3.1.2 Methods for determination of the distance from the observation stations to the aeroplane shall include theodolite triangulation techniques, scaling aeroplane dimensions on photographs made as the aeroplane flies directly over the measurement points, radar altimeters, and radar tracking systems. The method used shall be approved by the certificating authority.

3.1.3 Sound pressure level data for noise evaluation purposes shall be obtained with approved acoustical equipment and measurement practices that conform to the specifications given hereunder (in 3.2 to 3.4).

3.2 Measurement system

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

a) a microphone system with frequency response compatible with measurement and analysis system accuracy as stated in 3.3;

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

c) recording and reproducing equipment characteristics, frequency response, and dynamic range compatible with the response and accuracy requirements of 3.3;

d) acoustic calibrators using sine wave or broadband noise of known sound pressure level. If broadband noise is used, the signal shall be described in terms of its average and maximum root-mean-square (rms) value for non-overload signal level;

e) analysis equipment with the response and accuracy requirements of 3.4.

3.3 Sensing, recording and reproducing equipment

3.3.1 The sound produced by the aeroplane shall be recorded in such a way that the complete information, time history included, is retained. A magnetic tape recorder is acceptable.

3.3.2 The characteristics of the system shall comply with the recommendations given in International Electrotechnical Commission (IEC) Publication No. 179[3] with regard to the sections concerning microphone and amplifier characteristics.

Note.— The text and specifications of IEC Publication No. 179[3] *entitled "Precision Sound Level Meters" are incorporated by reference into this appendix and are made a part hereof.*[4]

3.3.3 The response of the complete system to a sensibly plane progressive sinusoidal wave of constant amplitude shall lie within the tolerance limits specified in IEC Publication No. 179,[3] over the frequency range 45 to 11 200 Hz.

3.3.4 If limitations of the dynamic range of the equipment make it necessary, high frequency pre-emphasis shall be added to the recording channel with the converse de-emphasis on playback. The pre-emphasis shall be so applied that the instantaneous recorded sound pressure level between 800 and 11 200 Hz of the maximum measured noise signal does not vary more than 20 dB between the levels of the maximum and minimum one-third octave bands.

3.3.5 The equipment shall be acoustically calibrated using facilities for acoustic free-field calibration and electronically calibrated as stated in 3.4.

3. As amended.
4. This publication was first issued in 1965 by the Central Office of the International Electrotechnical Commission, 3 rue de Varembé, Geneva, Switzerland.

