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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

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

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

Reference number
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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 6395 was prepared jointly by Technical Committees ISO/TC 43, *Acoustics* and ISO/TC 127, *Earth-moving machinery*.

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

0 Introduction

This International Standard is a special test code for specific types of earth-moving machinery. It is an extension of ISO 4872 which contains the general requirements for construction equipment.

A simulated dynamic rather than an actual work cycle test condition is chosen. Dynamic test conditions provide acceptable 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 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 6396. This other special test code is intended to be used to determine the noise emitted by earth-moving machinery, with the machine in dynamic test conditions, measured at the operator's position in terms of the equivalent continuous A-weighted sound pressure level.

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.

1 Scope

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

2 Field of application

This International Standard is applicable to the following specific crawler and wheeled types of earth-moving machinery (see also the annexes): excavators (hydraulic or rope-operated), tractors with dozer equipment, loaders, and backhoe loaders (also known as excavator-loaders) (see figures 1 to 4).

3 References

ISO 1585, *Road vehicles — Engines test code — Net power.*

ISO 4872, *Acoustics — Measurement of airborne noise emitted by construction equipment intended for outdoor use — Method for determining compliance with noise limits.* [1)]

ISO 6165, *Earth-moving machinery — Basic types — Vocabulary.*

IEC Publication 651, *Sound level meters.*

IEC Publication 804, *Integrating-averaging sound level meters.*

4 Definitions

For the purposes of this International Standard, the definitions given in ISO 4872, together with the following, apply.

4.1 equivalent continuous A-weighted sound pressure level, $L_{p\text{Aeq},T}$: The A-weighted sound pressure level averaged on a energy basis over the whole measurement period.

4.2 A-weighted sound power level, $L_{W\text{A}}$: The A-weighted sound power level using equivalent continuous A-weighted sound pressure levels averaged over the measurement surface and averaged on an energy basis over the whole measurement period.

5 Instrumentation

The instrumentation shall be capable of carrying out measurements as described in 8.1. Integrating-averaging sound level meters shall meet the requirements of IEC Publication 804 for a type 1 instrument. Alternative instrumentation, including the microphone and cable, shall meet the requirements of IEC Publication 651 for a type 1 instrument.

An omnidirectional microphone shall be used for measurements so as to reduce possible directivity errors. The microphone and its associated cable shall be chosen so that the combined sensitivity does not change significantly over the temperature range encountered during the measurements.

1) Cross-references to specific clauses, sub-clauses, etc. in ISO 4872 apply to the first edition published in 1978.

6 Test environment

6.1 General

The test environment specified in ISO 4872, clause 4 and annex A, applies. Additional requirements for this special test code are given in 6.2 to 6.6.

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

6.2 Test site and environmental correction, K

For test site measurement surfaces which consist of a hard reflecting plane, such as concrete or sealed asphalt [6.3.1 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, is less than or equal to 0,5 dB; it is, therefore, negligible and is disregarded.

For the all-sand test site [6.3.1 c)], an environmental correction K will have to be determined and used in the sound power calculation.

6.3 Test site

6.3.1 General

The following three types of test site measurement surface, described in 6.3.2, 6.3.3 and 6.3.4, are allowed:

a) hard reflecting plane (concrete or sealed asphalt);

b) combination of hard reflecting plane and sand;

c) 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 in the travel mode with the machine operating on the sand surface and with the microphone on the hard reflecting plane.

An alternative test site consisting of all sand may be used for testing crawler dozers and crawler loaders in the travel mode and stationary hydraulic mode, provided that:

1) the environmental correction, K, determined in accordance with ISO 4872, annex A, is less than 3,5 dB;

2) if K is greater than 0,5 dB the correction is accounted for in the calculation of the sound power level.

