COVER SHEET TO AMENDMENT 13

INTERNATIONAL STANDARDS
AND RECOMMENDED PRACTICES

ENVIRONMENTAL PROTECTION

ANNEX 16
TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME I
AIRCRAFT NOISE

EIGHTH EDITION — JULY 2017

INTERNATIONAL CIVIL AVIATION ORGANIZATION

Checklist of Amendments to Annex 16, Volume I

	Effective date	*Date of applicability*
Eighth Edition (incorporates Amendments 1 to 12)	21 July 2017	1 January 2018
Amendment 13 (adopted by the Council on 11 March 2020) Replacement pages (xviii), (xix), I-3, I-4, I-6, I-7, I-8, I-9, I-10, I-11, II-3-7, II-8-6, II-11-1, II-11-2, II-11-3, II-13-1, II-13-6, APP 2-2, APP 2-3, APP 2-4, APP 2-11, APP 2-12, APP 2-13, APP 2-20, APP 2-22, APP 2-23, APP 2-28, APP 2-33, APP 4-2, APP 4-3, APP 4-4, APP 4-5, APP 4-6, APP 4-7, APP 6-2, APP 6-5, APP 6-7, ATT A-3 and ATT F-1.	20 July 2020	1 January 2021

Transmittal note

Amendment 13

to the

International Standards and
Recommended Practices

ENVIRONMENTAL PROTECTION

(Annex 16, Volume I, to the Convention on International Civil Aviation)

1. Insert the following new and replacement pages in Annex 16 (Eighth Edition), Volume I, to incorporate Amendment 13 which becomes applicable on 1 January 2021:

a)	Pages (xviii) and (xix)	— Foreword
b)	Pages I-3, I-4 and I-6 to I-11	— Part I
c)	Page II-3-7	— Part II, Chapter 3
d)	Page II-8-6	— Part II, Chapter 8
e)	Pages II-11-1 to II-11-3	— Part II, Chapter 11
f)	Pages II-13-1 and II-13-6	— Part II, Chapter 13
g)	Pages APP 2-2 to APP 2-4, APP 2-11 to APP 2-13, APP 2-20, APP 2-22, APP 2-23, APP 2-28 and APP 2-33	— Appendix 2
h)	Pages APP 4-2 to APP 4-7	— Appendix 4
i)	Pages APP 6-2, APP 6-5 and APP 6-7	— Appendix 6
j)	Page ATT A-3	— Attachment A
k)	Page ATT F-1	— Attachment F

2. Record the entry of this amendment on page (iii).

20/7/20

Amendment	*Source(s)*	*Subject(s)*	*Adopted Effective Applicable*
8 (4th Edition)	Sixth Meeting of the Committee on Aviation Environmental Protection	a) ambient noise correction procedure including definitions for "background noise", "ambient noise" and "broadband noise"; b) allowable wind speed limits during testing; c) applicability language clarification including temporary changes in type design and provisions to allow the recertification of Chapter 5 aeroplanes to Chapter 4; d) rotorcraft-related technical issues; and e) new Attachments G and H containing guidelines for the administration of noise certification documentation and guidelines for obtaining helicopter noise data for land-use planning purposes, respectively.	23 February 2005 11 July 2005 24 November 2005
9 (5th Edition)	Seventh Meeting of the Committee on Aviation Environmental Protection	a) introduction of new text to Attachment H containing guidelines for obtaining helicopter noise data for land-use planning purposes by providing the option for additional microphone positions; b) change to Note 2 of the definition of "derived version of a helicopter" to clarify that it applies to Chapter 11 as well as Chapter 8 helicopters; c) noise certification procedures for helicopters amended to ensure that the maximum operational rotor speed will be used; d) clarification of the definitions relating to wind speeds during tests; e) update of the International Electrotechnical Commission (IEC) references; f) clarification regarding the increment to be added to the V_2 speed to determine the climb speed to be used during certification training; g) amendment of the applicability provisions to align them with similar provisions in other ICAO documents; and h) minor editorial changes.	7 March 2008 20 July 2008 20 November 2008
10 (6th Edition)	Eighth meeting of the Committee on Aviation Environmental Protection (CAEP/8); Secretariat with the assistance of the Aerodrome Meteorological Observation and Forecast Study Group (AMOFSG)	a) amendments to applicability provisions in order to remove unnecessary complexity, repetition and redundancy in the text while improving clarity and harmonization amongst different chapters; b) an update to the references to the *Environmental Technical Manual* (Doc 9501), Volume I — *Procedures for the Noise Certification of Aircraft*; c) new text in Chapter 3 to clarify noise certification take-off reference speed for cases where airworthiness certification take-off speed is not specified; d) improved readability and clarification of previously vague or incomplete guidance including the calculation of effective perceived noise level (EPNL), the adjustment of aircraft noise data to reference conditions using the simplified and integrated methods, measurement and characterization of atmospheric sound attenuation, and miscellaneous technical issues and editorial errors;	4 March 2011 18 July 2011 17 November 2011

Amendment	*Source(s)*	*Subject(s)*	*Adopted* *Effective* *Applicable*
		e) harmonization of language for noise certification procedures of tilt-rotors with that of helicopters already adopted in Chapters 8 and 11 of Annex 16, Volume I, in order to clarify that the maximum rotor revolutions per minute (RPM) corresponding with the reference flight condition shall be used; f) clarification that the maximum noise levels applicable to subsonic jet aeroplanes may be used as a guideline for supersonic aeroplanes; g) consequential amendment arising from Amendment 17 to Annex 5 replacing "km/h" by "m/s" as the SI unit to measure wind speed; and h) minor editorial changes.	
11-A	Twelfth meeting of the Operations Panel Working Group of the Whole (OPSP/WG/WHL/12)	Amendment concerning the development of aircraft operating procedures for noise abatement.	3 March 2014 14 July 2014 13 November 2014
11-B (7th Edition)	Ninth meeting of the Committee on Aviation Environmental Protection (CAEP/9)	a) increase in stringency of the turbojet and heavy propeller-driven aeroplane noise requirements, applicable to aeroplanes for which the application for a Type Certificate was submitted on or after 31 December 2017, and on or after 31 December 2020 for aeroplanes less than 55 000 kg in mass (new Chapter 14); b) introduction of noise certification requirements for tilt-rotors, applicable to aircraft for which the application for a Type Certificate was submitted on or after 1 January 2018 (new Chapter 13 — existing Attachment F guidance material remains for reference purposes); c) harmonization of sections on noise data validity and the scheduling of sound pressure level calibrations, and with regard to updating the specifications in the light of advances in audio recording technology; d) correction to the wind speed values given in m/s used for the definition of the noise certification test window; e) upgrade of the language in the title of Attachment A, and associated consequential amendments to equations for the calculation of maximum permitted noise levels as a function of take-off mass (i.e. including maximum permitted); and f) minor editorial changes to nomenclature, symbols and units.	3 March 2014 14 July 2014 1 January 2015
12 (8th Edition)	Tenth meeting of the Committee on Aviation Environmental Protection (CAEP/10)	a) harmonization of language used to define the reference atmosphere; b) removal of references to outdated flight path measurement techniques; c) corrections to guidelines for noise certification of tilt-rotors; and d) correction of miscellaneous technical editorial issues and an amalgamation of all symbols and units into one section.	3 March 2017 21 July 2017 1 January 2018

Amendment	*Source(s)*	*Subject(s)*	*Adopted Effective Applicable*
13	Eleventh meeting of the Committee on Aviation Environmental Protection (CAEP/11)	a) updates of the references to the International Electrotechnical Commission (IEC) Standards IEC61260 to IEC61260-1 and IEC61260-3; and b) general technical nomenclature and typographical issues, including revision of definitions that use the word “abeam”, new definition for “reference ground track”, revision of the specified tolerance for slow exponential time averaging, and proper use of modal verbs “must”, “shall” and “should”.	11 March 2020 20 July 2020 1 January 2021

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

Symbol	*Unit*	*Meaning*
c_R	m/s	*Reference speed of sound*. Speed of sound at a reference temperature condition (25°C).
c_{HR}	m/s	*Reference speed of sound at the altitude of the aeroplane*. The reference speed of sound corresponding to the ambient temperature – assuming a lapse rate of 0.65°C per 100 m – for a standard day at the aeroplane reference height above mean sea level.
M_{ATR}	—	*Helicopter rotor reference advancing blade tip Mach number*. The sum of the reference rotor rotational tip speed and the reference speed of the helicopter, divided by the reference speed of sound.
M_H	—	*Propeller helical tip Mach number*. The square root of the sum of the square of the propeller test rotational tip speed and the square of the test airspeed of the aeroplane, divided by the test speed of sound.
M_{HR}	—	*Propeller reference helical tip Mach number*. The square root of the sum of the square of the propeller reference rotational tip speed and the square of the reference speed of the aeroplane, divided by the reference speed of sound.
Best R/C	m/s	*Best rate of climb*. The certificated maximum take-off rate of climb at the maximum power setting and engine speed.
V_{AR}	m/s	*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.
V_{CON}	m/s	*Maximum airspeed in conversion mode*. The never-exceed airspeed of a tilt-rotor when in conversion mode.
V_G	m/s	*Ground speed*. The aircraft velocity relative to the ground.
V_{GR}	m/s	*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.
V_H	m/s	*Maximum airspeed in level flight*. The maximum airspeed of a helicopter in level flight when operating at maximum continuous power.

Symbol	*Unit*	*Meaning*
V_{MCP}	m/s	*Maximum airspeed in level flight*. The maximum airspeed of a tilt-rotor in level flight when operating in aeroplane mode at maximum continuous power.
V_{MO}	m/s	*Maximum operating airspeed*. The maximum operating limit airspeed of a tilt-rotor that may not be deliberately exceeded.
V_{NE}	m/s	*Never-exceed airspeed*. The maximum operating limit airspeed that may not be deliberately exceeded.
V_R	m/s	*Reference speed*. The aircraft true velocity at reference conditions in the direction of the reference flight path. *Note.— This symbol should not be confused with the symbol commonly used for aeroplane take-off rotation speed.*
V_{REF}	m/s	*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.
V_S	m/s	*Stalling airspeed*. The minimum steady airspeed in the landing configuration.
V_{tip}	m/s	*Tip speed*. The rotational speed of a rotor or propeller tip at test conditions, excluding the aircraft velocity component.
V_{tipR}	m/s	*Reference tip speed.* The rotational speed of a rotor or propeller tip at reference conditions, excluding the aircraft velocity component.
V_Y	m/s	*Speed for best rate of climb*. The test airspeed for best take-off rate of climb.
V_2	m/s	*Take-off safety speed*. The minimum airspeed for a safe take-off.

1.2 Time

Symbol	*Unit*	*Meaning*
t_0	s	*Reference duration*. The length of time used as a reference in the integration equation for computing EPNL, where $t_0 = 10$ s.
t_R	s	*Reference reception time*. The reference time of reception calculated from time of reference aircraft position and distance between aircraft and microphone used in the integrated procedure.
Δt	s	*Time increment.* The equal time increment between one-third octave band spectra, where $\Delta t = 0.5$ s.
δt_R	s	*Reference time increment*. The effective duration of a time increment between reference reception times associated with PNLT points used in the integrated method.

1.3 Indices

Symbol	*Unit*	*Meaning*
i	—	*Frequency band index.* 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.
k	—	*Time increment index*. 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.
k_F	—	*First time increment identifier*. Index of the first 10 dB-down point in the discrete measured PNLT time history.
k_{FR}	—	*Reference first time increment identifier*. Index of the first 10 dB-down point in the discrete PNLT time history for the integrated method.
k_L	—	*Last time increment identifier*. Index of the last 10 dB-down point in the discrete measured PNLT time history.
k_{LR}	—	*Reference last time increment identifier*. Index of the last 10 dB-down point in the discrete PNLT time history for the integrated method.
k_M	—	*Maximum PNLTM time increment index*. Time increment index of PNLTM.
t	s	*Elapsed time.* The length of time measured from a reference zero.
t_1	s	*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.)
t_2	s	*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.)

1.4 Noise metrics

Symbol	*Unit*	*Meaning*
EPNL	EPNdB	*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.)
$EPNL_A$	EPNdB	*Approach EPNL.* Effective perceived noise level at the aeroplane approach reference measurement points.
$EPNL_F$	EPNdB	*Flyover EPNL.* Effective perceived noise level at the aeroplane flyover reference measurement points.

Symbol	*Unit*	*Meaning*
$EPNL_L$	EPNdB	*Lateral EPNL.* Effective perceived noise level at the aeroplane lateral reference measurement points.
L_{AE}	dB(A)	*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 (dB(A), normalized to a reference duration of 1 second). (See Appendix 4, Section 3 for specifications.)
L_{AS}	dB(A)	*Slow A-weighted sound level*. Sound level with frequency weighting A and time weighting S for a specified instance in time.
L_{ASmax}	dB(A)	*Maximum slow A-weighted sound level*. The maximum value of L_{AS} over a specified time interval.
L_{ASmaxR}	dB(A)	*Reference maximum slow A-weighted sound level.* The maximum value of L_{AS} over a specified time interval corrected to reference conditions.
$LIMIT_A$	EPNdB	*Approach EPNL limit*. The maximum permitted noise level at the aeroplane approach reference measurement points.
$LIMIT_F$	EPNdB	*Flyover EPNL limit*. The maximum permitted noise level at the aeroplane flyover reference measurement points.
$LIMIT_L$	EPNdB	*Lateral EPNL limit*. The maximum permitted noise level at the aeroplane lateral reference measurement points.
n	noy	*Perceived noisiness.* The perceived noisiness of a one-third octave band sound pressure level in a given spectrum.
N	noy	*Total perceived noisiness.* The total perceived noisiness of a given spectrum calculated from the 24 values of *n*.
PNL	PNdB	*Perceived noise level.* 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.)
PNLT	TPNdB	*Tone-corrected perceived noise level.* The value of the PNL of a given spectrum adjusted for spectral irregularities.
$PNLT_R$	TPNdB	*Reference tone-corrected perceived noise level.* The value of PNLT adjusted to reference conditions.
PNLTM	TPNdB	*Maximum tone-corrected perceived noise level.* The maximum value of PNLT in a specified time history, adjusted for the bandsharing adjustment Δ_B.
$PNLTM_R$	TPNdB	*Reference maximum tone-corrected perceived noise level.* The maximum value of $PNLT_R$ in a specified time history, adjusted for the bandsharing adjustment Δ_B in the simplified method and Δ_{BR} in the integrated method.