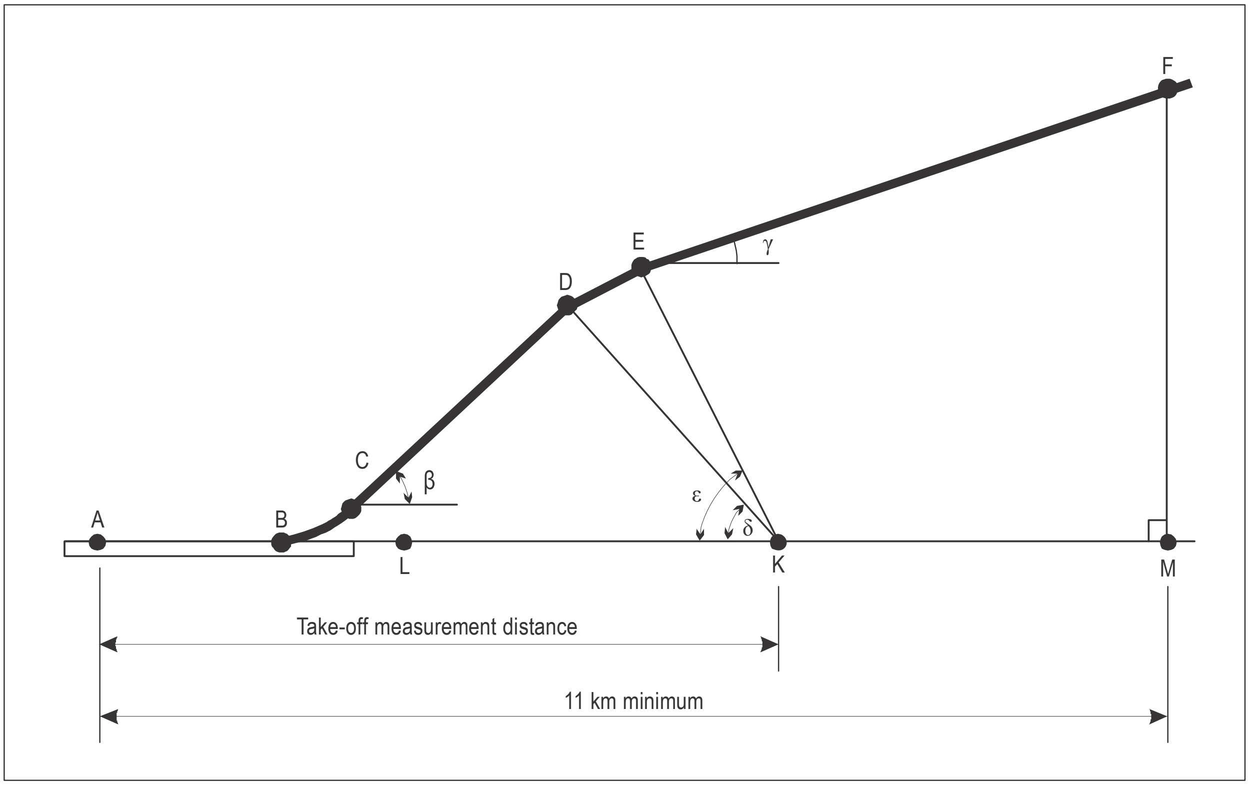


Figure A1-4. Measured take-off profile

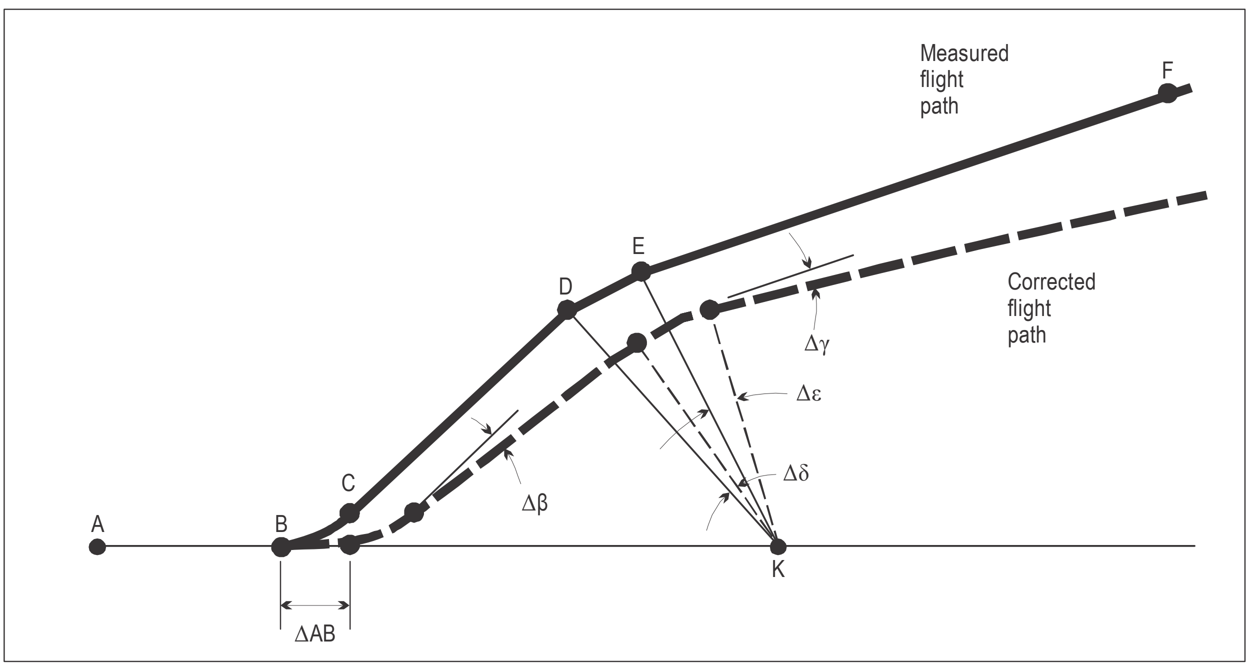


Figure A1-5. Comparison of measured and corrected take-off profiles

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 passes either over or abeam the microphone.

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

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

Maximum crosswind component. The maximum value within the series of individual values of the "cross-track" (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.

