Designation: E 1124 – 97

Standard Test Method for Field Measurement of Sound Power Level by the Two-Surface Method[1]

This standard is issued under the fixed designation E 1124; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the field, or *in situ* measurement of sound power level by the two-surface method. The test method is designed to minimize the effects of reverberant conditions, directivity of the noise source under consideration, and the effects of ambient noise from other nearby equipment operating at the same time.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 634 Terminology Relating to Environmental Acoustics[2]

2.2 *ANSI Standard:*

S1.4 Specification for Sound Level Meters[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology C 634.[4]

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *conformal surface*—the locus of points which lie at a fixed distance from the reference surface of a piece of equipment. Two conformal surfaces are used in this test method. These are surfaces over which the measuring microphones are swept. They are located at two different distances from the equipment. Fig. 1 shows a typical arrangement of these surfaces for a generalized piece of equipment.

3.2.2 *constituent surface area*—a portion of the conformal surface.

4. Summary of Test Method

4.1 The average one-third or full octave band sound pressure levels are measured over two different conformal surfaces which envelop the equipment. These conformal surfaces should be selected to consist of rectangular, cylindrical, and hemispherical constituent surfaces so that the surface areas may be easily calculated. From the difference between the two average sound pressure levels taken at each surface and from the areas of the surfaces the sound power level may be calculated. The calculation accounts for both the effect of the reverberant field and the noise of other equipment. It is permissible to define conformal surfaces that completely envelope the source, yet only measure over a portion of the conformal surface due to restrictions from process connections or accessibility.

5. Significance and Use

5.1 The function and operation of equipment in the field often preclude the measurement of the free-field sound pressure levels of a single piece of equipment in the absence of interfering sound from other equipment operating at the same time. The two-surface method will provide, in most cases, a reliable estimate of the normal sound power levels of a specimen operating in an adverse environment.

5.2 This test method is intended for use in the field in the presence of what is normally regarded as interfering background noise. This test method is based upon the work of Hubner[5,6] and Diehl,[7] but differs from all other current sound power measurement procedures by requiring simultaneous measurement at both conformal surfaces and by resolving time-averaged sound pressure levels at both surfaces to within 0.1 dB. These two features, simultaneous recording and 0.1-dB

[1] This test method is under the jurisdiction of ASTM Committee E-33 on Environmental Acousticsand is the direct responsibility of Subcommittee E33.08 on Mechanical and Electrical System Noise.

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[2] *Annual Book of ASTM Standards*, Vol 04.06.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Terminology C 634 – 85 was the edition used during the development of this test method.

[5] Hubner, G., "Analysis of Errors in Measuring Machine Noise Under Free Field Conditions," *Journal of the Acoustical Society of America*, Vol 54, No. 4, 1973, pp. 967–977.

[6] Hubner, G., "Qualification Procedures for Free Field Conditions for Sound Power Determination of Sound Sources and Methods for the Determination of the Appropriate Environmental Correction," *Journal of the Acoustical Society of America*, Vol 61, No. 2, 1977, pp. 456–464.

[7] Diehl, G. M., *Machinery Acoustics*, J. Wiley and Sons, New York, NY, 1973, pp. 97–103.

