
**Acoustics — Measurement of exterior noise
emitted by earth-moving machinery —
Stationary test conditions**

*Acoustique — Mesurage du bruit émis à l'extérieur par les engins
de terrassement — Conditions d'essai statiques*



Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

International Standard ISO 6393 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*, in collaboration with ISO/TC 127, *Earth moving machinery*.

This second edition cancels and replaces the first edition (ISO 6393:1985), which has been technically revised.

Annex A forms a normative part of this International Standard.

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Introduction

This International Standard is a special test code for specific types of earth-moving machinery.

Specific procedures are described in this special test code to enable the sound power emission in a stationary test to be determined in a manner which is repeatable. Attachments (bucket, dozer, etc.) for the manufacturer's production version are 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. It can also be used for evaluation purposes in noise reduction investigations.

An additional special test code is given in ISO 6394. This other special test code is intended to be used to determine the noise emitted by earth-moving machinery, measured at the operator's position while the machine is stationary, in terms of the equivalent continuous A-weighted sound pressure level.

Corresponding measurements of exterior noise and noise at the operator's position under dynamic test conditions are described in ISO 6395 and ISO 6396, respectively.

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Acoustics — Measurement of exterior noise emitted by earth-moving machinery — Stationary test conditions

1 Scope

This International Standard specifies a method for determining the exterior noise emitted by earth-moving machinery in terms of the A-weighted sound power level while the machine is stationary with the engine operating at rated speed under no-load conditions.

This International Standard is applicable to the following specific types of earth-moving machinery:

- excavators (hydraulic or rope-operated);
- crawler and wheel tractor-dozers;
- crawler and wheel loaders; and
- backhoe loaders.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 3744:1994, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane*.

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

IEC 60651, *Sound level meters*.¹⁾

IEC 60804, *Integrating-averaging sound level meters*.¹⁾

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 3744 and the following apply. For the convenience of users of this International Standard, some definitions are quoted from ISO 6165:1997.

¹⁾ IEC 60651 and IEC 60804 will be replaced by IEC 61672.

3.1**time-averaged A-weighted sound pressure level, $L_{pAeq,T}$** 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}**

A-weighted sound power level obtained from time-averaged A-weighted sound pressure levels averaged over the measurement surface on an energy basis

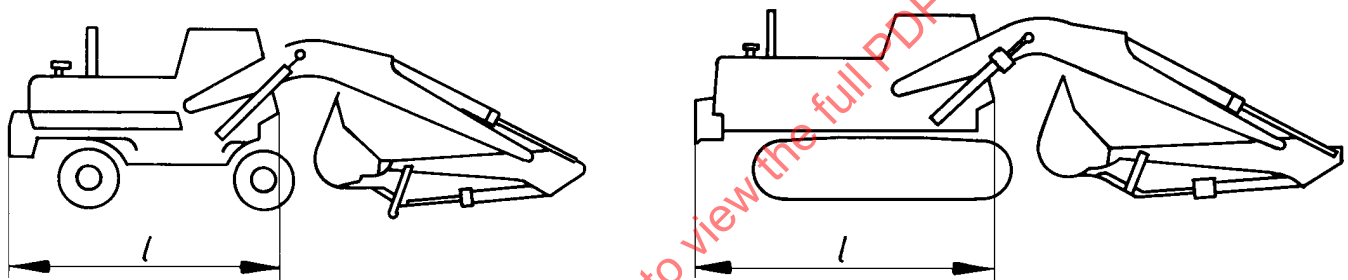
3.3**excavator**

self-propelled machine on crawler, wheels or legs, having an upper structure normally capable of a 360° swing with mounted equipment, primarily designed for excavating with a bucket, without moving the undercarriage during the work cycle

NOTE An excavator work cycle normally comprises excavating, elevating, swinging and discharging material.

[ISO 6165:1997]

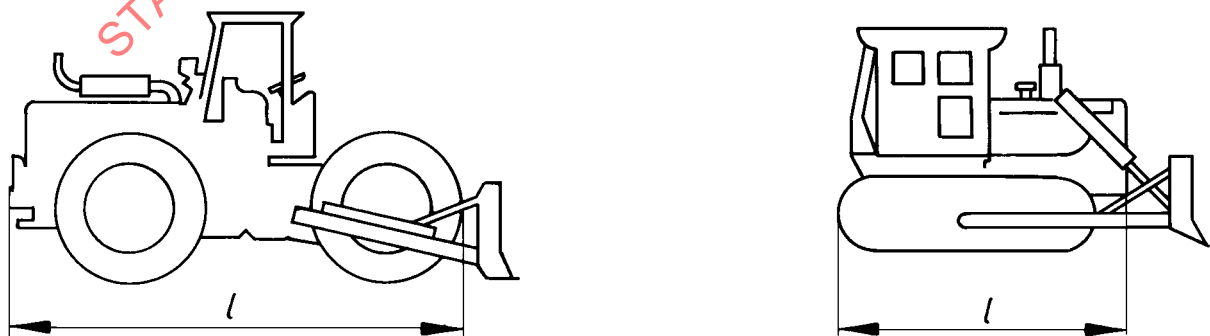
See Figure 1.