Note.— This demonstration of equivalent performance does not eliminate the need to calibrate and check each system as defined in 3.9.

3.5.2 The microphone shall be mounted with 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 predicted reference flight path of the aircraft and the measuring station. The microphone mounting arrangement shall minimize the interference of the supports with the sound to be measured. Figure A2-1 illustrates sound incidence angles on a microphone.

3.5.3 The free-field sensitivity level of the microphone and preamplifier in the reference direction, at frequencies over at least the range of one-third octave nominal midband frequencies from 50 Hz to 5 kHz inclusive, shall be within ±1.0 dB of that at the calibration check frequency, and within ±2.0 dB for nominal midband frequencies of 6.3 kHz, 8 kHz and 10 kHz.

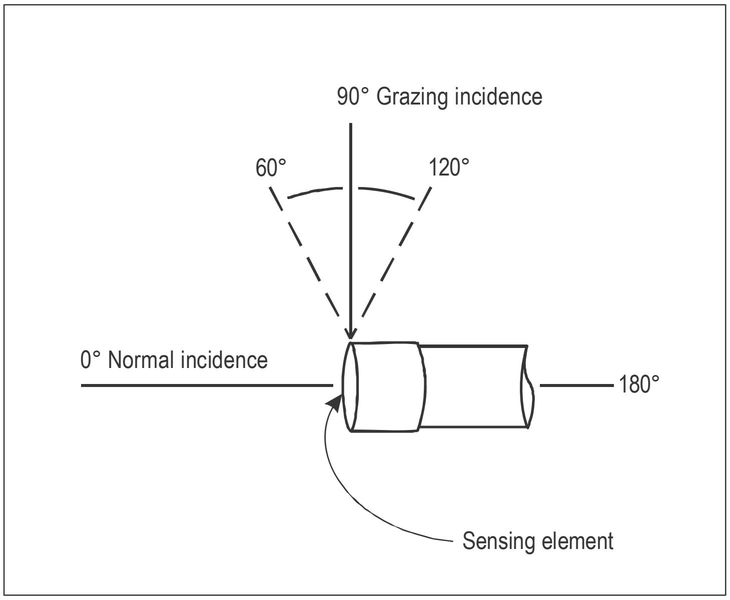
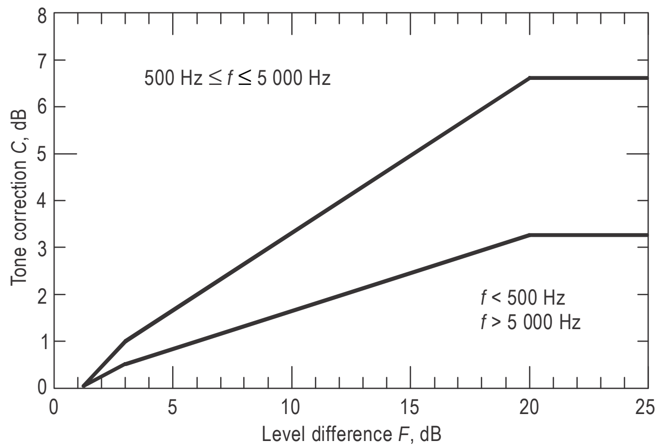


Figure A2-1. Illustration of sound incidence angles on a microphone

3.5.4 For sinusoidal sound waves at each one-third octave nominal midband frequency over the range from 50 Hz to 10 kHz inclusive, the free-field sensitivity levels of the microphone system at sound incidence angles of 30°, 60°, 90°, 120° and 150° shall not differ from the free-field sensitivity level at a sound incidence angle of 0° (“normal incidence”) by more than the values shown in Table A2-1. The free-field sensitivity level differences at sound incidence angles between any two adjacent sound incidence angles in Table A2-1 shall not exceed the tolerance limit for the greater angle.

Table A2-2. Tone correction factors



Frequency *f*, Hz	Level difference *F*, dB	Tone correction C, dB
50 ≤ *f* < 500	1½* ≤ *F* < 3 3 ≤ *F* < 20 20 ≤ *F*	*F*/3 — ½ *F/6* 3⅓
500 ≤ *f* ≤ 5 000	1½* ≤ *F* < 3 3 ≤ *F* < 20 20 ≤ *F*	2 *F*/3 — 1 *F*/3 6⅔
5 000 < *f* ≤ 10 000	1½* ≤ *F* < 3 3 ≤ *F* < 20 20 ≤ *F*	*F*/3 — ½ *F*/6 3⅓

* 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.