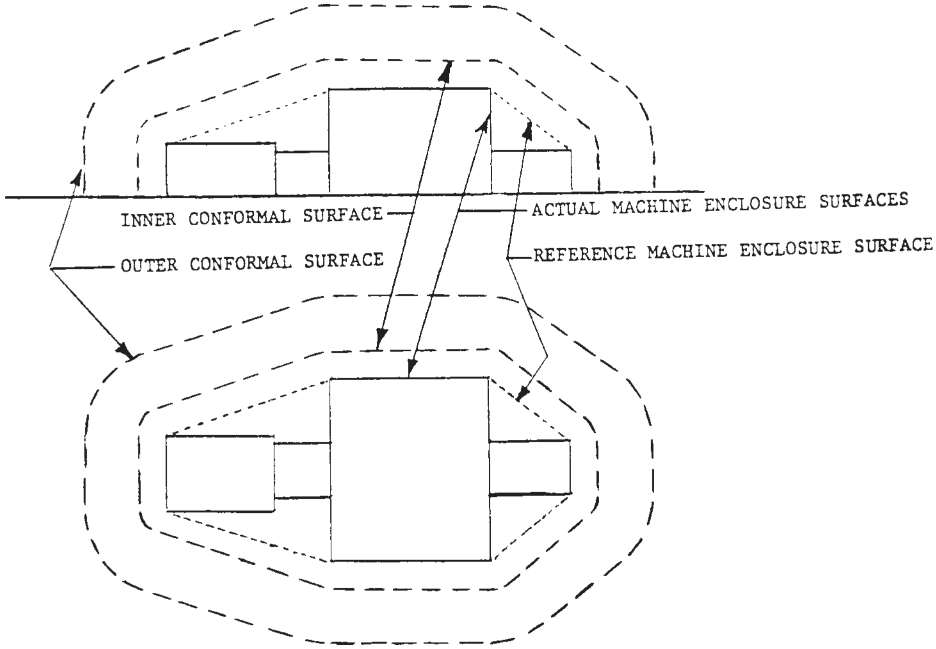

FIG. 1 Configuration of Conformal Surfaces, General Case

resolution, enable source sound power to be calculated when the direct sound field of the source is actually lower in level than the ambient noise.

5.3 The use of this test method is expected to be primarily for the relative assessment of the sound power from similar sources or for the prediction of sound levels in a plant based upon measurements of similar sources in another plant. This test method is believed to be capable of yielding a reasonably good estimate of absolute power level with proper care of application and full conformance to the provisions of this procedure.

5.4 The two-surface method is applicable only when the two measurement surfaces can be physically selected to produce positive values of the difference in average sound pressure level. That is, the inner surface sound pressure level minus the outer surface sound pressure level must be at least + 0.1 dB. This limitation applies to each frequency band and each constituent surface area investigated. Only the frequency band in which a zero or negative difference occurs is considered invalid and usually adjacent bands will be valid. In practice only rarely will all three one-third octave bands of a given octave yield invalid data at all constituent areas. Therefore less than complete results are permissible when one-third octave analysis is used and full octave results are reported.

5.5 The two-surface method may not produce results when testing some very large machines in very reverberant rooms or in rooms having a volume less than about 20 times the space enclosed by an envelope around the larger dimensions of the machine. In such cases, the sound pressure level close to the machine may not decrease in any regular way with increasing distance from a machine surface, making it impossible to select two measurement surfaces producing positive differences of sound pressure level.

6. Operating Conditions

6.1 Whenever possible, equipment under test must be operating in a mode acceptable to all parties involved in the test. Otherwise operating conditions must at least be monitored in order that the test results are properly qualified in terms of running speeds, flow rate, production rate, etc.

7. Apparatus

7.1 Due to the amount of data which must be gathered and processed, the following are considered to be the minimum equipment necessary to meet the requirements of this test procedure.

7.1.1 *Microphones*, that are matched in terms of frequency and pressure response. Begin by calibrating each data channel, using the same calibrator on each channel. Connect both microphone channels to the cables, connectors, amplifiers, and recorder to be used in data gathering. Then arrange the microphones side by side in the presence of broad band ambient noise and record for 60 s on both channels. The differences in the averaged sound pressure levels in each frequency band are calibration corrections which may be applied to either channel prior to any calculation.

7.1.2 *Magnetic Tape Recorder*, two-channel instrumentation grade having a frequency response of ±1 dB over the frequency range of interest.

7.1.2.1 It is recognized that even high-quality Amplitude Modulation (AM) tape recorders cannot maintain channel-to-channel frequency response within 0.1 dB. It is believed, however, that the requirement for determining the corrections in 7.1.1 based on 60-s average readings sufficiently compensates for expected instabilities, channel-to-channel. If digital frequency modulation (FM) or pulse code modulation (PCM) tape recorders are used, the procedure of 7.1.1 should still be used.