Symbol	*Unit*	*Meaning*
SPL	dB	*Sound pressure level.* 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. *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.*
SPL_R	dB	*Reference sound pressure level*. The one-third octave band sound pressure levels adjusted to reference conditions.
SPL_S	dB	*Slow weighted sound pressure level*. The value of one-third octave band sound pressure levels with time weighting S applied.
Δ_1	TPNdB	*PNLTM adjustment.* Under Appendix 2 or Attachment F. 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 PNLTM.
	dB(A)	Under Appendix 4. The adjustments to be added to the measured L_{AE} to account for noise level changes for spherical spreading and duration due to the difference between test and reference helicopter height.
	dB(A)	Under Appendix 6. For propeller-driven aeroplanes not exceeding 8 618 kg, the adjustment to be added to the measured L_{ASmax} to account for noise level changes due to the difference between test and reference aeroplane heights.
Δ_2	TPNdB	*Duration adjustment.* Under Appendix 2 or Attachment F. 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.
	dB(A)	Under Appendix 4. The adjustments to be added to the measured L_{AE} to account for noise level changes due to the difference between reference and adjusted airspeed.
	dB(A)	Under Appendix 6. For propeller-driven aeroplanes not exceeding 8 618 kg, the adjustment to be added to the measured L_{ASmax} to account for the noise level changes due to the difference between test and reference propeller helical tip Mach number.

Symbol	*Unit*	*Meaning*
Δ_3	TPNdB	*Source noise adjustment.* Under Appendix 2. 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.
	dB(A)	Under Appendix 6. For propeller-driven aeroplanes not exceeding 8 618 kg, the adjustment to be added to the measured L_{ASmax} to account for noise level changes due to the difference between test and reference engine power.
Δ_4	dB(A)	*Atmospheric absorption adjustment*. Under Appendix 6. For propeller-driven aeroplanes not exceeding 8 618 kg, the adjustment to be added to the measured L_{ASmax} for noise level changes due to the change in atmospheric absorption, caused by the difference between test and reference aeroplane heights.
Δ_B	TPNdB	*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. PNLTM is equal to the maximum PNLT plus Δ_B.
Δ_{BR}	TPNdB	*Reference bandsharing adjustment*. The adjustment to be added to the maximum $PNLT_R$ in the integrated method to account for possible suppression of a tone due to one-third octave bandsharing of that tone. $PNLTM_R$ is equal to the maximum $PNLT_R$ plus $\Delta_{BR.}$
Δ_{peak}	TPNdB	*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 PNLTM spectrum.

1.5 Calculation of PNL and tone correction

Symbol	*Unit*	*Meaning*
C	dB	*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.
f	Hz	*Frequency.* The nominal geometric mean frequency of a one-third octave band.
F	dB	*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.
$\log n(a)$	—	*Noy discontinuity coordinate.* The $\log n$ value of the intersection point of the straight lines representing the variation of SPL with $\log n$.
M	—	*Noy inverse slope.* The reciprocals of the slopes of straight lines representing the variation of SPL with $\log n$.

Symbol	*Unit*	*Meaning*
s	dB	*Slope of sound pressure level.* The change in level between adjacent one-third octave band sound pressure levels in a given spectrum.
Δs	dB	*Change in slope of sound pressure level.*
s'	dB	*Adjusted slope of sound pressure level.* The change in level between adjacent adjusted one-third octave band sound pressure levels in a given spectrum.
$\bar{s}$	dB	*Average slope of sound pressure level.*
SPL(a)	dB	*Noy discontinuity level.* The SPL value at the discontinuity coordinate of the straight lines representing the variation of SPL with log n.
SPL(b) SPL(c)	dB	*Noy intercept levels.* The intercepts on the SPL-axis of the straight lines representing the variation of SPL with log n.
SPL(d)	dB	*Noy discontinuity level*. The SPL value at the discontinuity coordinate where log n equals −1.
SPL(e)	dB	*Noy discontinuity level*. The SPL value at the discontinuity coordinate where log n equals log 0.3.
SPL′	dB	*Adjusted sound pressure level.* The first approximation to broadband sound pressure level in a one-third octave band of a given spectrum.
SPL″	dB	*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.

1.6 Flight path geometry

Symbol	*Unit*	*Meaning*
H	m	*Height*. The aircraft height at the point where the flight path intercepts the vertical geometrical plane perpendicular to the reference ground track at the centre microphone.
H_R	m	*Reference height*. The reference aircraft height at the point where the reference flight path intercepts the vertical geometrical plane perpendicular to the reference ground track at the centre microphone.
X	m	*Aircraft position along the ground track*. The position coordinate of the aircraft along the x-axis at a specific point in time.
Y	m	*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.
Z	m	*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.

Symbol	*Unit*	*Meaning*
θ	degrees	*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.
ψ	degrees	*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.
ψ_R	degrees	*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.

1.7 Miscellaneous

Symbol	*Unit*	*Meaning*
antilog	—	*Antilogarithm to the base 10.*
D	m	*Diameter.* Propeller or rotor diameter.
D_{15}	m	*Take-off distance.* The take-off distance required for an aeroplane to reach 15 m height above ground level.
e	—	*Euler's number*. The mathematical constant that is the base number of the natural logarithm, approximately 2.71828.
log	—	*Logarithm to the base 10.*
N	rpm	*Propeller speed.*
N_1	rpm	*Compressor speed.* The turbine engine low pressure compressor first stage fan speed.
RH	%	*Relative humidity.* The ambient atmospheric relative humidity.
T	°C	*Temperature.* The ambient atmospheric temperature.
u	m/s	*Wind speed along-track component*. The component of the wind speed vector along the reference ground track.
v	m/s	*Wind speed cross-track component*. The component of the wind speed vector horizontally perpendicular to the reference ground track.

Symbol	*Unit*	*Meaning*
α	dB/100 m	*Test atmospheric absorption coefficient.* 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.
α_R	dB/100 m	*Reference atmospheric absorption coefficient.* 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.
μ	—	*Engine noise performance parameter.* 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.

3.7.7 For take-off, lateral, and approach conditions, the variation in instantaneous indicated airspeed of the aeroplane shall be maintained within ±3 per cent of the average airspeed between the 10 dB-down points. This shall be determined by reference to the pilot's airspeed indicator. However, when the instantaneous indicated airspeed varies from the average airspeed over the 10 dB-down points by more than ±5.5 km/h (±3 kt), and this is judged by the certificating authority representative on the flight deck to be due to atmospheric turbulence, then the flight so affected shall be rejected for noise certification purposes.

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° approach path;

b) the approach shall be made at a stabilized airspeed equal to the best rate of climb speed, 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;

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

d) the constant approach configuration used in airworthiness certification tests, with the landing gear extended, shall be maintained throughout the approach reference procedure; and

e) the mass of the helicopter at touchdown shall be the maximum landing mass at which noise certification is requested.

8.7 Test procedures

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

8.7.2 The test procedures and noise measurements shall be conducted and processed in an approved manner to yield the noise evaluation measure designated as effective perceived noise level, EPNL, in units of EPNdB, as described in Appendix 2.

8.7.3 Test conditions and procedures shall be closely similar to reference conditions and procedures or the acoustic data shall be adjusted, by the methods outlined in Appendix 2, to the reference conditions and procedures specified in this chapter.

8.7.4 Adjustments for differences between test and reference flight procedures shall not exceed:

a) *for take-off:* 4.0 EPNdB, of which the arithmetic sum of Δ_1 and the term $-7.5 \log (QK/Q_r K_r)$ from Δ_2 shall not in total exceed 2.0 EPNdB;

b) *for overflight or approach:* 2.0 EPNdB.

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

8.7.6 The helicopter airspeed shall not vary from the reference airspeed appropriate to the flight demonstration by more than ±9 km/h (±5 kt) throughout the 10 dB-down period.

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

8.7.8 The helicopter shall fly within ±10° or ±20 m, whichever is greater, from the vertical above the reference track throughout the 10 dB-down period (see Figure 8-1).

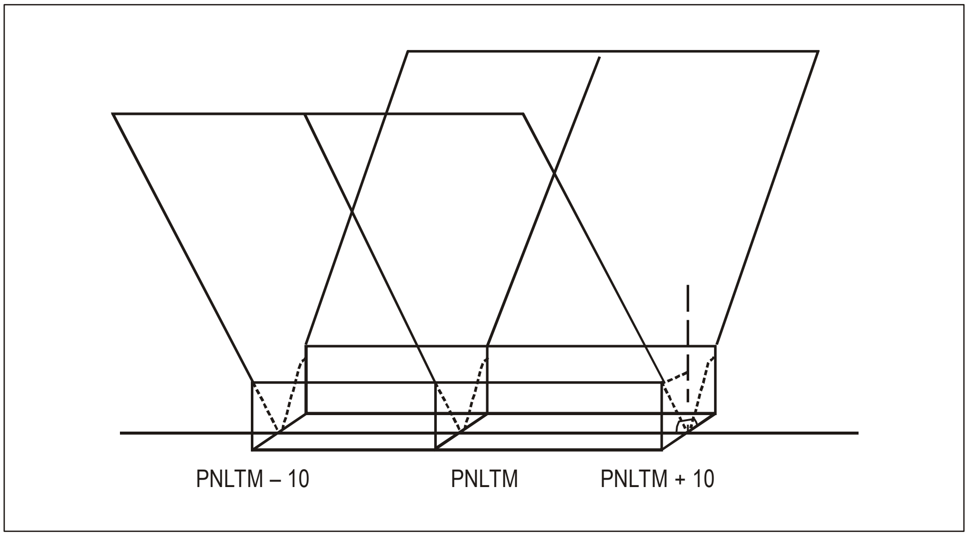


Figure 8-1. Helicopter lateral deviation tolerances

8.7.9 The helicopter height shall not vary during overflight from the reference height at the overhead point by more than ±9 m (±30 ft).

8.7.10 During the approach noise demonstration the helicopter shall be established on a stabilized constant speed approach within the airspace contained between approach angles of 5.5° and 6.5°.

8.7.11 Tests shall be conducted at a helicopter mass not less than 90 per cent of the relevant maximum certificated mass and may be conducted at a mass not exceeding 105 per cent of the relevant maximum certificated mass. For each of the three flight conditions, at least one test shall be completed at or above this maximum certificated mass.

Note.— Guidance material on the use of equivalent procedures is provided in the Environmental Technical Manual *(Doc 9501), Volume I —* Procedures for the Noise Certification of Aircraft.

CHAPTER 11. HELICOPTERS NOT EXCEEDING 3 175 kg MAXIMUM CERTIFICATED TAKE-OFF MASS

11.1 Applicability

Note.— See also Chapter 1, 1.10, 1.11, 1.12 and 1.13.

11.1.1 The Standards of this chapter shall be applicable to all helicopters having a maximum certificated take-off mass not exceeding 3 175 kg for which 11.1.2, 11.1.3 and 11.1.4 apply, except those specifically designed and used for agricultural, firefighting or external load-carrying purposes.

11.1.2 For a helicopter for which the application for the Type Certificate was submitted on or after 11 November 1993, except for those helicopters specified in 11.1.4, the maximum noise levels of 11.4.1 shall apply.

11.1.3 For a derived version of a helicopter for which the application for certification of the change in type design was submitted on or after 11 November 1993, except for those helicopters specified in 11.1.4, the maximum noise levels of 11.4.1 shall apply.

11.1.4 For all helicopters, including their derived versions, for which the application for the Type Certificate was submitted on or after 21 March 2002, the maximum noise levels of 11.4.2 shall apply.

11.1.5 Certification of helicopters which are capable of carrying external loads or external equipment shall be made without such loads or equipment fitted.

Note.— Helicopters which comply with the Standards with internal loads may be excepted when carrying external loads or external equipment, if such operations are conducted at a gross mass or with other operating parameters which are in excess of those certificated for airworthiness with internal loads.

11.1.6 An applicant under 11.1.1, 11.1.2, 11.1.3 and 11.1.4 may alternatively elect to show compliance with Chapter 8 instead of complying with this chapter.

11.2 Noise evaluation measure

The noise evaluation measure shall be the sound exposure level L_{AE} as described in Appendix 4.

11.3 Reference noise measurement points

A helicopter, when tested in accordance with these Standards, shall not exceed the noise levels specified in 11.4 at a flight path reference point located on the ground 150 m (492 ft) vertically below the flight path defined in the overflight reference procedure (see 11.5.2.1).

