Subject: Proposals for the amendment of Annex 16, Volume I concerning Standards and Recommended Practices relating to environmental protection – Aircraft noise

Action required: Comments to reach Montréal by 8 October 2016

Sir/Madam,

1. I have the honour to inform you that the Air Navigation Commission, at the fourth meeting of its 202nd Session held on 26 April 2016, considered proposals developed by the tenth meeting of the Committee on Aviation Environmental Protection (CAEP/10) to amend the Standards and Recommended Practices (SARPs) in Annex 16 — Environmental Protection, Volume I — Aircraft Noise relating to environmental protection, as shown in Attachment A.

2. The purpose of the amendment of the SARPs in Annex 16, Volume I is to address technical issues arising from the application of demonstration schemes and related guidance for aircraft noise certification. Proposals include:

   a) improved consistency in the way in which each of the chapters of Annex 16, Volume I defines the reference atmosphere to ensure a common interpretation (Proposal A);

   b) removal of references to outdated flight path measurement techniques and improved consistency with the extensively revised guidance material of the Environmental Technical Manual (ETM), Volume I, which was updated to reflect modern aircraft tracking methods using differential global positioning tracking systems (Proposal B);

   c) corrections to address editorial and technical errors in Annex 16, Volume I, Attachment F (Guidelines for noise certification of tilt-rotors) and standardize the terminology and symbols with the rest of Annex 16, Volume I (Proposal C); and

   d) changes and corrections due to minor technical errors in Annex 16, Volume I or for the purposes of consistency (Proposal D).
3. To facilitate your review of the proposed amendments, the rationale for each proposal has been provided in the text boxes immediately following the proposals throughout the attachment.

4. In examining the proposed amendments, you should not feel obliged to comment on editorial aspects as such matters will be addressed by the Air Navigation Commission during its final review of the draft amendments.

5. May I request that any comments you wish to make on the amendment proposals be dispatched to reach me not later than 8 October 2016. The Air Navigation Commission has asked me to specifically indicate that comments received after the due date may not be considered by the Commission and the Council. In this connection, should you anticipate a delay in the receipt of your reply, please let me know in advance of the due date.

6. The subsequent work of the Air Navigation Commission and the Council would be greatly facilitated by specific statements on the acceptability or otherwise of the proposals. Please note that for the review of your comments by the Air Navigation Commission and the Council, replies are normally classified as “agreement with or without comments”, “disagreement with or without comments” or “no indication of position”. If, in your reply, the expressions “no objections” or “no comments” are used, they will be taken to mean “agreement without comment” and “no indication of position”, respectively. In order to facilitate proper classification of your response, a form has been included in Attachment B which may be completed and returned together with your comments, if any, on the proposals in Attachment A.

7. Accept, Sir/Madam, the assurances of my highest consideration.

Fang Liu
Secretary General

Enclosures:
A — Proposed amendment to Annex 16, Volume I
B — Response form
NOTES ON THE PRESENTATION OF THE PROPOSED AMENDMENT

The text of the amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:

1. Text to be deleted is shown with a line through it. text to be deleted
2. New text to be inserted is highlighted with grey shading. new text to be inserted
3. Text to be deleted is shown with a line through it followed by the replacement text which is highlighted with grey shading. new text to replace existing text
Chapter 3.

1. — Subsonic Jet Aeroplanes — Application for Type Certificate submitted on or after 6 October 1977 and before 1 January 2006

2. — Propeller-Driven Aeroplanes Over 8 618 kg — Application for Type Certificate submitted on or after 1 January 1985 and before 1 January 2006

3.6 Noise certification reference procedures

3.6.1.5 The reference procedures shall be calculated under the following reference atmospheric conditions:

a) Sea level atmospheric pressure at sea level of 1 013.25 hPa, decreasing with altitude at a rate defined by the ICAO Standard Atmosphere;

b) Ambient air temperature at sea level of 25°C, i.e. ISA + 10°C; decreasing with altitude at a rate defined by the ICAO Standard Atmosphere (i.e. 0.65°C per 100 m);

c) Constant relative humidity of 70 per cent;

d) Zero wind; and

e) For the purpose of defining the reference take-off profiles for both take-off and lateral noise measurements, the runway gradient is zero; and

f) The reference atmosphere in terms of temperature and relative humidity is considered to be homogeneous (i.e. ambient temperature 25°C and relative humidity 70 per cent) for the purpose of calculating;
1) the reference sound attenuation rate due to atmospheric absorption; and

2) the reference speed of sound used in the calculation of the reference sound propagation geometry.

Note 1. — The reference atmosphere in terms of temperature and relative humidity is homogeneous when used for the calculation of atmospheric absorption coefficients. Details for calculating the variation of reference atmospheric pressure with altitude are given in the section of the Environmental Technical Manual (Doc 9501), Volume I — Procedures for the Noise Certification of Aircraft, concerning the ICAO Standard Atmosphere.

Note 2. — The characteristics of the ICAO Standard Atmosphere are provided in the Manual of the ICAO Standard Atmosphere (Doc 7488/3).

... CHAPTER 5. PROPELLER-DRIVEN AEROPLANES OVER 8 618 kg — Application for Type Certificate submitted before 1 January 1985

... 5.6 Noise certification reference procedures

... 5.6.1.5 The reference procedures shall be calculated under the following reference atmospheric conditions:

a) sea level atmospheric pressure at sea level of 1 013.25 hPa, decreasing with altitude at a rate defined by the ICAO Standard Atmosphere;

b) ambient air temperature at sea level of 25°C, decreasing with altitude at a rate defined by the ICAO Standard Atmosphere (i.e. 0.65°C per 100 m), i.e. ISA + 10°C except that at the discretion of the certificating authority, an alternative reference ambient air temperature at sea level of 15°C, i.e. ISA may be used;

c) constant relative humidity of 70 per cent; and

d) zero wind; and

e) the reference atmosphere in terms of temperature and relative humidity is considered to be homogeneous (i.e. ambient temperature 25°C and relative humidity 70 per cent) for the purpose of calculating:

1) the reference sound attenuation rate due to atmospheric absorption; and

2) the reference speed of sound used in the calculation of the reference sound propagation geometry.
CHAPTER 6. PROPELLER-DRIVEN AEROPLANES
NOT EXCEEDING 8 618 kg — Application for
Type Certificate submitted before 17 November 1988

6.4 Noise certification reference procedures

The reference procedure shall be calculated under the following reference atmospheric conditions:

a) sea level atmospheric pressure at sea level of 1 013.25 hPa, decreasing with altitude at a rate defined by the ICAO Standard Atmosphere; and

b) ambient air temperature at sea level of 25°C, i.e. ISA + 10°C, decreasing with altitude at a rate defined by the ICAO Standard Atmosphere (i.e. 0.65°C per 100 m);

Note 1.— Details for calculating the variation of reference atmospheric pressure with altitude are given in the section of the Environmental Technical Manual (Doc 9501), Volume I — Procedures for the Noise Certification of Aircraft, concerning the ICAO Standard Atmosphere.

Note 2.— The characteristics of the ICAO Standard Atmosphere are provided in the Manual of the ICAO Standard Atmosphere (Doc 7488/3).

CHAPTER 8. HELICOPTERS

8.6.1 General conditions

8.6.1.5 The reference procedures shall be established for calculated under the following reference atmospheric conditions:

a) sea level constant atmospheric pressure of 1 013.25 hPa;

b) constant ambient air temperature of 25°C, i.e. ISA + 10°C;

c) constant relative humidity of 70 per cent; and
d) zero wind.

CHAPTER 10. PROPELLER-DRIVEN AEROPLANES NOT EXCEEDING 8 618 kg — Application for Type Certificate or Certification of Derived Version submitted on or after 17 November 1988

10.5.1 General conditions

10.5.1.4 The reference procedures shall be calculated under the following atmospheric conditions:

a) sea level atmospheric pressure at sea level of 1 013.25 hPa, decreasing with altitude at a rate defined by the ICAO Standard Atmosphere;

b) ambient air temperature at sea level of 15°C, i.e. ISA, decreasing with altitude at a rate defined by the ICAO Standard Atmosphere (i.e. 0.65°C per 100 m);

c) constant relative humidity of 70 per cent; and

d) zero wind.

Note 1.— Details for calculating the variation of reference atmospheric pressure with altitude are given in the section of the Environmental Technical Manual (Doc 9501), Volume I — Procedures for the Noise Certification of Aircraft, concerning the ICAO Standard Atmosphere.

Note 2.— The characteristics of the ICAO Standard Atmosphere are provided in the Manual of the ICAO Standard Atmosphere (Doc 7488/3).

10.5.1.5 The acoustic reference atmospheric conditions shall be the same as the reference atmospheric conditions for flight.
CHAPTER 11. HELICOPTERS NOT EXCEEDING 3 175 kg
MAXIMUM CERTIFICATED TAKE-OFF MASS

11.5.1 General conditions

11.5.1.4 The reference procedure shall be established for the following reference atmospheric conditions:

a) sea level constant atmospheric pressure of 1 013.25 hPa;

b) constant ambient air temperature of 25°C;

c) constant relative humidity of 70 per cent; and

d) zero wind.

CHAPTER 13. TILT-ROTORS

13.6 Noise certification reference procedures

13.6.1.5 The reference procedures shall be established for calculated under the following reference atmospheric conditions:

a) sea level constant atmospheric pressure of 1 013.25 hPa;

b) constant ambient air temperature of 25°C, i.e. ISA +10°C;

c) constant relative humidity of 70 per cent; and

d) zero wind.
APPENDIX 6. EVALUATION METHOD FOR NOISE CERTIFICATION OF PROPELLER-DRIVEN AEROPLANES NOT EXCEEDING 8 618 kg — Application for Type Certificate or Certification of Derived Version submitted on or after 17 November 1988

Editorial Note. Changes proposed for consistency purposes and to correct errors are included in paragraphs 3 and 5.2 to provide clarity to the presentation of Proposal A.

3. NOISE UNIT DEFINITION

The \( L_{\text{Amax}} \) and \( L_{\text{ASmax}} \) is defined as the maximum level, in decibels, of the A-weighted sound pressure (slow response) with reference to the square of the standard reference sound pressure \( (P_0)^2 \), of 20 micropascals (\( \mu \)Pa).

5.2 Corrections and adjustments

5.2.1 The adjustments take account of the effects of:

a) differences in atmospheric absorption between meteorological test conditions and reference conditions;

b) differences in the noise sound propagation path length between the actual aeroplane flight path and the reference flight path;

c) the change in the helical tip Mach number between test and reference conditions; and

d) the change in engine power between test and reference conditions.

5.2.2 The noise level under reference conditions \( (L_{\text{Amax}})_{\text{REF}}, L_{\text{ASmaxR}} \) is obtained by adding increments for each of the above effects to the test day noise level \( (L_{\text{Amax}})_{\text{TEST}}, L_{\text{ASmax}} \).

\[
(L_{\text{Amax}})_{\text{REF}}, L_{\text{ASmaxR}} = L_{\text{Amax}} - L_{\text{ASmax}} + \Delta_1 + \Delta_2 + \Delta_3 + \Delta_4
\]

where

\( \Delta(M) \) is the adjustment for the change in atmospheric absorption between test and reference conditions;

\( \Delta_1 \) is the adjustment for noise sound propagation path lengths;

\( \Delta_2 \) is the adjustment for helical tip Mach number; and

\( \Delta_3 \) is the adjustment for engine power; and

\( \Delta_4 \) is the adjustment for the change in atmospheric absorption between test and reference conditions.
a) When the test conditions are within those specified in Figure A6-2, no adjustments for differences in atmospheric absorption need be applied, i.e., \( \Delta(M) \Delta_4 = 0 \). If conditions are outside those specified in Figure A6-2 then adjustments must be applied by an approved procedure or by adding an increment \( \Delta(M) \Delta_4 \) to the test day noise levels where:

\[
\Delta(M) = 0.01 (H_T \alpha - 0.2 H_R)
\]

\[
\Delta_4 = 0.01 (H \times \alpha_{500} - 0.2 H_R)
\]

and where \( H_T \) is the height in metres of the test aeroplane when directly over the noise measurement point, \( H_R \) is the reference height of the aeroplane above the noise measurement point, and \( \alpha_{500} \) is the rate of absorption at 500 Hz specified in Tables A1-5 to A1-16 of Appendix 1.

b) Measured noise levels should be adjusted to the height of the aeroplane over the noise measuring point on a reference day by algebraically adding an increment equal to \( \Delta_1 \). When test day conditions are within those specified in Figure A6-2:

\[
\Delta_1 = 22 \log \left( \frac{H_T}{H_R} \right)
\]

\[
\Delta_1 = 22 \log \left( \frac{H}{H_R} \right)
\]

When test day conditions are outside those specified in Figure A6-2:

\[
\Delta_1 = 20 \log \left( \frac{H_T}{H_R} \right)
\]

\[
\Delta_1 = 20 \log \left( \frac{H}{H_R} \right)
\]

where \( H_T \) is the height of the aeroplane when directly over the noise measurement point, and \( H_R \) is the reference height of the aeroplane over the measurement point.

c) No adjustments for helical tip Mach number variations need be made if the propeller helical tip Mach number is:

\[
\Delta_2 = K_2 \log \left( \frac{M_T}{M_R} \right)
\]

\[
\Delta = k_2 \log \left( \frac{M_{HR}}{M_{HR}} \right)
\]

which shall be added algebraically to the measured noise level, where \( M_T, M_R \) and \( M_{HR}, M_{HR} \) are the test and reference helical tip Mach numbers respectively. The value of \( K_2, k_2 \) shall be determined from approved data from the test aeroplane. In the absence of flight test data and at the discretion of the certificating authority a value of \( K_2, k_2 = 150 \) may be used for \( M_T, M_R \) less than \( M_{HR}, M_{HR} \); however, for \( M_T, M_R \) greater than or equal to \( M_{HR}, M_{HR} \) no correction is applied.

