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Acoustics — Procedure for describing aircraft noise heard on the ground

Acoustique — Méthode de représentation du bruit perçu au sol produit par un aéronef

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FOREWORD

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The member body of the following country expressed disapproval of the document on technical grounds :

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Acoustics — Procedure for describing aircraft noise heard on the ground

1 SCOPE

This International Standard provides a procedure for describing the noise heard on the ground from aircraft operations.

1.1 It provides specifications for the four steps to be followed for the purpose of describing the noise from a single aircraft operation, namely :

1) Data acquisition : the method of measurement and recording of the noise.

2) Data processing : the method of determining from these data the corresponding values on the appropriate noise scale.

3) Data normalization : the method for correction of the measured data to "reference" operational procedures and atmospheric conditions.

4) Data reporting : the method for reporting test results, including their statistical signifiance.

These specifications are given for two levels of sophistication of measurement :

a) Those requiring spectral analysis as a function of time, such as for noise certification of aircraft, for which a high reproducibility of the normalized results is required.

NOTE — The specifications given under this heading are not to be taken as defining the highest possible level of technique. Much higher levels are required and are used, for example, during the course of research and development work on aircraft noise.

b) Those requiring only frequency weighting, where sophistication of measurement is reduced for the sake of simplicity or low cost.

1.2 It also provides a method for determining a noise-exposure measure for a succession of operations in a given time-interval. The results may be used for evaluating the effects of aircraft noise on people, as for example by the methods of ISO/R 1996.

1.3 Specific purposes for which these methods might be used are also discussed, including certification, monitoring of noise levels and of noise exposure, and land-use planning.

2 FIELD OF APPLICATION

This International Standard is intended to apply quite generally to the description of the noise measured from all kinds of aircraft operations.

2.1 Two main operating conditions are distinguished :

a) aircraft in flight;

b) aircraft on the ground;

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2.2 Two main applications of the measurements are distinguished :

a) requiring the characterization of single events, such as for measurement of the noise from an individual aircraft against specified requirements or for monitoring at an airport;

b) requiring the determination of noise exposure for a succession of events.

2.3 Two main conditions under which the noise is heard are distinguished :

a) where the aircraft noise dominates all other kinds of noise to such an extent that it is assessed without regard to the noise environment existing in the absence of the aircraft;

b) where aircraft noise is assessed as one amongst all the other noises affecting a community, such as from road traffic or from industrial premises.

3 REFERENCES

ISO/R 1996, *Acoustics — Assessment of noise with respect to community response.*

ISO 1999, *Acoustics — Assessment of occupational noise exposure for hearing conservation purposes.*

IEC Publication 179, *Precision sound level meters.*

IEC Publication 537, *Frequency weighting for the measurement of aircraft noise (D-weighting).*

IEC Publication 561, *Electro-acoustical measuring equipment for aircraft noise certification.*

4 MEASUREMENTS REQUIRING SPECTRAL ANALYSIS AS A FUNCTION OF TIME

4.1 Data acquisition

To provide the necessary information on the noise produced by the aircraft at the observation point, the equipment and methods specified in this sub-clause shall be used.

4.1.1 *Equipment and calibration*

The microphone shall be placed so that the centre of its diaphragm is 1,2 m above the mean ground surface. A wind-shield shall be used.

NOTE — For the sake of continuity with procedures described in other ISO documents, a microphone height of 1,2 m has been retained in this International Standard.

All measurements shall be carried out so that the diaphragm of the microphone is substantially in the plane defined by the nominal flight path of the aircraft and the measuring point, i.e. at grazing incidence.

The electro-acoustical measuring chain from microphone to tape-recorder (where used) and its calibration shall be as specified in IEC Publication 561.

4.1.2 *Test environment*

The idealized test environment is an unobstructed hemisphere over a flat and totally reflecting ground surface, without excessive attenuation from anomalous atmospheric conditions and with no background noise. In the actual test conditions, the deviations from this idealized environment should desirably not cause more than 0,5 dB difference in the final result. This requirement demands at least the following conditions :

4.1.2.1 Locations for measuring noise from an aircraft in flight shall be surrounded by relatively flat terrain having no excessive sound absorption characteristics such as might be caused by thick, matted, or tall grass, shrubs, or wooded areas. No obstructions which significantly influence the sound field from the aircraft shall exist within a conical space above the point on the ground vertically below the microphone, the cone being defined by an axis normal to the ground and by a half-angle of 80° from this axis.