6.3.2 Hard reflecting plane (Test site measurement surface a)

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

6.3.3 Combination of hard reflecting plane and sand (Test site measurement surface b)

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 surface between the machine and the microphone shall be a hard reflecting plane, as described in 6.3.2. 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. Then operate the machine in a forward travel mode twice but in opposite directions for each of the three microphone positions. The reverse travel mode can be done in the same manner.

6.3.4 All-sand site (Test site measurement surface c)

The sand shall be as specified in 6.3.3.

6.4 Background noise

Background noise at each measurement position shall be at least 10 dB lower than the noise emitted by the machine.

6.5 Climatic conditions

Measurements shall not be carried out under the following conditions:

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

b) when ground surface is covered with snow;

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

d) when 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 effects of its use shall be allowed for in the calibration.

7 Measurement of equivalent continuous A-weighted sound pressure levels

7.1 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, 2, 3 and 4).

The basic length of the machine is equal to:

— for excavators: the total length of the upper structure, excluding attachments, main structural moving members such as boom and stick;

— for other machines: the total length of the machine, excluding attachments such as dozer blades and bucket.

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.

7.2 Microphone positions on the hemispherical measurement surface

There shall be six measurement positions, i.e. positions 2, 4, 6, 8, 10 and 12, arranged as defined in 7.2.3, alternative B, of ISO 4872. The microphone array and coordinates shall be as shown in figure 5.

7.3 Travel path and positioning of the machine

7.3.1 Travel path: for tests on all machines except for tests

— **on excavators** (see 7.3.2)

— **in the backhoe mode of operation for backhoe loaders** (see 7.3.3)

— **in the stationary hydraulic cycle mode of operation** (see 7.3.4)

The travel path of the machine is shown in figure 6. The centreline of the machine travel shall be the x-axis and the longitudinal axis of the machine shall coincide with this axis. The travel path length shall be AB, which is equal to 1,4 times the hemisphere radius (see ISO 4872). The centre of the travel path shall be along the x-axis. 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 6. The machine forward travel mode shall be from A to B and the reverse travel mode shall be from B to A.