Note.— The reference helical tip Mach number \( M_{HR} \) is the one corresponding to the reference conditions above the measurement point:

where
where $D$ is the propeller diameter in metres.

$V_T - V_R$ is the true airspeed of the aeroplane in reference conditions in metres per second.

$N$ is the propeller speed in reference conditions in rpm. If $N$ is not available, its value can be taken as the average of the propeller speeds over nominally identical power conditions during the flight tests.

$c_{HR}$ is the reference day speed of sound at the altitude of the aeroplane in metres per second based on the temperature at the reference height assuming an ISA a temperature lapse rate with height defined by the ICAO Standard Atmosphere (i.e. 0.65°C per 100 m).

d) Measured sound levels shall be adjusted for engine power by algebraically adding an increment equal to:

$$\Delta_3 = K_3 \log \left( \frac{P_T}{P_R} \right)$$

$$\Delta_3 = k_3 \log \left( \frac{P_0}{P} \right)$$

where $P_T$, $P$ and $P_R$, $P_0$ are the test and reference engine powers respectively obtained from the manifold pressure/torque gauges and engine rpm. The value of $K_3$, $k_3$ shall be determined from approved data from the test aeroplane. In the absence of flight test data and at the discretion of the certificating authority a value of $K_3$, $k_3 = 17$ may be used. The reference power $P_R$, $P_0$ shall be that obtained at the reference height pressure and temperature and pressure assuming an ISA temperature lapse rate with height assuming temperature and pressure lapse rates with height defined by the ICAO Standard Atmosphere.

Note 1.— Details for calculating the variation of reference atmospheric temperature and pressure with altitude are given in the section of the Environmental Technical Manual (Doc 9501), Volume I — Procedures for the Noise Certification of Aircraft, concerning the ICAO Standard Atmosphere.

Note 2.—The characteristics of the ICAO Standard Atmosphere are provided in the Manual of the ICAO Standard Atmosphere (Doc 7488/3).
ATTACHMENT F. GUIDELINES FOR NOISE CERTIFICATION OF TILT-ROTORS

6.1 General conditions

6.1.5 The reference procedures should be established for calculated conditions under the following reference atmospheric conditions:

a) sea level constant atmospheric pressure of 1013.25 hPa;

b) constant ambient air temperature of 25°C, i.e. ISA + 10°C;

c) constant relative humidity of 70 per cent; and

d) zero wind.

Proposal A Rationale:

The proposed amendment aims to ensure consistency in the way in which each of the chapters of Annex 16, Volume I defines the reference atmosphere to improve clarity and thereby ensure a common interpretation. The proposed changes use common text to define the same concept. Also the current situation whereby identical text (e.g. in current Chapter 3, 3.6.1.5 and Chapter 8, 8.6.1.5) has different intended meanings has been remedied. In addition, references to the ICAO Standard Atmosphere and to related guidance material in the ETM have been added.

This proposal also includes amendments to the definition of the reference day speed of sound in terms of a temperature lapse rate, and to the derivation of reference power in terms of temperature and pressure lapse rates, as defined by the ICAO Standard Atmosphere.
PROPOSAL B

FLIGHT PATH MEASUREMENT TECHNIQUES

APPENDIX 2. EVALUATION METHOD FOR NOISE CERTIFICATION OF:

1.—SUBSONIC JET AEROPLANES — Application for Type Certificate submitted on or after 6 October 1977

2.—PROPELLER-DRIVEN AEROPLANES OVER 8 618 kg — Application for Type Certificate submitted on or after 1 January 1985

3.—HELICOPTERS

4.—TILT-ROTORS

2.3 Flight path measurement

2.3.1 The aircraft height and lateral spatial position relative to the flight path measurement microphone(s) shall be determined by a method which is approved by the certificating authority and is independent of normal cockpit flight instrumentation, such as radar tracking, theodolite triangulation or photographic scaling techniques, to be approved by the certificating authority.

Note.—Guidance material on aircraft position measurement systems is provided in the Environmental Technical Manual (Doc 9501), Volume I — Procedures for the Noise Certification of Aircraft.

2.3.2 The aircraft position along the flight path shall be related synchronized to the noise recorded at the noise measurement locations by means of time-synchronizing signals over a distance and duration sufficient to assure that adequate data is obtained during the period that the noise is within 10 dB of the maximum value of PNLT.

APPENDIX 4. EVALUATION METHOD FOR NOISE CERTIFICATION OF HELICOPTERS NOT EXCEEDING 3 175 kg MAXIMUM CERTIFICATED TAKE-OFF MASS

2.3 Flight path measurement

2.3.1 The helicopter spatial position relative to the flight path reference point measurement microphone shall be determined by a method which is approved by the certificating authority and is
independent of normal cockpit flight instrumentation, such as radar tracking, theodolite triangulation or photographic scaling techniques, approved by the certificating authority.

Note.— Guidance material on aircraft position measurement systems is provided in the Environmental Technical Manual (*Doc 9501*), *Volume I* — Procedures for the Noise Certification of Aircraft.

APPENDIX 6. EVALUATION METHOD FOR NOISE CERTIFICATION OF PROPELLER-DRIVEN AEROPLANES

NOT EXCEEDING 8 618 kg — Application for Type Certificate or Certification of Derived Version submitted on or after 17 November 1988

2.3 Aeroplane testing procedures

2.3.1 The test procedures and noise measurement procedure shall be acceptable to the airworthiness and noise certificating authorities of the State issuing the certification approved by the certificating authority.

2.3.2 The flight test programme shall be initiated at the maximum take-off mass for the aeroplane, and the mass shall be adjusted to maximum take-off mass after each hour of flight time.

2.3.3 The flight test shall be conducted at $V_y \pm 9$ km/h ($V_y \pm 5$ kt) indicated airspeed.

2.3.4 The aeroplane spatial position relative to the flight path reference point measurement microphone shall be determined by a method approved by the certificating authority and is independent of normal cockpit flight instrumentation, such as radar tracking, theodolite triangulation or photographic scaling techniques, approved by the certificating authority.

Note.— Guidance material on aircraft position measurement systems is provided in the Environmental Technical Manual (*Doc 9501*), *Volume I* — Procedures for the Noise Certification of Aircraft.

2.3.5 The aeroplane height when directly over the microphone shall be measured by an approved technique. The aeroplane shall pass over the microphone within ±10° from the vertical and within ±20 per cent of the reference height (see Figure A6-1).

Proposal B Rationale:

The proposed amendment removes references to outdated flight path measurement techniques and aligns the text of Annex 16, Volume I with the extensively revised guidance material of the *Environmental Technical Manual* (ETM), Volume I.
Note.— See Part II, Chapter 13.

Note 1.— These guidelines are applicable to heavier than air aircraft that can be supported in flight chiefly by the reactions of the air on two or more power driven rotors on axes which can be changed from substantially vertical to horizontal.

Note 2.— These guidelines are not intended to be used for tilt-rotors that have one or more configurations that are certificated for airworthiness for STOL only. In such cases, different or additional guidelines would likely be needed.

3. NOISE MEASUREMENT REFERENCE POINTS

A tilt-rotor, when tested in accordance with the reference procedures of Section 6 and the test procedures of Section 7, should not exceed the noise levels specified in Section 4 at the following reference points:

... c) Approach reference noise measurement points:

1) a flight path reference point located on the ground 120 m (394 ft) vertically below the flight path defined in the approach reference procedure (see 6.4). On level ground, this corresponds to a position 1 140 m from the intersection of the 6.0°-degree approach path with the ground plane;

... 4. MAXIMUM NOISE LEVELS

For tilt-rotors specified in Section 1, the maximum noise levels, when determined in accordance with the noise evaluation method of Appendix 2 for helicopters, should not exceed the following:

a) At the take-off flight path reference point For take-off: 109 EPNdB for tilt-rotors in VTOL/conversion mode with maximum certificated take-off mass, at which the noise certification is requested, of 80 000 kg and over and decreasing linearly with the logarithm of the tilt-rotor mass at a rate of 3 EPNdB per halving of mass down to 89 EPNdB after which the limit is constant.

b) At the overflight path reference point For overflight: 108 EPNdB for tilt-rotors in
VTOL/conversion mode with maximum certificated take-off mass, at which the noise certification is requested, of 80 000 kg and over and decreasing linearly with the logarithm of the tilt-rotor mass at a rate of 3 EPNdB per halving of mass down to 88 EPNdB after which the limit is constant.

**Note 1.**—For the tilt-rotor in aeroplane mode, there is no maximum noise level.

**Note 2.**—VTOL/conversion mode is all approved configurations and flight modes where the design operating rotor speed is that used for hover operations.

c) **At the approach flight path reference point** for approach: 110 EPNdB for tilt-rotors in VTOL/conversion mode with maximum certificated take-off mass, at which the noise certification is requested, of 80 000 kg and over and decreasing linearly with the logarithm of the tilt-rotor mass at a rate of 3 EPNdB per halving of mass down to 90 EPNdB after which the limit is constant.

**Note.**—The equations for the calculation of noise levels as a function of take-off mass presented in Section 8.7 of Attachment A, for conditions described in Chapter 8, 8.4.1, are consistent with the maximum noise levels defined in these guidelines.

### 6.3 Overflight reference procedure

**6.3.1** The overflight reference procedure should be established as follows:

a) the tilt-rotor should be stabilized in level flight overhead the flight path reference point at a height of 150 m (492 ft);

b) a constant configuration selected by the applicant should be maintained throughout the overflight reference procedures;

c) the mass of the tilt-rotor should be the maximum take-off mass at which noise certification is requested;

d) in the VTOL/conversion mode, the nacelle angle at the authorized fixed operation point that is closest to the lowest nacelle angle certificated for zero airspeed, a speed of 0.9 $V_{CON}$ and a rotor speed stabilized at the maximum normal operating rpm certificated for level flight should be maintained throughout the overflight reference procedure;

**Note.**—For noise certification purposes, $V_{CON}$ is defined as the maximum authorized speed for VTOL/conversion mode at a specific nacelle angle.

e) in the aeroplane mode, the nacelles should be maintained on the down-stop throughout the overflight reference procedure, with:

1) rotor speed stabilized at the rpm associated with the VTOL/conversion mode and a speed of 0.9 $V_{CON}$; and

2) rotor speed stabilized at the normal cruise rpm associated with the aeroplane mode and at the corresponding 0.9 $V_{MCP}$ or 0.9 $V_{MO}$, whichever is lesser, certificated for level flight.

**Note 1.**—For noise certification purposes, $V_{MCP}$ is defined as the maximum operating limit airspeed for aeroplane mode corresponding to minimum engine installed, maximum continuous
power (MCP) available for sea level pressure (1013.25 hPa), 25°C ambient conditions at the relevant maximum certificated mass; and $V_{MO}$ is the maximum operating (MO) limit airspeed that may not be deliberately exceeded.

6.3.2. Note 2. — The values of $V_{CON}$ and $V_{MCP}$ or $V_{MO}$ used for noise certification should be quoted in the approved flight manual.

6.4. Approach reference procedure

The approach reference procedure should be established as follows:

a) the tilt-rotor should be stabilized and follow a 6.0° degree approach path;

... 7. TEST PROCEDURES

7.4. Adjustments for differences between test and reference flight procedures should not exceed:

a) for take-off: 4.0 EPNdB, of which the arithmetic sum of $\Delta_1$ and the term $-7.5 \log (Q_{K}/Q_{K_r})$ from $\Delta_2$ should not in total exceed 2.0 EPNdB; and

... 7.5. During the test the average rotor rpm should not vary from the normal maximum operating rpm by more than ±1.0 per cent during the 10 dB-down time period.

7.6. The tilt-rotor airspeed should not vary from the reference airspeed appropriate to the flight demonstration by more than ±9 km/h (±5 kt) throughout the 10 dB-down time period.

7.7. The number of level overflights made with a headwind component should be equal to the number of level overflights made with a tailwind component.

7.8. The tilt-rotor should fly within ±10° degrees or ±20 m (±65 ft), whichever is greater, from the vertical above the reference track throughout the 10 dB-down time period (see Figure 8-1 of Part II, Chapter 8).

7.9. The tilt-rotor height should not vary during overflight from the reference height at the overhead point throughout the 10 dB-down period by more than ±9 m (30 ft).

7.10. During the approach noise demonstration the tilt-rotor should be established on a stabilized constant speed approach within the airspace contained between approach angles of 5.5° degrees and 6.5° degrees throughout the 10 dB-down period.

Proposal C Rationale:

The proposed amendment deals with corrections to guidelines for noise certification of tilt-rotors to revise editorial and technical errors in Annex 16, Volume I, Attachment F (Guidelines for noise certification of tilt-rotor aircraft) and standardize the terminology and symbols with the rest Annex 16, Volume I.
### NOMENCLATURE: SYMBOLS AND UNITS

Note.—Many of the following definitions and symbols are specific to aircraft noise certification. Some of the definitions and symbols may also apply to purposes beyond aircraft noise certification.