NOTES

1 The requirements for relatively flat terrain having no excessive sound absorption characteristics would be met by using a ground surface 6 m × 6 m of concrete or an equivalent highly reflecting material. For measurements directly under the nominal flight path, the microphone should be near the centre of the square. For other measurements, the microphone should be positioned so that at least 5 m of the reflecting surface is between the aircraft and the microphone. Within a radius of 1 m centred on the microphone position, the surface should be flat within ± 5 mm; elsewhere within the square it should be flat within ± 30 mm. Overall, the surface should be horizontal within a tolerance of ± 3°.

2 Those people carrying out the measurements could themselves constitute such obstructions.

3 The microphone support should be so designed as to exert minimum influence on the directivity characteristics of the microphone, and not to introduce significant diffraction effects.

For measuring noise from an aircraft on the ground, the ground surface between the microphone and the aircraft shall be concrete or an equivalent highly reflecting material. No obstructions shall be permitted between the aircraft and the measurement position during the measurements of aircraft noise. No reflecting surfaces other than the ground shall be near enough to the sound path to influence the results.

4.1.2.2 The atmospheric conditions shall comply with the following :

a) There shall be no precipitation.

b) At relative humidity less than 20 %, the atmospheric temperature shall be not less than 5 °C.

c) The sound attenuation in air as given by the formula in clause A.2 of annex A for the 1/3 octave band centred on 8 kHz shall not be more than 10 dB per 100 m. The corresponding restrictions placed on temperature and humidity are shown in figure 1.

NOTE — Temperatures and humidities in the part of figure 1 below the restricted band should also be avoided if possible, since the sound attenuation in air given by the formula has not been verified experimentally at these temperatures and humidities.

d) The wind speed at a height of 10 m above the ground shall not be greater than 5 m/s (10 knots).

NOTE — Anomalous atmospheric conditions introducing excessive sound attenuation can occur when inversions of normal lapse rates for temperature and humidity exist, or when temperature and velocity inhomogeneities associated with atmospheric turbulence are present, as well as from excessive wind and the existence of precipitation.

4.1.2.3 The background noise shall be recorded before and after the tests and analysed in the same way, and reported by the same measures, as for the aircraft noise. Measurements of aircraft noise shall be considered reliable only when the measured maximum noise level of the aircraft exceeds these background noise levels by at least 20 dB.

NOTE — For the purpose of calculating the overall noise level of the aircraft (see, for example, 4.2.2), individual band levels should be adjusted to allow for background noise. Due to uncertainties and fluctuations which frequently occur with background noise, it is not practicable to specify a correction procedure which is valid for all cases.

It is recommended, however, that if the level in any 1/3 octave band of the aircraft noise does not exceed the background level in that frequency band by an adequate margin, for example 5 dB, that frequency band should not be included in the computation of the overall noise level of the aircraft.

