BRITISH STANDARD

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1985

Measurement of airborne noise from hydraulic fluid power systems and components —

Part 5: Simplified method of determining sound power levels from pumps using an anechoic chamber

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Machinery and Components Standards Committee (MCE/-) to Technical Committee MCE/18, upon which the following bodies were represented:

Association of British Mining Equipment Companies
Association of Hydraulic Equipment Manufacturers
British Compressed Air Society
British Hydromechanics Research Association
British Steel Corporation
British Telecommunications
Department of Trade and Industry (National Engineering Laboratory)
Electricity Supply Industry in England and Wales
Federation of Manufacturers of Construction Equipment and Cranes
Health and Safety Executive
Institution of Mechanical Engineers
Machine Tool Industry Research Association
Ministry of Defence
National Coal Board

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Bath University
Institution of Production Engineers

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Contents

Foreword

This Part of BS 5944 has been prepared under the direction of the Machinery and Components Standards Committee and is one of a group of British Standards related to the measurement of noise emanating from hydraulic fluid power systems and components.

It is intended that this standard will unify testing methods and enable the performance of different pumps to be compared on a common basis.

The standard comprises the following Parts.

— *Part 1: Method of test for pumps;*

— *Part 2: Method of test for motors;*

— *Part 3: Guide to the application of Part 1 and Part 2;*

— *Part 4: Method of determining sound power levels from valves controlling flow and pressure.*

Further Parts are planned.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 8, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

0 Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure in a closed circuit. Pumps are components which convert rotary mechanical power into fluid power. During the process of converting mechanical power into hydraulic fluid power, airborne noise, fluid-borne vibrations and structure-borne vibrations are radiated from the pump.

The airborne noise level of a hydraulic fluid power pump is an important consideration in component selection. The noise measurement technique should, therefore, be such as to yield accurate appraisals of these airborne noise levels. The determination of noise levels is complicated by the interactions which occur during noise measurement. The fluid-borne and structure-borne vibrations from the pump can be transmitted to the circuit and ultimately give rise to background airborne noise levels which could affect the determination of the pump airborne noise levels.

The procedures described in this Part of BS 5944 are intended to measure only the airborne noise radiated directly from the pump under test.

This standard closely follows the methods described in BS 5944-1 and BS 5944-2 but allows the use of alternative pump mounting and drive configurations which are simpler and cheaper to implement in an anechoic chamber. Much of the guidance given in BS 5944-3 is equally applicable to this standard. The data obtained has been shown to be sufficiently accurate in industrial terms for frequency A weighted, octave and 1/3 octave noise measurements.

1 Scope

This Part of BS 5944 describes procedures for the determination of the sound power levels of a hydraulic fluid power pump, under controlled conditions of installation and operation, suitable for providing a basis for comparing the noise levels of pumps in terms of:

a) A-weighted sound power level;

b) octave band sound power levels.

From these sound power levels, sound pressure levels may be calculated for reporting purposes (see clause **11**).

For general purposes, the frequency range of interest includes the octave bands with centre frequencies between 125 Hz and 8 000 Hz.

This method is applicable to all types of hydraulic fluid power pumps operating under steady-state conditions, irrespective of size, except for any limitations imposed by the size of the test environment (see clause **4**).

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 5944, the definitions given in BS 661 apply together with the following.

2.1
free sound field

a sound field produced in a homogeneous, isotropic medium free of boundaries

NOTE In practice, it is a field in which the effects of the boundaries are negligible over the frequency range of interest.

2.2
free-field over a reflecting plane

a field produced by a source in the presence of one reflecting plane on which the source is located

2.3
free-field over two reflecting planes

a field produced by a source in the presence of two mutually perpendicular reflecting planes

2.4
anechoic room

a test room having boundaries which absorb essentially all of the incident sound energy over the frequency range of interest, thereby affording free-field conditions over the measurement surface

2.5
mean-square sound pressure

the sound pressure averaged in space and time on a mean-square basis

NOTE In practice, this is estimated by space and time averaging over a finite path length or over a number of fixed microphone positions.

2.6
mean sound pressure level (L_p)

ten times the logarithm to the base 10 of the ratio of the mean-square sound pressure to the square of the reference sound pressure in decibels (dB)

NOTE The weighting network or the width of the frequency band used should always be indicated; for example, A-weighted sound pressure level, octave band sound pressure level. The reference sound pressure is 20 µPa.