#### 1.1 Velocity

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>c_R</td>
<td>m/s</td>
<td>Reference speed of sound. Speed of sound at reference conditions.</td>
</tr>
<tr>
<td>M_ATR</td>
<td></td>
<td>Helicopter rotor reference advancing blade tip Mach number. The sum of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the reference rotor rotational tip speed and the reference speed of the</td>
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<td></td>
<td></td>
<td>helicopter, divided by the reference speed of sound.</td>
</tr>
<tr>
<td>M_H</td>
<td></td>
<td>Propeller helical tip Mach number. The square root of the sum of the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>square of the propeller test rotational tip speed and the square of the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>test airspeed of the aeroplane, divided by the test speed of sound.</td>
</tr>
<tr>
<td>M_HR</td>
<td></td>
<td>Propeller reference helical tip Mach number. The square root of the sum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of the square of the propeller reference rotational tip speed and the</td>
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<td></td>
<td></td>
<td>square of the reference speed of the aeroplane, divided by the reference</td>
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<tr>
<td></td>
<td></td>
<td>speed of sound.</td>
</tr>
<tr>
<td>Best R/C</td>
<td>m/s</td>
<td>Best rate of climb. The certificated maximum take-off rate of climb at</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the maximum power setting and engine speed.</td>
</tr>
<tr>
<td>Symbol</td>
<td>Unit</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>(V_{AR})</td>
<td>km/h</td>
<td>Adjusted reference speed. On a non-standard test day, the helicopter reference speed adjusted to achieve the same advancing tip Mach number as the reference speed at reference conditions.</td>
</tr>
<tr>
<td>(V_{CON})</td>
<td>km/h</td>
<td>Maximum airspeed in conversion mode. The never-exceed airspeed of a tilt-rotor when in conversion mode.</td>
</tr>
<tr>
<td>(V_G)</td>
<td>km/h</td>
<td>Ground speed. The aircraft velocity relative to the ground.</td>
</tr>
<tr>
<td>(V_{GR})</td>
<td>km/h</td>
<td>Reference ground speed. The aircraft true velocity relative to the ground in the direction of the ground track under reference conditions. (V_{GR}) is the horizontal component of the reference aircraft speed (V_R).</td>
</tr>
<tr>
<td>(V_H)</td>
<td>km/h</td>
<td>Maximum airspeed in level flight. The maximum airspeed of a helicopter in level flight when operating at maximum continuous power.</td>
</tr>
<tr>
<td>(V_{MCP})</td>
<td>km/h</td>
<td>Maximum airspeed in level flight. The maximum airspeed of a tilt-rotor in level flight when operating in aeroplane mode at maximum continuous power.</td>
</tr>
<tr>
<td>(V_{MO})</td>
<td>km/h</td>
<td>Maximum operating airspeed. The maximum operating limit airspeed of a tilt-rotor that may not be deliberately exceeded.</td>
</tr>
<tr>
<td>(V_{NE})</td>
<td>km/h</td>
<td>Never exceed airspeed. The maximum operating limit airspeed that may not be deliberately exceeded.</td>
</tr>
<tr>
<td>(V_R)</td>
<td>km/h</td>
<td>Reference speed. The aircraft true velocity at reference conditions in the direction of the reference flight path.</td>
</tr>
<tr>
<td>(V_{REF})</td>
<td>km/h</td>
<td>Reference landing airspeed. The speed of the aeroplane, in a specific landing configuration, at the point where it descends through the landing screen height in the determination of the landing distance for manual landings.</td>
</tr>
<tr>
<td>(V_S)</td>
<td>km/h</td>
<td>Stalling airspeed. The minimum steady airspeed in the landing configuration.</td>
</tr>
<tr>
<td>(V_{tip})</td>
<td>m/s</td>
<td>Tip speed. The rotational speed of a rotor or propeller tip at test conditions, excluding the aircraft velocity component.</td>
</tr>
<tr>
<td>(V_{tipR})</td>
<td>m/s</td>
<td>Reference tip speed. The rotational speed of a rotor or propeller tip at reference conditions, excluding the aircraft velocity component.</td>
</tr>
<tr>
<td>(V_Y)</td>
<td>km/h</td>
<td>Speed for best rate of climb. The test airspeed for best take-off rate of climb.</td>
</tr>
</tbody>
</table>

Note: This symbol should not be confused with the symbol commonly used for aeroplane take-off rotation speed.
\( V_2 \) \( \text{km/h} \) *Take-off safety speed.* The minimum airspeed for a safe take-off.

### 1.2 Time

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_0 )</td>
<td>s</td>
<td><em>Reference duration.</em> The length of time used as a reference in the integration equation for computing EPNL, where ( t_0 = 10 \text{ s} ).</td>
</tr>
<tr>
<td>( t_R )</td>
<td>s</td>
<td><em>Reference reception time.</em> The reference time of reception calculated from time of reference aircraft position and distance between aircraft and microphone used in the integrated procedure.</td>
</tr>
<tr>
<td>( \Delta t )</td>
<td>s</td>
<td><em>Time increment.</em> The equal time increment between one-third octave band spectra, where ( \Delta t = 0.5 \text{ s} ).</td>
</tr>
<tr>
<td>( \delta t_R )</td>
<td>s</td>
<td><em>Reference time increment.</em> The effective duration of a time increment between reference reception times associated with PNLT points used in the integrated method.</td>
</tr>
</tbody>
</table>

### 1.3 Indices

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>( i )</td>
<td></td>
<td><em>Frequency band index.</em> The numerical indicator that denotes any one of the 24 one-third octave bands with nominal geometric mean frequencies from 50 to 10 000 Hz.</td>
</tr>
<tr>
<td>( k )</td>
<td></td>
<td><em>Time increment index.</em> The numerical indicator that denotes any one of the 0.5 second spectra in a noise time history. For the integrated method, the adjusted time increment associated with each value of ( k ) will likely vary from the original 0.5 second time increment when projected to reference conditions.</td>
</tr>
<tr>
<td>( k_F )</td>
<td></td>
<td><em>First time increment identifier.</em> Index of the first 10 dB-down point in the discrete measured PNLT time history.</td>
</tr>
<tr>
<td>( k_{FR} )</td>
<td></td>
<td><em>Reference first time increment identifier.</em> Index of the first 10 dB-down point in the discrete PNLT time history for the integrated method.</td>
</tr>
<tr>
<td>( k_L )</td>
<td></td>
<td><em>Last time increment identifier.</em> Index of the last 10 dB-down point in the discrete measured PNLT time history.</td>
</tr>
<tr>
<td>( k_{LR} )</td>
<td></td>
<td><em>Reference last time increment identifier.</em> Index of the last 10 dB-down point in the discrete PNLT time history for the integrated method.</td>
</tr>
<tr>
<td>Symbol</td>
<td>Unit</td>
<td>Meaning</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>$k_M$</td>
<td></td>
<td>Maximum PNLT time increment index. Time increment index of PNLTM.</td>
</tr>
<tr>
<td>$t$</td>
<td>s</td>
<td>Elapsed time. The length of time measured from a reference zero.</td>
</tr>
<tr>
<td>$t_1$</td>
<td>s</td>
<td>Time of first 10 dB-down point. The time of the first 10 dB-down point in a continuous function of time. (See $k_F$.)</td>
</tr>
<tr>
<td>$t_2$</td>
<td>s</td>
<td>Time of last 10 dB-down point. The time of the last 10 dB-down point in a continuous function of time. (See $k_L$.)</td>
</tr>
</tbody>
</table>

### 1.4 Noise Metrics

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{EPNL}$</td>
<td>$\text{EPNdB}$</td>
<td>Effective perceived noise level. A single-number evaluator for an aircraft pass-by, accounting for the subjective effects of aircraft noise on human beings, consisting of an integration over the noise duration of the perceived noise level (PNL) adjusted for spectral irregularities (PNLT), normalized to a reference duration of 10 seconds. (See Appendix 2, Section 4.1 for specifications.)</td>
</tr>
<tr>
<td>$\text{EPNL}_A$</td>
<td>$\text{EPNdB}$</td>
<td>Approach EPNL. Effective perceived noise level at the aeroplane approach reference measurement points.</td>
</tr>
<tr>
<td>$\text{EPNL}_F$</td>
<td>$\text{EPNdB}$</td>
<td>Flyover EPNL. Effective perceived noise level at the aeroplane flyover reference measurement points.</td>
</tr>
<tr>
<td>$\text{EPNL}_L$</td>
<td>$\text{EPNdB}$</td>
<td>Lateral EPNL. Effective perceived noise level at the aeroplane lateral reference measurement points.</td>
</tr>
<tr>
<td>$L_{\text{AE}}$</td>
<td>dB SEL</td>
<td>Sound exposure level (SEL). A single event noise level for an aircraft pass-by, consisting of an integration over the noise duration of the A-weighted sound level (dBA), normalized to a reference duration of 1 second. (See Appendix 4, Section 3 for specifications.)</td>
</tr>
<tr>
<td>$L_{\text{AS}}$</td>
<td>dB(A)</td>
<td>Slow A-weighted sound level. Sound level with frequency weighting A and time weighting S for a specified instance in time;</td>
</tr>
<tr>
<td>$L_{\text{ASmax}}$</td>
<td>dB(A)</td>
<td>Maximum Slow A-weighted sound level. The maximum value of $L_{\text{AS}}$ over a specified time interval.</td>
</tr>
<tr>
<td>$L_{\text{ASmaxR}}$</td>
<td>dB(A)</td>
<td>Reference maximum Slow A-weighted sound level. The maximum value of $L_{\text{AS}}$ over a specified time interval corrected to reference conditions.</td>
</tr>
<tr>
<td>Symbol</td>
<td>Unit</td>
<td>Meaning</td>
</tr>
<tr>
<td>--------</td>
<td>-----------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>LIMITₐ</td>
<td>EPNdB</td>
<td><em>Approach EPNL limit.</em> The maximum permitted noise level at the aeroplane approach reference measurement points.</td>
</tr>
<tr>
<td>LIMIT₇</td>
<td>EPNdB</td>
<td><em>Flyover EPNL limit.</em> The maximum permitted noise level at the aeroplane flyover reference measurement points.</td>
</tr>
<tr>
<td>LIMIT₇</td>
<td>EPNdB</td>
<td><em>Lateral EPNL limit.</em> The maximum permitted noise level at the aeroplane lateral reference measurement points.</td>
</tr>
<tr>
<td>n</td>
<td>noy</td>
<td><em>Perceived noisiness.</em> The perceived noisiness of a one-third octave band sound pressure level in a given spectrum.</td>
</tr>
<tr>
<td>N</td>
<td>noy</td>
<td><em>Total perceived noisiness.</em> The total perceived noisiness of a given spectrum calculated from the 24 values of n.</td>
</tr>
<tr>
<td>PNL</td>
<td>PNdB</td>
<td><em>Perceived noise level.</em> A perception-based noise evaluator representing the subjective effects of broadband noise received at a given point in time during an aircraft pass-by. It is the noise level empirically determined to be equally as noisy as a 1 kHz one-third octave band sample of random noise. (See Appendix 2, Section 4.2 for specifications.)</td>
</tr>
<tr>
<td>PNLT</td>
<td>TPNdB</td>
<td><em>Tone-corrected perceived noise level.</em> The value of the PNL of a given spectrum adjusted for spectral irregularities.</td>
</tr>
<tr>
<td>PNLT₉</td>
<td>TPNdB</td>
<td><em>Reference tone-corrected perceived noise level.</em> The value of PNLT adjusted to reference conditions.</td>
</tr>
<tr>
<td>PNLT₉M</td>
<td>TPNdB</td>
<td><em>Maximum tone-corrected perceived noise level.</em> The maximum value of PNLT in a specified time history, adjusted for the bandsharing adjustment Δ₉.</td>
</tr>
<tr>
<td>PNLT₉M₉</td>
<td>TPNdB</td>
<td><em>Reference maximum tone-corrected perceived noise level.</em> The maximum value of PNLT₉ in a specified time history, adjusted for the bandsharing adjustment Δ₉ in the simplified method and Δ₉R in the integrated method.</td>
</tr>
<tr>
<td>SPL</td>
<td>dB</td>
<td><em>Sound pressure level.</em> The level of sound, relative to the reference level of 20 μPa, at any instant of time that occurs in a specified frequency range. The level is calculated as ten times the logarithm to the base 10 of the ratio of the time-mean-square pressure of the sound to the square of the reference sound pressure of 20 μPa.</td>
</tr>
</tbody>
</table>

*Note:* — *Typical aircraft noise certification usage refers to a specific one-third octave band, e.g. SPL(i,k) for the i-th band of the k-th spectrum in an aircraft noise time-history.*

<p>| SPL₉   | dB        | <em>Reference sound pressure level.</em> The one-third octave band sound pressure levels adjusted to reference conditions. |</p>
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPL&lt;sub&gt;S&lt;/sub&gt;</td>
<td>dB</td>
<td>Slow-weighted sound pressure level. The value of one-third octave band sound pressure levels with time weighting S applied.</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;1&lt;/sub&gt;</td>
<td>TPNdB</td>
<td>PNLT&lt;sub&gt;M&lt;/sub&gt; adjustment. In the simplified adjustment method, the adjustment to be added to the measured EPNL to account for noise level changes due to differences in atmospheric absorption and noise path length between test and reference conditions at PNLT&lt;sub&gt;M&lt;/sub&gt;. For propeller aeroplanes, the adjustment to be added to L&lt;sub&gt;Amax&lt;/sub&gt; to account for noise level changes due to the difference between test and reference aeroplane heights.</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;2&lt;/sub&gt;</td>
<td>TPNdB</td>
<td>Duration adjustment. In the simplified adjustment method, the adjustment to be added to the measured EPNL to account for noise level changes due to the change in noise duration caused by differences between test and reference aircraft speed and position relative to the microphone.</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;3&lt;/sub&gt;</td>
<td>TPNdB</td>
<td>Source noise adjustment. In the simplified or integrated adjustment method, the adjustment to be added to the measured EPNL to account for noise level changes due to differences in source noise generating mechanisms between test and reference conditions.</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;4&lt;/sub&gt;</td>
<td>dB</td>
<td>Atmospheric absorption adjustment. For propeller aeroplanes, the adjustment to be added to the measured L&lt;sub&gt;Amax&lt;/sub&gt; for noise level changes due to the change in atmospheric absorption caused by the difference between test and reference aeroplane heights.</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;B&lt;/sub&gt;</td>
<td>TPNdB</td>
<td>Bandsharing adjustment. The adjustment to be added to the maximum PNLT to account for possible suppression of a tone due to one-third octave bandsharing of that tone. PNLT&lt;sub&gt;M&lt;/sub&gt; is equal to the maximum PNLT plus Δ&lt;sub&gt;B&lt;/sub&gt;.</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;BR&lt;/sub&gt;</td>
<td>TPNdB</td>
<td>Reference bandsharing adjustment. The adjustment to be added to the maximum PNLT&lt;sub&gt;R&lt;/sub&gt; in the integrated method to account for possible suppression of a tone due to one-third octave bandsharing of that tone. PNLT&lt;sub&gt;M&lt;/sub&gt;&lt;sub&gt;R&lt;/sub&gt; is equal to the maximum PNLT&lt;sub&gt;R&lt;/sub&gt; plus Δ&lt;sub&gt;BR&lt;/sub&gt;.</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;peak&lt;/sub&gt;</td>
<td>TPNdB</td>
<td>Peak adjustment. The adjustment to be added to the measured EPNL for when the PNLT for a secondary peak, identified in the calculation of EPNL from measured data and adjusted to reference conditions, is greater than the PNLT for the adjusted PNLT&lt;sub&gt;M&lt;/sub&gt; spectrum.</td>
</tr>
</tbody>
</table>
### 1.5 Calculation of PNL and Tone Correction

