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Abstract

A previously developed noise assessment procedure based on measurements of weighted overall noise levels for conventional aircraft is being used successfully for noise zoning around airports. The procedure now has been adapted for application also in the planning of urban heliport sites.

This paper first reviews the noise assessment procedure used for conventional aircraft, devoting particular attention to methods for extrapolating from measured or derived overall noise levels by accounting in an empirical fashion for the effects of sound attenuation in the air and over the ground and for the subjective effects of noise duration.

It then describes the adaptation of the procedure in the assessment of noise produced by helicopter operations. A simple method of accounting for subjective effects due to the impulsiveness of helicopter noise is also described.

The procedure dealt with is intended mainly for land use planning purposes. It requires only simple noise measurements or derivation of simplified data from the much more elaborate spectral analyses demanded for most aircraft noise certification work.

Introduction

The International Organisation for Standardization (ISO) for some years has been engaged in the standardisation of procedures for describing aircraft noise heard on the ground. Earlier this year it published International Standard ISO 3891, the first edition of a revised document which appeared originally in 1970 as ISO Recommendation R507. A current proposal for an amendment to ISO 3891 stipulates further corrections to be applied in the case of helicopter noise measurements so as to account for the effects of "blade slap".

Meanwhile, the International Civil Aviation Organisation (ICAO) has already been using such ISO recommendations in establishing procedures for aircraft noise certification. At the present time it is able to impose well-defined and more-or-less scientifically derived certification limits on all kinds of aircraft.

Unfortunately such restriction on noise generation at source solves only one part of the aircraft noise problem. Another part, equally important, has been given scant attention by the ISO and ICAO. This is the problem of predicting and assessing noise exposure around airports and heliports with the aim of establishing well-defined noise zones within which residential development should be curtailed. In the absence of such curtailment, relatively quiet aircraft operating well within

noise certification limits could still cause serious noise problems at airports that are allowed to be hemmed in by populated areas.

ISO 3891 recognises this problem, and even deals with the relatively simple type of noise measure required for assessing community noise. ("A-weighted" overall noise level instead of the elaborate and somewhat controversial "perceived noise level", used in certification, which necessitates spectral analysis and which is used to describe no other noise but that emitted by aircraft). However, the ISO document fails to stipulate any method for extrapolation from noise measurements, in spite of the fact that this constitutes an essential part in the land zoning procedure. Its proposed helicopter "blade slap" amendment also appears to be designed exclusively for certification purposes.

The present paper describes an extrapolation procedure, developed in South Africa, which is already being used for noise zoning around all the country's existing and proposed new airports and, since recently, heliports as well. Details of the basic procedure, applicable to fixed-wing aircraft only, have been published before (1) to (4). However, a few comparisons between certain aspects of the procedure and somewhat similar methods used elsewhere in the world are here given for the first time. This is included merely as background to the main purpose of this paper which is to describe the recent adaptation of the basic procedure so as to also include helicopter noise assessment and heliport zoning.

Basic Extrapolation Procedure

General

Noise zoning calculations involve the determination of contours of equal noise exposure level, or noisiness index, around an airport. The noise level components of these are derived from a set of so-called reference noise levels, obtained from measurements, each applicable to a particular phase of the aircraft operation, such as landing or take-off.

Thus, for an aircraft passing through each of a sequence of points along its flight path, a calculation is made of the slant distance from any such point to every intersection on a rectangular grid superimposed upon a map of the airport and its surroundings. The amount of noise reduction along each slant distance is then calculated, and subtracted from the reference noise level to find the level at each grid intersection. The maximum level at each intersection is noted, and points of equal value connected to produce noise level contours. Noise exposure contours are obtained in a similar way.

Reference noise levels are derived from noise level measurements, either those made for certification

purposes, or ones specially undertaken. In the latter case a measured result would be expressed simply as an overall weighted level L_A (in dB), the A-weighting sound level meter characteristic being used to account for the frequency response of the human ear. If derived from certification measurements, the available results, expressed as "perceived noise levels" (L_{PN}), would first have to be corrected to L_A values. In either case the maximum level measured at a particular ground station is then adjusted to the value corresponding to that which would have been measured at a slant distance of 100 m. This adjusted level is the reference noise level L_0 .

Such adjustment already requires a certain degree of extrapolation, but the main extrapolation procedure becomes involved when the reference level is adjusted to obtain the level at each of the grid inter-sections. Such adjustment requires correction for spherical divergence, atmospheric attenuation (a function of air temperature and humidity as well as of distance) and attenuation over the ground surface. Both air and ground attenuation are functions of noise spectrum characteristics, but these cannot be accounted for in an analytical fashion unless complete spectral data are available. The simplified procedure of using weighted overall levels requires empirical extrapolation.

Empirical extrapolation formulae for fixed-wing aircraft are discussed in the following sections, and are shown later to be applicable also in the case of helicopters. They are thus shown to be sufficiently valid for a variety of noise spectra: those produced by the turbojet, turbo-fan, turbo-prop and piston engines of fixed-wing aircraft, as well as by the turbine and piston engines, main and tail rotors of helicopters.

