VALIDATING THE CAA AIRCRAFT NOISE MODEL WITH NOISE MEASUREMENTS

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1. INTRODUCTION

The Environmental Research and Consultancy Department (ERCD) of the Civil Aviation Authority provides independent technical advice to the Department of the Environment, Transport and the Regions (DETR). This includes production of annual noise exposure contours for Heathrow, Gatwick and Stansted. An increasing proportion of ERCD's time is also devoted to the provision of noise contours for regional airports and local authorities.

ERCD developed the UK Aircraft Noise Contour Model – ANCON [1,2]. There are significant similarities between the FAA's Integrated Noise Model (INM) and ANCON, having both been created from the same guidance material produced by SAE [3], ECAC [4] and ICAO [5]. Both can be classed as deterministic models where the noise source is related to the flight trajectory. INM synthesises its flight profiles based on assumptions regarding aircraft takeoff weight, engine power settings and airline operating procedures. In contrast, ANCON uses observed flight profiles gathered from aircraft operating at Heathrow, Gatwick and Stansted and estimates engine power setting and airline procedure from this data.

This paper outlines the methodology employed in ANCON and describes how noise measurements are used by ERCD as a means of model validation.

2. NOISE MODELLING

Noise exposure contours at the three London airports are computed using a 16 hour Leq for an average summer day (0700 to 2300 local time) based on data collected over a 92 day period from mid June to mid September. The average summer day is considered to be appropriate because the air traffic is most intensive at this time of the year and warmer summer temperatures have a greater impact on aircraft performance.

The Leq noise exposure contours are traditionally presented as contours from 57dB(A) to 72dB(A) Leq at 3dB intervals. The procedure for producing these contours involves calculating the total aircraft noise exposure at a large number of grid points across the area under consideration. It is possible to output contours at any other Leq level, although accuracy of the model will diminish below 54dB(A) Leq, due to the scattering of flight tracks at large distances from the airport.

Radar data from air traffic control radars is fed to a noise and track keeping (NTK) system where it is combined with flight information such as the callsign, aircraft type and destination. From this data, average flight profiles are constructed for each aircraft type category. The NTK system also captures data from fixed and mobile noise monitors and matches this to the flight profile and callsign information. This enables the model's noise database to be updated on a regular basis.

ANCON calculates Leq at each grid point by summing the Sound Exposure Levels (SEL) caused by all passing aircraft. To compute the SEL at a particular grid point requires the following data:

- aircraft position – in 3 dimensions;
- aircraft velocity – relative to the grid point; and
- engine power setting/thrust.

The aircraft position and relative velocity are available from the radar data in the NTK system. Engine power setting/thrust can be derived from the mass of the aircraft (estimated) and aircraft performance data. Applying this data to a noise-power-distance (NPD) curve gives the SEL for an aircraft noise event.

Even with current PC technology, processing speed does not permit each individual aircraft movement to be considered separately. Movements are allocated to different aircraft 'types'. Aircraft that are noise significant by virtue of their large numbers or level of noise emissions are represented individually by type, e.g. B747-400. Some are grouped together with other types having similar noise characteristics. For each 'type' average profiles of height and speed against track distance are calculated from an analysis of radar data. These average profiles are subdivided into appropriate linear segments.

Average ground tracks for each route are calculated based on radar data. Accurate noise exposure estimation requires a realistic simulation of the lateral scatter of flight tracks actually observed in practice. This is done by creating additional tracks a number of standard deviations either side of the central average track. The standard deviations and the proportions of traffic allocated to each route are determined by analysis of the radar data.

At each grid point the logarithmic average of the SEL for the 16-hour period is computed and from this Leq can be obtained. This gives the Leq at a large number of grid points from which contours – the curve describing points of equal Leq – can be drawn. Contours are calculated according to the actual use of runways in the 92 day summer period of that particular year but since 1995 - a year of atypical runway usage - have also been calculated using a 'standard' modal split using a 20 year moving average. Modal split refers to the percentage of westerly vs easterly operations at each airport.

Contours are produced annually and published on the DETR web site: (www.aviation.detr.gov.uk).

3. NOISE MEASUREMENTS

The NTK system installed in 1992-93 currently comprises 10 fixed noise monitors at Heathrow, 5 at Gatwick and 8 at Stansted. These are linked to NTK workstations at each airport by means of standard telephone lines and are automatically downloaded every 24 hours. The fixed noise monitors are positioned at approximately 6.5km from the start-of-roll positions and are operated by BAA to monitor aircraft that exceed the departure noise limits. There are no similar noise limits for arriving aircraft.