NOTE 1—The frequency response and accuracy of the acoustical instruments are different from the interchannel resolution of the tape recorder. Both the frequency response discussed in 7.1.2 and the accuracy of the acoustical calibrators are distinctly different from the 0.1-dB resolution discussed in 5.2.

7.1.3 *Microphone Mounting Fixture*—A suggested fixture is shown in Fig. 2.

7.1.4 *Spectrum Analyzer*, real-time one-third or full octave, having a resolution of 0.1 dB with a digital display or printing capabilities.

NOTE 2—Real-time analyzers having a resolution of 0.25 dB may also be used. However, because of the requirement for a positive sound level difference, as discussed in 5.4, these analyzers may yield less complete results compared with what could be obtained with an analyzer with better resolution. In addition, the precision of the results will be reduced if only differences greater than 0.25 dB can be obtained.

7.2 Optional equipment may include:

7.2.1 *Programmable Calculator or Desktop Computer*.

7.2.2 *Data Processing*, direct from output of real-time analyzer.

8. Procedure

8.1 *Selection of Measurement Surfaces*:

8.1.1 Conduct a preliminary survey of the sound field to estimate the two optimum conformal measurement surfaces that will yield a measurable drop in average sound pressure level between the two surfaces for the frequency range of interest. As stated in Section 5, merely a 0.1 dB difference in average sound pressure levels constitutes a measurable drop. However, the surfaces should be chosen so as to maximize the difference since the overall accuracy of the estimated sound power levels will be thereby improved. Obviously, the closer the inner surface is to the equipment, the easier it will be to obtain a large positive difference, but possible near-field effects dictate an inner surface farther from the equipment. Such near-field effects cannot be quantified by this test method nor can their effect on the calculated power levels be determined, so that this procedure can only suggest that the inner surface microphone be always at least 0.15 m, and for larger machines at least 0.3 m, from the equipment surface thereby avoiding most such effects.

8.1.2 If the locations of the two conformal surfaces are too close together, measurable differences in average sound pressure levels will be difficult to obtain. On the other hand, no advantage is gained by using progressively larger outer surfaces once the outer surface microphone is in the fully reverberant field since the sound level, and therefore the differential, will be constant. No clear optimum ratio between these two surface areas can be prescribed for all equipment. As a guide, however, experience has shown that an area ratio of