Note.— See Attachment H (Guidelines for Obtaining Helicopter Noise Data for Land-use Planning Purposes) *that defines acceptable supplemental land-use planning (LUP) data procedures.*

11.4 Maximum noise level

11.4.1 For helicopters specified in 11.1.2 and 11.1.3, the maximum noise levels, when determined in accordance with the noise evaluation method of Appendix 4, shall not exceed 82 dB(A) for helicopters with maximum certificated take-off mass, at which the noise certification is requested, of up to 788 kg and increasing linearly with the logarithm of the helicopter mass at a rate of 3 decibels per doubling of mass thereafter.

11.4.2 For helicopters specified in 11.1.4, the maximum noise levels, when determined in accordance with the noise evaluation method of Appendix 4, shall not exceed 82 dB(A) for helicopters with maximum certificated take-off mass, at which the noise certification is requested, of up to 1 417 kg and increasing linearly with the logarithm of the helicopter mass at a rate of 3 decibels per doubling of mass thereafter.

Note.— See Attachment A for equations for the calculation of maximum permitted noise levels as a function of take-off mass.

11.5 Noise certification reference procedures

11.5.1 General conditions

11.5.1.1 The reference procedure shall comply with the appropriate airworthiness requirements and shall be approved by the certificating authority.

11.5.1.2 Except as otherwise approved, the overflight reference procedures shall be as defined in 11.5.2.

11.5.1.3 When it is shown by the applicant that the design characteristics of the helicopter would prevent flight being conducted in accordance with 11.5.2 the reference procedure shall be permitted to depart from the standard reference procedure, with the approval of the certificating authority, but only to the extent demanded by those design characteristics which make compliance with the reference procedures impossible.

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

a) 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.

11.5.1.5 The maximum normal operating rpm shall be taken as the highest rotor speed corresponding to the airworthiness limit imposed by the manufacturer and approved by the certificating authority for overflight. Where a tolerance on the highest rotor speed is specified, the maximum normal operating rotor speed shall be taken as the highest rotor speed about which that tolerance is given. If rotor speed is automatically linked with flight condition, the maximum normal operating rotor speed corresponding with the reference flight condition shall be used during the noise certification procedure. If rotor speed can be changed by pilot action, the maximum normal operating rotor speed specified in the flight manual limitation section for the reference conditions shall be used during the noise certification procedure.

11.5.2 Reference procedure

11.5.2.1 The 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 ± 15 m (492 ft ± 50 ft);

b) a speed of 0.9 V_H or 0.9 V_{NE} or 0.45 V_H + 120 km/h (65 kt) or 0.45 V_{NE} + 120 km/h (65 kt), whichever is the least, shall be maintained throughout the overflight procedure. 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°C ambient conditions at the relevant 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.

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

11.6 Test procedures

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

11.6.2 The test procedure and noise measurements shall be conducted and processed in an approved manner to yield the noise evaluation measure designated as sound exposure level (L_{AE}), in A-weighted decibels integrated over the duration time, as described in Appendix 4.

11.6.3 Test conditions and procedures shall be closely similar to reference conditions and procedures or the acoustic data shall be adjusted, by the methods outlined in Appendix 4, to the reference conditions and procedures specified in this chapter.

11.6.4 During the test, flights shall be made in equal numbers with tailwind and headwind components.

11.6.5 Adjustments for differences between test and reference flight procedures shall not exceed 2.0 dB(A).

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

11.6.7 The helicopter airspeed shall not vary from the reference airspeed appropriate to the flight demonstration as described in Appendix 4 by more than ±5.5 km/h (±3 kt) throughout the 10 dB-down period.

11.6.8 The helicopter shall fly within ±10° from the vertical above the reference track through the reference noise measurement position.

11.6.9 Tests shall be conducted at a helicopter mass not less than 90 per cent of the relevant maximum certificated mass and may be conducted at a mass not exceeding 105 per cent of the relevant maximum certificated mass.

Note.— Guidance material on the use of equivalent procedures is provided in the Environmental Technical Manual *(Doc 9501), Volume I —* Procedures for the Noise Certification of Aircraft.

CHAPTER 13. TILT-ROTORS

Note.— These Standards 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 procedures/conditions would likely be needed.

13.1 Applicability

Note.— See also Chapter 1, 1.10, 1.11, 1.12 and 1.13.

13.1.1 The Standards of this chapter shall be applicable to all tilt-rotors, including their derived versions, for which the application for a Type Certificate was submitted on or after 1 January 2018.

13.1.2 Noise certification of tilt-rotors which are capable of carrying external loads or external equipment shall be made without such loads or equipment fitted.

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 L_{AE} and L_{ASmax} as defined in Appendix 4, and one-third octave SPLs as defined in Appendix 2 corresponding to L_{ASmax} 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 13.6 and the test procedures of 13.7, shall not exceed the noise levels specified in 13.4 at the following reference points:

a) *Take-off reference noise measurement points:*

   1) a flight path reference point located on the ground vertically below the flight path defined in the take-off reference procedure (see 13.6.2) and 500 m (1 640 ft) horizontally in the direction of flight from the point at which transition to climbing flight is initiated in the reference procedure;

   2) two other points on the ground symmetrically disposed at 150 m (492 ft) on both sides of the flight path defined in the take-off reference procedure and lying on a line through the flight path reference point.

b) *Overflight reference noise measurement points:*

   1) a flight path reference point located on the ground 150 m (492 ft) vertically below the flight path defined in the overflight reference procedure (see 13.6.3);

2) two other points on the ground symmetrically disposed at 150 m (492 ft) on both sides of the flight path defined in the overflight reference procedure and lying on a line through the flight path reference point.

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 13.6.4). On level ground, this corresponds to a position 1 140 m (3 740 ft) from the intersection of the 6.0° approach path with the ground plane;

2) two other points on the ground symmetrically disposed at 150 m (492 ft) on both sides of the flight path defined in the approach reference procedure and lying on a line through the flight path reference point.

13.4 Maximum noise levels

13.4.1 For tilt-rotors specified in 13.1, the maximum noise levels, when determined in accordance with the noise evaluation method of Appendix 2 for helicopters, shall not exceed the following:

13.4.1.1 *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.

13.4.1.2 *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.

13.4.1.3 *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 7 of Attachment A, for conditions described in Chapter 8, 8.4.1, are consistent with the maximum noise levels defined in 13.4.

13.5 Trade-offs

If the maximum noise levels are exceeded at one or two measurement points:

a) the sum of excesses shall not be greater than 4 EPNdB;

b) any excess at any single point shall not be greater than 3 EPNdB; and

c) any excess shall be offset by corresponding reductions at the other point or points.

b) the approach shall be in an airworthiness approved configuration in which maximum noise occurs, at a stabilized airspeed equal to the best rate of climb speed corresponding to the nacelle angle, or the lowest approved airspeed for the approach, whichever is the greater, and with power stabilized during the approach and over the flight path reference point, and continued to a normal touchdown;

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

d) the constant approach configuration used in airworthiness certification tests, with the landing gear extended, shall be maintained throughout the approach reference procedure; and

e) the mass of the tilt-rotor at touchdown shall be the maximum landing mass at which noise certification is requested.

13.7 Test procedures

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

13.7.2 The test procedures and noise measurements shall be conducted and processed in an approved manner to yield the noise evaluation measure designated in 13.2.

13.7.3 Test conditions and procedures shall be similar to reference conditions and procedures or the acoustic data shall be adjusted, by the methods outlined in Appendix 2 for helicopters, to the reference conditions and procedures specified in this chapter.

13.7.4 Adjustments for differences between test and reference flight procedures shall not exceed:

a) *for take-off:* 4.0 EPNdB, of which the arithmetic sum of Δ_1 and the term $-7.5 \log QK/Q_rK_r$ from Δ_2 shall not in total exceed 2.0 EPNdB; and

b) *for overflight or approach:* 2.0 EPNdB.

13.7.5 During the test the average rotor rpm shall not vary from the normal maximum operating rpm by more than ±1.0 per cent throughout the 10 dB-down period.

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

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

13.7.8 The tilt-rotor shall fly within ±10° or ±20 m (±65 ft), whichever is greater, from the vertical above the reference track throughout the 10 dB-down period (see Figure 8-1).

13.7.9 The height of the tilt-rotor shall not vary during overflight from the reference height throughout the 10 dB-down period by more than ±9 m (±30 ft).

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

13.7.11 Tests shall be conducted at a tilt-rotor mass not less than 90 per cent of the relevant maximum certificated mass and may be conducted at a mass not exceeding 105 per cent of the relevant maximum certificated mass. For each of the flight conditions, at least one test shall be completed at or above this maximum certificated mass.

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 1.— This noise evaluation method includes:

a) noise certification test and measurement conditions;

b) measurement of aeroplane and helicopter noise received on the ground;

c) calculation of effective perceived noise level from measured noise data; and

d) reporting of data to the certificating authority and correcting measured data.

Note 2.— The instructions and procedures given in the method are clearly delineated to ensure uniformity during compliance tests, and to permit comparison between tests of various types of aircraft conducted in various geographical locations.

Note 3.— A complete list of symbols and units is included in Part I 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 7 and 8 of this appendix.

2. NOISE CERTIFICATION TEST AND MEASUREMENT CONDITIONS

2.1 General

This section prescribes the conditions under which noise certification tests shall be conducted and the measurement procedures that shall be used.

Note.— Many applications for a noise certificate involve only minor changes to the aircraft type design. The resultant changes in noise can often be established reliably without the necessity of resorting to a complete test as outlined in this appendix. For this reason certificating authorities are encouraged to permit the use of appropriate "equivalent procedures". Also, there are equivalent procedures that may be used in full certification tests, in the interest of reducing costs and providing reliable results. Guidance material on the use of equivalent procedures in the noise certification of subsonic jet and propeller-driven aeroplanes and helicopters is provided in the Environmental Technical Manual *(Doc 9501), Volume I* — Procedures for the Noise Certification of Aircraft.

2.2 Test environment

2.2.1 Microphone locations

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

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

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" (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 flight path intercepts the vertical geometrical plane perpendicular to the reference ground track at the centre microphone.

Note.— The reference ground track is defined in 8.1.3.5.

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 flight path intercepts the vertical geometrical plane perpendicular to the reference ground track at the centre 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 flight path intercepts the vertical geometrical plane perpendicular to the reference ground track at the centre 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" (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 × (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.)

***Wind direction sample (at a certain moment)*.** The value obtained at that moment from a wind direction sensor/system with characteristics as follows:

Wind speed operating range:	1 m/s (2 kt) to more than 10 m/s (20 kt);
Linearity:	±5 degrees over the specified range; and
Resolution:	5 degrees.

Note.— For the entire wind sensing system used to obtain wind speed and direction samples, the combined dynamic characteristics, including physical inertia of the sensor(s), and any temporal processing, such as filtering of the sensor signal(s), or smoothing or averaging of the wind sensor data, shall be equivalent to a first order system (such as an R/C circuit) with a time constant of no greater than 3 seconds at a wind speed of 5 m/s (10 kt).

***Wind speed sample (at a certain moment)*.** The value measured at that moment for wind speed using a sensor/system with characteristics as follows:

Range:	1 m/s (2 kt) to more than 10 m/s (20 kt);
Linearity:	±0.5 m/s (±1 kt) over the specified range; and
Distance constant (response length):	less than 5 metres for systems having dynamic behaviour best characterized by a distance constant; or
Time constant:	less than 3 seconds for wind speeds at or above 5 m/s (10 kt) for systems having dynamic behaviour best characterized by a time constant.

***Wind vector (at a certain moment)*.** At least once every second the wind vector shall be determined. Its magnitude will be represented at a certain moment by the wind speed sample at that moment and the direction of the vector shall be represented by the wind direction sample at that moment.

2.2.2.2 *Measurement*

2.2.2.2.1 Measurements of the ambient temperature and relative humidity shall be made at 10 m (33 ft) above the ground. For aeroplanes the ambient temperature and relative humidity shall also be determined at vertical increments not greater than 30 m (100 ft) over the sound propagation path. For an aircraft test run to be acceptable, measurements of ambient temperature and relative humidity shall be obtained before and after the test run. Both measurements shall be representative of the prevailing conditions during the test run and at least one of the measurements of ambient temperature and relative humidity shall be within 30 minutes of the test run. The temperature and relative humidity data at the actual time of the test run shall be interpolated over time and height, as necessary, from the measured meteorological data.

Note.— The temperature and relative humidity measured at 10 m (33 ft) are assumed to be constant from 10 m (33 ft) to the ground.

2.2.2.2.2 Measurements of wind speed and direction shall be made at 10 m (33 ft) above the ground throughout each test run.

2.2.2.2.3 The meteorological conditions at 10 m above the ground shall be measured within 2 000 m (6 562 ft) of the microphone locations. They shall be representative of the conditions existing over the geographical area in which noise measurements are made.

2.2.2.3 *Instrumentation*

2.2.2.3.1 Instrumentation for the measurement of temperature and humidity between the ground and the aeroplane, including instrumentation for the determination of the height at which these measurements are made, and the manner in which such instrumentation is used shall, to the satisfaction of the certificating authority, enable the sampling of atmospheric conditions at 30 m (100 ft) vertical height increments or less.

2.2.2.3.2 All wind speed samples shall be taken with the sensor installed such that the horizontal distance between the anemometer and any obstruction is at least 10 times the height of the obstruction. Installation error for the wind direction sensor shall be no greater than 5 degrees.

2.2.2.3.3 The instrumentation for noise and meteorological measuring and aircraft flight path tracking shall be operated within the environmental limitations specified by the manufacturer.

