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A NEW AIRCRAFT NOISE EXPOSURE PREDICTION MODEL

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INTRODUCTION

A general tool for land-use planning in the vicinity of airports is noise exposure contours. The contours are perimeter lines of equal noise exposure.

The noise exposure is the 24-hour time average of the mean square sum of the single event sound exposure levels (SEL) which occur in the 24-hour time interval. The sound exposure levels are normally adjusted for the time-of-day.

In conventional methodologies for computing the single event sound exposure levels the course of action is:

- o SEL is specified for points directly beneath a straight flight path for a range of engine power settings and minimum distances to the path at reference conditions of speed, temperature, and humidity.
- o From aircraft performance data including flight trajectories and associated operational information the closest point on the track to the observer is determined.
- o SEL-calculations are performed assuming that the aircraft is following the tangent of the track through this point with operational parameters corresponding to the point.
- o If the track cannot be regarded as straight (curved tracks) or if the aircraft performance data differ from the preconditions, corrections are sometimes applied.

BASIC PRINCIPLE OF THE DANISH PREDICTION METHOD

The use of time-integrated metrics as input for a methodology represents a convenient data reduction as it eliminates the directivity pattern. However, one obvious disadvantage is, once the simplification has been made, the difficulty in handling situations deviating from the measurement conditions. In particular near the runway and close to a turn corrections cannot be readily made. The most proper solution is to use a simulation technique. This will unfortunately increase the computation time substantially.

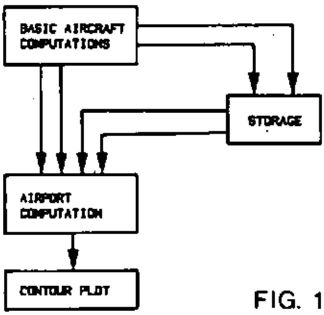

FIG. 1

From this point of view we have chosen a three-step model [1] as shown in Fig.1.

As the first step SEL from one aircraft following a straight flight track is computed in a grid with size and spacing choen by the user using a simulation technique. The SEL-matrix is stored and can be used in subsequent computations.

As the second step the noise exposure from all aircraft operations is calculated in a grid from the results of the first step.

Eventually the contours are evaluated from this grid.

AIRCRAFT NOISE COMPUTATION

The sound exposure levels L_{AE} from one aircraft following a straight flight track are computed in a grid. The computation is done as a simulation of the physical phenomena according to the definition of L_{AE}:

$$L_{AE} = 10 \lg_{10} \int_{-\infty}^{\infty} 10^{L_A(t)/10} dt \qquad (1)$$

To compute the A-weighted sound pressure level $L_A(t)$ the following information is required:

- o aircraft performance data such as position and direction as a function of time (geometrical parameters)
- o noise level as a function of distance, direction, velocity, and engine power of the aircraft (acoustical parameters)
- o influence of the ground attenuation

Landings are computed as reversed take-offs with a few modifications.

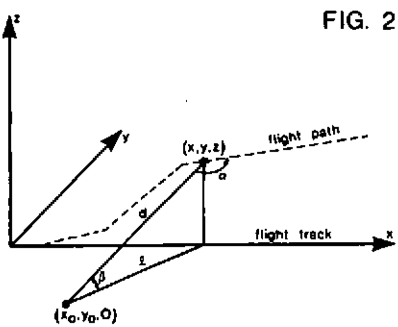

FIG. 2

Geometrical computations

The parameters d, ℓ, α, and β necessary for the subsequent acoustical computations are defined in Fig.2. To compute these parameters the flight is defined by:

- o flight speed as function of distance x from start-of-roll (take-offs) or end-of-roll (landings)
- o flight altitude z as a function of x

Acoustical computations

The basic input noise descriptor in the method is the sound exposure level L_{AE} as a function of distance and thrust, but in order to compute $L_A(t)$ in equation 1 information is required on:

- o L_A as function of distance d, direction α, thrust δ, and velocity v under fly-over conditions
- o ground attenuation as function of ℓ and β