2.7
sound power level (L_w)

ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power in decibels (dB)

NOTE The weighting network or the width of the frequency band used should always be indicated. The reference sound power is 1 pW.

2.8
volume of source under test

the volume of the envelope of the whole pump under test

3 Measurement uncertainty

With the exception of the measurement environment specified in **4.1**, use methods of measurement which tend to result in standard deviations which are equal to or less than those given in Table 1. To meet this requirement the engineering methods given in clause **4** and Appendix A of BS 4196-4:1981 shall be used.

4 Test environment

4.1 Conduct the tests in an environment generally in accordance with that described in BS 4196-4 and which provides "free-field" conditions over two mutually perpendicular reflecting planes, at least one of which extends beyond the projected area of the microphone measuring array.

NOTE The other reflecting surface, which will usually be formed by an acoustic enclosure over the pump mounting, may be smaller if required.

Table 1 — Standard deviation of sound power level determination

Octave band centred on frequency of	Standard deviation
Hz	dB
125	5.0
250	3.0
500	2.0
1 000 to 4 000	2.0
8 000	3.0

NOTE 1 The standard deviations include the effects of allowable variations in the positioning of the measurement points and in the selection of any prescribed measurement surface, but exclude variations in the sound power output of the source from test to test.
NOTE 2 The A-weighted sound power level will, in most practical cases, be determined with a standard deviation of approximately 2 dB.

4.2 Calibrate the acoustic test environment thus formed by the substitution technique.

NOTE A reference sound source meeting the requirements of BS 4196-00[1)] may be used for calibration purposes.

Ascertain the environmental corrections for each frequency band of interest (see **10.4**).

5 Instrumentation

5.1 Use instrumentation to measure fluid flow, fluid pressure, pump speed and fluid temperature in accordance with the recommendations for "industrial class" accuracy of testing, i.e. class C given in Appendix A.

5.2 Use type 2 instruments for acoustical measurements in accordance with BS 5969. This instrumentation shall be in accordance with BS 4196-4 for both performance and calibration.

6 Installation conditions for pump

6.1 Pump location

Locate the pump with its mounting flange flush with one reflecting plane. Arrange the second reflecting plane to intersect the first at right angles as close to the pump as practicable.

6.2 Pump mounting

6.2.1 Use a method of mounting the pump that will minimize the noise radiated as a result of pump vibrations.

6.2.2 Construct the mounting bracket of high damping material, or with sound damping and sound insulating material applied to the bracket as required.

6.2.3 If necessary, employ vibration isolation techniques, even if the pump is securely mounted.

6.3 Pump drive

Locate the drive motor outside the test space and drive the pump through flexible couplings and an intermediate shaft or isolate the motor in an acoustic enclosure.

6.4 Hydraulic circuit

6.4.1 Include in the circuit all oil filters, oil coolers, reservoirs and restrictor valves as required to meet the pump hydraulic operation conditions (see clause **7**).

6.4.2 Use test fluid and filtration in accordance with the manufacturer's recommendations.

6.4.3 Install inlet and discharge lines having bores in accordance with the manufacturer's recommended practice. Exercise extra care when assembling inlet lines to prevent air leaking into the circuit.

6.4.4 Mount the inlet pressure gauge at the same height as the inlet fitting or calibrate for any height difference.

[1)] In preparation. In the meantime ISO/DIS 3748, prepared by the International Organization for Standardization, may be used.

6.4.5 Select the lengths of pipe between the pump and the load valve which minimize setting up standing waves in the discharge line which can increase the sound radiated from the pump.

NOTE It has been found that a long length of hydraulic hose can minimize standing wave effects.

6.4.6 Use a stable load valve.

NOTE Unstable load valves in the discharge line can generate and transmit noise through the fluid and piping which can emerge as airborne sound at the pump.

6.4.7 Position the load valve as far as possible from the pump, preferably outside the test room, to minimize interaction. Locate the load valve close to the pump only when adequate control of its acoustic performance can be provided.

6.4.8 Enclose all fluid lines and load valves in the test space within acoustic ducts and enclosures, as required, to meet the specified background noise suppression (see **9.1**). Use enclosures having a sound transmission loss of at least 10 dB at 125 Hz and greater loss at higher frequencies.

7 Operating conditions

7.1 Determine the sound power levels of the pump for any desired set of operation conditions (see **10.4**).

7.2 Maintain these test conditions during the test within the limits given in Table 2.

7.3 Test the pump in the "as delivered" condition together with any integral ancillary pumps and valves operating normally during the test, so as to include their noise contributions to the airborne noise level of the pump.