2.2.2.4 *Test window*

2.2.2.4.1 For aircraft test runs to be acceptable, they shall be carried out under the following atmospheric conditions, except as provided in 2.2.2.4.2:

a) there shall be no precipitation;

b) the ambient air temperature shall not be greater than 35°C and shall not be less than –10°C over the sound propagation path between a point 10 m (33 ft) above the ground and the aircraft;

c) the relative humidity shall not be greater than 95 per cent and shall not be less than 20 per cent over the sound propagation path between a point 10 m (33 ft) above the ground and the aircraft;

d) the sound attenuation coefficient in the 8 kHz one-third octave band shall not be more than 12 dB/100 m over the sound propagation path between a point 10 m (33 ft) above the ground and the height of the aircraft at PNLTM;

Note.— Section 7 of this appendix specifies the method for calculation of sound attenuation coefficients based on temperature and humidity.

e) for aeroplanes the average wind speed at 10 m (33 ft) above the ground shall not exceed 6.2 m/s (12 kt) and the maximum wind speed at 10 m (33 ft) above the ground shall not exceed 7.7 m/s (15 kt);

f) for aeroplanes the average crosswind component at 10 m (33 ft) above the ground shall not exceed 3.6 m/s (7 kt) and the maximum crosswind component at 10 m (33 ft) above the ground shall not exceed 5.1 m/s (10 kt);

g) for helicopters the average wind speed at 10 m (33 ft) above the ground shall not exceed 5.1 m/s (10 kt);

h) for helicopters the average crosswind component at 10 m (33 ft) above the ground shall not exceed 2.6 m/s (5 kt); and

i) there shall be no anomalous meteorological or wind conditions that would significantly affect the measured noise levels.

3.6.4 For analogue tape recordings, the amplitude fluctuations of a 1 kHz sinusoidal signal recorded within 5 dB of the level corresponding to the calibration sound pressure level shall not vary by more than ±0.5 dB throughout any reel of the type of magnetic tape utilized. Conformance to this requirement shall be demonstrated using a device which has time-averaging properties equivalent to those of the spectrum analyser.

3.6.5 For all appropriate level ranges and for steady sinusoidal electrical signals applied to the input of the measurement system exclusive of the microphone system, but including the microphone preamplifier, and any other signal-conditioning elements that are considered to be part of the microphone system, at one-third octave nominal midband frequencies of 50 Hz, 1 kHz and 10 kHz, and the calibration check frequency, if it is not one of these frequencies, the level non-linearity shall not exceed ±0.5 dB for a linear operating range of at least 50 dB below the upper boundary of the level range.

Recommendation.— *Level linearity of measurement system components should be tested according to the methods described in IEC 61265*[1] *as amended*.

Note.— It is not necessary to include microphone extension cables as configured in the field.

3.6.6 On the reference level range, the level corresponding to the calibration sound pressure level shall be at least 5 dB, but no more than 30 dB less than the upper boundary of the level range.

3.6.7 The linear operating ranges on adjacent level ranges shall overlap by at least 50 dB minus the change in attenuation introduced by a change in the level range controls.

Note.— It is possible for a measurement system to have level range controls that permit attenuation changes of, for example, either 10 dB or 1 dB. With 10 dB steps, the minimum overlap required would be 40 dB, and with 1 dB steps the minimum overlap would be 49 dB.

3.6.8 Provision shall be made for an overload indication to occur during an overload condition on any relevant level range.

3.6.9 Attenuators included in the measurement system to permit range changes shall operate in known intervals of decibel steps.

3.7 Analysis systems

3.7.1 The analysis system shall conform to the specifications in 3.7.2 to 3.7.7 for the frequency bandwidths, channel configurations and gain settings used for analysis.

3.7.2 The output of the analysis system shall consist of one-third octave band sound pressure levels as a function of time, obtained by processing the noise signals (preferably recorded) through an analysis system with the following characteristics:

a) a set of 24 one-third octave band filters, or their equivalent, having nominal midband frequencies from 50 Hz to 10 kHz inclusive;

b) response and averaging properties in which, in principle, the output from any one-third octave filter band is squared, averaged and displayed or stored as time-averaged sound pressure levels;

1. IEC 61265:1995 entitled "Electroacoustics — Instruments for measurement of aircraft noise — Performance requirements for systems to measure one-third-octave band sound pressure levels in noise certification of transport-category aeroplanes". This IEC publication may be obtained from the Central Office of the International Electrotechnical Commission, 3 rue de Varembé, Geneva, Switzerland.

c) the interval between successive sound pressure level samples shall be 500 ms ± 5 ms for spectral analysis with or without SLOW-time-weighting;

d) for those analysis systems that do not process the sound pressure signals during the period of time required for readout and/or resetting of the analyser, the loss of data shall not exceed a duration of 5 ms; and

e) the analysis system shall operate in real time from 50 Hz to at least 12 kHz inclusive. This requirement applies to all operating channels of a multichannel spectral analysis system.

3.7.3 The one-third octave band analysis system shall conform to the class 1 performance requirements of IEC 61260-1[2] as amended, over the range of one-third octave filters having nominal midband frequencies from 50 Hz to 10 kHz inclusive.

Note.— The certificating authority may allow the substitution of an analysis system that complies with class 2 performance requirements of IEC 61260-1[2] or with class 1 or class 2 of an earlier version of IEC 61260.

Recommendation.—*Tests of the one-third octave band analysis system should be made according to the methods described in IEC 61260-3[3] or by an equivalent procedure approved by the certificating authority, for relative attenuation, anti-aliasing filters, real-time operation, level linearity, and filter integrated response (effective bandwidth).*

3.7.4 When SLOW-time-averaging is performed in the analyser, the response of the one-third octave band analysis system to a sudden onset or interruption of a constant sinusoidal signal at the respective one-third octave nominal midband frequency shall be measured at sampling instants 0.5, 1, 1.5 and 2 seconds after both the onset and the interruption. The rising response shall be –4 ± 1 dB at 0.5 seconds, –1.75 ± 0.75 dB at 1 second, –1 ± 0.5 dB at 1.5 seconds and –0.5 ± 0.5 dB at 2 seconds relative to the steady-state level. The sum of the rising and corresponding falling shall be –6.5 ± 1 dB, at both 0.5 and 1 seconds. The sum of the rising and falling responses shall be –6.5 dB or less at 1.5 seconds and –7.5 dB or less at 2 seconds, and subsequent times relative to the steady-state levels. This equates to an exponential averaging process (SLOW weighting) with a nominal 1-second time constant.

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:

$$\mathrm{SPL_s}(i,k) = 10 \log \left[(0.60653)\, 10^{0.1\mathrm{SPL_s}[i,(k-1)]} + (0.39347)\, 10^{0.1\mathrm{SPL}(i,k)}\right]$$

where $\mathrm{SPL_s}(i,k)$ is the simulated SLOW-weighted sound pressure level and $\mathrm{SPL}(i,k)$ 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 $\mathrm{SPL_s}[i,(k-1 = 0)]$ 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 $k = 4$:

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

where $\mathrm{SPL_s}(i,k)$ is the simulated SLOW-weighted sound pressure level and $\mathrm{SPL}(i,k)$ 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.

2. IEC 61260-1:2014 entitled "Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications". This IEC publication may be obtained from the Central Office of the International Electrotechnical Commission, 3 rue de Varembé, Geneva, Switzerland.
3. IEC 61260-3:2016 entitled "Electroacoustics — Octave-band and fractional-octave-band filters — Part 3: Periodic tests". This IEC publication may be obtained from the Central Office of the International Electrotechnical Commission, 3 rue de Varembé, Geneva, Switzerland.

The sum of the weighting factors is 1.0 in the two equations. Sound pressure levels calculated by means of either equation are valid for the sixth and subsequent 0.5 seconds data samples, or for times greater than 2.5 seconds after initiation of data analysis.

Note.— The coefficients in the two equations were calculated for use in determining equivalent SLOW-weighted sound pressure levels from samples of 0.5 seconds time average sound pressure levels. The equations should not be used with data samples where the averaging time differs from 0.5 seconds.

3.7.6 The instant in time by which a SLOW-time-weighted sound pressure level is characterized shall be 0.75 seconds earlier than the actual readout time.

Note.— The definition of this instant in time is required to correlate the recorded noise with the aircraft position when the noise was emitted and takes into account the averaging period of the SLOW weighting. For each one-half second data record this instant in time may also be identified as 1.25 seconds after the start of the associated 2-second averaging period.

3.7.7 The resolution of the sound pressure levels, both displayed and stored, shall be 0.1 dB or better.

3.8 Calibration instrumentation

3.8.1 All instrumentation used for calibration and determination of corrections shall be approved by the certificating authority.

3.8.2 The sound calibrator shall at least conform to the class 1 requirements of IEC 60942.[4] The sound pressure level produced in the cavity of the coupler of the sound calibrator shall be calculated for the test environmental conditions using the manufacturer's supplied information on the influence of atmospheric air pressure and temperature. The output of the sound calibrator shall be determined within six months of each aircraft noise measurement by a method traceable to a national standards laboratory. Tolerable changes in output from the previous calibration shall be not more than 0.2 dB.

3.8.3 If pink noise is used to determine the corrections for system frequency response in 3.9.7, then the output of the noise generator shall be determined within six months of each aircraft noise measurement by a method traceable to a national standards laboratory. Tolerable changes in the relative output from the previous calibration in each one-third octave band shall be not more than 0.2 dB.

3.9 Calibration and checking of system

3.9.1 Calibration and checking of the measurement system and its constituent components shall be carried out to the satisfaction of the certificating authority by the methods specified in 3.9.2 to 3.9.9. All calibration corrections and adjustments, including those for the environmental effects on sound calibrator output level, shall be reported to the certificating authority and applied to the measured one third octave sound pressure levels determined from the output of the analyser. Aircraft noise data collected during an overload condition of any measurement system components in the signal path prior to and including the recorder are invalid and shall not be used. If the overload condition occurred during analysis or at a point in the signal path after the recorder, the analysis shall be repeated with reduced sensitivity to eliminate the overload.

3.9.2 The acoustical sensitivity of the measurement system shall be established using a sound calibrator generating a known sound pressure level at a known frequency. Sufficient sound pressure level calibrations shall be recorded during each test day to ensure that the acoustical sensitivity of the measurement system is known for the prevailing environmental

4. IEC 60942:2003 entitled "Electroacoustics — Sound calibrators". This IEC publication may be obtained from the Central Office of the International Electrotechnical Commission, 3 rue de Varembé, Geneva, Switzerland.

conditions corresponding with each aircraft noise measurement. Measured aircraft noise data shall not be considered valid for certification purposes unless preceded and succeeded by valid sound pressure level calibrations. The measurement system shall be considered satisfactory if the difference between the acoustical sensitivity levels recorded immediately before and immediately after each group of aircraft noise measurements on a given day is not greater than 0.5 dB. The 0.5 dB limit applies after any atmospheric pressure corrections have been applied to the calibrator output level. The arithmetic mean of the preceding and succeeding calibrations shall be used to represent the acoustical sensitivity level of the measurement system for each group of aircraft noise measurements. The calibration corrections shall be reported to the certificating authority and applied to the measured one-third octave band sound pressure levels determined from the output of the analyser.

3.9.3 For analogue (direct or FM) magnetic tape recorders each volume of recording medium, such as a reel, cartridge, or cassette, shall carry a sound pressure level calibration of at least 10 seconds duration at its beginning and end.

3.9.4 The free-field frequency response of the microphone system may be determined by using an electrostatic actuator in combination with the manufacturer’s data or by testing in an anechoic free-field facility. The corrections for frequency response shall be determined within 90 days of each aircraft noise measurement and shall be reported to the certificating authority. They shall be applied to the measured one-third octave band sound pressure levels determined from the output of the analyser.

3.9.5 When the angles of incidence at the microphone of sound emitted from the aircraft are within ±30º of grazing incidence (see Figure A2-1), a single set of free-field corrections based on grazing incidence is considered sufficient for the correction of directional response effects. Otherwise appropriate corrections for incidence effects shall be determined at the angle of incidence for each one-half second sample. Such corrections shall be reported to the certificating authority and applied to the measured one third octave band sound pressure levels determined from the output of the analyser.

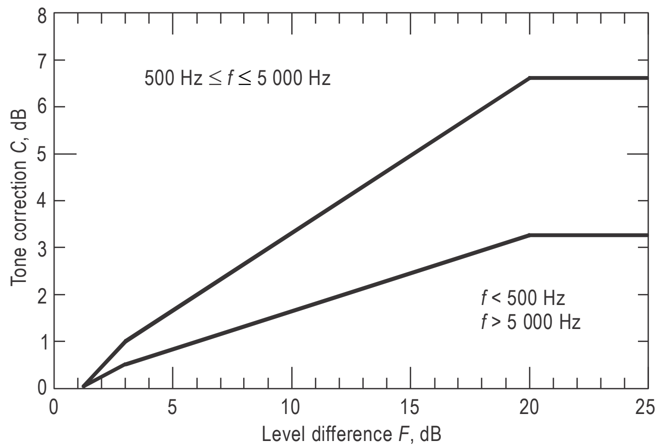
3.9.6 The free-field insertion effects of the windscreen for each one-third octave nominal midband frequency from 50 Hz to 10 kHz inclusive shall be determined with sinusoidal sound signals at appropriate incidence angles on the inserted microphone. For a windscreen which is undamaged and uncontaminated, the insertion effects may be taken from the manufacturer’s data. In addition, the insertion effects of the windscreen may be determined within six months of each aircraft noise measurement by a method traceable to a national standards laboratory. Tolerable changes in the insertion effects from the previous calibration at each one-third octave frequency band shall be not more than 0.4 dB. The corrections for the free-field insertion effects of the windscreen shall be reported to the certificating authority and applied to the measured one-third octave sound pressure levels determined from the output of the analyser.