In addition to noise level adjustment, extrapolation requires consideration of the noise duration associated with each aircraft flyover, since this factor constitutes and important contribution towards total noisiness. An empirical duration formula is therefore also provided.

The total measure of noise exposure is termed the noisiness index (NI), and thus becomes the unit adopted in contour mapping. The procedure for determining NI is defined by the following equation.

$$NI = 10 \log_{10} \frac{1}{\tau_0} \sum \tau 10^{L_A/10} \quad (1)$$

$$\text{where } L_A = L_0 - \Delta L_s - \Delta L_a - \Delta L_g \quad (2)$$

and $\Delta L_s =$ Attenuation due to spherical divergence = $20 \log_{10} (s/s_0)$

$\Delta L_a =$ Atmospheric attenuation

$\Delta L_g =$ Ground attenuation

$s =$ Slant distance (metres)

$s_0 =$ 100 metres

$\tau =$ Equivalent noise duration (seconds)

$\tau_0 =$ $86,4 \times 10^3$ seconds (= 24 h)

$n =$ Number of aircraft movements

South African authorities, in their land use planning, stipulate that the NI = 70 contour should delineate the smallest zone within which residential development is not to be allowed. Certain local authorities impose a stricter requirement: NI = 65. A value of NI between 65 and 70, a range suggested by the results of a sociological survey⁽¹⁾ conducted in the vicinity of Jan Smuts airport, corresponds approximately to the following noise exposure indices used in other countries.

WECPNL (ICAO)*	80
NNI (UK)	45
NEF (USA)	33
CNR (USA)	107
N (France)	90
Q (Germany)	75
B (Netherlands)	50

Slant Distance

The slant distance from any particular point along the flight path of an aircraft to an intersection on the ground grid may be determined by simple geometry. However, since the height of an aircraft at a given distance along its ground track, from start of roll or to touch-down, depends upon such factors as engine power setting, flap setting, loading and atmospheric density, its flight path is not always accurately known or readily predictable:

In the noise assessment method for large transport aircraft the flight path is therefore calculated from basic data⁽¹⁾, such as lift and drag coefficients for different flap settings, engine thrust or power curves, and so on, taken together with information about the pilot's procedural instructions. In the case of light aircraft the flight procedures are less predictable, so that measurements of typical take-off and landing flight paths may have to be made⁽⁴⁾. This is quite readily done by photographic means.

For turbofan engines or propellers it usually may be assumed that the maximum noise level is radiated within a vertical plane more-or-less at right angles to the longitudinal axis of the aircraft. However, in some instances, such as in the case of pure jet engines, the angle of maximum noise radiation may be different. This could then cause complications in the calculation of slant distance⁽¹⁾⁽³⁾.

Air Attenuation

Atmospheric attenuation (in overall level) may be calculated from the empirical equation:

$$\Delta L_a = \epsilon \left[\frac{s - s_0}{s_0} \right] + \psi \log_{10} \frac{s}{s_0} \quad (3)$$

where $\epsilon =$ attenuation (dB/100 m) in the third-octave spectral band centred on 500 Hz, for prevailing conditions of air temperature and humidity, as given in ISO 3891.

$s =$ slant distance (m)

$s_0 =$ 100 m

$\psi =$ air attenuation index

*WECPNL (ICAO) and NI (SA) are readily convertible, as follows⁽³⁾: WECPNL = NI + 13

Empirically determined values of the air attenuation index are: $\psi = 4$ for both take-off and landing in the case of piston-engined aircraft; $\psi = 0$ for jet aircraft at take-off and $\psi = 4$ during approach.

These values of ψ were determined as follows: For each of several types of aircraft (taking off or landing) a third-octave band noise spectrum measured at the distance $s_0 = 100$ m was used to calculate overall levels L_0 at 100 m and L_A at the various distances $s = 200, 400, 800, 1600$ and 3200 m, using the standard ISO air attenuation tables to account for attenuation in individual frequency bands. The value of ψ at each distance was then calculated from the relationship (derived from Equations (2) and (3)):

$$\psi = \frac{1}{\log_{10} \frac{s}{100}} \left[L_0 - L_A - 20 \log_{10} \frac{s}{100} - \epsilon \left(\frac{s - 100}{100} \right) \right] \quad (4)$$

and a mean of these values found by first taking the average over all distances and then averaging this result with the value at 3200 m.

The accuracy of Equation (3) was re-tested recently by carrying out comparative air attenuation calculations using noise spectra produced during take-off and approach by five aircraft (Boeing 707 A, 707 B, 727, 737 and 747) at slant distances of 200, 400, 800, 1600 and 3200 m. Six combinations of air temperature and relative humidity were considered, taking the following values: Temperature $-10, 25, 30$ and 40° ; Relative humidity: 10%, 70% and 100%. The results obtained are shown in Figure 1.