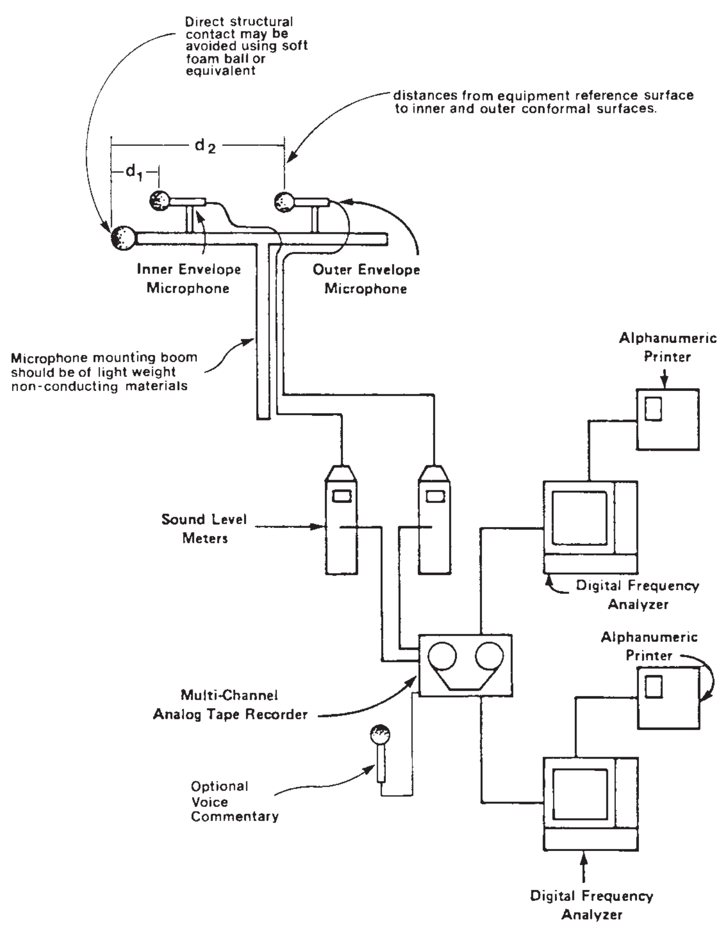

FIG. 2 Example of Suggested Measurement System

about 1.4 to 2.0, between the outer and inner surfaces, is a reasonable range that may be used in most cases.

8.1.3 Select simple geometric shapes for conformal surfaces. Fig. 1 shows an example of a generalized situation. In Fig. 1, even though the equipment itself can be approximated by rectangular or cylindrical surfaces which just enclose the equipment, the reference surface is chosen so that the two conformal measurement surfaces are convex. It may be helpful to imagine the major equipment reference surfaces to be defined by a membrane stretched over the equipment after the removal of minor projections, gages, tubes, and cables not expected to be noise sources themselves. Ideally, the sound intensity vector would be normal to both measurement surfaces at all points. Although this cannot be determined using this test method it may be helpful if the surveyor will attempt to visualize the expected sound field and so might adjust the selection of conformal surfaces accordingly.

8.1.4 It is permissible to subdivide the conformal surfaces into several constitutent surface areas for ease of data collection or because of inaccessibility. Any number of constituent surface areas may be used to cover the conformal surface. Since the conformal surfaces will be measured simultaneously with the inner and outer microphones, care should be taken that the constituent surface area boundaries define related regions on the inner and outer surfaces. These constituent surface areas will not necessarily be composed of geometrically similar inner and outer surfaces because of the usually complex shape of the equipment sources themselves.

8.1.5 Fig. 3 is an example of the application of these guidelines for the selection of measurement surfaces. A large coal pulverizer was measured using this test method. The actual shapes of conformal surfaces are shown as well as an indication of the extent of measurement coverage. Constituent surface areas were used for the dome, grinding zone, and upper and lower pedestal. Less than 100 % coverage was used and was accounted for as discussed in 9.4.

8.1.6 No optimum distances from the equipment surface to either conformal surface can be prescribed for all equipment. However, for sources whose smallest dimension is 1 m, it is recommended the inner surface distance be at least 0.2 m. Also, for sources whose smallest dimension is 3 m, it is recommended the outer surface distance be less than 2 m.

8.2 *Data Acquisition*:

8.2.1 Obtain simultaneous measurements of the sound pressure level at the two microphone positions along a line normal, that is perpendicular to, the inner conformal surface. See 7.1.3 for a suggested microphone mounting fixture. Determine the average sound pressure level over each constituent surface area using a continuous uniform microphone sweep as indicated in Fig. 4.

8.2.2 If the inner and outer measurement surfaces are subdivided into smaller constituent areas for the survey, the average sound pressure levels over the entire inner and outer conformal surfaces are determined by summing the values obtained for the respective constituent areas, as shown in 9.3.

8.2.3 The microphone sweeping speed shall be sufficiently slow, continuous, and uniform that when the data are continuously recorded a representative average sound pressure level is obtained for each constituent area swept by the microphone(s). A reasonable averaging period is usually between 30 and 60 s for each constituent area. A reasonable sweeping speed is usually about 0.5 m/s.

8.2.4 Fig. 5 illustrates an alternate data collection technique in which a large number of uniform constituent surface areas are measured by moving the microphones continuously within a small 0.1 to 0.2-m diameter circle near the centers of each constituent surface area. Sound pressure level measurements for each constituent surface area will consist of 15-s averages, minimum, and will be averaged for sound power calculations as in 9.3.