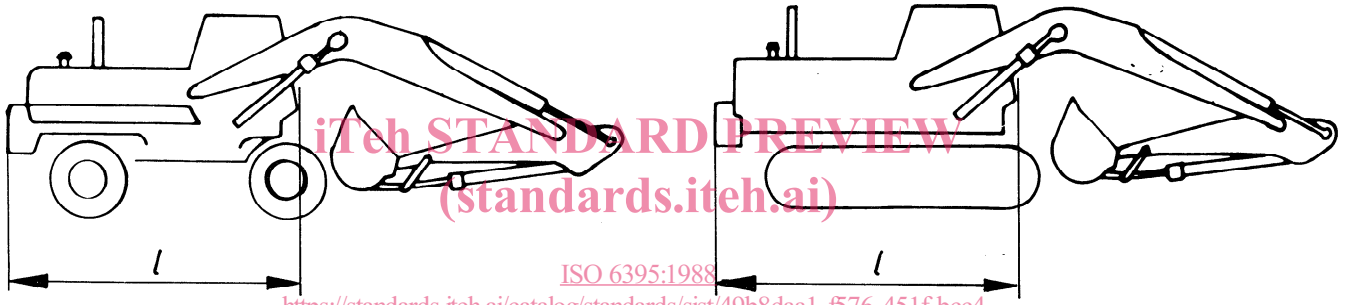


Figure 1 — Excavator

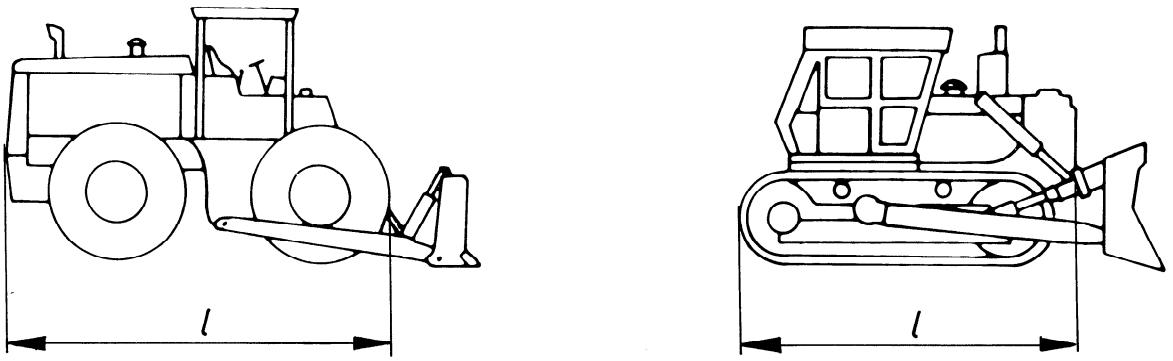


Figure 2 — Tractor with dozer equipment

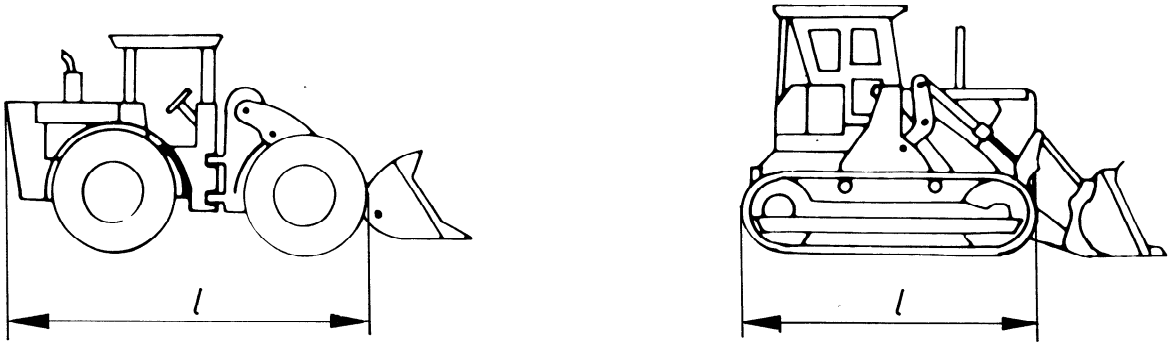


Figure 3 — Loader

