressure level, $L_{pA,T}$, in decibels, for a combined cycle using Equation (C.1):

$$L_{pA,T} = 10\lg \frac{1}{T_1 + T_2}\left(T_1 \times 10^{0,1\, L_{pA,1}} + T_2 \times 10^{0,1\, L_{pA,2}} \right) \text{ dB} \qquad \text{(C.1)}$$

where

T_1	is the time interval for forward travel mode over the specified travel path;
T_2	is the time interval for reverse travel mode over the specified travel path;
$L_{pA,1}$, $L_{pA,2}$	are the quantities determined during time intervals T_1 and T_2.

Annex D
(normative)

Loaders

D.1 Definition

The definition of loader given in ISO 6165 applies.

D.2 Measuring surface machine positioning

The machine shall be positioned as specified in 6.3.1 for travel mode and in 6.3.2 for stationary work cycle mode.

The measuring surface shall be as specified in 5.3.2 for wheeled loaders and in 5.3.3 or 5.3.4 for crawler loaders.

D.3 Machine set-up

The machine set-up shall be as specified in Clause 7.

All actuating movement shall be carried out at maximum velocity but without activating relief valves or contacting the end of travel barriers.

D.4 Machine operation

D.4.1 General

The dynamic cycle is a combination of the travel and stationary work cycle modes.

D.4.2 Travel mode

D.4.2.1 Operation mode

The mode of operation of the machine shall be as specified in Clause 7.

D.4.2.2 Calculation for travel mode

Since forward and reverse are two distinct modes of operation, both the time and sound pressure level shall be measured as separate entities for each travel direction. Calculate the time-averaged A-weighted sound pressure level, $L_{pA,3}$, in decibels, for a combined travel cycle using Equation (D.1):

$$L_{pA,3} = 10 \lg \frac{1}{T_1 + T_2} \left(T_1 \times 10^{0,1\, L_{pA,1}} + T_2 \times 10^{0,1\, L_{pA,2}} \right) \text{ dB} \quad \text{(D.1)}$$

where

T_1 is the time interval for forward travel mode over the specified travel path;

T_2 is the time interval for reverse travel mode over the specified travel path;

$L_{pA,1}$, $L_{pA,2}$ are the quantities determined during the T_1 and T_2 time intervals.

D.4.3 Stationary work cycle mode

The engine shall be operated at its maximum governed speed (high idle). The transmission control shall be set to neutral. Raise the bucket from the carry position to 75 % of maximum lift height and then return to carry position three times. This sequence of actions is considered to be a single cycle for the stationary hydraulic mode.

D.4.4 Calculation for combined travel and stationary work cycle modes

Calculate the time-averaged A-weighted sound pressure level, $L_{pA,T}$, in decibels, for a combined travel and stationary work cycle modes cycle using Equation (D.2):

$$L_{pA,T} = 10 \lg\left(0{,}5 \times 10^{0{,}1 L_{pA,3}} + 0{,}5 \times 10^{0{,}1 L_{pA,4}}\right) \text{ dB} \quad \text{(D.2)}$$

where

$L_{pA,3}$ is the quantity determined in travel mode over the specified path;

$L_{pA,4}$ is the quantity determined with the loader in stationary work cycle mode.

Annex E
(normative)

Backhoe loaders

E.1 Definition

The definition of backhoe loader given in ISO 6165 applies.

E.2 Measuring surface and machine positioning

The machine shall be positioned as specified in 6.3.1 for travel mode and in 6.3.2 for stationary work cycle mode.

The measuring surface shall be as specified in 5.3.2 for wheeled backhoe loaders, and in 5.3.3 or 5.3.4 for crawler type backhoe loaders.

E.3 Machine set-up

The machine set-up shall be as specified in Clause 7. For backhoe operation, the engine rotational speed shall be set as specified by the machine manufacturer.

All actuating movement shall be carried out at maximum velocity but without activating relief valves or contacting the end of travel barriers.

E.4 Machine operation

E.4.1 General

The dynamic cycle is a combination of the travel and stationary work cycle modes for the loader portion of the machine, and of the work cycle mode for the backhoe.

E.4.2 Loader portion — Travel and stationary work cycle modes

Execute the loader mode of operation in accordance with the procedure specified in D.4, with the bucket of the backhoe in a carry position.

E.4.3 Backhoe — Work cycle mode

Execute the backhoe mode of operation in accordance with the procedures specified in B.4.1 and B.4.2, but substituting 45° for each 90° angle specified in those subclauses.

E.4.4 Calculation for combined backhoe and loader cycle

Calculate the time-averaged A-weighted sound pressure level, $L_{pA,T}$, in decibels, for a combined backhoe and loader cycle using Equation (E.1).

$$L_{pA,T} = 10 \lg \left(0{,}8 \times 10^{0{,}1 L_{pA,B}} + 0{,}2 \times 10^{0{,}1 L_{pA,L}} \right) \text{ dB} \qquad \text{(E.1)}$$

where

$L_{pA,B}$ is the quantity determined in the backhoe work cycle mode;

$L_{pA,L}$ is the quantity determined with the operation of the loader portion (travel and stationary work cycle modes).

Annex F
(normative)

Dumpers

F.1 Definition

The definition of dumper given in ISO 6165 applies.

F.2 Measuring surface and positioning of machine

The machine shall be positioned as specified in 6.3.1 for travel mode and 6.3.2 for stationary work cycle mode.

