The influence of subjective response on the choice of measurement for aircraft arrival noise at Nantucket Airport

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The Nantucket Airport in Masschusetts serves primariliy turboprop commuter aircraft, and private or charter jets, with most of its operations in the summer. A seasonal homeowner was severely affected by arrival flight noise and requested noise measurements and noise control recommendations for this architect-designed residence. Time was spent with the homeowner to understand steps already taken, and problems still causing trouble.

Standard measurement procedures for aircraft operations in the United States call for the use of A-weighted, slow response for the assessment of noise impact. Since the noise sources at this airport have strong tonal components (from the propellers), and noise control recommendations were sought, one-second 1/3-octave band levels were used to both document the observed problem, and to estimate the field transmission loss of the windows and doors. Measurements were made during a Friday afternoon when arriving aircraft were mostly 1.5 to 2 minutes apart. A-weighted maximum and single event levels (SELs) were also measured for each overflight, for comparison with published aircraft data. A "short circuit" was found due to an exposed vent pipe, which resulted in no transmission loss in the 100 Hz band. Appropriate recommendations were made.

1 Introduction

A seasonal homeowner on the island of Nantucket, MA had been severely affected by aircraft fly-overs from the Nantucket Memorial Airport. The author was contacted to make measurements when there was expected to be heavy air traffic and to make recommendations on reducing the noise inside the architect-designed home, which had an open plan, a cathedral ceiling on the second floor, and large numbers of windows on the main (first) floor.

The homeowner was too far away and the noise levels from the aircraft insufficiently loud to have been the responsibility of the airport to quiet. The homeowner thus wanted to know what measures could be taken to improve the amount of sound in the summer residence.

This paper will discuss the choice of measurements and the methodology, in addition to reporting on the work done.

2 Definition of the problem

The island of Nantucket in Massachusetts, USA is a vacation destination for many in the summer. It is served by ferry and air. Annual operations at the Nantucket Memorial Airport were about 161,000 in 2006, with maximum monthly operations of about 23,000 in July or August, and up to about 64 instrument operations per hour in the summer. The airport has three runways, 6/24. 12/30, and 15/33 with only the longest, Runway 6/24, at 6303 ft, instrumented.

The airport serves primarily Cessna 402 aircraft, which are used to shuttle workers and vacationers from Boston's Logan Airport, and smaller airports in New Bedford, Hyannis, and Martha's Vineyard, MA, and Providence, RI. In addition, the airport serves private and charter jets. As a result, the peak traffic occurs on Friday or Sunday.

The homeowner in question lives on the east side of the island, and was directly under the instrument approach to Runway 24. This runway would be used in westerly winds, and a review of the Airport Monitor (a radar display provided by some airports) data showed aircraft to be generally at 1100 to 1200 ft (340 to 370 m) altitude in these conditions.

The home in question was architect designed and had large double-pane windows and doors on the main (first) floor in the public spaces. The house was open plan, with rafters visible, and no ceilings inside most of the rooms. The homeowner was concerned what could be done about the aircraft noise, as it was too high inside.

It was arranged that measurements would be taken on a Friday afternoon, when the winds were expected to be westerly. Measurements were to be made both outside and in, as an assessment of the sound transmission of the structure was desired.

Upon meeting with the homeowner, it was learned that air conditioning had been installed the previous season in an effort to improve the situation, and that there was a particular problem with overflights seeming to be inside in the master bedroom on the second floor.

3 Methodology

3.1 Choice of noise metrics

The standard metric used to describe aircraft noise in the United States is the A-weighted sound level (dBA) and slow response (1 second) of the meter. For analysis of individual aircraft events, this is expanded to become the Sound Exposure Level , or sometimes Single Event Level (SEL), the total aircraft sound during the "event", or, alternatively, the sound level containing the same amount of energy but which is only one second long. This metric is useful for "adding up" sound exposure as we do in the United States for computations leading to DNL (Day-Night Equivalent Level). However, it gives no information on how to assist the homeowner.

Because the predominent noise source at the Nantucket Airport is the Cessna 402, a twin-engine propeller aircraft, it was expected that the blade passage frequency would be a factor in the problem. It was, therefore, decided to devide the problem into bands. It was expected that a doppler shift could be observed in frequency from the propellers, but only if the resolution was 1/3-octave or better.

It was, therefore, decided to measure 1/3 octave band levels and average over one second, so that the results could be combined and result in slow, A-weighted, C-weighted, and SELs.