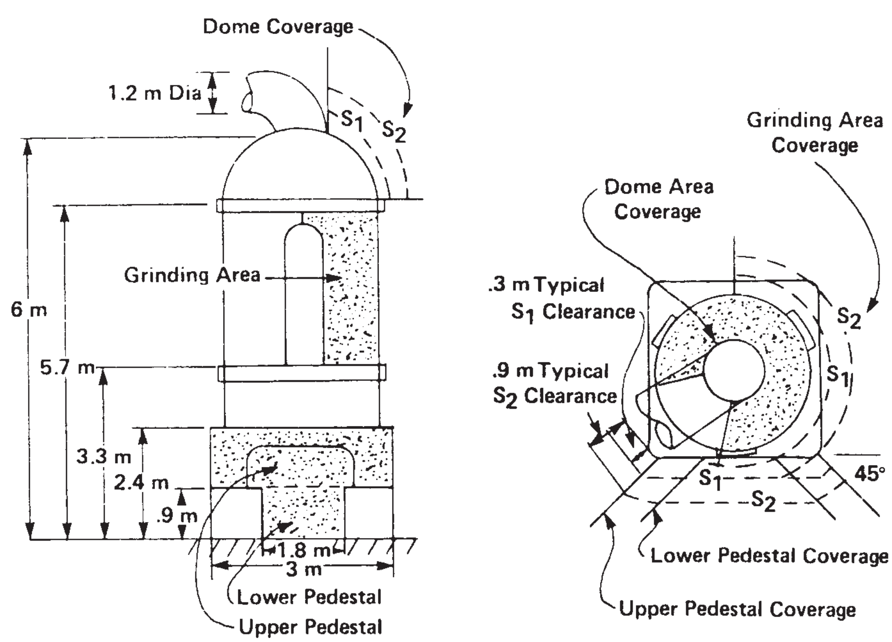

FIG. 3 Side View and Top View of Pulverizer

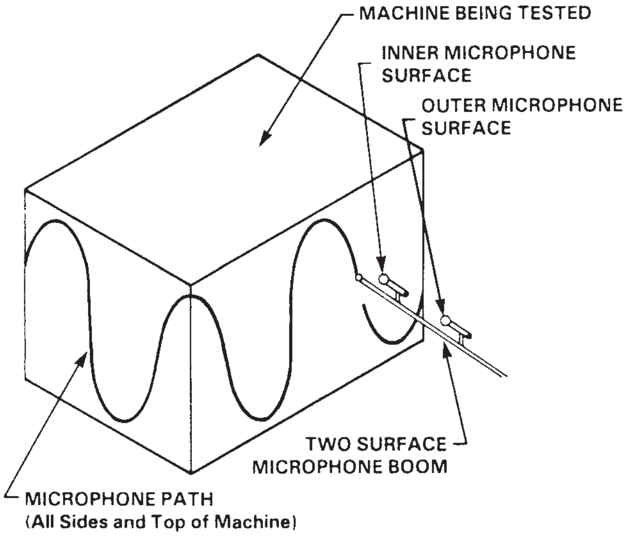

FIG. 4 Cross Sweep Data Collection Approach

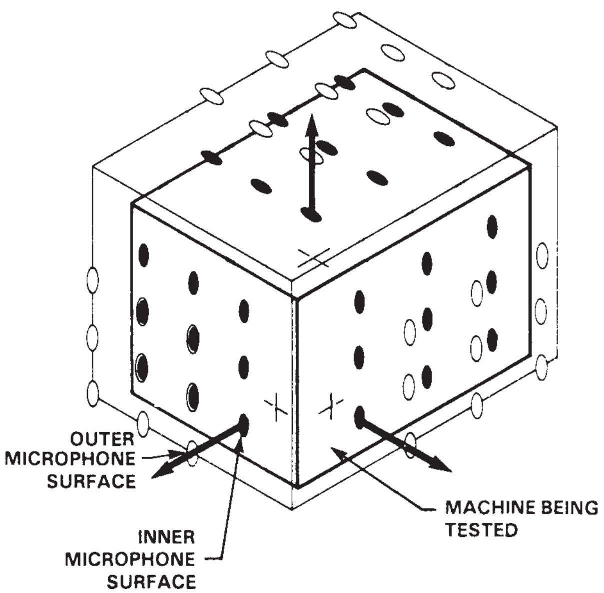

FIG. 5 Detailed Data Collection Approach

9. Calculations

9.1 Calculate for each one-third or full octave band the sound power level of the equipment from the expressions:

$$k = 10^{0.1(L_1 - L_2)}$$

$$C = 10 \log[(k/(k-1)) \cdot ((S_2 - S_1)/S_2)]$$

$$L_w = L_1 - C + 10 \log S_1 \text{ for } L_1 \geq L_2 + 0.1$$

$$L_w = 0 \text{ for } L_1 < L_2 + 0.1$$

where:

L_1 = sound pressure level averaged over the inner surface, dB,
L_2 = sound pressure level averaged over the outer surface, dB,
C = reverberant noise correction, dB,
S_1 = area of the inner surface measurement, m^2,
S_2 = area of the outer surface measurement, m^2, and
L_w = one-third or full octave band sound power level, dB, (re 10^{-12} W).

9.2 The calculation of 9.1 must be performed for each frequency band.

9.3 When several constituent surface areas are surveyed using this test method, L_1 and L_2 in 9.1 may be determined in the following manner:

$$L_1 = 10 \log \left(\frac{1}{n} \sum_{i=1}^{n} 10^{0.1 (L_1)_i} \right)$$

$$L_2 = 10 \log \left(\frac{1}{n} \sum_{i=1}^{n} 10^{0.1 (L_2)_i} \right)$$

where:

$(L_1)_i$, $(L_2)_i$ = sound pressure level averaged over the *i*th inner (1) or outer (2) constituent surface area, dB, and
n = number of constituent surface areas measured.