In addition to the fixed monitors, a pool of approximately 25 mobile noise monitors is shared among the three London airports and the CAA. These can be deployed anywhere inside the NTK radar coverage area. However, in practice there can often be problematic ambient noise sources and access restrictions in the areas of interest around all three London airports and the positioning of monitors can be severely restricted. Even so, the extensive number of sites used in the past few years around London Heathrow is evident in Figure 1.

Typically, ERCD will deploy 4-6 mobile noise monitors at each airport to supplement data from the fixed noise monitors for noise model validation. ERCD obtains this data from the airports' NTK systems via its own workstation at the CAA. The CAA's NTK terminal is linked to terminals at Heathrow, Gatwick and Stansted via a high-speed data connection. For Heathrow, which is London's busiest airport, this means that nearly 250,000 noise measurements are collected and analysed over the summer period.

When a new monitoring location has been identified, the site is surveyed using GPS equipment to obtain its position to 10m accuracy or better. Once deployed, a mobile noise monitor will typically require weekly site visits to change the batteries and to download stored data onto a laptop PC. However, recent memory upgrades and the acquisition of several solar panels now mean that certain sites can be visited less frequently if required. Mobile phone connections can also be used for sites where regular access is restricted.

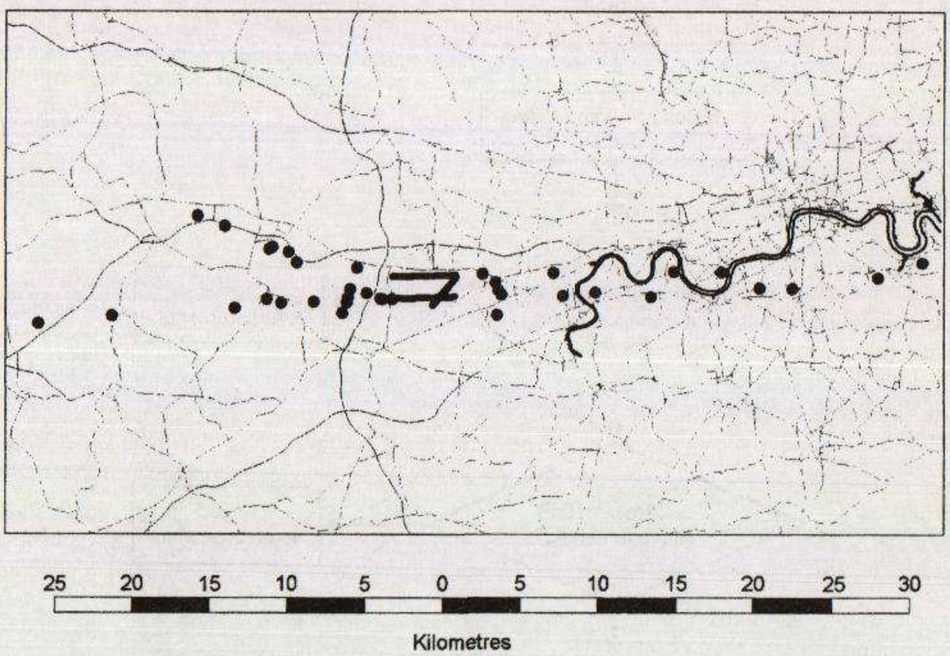

Figure 1: Monitors used by ERCD during 1997-2000 at London Heathrow

Collected noise measurements are processed using the scheme presented in Figure 2. A principal requirement of the NTK system is to identify which noise events should be matched to local aircraft movements. Depending on the monitor location, noise events may be picked up from other sources such as non-local aircraft flyovers or nearby road traffic. Optimal configuration of key parameters such as threshold level and minimum event duration reduce the likelihood of recording extraneous noise events. Threshold levels between 55dB(A) and 65dB(A) are generally used at the London airports, depending on the level of ambient noise. Accurate noise-to-track matching is helped by ensuring that the real-time clocks in the noise monitors are synchronised with the time-stamped radar feed.