**Figure 1 — Excavator****3.4****tractor-dozer**

self-propelled crawler or wheeled machine with equipment having either a dozing attachment which cuts, moves and grades material through forward motion of the machine, or a mounted attachment used to exert a push or a pull force

[ISO 6165:1997]

See Figure 2.

**Figure 2 — Tractor-dozer**

3.5

loader

self-propelled crawler or wheeled machine, having front-mounted equipment primarily designed for loading operation (bucket use), which loads or excavates through forward motion of the machine

NOTE A loader work cycle normally comprises filling, elevating, transporting and discharging material.

[ISO 6165:1997]

See Figure 3.

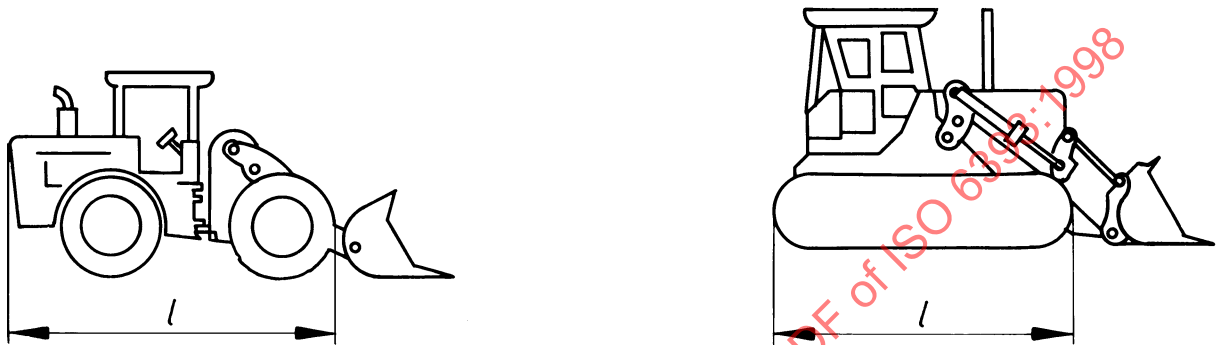


Figure 3 — Loader

3.6

backhoe loader

self-propelled crawler or wheeled machine, having a main frame designed to carry both front-mounted equipment and rear-mounted backhoe equipment (normally with outriggers); when used in the backhoe mode, the machine is stationary and normally digs below ground level; when used in the loader mode (bucket use), the machine loads through forward motion

NOTE A backhoe work cycle normally comprises excavating, elevating, swinging and discharging material. A loader work cycle normally comprises filling, elevating, transporting and discharging material.

[ISO 6165:1997]

See Figure 4.

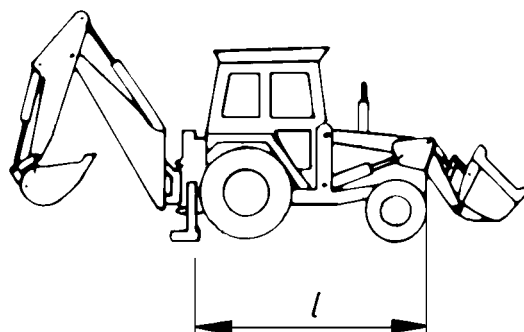


Figure 4 — Backhoe loader

4 Instrumentation

The instrumentation shall be capable of carrying out measurements as described in 8.1. The preferred instrumentation system for acquiring the data is an integrating-averaging sound level meter complying with the

requirements of IEC 60804 for a class 1 instrument. Alternative instrumentation, including the microphone and cable, shall meet the requirements of IEC 60651 for a class 1 instrument.

NOTE The sensitivity to environmental conditions is especially relevant for this type of measurement. It is recommended to ask the manufacturer for evidence that related tests according to IEC 60651 were carried out with a positive result.

5 Test environment

5.1 General

For the purposes of this International Standard, the test environment specified in ISO 3744:1994, clause 4 and annex A, applies. Additional requirements are given in 5.2 to 5.6.

5.2 Test site

5.2.1 General

The following two types of test site surface, described in 5.2.2 and 5.2.3, are allowed:

- a) hard reflecting plane (concrete or sealed asphalt);
- b) combination of hard reflecting plane and sand.