3.2 Noise measurements

The measurements were made with a precision sound level meter, calibrated prior to the measurements (standard procedure). Measurements were made outdoors in the back of the house on the patio (the east side) which overlooked a fen and where aircraft could be observed as to type and direction of travel. Measurements were also made indoors, with the doors and windows closed and the air conditioning on. There were three indoor locations: just inside the patio doors in the dining room; and in the master and second bedroom on the second floor. The time was recorded using an atomic clock, which was verified to be synchronous with the radar data. The sound level meter was set to this time before the measurements.

Third-octave band data were automatically recorded in the meter every second during each (aircraft) event. Ambient levels were also recorded, when no aircraft were present. The meter aggregated the events into single event levels, in dBA, and also recorded maximum A- and C-weighted levels. The C-weighted data were not used in this analysis.

3.3 Aircraft observations

Data on aircraft altitudes, types, and runway used were obtained from the Airport Monitor, an archival radar database available for the Nantucket Memorial Airport on their website. The data presented combine that data with the author's observations.

In the three hours of measurements (between 13:40 and 16:45 local time), readings were taken of 65 aircraft overflights. Not all of the aircraft which operated during the three hours were measured. Around 16:00, there were a number of flights which did not land (apparently due to severe fog at the airport). Earlier in the afternoon, around 14:15 to 14:30, visibility increased enough for there to be some visual approaches (not directly overhead).

The minimum time separation between aircraft overflights was about 90 seconds (1.5 minutes). The length of corresponding noise event was typically 55 seconds outdoors.

A majority of the aircraft measured were C402 aircaft, since this is, by far, thte most common type operating at Nantucket Memorial Airport. Operators of the C402 aircraft were Cape Air, Nantucket Airlines, Nantucket Shuttle, and Island Airlines. Of the 65 aircraft measured, 32 were C402s.

Aircraft were observed to be between 800 and 1600 ft (250 and 500 m) on the day of testing. The higher aircraft were during the visual approaches, and the lower during fog.

3.4 Other observations

As noted above, weather observations were obtained at the airport during the time of the noise measurements. These were provided by the National Weather Service. Between 12:53 and 17:53, there were a number of different weather conditions. Temperatures were between 71 and 74 F (22 and 24 C), dew points between 67 and 69 C (19 and 21 C), and barometric pressures were between 1013.6 and 1016.3 mbar. Winds were S to SW at 7 to 13 mph (11 to 21 kph). Visibility was between .15 and 10 mi (.24 and 16 km). Fog was present in four of the six hourly observations, with visibility between .15 and .5 mi (.24 and .81 km) in those hours. The hourly data are given in Table 1, below.

Time	Wind kph	Vis. km	T. C	DwPt C	Press mbar	Weather
12:53	S15	.81	22	21	1016.3	Fog
13:53	SW21	11	23	20	1015.8	Overcast
14:53	S20	16	23	21	1015.2	Ptly Cldy
15:53	S16	.41	22	19	1014.7	Fog
16:53	S11	.24	22	21	1014.2	Fog
17:53	SW11	.41	22	20	1013.6	Fog

Table 1 Weather conditions at time of test

4 Results

The results of the measurements indicated that jet operations were louder than turboprops, and that indoor levels were less than outdoor. For outdoor measurements, maximum A-weighted levels were between 71 and 77 dBA for jets, between 63 and 76 dBA for all turboprops, and between 67 and 73 dBA for C402s. Indoor levels (for the C402s) were between 45 and 50 in the dining room, between 50 and 55 dBA in the upstairs bedrooms. Using these data, measured noise reduction was 23 dBA in the dining room, 18 to 19 dBA in the upstairs bedrooms.

The double pane windows and doors on the first floor were only .5 inches (1.27 cm) and was expected to have a Sound Transmission Class (STC) of 28 dBA. Studies have shown that measured transmission loss in homes is about 5 dBA less than the rated STC. The measured noise reduction on the first floor of 23 dBA is, therefore, consistent with the window construction there.

The lower noise reduction on the second floor was found to be due to a "flanking path". Individual records of C402 overflights had a tonal component from its propellors at 125 Hz (100 Hz when receding). Examination of the 1/3-octave band levels showed an amplification of the aircraft noise in the 100 Hz band. For one aircraft, with the approaching propeller tone in the 100 Hz band, the effect was extreme.

The construction of the master suite had partial walls to the master bath, and exposed vent piping. This pipe was of copper, with no lagging, and visible from the master bedroom. It was concluded that this was the cause of the low frequency problems observed in the master bedroom, and appropriate recommendations were made to the homeowner.

5 Conclusion

An interesting aircraft noise problem at the Nantucket Memorial Airport has been discussed. Diagnostic tests were performed on the aircraft overflights using 1/3-octave band sound levels averaged over 1 second. These were used individually to diagnose a flanking path in the residence, and aggregated to confirm the low sound reduction resulting from the design of the home.