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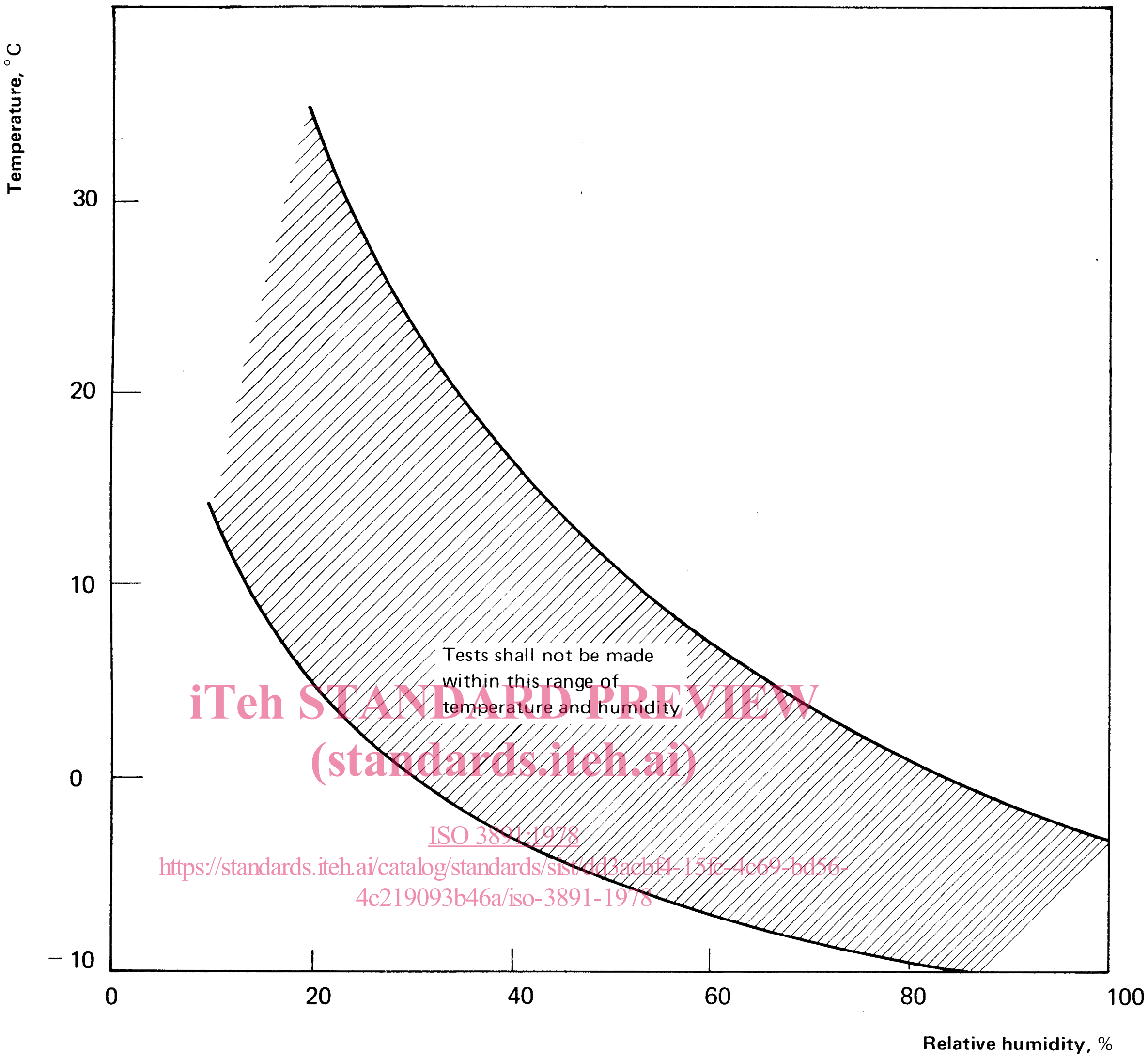

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FIGURE 1 — **Permissible conditions of temperature and relative humidity in test environment according to 4.1.2.2 c)**

4.2 Data processing

To provide from the measured noise data the values of the appropriate noise scale characterizing each noise event measured, the equipment and methods specified in this sub-clause shall be used.

4.2.1 *Equipment needed to provide spectrum analysis as a function of time*

The equipment and its calibration shall be as specified in IEC Publication 561.

NOTE — Equipment with more rapid rate of response should be used where detailed information is required on the time-history of noises of very short duration.

4.2.2 *Calculation of perceived noise level from measured noise data*

4.2.2.1 Quantities and units

To obtain from these measurements perceived noise levels, L_{PN}, and tone-corrected perceived noise levels, L_{TPN}, of a given sound, in decibels, the calculation procedures of this sub-clause shall be used.

NOTES

1 The designation "PNL" is sometimes used elsewhere as an abbreviation for "perceived noise level", the unit being designated "PNdB"; here, "perceived noise level" is designated L_{PN} and the unit is the decibel (dB).

Similarly, the designation "PNLT" is sometimes used elsewhere as an abbreviation for "tone-corrected perceived noise level", the unit being designated "PNdB"; here, "tone-corrected perceived noise level" is designated L_{TPN} and the unit is the decibel (dB).

2 The measurements may also be used to derive values on other noise scales such as A-weighted sound pressure level, L_A, from the spectral analysis, if so desired.