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>dB</td>
<td>Tone correction factor. The factor to be added to the PNL of a given spectrum to account for the presence of spectral irregularities such as tones.</td>
</tr>
<tr>
<td>$i$</td>
<td>Hz</td>
<td>Frequency. The nominal geometric mean frequency of a one-third octave band.</td>
</tr>
<tr>
<td>$E$</td>
<td>dB</td>
<td>Delta-dB. The difference between the original sound pressure level and the final broadband sound pressure level of a one-third octave band in a given spectrum.</td>
</tr>
<tr>
<td>$\log n(a)$</td>
<td></td>
<td>Noy discontinuity coordinate. The log $n$ value of the intersection point of the straight lines representing the variation of SPL with log $n$.</td>
</tr>
<tr>
<td>$M$</td>
<td></td>
<td>Noy inverse slope. The reciprocals of the slopes of straight lines representing the variation of SPL with log $n$.</td>
</tr>
<tr>
<td>$s$</td>
<td>dB</td>
<td>Slope of sound pressure level. The change in level between adjacent one-third octave band sound pressure levels in a given spectrum.</td>
</tr>
<tr>
<td>$\Delta s$</td>
<td>dB</td>
<td>Change in slope of sound pressure level.</td>
</tr>
<tr>
<td>$s'$</td>
<td>dB</td>
<td>Adjusted slope of sound pressure level. The change in level between adjacent adjusted one-third octave band sound pressure levels in a given spectrum.</td>
</tr>
<tr>
<td>$\bar{s}$</td>
<td>dB</td>
<td>Average slope of sound pressure level.</td>
</tr>
<tr>
<td>$\text{SPL}(a)$</td>
<td>dB</td>
<td>Noy discontinuity level. The SPL value at the discontinuity coordinate of the straight lines representing the variation of SPL with log $n$.</td>
</tr>
<tr>
<td>$\text{SPL}(b)$</td>
<td>dB</td>
<td>Noy intercept levels. The intercepts on the SPL-axis of the straight lines representing the variation of SPL with log $n$.</td>
</tr>
<tr>
<td>$\text{SPL}(c)$</td>
<td>dB</td>
<td>Noy discontinuity level. The SPL value at the discontinuity coordinate where log $n$ equals $-1$.</td>
</tr>
<tr>
<td>$\text{SPL}(d)$</td>
<td>dB</td>
<td>Noy discontinuity level. The SPL value at the discontinuity coordinate where log $n$ equals $\log 0.3$.</td>
</tr>
<tr>
<td>$\text{SPL}(e)$</td>
<td>dB</td>
<td>Adjusted sound pressure level. The first approximation to broadband sound pressure level in a one-third octave band of a given spectrum.</td>
</tr>
<tr>
<td>$\text{SPL}'$</td>
<td>dB</td>
<td>Final broadband sound pressure level. The second and final approximation to broadband sound pressure level in a one-third octave band of a given spectrum.</td>
</tr>
</tbody>
</table>
### 1.6 Flight Path Geometry

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>m</td>
<td>Height. The aircraft height when overhead or abeam of the centre microphone.</td>
</tr>
<tr>
<td>H&lt;sub&gt;R&lt;/sub&gt;</td>
<td>m</td>
<td>Reference height. The reference aircraft height when overhead or abeam of the centre microphone.</td>
</tr>
<tr>
<td>X</td>
<td>m</td>
<td>Aircraft position along the ground track. The position coordinate of the aircraft along the x-axis at a specific point in time.</td>
</tr>
<tr>
<td>Y</td>
<td>m</td>
<td>Lateral aircraft position relative to the reference ground track. The position coordinate of the aircraft along the y-axis at a specific point in time.</td>
</tr>
<tr>
<td>Z</td>
<td>m</td>
<td>Vertical aircraft position relative to the reference ground track. The position coordinate of the aircraft along the z-axis at a specific point in time.</td>
</tr>
<tr>
<td>θ</td>
<td>degrees</td>
<td>Sound emission angle. The angle between the flight path and the direct sound propagation path to the microphone. The angle is identical for both the measured and reference flight paths.</td>
</tr>
<tr>
<td>ψ</td>
<td>degrees</td>
<td>Elevation angle. The angle between the sound propagation path and a horizontal plane passing through the microphone, where the sound propagation path is defined as a line between a sound emission point on the measured flight path and the microphone diaphragm.</td>
</tr>
<tr>
<td>ψ&lt;sub&gt;R&lt;/sub&gt;</td>
<td>degrees</td>
<td>Reference elevation angle. The angle between the reference sound propagation path and a horizontal plane passing through the reference microphone location, where the reference sound propagation path is defined as a line between a sound emission point on the reference flight path and the reference microphone diaphragm.</td>
</tr>
</tbody>
</table>
1.7 Miscellaneous

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>antilog</td>
<td>—</td>
<td><em>Antilogarithm to the base 10.</em></td>
</tr>
<tr>
<td>D</td>
<td>m</td>
<td><em>Diameter.</em> Propeller or rotor diameter.</td>
</tr>
<tr>
<td>D₁₅</td>
<td>m</td>
<td><em>Take-off distance.</em> The take-off distance required for an aeroplane to reach 15 m height above ground level.</td>
</tr>
<tr>
<td>e</td>
<td>—</td>
<td><em>Euler’s number.</em> The mathematical constant that is the base number of the natural logarithm, approximately 2.78183.</td>
</tr>
<tr>
<td>log</td>
<td>—</td>
<td><em>Logarithm to the base 10.</em></td>
</tr>
<tr>
<td>N</td>
<td>rpm</td>
<td><em>Propeller speed.</em></td>
</tr>
<tr>
<td>N₁</td>
<td>rpm</td>
<td><em>Compressor speed.</em> The turbine engine low pressure compressor first stage fan speed.</td>
</tr>
<tr>
<td>RH</td>
<td>%</td>
<td><em>Relative humidity.</em> The ambient atmospheric relative humidity.</td>
</tr>
<tr>
<td>T</td>
<td>°C</td>
<td><em>Temperature.</em> The ambient atmospheric temperature.</td>
</tr>
<tr>
<td>u</td>
<td>m/s</td>
<td><em>Wind speed along-track component.</em> The component of the wind speed vector along the reference ground track.</td>
</tr>
<tr>
<td>v</td>
<td>m/s</td>
<td><em>Wind speed cross-track component.</em> The component of the wind speed vector horizontally perpendicular to the reference ground track.</td>
</tr>
<tr>
<td>α</td>
<td>dB/100 m</td>
<td><em>Test atmospheric absorption coefficient.</em> The sound attenuation rate due to atmospheric absorption that occurs in a specified one-third octave band for the measured ambient temperature and relative humidity.</td>
</tr>
<tr>
<td>αᵣ</td>
<td>dB/100 m</td>
<td><em>Reference atmospheric absorption coefficient.</em> The sound attenuation rate due to atmospheric absorption that occurs in a specified one-third octave band for a reference ambient temperature and relative humidity.</td>
</tr>
<tr>
<td>µ</td>
<td>—</td>
<td><em>Engine noise performance parameter.</em> For jet aeroplanes, typically the normalized low pressure fan speed, normalized engine thrust, or engine pressure ratio used in the calculation of the source noise adjustment.</td>
</tr>
</tbody>
</table>

PART I. DEFINITIONS

**Auxiliary power unit**: *Auxiliary power unit (APU).* A self-contained power unit on an aircraft providing electrical/pneumatic power to aircraft systems during ground operations or in-flight separate from the propulsion engine/s.
State of Registry. The State on whose register the aircraft is entered.

CHAPTER 3.

1.— SUBSONIC JET AEROPLANES — Application for Type Certificate submitted on or after 6 October 1977 and before 1 January 2006

2.— PROPELLER-DRIVEN AEROPLANES OVER 8 618 kg — Application for Type Certificate submitted on or after 1 January 1985 and before 1 January 2006

3.6 Noise certification reference procedures

3.6.3 Approach reference procedure

The approach reference flight path shall be calculated as follows:

a) the aeroplane shall be stabilized and following a 3° glide path;

b) a steady approach speed of $V_{REF} + 19\text{ km/h} (V_{REF} + 10\text{ kt})$, with thrust or power stabilized, shall be maintained over the measurement point;

Note.— In airworthiness terms $V_{REF}$ is defined as the “reference landing speed”. Under this definition reference landing speed means “the speed of the aeroplane, in a specified landing configuration, at the point where it descends through the landing screen height in the determination of the landing distance for manual landings”.

CHAPTER 6. PROPELLER-DRIVEN AEROPLANES

NOT EXCEEDING 8 618 kg — Application for Type Certificate submitted before 17 November 1988

6.5 Test procedures

6.5.1 Either the test procedures described in 6.5.2 and 6.5.3 or equivalent test procedures approved by the certificating authority shall be used.

6.5.2 Tests to demonstrate compliance with the maximum noise levels of 6.3 shall consist of a series of level flights overhead the measuring station at a height of
8.6.2 Take-off reference procedure

The take-off reference flight procedure shall be established as follows:

a) the helicopter shall be stabilized at the maximum take-off power corresponding to minimum installed engine(s) specification power available for the reference ambient conditions or gearbox torque limit, whichever is lower, and along a path starting from a point located 500 m prior to the flight path reference point, at 20 m (65 ft) above the ground;

b) the best rate of climb speed, $V_Y$, or the lowest approved speed for the climb after take-off, whichever is the greater, shall be maintained throughout the take-off reference procedure;

c) the steady climb shall be made with the rotor speed stabilized at the maximum normal operating rpm certificated for take-off;

d) a constant take-off configuration selected by the applicant shall be maintained throughout the take-off reference procedure with the landing gear position consistent with the airworthiness certification tests for establishing the best rate of climb speed, $V_Y$;

e) the mass of the helicopter shall be the maximum take-off mass at which noise certification is requested; and

f) the reference take-off path is defined as a straight line segment inclined from the starting point (500 m prior to the centre microphone location and 20 m (65 ft) above ground level) at an angle defined by best rate of climb and $V_Y$ for minimum specification engine performance.

8.6.3 Overflight reference procedure

8.6.3.1 The overflight reference procedure shall be established as follows:

a) the helicopter shall be stabilized in level flight overhead the flight path reference point at a height of 150 m (492 ft);

b) a speed of $0.9 V_H$ or $0.9 V_{NE}$ or $0.45 V_H + 120$ km/h $(0.45 V_H + 65$ kt) or $0.45 V_{NE} + 120$ km/h $(0.45 V_{NE} + 65$ kt), whichever is the least, shall be maintained throughout the overflight reference procedure;

Note.— For noise certification purposes, $V_H$ is defined as the airspeed in level flight obtained using the torque corresponding to minimum engine installed, maximum continuous power available for sea level pressure $(1 013.25$ hPa), $25^\circ C$ ambient conditions at the relevant
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maximum certificated mass. $V_{NE}$ is defined as the not-to-exceed airworthiness airspeed imposed by the manufacturer and approved by the certificating authority.

c) the overflight shall be made with the rotor speed stabilized at the maximum normal operating rpm certificated for level flight;

d) the helicopter shall be in the cruise configuration; and

e) the mass of the helicopter shall be the maximum take-off mass at which noise certification is requested.

8.6.3.2 The value of $V_H$ and/or $V_{NE}$ used for noise certification shall be quoted in the approved flight manual.

8.6.4 Approach reference procedure

The approach reference procedure shall be established as follows:

a) the helicopter shall be stabilized and following a $6.0^\circ$ approach path;

b) the approach shall be made at a stabilized airspeed equal to the best rate of climb speed, $V_z$, $V_Y$, or the lowest approved speed for the approach, whichever is the greater, with power stabilized during the approach and over the flight path reference point, and continued to a normal touchdown;

. . .

CHAPTER 10. PROPELLER-DRIVEN AEROPLANES NOT EXCEEDING 8 618 kg — Application for Type Certificate or Certification of Derived Version submitted on or after 17 November 1988

. . .

10.2 Noise evaluation measure

The noise evaluation measure shall be the maximum A-weighted noise level ($L_{Amax}$), $L_{ASmax}$ as defined in Appendix 6.

. . .

10.5.2 Take-off reference procedure

. . .

Second phase

a) the beginning of the second phase corresponds to the end of the first phase;
b) the aeroplane shall be in the climb configuration with landing gear up, if retractable, and flap setting corresponding to normal climb throughout this second phase;

c) the speed shall be the best rate of climb speed, $V_y$, $V_Y$; and

d) take-off power and, for aeroplanes equipped with variable pitch or constant speed propellers, rpm shall be maintained throughout the second phase. If airworthiness limitations do not permit the application of take-off power and rpm up to the reference point, then take-off power and rpm shall be maintained for as long as is permitted by such limitations and thereafter at maximum continuous power and rpm. Limiting of time for which take-off power and rpm shall be used in order to comply with this chapter shall not be permitted. The reference height shall be calculated assuming climb gradients appropriate to each power setting used.