The hard reflecting plane 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.

The combination of hard reflecting plane and sand shall be used for testing crawler dozers and crawler loaders with the machine operating on the sand surface and with the microphone on the hard reflecting plane.

5.2.2 Hard reflecting plane [Test site surface a)]

The test area bordered by the microphones shall consist of concrete or sealed asphalt.

5.2.3 Combination of hard reflecting plane and sand [Test site surface b)]

The travel path on which the machine is placed 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 surface between the machine and the microphones shall be a hard reflecting plane, as described in 5.2.2. This provides a reflecting plane rather than an absorptive surface for the measuring environment.

A minimum size combination site can be used by having just a single reflecting plane with a sand path along the side. In this case, a set of measurements with three microphones shall be carried out on one side of the machine. Another set shall then be carried out for the other side after turning the machine 180°.

5.3 Test site and environmental correction, K_2

For test site surfaces which consist of a hard reflecting plane, such as concrete or sealed asphalt [5.2.1 a) and b)], and with no sound-reflecting obstacles within a distance from the source equal to three times the greatest distance from the source centre to the lower measurement positions (measurement hemisphere radius), it may be assumed that the environmental correction K_2 is less than or equal to 0,5 dB. It is, therefore, negligible and is disregarded.

5.4 Background noise

At each measurement position, background noise shall be at least 10 dB lower than the noise emitted by the machine (both time-averaged and A-weighted).

5.5 Climatic conditions

When precipitation (i.e. rain, snow or hail) is falling or when the ground surface is covered with snow, it is recommended that measurements should not be carried out.

The wind speed shall not exceed 5 m/s.

5.6 Signal devices

Any signal devices, such as forward warning horn or back-up alarm, shall not be activated during this test.

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 (see Figures 1 to 4). The basic length encloses the main body of the machine and excludes major attachments, such as dozer blades, buckets and boom.

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 1,5 m but less than 4 m;
- 16 m when the basic length, l , of the machine to be tested is greater than 4 m.

6.2 Microphone positions on the hemispherical measurement surface

Six measurement positions shall be used. Microphone positions and their coordinates shall be as shown in Figure 5 and given in Table 1.

6.3 Positioning of the machine

6.3.1 Loaders, backhoe loaders and tractor-dozers

The machine centreline shall coincide with the hemisphere centreline which is the intersection of the x - and y -axes shown in Figure 5. The front of the machine shall face microphone positions Nos. 1 and 4. The midpoint of the basic length l (see Figures 2 and 3) is defined as the machine centreline for positioning purposes.

6.3.2 Excavators

The machine centreline shall coincide with the hemisphere centreline which is the intersection of the x - and y -axes shown in Figure 5. The front of the machine shall face microphone positions Nos. 1 and 4. The centre of rotation of the upper structure of the excavator (see Figure 1) is defined as the machine centreline for positioning purposes.

6.4 Measurement time

The total measurement time for each reading at each measurement position in a stabilized operating mode shall be in the range of 15 s to 30 s.

Dimensions in metres

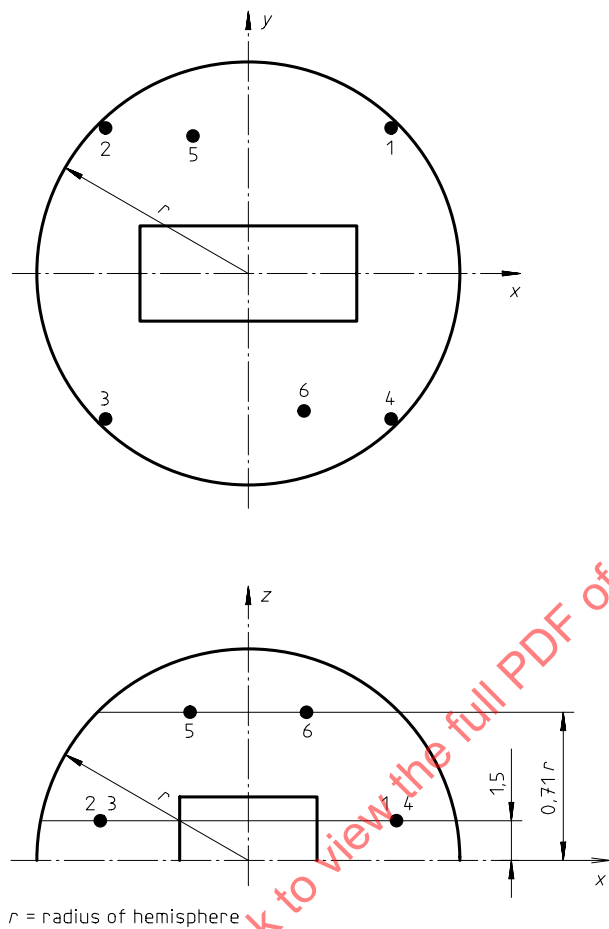


Figure 5 — Microphone array on the hemisphere (see Table 1)