3.9.7 The frequency response of the entire measurement system, exclusive of the microphone and windscreen, but otherwise configured as deployed in the field during the aircraft noise measurements, shall be established. Corrections shall be determined for each one-third octave nominal midband frequency from 50 Hz to 10 kHz inclusive. The determination shall be made at a level within 5 dB of the level corresponding to the calibration sound pressure level on the reference level range and shall utilize pink random or pseudo-random noise or alternatively discrete sine or swept sine signals. The corrections for frequency response shall be reported to the certificating authority and applied to the measured one-third octave sound pressure levels determined from the output of the analyser. If the system frequency response corrections are determined away from the field then frequency response testing shall be performed in the field to ensure the integrity of the measurement system.

3.9.8 For analogue (direct or FM) magnetic tape recorders, each volume of recording medium such as a reel, cartridge, or cassette shall carry at least 30 seconds of pink random or pseudo-random noise at its beginning and end. Aircraft noise data obtained from analogue tape-recorded signals shall be accepted as valid only if level differences in the 10 kHz one-third octave band are not more than 0.75 dB for the signals recorded at the beginning and end. For systems using analogue (direct or FM) magnetic tape recorders frequency response corrections shall be determined from pink noise recordings performed in the field during deployment for aircraft noise measurements.

3.9.9 The performance of switched attenuators in the equipment used during noise certification measurements and calibration shall be checked within six months of each aircraft noise measurement to ensure that the maximum error does not exceed 0.1 dB. The accuracy of gain-changes shall be tested or determined from manufacturers specifications to the satisfaction of the certificating authority.

Table A2-2. Tone correction factors



Frequency f, Hz	Level difference F, dB	Tone correction C, dB
$50 \leq f < 500$	$1\frac{1}{2}^* \leq F < 3$	$F/3 - \frac{1}{2}$
	$3 \leq F < 20$	$F/6$
	$20 \leq F$	$3\frac{1}{3}$
$500 \leq f \leq 5\,000$	$1\frac{1}{2}^* \leq F < 3$	$2\,F/3 - 1$
	$3 \leq F < 20$	$F/3$
	$20 \leq F$	$6\frac{2}{3}$
$5\,000 < f \leq 10\,000$	$1\frac{1}{2}^* \leq F < 3$	$F/3 - \frac{1}{2}$
	$3 \leq F < 20$	$F/6$
	$20 \leq F$	$3\frac{1}{3}$

* See Step 8 of 4.3.1.

4.3.2 This procedure will underestimate EPNL if an important tone is of a frequency such that it is recorded in two adjacent one-third octave bands. It shall be demonstrated to the satisfaction of the certificating authority:

either that this has not occurred,

or that if it has occurred that the tone correction has been adjusted to the value it would have had if the tone had been recorded fully in a single one-third octave band.

4.4 Maximum tone corrected perceived noise level

4.4.1 The tone corrected perceived noise levels, PNLT(k), are calculated from measured one-half second values of SPL in accordance with the procedure of Section 4.3. The maximum tone corrected perceived noise level, PNLTM, shall be the maximum value of PNLT(k), adjusted if necessary for the presence of bandsharing by the method of Section 4.4.2. The increment associated with PNLTM is designated as k_M.

Note.— Figure A2-2 is an example of a flyover noise time history where the maximum value is clearly indicated.

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, Δ_B, and a value of PNLTM adjusted for bandsharing.

$$C_{avg} = [C(k_M - 2) + C(k_M - 1) + C(k_M) + C(k_M + 1) + C(k_M + 2)] / 5$$

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

$$PNLTM = PNLT(k_M) + \Delta_B$$

4.4.3 The value of PNLTM adjusted for bandsharing shall be used for the calculation of EPNL.

4.5 Noise duration

4.5.1 The limits of the noise duration are bounded by the first and last 10 dB-down points. These are determined by examination of the PNLT(k) time history with respect to PNLTM:

a) the earliest value of PNLT(k) which is greater than PNLTM – 10 dB is identified. This value and the value of PNLT for the preceding point are compared. Whichever of these two points is associated with the value closest to PNLTM – 10 dB is identified as the first 10 dB-down point. The associated increment is designated as k_F; and

b) the last value of PNLT(k) which is greater than PNLTM – 10 dB is identified. This value and the value of PNLT for the following point are compared. Whichever of these two points is associated with the value closest to PNLTM – 10 dB is identified as the last 10 dB-down point. The associated increment is designated as k_L.

Note.— Figure A2-2 illustrates the selection of the first and last 10 dB-down points, k_F *and* k_L.

4.5.2 The noise duration in seconds shall be equal to the number of PNLT(k) values from k_F to k_L inclusive, times 0.5.

4.5.3 The value of PNLTM used for determination of the 10 dB-down points shall include the adjustment for the presence of bandsharing, Δ_B, by the method of Section 4.4.2.

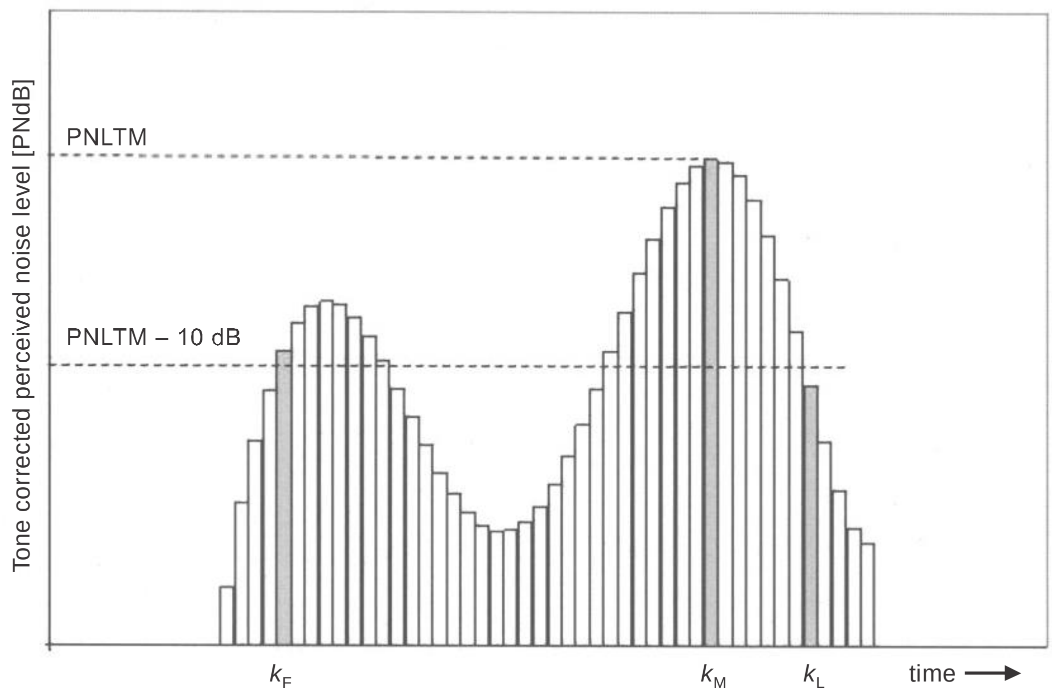


Figure A2-2. Example of a flyover noise time history

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.

$$\text{EPNL} = 10 \log \frac{1}{t_0} \int_{t_1}^{t_2} 10^{0.1\,\text{PNLT}(t)} dt$$

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:

$$\text{EPNL} = 10 \log \frac{1}{t_0} \sum_{k_F}^{k_L} 10^{0.1\,\text{PNLT}(k)} \Delta t$$

For $t_0 = 10$ and $\Delta t = 0.5$, this expression can be simplified as follows:

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

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.

4.6.3 The value of PNLTM used for determination of EPNL shall include the adjustment for the presence of bandsharing, $\Delta_{B,}$ by the method of Section 4.4.2.

4.7 Mathematical formulation of noy tables

4.7.1 The relationship between sound pressure level (SPL) and the logarithm of perceived noisiness is illustrated in Table A2-3 and Figure A2-3.

4.7.2 The important aspects of the mathematical formulation are:

a) the slopes ($M(b)$, $M(c)$, $M(d)$ and $M(e)$) of the straight lines;

b) the intercepts (SPL(b) and SPL(c)) of the lines on the SPL axis; and

c) the coordinates of the discontinuities, SPL(a) and log $n(a)$; SPL(d) and log n = –1.0; and SPL(e) and log n = log (0.3).

4.7.3 The equations are as follows:

a) SPL ≥ SPL(a)
n = antilog {$M(c)$ [SPL – SPL(c)]}

b) SPL(b) ≤ SPL < SPL(a)
n = antilog {$M(b)$ [SPL – SPL(b)]}

c) SPL(e) ⩽ SPL < SPL(b)
n = 0.3 antilog {$M(e)$ [SPL – SPL(e)]}

d) SPL(d) ⩽ SPL < SPL(e)
n = 0.1 antilog {$M(d)$ [SPL – SPL(d)]}

4.7.4 Table A2-3 lists the values of the constants necessary to calculate perceived noisiness as a function of sound pressure level.

5. REPORTING OF DATA TO THE CERTIFICATING AUTHORITY

5.1 General

5.1.1 Data representing physical measurements or corrections to measured data shall be recorded in permanent form and appended to the record.

5.1.2 All corrections shall be approved by the certificating authority. In particular the corrections to measurements for equipment response deviations shall be reported.

5.1.3 Estimates of the individual errors inherent in each of the operations employed in obtaining the final data shall be reported, if required.

Table A2-3. Constants for mathematically formulated noy values

BAND (i)	ISO BAND	f Hz	SPL(a)	SPL(b)	SPL(c)	SPL(d)	SPL(e)	$M(b)$	$M(c)$	$M(d)$	$M(e)$
1	17	50	91.0	64	52	49	55	0.043478	0.030103	0.079520	0.058098
2	18	63	85.9	60	51	44	51	0.040570	0.030103	0.068160	0.058098
3	19	80	87.3	56	49	39	46	0.036831	0.030103	0.068160	0.052288
4	20	100	79.9	53	47	34	42	0.036831	0.030103	0.059640	0.047534
5	21	125	79.8	51	46	30	39	0.035336	0.030103	0.053013	0.043573
6	22	160	76.0	48	45	27	36	0.033333	0.030103	0.053013	0.043573
7	23	200	74.0	46	43	24	33	0.033333	0.030103	0.053013	0.040221
8	24	250	74.9	44	42	21	30	0.032051	0.030103	0.053013	0.037349
9	25	315	94.6	42	41	18	27	0.030675	0.030103	0.053013	0.034859
10	26	400	∞	40	40	16	25	0.030103		0.053013	0.034859
11	27	500	∞	40	40	16	25	0.030103		0.053013	0.034859
12	28	630	∞	40	40	16	25	0.030103		0.053013	0.034859
13	29	800	∞	40	40	16	25	0.030103		0.053013	0.034859
14	30	1 000	∞	40	40	16	25	0.030103		0.053013	0.034859
15	31	1 250	∞	38	38	15	23	0.030103	NOT APPLICABLE	0.059640	0.034859
16	32	1 600	∞	34	34	12	21	0.029960		0.053013	0.040221
17	33	2 000	∞	32	32	9	18	0.029960		0.053013	0.037349
18	34	2 500	∞	30	30	5	15	0.029960		0.047712	0.034859
19	35	3 150	∞	29	29	4	14	0.029960		0.047712	0.034859
20	36	4 000	∞	29	29	5	14	0.029960		0.053013	0.034859
21	37	5 000	∞	30	30	6	15	0.029960		0.053013	0.034859
22	38	6 300	∞	31	31	10	17	0.029960	0.029960	0.068160	0.037349
23	39	8 000	44.3	37	34	17	23	0.042285	0.029960	0.079520	0.037349
24	40	10 000	50.7	41	37	21	29	0.042285	0.029960	0.059640	0.043573

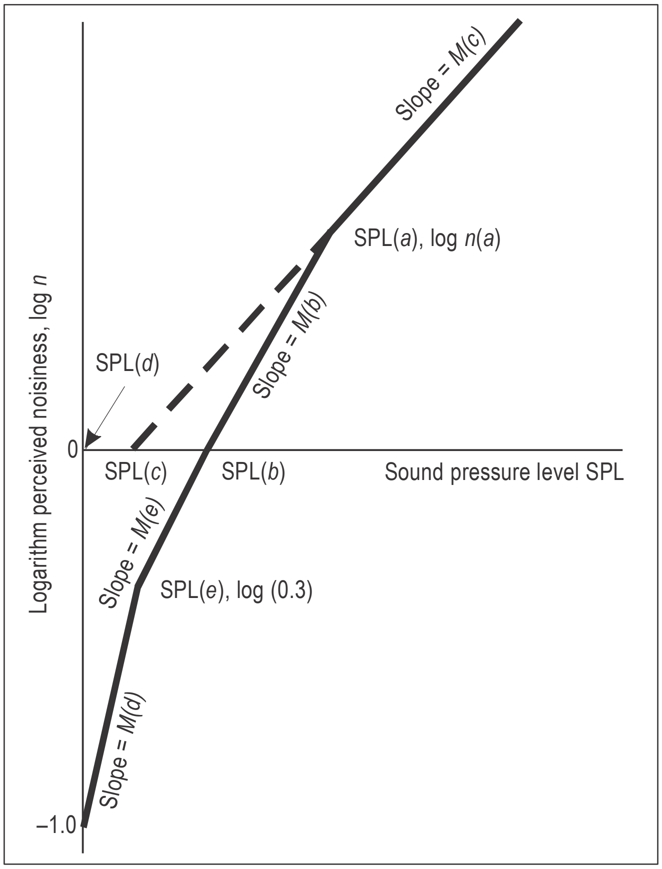


Figure A2-3. Perceived noisiness as a function of sound pressure level

5.2 Data reporting

5.2.1 Measured and corrected sound pressure levels shall be presented in one-third octave band levels obtained with equipment conforming to the Standards described in Section 3 of this appendix.