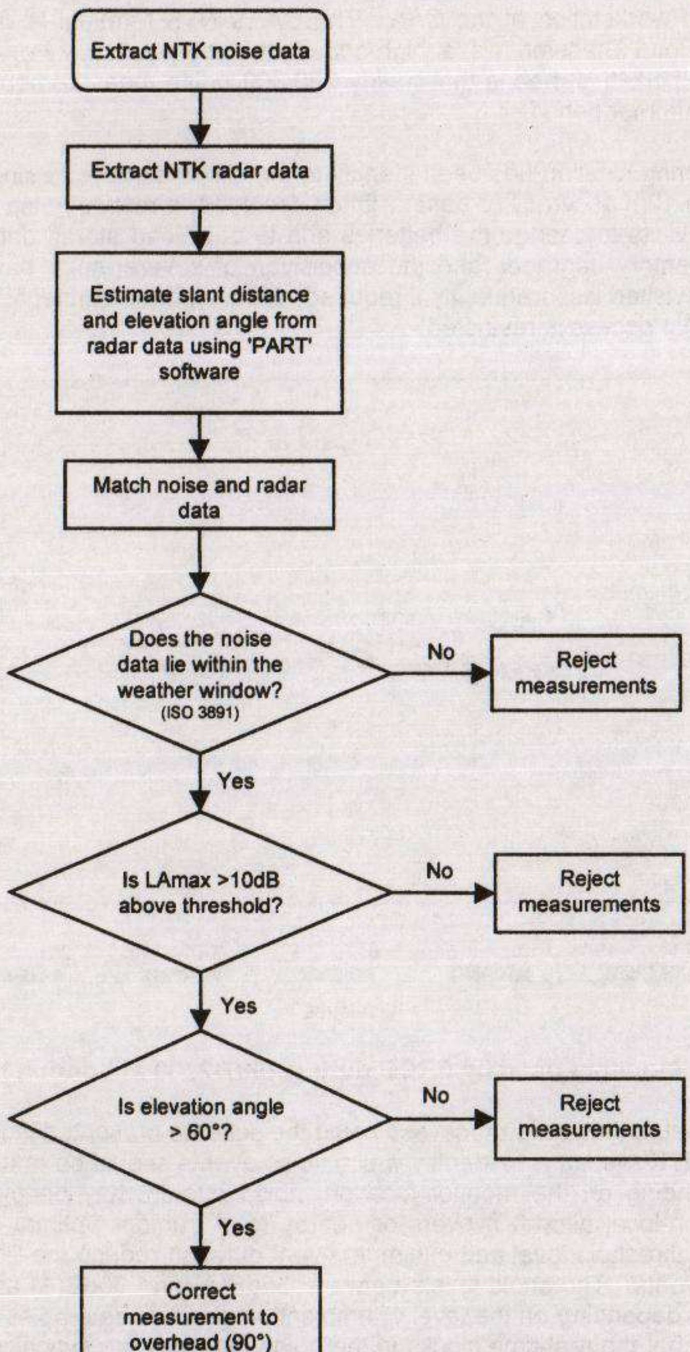

Figure 2: Noise measurement data processing

Before any validation work is carried out, the following steps are undertaken to ensure that the final data set contains high quality noise measurements:

1. The measured noise levels are screened to exclude data that lie outside an appropriate weather window [6]. However, measurements within the window are not normalised for variations in atmospheric conditions.
2. Noise measurements that did not exceed the threshold level of the noise monitor by at least 10dB are discarded.
3. The NTK radar data is processed using in-house PC software to calculate for each flight the slant distance (minimum distance) and angle of elevation between the radar track and each noise monitor (Figure 3). To minimise the effects of lateral attenuation (source directivity and overground attenuation), measurements obtained with elevation angles less than 60 degrees are rejected. The remaining measurements are then adjusted for variations in slant distance using NPD relationships.