The calculation procedures give an approximation to the perceived noise level as determined by subjective experiment on a fundamental psycho-acoustical basis, namely that perceived noise level of a given sound is numerically equal to the sound pressure level of a reference sound that is judged by listeners to have the same perceived noisiness as the given sound.

The calculation procedures make use of a unit of perceived noisiness, the noy. The numerical value of the calculated perceived noisiness of a sound within a given frequency band, in noys, is related to the band sound pressure level. The relation is given in table 13 and illustrated in figure 2, and the equivalent relationship is noted in table 14 (annex B).

NOTE — This calculation procedure may not adequately account for the subjective effect of a strongly impulsive characteristic of noise such as may be produced by some helicopters. Methods for accounting for the subjective effect of impulsive sounds are under investigation.

4.2.2.2 Calculation procedure for a broad band noise spectrum without pronounced irregularities

Perceived noise level is calculated according to the following procedure :

Step 1

The sound pressure level at any time in each 1/3 octave band from 50 Hz to 10 000 Hz is converted to a perceived noisiness, n, by reference to table 13 or the mathematical relationship and table 14, by entering table 13 or the calculation procedure at the appropriate band centre frequency.

Step 2

The noisiness values, n, found in step 1 are combined to obtain the total noisiness, N, in noys, by the formula

$$N = n_{max} + 0{,}15\,(\Sigma n - n_{max})$$

where

n_{max} is the greatest values of n;

Σn is the sum of the noisiness values in all the bands.

Step 3

N is converted into perceived noise level, L_{PN}, by the use of table 15, annex B, which expresses the following relations between N, in noys, and L_{PN}, in decibels :

$$N = 2^{(L_{PN} - 40)/10}$$

where

$$L_{PN} = 40 + \frac{10 \log_{10} N}{\log_{10} 2}$$

4.2.2.3 Correction for use when the noise spectrum shows pronounced irregularities such as pure tones

Tone-corrected perceived noise level at any instant, L_{TPN}, for a sound having tonal components or other pronounced irregularities in the spectrum is obtained by adding a correction, C, as defined below, to the perceived noise level, L_{PN}, determined as described above. (Illustration of the following steps is given in annex C.)

NOTE — If a spectrum irregularity requiring a tone correction is identified, it is desirable to determine if it is due to the presence of a tone or to spurious effects such as results from ground reflections or from the elimination of a frequency band as required by 4.1.2.3. The effect of ground reflection may be determined by, for example, comparing the spectrum of the noise signal with that from a microphone at the same measurement position but mounted essentially flush with the ground. If the tone correction is due to spurious effects, it should be ignored in the computation of L_{TPN}.

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Step 1

Compute $D_{j,i}$ where

i is the 1/3 octave band number, and $j = i + 1$;

$i = 1$ corresponds to the band with centre frequency of 80 Hz and successive values of i correspond to increasing frequency;

L_i is the band sound pressure of the ith frequency band;

$D_{j,i}$ is the arithmetic difference between the levels L_i in the frequency bands j and i.

Step 2

Encircle those values of $D_{j,i}$ where

$$|D_{j,i} - D_{j-1,\,i-1}| > 5 \text{ dB}$$

Step 3

a) If the encircled $D_{j,i}$ is positive and algebraically greater than $D_{j-1,\,i-1}$, encircle L_j.

b) If the encircled $D_{j,i}$ is zero or negative and $D_{j-1,\,i-1}$ is positive, encircle L_i.

Step 4

a) For all non-encircled L_i, set $L'_i = L_i$.

b) For encircled values of L_i, set L'_i equal to the arithmetic average of L_{i-1} and L_{i+1}.

If the SPL value in the highest frequency band is encircled, set $L'_{22} = L_{21} + D_{21,\,20}$.

Step 5

Compute $D'_{j,i}$ where $D'_{j,i}$ is the arithmetic difference between the levels L'_i in the frequency bands j and i.

STEP 6

Compute $\overline{D_{j,i}}$ as the arithmetic average of $D'_{j-1,i-1}$, $D'_{j,i}$ and $D'_{j+1,i+1}$.

Where $i = 1$, set $D'_{j-1,i-1}$ equal to $D'_{j,i}$.