5.2.2 The type of equipment used for measurement and analysis of all acoustic performance and meteorological data shall be reported.

5.2.3 The following atmospheric environmental data, measured immediately before, after, or during each test at the observation points prescribed in Section 2 of this appendix shall be reported:

a) air temperature and relative humidity;

b) wind speeds and wind directions; and

c) atmospheric pressure.

5.2.4 Comments on local topography, ground cover, and events that might interfere with sound recordings shall be reported.

Table A2-4. Values of η(δ)

δ	η(δ)	δ	η(δ)
0.00	0.000	2.50	0.450
0.25	0.315	2.80	0.400
0.50	0.700	3.00	0.370
0.60	0.840	3.30	0.330
0.70	0.930	3.60	0.300
0.80	0.975	4.15	0.260
0.90	0.996	4.45	0.245
1.00	1.000	4.80	0.230
1.10	0.970	5.25	0.220
1.20	0.900	5.70	0.210
1.30	0.840	6.05	0.205
1.50	0.750	6.50	0.200
1.70	0.670	7.00	0.200
2.00	0.570	10.00	0.200
2.30	0.495		

A term of quadratic interpolation shall be used where necessary.

Table A2-5. Value of f_o

Centre frequency of the 1/3 octave band (Hz)	f_o *(Hz)*	*Centre frequency of the 1/3 octave band (Hz)*	f_o *(Hz)*
50	50	800	800
63	63	1 000	1 000
80	80	1 250	1 250
100	100	1 600	1 600
125	125	2 000	2 000
160	160	2 500	2 500
200	200	3 150	3 150
250	250	4 000	4 000
315	315	5 000	4 500
400	400	6 300	5 600
500	500	8 000	7 100
630	630	10 000	9 000

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 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.

Note.— The "noise flight path" referred to in 8.1.1 and 8.1.2 is defined in accordance with the requirements of 2.3.2.

8.1.1 Aeroplane flight profiles

8.1.1.1 *Reference lateral full-power profile characteristics*

Figure A2-4 illustrates the profile characteristics for the aeroplane take-off procedure for noise measurements made at the lateral full-power noise measurement points:

a) the aeroplane begins the take-off roll at point A and lifts off at point B at full take-off power. The climb angle increases between points B and C. From point C the climb angle is constant up to point F, the end of the noise flight path; and

b) positions K_{2L} and K_{2R} are the left and right lateral noise measurement points for jet aeroplanes, located on a line parallel to and at the specified distance from the runway centre line, where the noise level during take-off is greatest. Position K_4 is the "lateral" full-power noise measurement point for propeller-driven aeroplanes located on the extended centre line of the runway vertically below the point on the climb-out flight path where the aeroplane is at the specified height.

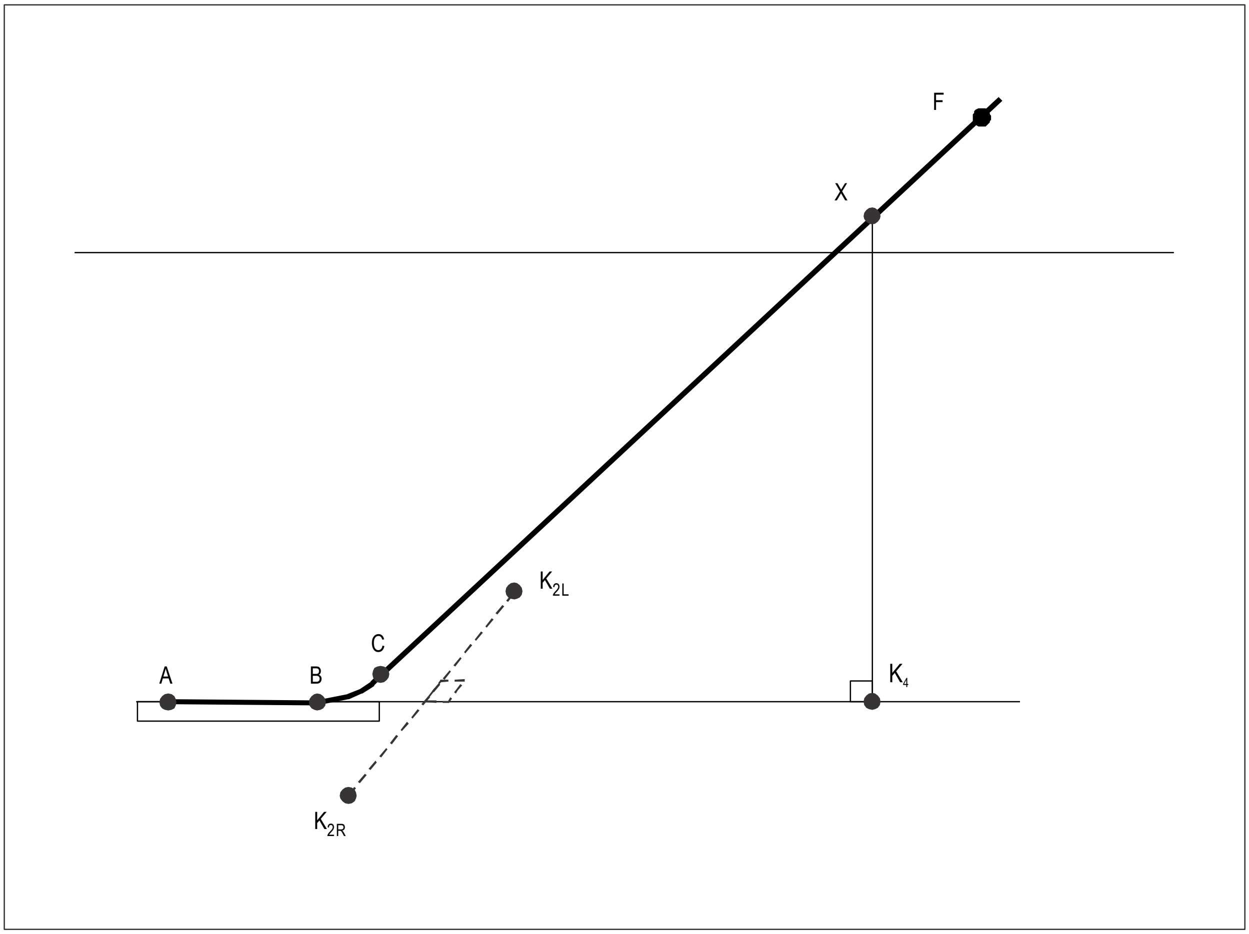


Figure A2-4. Reference aeroplane lateral full-power profile characteristics

b) position K_3 is the approach noise measurement point, and K_3H is the specified height of the helicopter overhead the approach noise measurement point. Positions K_3' and K_3'' are associated noise measurement points located on a line $K_3'K_3''$ at right angles to the approach flight track PU and at the specified distance either side of K_3.

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_rY_r that of the corresponding reference flight path (Figure A2-10 b)); and

b) K is the actual noise measurement point and K_r the reference noise measurement point. Q represents the aircraft position on the measured flight path at which the noise was emitted and observed as PNLTM at point K. The angle between QK and the direction of flight along the measured flight path is θ, the sound emission angle. Q_r is the corresponding position on the reference flight path where the angle between Q_rK_r is also θ. QK and Q_rK_r are, respectively, the measured and reference sound propagation paths.

Note.— This situation will apply in the case of aeroplanes for the flyover, approach, and for propeller-driven aeroplanes only, the lateral full-power noise measurements, and in the case of helicopters for the take-off, overflight, and approach noise measurements for the centre microphone only.

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_rY_r that of the corresponding reference flight path (Figure A2-11 b)); and

b) K is the actual noise measurement point and K_r the reference noise measurement point. Q represents the aircraft position on the measured flight path at which the noise was emitted and observed as PNLTM at point K. The angle between QK and the direction of flight along the measured flight path is θ, the sound emission angle. The angle between QK and the ground is ψ, the elevation angle. Q_r is the corresponding position on the reference flight path where the angle between Q_rK_r and the direction of flight along the reference flight path is also θ, and the angle between Q_rK_r and the ground is ψ_R, where in the case of aeroplanes, the difference between ψ and ψ_R is minimized.

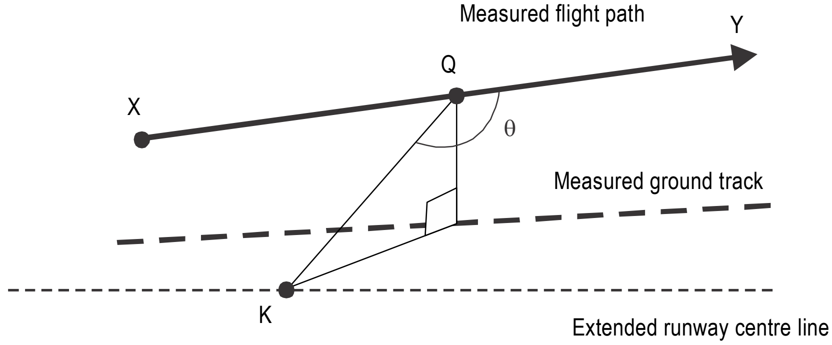
Note.— This situation will apply in the case of jet aeroplanes for the lateral full-power noise measurements, and in the case of helicopters for the take-off, overflight and approach noise measurements for the two laterally displaced microphones only.

8.1.3.3 In both situations the sound emission angle θ shall be established using three-dimensional geometry.

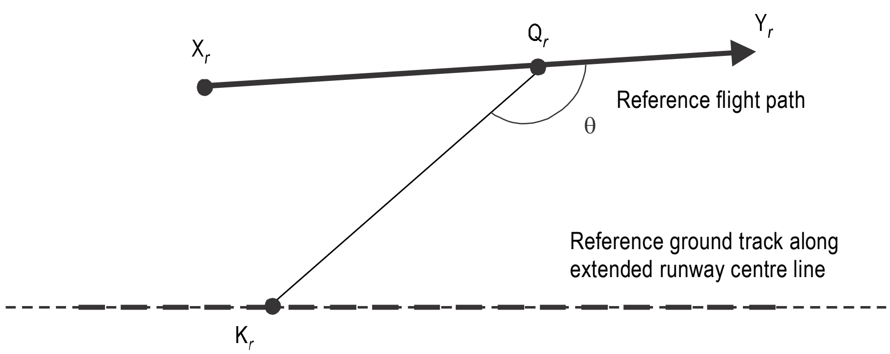
8.1.3.4 In the case of lateral full-power noise measurements of jet aeroplanes the extent to which differences between ψ and ψ_R can be minimized is dependent on the geometrical restrictions imposed by the need to maintain the reference microphone on a line parallel to the extended runway centre line.

Note.— In the case of helicopter measurements, there is no requirement to minimize the difference between ψ and ψ_R.

8.1.3.5 The reference ground track is defined as the vertical projection of the reference flight path onto the ground.



a) Measured flight path



b) Reference flight path

Figure A2-10. Profile characteristics influencing noise level for microphone located beneath the flight path

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

Note.— See Part II, Chapter 11.

1. INTRODUCTION

Note 1.— This noise evaluation method includes:

a) noise certification test and measurement conditions;

b) definition of sound exposure level using measured noise data;

c) measurement of helicopter noise received on the ground;

d) adjustment of flight test results; and

e) reporting of data to the certificating authority.

Note 2.— The instructions and procedures given in the method are intended to ensure uniformity during compliance tests of various types of helicopters conducted in various geographical locations. The method applies only to helicopters meeting the applicability clauses of Part II, Chapter 11, of this Annex.

2. NOISE CERTIFICATION TEST AND MEASUREMENT CONDITIONS

2.1 General

This section prescribes the conditions under which noise certification shall be conducted and the meteorological and flight path measurement procedures that shall be used.

2.2 Test environment

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

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

2.2.2 The tests shall be carried out under the following atmospheric conditions:

a) no precipitation;

b) relative humidity not higher than 95 per cent or lower than 20 per cent and ambient temperature not above 35°C and not below 2°C at a height between 1.2 m (4 ft) and 10 m (33 ft) above ground; combinations of temperature and humidity which lead to an absorption coefficient in the 8 KHz one-third octave band of greater than 10 dB/100 m shall be avoided;

Note.— Absorption coefficients as a function of temperature and relative humidity are given in Section 7 of Appendix 2 or SAE ARP 866A.

c) at a height between 1.2 m (4 ft) and 10 m (33 ft) above ground, average wind speed shall not exceed 5.1 m/s (10 kt) and the average crosswind component shall not exceed 2.6 m/s (5 kt); and

Note.— The noise certification test windows for wind speed expressed in m/s are the result of converting historically used values expressed in knots using a conversion factor consistent with Annex 5, Chapter 3, Table 3-3, and rounded to 0.1 m/s. The values as given here, expressed in either unit are considered equivalent for establishing adherence to the wind speed test windows for noise certification purposes.

d) no other anomalous meteorological conditions that would significantly affect the noise level when recorded at the measuring points specified by the certificating authority.