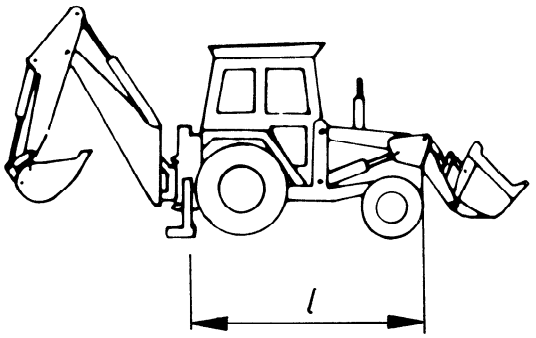
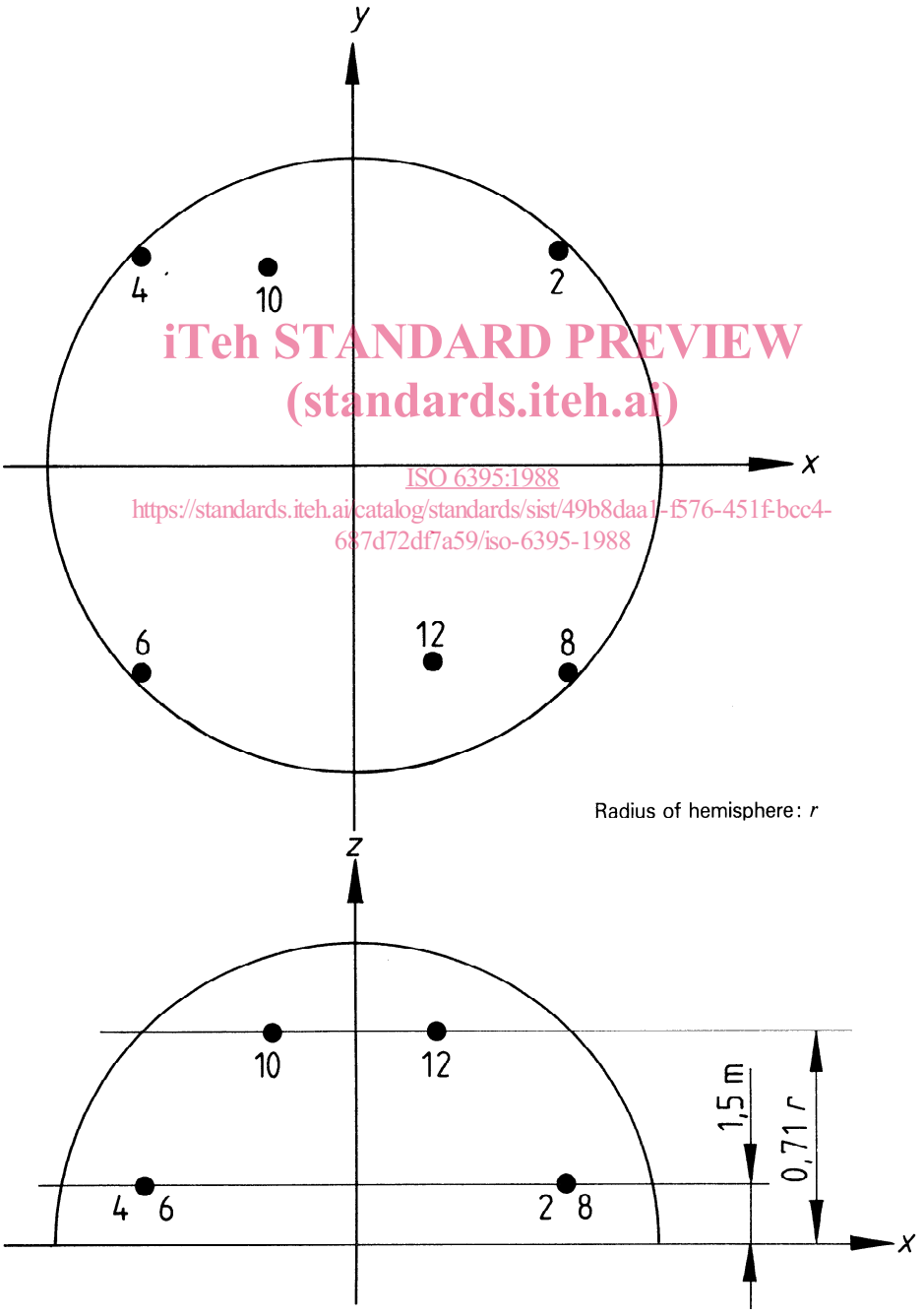


Figure 4 — Backhoe loader



NOTE — For the coordinates of the six measurement positions, see ISO 4872, table 2 (alternative B).