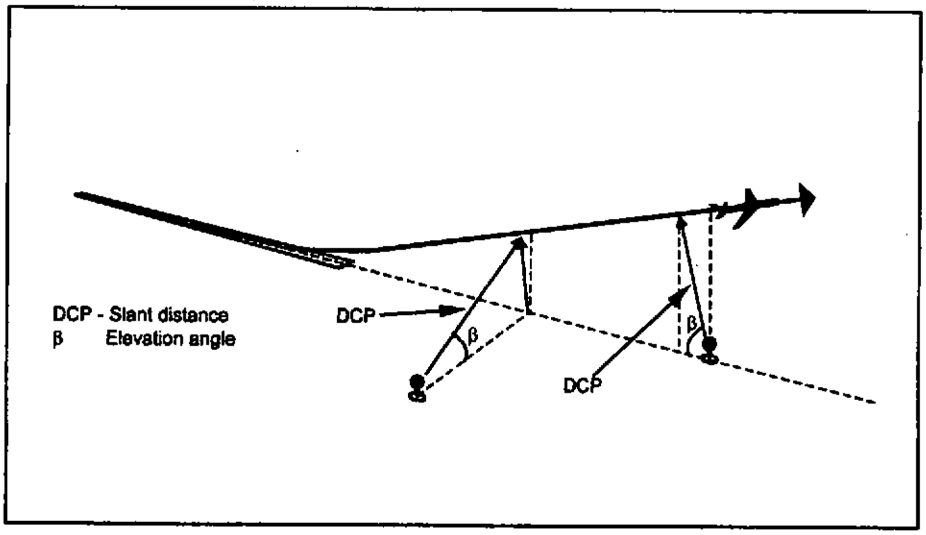

Figure 3: Determination of slant distance and elevation angle

4. VALIDATING THE MODEL

As mentioned earlier, there are significant similarities between INM and ANCON. The noise computation methodology is essentially identical. Both models follow international recommended practice and use industry supplied NPD data to relate aircraft thrust and height with noise emission for individual aircraft types. In fact, using identical input data produces similar results with either model. However, at the London airports, over one third of movements are made by aircraft with no matching INM NPD data available. It is for this reason that a local database has been developed by adjusting the basic NPD data.

The output from ANCON is validated by comparing SEL noise calculations at grid points with noise measurements made at equivalent distances from the airport. A typical example is shown in Figure 4.

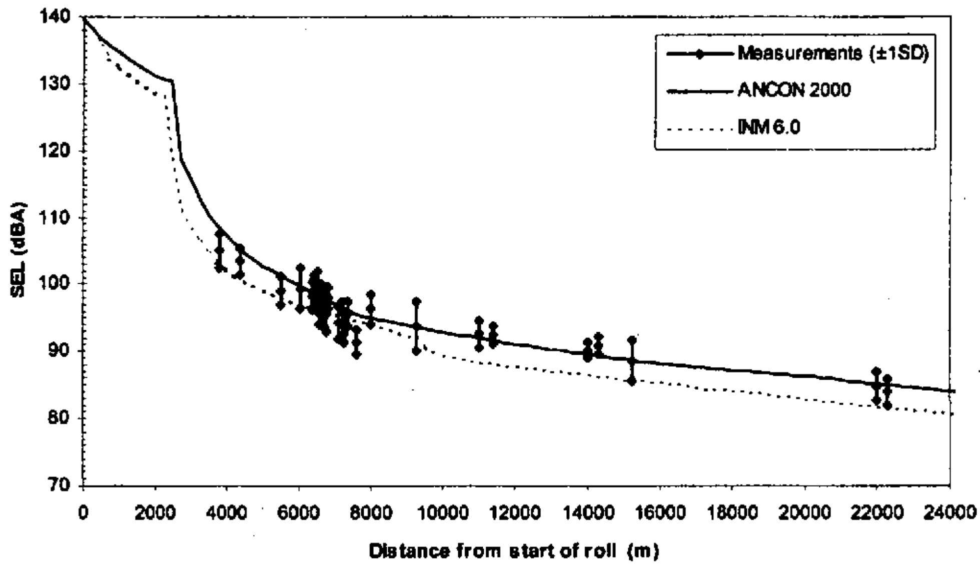

Figure 4: Predicted and Measured SEL levels vs distance from start of roll

Here, the ANCON prediction is seen to closely match the measured noise levels of a four-engined aircraft departing from Heathrow Airport, even at distances beyond 20km from start-of-roll. The dotted line in Figure 4 is the standard INM prediction, which is seen to under-estimate noise levels for this aircraft type. For this particular aircraft type, the disparity between INM and measurement is mainly due to INM's poor standard assumptions regarding the synthesis of flight-profiles to represent operations at London Heathrow.

To assess more precisely the accuracy of industry-supplied NPD data it is necessary to separate the effects of aircraft performance from source noise and propagation. This was done for a recent DETR study [7] investigating approach noise at Heathrow. Noise measurements were collected from five monitor locations under the westerly approach path. Finding suitable sites at distances over 20km from the landing threshold proved to be quite difficult. Concern was expressed over potential contamination of aircraft noise events with noise from other transport sources and the ability to capture the full noise event (10dB below LAmax) was also questioned. As a result, attended measurements were collected from the two outer sites using ERCD staff and equipment. Over the five noise monitors, propagation distances varied from 500 to 5,000ft and with a 25dB range in noise levels.

The ANCON noise model was then used to predict noise levels at the monitor locations for individual flights, using each specific flight's radar trajectory. Noise predictions were made in order to assess the accuracy of the industry NPD data supplied with INM as oppose to using the locally validated NPD data.

Figure 5 shows predicted vs measured SEL levels for Boeing 747-400 approach operations at London Heathrow. The industry supplied NPD data for this aircraft model results in excellent agreement between predicted and measured noise levels regardless of power level or propagation distance. It can also be seen that once the measured data has been processed according to Figure 2 that there is little measurement scatter. The greatest variation from predicted levels is just over 2dB. It should be noted that three engine models are available for the Boeing 747-400 and that the industry supplied data relates to the Pratt & Whitney PW4056 powered variant.