A survey undertaken to establish whether other empirical formulae for the calculation of air attenuation had been developed elsewhere yielded information on such methods used in France and the United Kingdom. Results produced by these methods and by the

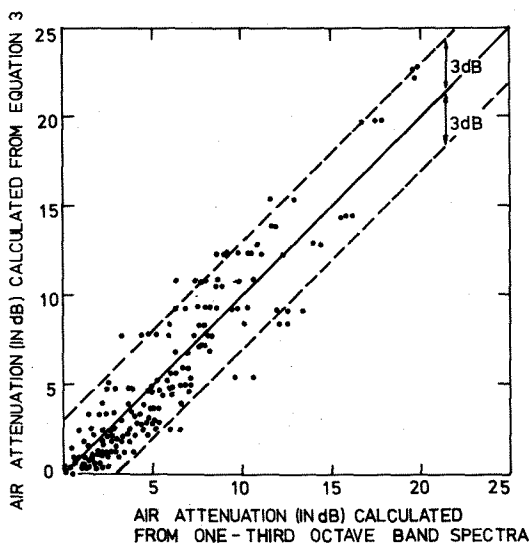


Figure 1 Comparative accuracy of air attenuation calculations involving a variety of aircraft types, operations, distances and meteorological conditions.

South African method were analysed and compared⁽⁵⁾ with one another as well as with similar results reported from the United States of America. The USA calculations had been based on certification-type spectral analyses.

The French formula yields two curves, shown in Figure 2, which represent limiting values bounding a range of aircraft types. At the larger slant distances these curves coincide reasonably well with the South African curves for different values of ψ and ϵ . However, at smaller distances both the French and UK curves tend to bulge higher than the South African ones. A comparative analysis of the US data, derived from full spectral analysis, confirmed the validity of the flatter shape⁽⁵⁾. Comparison with US data at larger slant distances was not possible since at such distances the inseparable effects of ground attenuation, which were included, became significant.

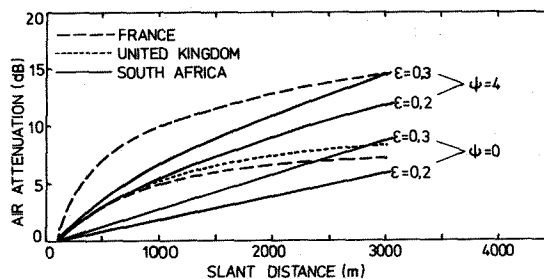


Figure 2 Air attenuation calculated by different formulae.

Ground Attenuation

Ground attenuation (in overall level) may be calculated from the empirical equation:

$$\Delta L_g = \eta (7 + 10 \log_{10} \frac{s}{s_0}) e^{-\gamma/2} \quad (5)$$

where η = a factor accounting for ground surface conditions (see below)

s = slant distance

s_0 = 100 m

γ = arc sin (h/s), in degrees

h = aircraft height

Appropriate values for the factor η are as follows:

- 0,5 for hard surfaces
- 1,0 for grass up to 300 mm high
- 3,5 for wheat or shrub up to 1,2 m high
- 7,0 for forests with thick undergrowth

The development of this formula is fully dealt with elsewhere⁽¹⁾. As had been done when examining air attenuation effects, measured noise spectra were used to compute overall levels at various distances in the absence of ground attenuation. The procedure was then repeated, but with the spectra at successive distances corrected for ground-to-ground attenuation on the basis of published data⁽⁶⁾. Differ-

ences between these two sets of overall levels thus represented the ground attenuation from source to observer, both at ground level, over a grass field. From other published data the factor η was obtained(7) and the factor $e^{-\gamma/2}$ derived(8). The latter factor accounts for the influence of aircraft height above the ground. At a subtended angle γ greater than about seven degrees the ground attenuation becomes negligible. At small angles it is substantial.

The validity of the ground-to-ground part of the attenuation formula has been confirmed experimentally for a variety of noise spectra: those produced by turbo-jet, turbo-fan and prop-jet engines, by piston-engined light aircraft and by helicopters, both piston- and turbo-engined.

Other empirical formulae for ground attenuation are used elsewhere in the world. Comparisons with these have been made(5) and have revealed considerable differences. This is illustrated in Figure 3, where calculated ground attenuation values are plotted against slant distance for each of four different aircraft heights, and the corresponding elevation angles (β) indicated on each abscissa. Each graph shows two curves labelled "FR", which are produced by the French formula. One is for take-off (TO) and the other for approach (A) of jet transport aircraft.

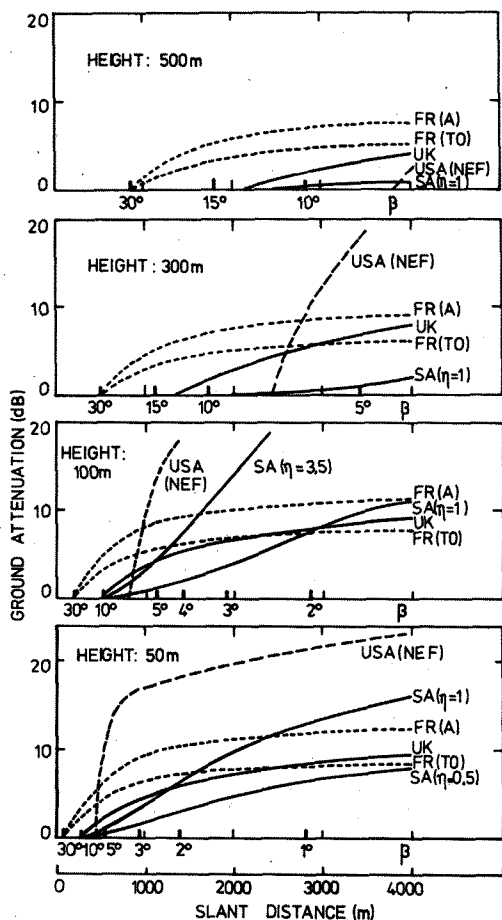


Figure 3 Ground attenuation calculated by different formulae.