Table 2 — Allowable variations in test conditions

Test parameter	Allowable variation
Flow	± 2 %
Pressure	± 2 %
Speed	± 1 %
Temperature	± 2 °C

8 Location and number of sound measuring points

Provide and locate measuring microphones in a quadrispherical array in accordance with Appendix B. Centre the quadrispherical array at the intersection of the two reflecting planes, on the projected centre line of the pump.

9 Test procedure

9.1 Background noise measurements

9.1.1 Measure the background noise over the frequency range of interest that is present during the pump noise test which does not emanate from the pump itself.

NOTE Over the frequency range of interest, the band sound pressure levels of this background noise should be at least 6 dB below the pump band sound pressure levels at each measurement point.

9.1.2 Correct for this background noise, if evidenced by measurement, by applying the corrections for this purpose given in BS 4196-4.

9.1.3 When measuring band levels of background noise is not practical, ensure that the A-weighted background sound level of each measurement point is at least 6 dB below the pump A-weighted sound level. Correct these A-weighted measurements for background noise.

NOTE 1 Easing the requirements for background noise levels can lead to an overestimate of the pump band sound pressure levels.

NOTE 2 The A-weighted background sound level at each measurement point may be checked by covering the pump with sound insulating materials capable of a transmission loss of at least 10 dB over the frequency range which is "determining" the A-weighted sound level of the pump.

9.1.4 If the background level is found to be too high, check for further noise control of the pump mounting, drive or hydraulic circuit as indicated.

9.1.5 Ensure that the orientation of the microphones and the period of observation are as specified in BS 4196-4.

9.2 Pump measurements

9.2.1 *General.* Prior to commencement of a series of tests, operate the pump for a sufficient time to purge air from the system and to stabilize all variables, including fluid condition, to within the limits given in Table 2.

Measure the following for each test:

a) pump speed and flow rate;

b) fluid temperature and pressure at pump inlet and fluid pressure at discharge fittings, or at the test point provided by the pump manufacturer;

c) band sound pressure levels at each measurement point over the frequency range of interest;

d) A-weighted sound level at each measurement point, if required by the relevant British Standard.

9.2.2 ***New or rebuilt pumps***

9.2.2.1 Repeat the initial pump measurement test of the series at the end of a test series or after 1 h of testing.

9.2.2.2 Invalidate the whole test series if the A-weighted sound level at any selected measurement point does not duplicate that of the first test within 2 dB(A).

10 Calculation of pump mean sound pressure levels and sound power levels

10.1 Calculate the mean pump sound pressure levels by the method described in BS 4196-4. Do not apply the room correction factor K in this calculation as it is taken into account in **10.4**.

10.2 Correct the measured band sound pressure levels (and A-weighted sound levels where appropriate) at each measurement position for the measured background noise (background noise corrections).

10.3 Use these corrected levels to calculate the pump mean band sound pressure levels and mean A-weighted sound pressure level.

10.4 Calculate the pump sound power level by making the corrections described in Appendix C.

11 Calculation of mean sound pressure level at a reference distance

Calculate the mean sound pressure level at a reference distance by the method described in Appendix D.

12 Information to be recorded

12.1 General information

a) name and address of pump manufacturer and, if applicable, user;

b) reference number(s) for identification of the pump;

c) name and address of persons or organization responsible for the acoustic tests on the pump;

d) date and place of acoustic tests;

e) a statement that the sound power levels of the pump have been obtained in full conformance with this British Standard, i.e. BS 5944-5.

12.2 Description of pump

a) type of pump (e.g. gear, piston), including ancillary equipment;

b) type of displacement (e.g. fixed or variable);

c) pump overall linear dimensions (with sketch if necessary);

d) pump maximum displacement;

e) type of displacement controller and setting.

12.3 Acoustic environment for tests

a) the test room internal dimensions and the type of acoustic field for the measurements (e.g. free-field over two reflecting planes);

b) the test room acoustic treatment;

c) ambient temperature (in °C), relative humidity (in %) and barometric pressure (in mbar);

d) results of acoustical qualification of test environment as required by BS 4196-4.

12.4 Reference sound source

a) manufacturer, type and serial number;

b) sound power level calibration data including name of calibrating laboratory and date of calibrations.