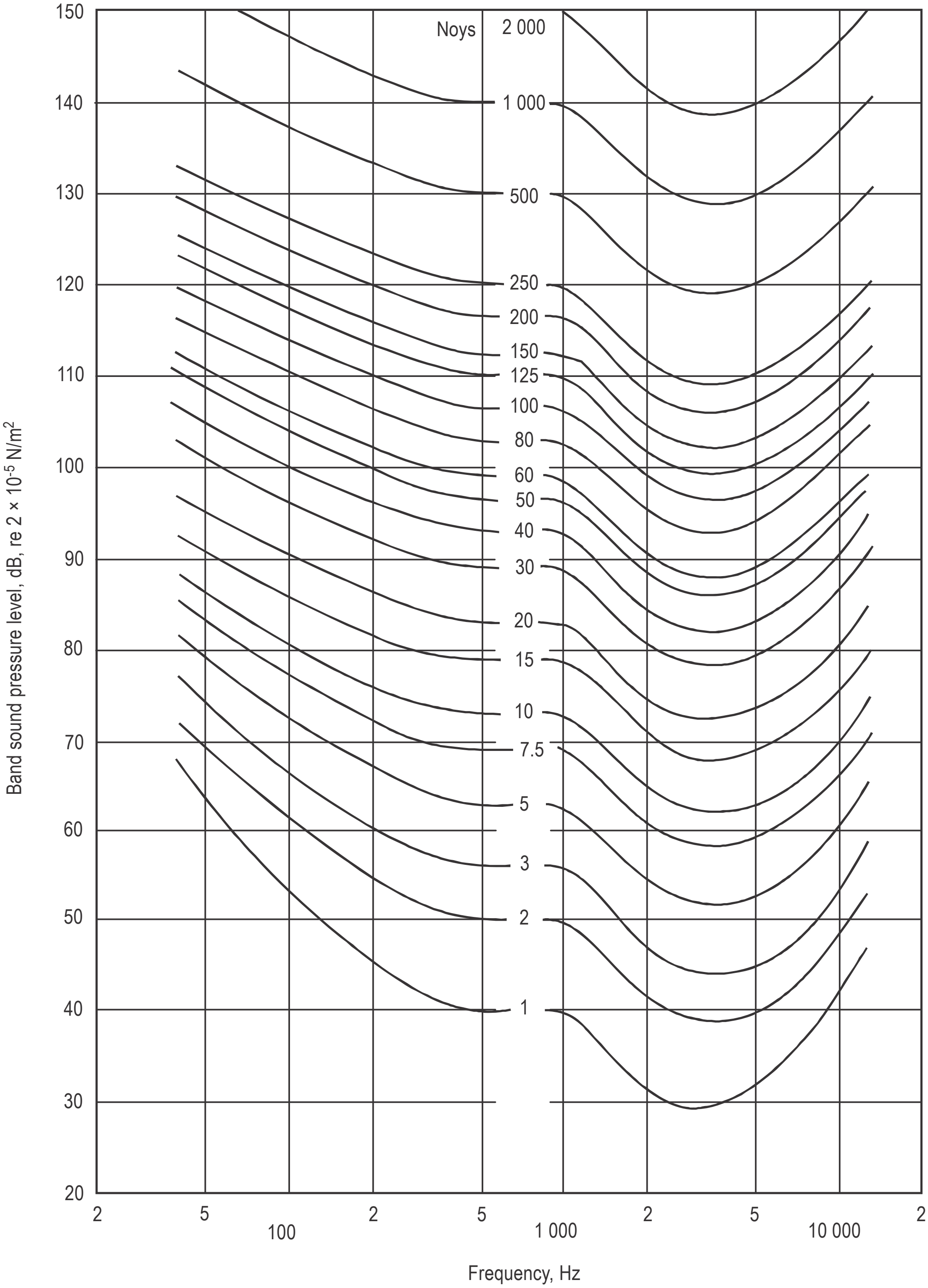


Figure A5-1. Contours of perceived noisiness

4.3 Sensing, recording and reproducing equipment

4.3.1 The sound level produced by the aeroplane shall be recorded. A magnetic tape recorder, graphic level recorder or sound level meter is acceptable at the option of the certificating authority.