In assessing the discrepancies among results obtained, it may be more instructive to consider the ground-to-ground component and the transition from ground to air separately. Figure 4 depicts the different ground-to-ground attenuation curves, and Figure 5 shows the corresponding transition characteristics.

The most important differences appear to emerge in Figure 5. The USA and SA curves imply that ground attenuation becomes insignificant at elevation

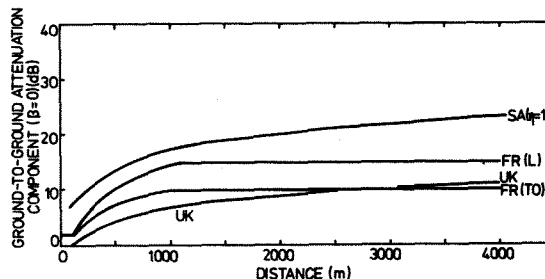


Figure 4 Ground-to-ground attenuation comparison.

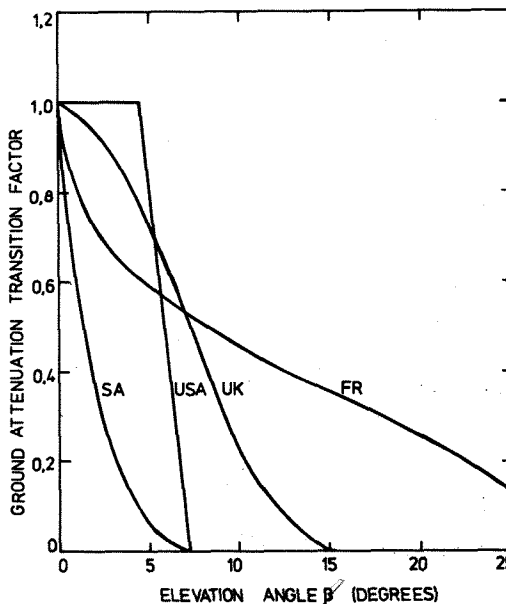


Figure 5 Ground attenuation transition factors.

angles $\beta > 7^\circ$, whereas the UK and French curves show considerable attenuation at much larger angles. Only the USA curve suggests a discontinuity of transition at an angle $\beta = 4^\circ$. However, it is believed that USA practice has since been modified to produce a curve somewhere between those of the UK and SA.

Figure 6 provides an illustration of the way in which the effects of ground attenuation cause a substantial curvature in the noise level contours of an aircraft on approach. It also gives some indication of the accuracy obtained with the ground attenuation formula used in South Africa.

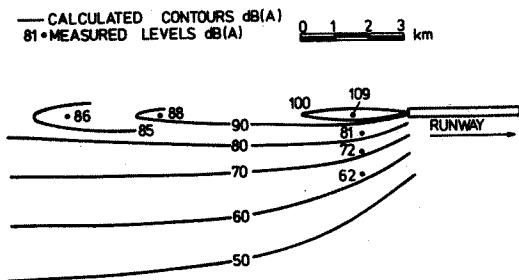


Figure 6 Comparison between calculated and measured noise levels of a B 727 aircraft landing at Jan Smuts Airport (Altitude : 1695 m).

Noise Duration

The empirical formulae for air and ground attenuation calculation based on overall noise levels are required to render noise zoning computations practicable. In principle it is still possible to base calculations on spectral data; indeed, in a few places, where very extensive computer facilities are available this may even be done. However, for predicting equivalent noise duration (τ in Equation (1)) there exists no way in which non-empirical extrapolation can be done with any degree of accuracy. The relationship $\tau \sim s'/u$, where s' is the shortest distance (in metres) between ground point and flight path, and u is the aircraft speed (in m/s), may be used for duration corrections over short distances, but it soon fails over the larger distances involved in zoning calculations.

For this reason, an empirical formula was developed(2) to achieve an encompassing fit with experimental results. The formula appears as follows:

$$\tau = \frac{1,85 s'}{u (1 + e^{-\gamma/2})} \left[1 - e^{-(L_A - L_a)/4,34} \right] \quad (6)$$

where L_a is the ambient A-weighted overall noise level prevailing in the vicinity of the airport concerned.

The square-bracketed factor in which L_a is contained is needed to limit the duration correction at distances where much of the flyover noise (maximum level L_A) may be masked by ambient noise (level L_a) in such a way as to render the noise audible for only a short period. The form of the factor was derived from a computer simulation of fly-over noise. It was found that for $(L_A - L_a) < 4$ dB the omission of the factor could lead to seriously excessive duration allowances.