12.5 Mounting and installation conditions of pump

a) description of pump mounting conditions;

b) nature and characteristics of hydraulic circuit and details of any acoustic insulation treatment;

c) nature and description of other machines being used which could have an influence on the measured sound pressure levels of the pump.

12.6 Location of pump in test environment

A sketch showing the location of the pump in relation to walls, floor and ceiling of test room, and also showing the location of other reflecting or absorbing screens and noise sources which can influence measurements.

12.7 Instrumentation

a) details of equipment used to monitor pump operating conditions (see **12.8**), including type, serial number and manufacturer;

b) details of equipment used for acoustic measurements including name, type, serial number and manufacturer;

c) bandwidth of frequency analyzer;

d) overall frequency response of instrumentation system and date and method of calibration;

e) method of calibration of microphones and date and place of calibration.

12.8 Pump operating conditions

For each test:

a) full description of fluid, including classification in accordance with BS 6413-4;

b) fluid viscosity classification in accordance with BS 4231 (in mm^2/s [2]);

[2] 1 mm^2/s = 1 cSt.

c) shaft speed (r/min);

d) inlet pressure (in bar);

e) outlet pressure (in bar);

f) pump delivery (flow), either measured or calculated (in L/min);

g) temperature of fluid at pump inlet (in °C).

12.9 Acoustical data

All data as required by BS 4196-4.

13 Test report

The test report shall contain the following information:

a) the A-weighted sound power level and octave band sound power levels for each frequency band of interest for each set of operating conditions;

b) a statement that the sound power levels have been obtained in full conformance with the procedures of this British Standard, i.e. BS 5944-5, and the specified paragraphs of BS 4196-4.

Appendix A Errors and classes of measurement

A.1 Classes of measurement

Depending on the accuracy required, the tests described in BS 5944-1 and BS 5944-2 may be carried out to one of three classes of measurement, A, B or C; the classes of measurement being agreed between the parties concerned. The use of class A and class B is restricted to special cases where there is a need to have the performance more precisely defined. Such tests require more accurate apparatus and methods, possibly increasing the costs of such tests. This Part of BS 5944, however, specifies class C accuracy.

A.2 Errors

Use any device or method that by calibration or comparison with British Standards has been demonstrated to be capable of measuring with systematic errors not exceeding the limits for class C given in Table 3.

Table 3 — Permissible systematic errors of measuring instruments as determined during calibration

Class of measurement	Units	A (see **A.1**)	B (see **A.1**)	C
Flow	%	± 0.5	± 1.5	± 2.5
Pressure	%	± 0.5	± 1.5	± 2.5
Temperature	°C	± 0.5	± 1.0	± 2.0

NOTE The percentage limits are of the value of the quantity being measured and not of the maximum values of the test or the maximum reading of the instrument.

Appendix B Reference dimensions, axes and location of sound measuring points

B.1 Reference box

The maximum size of the pump for a particular quadrispherical measuring array of radius r (in m) is defined by a hypothetical reference box (rectangular parallelepiped) that just enclosed the pump and terminates on the reflecting planes. This reference box should enclose the whole pump body and any large directly attached appendages such as valve bodies or control hand wheels. The acoustic enclosures around the fluid lines and mount (if fitted) should also extend to within this box.

The locations of the reference box, the reflecting planes and the microphone array are defined by a coordinate system with the horizontal axes X and Y in the ground reflecting plane and with the vertical axis Z passing through one end of the box along the plane of the second, perpendicular reflecting plane. The characteristic dimension of the reference box D_0 (in m) is the distance from the origin of the coordinate system to one of the upper corners of the box, remote from the mounting flange and is given by the following equation.

$$D_0 = [l_1^2 + (0.05\ l_2)^2 + l_3^2]^{1/2} \qquad (1)$$

where

- l_1 is the length of the reference box (in m);
- l_2 is the width of the reference box (in m);
- l_3 is the height of the reference box (in m).

This hypothetical box and its relationship to the coordinate system, reflecting planes and the measuring array is shown in Figure 1.

B.2 Quadrispherical microphone array

Pump noise is usually dominated by pure tones; such discrete frequencies can cause measurement inaccuracies due to interference patterns or standing waves set up by the interaction of directly radiated and reflected sound within the measurement environment. The quadrispherical array of microphones located on the coordinates given in Table 4 minimizes the likelihood of error in estimating the spatial average sound pressure level due to this problem.