9.4 Whenever the constituent surface areas, taken together, do not completely cover the theoretical conformal surface, the calculated sound power level of 9.1 using the sum of only the actual measurement surface areas, must be adjusted to obtain the assumed total source sound power as follows:

$$(L_w)_t = L_w + 10 \log \left(\frac{(S_i)_t}{S_i} \right)$$

where:

$(L_w)_t$ = total source one-third or full octave band sound power level, dB, (re 10^{-12} W),
L_w = one-third or full octave band sound power level, dB, (re 10^{-12} W), from 9.1 based upon actual S_i smaller than total conformal surface area,
$(S_i)_t$ = total area of actual inner conformal surface, m^2, and
S_i = area of inner surface measurement, m^2, from 9.1.

9.5 Whenever the assumption of 9.4 is used, this fact shall be clearly stated in the report since in most cases the judgement of the surveyor is the sole basis of the assumption.

10. Report

10.1 The report shall include the following information:

10.1.1 A statement that the requirements of this test method were followed and any exceptions noted.

10.1.2 A description of the equipment measured, with model number and drawings if possible. A sketch with dimensions of nearby equipment and equipment whose noise level influences the background level. Include operating conditions of this equipment that would affect measurements of the equipment under test.

10.1.3 A statement on the operating conditions of the equipment under test and notations made regarding loose parts, leaks, etc. that might affect test results.