However, noise certification data suggest all three engine models are very similar. This would appear to be confirmed by the results shown here.

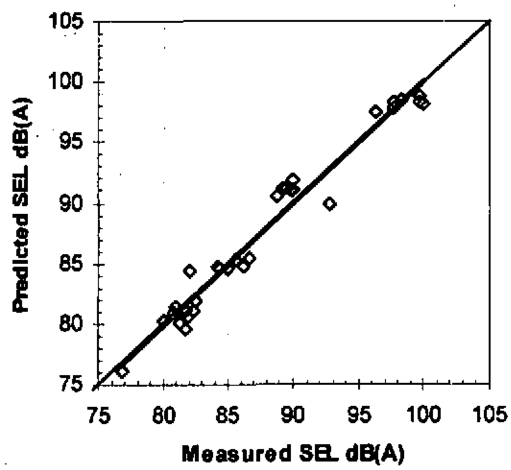

Figure 5: Predicted vs Measured approach noise levels for Boeing 747-400 (from [7])

Figure 6 shows the differences obtained when using industry NPD data and ERCD corrected NPD data for B767-300 approaches at Heathrow. The industry supplied data is based on certificated noise levels of a CF6 powered B767-200. Figure 6 shows that by using the standard data, predicted noise levels are underestimated by 2-3dB at relatively low noise levels and by as much as 5dB at the close-in site corresponding to the highest noise levels. The main reason for this difference is probably the lack of empirical NPD data for this airframe-engine combination. The measurements presented in Figure 6 are for Boeing 767's with Rolls Royce RB211 engines. ERCD allows for this and uses NPD data based on local measurements, which provide a better estimate of approach noise levels for this aircraft type.

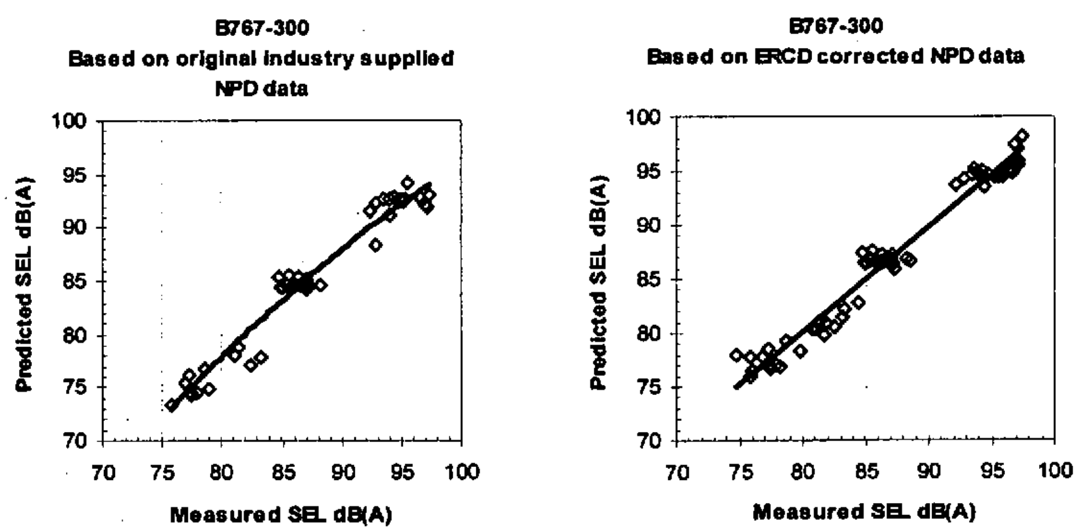

Figure 6: Comparison of Industry and ERCD corrected NPD data (from [7])

5. SUMMARY

Aircraft noise modelling has been used successfully for several decades to quantify the noise exposure experienced in the vicinity of civil airports. This paper has illustrated the complexities involved in current aircraft noise models and the efforts taken to ensure that the UK Aircraft Noise Contour Model ANCON produces accurate noise predictions and contours.

The paper also highlights that the production of accurate defensible output is by no means a simple, inexpensive task. When using any aircraft noise model, including readily available models such as the INM, users should take care to ensure that the data reflect local airport operations and long-term measurements from the vicinity of the airport.

The CAA intends to continue developing the model and maintaining the model database to reflect best practice and current operating procedures in the UK. In this way the Environmental Research and Consultancy Department is able to meet the requirements of the UK Government, of regional airports and of local authorities.

6. REFERENCES

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