The measuring surface shall be as specified in 5.3.2. for wheeled dumper, and 5.3.3 or 5.3.4 for crawler dumper.

F.3 Machine set-up

The machine set-up shall be as specified in Clause 7.

All actuating movement shall be carried out at maximum velocity but without activating relief valves or contacting the end of travel barriers.

F.4 Machine operation

F.4.1 General

The dynamic cycle is a combination of travel and stationary work cycle modes.

F.4.2 Travel mode

The measurement shall only be made in forward travel mode.

The travel speed shall be as specified in 7.4. If the travel speed as specified in 7.4 cannot be achieved, the maximum speed in the first gear shall be used.

F.4.3 Stationary work cycle mode

The engine shall be operated at its maximum governed speed (high idle). The transmission control shall be set to neutral. Move the dump body from the travel position to 75 % of maximum dump position, then return it to the travel position three times. This sequence of actions is considered to be a single cycle for the stationary work cycle mode. If no engine power is used to dump the body, the engine shall be operated at minimum governed speed (low idle) with the transmission in neutral. The measurement shall be performed without dumping the body, the period of observation shall be 15 s.

F.4.4 Stationary low-idle mode

The engine shall be operated at its minimum governed speed (low idle) in a stabilized no-load condition. The transmission control shall be set to neutral. The total measurement time shall be in the range of 15 s to 30 s. This sequence of actions is considered to be a single cycle for the stationary low-idle mode.

F.4.5 Calculation for combined cycle of travel, stationary work cycle and stationary low-idle modes

Calculate the time-averaged A-weighted sound pressure level, $L_{pA,T}$, in decibels, for a combined travel, stationary work cycle and stationary low-idle modes cycle using Equation (F.1).

$$L_{pA,T} = 10 \lg\left(0{,}8 \times 10^{0{,}1 L_{pA,1}} + 0{,}05 \times 10^{0{,}1 L_{pA,2}} + 0{,}15 \times 10^{0{,}1 L_{pA,3}}\right) \text{ dB} \quad \text{(F.1)}$$

where

$L_{pA,1}$ is the quantity determined in travel mode over the specified path;

$L_{pA,2}$ is the quantity determined with the dumper in stationary work cycle mode;

$L_{pA,3}$ is the quantity determined with the dumper in stationary low-idle mode.

Annex G
(normative)

Graders

G.1 Definition

The definition of grader given in ISO 6165 applies.

G.2 Measuring surface and positioning of machine

The machine shall be positioned as specified in 6.3.1.

The measuring surface shall be as specified in 5.3.2.

G.3 Machine set-up

The machine set-up shall be as specified in Clause 7.

G.4 Machine operation

The measurement shall only be made in forward travel mode.

The travel speed shall be as specified in Clause 7.

Annex H
(normative)

Landfill compactors

H.1 Definition

The definition of landfill compactor given in ISO 6165 applies.

H.2 Measuring surface and positioning of machine

The machine shall be positioned as specified in 6.3.1.

The measuring surface shall be as specified in 5.3.2 or 5.3.3.

H.3 Machine set-up

The machine set-up shall be as specified in Clause 7.

To simplify the operation procedure, landfill compactors may be tested with rubber tyres fitted to enable testing on a hard surface. If machines are tested with steel wheels fitted, a measuring surface as defined in 5.3.3 or 5.3.4 should be used.

H.4 Machine operation

H.4.1 General

The operation mode of the machine shall be as specified in Clause 7.

If the travel speed as specified in 7.4 cannot be achieved, the maximum speed in first gear should be used.

H.4.2 Calculation for travel mode

Since forward and reverse modes are two distinct modes of operation, both the time and the sound pressure level shall be measured as separate values for each travel direction. Calculate the time-averaged A-weighted sound pressure level, $L_{pA,T}$, in decibels, for the combined travel cycle using Equation (H.1).

$$L_{pA,T} = 10 \lg \frac{1}{T_1 + T_2} \left(T_1 \times 10^{0,1 L_{pA,1}} + T_2 \times 10^{0,1 L_{pA,2}} \right) \quad \text{(H.1)}$$

where

T_1 is the time interval for the forward travel mode over the specified travel path;

T_2 is the time interval for the reverse travel mode over the specified travel path;

$L_{pA,1}$, $L_{pA,2}$ are the quantities determined during time intervals T_1 and T_2.

Annex I
(normative)

Trenchers

I.1 Definition

The definition of trencher given in ISO 6165 applies.

I.2 Measuring surface and positioning of the machine

The machine shall be positioned as specified in 6.3.2.

The measuring surface shall be as specified in 5.3.2.

I.3 Machine set-up

The machine set-up shall be as specified in Clause 7.

The boom of the chain-line trencher shall be in the horizontal position.

The wheel disk shall be positioned as close as possible to the ground.

I.4 Machine operation

I.4.1 Chain-line trencher stationary work cycle mode

The drive mechanism for rotating the trenching chain shall be operated at the maximum recommended operating speed with the trenching chain removed.

The total measuring time shall be 15 s to 30 s. This sequence is considered to be a single cycle.

I.4.2 Disk trencher stationary work cycle mode

The disk wheel shall be in operation at no load at the maximum recommended operating speed.

The total measuring time shall be 15 s to 30 s. This sequence is considered as a single cycle.