10.6 Test procedures

10.6.1 The test procedures shall be acceptable to the airworthiness and noise certificating authorities of the State issuing the certificate.

10.6.2 The test procedures and noise measurements shall be conducted and processed in an approved manner to yield the noise evaluation measure in units of $L_{A_{max}}$ $L_{A_{max}}$ as described in Appendix 6.
CHAPTER 13. TILT-ROTORS

13.2 Noise evaluation measure

The noise evaluation measure shall be the effective perceived noise level in EPNdB as described in Appendix 2 of this Annex. The correction for spectral irregularities shall start at 50 Hz (see 4.3.1 of Appendix 2).

Note.—Additional data in SEL and \( L_{AS_{max}} \) as defined in Appendix 4, and one-third octave SPLs as defined in Appendix 2 corresponding to \( L_{AS_{max}} \) should be made available to the certificating authority for land-use planning purposes.

13.3 Noise measurement reference points

A tilt-rotor, when tested in accordance with the reference procedures of Section 6 13.6 and the test procedures of Section 7 13.7, shall not exceed the noise levels specified in 13.4 at the following reference points:

13.6.2 Take-off reference procedure

The take-off reference flight procedure shall be established as follows:

f) the reference take-off path is defined as a straight line segment inclined from the starting point (500 m (1 640 ft) prior to the centre noise measurement point and 20 m (65 ft) above ground level) at an angle defined by best rate of climb (BRC) and the best rate of climb speed corresponding to the selected nacelle angle and for minimum specification engine performance.

13.6.3 Overflight reference procedure

13.6.3.1 The overflight reference procedure shall be established as follows:

d) in the VTOL/conversion mode, the nacelle angle at the authorized fixed operation point that is closest to the lowest nacelle angle certificated for zero airspeed, a speed of \( 0.9 V_{CON} \) and a rotor speed stabilized at the maximum normal operating rpm certificated for level flight shall be maintained throughout the overflight reference procedure;
Note. — For noise certification purposes, $V_{CON}$ is defined as the maximum authorized speed for VTOL/conversion mode at a specific nacelle angle.

e) in the aeroplane mode, the nacelles shall be maintained on the down-stop throughout the overflight reference procedure, with:

1) rotor speed stabilized at the rpm associated with the VTOL/conversion mode and a speed of $0.9V_{CON}$; and

2) rotor speed stabilized at the normal cruise rpm associated with the aeroplane mode and at the corresponding $0.9V_{MCP}$, $0.9V_{MCP}$ or $0.9V_{MO}$, whichever is lesser, certificated for level flight.
APPENDIX 2. EVALUATION METHOD FOR NOISE CERTIFICATION OF:

1.—SUBSONIC JET AEROPLANES — Application for Type Certificate submitted on or after 6 October 1977

2.—PROPELLER-DRIVEN AEROPLANES OVER 8 618 kg — Application for Type Certificate submitted on or after 1 January 1985

3.—HELICOPTERS

4.—TILT-ROTORS

Note.— See Part II, Chapters 3, 4, 8, 13 and 14.

1. INTRODUCTION

Note 3.— A complete list of symbols and units is included after the Table of Contents of this Annex. The mathematical formulation of perceived noisiness, a procedure for determining atmospheric attenuation of sound, and detailed procedures for correcting noise levels from non-reference to reference conditions are included in Sections 6 to 7 and 8 of this appendix.

2.2.2 Atmospheric conditions

2.2.2.1 Definitions and specifications

For the purposes of noise certification in this section the following specifications apply:

Average crosswind component shall be determined from the series of individual values of the “cross-track-crosstrack” (v) component of the wind samples obtained during the aircraft test run, using a linear averaging process over 30 seconds or an averaging process that has a time constant of no more than 30 seconds, the result of which is read out at a moment approximately 15 seconds after the time at which the aircraft passes either over or abreast the microphone.

Average wind speed shall be determined from the series of individual wind speed samples obtained during the aircraft test run, using a linear averaging process over 30 seconds, or an averaging process that has a time constant of no more than 30 seconds, the result of which is read out at a moment approximately 15 seconds after the time at which the aircraft passes either over or abreast the microphone. Alternatively, each wind vector shall be broken down into its “along-track” (u) and “cross-track” (v) components. The u and v components of the series of individual wind samples obtained during the aircraft test run shall be separately averaged using a linear averaging
process over 30 seconds, or an averaging process that has a time constant of no more than 30 seconds, the result of which is read out at a moment approximately 15 seconds after the time at which the aircraft passes either over or abeam the microphone. The average wind speed and direction (with respect to the track) shall then be calculated from the averaged u and v components according to Pythagorean Theorem and “arctan(v/u)”. 

**Distance constant (or response length).** The passage of wind (in metres) required for the output of a wind speed sensor to indicate $100 \times (1−1/e)$ per cent (about 63 per cent) of a step-function increase of the input speed.

**Maximum crosswind component.** The maximum value within the series of individual values of the “cross track/cross-track” (v) component of the wind samples recorded every second over a time interval that spans the 10 dB-down period.

**Maximum wind speed.** The maximum value within the series of individual wind speed samples recorded every second over a time interval that spans the 10 dB-down period.

**Sound attenuation coefficient.** The reduction in level of sound within a one-third octave band, in dB per 100 metres, due to the effects of atmospheric absorption of sound. Equations for the calculation of sound attenuation coefficients from values of atmospheric temperature and relative humidity are provided in Section 7.

**Time constant (of a first order system).** The time required for a device to detect and indicate $100 \times (1−1/e)$ per cent (about 63 per cent) of a step function change. (The mathematical constant, $e$, is the base number of the natural logarithm, approximately 2.7183 — also known as Euler’s number, or Napier’s constant.)

### 3.1 Definitions

**Free-field sensitivity of a microphone system.** In volts per pascal, for a sinusoidal plane progressive sound wave of specified frequency, at a specified sound incident angle, the quotient of the root-mean-square voltage at the output of a microphone system and the root-mean-square sound pressure that would exist at the position of the microphone in its absence.
3.7 Analysis systems

3.7.5 When the one-third octave band sound pressure levels are determined from the output of the analyser without SLOW-time-weighting, SLOW-time-weighting shall be simulated in the subsequent processing. Simulated SLOW-weighted sound pressure levels can be obtained using a continuous exponential averaging process by the following equation:

\[
L_s(i,k) = 10 \log \left\{ (0.60653) 10^{0.1 \times L_{\text{SPL}}(i,(k-1))} + (0.39347) 10^{0.1 \times L_{\text{SPL}}(i,k)} \right\}
\]

\[
\text{SPL}_s(i,k) = 10 \log \left\{ (0.60653) 10^{0.1 \times \text{SPL}_s(i,(k-1))} + (0.39347) 10^{0.1 \times \text{SPL}_s(i,k)} \right\}
\]

where \(L_s(i,k)\) is the simulated SLOW-weighted sound pressure level and \(L_{\text{SPL}}(i,k)\) is the as-measured 0.5 seconds time average sound pressure level determined from the output of the analyser for the \(k\)-th instant of time and the \(i\)-th one-third octave band. For \(k = 1\), the SLOW-weighted sound pressure \(L_s[i,(k-1 = 0)]\) on the right-hand side shall be set to 0 dB.

An approximation of the continuous exponential averaging is represented by the following equation for a four sample averaging process for \(k = 4\):

\[
L_s(i,k) = 10 \log \left\{ (0.13) 10^{0.1 \times L_{\text{SPL}}(i,(k-3))} + (0.21) 10^{0.1 \times L_{\text{SPL}}(i,(k-2))} + (0.27) 10^{0.1 \times L_{\text{SPL}}(i,(k-1))} + (0.39) 10^{0.1 \times L_{\text{SPL}}(i,k)} \right\}
\]

\[
\text{SPL}_s(i,k) = 10 \log \left\{ (0.13) 10^{0.1 \times \text{SPL}_s(i,(k-3))} + (0.21) 10^{0.1 \times \text{SPL}_s(i,(k-2))} + (0.27) 10^{0.1 \times \text{SPL}_s(i,(k-1))} + (0.39) 10^{0.1 \times \text{SPL}_s(i,k)} \right\}
\]

where \(L_s(i,k)\) is the simulated SLOW-weighted sound pressure level and \(L_{\text{SPL}}(i,k)\) is the as-measured 0.5 seconds time average sound pressure level determined from the output of the analyser for the \(k\)-th instant of time and the \(i\)-th one-third octave band.

4.1 General

4.1.3 The calculation procedure which utilizes physical measurements of noise to derive the EPNL evaluation measure of subjective response shall consist of the five following steps:

a) each of the 24 one-third octave band sound pressure levels in each measured one-half second spectrum is converted to perceived noisiness by the method of Section 4.7. The noy values are combined and then converted to instantaneous perceived noise level, PNL\((k)\) for each spectrum, measured at the \(k\)-th instant of time, by the method of Section 4.2;

b) for each spectrum a tone correction factor, \(C(k)\), is calculated by the method of Section 4.3 to account for the subjective response to the presence of spectral irregularities;

c) the tone correction factor is added to the perceived noise level to obtain the tone corrected perceived noise level, PNLT\((k)\), for each spectrum:

\[
\text{PNLT}(k) = \text{PNL}(k) + C(k)
\]
4.2 Perceived noise level

Note.—Perceived noise level, PNL(k), as a function of total perceived noisiness is plotted in the section of the Environmental Technical Manual (Doc 9501), Volume I — Procedures for the Noise Certification of Aircraft, concerning reference tables used in the manual calculation of effective perceived noise level.

4.3 Correction for spectral irregularities

4.3.1 Noise having pronounced spectral irregularities (for example, the maximum discrete frequency components or tones) shall be adjusted by the correction factor, \( C(k) \), calculated as follows:

\[
\text{Tone corrected perceived noise levels } \text{PNLT}(k) \text{ shall be determined by adding the } C(k) \text{ values to corresponding } PNL(k) \text{ values, that is:}
\]

\[
\text{PNLT}(k) = PNL(k) + C(k)
\]

For any \( i \)-th one-third octave band, at any \( k \)-th increment of time, for which the tone correction factor is suspected to result from something other than (or in addition to) an actual tone (or any spectral irregularity other than aircraft noise), an additional analysis may be made using a filter with a bandwidth narrower than one-third of an octave. If the narrow band analysis corroborates these suspicions, then a revised value for the broadband sound pressure level, \( \text{SPL}'(i,k) \), shall be determined from the narrow band analysis and used to compute a revised tone correction factor for that particular one-third octave band.

Note.—Other methods of rejecting spurious tone corrections such as those described in Appendix 2 Chapter 4 of the Environmental Technical Manual (Doc 9501), Volume I — Procedures for the Noise Certification of Aircraft may be used.

4.4 Maximum tone corrected perceived noise level

4.4.2 The tone at PNLTM may be suppressed due to one-third octave bandsharing of that tone. To identify whether this is the case, the average of the tone correction factors of the PNLTM spectrum and the two preceding and two succeeding spectra is calculated. If the value of the tone correction factor \( C(k_{M}) \) for the spectrum associated with PNLTM is less than the average value of \( C(k) \) for the
five consecutive spectra ($k_M-2$) through ($k_M+2$), then the average value $C_{avg}$ shall be used to compute a bandsharing adjustment, $\Delta B$, and a value of PNLTM adjusted for bandsharing.

$$C_{avg} = \frac{C(k_M-2) + C(k_M-1) + C(k_M) + C(k_M+1) + C(k_M+2)}{5}$$

If $C_{avg} > C(k_M)$, then $\Delta B = C_{avg} - C(k_M)$ and

4.6 Effective perceived noise level

4.6.1 If the instantaneous tone corrected perceived noise level is expressed in terms of a continuous function with time, PNLT($t$), then the effective perceived noise level, EPNL, would be defined as the level, in EPNdB, of the time integral of PNLT($t$) over the noise event duration, normalized to a reference duration, $T_0$, of 10 seconds. The noise event duration is bounded by $t_1$, the time when PNLT($t$) is first equal to PNLTM – 10, and $t_2$, the time when PNLT($t$) is last equal to PNLTM – 10.

$$EPNL = 10 \log \frac{1}{T_0} \int_{t_1}^{t_2} 10^{PNLT(t)} dt$$

4.6.2 In practice PNLT is not expressed as a continuous function with time since it is computed from discrete values of PNLT($k$) every half second. In this case the basic working definition for EPNL is obtained by replacing the integral in Section 4.6.1 with the following summation expression:

$$EPNL = 10 \log \frac{1}{T_0} \sum_{k_L}^{k_F} \Delta t \times PNLT(k)$$

For $T_0 = 10$ and $\Delta t = 0.5$, this expression can be simplified as follows:

$$EPNL = 10 \log \sum_{k_L}^{k_F} 10^{0.1 PNLT(k)} - 13$$

Note.— 13 dB is a constant relating the one-half second values of $PNLT(k)$ to the 10-second reference duration $T_0$: $10 \log (0.5/10) = -13$. 