Table 4 — Coordinates of microphone locations

Microphone no.[a]	Coordinate		
	X^b r	Yt r	Z^b r
1	0.74	– 0.63	0.22
2	0.93	– 0.32	0.20
3	0.91	0.29	0.31
4	0.70	0.59	0.41
5	0.16	0.87	0.45
6	0.21	– 0.90	0.38
7	0.39	– 0.58	0.71
8	0.74	– 0.04	0.67
9	0.29	0.48	0.83
10	0.13	– 0.05	0.99

[a] Normally ten measurement locations will be adequate, but this figure may be reduced if it can be shown that the maximum difference between individual samples does not exceed the number of sample points for the frequency band of interest. It will be found that this alternative is more difficult to achieve as the frequency band width is reduced.
[b] Where the radius of the microphone array $r \geqslant 2D_0$ and = 1 m, 2 m or 4 m.

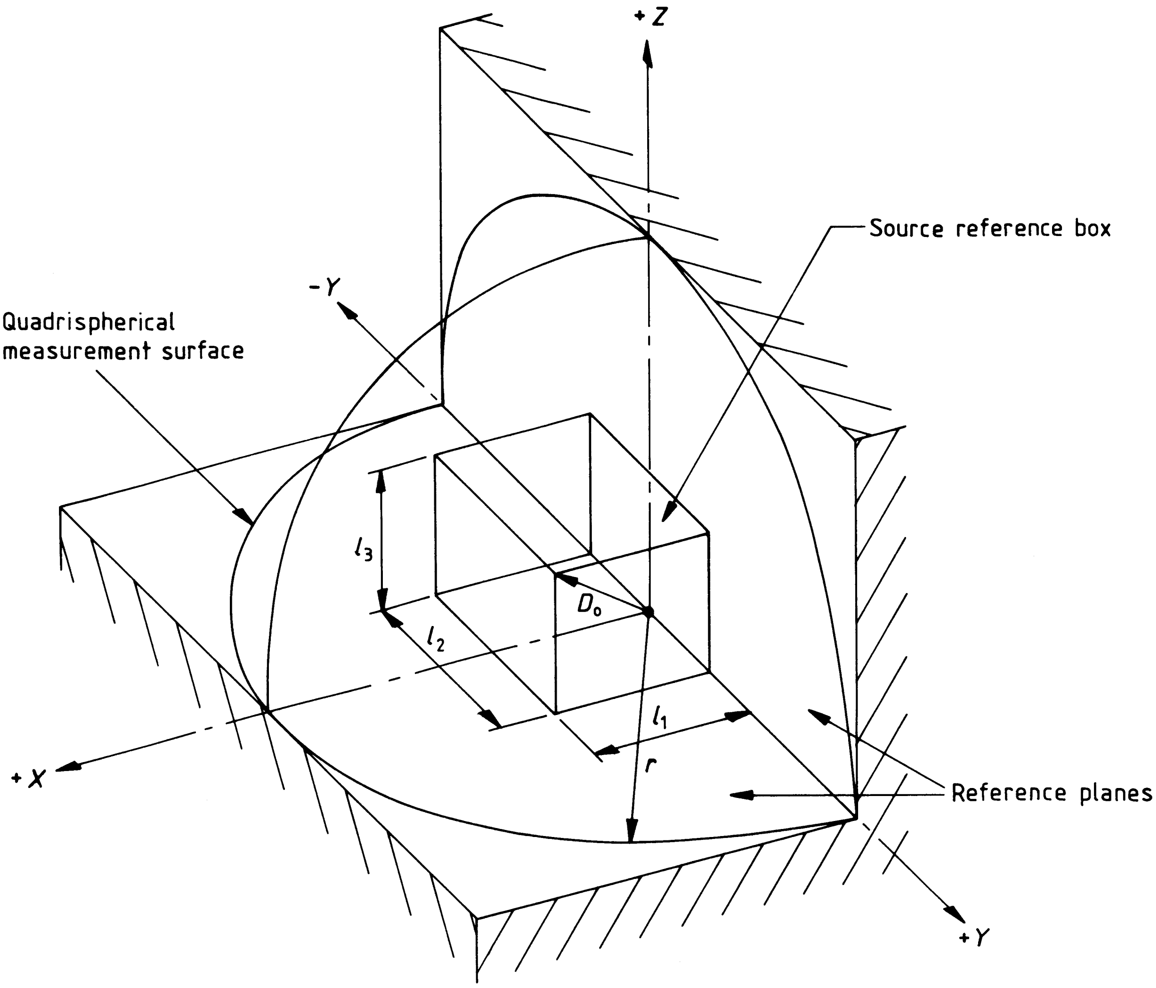

Figure 1 — Key reference axes and dimensions

Appendix C Corrections for pump sound power level

The corrected pump sound power level L_w (in dB; reference 1 pW) may be estimated from the following equation.