Where $i = 21$, set $D'_{j+1,i+1}$ equal to $D'_{j,i}$.

STEP 7

Set $\overline{L_1}$ equal to L_1. Determine all other values of $\overline{L_j}$ by adding $\overline{D_{j,i}}$ to $\overline{L_i}$.

STEP 8

Determine F_i, where

$$F_i = (L_i - \overline{L_i}) > 0$$

STEP 9

Determine the tone correction, C, from the following equations :

$$\left.\begin{array}{ll} C = F/3 & 0 \leqslant F < 20 \\ C = 6{,}7 & 20 \leqslant F \end{array}\right\} \text{for 1/3 octave bands between 500 to 5 000 Hz.}$$

$$\left.\begin{array}{ll} C = F/6 & 0 \leqslant F < 20 \\ C = 3{,}3 & 20 \leqslant F \end{array}\right\} \text{for 1/3 octave bands in the range 50 to 10 000 Hz, but outside the range 500 to 5 000 Hz.}$$

STEP 10

The maximum value of C determined in step 9 defines the tone correction that is to be added to the perceived noise level determined in 4.2.2.2, to obtain L_{TPN}.

4.2.3 *Calculation of effective perceived noise level*

4.2.3.1 DEFINITION OF EFFECTIVE PERCEIVED NOISE LEVEL

The total subjective effect of an aircraft flyover depends not only on the maximum tone-corrected perceived noise level, L_{TPNmax}, but also on the variation of the noise with time.

To take into account the influence of time, the effective perceived noise level, L_{EPN}, is defined by the equation

$$L_{EPN} = 10 \log_{10} \frac{1}{T_o} \int_{-\infty}^{+\infty} 10^{L_{TPN}/10} \, dt$$

where L_{TPN} is the tone-corrected perceived noise level as determined by the procedures specified in 4.2.2.1, 4.2.2.2, and 4.2.2.3, and $T_o = 10$ s.

Effective perceived noise level may also be expressed as the algebraic sum of L_{TPNmax} and a *duration allowance* Δ'_{PN} or Δ''_{PN}, as defined in 4.2.3.4.

NOTES

1 The quantity L_{TPN} in the above definitions may be replaced by L_{PN} if it can be shown that the tone corrections are small enough to be disregarded.

2 The designation "EPNL" is sometimes used elsewhere as an abbreviation for "effective perceived noise level", the unit being designated EPNdB; here, "effective perceived noise level" is designated L_{EPN} and the unit is the decibel (dB).

4.2.3.2 BASIC DEFINITION OF DURATION ALLOWANCE

Consider a notional *equivalent duration*, τ seconds, such that the integrated energy[1] in a noise at constant level L_{max}, the maximum level observed, for time τ is equal to the integrated energy in the actual noise whose instantaneous noise level is L. Then

$$\tau \times 10^{L_{max}/10} = \int_{-\infty}^{+\infty} 10^{L/10} \, dt$$

The duration allowance, Δ, expressed in decibels, is defined as the ratio of τ to an arbitrarily chosen *reference duration*, τ_{ref} seconds :

$$\Delta = 10 \log_{10} (\tau / \tau_{ref})$$

When applied to the calculation of effective perceived noise level, the symbol L above is understood to refer to perceived noise level, L_{PN}, or tone-corrected perceived noise level, L_{TPN}, as appropriate. For other purposes (see 5.2), it may refer to a weighted sound level.

4.2.3.3 REFERENCE DURATION

For the calculation of effective perceived noise level, the value of τ_{ref} in the expression for the duration allowance is taken, by convention, to be 10 s.

NOTE — For other purposes a different reference duration is recommended (see, for example, 5.2.1 b)).

4.2.3.4 PRACTICAL DEFINITION OF DURATION ALLOWANCE

a) For practical purposes, L_{TPN} may be integrated over the total time-interval $t_2 - t_1$ during which the instantaneous value of L_{TPN} is within a specified value (not less than 10 dB) of the maximum value L_{TPNmax}.

NOTE — The time-interval $t_2 - t_1$ shall be taken as the total time between the instants t_1, when the noise level (for a single event) first rises to the specified level (for example $L_{TPNmax} - 10$ dB), and t_2, when the noise level last decreases to the specified level.