The factor $1/(1 + e^{-\gamma/2})$ is needed to account for the effects of ground attenuation where during initial and ultimate phases of flyover the elevation angle β is small, low levels rendered inaudible, and duration accordingly reduced.

The validity of the formula has been confirmed for the flyover noise of jet transport aircraft, piston-engined light aircraft and helicopters, by comparing duration values yielded by it with results obtained from "energy"-integrations of measured noise level

histories, in accordance with the definition of equivalent duration:

$$\tau = \frac{\int 10^{L_{Ai}/10} dt}{10^{L_A/10}} \quad (7)$$

where L_{Ai} is the noise level at time t , the level L_A being the maximum value of L_{Ai} .

The only confirmation that could be obtained from results reported elsewhere involved comparing values of $\Delta_{PN} = 10 \log_{10} (\tau/10)$ with corresponding values of the quantity $(L_{EPN} - L_{PN})$. The effective perceived noise level L_{EPN} and the perceived noise level L_{PN} are the units used in certification measurements, and by definition their difference amounts to the duration allowance Δ_{PN} .

Information obtained from the USA was used in making such a comparison(5), and yielded discrepancies of less than (or at worst equal to) 2 dB over various distances from 100 m to 3050 m, for two different aircraft, at different speeds, one in cruise and the other on approach.

A somewhat similar exercise was also carried out using the A-weighted levels of helicopter noise measured during the test programme referred to in the sections following. During these tests both L_A and L_{eq} levels were measured, L_{eq} being defined as:

$$L_{eq} = 10 \log_{10} \frac{1}{T} \int 10^{L_{Ai}/10} dt \quad (8)$$

where T may be any given period of time.

Thus (see Equation (7)):

$$\begin{aligned} L_{eq} + 10 \log_{10} T &= 10 \log_{10} \int 10^{L_{Ai}/10} dt \\ &= L_A + 10 \log_{10} \tau \quad (9) \end{aligned}$$

Since L_{eq} , L_A and recording time T were all known, τ could be determined. Again the empirical values were confirmed.

Helicopter Noise Assessment

Reference Noise Level

In the case of fixed-wing aircraft, as mentioned before, reference noise levels for use in zoning calculations could either be derived from the results of certification data or measured especially by relatively simple means. In the case of helicopters, it seems probable that certification data might be of little use, since it is anticipated that the ICAO might confine certification measurements to the approach and flyover conditions. For zoning purposes it is essential to have reference levels for hover and take-off as well.

In this connection it should be borne in mind that

certification requires maximum accuracy and repeatability, and that this is incompatible with the complexity and variability of hover and take-off noise spectra. For zoning purposes such a high degree of accuracy is not required.

A minimum scheme for a noise survey to establish the required reference noise levels for zoning purposes needs only four (or even three) measuring points (see Figure 7). Two of these could be situated along a line drawn through the landing pad, at right angles to the ground track of the helicopter, at distances of 100 m on either side of the pad. The other two could be situated along the ground track, at distances of 300 m on either side of the pad. The latter two points are for the measurement of approach and take-off noise respectively. However, if the test helicopter can be turned around to execute both take-off and approach along the same track, on only one side of the pad, both approach and take-off noise can be measured at the third point, rendering the fourth redundant.

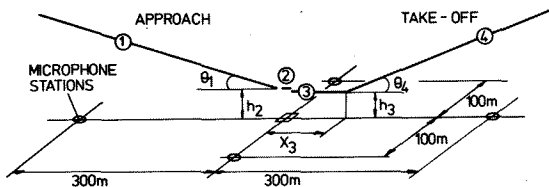


Figure 7 Simplified flight path segments and proposed locations for microphone stations.

Only A-weighted maximum overall noise levels (L_A) need to be measured, and these must yield four reference values: for take-off, approach, hover and flyover. Take-off or approach level is measured as the aircraft passes over on an established flight path, consistent with "normal" operational procedures and "typical" loading and weather conditions. Flyover level is recorded at any or all of the measuring points as the aircraft passes over along the same track as that used for take-off and approach, at a height of 100 m and/or 150 m, and at normal cruise speed. Hover noise measurement is more complicated. The noise should be measured at both the two lateral points while the helicopter is hovering over the pad at the height normally associated with transition from landing approach to touch-down. Eight such measurements should be made, one each for the helicopter facing in a different direction, it being rotated through increments of 45° starting from the direction of the ground track.

The measured take-off, approach and fly-over levels (L_A) are readily converted to reference noise levels (L_0) by correcting for differences between actual slant distances and the 100 m reference distance, using Equation (2). The hover levels require prior inspection to determine the magnitude and direction of radiation of the maximum value recorded. This one is then taken to be the reference level.

It should be noted that in the hover condition the levels on either side of the helicopter could differ by as much as 10 dB. Using the higher value in land zoning calculations does not necessarily imply undue pessimism since it must be taken into account that the normal approach path towards a helipad could, depending upon wind direction, also serve as the take-off path, thus rotating the noise radiation pattern through 180° .