Note.— Meteorological specifications are given in Section 2.2.2.1 of Appendix 2.

2.2.3 The atmospheric conditions shall be measured within 2 000 m (6 562 ft) from the microphone locations and shall be representative of the conditions existing over the geographical area in which noise measurements are made.

2.3 Flight path measurement

2.3.1 The helicopter spatial position relative to the measurement microphone shall be determined by a method which is approved by the certificating authority and is independent of cockpit flight instrumentation.

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 Position and performance data required to make the adjustments referred to in Section 5 of this appendix shall be recorded at an approved sampling rate. Measuring equipment shall be approved by the certificating authority.

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_{ASmax}.

Note.— L_{ASmax} 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_{ATR}, is defined as the ratio of the arithmetic sum of the reference blade tip rotational speed, V_{tipR}, and the reference helicopter true airspeed, V_R, divided by the reference speed of sound, c_R at 25°C such that:

$$M_{ATR} = \frac{(V_{tipR} + V_R)}{c_R}$$

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 μPa and a reference duration of one second.

3.2 This unit is defined by the expression:

$$L_{AE} = 10 \log \frac{1}{t_0} \int_{t1}^{t2} \left(\frac{p_A(t)}{p_0} \right)^2 dt$$

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:

$$L_{AE} = 10 \log \frac{1}{t_0} \sum_{k_F}^{k_L} 10^{0.1 L_{As}(k)} \Delta t$$

where $L_{AS}(k)$ is the time varying A-frequency-weighted S-time-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 Δt is the time increment between samples.

3.4 The integration time $(t_2 - t_1)$ in practice shall not be less than the 10 dB-down period during which $L_{AS}(t)$ first rises to 10 dB(A) below its maximum value and last falls below 10 dB(A) of its maximum value.

4. MEASUREMENT OF HELICOPTER NOISE RECEIVED ON THE GROUND

4.1 General

4.1.1 All measuring equipment shall be approved by the certificating authority.

4.1.2 Sound pressure level data for noise evaluation purposes shall be obtained with acoustical equipment and measurement practices that conform to the specifications given in 4.2.

4.2 Measurement system

The acoustical measurement system shall consist of approved equipment equivalent to the following:

a) a microphone system with performance characteristics meeting the requirements of 4.3;

b) tripods or similar microphone mountings that minimize interference with the sound being measured;

c) recording and reproducing equipment with performance characteristics meeting the requirements of 4.3; and

d) sound calibrators using sine wave signals of known sound pressure level meeting the requirements of 4.3.

4.3 Sensing, recording and reproducing equipment

4.3.1 The microphone shall be of the type that has a pressure or a diffuse-field sensitivity whose frequency response is nearly flat at grazing incidence.

4.3.2 The L_{AE} may be directly determined from an integrating sound level meter. Alternatively, with the approval of the certificating authority the sound pressure signal produced by the helicopter may be stored on an analogue magnetic tape recorder or a digital audio recorder for later evaluation using an integrating sound level meter. The L_{AE} may also be calculated from one-third octave band data obtained from measurements made in conformity with Section 3 of Appendix 2 and using the equation given in 3.3. In this case each one-third octave band sound pressure level shall be weighted in accordance with the A-weighting values given in IEC Publication 61672-1.[1]

4.3.3 The characteristics of the complete system with regard to directional response, frequency weighting A, time weighting S (slow), level linearity, and response to short-duration signals shall comply with the class 1 specifications given in IEC 61672-1.[1] The complete system may include tape recorders or digital audio recorders according to IEC 61672-1.[1]

Note.— The certificating authority may approve the use of equipment compliant with class 2 of the current IEC standard, or the use of equipment compliant with class 1 or Type 1 specifications of an earlier standard, if the applicant can show that the equipment had previously been approved for noise certification use by a certificating authority. This includes the use of a sound level meter and graphic level recorder to approximate L_{AE} using the equation given in 3.3. The certificating authority may also approve the use of magnetic tape recorders that comply with the specifications of the older IEC 561 standard if the applicant can show that such use had previously been approved for noise certification use by a certificating authority.

4.3.4 The overall sensitivity of the measurement system shall be checked before the start of testing, after testing has ended and at intervals during testing using a sound calibrator generating a known sound pressure level at a known frequency. The sound calibrator shall conform to the class 1 requirements of IEC 60942.[2] The output of the sound calibrator shall have been checked by a standardizing laboratory within 6 months of each aircraft noise measurement. Tolerable changes in output shall be not more than 0.2 dB. Measured aircraft noise data shall not be considered valid for certification purposes unless preceded and succeeded by valid sound pressure level calibrations. The measurement system shall be considered satisfactory if the difference between the acoustical sensitivity levels recorded immediately before and immediately after each group of aircraft noise measurements on a given day is not greater than 0.5 dB.

1. IEC 61672-1: 2002 entitled “Electroacoustics — Sound level meters — Part I: Specifications”. This IEC publication may be obtained from the Bureau central de la Commission électrotechnique internationale, 3 rue de Varembé, Geneva, Switzerland.
2. IEC 60942: 2003 entitled “Electroacoustics — Sound calibrators”. This IEC publication may be obtained from the Bureau central de la Commission électrotechnique internationale, 3 rue de Varembé, Geneva, Switzerland.

Note.— The certificating authority may approve the use of calibrators compliant with class 2 of the current IEC standard, or the use of calibrators compliant with class 1 of an earlier standard, if the applicant can show that the calibrator had previously been approved for noise certification use by a certificating authority.

4.3.5 When the sound pressure signals from the helicopter are recorded, the L_{AE} may be determined by playback of the recorded signals into the electrical input facility of an approved sound level meter that conforms to the class 1 performance requirements of IEC 61672-1.[3] The acoustical sensitivity of the sound level meter shall be established from playback of the associated recording of the signal from the sound calibrator and knowledge of the sound pressure level produced in the coupler of the sound calibrator under the environmental conditions prevailing at the time of the recording of the sound from the helicopter.

4.3.6 A windscreen should be employed with the microphone during all measurements of helicopter sound levels. Its characteristics should be such that when it is used, the complete system including the windscreen will meet the specifications in 4.3.3.

4.4 Noise measurement procedures

4.4.1 The microphone shall be mounted with the centre of the sensing element 1.2 m (4 ft) above the local ground surface and shall be oriented for grazing incidence, i.e. with the sensing element substantially in the plane defined by the nominal flight path of the helicopter and the measuring station. The microphone mounting arrangement shall minimize the interference of the supports with the sound to be measured.

4.4.2 If the helicopter sound pressure signal is recorded, the frequency response of the electrical system shall be determined, during each test series, at a level within 10 dB of the full-scale reading used during the tests, utilizing random or pseudo-random pink noise. The output of the noise generator shall have been checked by an approved standards laboratory within six months of the test series, and tolerable changes in the relative output at each one-third octave band shall be not more than 0.2 dB. Sufficient determinations shall be made to ensure that the overall calibration of the system is known for each test.

4.4.3 Where an analogue magnetic tape recorder forms part of the measuring chain, each reel of magnetic tape shall carry 30 s of this electrical calibration signal at its beginning and end for this purpose. In addition, data obtained from tape-recorded signals shall be accepted as reliable only if the level difference in the 10 kHz one-third octave band filtered levels of the two signals is not more than 0.75 dB.

Note.— Digital audio recorders typically do not exhibit substantial variation in frequency response or level sensitivity; therefore the pink noise testing described in 4.4.2 is not necessary for digital audio recorders.

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_{ASmax} 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. ADJUSTMENT TO TEST RESULTS

5.1 When certification test conditions differ from the reference conditions, appropriate adjustments shall be made to the measured noise data by the methods of this section.

3. IEC 61672-1: 2002 entitled "Electroacoustics — Sound level meters — Part I: Specifications". This IEC publication may be obtained from the Bureau central de la Commission électrotechnique internationale, 3 rue de Varembé, Geneva, Switzerland.

5.2 Corrections and adjustments

5.2.1 The adjustments may be limited to the effects of differences in spherical spreading between the helicopter test flight path and the reference flight path (and between reference and adjusted reference airspeed). No adjustment for the differences in atmospheric attenuation between the test and reference meteorological conditions and between the helicopter test and reference ground speeds need be applied.

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

$$\Delta_1 = 12.5 \log (H/150)$$

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:

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

where Δ_2 is the quantity in decibels that shall be algebraically added to the measured L_{AE} 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_R is the reference airspeed as prescribed under Part II, Chapter 11, 11.5.2, and V_{AR} is the adjusted reference airspeed as prescribed in 2.4.2 of this appendix.

6. REPORTING OF DATA TO THE CERTIFICATING AUTHORITY AND VALIDITY OF RESULTS

6.1 Data reporting

6.1.1 Measured and corrected sound pressure levels obtained with equipment conforming to the specifications described in Section 4 of this appendix shall be reported.

6.1.2 The type of equipment used for measurement and analysis of all acoustic helicopter performance and meteorological data shall be reported.

6.1.3 The following atmospheric environmental data, measured immediately before, after, or during each test at the observation point prescribed in Section 2 of this appendix shall be reported:

a) air temperature and relative humidity;

b) wind speeds and wind directions; and

c) atmospheric pressure.

6.1.4 Comments on local topography, ground cover and events that might interfere with sound recording shall be reported.

6.1.5 The following helicopter information shall be reported:

a) type, model and serial numbers of helicopter, engine(s) and rotor(s);

b) any modifications or nonstandard equipment likely to affect the noise characteristics of the helicopter;

c) maximum certificated take-off and landing mass;

d) indicated airspeed in kilometres per hour (knots) and rotor speed in rpm during each demonstration;

e) engine performance parameters during each demonstration; and

f) helicopter height above the ground during each demonstration.

6.2 Reporting of noise certification reference conditions

Helicopter position and performance data and noise measurements shall be corrected to the noise certification reference conditions specified in Part II, Chapter 11, 11.5. These conditions, including reference parameters, procedures and configurations shall be reported.

6.3 Validity of results

6.3.1 The measuring point shall be overflown at least six times. The test results shall produce an average L_{AE} 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 for the reference procedure.

6.3.2 The sample shall be large enough to establish statistically a 90 per cent confidence limit not exceeding ±1.5 dB(A). No test results shall be omitted from the averaging process unless approved by the certificating authority.

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 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

Note.— See Part II, Chapter 10.

1. INTRODUCTION

Note 1.— This noise evaluation method includes:

a) noise certification test and measurement conditions;

b) noise unit;

c) measurement of aeroplane noise received on the ground;

d) adjustments to test data; and

e) reporting of data to the certificating authority and validity of results.

Note 2.— The instructions and procedures given in the method are clearly delineated to ensure uniformity during compliance tests and to permit comparison between tests of various types of aeroplanes, conducted in various geographical locations. The method applies only to aeroplanes within the applicability clauses of Part II, Chapter 10.

2. NOISE CERTIFICATION TEST AND MEASUREMENT CONDITIONS

2.1 General

This section prescribes the conditions under which noise certification tests shall be conducted and the measurement procedures that shall be used to measure the noise made by the aeroplane for which the test is conducted.

2.2 General test conditions

2.2.1 Locations for measuring noise from an aeroplane in flight shall be surrounded by relatively flat terrain having no excessive sound absorption characteristics such as might be caused by thick, matted or tall grass, shrubs or wooded areas. No obstructions which significantly influence the sound field from the aeroplane shall exist within a conical space above the measurement position, the cone being defined by an axis normal to the ground and by a half-angle 75° from this axis.

2.2.2 The tests shall be carried out under the following atmospheric conditions:

a) no precipitation;

b) relative humidity not higher than 95 per cent and not lower than 20 per cent and ambient temperature not above 35°C and not below 2°C;

c) average wind speed shall not exceed 5.1 m/s (10 kt) and crosswind average wind speed shall not exceed 2.6 m/s (5 kt);

Note 1.— Meteorological specifications are defined in Section 2.2.2.1 of Appendix 2.

Note 2.— The noise certification test windows for wind speed expressed in m/s are the result of converting historically used values expressed in knots using a conversion factor consistent with Annex 5, Chapter 3, Table 3-3, and rounded to 0.1 m/s. The values as given here, expressed in either unit are considered equivalent for establishing adherence to the wind speed test windows for noise certification purposes.

d) no other anomalous meteorological conditions that would significantly affect the noise level of the aeroplane when the noise is recorded at the measuring points specified by the certificating authority; and

e) the meteorological measurements shall be made between 1.2 m and 10 m above ground level. If the measurement site is within 2 000 m of an airport meteorological station, measurements from this station may be used.

2.2.3 The atmospheric conditions shall be measured within 2 000 m (6 562 ft) from the microphone locations and shall be representative of the conditions existing over the geographical area in which noise measurements are made.

2.3 Aeroplane testing procedures

2.3.1 The test procedures and noise measurement procedure shall be 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 ± 9 km/h (V_Y ± 5 kt) indicated airspeed.

2.3.4 The aeroplane spatial position relative to the measurement microphone shall be determined by a method approved by the certificating authority and is independent of cockpit flight instrumentation.

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 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).