Table 1 — Coordinates for microphone positions

Microphone No.	$\frac{x}{r}$	$\frac{y}{r}$	$\frac{z}{m}$
1	0,7	0,7	1,5
2	− 0,7	0,7	1,5
3	− 0,7	− 0,7	1,5
4	0,7	− 0,7	1,5
5	− 0,27	0,65	0,71 r
6	0,27	− 0,65	0,71 r

7 Setting-up and operation of machinery

See annex A.

The engine shall be brought first to a low idle condition and then up to the manufacturer's specified rated speed at a stabilized no-load condition prior to each data-taking sequence.

8 Acoustic measurements

8.1 Quantities to be measured

The time-averaged A-weighted sound pressure level, $L_{pAeq,T}$, in decibels, is determined either by using equation (1) or by using a digital integration [equation (2)].

$$L_{pAeq,T} = 10 \lg \left[\frac{1}{T} \int_0^T \frac{p_A^2(t)}{p_0^2} dt \right] \text{ dB} \quad \dots (1)$$

where

T is the measurement period, i.e. the period of time for which the machine is operated during the test;

$p_A(t)$ is the instantaneous A-weighted sound pressure of the sound signal;

p_0 is the reference sound pressure (20 μPa).

$$L_{pAeq,T} = 10 \lg \left[\sum_{i=1}^n \frac{t_i}{100} 10^{0,1L_{pAi}} \right] \text{ dB} \quad \dots (2)$$

where

t_i is the numerical value of the percentage of time for the sound pressure level, L_{pAi} , from the whole time interval, T , of the test, with the cell width for L_{pAi} being 1,0 dB or less;

L_{pAi} are the values of A-weighted sound pressure levels obtained with instrumentation complying with the requirements of IEC 60651 for a class 1 instrument and set for the time-weighting characteristics.

8.2 Number of measurements

A minimum of three measurement series at all microphone positions shall be required. In order to meet the requirements specified in 9.3, additional measurement series may be necessary.

9 Calculation of A-weighted sound power level from time-averaged A-weighted sound pressure levels averaged over the measurement surface

9.1 Calculation of time-averaged A-weighted sound pressure level averaged over the measurement surface, $\overline{L_{pAeq,T}}$

The time-averaged A-weighted sound pressure level averaged over the measurement surface, $\overline{L_{pAeq,T}}$, in decibels (reference: 20 μPa), shall be calculated from the measured values of the equivalent continuous A-weighted sound pressure levels by means of the following equation:

$$\overline{L_{pAeq,T}} = 10 \lg \left[\frac{1}{N} \sum_{i=1}^N 10^{0,1L_{pAeqi}} \right] \text{ dB} \quad \dots (3)$$

where

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

N is the total number of microphone positions.

9.2 Calculation of A-weighted sound power level

The A-weighted sound power level, L_{WA} , in decibels, of the machinery shall be calculated using the following equation:

$$L_{WA} = (\overline{L_{pAeq,T}} - K_2) + 10 \lg \frac{S}{S_0} \quad \text{dB} \quad \dots (4)$$

where

S is the area of the measurement surface, in square metres (for a hemispherical measurement surface, $S = 2\pi r^2$);

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

$10 \lg \frac{S}{S_0} = 20$ for 4 m radius, 28 for 10 m radius and 32 for 16 m radius;

K_2 is the environmental correction, in decibels (see annex A of ISO 3744:1994 and 5.3 of this International Standard).

9.3 Determination of measurement result

Calculate at least three values of the sound power level from the three sets of data obtained at all microphone positions (see 8.2). It is necessary to have two of these values within a 1 dB range of each other. The reported value of the A-weighted sound power level will be the arithmetic mean of the two highest values that are within a 1 dB range of each other.

10 Information to be recorded

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

10.1 Machinery under test

- Machine manufacturer.
- Machine model number.
- Serial number.
- Machine arrangement, including major attachments and the manufacturer's specified rated speed which is the speed at which the engine develops rated power in accordance with ISO 9249.

10.2 Acoustic environment

- Description of the test site and the type of test site surface or surfaces used, including a sketch showing the position of the machine.
- Air temperature, barometric pressure, relative humidity and wind velocity at the test site.

10.3 Instrumentation

- Equipment used for the acoustical measurements, including name, type, serial number and manufacturer.
- Method used to calibrate the instrumentation system.
- Data and place of calibration of the sound calibrator and the instrumentation system.