Figure 5 — Microphone array on the hemisphere

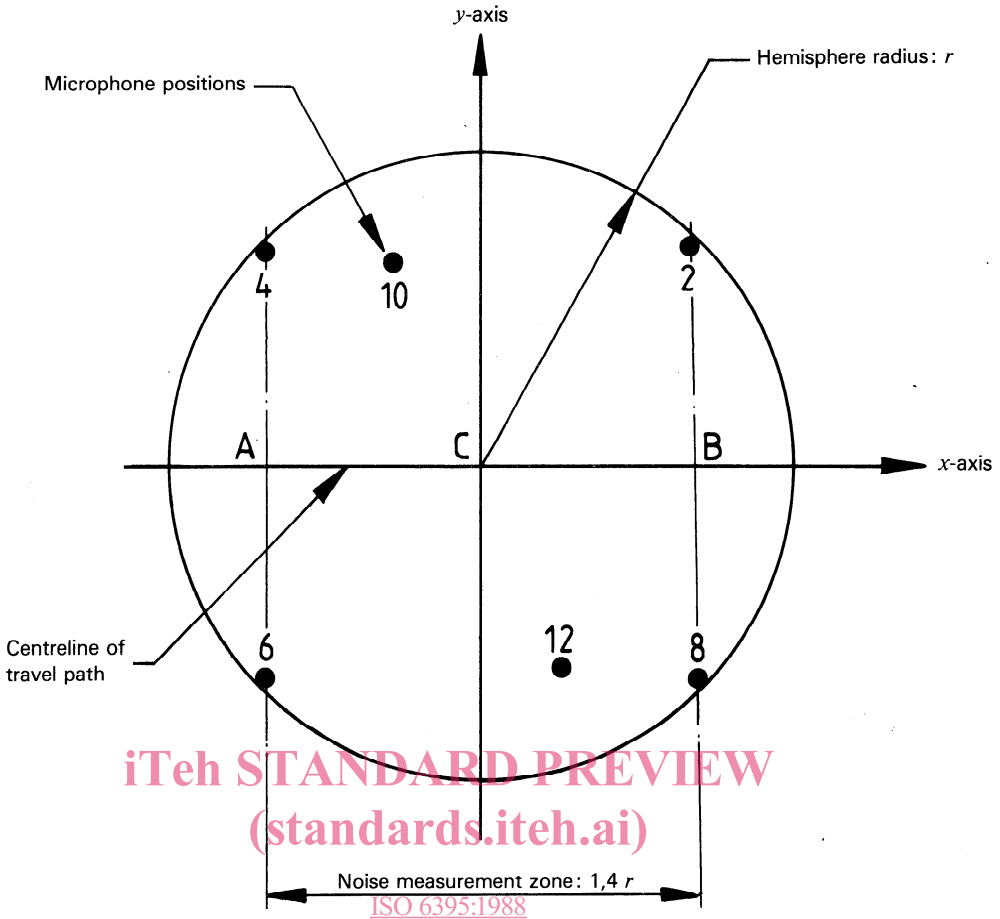


Figure 6 — Travel path

7.3.2 Positioning of the machine: for tests on excavators

The centre of rotation of the upper structure of the excavator in figure 1 is defined as the machine centre for the purpose of locating the machine. This centre shall coincide with the centre of the hemisphere, C, in figure 6. The longitudinal axis of the machine shall coincide with the x-axis and the front of the machine shall face direction B. Machine operation where the machine is positioned is specified in annex A.

7.3.3 Positioning of the machine: for tests in the backhoe mode of operation for backhoe loaders

The longitudinal axis of the machine shall coincide with the x-axis and the front of the machine shall face direction A, i.e. the backhoe part of the backhoe loader in figure 4 shall face direction B. The mid-point of the basic length, l, in figure 4 shall coincide with the centre of the hemisphere, C, in figure 6. Machine operation where the machine is positioned is specified in annex D.

7.3.4 Positioning of the machine: for tests on all loaders in the stationary hydraulic mode of operation

The longitudinal axis of the loader shall coincide with the x-axis and the front of the machine shall face direction B. The mid-point of the basic length, l, in figure 3 shall coincide with the centre of the hemisphere, C, in figure 6. Machine operation where the machine is positioned is specified in annex C.

8 Acoustic measurements

8.1 Measuring instrumentation

The preferred instrumentation system for acquiring the data is an integrating-averaging sound level meter complying with the requirements of IEC Publication 804 for a type 1 instrument. The equivalent continuous A-weighted sound pressure level, $L_{pAeq,T}$, in decibels, is determined either by using the following equation:

$$L_{pAeq,T} = 10 \lg \left[\frac{1}{T} \int_0^T \frac{p_A^2(t)}{p_0^2} \mathrm{d}t \right] \quad \ldots (1)$$

where

T is the measurement period, i.e. the period of time for which the machinery 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);

or, alternatively, by digital integration using the following equation:

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

where

$\frac{t_i}{100}$ 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 cell width for L_{pAi} being 1 dB or less,

L_{pAi} are the values of the A-weighted sound pressure level obtained with instrumentation complying with the requirements of IEC Publication 651 for a type 1 instrument and set for the time-weighting characteristic S.