2.3.6 Aeroplane speed, position and performance data required to make the adjustments referred to in Section 5 of this appendix shall be recorded when the aeroplane is directly over the measurement site. Measuring equipment shall be approved by the certificating authority.

2.3.7 An independent device accurate to within ±1 per cent shall be used for the measurement of propeller rotational speed to avoid orientation and installation errors when the test aeroplane is equipped with mechanical tachometers.

3. NOISE UNIT DEFINITION

The L_{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) of 20 micropascals (μPa).

noise. The output of the noise generator shall have been checked by an approved standards laboratory within six months of the test series, and tolerable changes in the relative output at each one-third octave band shall be not more than 0.2 dB. Sufficient determinations shall be made to ensure that the overall calibration of the system is known for each test.

4.4.3 Where a magnetic tape recorder forms part of the measuring chain, each reel of magnetic tape shall carry 30 s of this electrical calibration signal at its beginning and end for this purpose. In addition, data obtained from tape-recorded signals shall be accepted as reliable only if the level difference in the 10 kHz one-third octave band filtered levels of the two signals is not more than 0.75 dB.

Note.— Digital audio recorders typically do not exhibit substantial variation in frequency response or level sensitivity, therefore the pink noise testing described in 4.4.3 is not necessary for digital audio recorders. Design characteristics for digital audio recorders should be compliant with class 1 performance specifications of IEC 61672-1.[3]

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 aeroplane noise measurements. If the maximum A-frequency-weighted and S-time-weighted sound level of the aeroplane does not exceed the A-frequency-weighted sound level of the background noise by at least 10 dB, a take-off measurement point nearer to the start of roll shall be used and the results adjusted to the reference measurement point by an approved method.

5. ADJUSTMENT TO TEST RESULTS

5.1 When certification test conditions differ from the reference conditions, appropriate adjustments shall be made to the measured noise data by the methods of this section.

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 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_{ASmaxR} shall be obtained by adding increments for each of the above effects to the test day noise level, L_{ASmax}.

$$L_{ASmaxR} = L_{ASmax} + \Delta_1 + \Delta_2 + \Delta_3 + \Delta_4$$

where

Δ_1 is the adjustment for sound propagation path lengths;
Δ_2 is the adjustment for helical tip Mach number;
Δ_3 is the adjustment for engine power; and
Δ_4 is the adjustment for the change in atmospheric absorption between test and reference conditions.

3. IEC 61672-1: 2002 entitled “Electroacoustics — Sound level meters — Part I: Specifications”. This IEC publication may be obtained from the Bureau central de la Commission électrotechnique internationale, 3 rue de Varembé, Geneva, Switzerland.

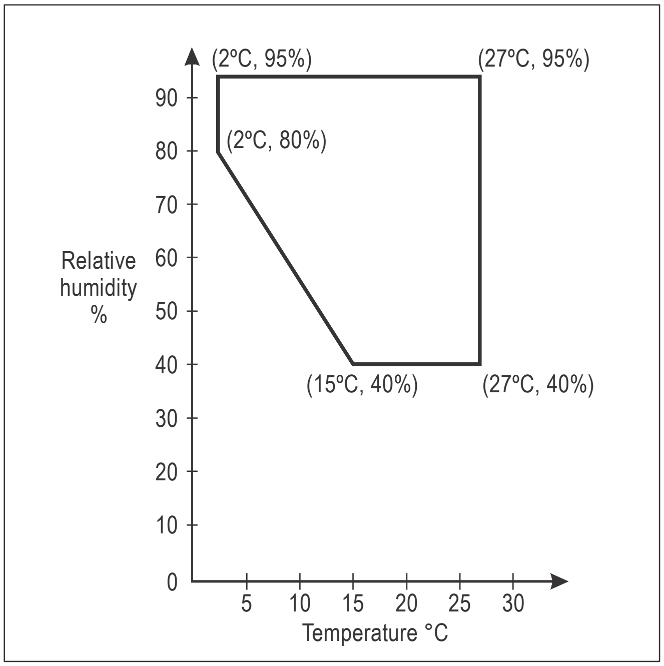


Figure A6-2. Measurement window for no absorption correction

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. $\Delta_4 = 0$. If conditions are outside those specified in Figure A6-2 then adjustments must be applied by an approved procedure or by adding an increment Δ_4 to the test day noise levels where:

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

and where H 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 α_{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 Δ_1. When test day conditions are within those specified in Figure A6-2:

$$\Delta_1 = 22 \log (H/H_R)$$

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

$$\Delta_1 = 20 \log (H/H_R)$$

where H 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:

1) at or below 0.70 and the test helical tip Mach number is within 0.014 of the reference helical tip Mach number;

2) above 0.70 and at or below 0.80 and the test helical tip Mach number is within 0.007 of the reference helical tip Mach number;

3) above 0.80 and the test helical tip Mach number is within 0.005 of the reference helical tip Mach number. For mechanical tachometers, if the helical tip Mach number is above 0.8 and the test helical tip Mach number is within 0.008 of the reference helical tip Mach number.

Outside these limits measured noise levels shall be adjusted for helical tip Mach number by an increment equal to:

$$\Delta_2 = k_2 \log (M_{HR}/M_H)$$

which shall be added algebraically to the measured noise level, where M_H and M_{HR} are the test and reference helical tip Mach numbers respectively. The value of 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 = 150 may be used for M_H less than M_{HR}; however, for M_H greater than or equal to 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

$$M_{HR} = \frac{\left[\left(\frac{D\pi N}{60}\right)^2 + V_R^2\right]^{1/2}}{C_{HR}}$$

where D *is the propeller diameter in metres.*

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 corresponding to the ambient temperature – assuming a lapse rate of 0.65°C per 100 m – for a standard day at the aeroplane reference height above mean sea level.*

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

$$\Delta_3 = k_3 \log (P_R/P)$$

where P_R and P are the test and reference engine powers respectively obtained from the manifold pressure/torque gauges and engine rpm. The value of 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 = 17 may be used. The reference power P_R shall be that obtained at the reference height temperature and pressure 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 (extended to 80 kilometres (262 500 feet) *(Doc 7488/3).*

6. REPORTING OF DATA TO THE CERTIFICATING AUTHORITY AND VALIDITY OF RESULTS

6.1 Data reporting

6.1.1 Measured and corrected sound pressure levels obtained with equipment conforming to the specifications described in Section 4 of this appendix shall be reported.

6.1.2 The type of equipment used for measurement and analysis of all acoustic aeroplane performance and meteorological data shall be reported.

6.1.3 The following atmospheric environmental data, measured immediately before, after, or during each test at the observation points prescribed in Section 2 of this appendix shall be reported:

a) air temperature and relative humidity;

b) wind speeds and wind directions; and

c) atmospheric pressure.

6.1.4 Comments on local topography, ground cover and events that might interfere with sound recordings shall be reported.

6.1.5 The following aeroplane information shall be reported:

a) type, model and serial numbers of aeroplane, engine(s) and propeller(s);

b) any modifications or non-standard equipment likely to affect the noise characteristics of the aeroplane;

c) maximum certificated take-off mass;

d) for each overflight, airspeed and air temperature at the flyover altitude determined by properly calibrated instruments;

e) for each overflight, engine performance as manifold pressure or power, propeller speed in revolutions per minute and other relevant parameters determined by properly calibrated instruments;

f) aeroplane height above the measurement point; and

g) corresponding manufacturer's data for the reference conditions relevant to 6.1.5 d), e) and f).

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 value, $L_{ASmax,}$ 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.

6.2.2 The samples shall be large enough to establish statistically a 90 per cent confidence limit not exceeding ±1.5 dB(A). No test results shall be omitted from the averaging process, unless otherwise specified by the certificating authority.

8. CONDITIONS DESCRIBED IN CHAPTER 8, 8.4.2

M = Maximum take-off mass in 1 000 kg	0	0.788	80.0
Take-off noise level (EPNdB)	86	87.03 + 9.97 log M	l06
Approach noise level (EPNdB)	89	90.03 + 9.97 log M	109
Overflight noise level (EPNdB)	84	85.03 + 9.97 log M	104

9. CONDITIONS DESCRIBED IN CHAPTER 10, 10.4 A) AND 10.4 B)

10.4 a):

M = Maximum take-off mass in 1 000 kg	0	0.6	1.4	8.618
Noise level in dB(A)	76	83.23 + 32.67 log M	88	

10.4 b):

M = Maximum take-off mass in 1 000 kg	0	0.57	1.5	8.618
Noise level in dB(A)	70	78.71 + 35.70 log M	85	

10. CONDITIONS DESCRIBED IN CHAPTER 11, 11.4.1

M = Maximum take-off mass in 1 000 kg	0	0.788	3.175
Noise level in dB(A)	82	83.03 + 9.97 log M	

11. CONDITIONS DESCRIBED IN CHAPTER 11, 11.4.2

M = Maximum take-off mass in 1 000 kg	0	1.417	3.175
Noise level in dB(A)	82	80.49 + 9.97 log M	

12. CONDITIONS DESCRIBED IN CHAPTER 14, 14.4.1

<table>
<tr><td colspan="2">M = Maximum take-off mass in 1 000 kg</td><td>0</td><td>2</td><td>8.618</td><td>20.234</td><td>28.615</td><td>35</td><td>48.125</td><td>280</td><td>385</td><td>400</td></tr>
<tr><td colspan="2">Lateral full-power noise level (EPNdB)
All aeroplanes</td><td>88.6</td><td>86.03754 + 8.512295 log M</td><td colspan="3">94</td><td colspan="4">80.86511 + 8.50668 log M</td><td>103</td></tr>
<tr><td colspan="2">Approach noise level (EPNdB)
All aeroplanes</td><td>93.1</td><td>90.77481 + 7.72412 log M</td><td colspan="3">98</td><td colspan="2">86.03167 + 7.75117 log M</td><td colspan="3">105</td></tr>
<tr><td rowspan="3">Flyover noise levels (EPNdB)</td><td>2 engines or less</td><td rowspan="3">80.6</td><td rowspan="3">76.57059 + 13.28771 log M</td><td colspan="4">89</td><td colspan="2">66.64514 + 13.28771 log M</td><td colspan="2">101</td></tr>
<tr><td>3 engines</td><td colspan="2">89</td><td colspan="4">69.64514 + 13.28771 log M</td><td colspan="2">104</td></tr>
<tr><td>4 engines or more</td><td>89</td><td colspan="5">71.64514 + 13.28771 log M</td><td colspan="2">106</td></tr>
</table>

Note.— The slope of the limit lines in the lower and higher weight regions are essentially the same. The observed minor differences between the coefficients of the equations defining the slopes of the lateral and approach lines are a consequence of the limits in Chapter 14, Sections 14.4.1.1 and 14.4.1.3, being defined with fixed end-points. For all practical purposes the minor differences between the coefficients are considered to be insignificant.

Each of the following conditions shall apply:

$(LIMIT_L - EPNL_L) \geq 1$; $(LIMIT_A - EPNL_A) \geq 1$; and $(LIMIT_F - EPNL_F) \geq 1$;

$[(LIMIT_L - EPNL_L) + (LIMIT_A - EPNL_A) + (LIMIT_F - EPNL_F)] \geqslant 17$

where

$EPNL_L$, $EPNL_A$ and $EPNL_F$ are respectively the noise levels at the lateral, approach and flyover reference noise measurement points when determined, to one decimal place, in accordance with the noise evaluation method of Appendix 2; and

$LIMIT_L$, $LIMIT_A$, and $LIMIT_F$ are respectively the maximum permitted noise levels at the lateral, approach and flyover reference noise measurement points determined, to one decimal place, in accordance with the equations for the conditions described in Chapter 14, 14.4.1.

ATTACHMENT F. GUIDELINES FOR NOISE CERTIFICATION OF TILT-ROTORS

Note.— See Part II, Chapter 13.

Note.— 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.

1. APPLICABILITY

The following guidelines should be applied to all tilt-rotors, including their derived versions, for which the application for a Type Certificate was submitted on or after 13 May 1998 and before 1 January 2018.

Note.— Certification of tilt-rotors which are capable of carrying external loads or external equipment should be made without such loads or equipment fitted.

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 L_{AE} *and* L_{ASmax} *as defined in Appendix 4, and one-third octave SPLs as defined in Appendix 2 corresponding to* L_{ASmax} *should be made available to the certificating authority for land-use planning purposes.*

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:

a) *Take-off reference noise measurement points:*

1) a flight path reference point located on the ground vertically below the flight path defined in the take-off reference procedure (see 6.2) and 500 m horizontally in the direction of flight from the point at which transition to climbing flight is initiated in the reference procedure;

2) two other points on the ground symmetrically disposed at 150 m on both sides of the flight path defined in the take-off reference procedure and lying on a line through the flight path reference point.

b) *Overflight reference noise measurement points:*

1) a flight path reference point located on the ground 150 m (492 ft) vertically below the flight path defined in the overflight reference procedure (see 6.3);

2) two other points on the ground symmetrically disposed at 150 m on both sides of the flight path defined in the overflight reference procedure and lying on a line through the flight path reference point.

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° approach path with the ground plane;

2) two other points on the ground symmetrically disposed at 150 m on both sides of the flight path defined in the approach reference procedure and lying on a line through the flight path reference point.

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) *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) *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) *Fort 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 7 of Attachment A, for conditions described in Chapter 8, 8.4.1, are consistent with the maximum noise levels defined in these guidelines.

5. TRADE-OFFS

If the maximum noise levels are exceeded at one or two measurement points:

a) the sum of excesses should not be greater than 4 EPNdB;