TABLE 1 Standard Deviations of Sound Power Measurements on 53 Coal Pulverizers

	Octave Band Center Frequency, Hz									
	31.5	63	125	250	500	1 K	2 K	4 K	8 K	16 K
Standard Deviation, dB	±2.4	±2.3	±2.4	±1.6	±1.8	±2.1	±2.3	±3.8	±3.9	±2.1

TABLE 2 Standard Deviations of Sound Power Measurements on Calibrated Sound Sources

	Octave Band Center Frequency, Hz							
	63	125	250	500	1 K	2 K	4 K	8 K
Standard Deviation, dB	±0.46	±0.45	±0.44	±0.27	±0.21	±0.26	±0.23	±0.25

TABLE 3 Difference Between Reverberant Room Sound Power Level ($L_w)_R$ and In-Situ Sound Power Level ($L_w)_I$ in Various Industrial Settings, of a Calibrated Sound Source

	Octave Band Center Frequency, Hz							
	63	125	250	500	1 K	2 K	4 K	8 K
$(L_w)_I - (L_w)_R$	+ 10.4	−0.3	−1.6	−0.3	−0.8	−1.0	−0.2	+ 1.

10.1.4 A description and sketch of the two measurement surfaces, and how their areas were defined and measured. A description and sketch of constituent surface areas, if applicable.

10.1.5 The sound power levels by one-third octave or full-octave bands. The overall sound power level. Levels should be rounded to the nearest whole decibel.

10.1.6 A discussion of any special adjustments or difficulties dictated by the circumstances of the test. Whenever the entire conformal surface cannot be covered in data measurement sweeps with the microphones, a description of the areas covered should be given. A listing should be given for any frequency bands whose sound power levels calculated according to 9.1 were invalid; that is, zero.

10.1.7 A description of the instruments used including model and serial numbers, and their calibration records.

11. Precision and Bias [8]

11.1 The precision of this test method is very much a function of the care with which it is implemented, the complexity and accessibility of the noise source, and the degree to which the surveyor attempts to define the detailed noise characteristics of the noise source.

11.2 As stated in 5.3, this test method is primarily intended for relative assessments of similar sound sources, or for the prediction of sound levels in one plant based upon similar measurements from another plant. Both these objectives are served if the test method can be shown to be "precise," that is, repeatable, from test to test using similar sources and settings. The absolute accuracy of the test method, its ability to measure the true sound power of the source, may be considered as one element in the "bias" of the method. Section 5.3 stated that "the method is believed to be capable of yielding a reasonably good estimate" of power. The basis of this belief is the task group's experience in using the method during the course of developing this test method.

11.3 Table 1 presents one result of assessing the precision of the test method. For the case of large power plant coal pulverizers, where shapes are generally approximated by vertical cylinders 2 to 4 m in diameter and 6 to 12 m in height, the task group found standard deviations in octave band sound power levels as shown. These results are from nine different plants, using four different survey teams, covering 53 pulverizers representing 5 different types of pulverizers.

11.4 Table 2 presents another result of assessing the precision of the test method. This case involved seventeen tests of a calibrated sound source in nine different industrial settings using this test method. Background noise levels in one setting were approximately 20 dB below the sound pressure levels of the source at 1 m, whereas for the other eight settings background sound pressure levels varied from 1 to 10 dB below the level of the source at 1 m.

11.5 Table 3 shows the octave band sound power level differences for the calibrated sound source used for Table 2 when measured: (*1*) in a reverberant room at a test laboratory, versus (*2*) the averaged sound power levels from the seventeen runs used in Table 2.

11.6 Based on the results of the tests presented in Table 1, Table 2, and Table 3, the task group concludes that the precision of the test method has been demonstrated to be acceptable for the octave bands 63 Hz through 8 KHz for large sources such as pulverizers, and the bias of the test method has been demonstrated to be acceptable for the octave bands 125 Hz through 8 KHz for small sources on the order of calibrated sound sources. Both precision and bias are expected to be similar for other size sources within qualifications such as are given in 5.5.

11.7 A user may generate an independent measure of precision or bias in terms of standard deviations in decibels in octave bands if a sufficient number of independent tests are conducted and if a brief description of the statistical treatment is included in the report.

11.8 Precision of recorded data is commensurate with the tolerances specified in ANSI S1.4 for precision sound level meters.

[8] Supporting data are available on loan from ASTM Headquarters. Request RR: E33 – 1003.

12. Keywords

12.1 field sound power; industrial noise; machinery noise; sound power; two-surface method