1) The term "energy" is used here loosely to mean a quantity proportional to the square of sound pressure.

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The equivalent duration, τ', is then given, in seconds, by the formula

$$\tau' \times 10^{L_{TPNmax}/10} = \int_{t_2}^{t_1} 10^{L_{TPN}/10}\, dt$$

and the practical duration allowance, Δ'_{PN}, in decibels, by the formula

$$\Delta'_{PN} = 10 \log_{10} (\tau'/\tau_{ref})$$

where τ_{ref} is equal to 10 s, as stated in 4.2.3.3.

b) When the noise level is described by values of L_{TPN} over sufficiently small intervals of time, Δt (not more than 0,5 s), the equivalent duration, τ'', is given, in seconds, by the formula

$$\tau'' \times 10^{L_{TPNmax}/10} = \Delta t \times \sum_k 10^{L_{TPNk}/10}$$

where L_{TPNk} is the value of L_{TPN} for the kth time-interval during which L_{TPN} is greater than the minimum value being considered. The duration allowance, Δ''_{PN}, is then given, in decibels, by the formula

$$\Delta''_{PN} = 10 \log_{10} (\tau''/\tau_{ref})$$

where τ_{ref} is equal to 10 s.

NOTE — The summation may alternatively be performed for values of Δt corresponding to discrete intervals (not greater than 0,5 dB) of L_{TPN}.

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4.3 Data normalization

Differences between the test conditions (under which the noise was measured) and the reference conditions (for which the results are required) require that "adjustments" be made to the levels used for arriving at the L_{EPN} figures for four different effects :

a) Differences in the sound attenuation coefficients in air (in excess of that due to spherical divergence) and hence in the attenuation of the noise.

Values of attenuation coefficients at various values of atmospheric temperature and humidity and meteorological measurements to utilize these values, are given in annex A.

NOTE — With the limitation imposed on the test conditions by 4.1.2.2, the adjustment for differences in atmospheric attenuation coefficients between test and reference conditions is also thereby limited. For the commonly used reference condition of 25 °C and 70 % relative humidity, the adjustment is limited to 5 dB per 100 m in the 1/3 octave band centred at 8 kHz; for an alternative reference condition of 15 °C and 70 % relative humidity, the adjustment is limited to 4 dB per 100 m.

b) Differences in the path distance travelled by the noise and hence in its attenuation (by divergence and by atmospheric absorption) and its duration (proportional to the shortest distance between the aircraft flight path and the measurement point).

Information on the aircraft operating conditions must be recorded in synchronization with the acoustical data and on its position in order to determine the true path distance from the point of emission of the noise to the measurement point.

c) Differences in the speed of the aircraft over the measurement point and hence in the duration of the noise (inversely proportional to the speed).

d) Differences in the noise emitted at its source at the aircraft.

Appropriate "adjustments" shall be applied based on manufacturer's information.

NOTE — When the sound being measured arrives at an angle of less than 10° to the ground surface, ground proximity effects are difficult to quantify. Procedures for normalization of the data are not provided for such cases.

4.4 Data reporting

4.4.1 Full particulars of the test conditions and results of all the tests shall be reported, including

a) the relevant atmospheric conditions (the wind to be reported in terms of maximum, minimum and average speeds and direction);

b) comments on local topography, ground cover and events which might have interfered with noise readings;

c) the aircraft configuration (such as wing-flap and landing gear positions), the relevant flight procedure and operating conditions (including the use of systems influencing engine power), and readings of the aircraft position over the relevant time period;

d) details of equipment used for flight path measurement and noise measurement and analysis;

e) the acoustical readings taken, the "adjustments" to be applied to these readings, and the adjusted figures.

4.4.2 Sufficient tests shall have been made at each operating condition to establish the statistical consistency of the results.

The normalized effective perceived noise level obtained at each operating condition shall be averaged arithmetically. Such average results can be expected to have a 90 % confidence interval not exceeding ± 1 dB established statistically from six tests. The confidence interval for the mean value of a set of measurements can be computed from the standard deviation of the measured values, as a function of the number of measurements, from table 16 in annex D.