$$L_w = \overline{L}_p + 10 \log_{10} (S/S_0) + K \quad (2)$$

where

- $\overline{L}_p$ is the spatial mean sound pressure level (in dB; reference 20 μPa);
- S is the measurement surface area (in m^2);
- S_0 is the reference area (= 1 m^2);
- K is the room correction factor (as determined by environmental qualification procedures given in Appendix A of BS 4196-4:1981).

In a free field over a single reflecting plane, when $S = 2\pi r^2$ and r = 1 m, then L_w may be estimated from the following equation.

$$L_w = \overline{L}_p + (8 \text{ dB}) + K \quad (3)$$

In a free field over two reflecting planes, when $S = \pi r^2$ and r = 1 m, then L_w may be estimated from the following equation.

$$L_w = \overline{L}_p + (5 \text{ dB}) + K \quad (4)$$

If the second reflecting plane is formed by the pump mount or its acoustic enclosure and does not extend out to the full projected area of the microphone measuring surface, the correction will fall between the two extremes given in equations 3 and 4. This correction therefore needs to be determined by experiment.

The relationship between sound power and sound pressure can be found by substituting a reference sound source (a device which emits an accurately known sound power) for the pump. Blank off the exposed mounting flange and seal the fluid lines. Support these in position together with their acoustic treatment. The reference sound source should be positioned as close as possible to the pump's normal location. It is inevitable that some slight inaccuracies will be caused by the airflows around a fan type source being deflected by the pump mount. Position the source to minimize this effect, while still remaining within the envelope determined by the maximum allowable source dimension. This dimension is determined by the microphone measurement array radius r. It is essential that this radius be the same as that used for the pump noise measurements.

The environmental correction in any particular frequency band is found from the following equation.

$$L_w = \bar{L}_p + (L_{ws} - L_{ps}) \qquad (5)$$

where the suffix s denotes reference sound source values. The environmental correction found by this substitution technique will include the room correction factor K. Therefore, care should be taken to ensure that it is not applied twice (see **10.1**).

Appendix D Calculation of mean sound pressure level at a reference distance

The calculation of the spatial mean sound pressure level $\bar{L}_p$ (in dB; reference 20 µPa) at a distance r (in m) from the equivalent point source radiating into a free-field over a reflecting plane (hemispherical radiation) from the calculated pump sound power level is defined in BS 4196-0 as:

$$\bar{L}_p = L_w - 10 \log (2\pi r^2/S_0) \qquad (6)$$

where

L_w is the A-weighted or band power level of pump under test (in dB; reference 1 pW);

$2\pi r^2$ is the area of hemisphere (in m^2) of radius r (in m);

S_0 = 1 m^2.

NOTE For reporting purposes, choose a reference distance of r = 1 m in which case the numerical value of $\bar{L}_p$ is obtained by subtracting 8 dB from the numerical value of the calculated sound power level L_w.

Publications referred to

BS 661, *Glossary of acoustical terms.*

BS 4196, *Sound power levels of noise sources.*

BS 4196-0, *Guide for the use of basic standards and for the preparation of noise test codes.*

BS 4196-4, *Engineering methods for the determination of sound power levels for sources in free-field conditions over a reflecting plane.*

BS 4231, *Classification for viscosity grades of industrial liquid lubricants.*

BS 5944, *Measurement of airborne noise from hydrualic fluid power systems and components.*

BS 5944-1, *Method of test for pumps.*

BS 5944-2, *Method of test for motors.*

BS 5944-3, *Guide to the application of Part 1 and Part 2.*

BS 5944-4, *Method of determining sound power levels from valves controlling flow and pressure*[3)].

BS 5969, *Specification for sound level meters.*

BS 6413, *Lubricants, industrial oils and related products (class L).*

BS 6413-4, *Classification for family H (hydraulic systems).*

ISO/DIS 3748, *Acoustics — Determination of sound power levels of noise sources — Engineering method for small nearly omnidirectional sources under free-field conditions over a reflecting plane*[4)].

[3)] Referred to in the foreword only.
[4)] Soon to be published as ISO 3748 and subsequently as a further Part of BS 4196.

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