It is also important to note that the noise measurements carried out at a particular site should only be used in the zoning of sites situated at similar ground altitudes and in regions where similar ambient temperatures prevail. At a site situated differently the prevailing air density could be sufficiently different not only to substantially modify the flight path geometry, but also to influence the character of the noise produced.

Consideration of the complicated noise radiation pattern associated with a varied array of helicopter noise sources (engine, rotor, tailrotor) and of the way in which spectral characteristics change with different modes of flight, has tended hitherto to discourage attempts at formulating the simple descriptors required for heliport noise zoning. However, as will be illustrated in the following sections, it is now found that the relatively simple treatment suggested here produces adequate and sufficiently accurate procedures for zoning purposes.

Slant Distance

For the purposes of zoning calculations the simplified flight path configuration illustrated in Figure 7 is assumed to be representative. It is divided into five segments:

- (1) Approach at an angle θ_1 .
- (2) Hover prior to touch-down at a height h_2 .
- (3) Horizontal take-off acceleration over a distance x_3 and at height h_3 .
- (4) Take-off climb at angle θ_4 .
- (5) Cruise at height h_5 .

The various heights and angles are best determined by photographic means, but could be confirmed against cockpit readings of speed, altitude and rates of climb and descent. In the photographic analysis it is often convenient to scale distances by comparing them with known aircraft dimensions. Once the heights and angles are determined the slant distances from points along the flight path to points on the ground grid intersections are readily calculated.

It should perhaps again be emphasised that the flight path configuration is much influenced by air density conditions associated with prevailing ambient temperature and heliport altitude.

Extrapolation

Reference noise levels and slant distances for helicopter operations are thus defined, enabling the extrapolations required for heliport zoning to be undertaken.

Tests conducted with three helicopters (a turbine-engined Alouette III, a piston-engined Hughes 300C, and a turbine-engined Bell Jet Ranger 206B) showed

that the empirical formulae for air attenuation (Equation (3)) and ground attenuation (Equation (5)) remained valid. The value of the air attenuation index was found to be $\psi = 4$. The noise level contours shown in Figure 8 illustrate the accuracy of extrapolation achieved.

In the contour set for Hughes landing there are two measured levels shown in broken circles. These are hover levels on the less noisy side of the helicopter. The contours for Alouette landing show similar levels, but these and their counterparts on the noisy side are displaced by an angle of 45° . This corresponds to the measured angle of maximum noise radiation during hover.

The reference noise levels used in the computations were derived from measurements and are listed in Table 1.

The empirical formula for equivalent duration (Equation (6)) was also found to remain valid for helicopter operations. Of course, the duration of hover prior to touch-down has to be determined separately. This could be done by direct timing or by subsequent analysis of ciné records. The average helicopter speed during the take-off segment may be assumed to be half the speed attained at the end of the segment, while speeds in the approach and climb segments are assumed to remain constant.

Table 1

Reference levels L_0 in dB

HELICOPTER	FLIGHT SEGMENT			
	1 APPROACH	2 HOVER	3 TO ACCEL.	4 TO CLIMB
Bell	72	77	73	73
Hughes	78*	82	82	82
Alouette	86*	92	89	89

*Determined from measurements made at a distance of 700 m from the pad along the approach track.

On the basis of these assumptions, and using Equation (1), contours of equal noisiness index (NI) were computed for the three aircraft tested, each for an assumed 50 movements per day. The results obtained are shown in Figure 9. It should be borne in mind that these contours, as well as those of Figure 8, apply at a site near Pretoria, situated at a ground altitude of 1400 m. Ambient temperatures were 19°C during the Alouette and Hughes flights, and 35°C during the Bell flights.