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<tr>
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<td>0.042285</td>
<td>0.029960</td>
<td>0.059640</td>
</tr>
</tbody>
</table>

Figure A2.3. Example of perceived noise level corrected for tones as a function of aeroplane flyover time. Perceived noisiness as a function of sound pressure level.
6. NOMENCLATURE: SYMBOLS AND UNITS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>antilog</td>
<td>—</td>
<td>Antilogarithm to the base 10.</td>
</tr>
<tr>
<td>( C(k) )</td>
<td>dB</td>
<td>Tone correction factor. The factor to be added to PNL((k)) to account for the presence of spectral irregularities such as tones at the ( k )-th increment of time.</td>
</tr>
<tr>
<td>( d )</td>
<td>s</td>
<td>Duration time. The length of the significant noise time history being the time interval between the limits of ( t(1) ) and ( t(2) ) to the nearest 0.5 second.</td>
</tr>
<tr>
<td>( D )</td>
<td>dB</td>
<td>Duration correction. The factor to be added to PNLTM to account for the duration of the noise.</td>
</tr>
<tr>
<td>( EPNL )</td>
<td>EPNdB</td>
<td>Effective perceived noise level. The value of PNL, adjusted for both the spectral irregularities and the duration of the noise. (The unit EPNdB is used instead of the unit dB.)</td>
</tr>
<tr>
<td>( f(i) )</td>
<td>Hz</td>
<td>Frequency. The geometrical mean frequency for the ( i )-th one-third octave band.</td>
</tr>
<tr>
<td>( F(i,k) )</td>
<td>dB</td>
<td>Delta-dB. The difference between the original sound pressure level and the final broadband sound pressure level in the ( i )-th one-third octave band at the ( k )-th interval of time.</td>
</tr>
<tr>
<td>( h )</td>
<td>dB</td>
<td>dB down. The level to be subtracted from PNLTM that defines the duration of the noise.</td>
</tr>
<tr>
<td>( H )</td>
<td>%</td>
<td>Relative humidity. The ambient atmospheric relative humidity.</td>
</tr>
<tr>
<td>( i )</td>
<td>—</td>
<td>Frequency band index. The numerical indicator that denotes any one of the 24 one-third octave bands with geometrical mean frequencies from 50 to 10,000 Hz.</td>
</tr>
<tr>
<td>( k )</td>
<td>—</td>
<td>Time increment index. The numerical indicator that denotes the number of equal-time increments that have elapsed from a reference zero.</td>
</tr>
<tr>
<td>( \log )</td>
<td>—</td>
<td>Logarithm to the base 10.</td>
</tr>
<tr>
<td>( \log n(a) )</td>
<td>—</td>
<td>Noy discontinuity coordinate. The log ( n ) value of the intersection point of the straight lines representing the variation of SPL with log ( n ).</td>
</tr>
<tr>
<td>( M(b), M(c), \text{etc.} )</td>
<td>—</td>
<td>Noy inverse slope. The reciprocals of the slopes of straight lines representing the variation of SPL with log ( n ).</td>
</tr>
<tr>
<td>( n )</td>
<td>noy</td>
<td>Perceived noisiness. The perceived noisiness at any instant of time that occurs in a specified frequency range.</td>
</tr>
<tr>
<td>( n(i,k) )</td>
<td>noy</td>
<td>Perceived noisiness. The perceived noisiness at the ( k )-th instant of time that occurs in the ( i )-th one-third octave band.</td>
</tr>
<tr>
<td>Symbol</td>
<td>Unit</td>
<td>Meaning</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>$n(k)$</td>
<td>noy</td>
<td>Maximum perceived noisiness. The maximum value of all of the 24 values of $n(i)$ that occurs at the $k$-th instant of time.</td>
</tr>
<tr>
<td>$N(k)$</td>
<td>noy</td>
<td>Total perceived noisiness. The total perceived noisiness at the $k$-th instant of time calculated from the 24 instantaneous values of $n(i,k)$.</td>
</tr>
<tr>
<td>$p(b), p(c), \text{etc.}$</td>
<td>—</td>
<td>Noy slope. The slopes of straight lines representing the variation of SPL with log $n$.</td>
</tr>
<tr>
<td>PNL</td>
<td>PNdB</td>
<td>Perceived noise level. The perceived noise level at any instant of time. (The unit PNdB is used instead of the unit dB.)</td>
</tr>
<tr>
<td>PNL($k$)</td>
<td>PNdB</td>
<td>Perceived noise level. The perceived noise level calculated from the 24 values of SPL($i,k$) at the $k$-th increment of time. (The unit PNdB is used instead of the unit dB.)</td>
</tr>
<tr>
<td>PNLM</td>
<td>PNdB</td>
<td>Maximum perceived noise level. The maximum value of PNL($k$). (The unit PNdB is used instead of the unit dB.)</td>
</tr>
<tr>
<td>PNLT</td>
<td>TPNdB</td>
<td>Tone-corrected perceived noise level. The value of PNL adjusted for the spectral irregularities that occur at any instant of time. (The unit TPNdB is used instead of the unit dB.)</td>
</tr>
<tr>
<td>PNLT($k$)</td>
<td>TPNdB</td>
<td>Tone-corrected perceived noise level. The value of PNL($k$) adjusted for the spectral irregularities that occur at the $k$-th increment of time. (The unit TPNdB is used instead of the unit dB.)</td>
</tr>
<tr>
<td>PNLTM</td>
<td>TPNdB</td>
<td>Maximum tone-corrected perceived noise level. The maximum value of PNLT($k$). (The unit TPNdB is used instead of the unit dB.)</td>
</tr>
<tr>
<td>PNLT$_r$</td>
<td>TPNdB</td>
<td>Tone-corrected perceived noise level adjusted for reference conditions.</td>
</tr>
<tr>
<td>$s(i,k)$</td>
<td>dB</td>
<td>Slope of sound pressure level. The change in level between adjacent one-third octave band sound pressure levels at the $i$-th band for the $k$-th instant of time.</td>
</tr>
<tr>
<td>$\Delta s(i,k)$</td>
<td>dB</td>
<td>Change in slope of sound pressure level.</td>
</tr>
<tr>
<td>$s'(i,k)$</td>
<td>dB</td>
<td>Adjusted slope of sound pressure level. The change in level between adjacent adjusted one-third octave band sound pressure levels at the $i$-th band for the $k$-th instant of time.</td>
</tr>
<tr>
<td>$s(i,k)$</td>
<td>dB</td>
<td>Average slope of sound pressure level.</td>
</tr>
<tr>
<td>SPL</td>
<td>dB re 20 µPa</td>
<td>Sound pressure level. The sound pressure level at any instant of time that occurs in a specified frequency range.</td>
</tr>
<tr>
<td>SPL($a$)</td>
<td>dB re 20 µPa</td>
<td>Noy discontinuity coordinate. The SPL value of the intersection point of the straight lines representing the variation of SPL with log $n$.</td>
</tr>
<tr>
<td>Symbol</td>
<td>Unit</td>
<td>Meaning</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SPL(b)</td>
<td>dB re 20 µPa</td>
<td>Noy intercept. The intercepts on the SPL-axis of the straight lines representing the variation of SPL with log n.</td>
</tr>
<tr>
<td>SPL(c)</td>
<td>dB re 20 µPa</td>
<td>Sound pressure level. The sound pressure level at the k-th instant of time that occurs in the i-th one-third octave band.</td>
</tr>
<tr>
<td>SPL(i,k)</td>
<td>dB re 20 µPa</td>
<td>Adjusted sound pressure level. The first approximation to broadband sound pressure level in the i-th one-third octave band for the k-th instant of time.</td>
</tr>
<tr>
<td>SPL'(i,k)</td>
<td>dB re 20 µPa</td>
<td>Maximum sound pressure level. The sound pressure level that occurs in the i-th one-third octave band of the spectrum for PNLTM.</td>
</tr>
<tr>
<td>SPL''(i,k)</td>
<td>dB re 20 µPa</td>
<td>Corrected maximum sound pressure level. The sound pressure level that occurs in the i-th one-third octave band of the spectrum for PNLTM corrected for atmospheric sound absorption.</td>
</tr>
<tr>
<td>t</td>
<td>s</td>
<td>Elapsed time. The length of time measured from a reference zero.</td>
</tr>
<tr>
<td>t1, t2</td>
<td>s</td>
<td>Time limit. The beginning and end, respectively, of the significant noise time history defined by h.</td>
</tr>
<tr>
<td>Δt</td>
<td>s</td>
<td>Time increment. The equal increments of time for which PNL(k) and PNLT(k) are calculated.</td>
</tr>
<tr>
<td>T</td>
<td>s</td>
<td>Normalizing time constant. The length of time used as a reference in the integration method for computing duration corrections, where T = 10 s.</td>
</tr>
<tr>
<td>t(°C)</td>
<td>°C</td>
<td>Temperature. The ambient atmospheric temperature.</td>
</tr>
<tr>
<td>α(i)</td>
<td>dB/100 m</td>
<td>Test atmospheric absorption. The atmospheric attenuation of sound that occurs in the i-th one-third octave band for the measured atmospheric temperature and relative humidity.</td>
</tr>
<tr>
<td>α(i) o</td>
<td>dB/100 m</td>
<td>Reference atmospheric absorption. The atmospheric attenuation of sound that occurs in the i-th one-third octave band for a reference atmospheric temperature and relative humidity.</td>
</tr>
<tr>
<td>Α1</td>
<td>degrees</td>
<td>First constant* climb angle.</td>
</tr>
<tr>
<td>Α2</td>
<td>degrees</td>
<td>Second constant** climb angle.</td>
</tr>
<tr>
<td>δ</td>
<td>degrees</td>
<td>Thrust cutback angles. The angles defining the points on the take-off flight path at which thrust reduction is started and ended, respectively.</td>
</tr>
<tr>
<td>η</td>
<td>degrees</td>
<td>Approach angle.</td>
</tr>
<tr>
<td>Symbol</td>
<td>Unit</td>
<td>Meaning</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>η</td>
<td>degrees</td>
<td>Reference approach angle.</td>
</tr>
<tr>
<td>θ</td>
<td>degrees</td>
<td>Noise angle (relative to flight path). The angle between the flight path and noise path. It is identical for both measured and corrected flight paths.</td>
</tr>
<tr>
<td>ψ</td>
<td>degrees</td>
<td>Noise angle (relative to ground). The angle between the noise paths and the ground. It is identified for both measured and corrected flight paths.</td>
</tr>
<tr>
<td>µ</td>
<td>degrees</td>
<td>Engine noise emission parameter. (See 9.3.4.)</td>
</tr>
<tr>
<td>Δ₁</td>
<td>EPNdB</td>
<td>PNLT correction. The correction to be added to the EPNL calculated from measured data to account for noise level changes due to differences in atmospheric absorption and noise path length between reference and test conditions.</td>
</tr>
<tr>
<td>Δ₂</td>
<td>EPNdB</td>
<td>Adjustment to duration correction. The adjustment to be made to the EPNL calculated from measured data to account for noise level changes due to the noise duration between reference and test conditions.</td>
</tr>
<tr>
<td>Δ₃</td>
<td>EPNdB</td>
<td>Source noise adjustment. The adjustment to be made to the EPNL calculated from measured data to account for noise level changes due to differences between reference and test engine regime.</td>
</tr>
</tbody>
</table>

* Gear up, speed of at least \( V_2 + 19 \) km/h (\( V_2 + 10 \) kt), take-off thrust.
* * Gear up, speed of at least \( V_2 + 19 \) km/h (\( V_2 + 10 \) kt), after cutback.

### 7. SOUND ATTENUATION IN AIR

7.2 The relationship between sound attenuation, frequency, temperature and humidity is expressed by the following equations:

\[
\alpha(i) = 10^{2.05 \log (f_0/1000) + 1.1394 \times 10^{-3} \times T - 1.916984} + \eta(\delta) \times 10^{(\log (f_0) + 8.42994 \times 10^{-3} \times T - 2.755624)}
\]

\[
\delta = \left[ \frac{1010}{f_0} \right]^{10 \log \left[ 10^{1.328924 + 3.179768 \times 10^{-2} \times T} \right]} \times 10^{-2.173716 \times 10^{-3} \times T^2 + 1.7496 \times 10^{-6} \times T^3}
\]
where:

\[ \eta(\delta) \text{ is given by Table A2-4 and } f_o \text{ by Table A2-5; } \]

\[ \alpha(i) \text{ being the attenuation coefficient in } \text{dB}/100 \text{ m; } \]

\[ \theta_T \text{ being the temperature in } ^\circ\text{C; and } \]

\[ RH \text{ being the relative humidity expressed as a percentage. } \]

7.3 The equations given in 7.2 are convenient for calculation by means of a computer.

---

8. ADJUSTMENT OF AIRCRAFT FLIGHT TEST RESULTS

8.1 Flight profiles and noise geometry

Flight profiles for both test and reference conditions are described by their geometry relative to the ground, the associated aircraft ground speed, and, in the case of aeroplanes, the associated engine control noise performance parameter(s) used for determining the acoustic emission of the aeroplane. Idealized aircraft flight profiles are described in 8.1.1 for aeroplanes and 8.1.2 for helicopters.

8.1.2 Helicopter flight profiles

8.1.2.1 Reference take-off profile characteristics

Figure A2-7 illustrates the profile characteristics for the helicopter take-off procedure for noise measurements made at the take-off noise measurement point:

a) the helicopter is initially stabilized in level flight at point A at the best rate of climb speed \( V_y \). The helicopter continues to point B where take-off power is applied, and a steady climb is initiated. A steady climb is maintained through point X and beyond to point F, the end of the noise flight path; and

---

8.1.3 Adjustment of measured noise levels from measured to reference profile in the calculation of EPNL

Note.— The “useful portion of the measured flight path” referred to in this section is defined in accordance with the requirements of 2.3.2.

8.1.3.1 For the case of a microphone located beneath the flight path, the portions of the test flight path and the reference flight path which are significant for the adjustment of the measured noise levels from the measured profile to the reference profile in the EPNL calculation are illustrated in Figure A2-10, where:

a) XY represents the useful portion of the measured flight path (Figure A2-10 a)), and X,Y, that of
the corresponding reference flight path (Figure A2-10 b)); and

b) K is the actual noise measurement point and K, the reference noise measurement point. Q represents the aircraft position on the measured flight path at which the noise was emitted and observed as PNLT M at point K. The angle between QK and the direction of flight along the measured flight path is $\theta$, the acoustic sound emission angle. Q is the corresponding position on the reference flight path where the angle between Q,K, is also $\theta$. QK and Q,K, are, respectively, the measured and reference noise sound propagation paths.