The main idea in this part of the methodology is to set up a generalized model expressing L_A from L_{AE}:

$$L_A(d,\alpha) = A \sin^4 \sqrt{(\pi - \alpha)\pi} + L_{AE}(d \cdot c_1) - 10 \lg_{10} d + c_2 \quad (2)$$

where A is a directivity pattern parameter and c_1 and c_2 are constants. The procedure is now to choose a directivity pattern by A and estimate c_1 and c_2 to give smallest possible deviation between calculated (equation 1) and measured values of L_{AE} (the deviation is generally less than 0.2 dB in the relevant range of distance). In addition to this, corrections are added to $L_A(d,\alpha)$ for:

- o engine power
- o forward flight effects on noise radiation during ground roll (A becomes a function of v)
- o thrust reversal during landings (change in directivity pattern)
- o ground attenuation (SAE AIR 1751 modified to instant levels)

AIRPORT NOISE COMPUTATION

This step includes:

- o lateral dispersion
- o sound exposure levels for curved track
- o number of operations and time-of-day weighting

Lateral dispersion

Lateral dispersion is included in the methodology as a modification to the single aircraft SEL-computation $L_{AE}(x_o,y_o)$. L_{AE} including lateral dispersion is given by:

$$L'_{AE}(x_o,y_o) = 10 \log \int_{-\infty}^{\infty} 10^{L_{AE}(x_o,y_o-y)/10} P(x_o,y)\, dy \quad (3)$$

where $P(x,y)$ is the probability function defining the distribution of traffic in a cross section perpendicular to the flight track. $P(x,y)$ is defined by the user for each aircraft type and flight track.

Curved tracks

Flight tracks are defined as a sequence of straight and circular segments. In the case of curved tracks the course of computation is:

- o The circular segments is divided into straight subsegments so that the track consists of straight segments only.
- o The sound exposure level from the straight flight containing the segment is computed based on the single aircraft computations above

above including lateral dispersion if desired.

- The amount of energy c received from the segment relative to the entire straight flight track is computed based on assumptions on received energy versus immission angle.
- The contributions from all segments are finally added:

$$L_{AE,curved} = 10 \lg_{10} \sum_j c_j \, 10^{L_{AE,straight}/10} \quad (4)$$

This method yields a good prediction accuracy in the case of curved tracks. Fig.3a shows the prediction error relative to a simulation of the aircraft operation in a grid around a 180° flight track turn with spacing 200 × 200 m. For comparison, in Fig.3b the prediction error is shown if no correction for curved tracks is applied (which is the case for most conventional methods).

FIG. 3a

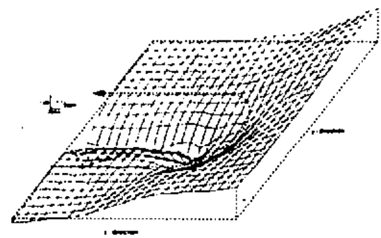

FIG. 3b

Noise exposure

The total noise exposure is computed by:

$$L_{DEN} = 10 \lg_{10} \frac{1}{86400} \sum_i \sum_j n_{w,i,j} \, 10^{L_{AE,i,j}/10} \quad (5)$$

where $n_{w,i,j}$ is the time-of-day weighted number of operations for the i'th aircraft type and the j'th flight track and 86400 are number of sec. per day. n_w is defined as:

$$n_w = n_d + 3.16\, n_e + 10\, n_n \quad (6)$$

n_d, n_e, and n_n are the number of operations during day-, evening-, and nighttime, respectively.

REFERENCES

[1] B. Plovsing and C. Svane, "Aircraft Noise Exposure Prediction Model. Guidelines for the Methodology of a Danish Computer Program". Report No. 101, Danish Acoustical Institute 1983.

[2] Poul Hansen, "A Digital Airport Noise Computation Program". Report No. 26, Danish Acoustical Laboratory (per 1983-01-01 Institute) 1983.