The "measured" values indicated on these contours

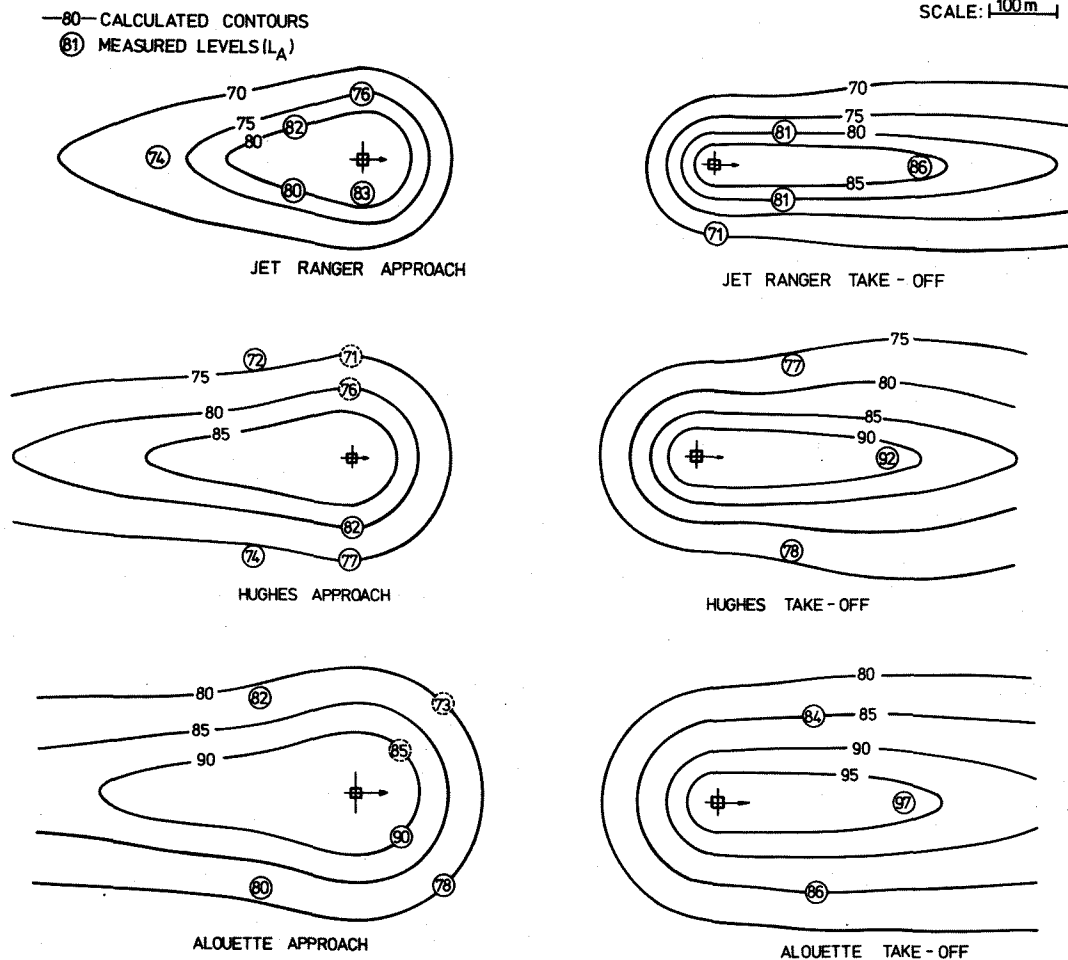


Figure 8 Noise level countours.

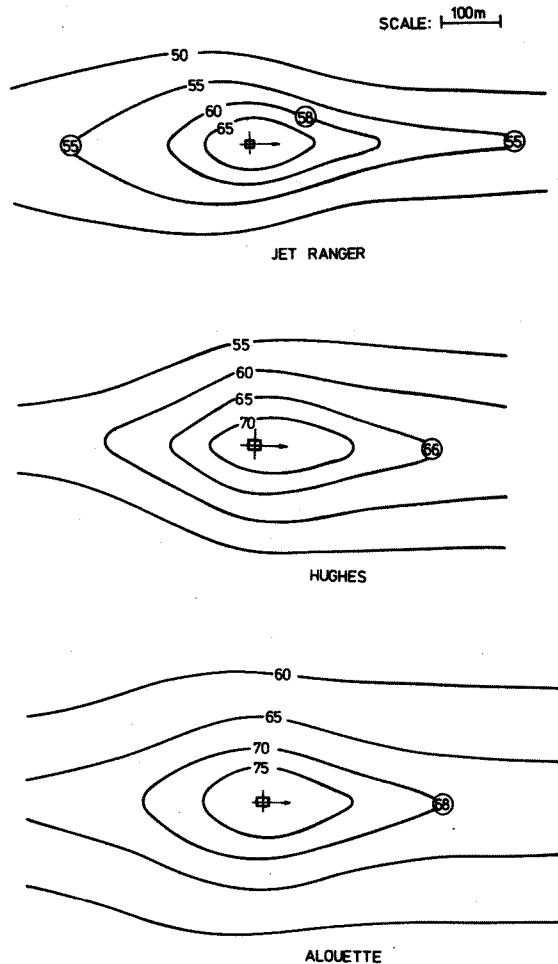


Figure 9 Predicted NI contours for 50 movements per day. Ringed values were derived from measurements.

were also obtained from Equation (1), but with measured values of L_A inserted, and with τ obtained from Equation (9) for measured values of L_{eq} and L_A . Agreement between computed contours and "measured" points is seen to be good.

As mentioned earlier, the conservative limiting value of NI, defining the area within which noise exposure is considered excessive, is NI = 65. According to the curves of Figure 9, a Bell helicopter traffic density of 50 movements per day should then not cause excessive disturbance were they to operate in the Pretoria area from a clear heliport zone slightly less than 200 m long and 100 m wide.

Flyover Noise

In general it could be expected that heliports would be established in business and industrial areas of cities, rather than in residential areas. However, the helicopters may fly routes that take them over residential suburbs. It could then become desirable to impose height restrictions on such fly-overs.

Having determined a reference noise level L_0 for fly-over noise, the level that will be perceived on

the ground directly below a helicopter flying at height h may be calculated from Equations (2) and (3), taking $\Delta L_g = 0$, $\epsilon(s - s_0)/s_0 \approx 1$ and $\psi = 4$. Thus:

$$L_A \approx L_0 - 24 \log_{10} \frac{h}{100} \quad (10)$$

By way of example, Table 2 lists predicted noise levels produced by the three helicopters tested, flying over at 300 m.