4.3.2 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 the IEC Publication 61672-1.[1] The complete system may include tape 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 earlier standards, as an alternative to equipment compliant with class 1 of the current IEC standard, if the applicant can show that the equipment had previously been approved for noise certification use by a certificating authority. 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.

4.3.3 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.

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.

4.3.4 When the sound from the aeroplane is tape recorded, the maximum A-frequency-weighted and S-time-weighted sound level 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.[1] 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 aeroplane.

4.4 Noise measurement procedures

4.4.1 The microphone shall be a 12.7 mm diameter pressure type, with its protective grid, mounted in an inverted position such that the microphone diaphragm is 7 mm above and parallel to a circular metal plate. This white-painted metal plate shall be 40 cm in diameter and at least 2.5 mm thick, and shall be placed horizontally and flush with the surrounding ground surface with no cavities below the plate. The microphone shall be located three-quarters of the distance from the centre to the edge along a radius normal to the line of flight of the test aeroplane.

4.4.2 If the noise signal is tape-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 pseudorandom pink

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.

ATTACHMENTS TO ANNEX 16, VOLUME I

ATTACHMENT A. EQUATIONS FOR THE CALCULATION OF MAXIMUM PERMITTED NOISE LEVELS AS A FUNCTION OF TAKE-OFF MASS

Note.— See Part II, 2.4.1, 2.4.2, 3.4.1, 4.4, 5.4, 6.3, 8.4.1, 8.4.2, 10.4, 11.4.1, 11.4.2, 13.4 and 14.4.1.

1. CONDITIONS DESCRIBED IN CHAPTER 2, 2.4.1

M = Maximum take-off mass in 1 000 kg	0	34	272
Lateral noise level (EPNdB)	102	91.83 + 6.64 log M	108
Approach noise level (EPNdB)	102	91.83 + 6.64 log M	108
Flyover noise level (EPNdB)	93	67.56 + 16.61 log M	108

2. CONDITIONS DESCRIBED IN CHAPTER 2, 2.4.2

<table>
<tr><th colspan="2">M = Maximum take-off mass in 1 000 kg</th><th>0</th><th>34</th><th>35</th><th>48.3</th><th>66.72</th><th>133.45</th><th>280</th><th>325</th><th>400</th></tr>
<tr><td colspan="2">Lateral noise level (EPNdB)
All aeroplanes</td><td colspan="2">97</td><td colspan="6">83.87 + 8.51 log M</td><td>106</td></tr>
<tr><td colspan="2">Approach noise level (EPNdB)
All aeroplanes</td><td colspan="2">101</td><td colspan="4">89.03 + 7.75 log M</td><td colspan="3">108</td></tr>
<tr><td rowspan="3">Flyover
noise levels
(EPNdB)</td><td>2 engines</td><td colspan="3">93</td><td colspan="4">70.62 + 13.29 log M</td><td colspan="2">104</td></tr>
<tr><td>3 engines</td><td>93</td><td colspan="3">67.56 + 16.61 log M</td><td colspan="3">73.62 + 13.29 log M</td><td colspan="2">107</td></tr>
<tr><td>4 engines</td><td>93</td><td colspan="4">67.56 + 16.61 log M</td><td colspan="2">74.62 + 13.29 log M</td><td colspan="2">108</td></tr>
</table>

3. CONDITIONS DESCRIBED IN CHAPTER 3, 3.4.1

<table>
<tr><th colspan="2">M = Maximum take-off mass in 1 000 kg</th><th>0</th><th>20.2</th><th>28.6</th><th>35</th><th>48.1</th><th>280</th><th>385</th><th>400</th></tr>
<tr><td colspan="2">Lateral full-power noise level
(EPNdB)
All aeroplanes</td><td colspan="3">94</td><td colspan="4">80.87 + 8.51 log M</td><td>103</td></tr>
<tr><td colspan="2">Approach noise level (EPNdB)
All aeroplanes</td><td colspan="3">98</td><td colspan="2">86.03 + 7.75 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 colspan="4">89</td><td colspan="2">66.65 + 13.29 log M</td><td colspan="2">101</td></tr>
<tr><td>3 engines</td><td colspan="2">89</td><td colspan="4">69.65 + 13.29 log M</td><td colspan="2">104</td></tr>
<tr><td>4 engines
or more</td><td>89</td><td colspan="5">71.65 + 13.29 log M</td><td colspan="2">106</td></tr>
</table>