8.2 Number of dynamic cycles

Three dynamic cycles shall be carried out resulting in three measurements to be taken at each of the six microphone positions. In order to meet the requirements laid down in 9.3, additional dynamic cycles may be necessary.

9 Calculation of A-weighted sound power level using equivalent continuous A-weighted sound pressure levels averaged over the measurement surface

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

The equivalent continuous 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 using the following equation:

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

where

L_{pAeqi} is the equivalent continuous A-weighted sound pressure level resulting from the ith microphone position, in decibels (reference: 20 µPa);

N is the total number of microphone positions (for this test method, six 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:

$$L_{WA} = \overline{L_{pAeq,T}} - K + 10 \lg \frac{S}{S_0} \quad \ldots (4)$$

where

K is the environmental correction (see 6.2 and 6.3.1);

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

$S_0 = 1\ m^2$;

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

9.3 Determination of measurement result

Calculate the three values of the sound power level from the three sets of data obtained at all microphone positions (see 8.2). If two of the three values so obtained do not differ by more than 1 dB, further measurements are not necessary. If this is not the case, continue taking measurements until two values within 1 dB of each other are obtained. Report, as the value of the A-weighted sound power level, the arithmetic mean of the two highest values that are within 1 dB of each other.

10 Information to be recorded

10.1 Machinery under test

The following information shall be recorded:

a) the machine manufacturer;

b) the machine model number;

c) the serial number;

d) the machine arrangement, including major attachments, the engine speed at maximum governor position (high idle) and the gear ratios or control settings.

10.2 Acoustic environment

The following information shall be recorded:

a) a description of the test site and the type of test site measurement surface(s) used, including a sketch showing the position of the machine;

b) the air temperature, barometric pressure, relative humidity and wind speed at the test site.

10.3 Instrumentation

The following information shall be recorded:

a) the instrumentation used for the measurements, including name, type, serial number and manufacturer;

b) the method used to calibrate the instrumentation system;

c) the date and place of calibration of the acoustical calibrator.

10.4 Acoustical data

The following information shall be recorded:

a) the location of the microphones;

b) the equivalent continuous A-weighted sound pressure level at each microphone position for each measurement carried out in accordance with 8.2;

c) the A-weighted sound pressure level of the background noise at each microphone position; all intermediate results, such as sound pressure and area calculation, shall be expressed to one decimal point;

d) the equivalent continuous A-weighted sound pressure level averaged over the measurement surface, calculated in accordance with 9.1;

e) the A-weighted sound power level calculated in accordance with 9.2.

11 Information to be reported

The following information shall be reported:

a) the A-weighted sound power level, determined in accordance with 9.3, rounded to the nearest whole number ($<0{,}5$, use lower number; $\geqslant 0{,}5$, use higher number);

b) the machine manufacturer, model number, serial number, net power, in kilowatts, as defined in ISO 1585, machine arrangement, including major attachments, and the type of test site measurement surface used;

c) the engine speed at maximum governor control position (high idle) with the machine stationary and transmission in neutral.

12 Bibliography

ISO 6393, *Acoustics — Measurement of airborne noise emitted by earth-moving machinery — Method for determining compliance with limits for exterior noise — Stationary test condition.*

ISO 6394, *Acoustics — Measurement of airborne noise emitted by earth-moving machinery — Operator's position — Stationary test condition.*

ISO 6396, *Acoustics — Measurement of noise emitted by earth-moving machinery at the operator's position — Simulated work cycle test conditions.*