5 MEASUREMENTS REQUIRING ONLY FREQUENCY WEIGHTING

Sophistication of measurement and test procedure has been relaxed in the specifications of this clause (compared with those of clause 4) for the sake of simplicity and low cost.

The main simplifications are in the elimination of the 1/3 octave band analysis and the continuous data averaging and read-out. As a result, the data cannot in general be normalized for variations in atmospheric conditions, and can only be normalized approximately for variations in distance.

The specifications of this clause are applicable under all the conditions discussed in clause 2, i.e. for aircraft in flight and on the ground, for the characterization of single noise events and for noise exposure determination, where aircraft noise dominates the environment and also where it is assessed as one amongst all other noises.

5.1 Data acquisition

To provide the necessary information on the noise produced by the aircraft at the observation point, the equipment and methods specified in this sub-clause shall be used.

5.1.1 *Equipment to be used where only the maximum level of the noise events is required*

A sound level meter shall be used with an omnidirectional microphone which complies with IEC Publication 179, with dynamic characteristics designated "slow", with either D-weighting[1)] or A-weighting as required, (see 5.2), including any insertion losses produced by wind-shields or other protective enclosures round the microphone.

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In special cases, for example low flying aircraft at high speed, the "fast" dynamic characteristics may be necessary to obtain a more representative measurement.

NOTES

1 For microphones used for continuously monitoring noise levels from aircraft operations, the effect of the above-mentioned enclosures may be such that the requirements of IEC Publication 179 on the directionality of the microphone are not completely met. The ensuing loss of accuracy can be considered acceptable for this purpose if the sensitivity of the microphone to plane sound waves arriving from any direction within 45° of the axis of calibration does not differ by more than 1 dB below 1 000 Hz, 2 dB between 1 000 and 4 000 Hz, and 4 dB from 4 000 to 11 200 Hz, from the sensitivity to plane sound waves arriving along other directions within the same 45°.

2 Other equivalant equipment may be used if complying with the same characteristics.

5.1.2 *Equipment to be used where the variation of level over a period of time is also required*

A recording device shall be used. Its characteristics shall be such that the recorded values of weighted sound level as a function of time are within 2 dB of those obtained when using a system having the characteristics required for clause 4.

NOTE — Where only the integrated sound level over a given period is required, the recorder may be replaced by an integrating device having equivalent performance.

5.1.3 *Acoustical sensitivity check*

The overall sensitivity of the measuring system shall be checked before or after the measurement of the noise level for a sequence of aircraft operations, using an acoustic calibrator generating a known sound pressure level at a known frequency.

NOTE — A pistonphone operating at a nominal 124 dB and 250 Hz is generally used for this purpose. In the case of remote or inaccessible locations of microphones, a calibrated sound source may be provided at the microphone instead.

5.1.4 *Test environment*

The idealized test environment is an unobstructed hemisphere over a flat and totally reflecting ground surface, without excessive attenuation from anomalous atmospheric conditions and with no background noise.

NOTE — For the continuous monitoring of noise levels from aircraft operations, these environmental requirements will often not be met. It must then be recognized that the scatter in the measured figures may be rather large (see 5.4.3).

In the actual test conditions, the deviations from this idealized environment should desirably not cause more than 0,5 dB difference in the final result. This requirement demands at least the following conditions :

5.1.4.1 Locations for measuring noise from an aircraft in flight shall be surrounded by relatively flat terrain having no excessive sound absorption characteristics such as might be caused by thick, matted or tall grass, shrubs, or wooded areas. No obstructions which significantly influence the sound field from the aircraft shall exist within a conical space above the point on the ground vertically below the microphone, the cone being defined by an axis normal to the ground and by a half-angle 80° from this axis.

NOTES

1 Those people carrying out the measurements could themselves constitute such obstructions.

2 The microphone support should be so designed as to exert minimum influence on the directivity characteristics of the microphone, and not to introduce significant diffraction effects.

For measuring noise from an aircraft on the ground, the ground surface between the microphone and the aircraft shall be concrete or an equivalent highly reflecting material. No obstructions shall be permitted between the aircraft and the measurement position during the measurements of aircraft noise. No reflecting surfaces other than the ground shall be near enough to the sound path to influence the results.

1) See IEC Publication 537.