8.1.3.2 For the case of a microphone laterally displaced to the side of the flight path, the portions of the test flight path and the reference flight path which are significant for the adjustment of the measured noise levels from the measured profile to the reference profile in the EPNL calculation are illustrated in Figure A2-11, where:

a) XY represents the useful portion of the measured flight path (Figure A2-11 a)), and X,Y, that of the corresponding reference flight path (Figure A2-11 b)); and

b) K is the actual noise measurement point and K, the reference noise measurement point. Q represents the aircraft position on the measured flight path at which the noise was emitted and observed as PNLT M at point K. The angle between QK and the direction of flight along the measured flight path is $\theta$, the acoustic sound emission angle. The angle between QK and the ground is $\psi$, the elevation angle. Q is the corresponding position on the reference flight path where the angle between Q,K, and the direction of flight along the reference flight path is also $\theta$, and the angle between Q,K, and the ground is $\psi$, where in the case of aeroplanes, the difference between $\psi$ and $\psi$ is minimized.

8.1.3.3 In both situations the acoustic sound emission angle $\theta$ shall be established using three-dimensional geometry.

8.1.3.4 In the case of lateral full-power noise measurements of jet aeroplanes the extent to which differences between $\psi$ and $\psi$, can be minimized is dependent on the geometrical restrictions imposed by the need to maintain the reference microphone on a line parallel to the extended runway centre line.

Note.— In the case of helicopter measurements, there is no requirement to minimize the difference between $\psi$ and $\psi$.R.

8.2 Selection of adjustment method

8.2.3 For aeroplanes, either the simplified method, described in 8.3, or the integrated method, described in 8.4, shall be used for the lateral, flyover or approach conditions. The integrated method shall be used when:

a) for flyover, the absolute value of the difference between the value of $\text{EPNL}_m$, $\text{EPNL}_r$, when calculated according to the simplified method described in 8.3, and the measured value of $\text{EPNL}$
calculated according to the procedure described in 4.1.3 is greater than 8 EPNdB;

b) for approach, the absolute value of the difference between the value of $\text{EPNL}_r - \text{EPNL}_R$, when calculated according to the simplified method described in 8.3, and the measured value of EPNL calculated according to the procedure described in 4.1.3 is greater than 4 EPNdB; or

c) for flyover or approach, the value of $\text{EPNL}_r - \text{EPNL}_R$, when calculated according to the simplified method described in 8.3, is greater than the maximum noise levels prescribed in 3.4 of Part II, Chapter 3, less 1 EPNdB.

Note. — Part II, Chapter 3, 3.7.6, specifies limitations regarding the validity of test data based upon both the extent to which $\text{EPNL}_r - \text{EPNL}_R$ differs from $\text{EPNL}_r$ and also the proximity of the final $\text{EPNL}_r - \text{EPNL}_R$ values to the maximum permitted noise levels, regardless of the method used for adjustment.

8.3 Simplified method of adjustment

8.3.1 General

8.3.1.1 The simplified adjustment method consists of the determination and application of adjustments to the EPNL calculated from the measured data for the differences between measured and reference conditions at the moment of PNLTM. The adjustment terms are:

a) $\Delta_1$ — adjustment for differences in the PNLTM spectrum under test and reference conditions (see 8.3.2);

b) $\Delta_{\text{peak}}$ — adjustment for when the PNLT for a secondary peak, identified in the calculation of EPNL from measured data and adjusted to reference conditions, is greater than the PNLT for the adjusted PNLTM spectrum (see 8.3.3);

... 

8.3.1.2 The coordinates (time, X, Y and Z) of the reference data point associated with the emission of PNLTM $\text{PNLTM}_R$ shall be determined such that the acoustic sound emission angle $\theta$ on the reference flight path, relative to the reference microphone, is the same value as the acoustic sound emission angle of the as-measured data point associated with PNLTM.

8.3.1.3 The adjustment terms described in 8.3.2 to 8.3.5 are applied to the EPNL calculated from measured data to obtain the simplified reference condition effective perceived noise level, $\text{EPNL}_r - \text{EPNL}_R$ as described in 8.3.6.

... 

8.3.2 Adjustments to spectrum at PNLTM

8.3.2.1 The one-third octave band levels $\text{SPL}(i)$ used to construct $\text{PNL}(kM)$ (the PNL at the moment of PNLTM observed at measurement point K) shall be adjusted to reference levels $\text{SPL}_r(i)$ as follows:

$$\text{SPL}_r(i) = \text{SPL}(i) + 0.01 [\alpha(i) - \alpha(i)_r] QK + 0.01 \alpha(i)_r [QK - Q_{K_r}] + 20 \log (QK/Q_{K_r})$$
\[
\text{SPL}_R(i) \text{ SPl}(i) + 0.01 \left[ a(i) - a_R(i) \right] QK = \\
+ 0.01 a_R(i) (QK - QK_r) \\
+ 20 \log \left( \frac{QK}{QK_r} \right)
\]

In this expression:

— the term \(0.01 \left[ a(i) - a_R(i) \right] QK\) accounts for the effect of the change in sound attenuation due to atmospheric absorption, and \(a(i)\) and \(a_R(i)\) are the coefficients for the test and reference atmospheric conditions, respectively, obtained from Section 7;

— the term \(0.01 a_R(i) (QK - QK_r)\) accounts for the effect of the change in the noise sound propagation path length on the sound attenuation due to atmospheric absorption;

— the term \(20 \log \left( \frac{QK}{QK_r} \right)\) accounts for the effect of the change in the noise sound propagation path length due to spherical spreading (also known as the “inverse square” law);

— \(QK\) and \(QK_r\) are measured in metres, and \(a(i)\) and \(a_R(i)\) are obtained in the form of dB/100 m.

Note.— Refer to Figures A2-10 and A2-11 for identification of positions and distances referred to in this paragraph.

8.3.2.2 The adjusted values of \(\text{SPL}_R(i)\) obtained in 8.3.2.1 shall be used to calculate a reference condition \(\text{PNLT}_r(kM)\), \(\text{PNLT}_R(kM)\), as described in 4.2 and 4.3 of this appendix. The value of the bandsharing adjustment, \(\Delta_B\), calculated for the test-day \(\text{PNLT}_R\) by the method of 4.4.2, shall be added to this \(\text{PNLT}_R(kM)\) value to obtain the reference condition \(\text{PNLT}_R\):

\[
\text{PNLT}_R = \text{PNLT}_R(kM) + \Delta_B
\]

An adjustment term, \(\Delta_1\), is then calculated as follows:

\[
\Delta_1 = \text{PNLT}_R - \text{PNLT}
\]

8.3.3 Adjustment for secondary peaks

8.3.3.1 During a test flight any values of \(\text{PNLT}\) that are within 2 dB of \(\text{PNLT}\) are defined as “secondary peaks”. The one-third octave band levels for each “secondary peak” shall be adjusted to reference conditions according to the procedure defined in 8.3.2.1. Adjusted values of \(\text{PNLT}_R\) shall be calculated for each “secondary peak” as described in 4.2 and 4.3 of this appendix. If any adjusted peak value of \(\text{PNLT}_R\) exceeds the value of \(\text{PNLT}_R\), a \(\Delta_{\text{peak}}\) adjustment shall be applied.

8.3.3.2 \(\Delta_{\text{peak}}\) shall be calculated as follows:

\[
\Delta_{\text{peak}} = \text{PNLT}_R(M_{\text{Max Peak}}) - \text{PNLT}_R(kM) - \text{PNLT} \text{R}(kM_2) - \text{PNLT}_R(kM) + \Delta_B
\]

where \(\text{PNLT}_R(M_{\text{Max Peak}})\) is the reference condition \(\text{PNLT}\) value of the largest of the
secondary peaks; and $\text{PNLT}_{2}$, $\text{PNLT}_{r}$ is the reference condition PNLT value at the moment of PNLT.

8.3.3.3 $\Delta_{\text{peak}} - \Delta_{\text{peak}}$ shall be added algebraically to the EPNL calculated from measured data as described in 8.3.6.

8.3.4 Adjustment for effects on noise duration

8.3.4.2 Referring to the flight paths shown in Figures A2-10 and A2-11, the adjustment term $\Delta_{2}$ shall be calculated from the measured data as follows:

$$\Delta_{2} = -7.5 \log \left( \frac{Q_{K}}{Q_{r}} \right) + 10 \log \left( \frac{V_{G}}{V_{GR}} \right)$$

where:

$V_{G}$ is the test ground speed (horizontal component of the test airspeed); and

$V_{GR}$ is the reference ground speed (horizontal component of the reference airspeed).

8.3.5 Source noise adjustments

8.3.5.1 The source noise adjustment shall be applied to take account of differences in test and reference source noise generating mechanisms. For this purpose the effect on aircraft propulsion source noise of differences between the acoustically significant propulsion operating parameters actually realized in the certification flight tests and those calculated or specified for the reference conditions of Chapter 3, 3.6.1.5, is determined. Such operating parameters may include for jet aeroplanes, the engine control noise performance parameter $\mu$ (typically normalized low pressure fan speed, normalized engine thrust or engine pressure ratio), for propeller-driven aeroplanes both shaft horsepower and propeller helical tip Mach number and for helicopters, during overflight only, advancing rotor blade tip Mach number. The adjustment shall be determined from manufacturer’s data approved by the certificating authority.

8.3.5.2 For aeroplanes, the adjustment term $\Delta_{3}$ shall normally be determined from sensitivity curve(s) of EPNL versus the propulsion operating parameter(s) referred to in 8.3.5.1. It is obtained by subtracting the EPNL value corresponding to the measured value of the correlating parameter from the EPNL value corresponding to the reference value of the correlating parameter. The adjustment term $\Delta_{3}$ shall be added algebraically to the EPNL value calculated from the measured data (see 8.3.6).

Note.— Representative data for jet aeroplanes are illustrated in Figure A2-12 which shows a curve of $\text{EPNL}$ versus the engine control noise performance parameter $\mu$. The EPNL data is adjusted to all other relevant reference conditions (aeroplane mass, speed, height and air temperature) and, at each value of $\mu$, for the difference in noise between the installed engine and the flight manual standard of engine.

8.3.5.5 For helicopter overflight, if any combination of the following three factors results in the measured value of an agreed noise correlating parameter deviating from the reference value of this parameter, then source noise adjustments shall be determined from manufacturer’s data approved by the certificating authority:
a) airspeed deviations from reference; 

b) rotor speed deviations from reference; and/or 

c) temperature deviations from reference.

This adjustment should normally be made using a sensitivity curve of $PNLT_{MN}$ versus advancing blade tip Mach number. The adjustment may be made using an alternative parameter, or parameters, approved by the certificating authority.

Note 1.— If it is not possible during noise measurement tests to attain the reference value of advancing blade tip Mach number or the agreed reference noise correlating parameter, then an extrapolation of the sensitivity curve is permitted, provided the data cover an adequate range of values, agreed by the certificating authority, of the noise correlating parameter. The advancing blade tip Mach number, or agreed noise correlating parameter, shall be computed from as measured data. Separate curves of $PNLT_{MN}$ versus advancing blade tip Mach number, or another agreed noise correlating parameter, shall be derived for each of the three certification microphone locations, centre line, left sideline and right sideline, defined relative to the direction of flight of each test run.

8.3.6 Application of adjustment terms for simplified method

Determine $EPNL_{MN}$ for reference conditions, $EPNL_{MN}$, using the simplified method, by adding the adjustment terms identified in 8.3.2 through 8.3.5 to the $EPNL_{MN}$ calculated for measurement conditions as follows:

$$EPNL_{MN} = EPNL + \Delta_1 + \Delta_{\text{peak}} + \Delta_2 + \Delta_3$$

8.4 Integrated method of adjustment

8.4.1 General

8.4.1.1 The integrated method consists of recomputing, under reference conditions, points in the PNLT time history corresponding to measured points obtained during the tests, and then computing $EPNL$ directly for the new time history.

8.4.1.2 The emission coordinates (time, X, Y, and Z) of the reference data point associated with each PNLT,($k$) shall be determined such that the acoustic sound emission angle $\theta$ on the reference flight path, relative to the reference microphone, is the same value as the acoustic sound emission angle of the as-measured data point associated with PNLT($k$).

Note.— As a consequence, and unless the test and reference conditions are identical, the reception time intervals between the reference data points will typically neither be equally-spaced nor equal to one-half second.

8.4.1.3 The steps in the integrated procedure are as follows:
a) The spectrum associated with each test-day data point, PNLT\(_k\), is adjusted for spherical spreading and attenuation due to atmospheric absorption, to reference conditions (see 8.4.2.1);

b) A reference tone-corrected perceived noise level, PNLT\(_{Rk}\), is calculated for each one-third octave band spectrum (see 8.4.2.2);

c) The maximum value, PNLT\(_{TMR}\), and first and last 10 dB-down points are determined from the PNLT\(_{Rk}\) series (see 8.4.2.3 and 8.4.3.1);

d) The effective duration, δt\(_R(k)\), is calculated for each PNLT\(_{Rk}\) point, and the reference noise duration is then determined (see 8.4.3.2 and 8.4.3.3);

e) The integrated reference condition effective perceived noise level, EPNLT\(_R\), is determined by the logarithmic summation of PNLT\(_{Rk}\) levels within the noise duration normalized to a duration of 10 seconds (see 8.4.4); and

f) A source noise adjustment is determined and applied (see 8.4.5).

8.4.2 PNLT computations

8.4.2.1 The measured values of SPL\(_{i,k}\) shall be adjusted to the reference values SPL\(_{Ri,k}\), for the differences between measured and reference sound propagation path lengths and between measured and reference atmospheric conditions, by the methods of 8.3.2.1. Corresponding values of PNLT\(_{Rk}\) shall be computed as described in 4.2.