Table 2

Flyover noise levels at $h = 300$ m

AIRCRAFT	L_A (in dB)
Bell	66
Hughes	71
Alouette	79

Such information about noise levels generated in a community, even where noise exposure levels (NI) may be relatively low, are often of interest to town planners and architects.

Blade Slap Noise

So far no mention has been made of a particularly irritating sound sometimes produced by a helicopter, namely the noise due to blade slap. As it happened, no blade slap noise was encountered during the noise surveys dealt with in the preceding sections. Nevertheless, this type of noise does occur quite often, and must be taken into consideration.

To account for the subjective effects of blade slap noise it is necessary to add an impulsiveness correction (Δ_I) to any measured noise level (L_A). A simple way of determining the value of the correction has been devised⁽⁹⁾, and may be formulated as follows:

$$\Delta_I = L_{eq(I)} - L_{eq} \quad (11)$$

where L_{eq} is the equivalent noise level (see Equation(8)) measured on an instrument set to "slow" response, and $L_{eq(I)}$ is the corresponding value measured with the instrument set to the standard "impulse" characteristic.

A much more complicated method, and one which appears to be designed exclusively for certification measurements, is currently being considered for adoption by the ISO in a first draft proposal for amendment to ISO 3891. It requires an analysis, done in half-second intervals, and involving signal sampling rates of the order of 5 k Hz, to compute a parameter I which is then a function of noise wave form magnitude. Eventually, on a purely empirical basis, the correction Δ_I is defined as:

$$\Delta_I = 0,8 (10 \log_{10} I - 3) \quad (12)$$

The constants are introduced and their values chosen so as to limit the correction to a "reasonable" maximum magnitude (5,5 dB), and so as to ensure that its adoption would not in any way impinge upon or influence the noise certification of jet transport aircraft.

It is of interest to compare results produced according to this concept with those yielded by Equation (11). This may be done by using information obtained from Westland Helicopters Limited⁽¹⁰⁾ about subjective reactions to recordings of the noise produced by a number of helicopters and helicopter operations, together with information obtained from the originators⁽¹¹⁾ of the parameter I used in Equation (12). The latter had analysed the same noise recordings, determining a value of I for each. Definition of the parameter has since been somewhat refined by the incorporation of different integration periods and normalised sampling, but although its numerical value has thus changed its essential character remains unaltered.

The results of the analysis, i.e. values of I for the various recordings, yield the points plotted in Figure 10(a) when inserted into a different empirical formula, one which defines:

$$\Delta_I = 0,24 (10 \log_{10} I - 4,2) \quad (13)$$

The curve drawn through the points on this graph is identical to the curve shown in Figure 10(b), the points on which had been derived from the same recorded data but by using Equation (11). Clearly, the simple method of measuring directly the values of $L_{eq}(I)$ and L_{eq} produces essentially the same result as is achieved by the much more complicated analysis required to determine I.

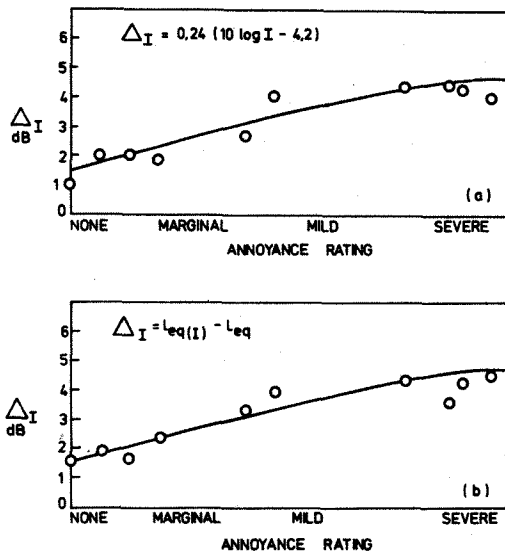


Figure 10 Comparison of impulsiveness corrections determined by different methods.

In passing it may be mentioned that the idea of defining Δ_I as in Equation (11) arose from work done in connection with community response to fluctuating noise. It had been found⁽¹²⁾ that differences between $L_{eq}(I)$ and L_{eq} not only correlated well with results produced by the so-called derivative methods for the assessment of fluctuating noise (measures based on functions of dL_A/dt)⁽¹³⁾ but that, quite fortuitously, they also appeared particularly sensitive to the presence of helicopter blade slap noise.

Conclusion

Although the relatively simple procedure for the assessment of noise exposure around heliports proposed here involves no spectral analyses of noise, and is based on the assumption of a much simplified flight path, it nevertheless appears to produce results with an accuracy which is almost surprising. An accuracy which certainly seems sufficient for noise zoning purposes.

However, it is recognised that while basically the same procedure has been well-proven already in the case of fixed-wing aircraft, its application to helicopters so far has been limited to the tests and calculations dealt with in this paper. Further evaluations, involving a wider range of helicopter types, remain desirable.

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