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A PROCEDURE FOR THE CALCULATION OF AIRPLANE NOISE

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ABSTRACT
This work describes a new numerical method for calculating sound exposure levels at any ground locations resulting from operations of jet and propeller driven aircraft in the vicinity of an airport. The procedures assume that reference noise and performance data are available for each aircraft involved. The new fundamental element of the procedures is a method for calculating the A-weighted sound exposure levels (SEL) that would be produced, on average, by any specific aircraft when performing any specified operation. Procedures are given for calculating sound exposure levels for individual aircraft operations and for the average sound levels produced by the cumulative effects of a series of different aircraft operations. The principal purpose of using this numerical methods which calculate contours of equal average sound level is to assist in land use planning around airports.

1 - PERFORMANCE CALCULATION
The aircraft used in this simulation has a maximum takeoff weight of 32000 Kg and it is powered by two low bypass jet engines. Aeroplane performance data are available in table n. 1.
Initial climb speed:
The calibrated initial climb speed is [1]:

$$V_c = C\sqrt{W}$$

where $C = 0.574$, $V_c = 0.574\ \sqrt{71000} = 152.9$ Knots.
Equivalent takeoff ground roll [1]:
The equivalent takeoff ground roll distance is [1]:

$$s_g = B\theta_{am}\left(W/\delta_{am}\right)^2 / \left[NP_n/\delta_{am}\right]$$

where $B = 0.0149$ and $N = 2$ (Number of engines).
Therefore:

$$S_g = \left\langle \frac{1..0\,(0.0149)\,(71000)^2}{2\,(8520)} \right\rangle = 4408 \text{ ft}$$

Initial climb (Sea Level to 1000 ft):
The average geometric climb is [1]:

$$S_g \frac{1000}{\tan\gamma} = \frac{1000}{0.1654} 6046 \text{ ft}$$

Acceleration and flap retraction:
The horizontal, or ground track, distance, is [2]:

$$s_a = (1/2g)\,(0.95)\left(V_{tb}^2 - V_{ta}^2\right)/\left\{\frac{N\,(F_n/\partial_{am})}{(W/\partial_{am})} - R_{avg} - \frac{V_{tg}}{101..3V_{tavg}}\right\}$$

<u>*Continued climb*</u>:
<u>*Average altitude = 2130 ft*</u>:

$$\Delta\mathrm{h} = 3000 - 1259 = 1741 \quad \mathrm{ft}$$
$$\mathrm{S_c} = \frac{\Delta\mathrm{h}}{\tan} = \frac{1755}{\tan 7.13} = 13906 \mathrm{\ ft}$$

2 - NOISE CALCULATION

The representative aircraft has noise-power-distance data relating to SEL [2] power setting and minimum slant distance described in table II. The calculation of SEL for any point P on the ground can be now accomplished.

<u>*Representative Locations*</u>:
Consider three locations which are 610 m (2000 ft) to the side of the takeoff ground track.
The three points are:
P(1): (-1500,2000), P(2): (1500,2000), P(3): (7000,2000), Start of roll: (0,0)

<u>*Sound exposure level at point P1*</u>:
The sound exposure level at P(1) is dependent upon the aircraft to observer distance at the start of roll, the directivity angle, and the takeoff power. The equation for the noise calculation is:

$$L_{ae}\,(P_1) = L_{ae}\,(P, d) + \Delta_v - \lambda\,(0, r) + \lambda_1$$

The speed adjustment for duration is [3]:

$$\Delta_\mathrm{v} = 10\mathrm{lg}\,(160/32) = 7.0 \mathrm{\ dB}$$

Lateral attenuation is computed as described in reference [4]:

$$\lambda\,(0, \mathrm{r}) = 15.09\left(1 - \mathrm{e}^{-2.088}\right) = 13.2 \mathrm{\ dB}$$

The directivity adjustment is [3]:

$$\Delta_l = 1.9 \mathrm{\ dB}$$

The corrected level is:

$$L_{ae}\,(P_1) = 97.4 + 7.0 - 13.2 + 1.9 = 93.1 \mathrm{\ dB}$$

<u>*SEL at P(2), (1500,2000)*</u>:
Sound exposure level at P(2) is determined by adjusting the reference level, corresponding to takeoff power, for velocity and lateral attenuation.

$$L_{ae}\,(P_2) = L_{ae}\,(P, d) + \Delta_v - \lambda\,(0, d)$$

The aircraft speed is [5]:

$$V = \sqrt{32^2 + (152.9^2 - 32^2)\,(1500/4408)} = 92.9 \mathrm{\ nodi}$$

The speed adjustment for duration is [3]:

$$\Delta_v = 10\mathrm{lg}\,(152.9/92.9) = 2.2 \mathrm{\ dB}$$

Lateral attenuation is computed by [4]:

$$\lambda\,(0, d) = 15.09\left(1 - e^{-1.67}\right) = 12.3 \mathrm{\ d\ B}$$

The correct noise level is:

$$L_{ae}(P_2) = 99.1 + 2.2 - 12.3 = 89.0 \text{ dB}$$

SEL at P3:
The point P(3) is beyond the point of lift-off and the ground track is straight, there are only two adjustment factors:

$$L_{ae}(P_3) = L_{ae}(P, d) + \Delta_v - \lambda(\beta, l)$$

Duration correction is:

$$\Delta_v = 10\lg(164/150) = 0.2 \text{ dB}$$

Lateral attenuation is calculated by:

$$\lambda(\beta, l) = (12.25)(5.28)/13.86 = 4.7 \text{ dB}$$

The corrected SEL is:

$$L_{ae}(P_3) = 99.1 + 0.2 - 4.7 = 94.6 \text{ dB}$$

Segment	flight alt.	Path altitude	speed	thrust
takeoff	0	0	0	EPR to
Initial climb	0-1000	4408-10454	152.9-152.9	8520
Flap retracts	1259	14658	180	8108
Continue climb	3000	28564	180	8430
Accelerate	3845	46907	250	7895

Table 1: Calculated takeoff profile.

distance (meters)	takeoff thrust	climb thrust	cruise thrust
80	116.5	102.0	96.4
125	112.3	100.9	95.7
200	110.2	99.4	94.2
400	103.6	97.0	92.1
630	99.8	94.4	88.7

Table 2: Noise-power-distance curves.

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