8.4.2.2 For each value of PNLT\(_{Rk}\), a tone correction factor C\(_R(k)\) shall be determined by analysing each reference value SPL\(_{Ri,k}\) by the methods of 4.3, and added to PNLT\(_{Rk}\) to obtain PNLT\(_{Rk}\).

8.4.2.3 The maximum reference condition tone corrected perceived noise level, PNLT\(_{TMR}\), shall be identified, and a new reference condition bandsharing adjustment, Δ\(_BR\), determined and applied as described in 4.4.2.

Note.—Due to differences between test and reference conditions, it is possible that the maximum PNLT\(_R\) value will not occur at the data point associated with PNLT\(_{TMR}\). The determination of PNLT\(_{TMR}\) is independent of PNLT\(_R\).

8.4.3 Noise duration

8.4.3.1 The limits of the noise duration shall be defined as the 10 dB-down points obtained from the series of reference condition PNLT\(_k\) values. Identification of the 10 dB-down points shall be performed in accordance with 4.5.1. In the case of the integrated method, the first and last 10 dB-down points shall be designated as \(t_{LR}\) and \(t_{FR}\), respectively.

8.4.3.2 The noise duration for the integrated reference condition shall be equal to the sum of the effective durations, δt\(_R(k)\), associated with each of the PNLT\(_{Rk}\) data points within the 10 dB-down period, inclusive.

8.4.3.3 The effective duration, δt\(_R(k)\), shall be determined for each PNLT\(_{Rk}\) reference condition data point as follows:

\[
\delta t_R(k) = \frac{1}{2} \left[ (t_R(k) - t_R(k-1)) + (t_R(k+1) - t_R(k)) \right]
\]
where:

$\delta t_r(k) = [(t_r(k) - t_r(k-1)) + (t_r(k+1) - t_r(k))] / 2$

$t_r(k)$ is the time associated with $PNLT_r(k)$; $PNLT_R(k)$ is the time associated with $PNLT_R(k)$; $PNLT_r(k-1)$ is the time associated with $PNLT_r(k-1)$, the data point preceding $PNLT_R(k-1)$; and $t_r(k+1)$ is the time associated with $PNLT_r(k+1)$, the data point following $PNLT_R(k)$.

Note 1.— Due to differences in flight path geometry, airspeed and sound speed between test and reference conditions, the times, $t_r(k)$, associated with the $PNLT_r(k)$ points projected to the reference flight path are likely to occur at varying, non-uniform time intervals.

Note 2.— Relative values of time $t_r(k)$ for the reference data points can be determined by using the distance between such points on the reference flight path, and the reference aircraft airspeed $V_r$.

Note 3.— The Environmental Technical Manual (Doc 9501), Volume I—Procedures for the Noise Certification of Aircraft, provides additional guidance for one method for performing the integrated procedure, including the determination of effective durations, $\delta t_r(k)$, for the individual data points of the reference time history.

8.4.4 Calculation of integrated reference condition EPNL

8.4.4.1 The equation for calculating reference condition EPNL using the integrated method, $EPNL_R$, is similar to the equation for test-day EPNL given in 4.6. However, the numerical constant related to one-half second intervals is eliminated, and a multiplier is introduced within the logarithm to account for the effective duration of each $PNLT_r(k)$ value, $\delta t_r(k)$:

$$EPNL_R = 10 \log \frac{1}{t_0} \sum_{k=FR}^{k_{LR}} 10^{0.1PNLT_R(k)} \delta t_R(k)$$

where:

the reference time, $T_0$, is 10 seconds;

$k_{FR}$ and $k_{LR}$ are the first and last 10 dB-down points as defined in 8.4.3.1; and

$\delta t_R(k)$ is the effective duration as defined in 8.4.3.3 of each reference condition $PNLT_R(k)$ value.

8.4.5 Source noise adjustment

8.4.5.1 Finally, a source noise adjustment shall be determined by the methods of 8.3.5, and added to
the EPNL, EPNL determined in 8.4.4.1.

APPENDIX 3. EVALUATION METHOD FOR NOISE CERTIFICATION
OF PROPELLER-DRIVEN AEROPLANES NOT EXCEEDING
8 618 kg — Application for Type Certificate
submitted before 17 November 1988

4.2.2 Correction of noise received on the ground

The noise measurements made at heights different from 300 m (985 ft) shall be adjusted to 300 m (985 ft) by the inverse square law.

4.2.3 Performance correction

4.2.3.2 The performance correction shall be calculated by using the following formula:

$$\Delta dB = 49.6 - 20 \log \left( \frac{3 500 - D_{15}}{V_y} \right) + 15$$

where

- $D_{15} = \text{Take-off distance to 15 m at maximum certificated take-off mass and maximum take-off power (paved runway)}$

- $\text{Best R/C} = \text{Best rate of climb at maximum certificated take-off mass and maximum take-off power}$

- $V_y = \text{Climb speed corresponding to R/C at maximum take-off power and expressed in the same units}$.

APPENDIX 4. EVALUATION METHOD FOR NOISE CERTIFICATION
OF HELICOPTERS NOT EXCEEDING 3 175 kg MAXIMUM
CERTIFICATED TAKE-OFF MASS

2.4 Flight test conditions
2.4.1 The helicopter shall be flown in a stabilized flight condition over a distance sufficient to ensure that the time-varying sound level is measured during the entire time period that the sound level is within 10 dB(A) of \( L_{A_{\text{max}}} - L_{A_{\text{Smax}}} \).

*Note.*—\( L_{A_{\text{max}}} - L_{A_{\text{Smax}}} \) is defined as the maximum of the A-frequency-weighted S-time-weighted sound level measured during the test run.

2.4.2 The helicopter flyover noise test shall be conducted at the airspeed referred to in Part II, Chapter 11, 11.5.2, with such airspeed adjusted as necessary to produce the same advancing blade tip Mach number as associated with the reference conditions.

2.4.3 The reference advancing blade tip Mach number \((M_{pR})_R\) and \((M_{ATR})_R\) is defined as the ratio of the arithmetic sum of the blade tip rotational speed \(V_{tipR}\) and the reference helicopter true airspeed \(V_R\), divided by the speed of sound \(c_R\), at 25°C such that:

\[
M_{pR} = \frac{(V_{tipR} + V_T)}{c_R}
\]

\[
(M_{ATR})_R = \frac{(V_{tipR} + V_T)}{c_R}
\]

3. **NOISE UNIT DEFINITION**

3.1 The sound exposure level \( L_{AE} \) is defined as the level, in decibels, of the time integral of squared A-weighted sound pressure \( p_A \) over a given time period or event, with reference to the square of the standard reference sound pressure \( p_0 \) of 20 \( \mu \)Pa and a reference duration of one second.

3.2 This unit is defined by the expression:

\[
L_{AE} = 10 \log \frac{1}{t_0} \int_{t_1}^{t_2} \left( \frac{p_A(t)}{p_0} \right)^2 dt
\]

where \( t_0 \) is the reference integration time of one second and \( (t_2 - t_1) \) is the integration time interval.

3.3 The above integral can be approximated from periodically sampled measurement as:

\[
L_{AE} = 10 \log \frac{1}{t_0} \sum_{k=F}^{k=E} 10^{0.1L_{AE}(k)} \Delta t
\]

\[
L_{AE} = 10 \log \frac{1}{t_0} \sum_{k=F}^{k=E} 10^{0.1L_{AS}(k)} \Delta t
\]
where $L_A(k)$ is the time varying A-frequency-weighted sound level measured at the $k$-th instant of time, $k_F$ and $k_L$ are the first and last increment of $k$, and $\Delta t$ is the time increment between samples.

4.4 Noise measurement procedures

4.4.4 The A-frequency-weighted sound level of the background noise, including ambient noise and electrical noise of the measurement systems, shall be determined in the test area with the system gain set at levels which will be used for helicopter noise measurements. If the $L_{Amax}$ of each test run does not exceed the A-frequency-weighted sound level of the background noise by at least 15 dB(A), flyovers at an approved lower height may be used and the results adjusted to the reference measurement height by an approved method.

5.2 Corrections and adjustments

5.2.2 The adjustments for spherical spreading and duration may be approximated from:

$$\Delta_1 = 12.5 \log \left( \frac{H}{150} \right) \text{dB}$$

where $H$ is the height, in metres, of the test helicopter when directly over the noise measurement point.

5.2.3 The adjustment for the difference between reference airspeed and adjusted reference airspeed is calculated from:

$$\Delta_2 = 10 \log \left( \frac{V_{AR}}{V_R} \right) \text{dB}$$

where $\Delta_2$ is the quantity in decibels that must be algebraically added to the measured SEL noise level to correct for the influence of the adjustment of the reference airspeed on the duration of the measured flyover event as perceived at the noise measurement station. $V_{AR}$ is the reference airspeed as prescribed under Part II, Chapter 11, 11.5.2, and $V_R$ is the adjusted reference airspeed as prescribed in 2.4.2 of this appendix.

6.3 Validity of results

Note.—Methods for calculating the 90 per cent confidence interval are given in the section of the Environmental Technical Manual (Doc 9501), Volume I—Procedures for the Noise Certification of Aircraft concerning the calculation of confidence intervals.
APPENDIX 5.  MONITORING AIRCRAFT NOISE ON AND IN THE VICINITY OF AERODROMES

1. INTRODUCTION

Note 3.—This appendix specifies the measuring equipment to be used in order to measure noise levels created by aircraft in the operation of an aerodrome. The noise levels measured according to this appendix are approximations to perceived noise levels \( PNL \), in PNdB, as calculated by the method described in Appendix 1, 4.2.

APPENDIX 6.  EVALUATION METHOD FOR NOISE CERTIFICATION OF PROPELLER-DRIVEN AEROPLANES NOT EXCEEDING 8 618 kg — Application for Type Certificate or Certification of Derived Version submitted on or after 17 November 1988

6.2 Validity of results

6.2.1 The measuring point shall be overflown at least six times. The test results shall produce an average noise level \( L_{A_{\text{max}}} \) value, \( L_{A_{\text{ASmax}}} \), and its 90 per cent confidence limits, the noise level being the arithmetic average of the corrected acoustical measurements for all valid test runs over the measuring point.

ATTACHMENT D.  GUIDELINES FOR EVALUATING AN ALTERNATIVE METHOD OF MEASURING HELICOPTER NOISE DURING APPROACH

2.3 Approach reference procedure

The approach reference procedure shall be established as follows:

a) the helicopter shall be stabilized and following approach paths of 3°, 6° and 9°;
b) the approach shall be made at a stabilized airspeed equal to the best rate of climb speed, $V_x$, $V_Y$, or the lowest approved speed for the approach, whichever is the greater, with power stabilized during the approach and over the flight path reference point, and continued to a normal touchdown;

ATTACHMENT F. GUIDELINES FOR NOISE CERTIFICATION OF TILT-ROTORS

2. NOISE EVALUATION MEASURE

The noise evaluation measure should be the effective perceived noise level in EPNdB as described in Appendix 2 of this Annex.

Note.— Additional data in SEL and $L_{A_{max}} L_{A_{Smax}}$ as defined in Appendix 4, and one-third octave SPLs as defined in Appendix 2 corresponding to $L_{A_{max}} L_{A_{Smax}}$ should be made available to the certificating authority for land-use planning purposes.

ATTACHMENT H. GUIDELINES FOR OBTAINING HELICOPTER NOISE DATA FOR LAND-USE PLANNING PURPOSES

2. DATA COLLECTION PROCEDURES

2.1 Data suitable for land-use planning purposes may be derived directly from Chapter 8 noise certification data. Chapter 8 applicants may optionally elect to acquire data suitable for land-use planning purposes via alternative take-off, approach and/or flyover procedures defined by the applicant and approved by the certificating authority. Alternative flyover procedures should be performed overhead the flight path reference point at a height of 150 m (492 ft). In addition, an applicant may optionally elect to provide data at additional microphone locations.

2.2 Chapter 11 noise certification data may be provided for land-use planning purposes. Chapter 11 applicants may optionally elect to provide data acquired via alternative flyover procedures at 150 m (492 ft) above ground level. In acquiring data for land-use planning purposes, Chapter 11 applicants should give consideration to acquiring data from two additional microphones symmetrically disposed at 150 m on each side of the flight path and/or additional take-off and approach procedures defined by the applicant and approved by the certificating authority. In addition, an applicant may optionally elect to provide data at additional microphone locations.

3. REPORTING OF DATA
line and right sideline measurement points defined relative to the direction of flight for each test pass run. Additional data in other noise metrics may also be provided and should be derived in a manner that is consistent with the prescribed noise certification analysis procedure.

\[ \ldots \]

**Proposal D Rationale:**

All the proposed amendments are corrections due to minor technical errors in Annex 16, Volume I or for consistency purposes. This includes an amalgamation of all symbols and units from across Annex 16, Volume I into one new section (*NOMENCLATURE: SYMBOLS AND UNITS*).
RESPONSE FORM TO BE COMPLETED AND RETURNED TO ICAO TOGETHER WITH ANY COMMENTS YOU MAY HAVE ON THE PROPOSED AMENDMENTS

To: The Secretary General
International Civil Aviation Organization
999 Robert Bourassa Boulevard
Montreal, Quebec
Canada, H3C 5H7

(State) 

Please make a checkmark (✔) against one option for each amendment. If you choose options “agreement with comments” or “disagreement with comments”, please provide your comments on separate sheets.

<table>
<thead>
<tr>
<th>Amendment to Annex 16 — Environmental Protection, Volume I — Aircraft Noise (Attachment A refers)</th>
<th>Agreement without comments</th>
<th>Agreement with comments*</th>
<th>Disagreement without comments</th>
<th>Disagreement with comments</th>
<th>No position</th>
</tr>
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*“Agreement with comments” indicates that your State or organization agrees with the intent and overall thrust of the amendment proposal; the comments themselves may include, as necessary, your reservations concerning certain parts of the proposal and/or offer an alternative proposal in this regard.

Signature: ___________________________ Date: ___________________________

— END —