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

Reference number
ISO 6395:2008(E)

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Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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.

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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.

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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
$L_{p\mathrm{A},T}$
A-weighted sound pressure level averaged on an energy basis over the whole measurement period, T

3.2
A-weighted sound power level
$L_{W\mathrm{A}}$
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.)

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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.

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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.

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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.

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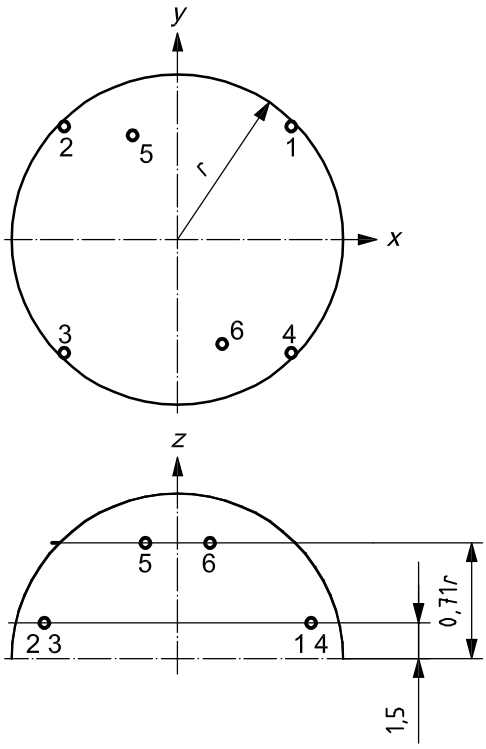
Dimensions in metres



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.

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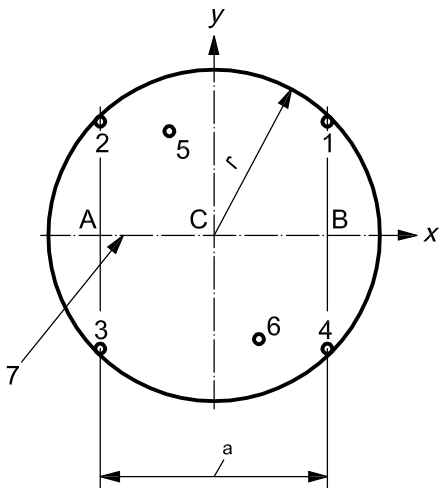
6.3.1 Travel mode

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.

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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):

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

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.

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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_{WA}, in decibels, of the machinery shall be calculated using Equation (2):

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

where

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

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

where

$L_{pA,i}$ 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);

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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;

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