

**METHODS OF COMPARING AIRCRAFT TAKEOFF
AND APPROACH NOISES**

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Revised

INTRODUCTION - For many years studies have been underway in an effort to develop means for predicting the subjective reaction of people to noise in terms of its physical characteristics. Considerable progress has been made in this field during the last 30 years. At the present time means are available for predicting the manner in which the average of a large number of people will rate certain broad band noises in terms of loudness or annoyance, provided the subjects are exposed to each of these noises under identical physical and psychological conditions. Studies are being made in an effort to develop means for predicting the relative subjective reaction to noises of varying time duration and to noises having discrete frequencies. It is anticipated that usable results will be available from these studies in the near future. However, some of the noises produced by jet engine compressors are quite complicated compared with the broad band noise plus one pure tone or a tone and its harmonics being used in these studies. It is anticipated that means for predicting the relative subjective reaction to some of these noises will not be obtained in the near future and may never be obtained. It is therefore necessary that some other means be made available for determining the subjective reaction of people to complex jet aircraft noises.

It is the purpose of this information report to describe a method for rating complex aircraft noises or noise flyover cycles which cannot be handled by means of mathematical formulae by comparing them with simpler aircraft noises or noise flyover cycles which can be handled by mathematical formulae.

The report describes the need for an objective means for rating aircraft noise and recommends areas which should be investigated.

1. EXPOSING THE LISTENER TO AIRCRAFT NOISES FOR THE PURPOSE OF MAKING COMPARISONS

- 1.1 **Introduction** - This is an outline of methods used in exposing individuals on the ground to noise produced by aircraft flying overhead during a takeoff from or a landing approach to an airport and/or simulating these exposures for the purpose of making comparisons. An exposure involves the subject being exposed to the aircraft noise from the time it is first heard, as the aircraft approaches the subject, until it cannot be heard, after the aircraft has passed by. The actual time duration will depend on the aircraft noise level and its radiation pattern and on the background noise level. For the purpose of making comparisons of noise exposures, the exposure time is considered to be the time during which the aircraft noise is above an arbitrary noise background level.

A noise-exposure comparison may be made for any ground location as the aircraft takes off from, or approaches, a nearby airport, using a specified flight path, aircraft configuration, and power-plant-operating regime. The usual comparison involves the use of a location on the ground directly under the flight path at a distance from the airport runway representing the distance to the nearest residential community. For takeoff comparisons, the distance is from the beginning of takeoff roll at the far end of the runway; and for approach comparisons, the distance is from the touch-down point on the

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near end of the runway. The ground location for the subject being exposed to aircraft noise may be outside or inside of a residence or other building.

- 1.2 Methods - The following is a review of five methods which have been used in comparing the noise of aircraft flyovers or simulated flyovers.
 - 1.2.1 Listening to the flyovers themselves is the most realistic method of making comparisons, but it has the disadvantage that if the time delay between flyovers is too long, it is difficult for the subject to remember accurately his reaction to the first flyover after the second aircraft has passed.
 - 1.2.2 Simulated comparisons may be made by operating actual aircraft power plants on stationary test stands in the open and driving the subjects by in an auto or truck. This simulation will be unrealistic with respect to flybys, in that the auto or truck will not be able to move fast enough to simulate the flight speed of the aircraft, and the aircraft aerodynamic noise and doppler effects are absent or different. However, comparisons made by this method may be extremely valuable during engine development.
 - 1.2.3 Comparisons may also be made by making tape recordings of the flyover noise from the aircraft to be used in the comparisons, and playing back this noise in a special room using special playback equipment. The room must be treated to minimize standing waves and the playback system should be capable of reproducing the noise in the room at the same level as the original noise for all frequencies. This method has the disadvantage that if the noise is recorded in the open and played back in a room at the same level, the quality may be quite different than it is outdoors. Another factor is that in the open the noise comes from one direction but comes from many directions in a room. This tape recording scheme can also be used in connection with aircraft engines on outdoor test stands. A car can carry the recording equipment past the test stand at a distance less than the flyby altitude and at a speed correspondingly lower than the airplane speed to attain a simulated flyover noise cycle. Then the recorded noise level can be attenuated to simulate airplane altitude and the spectrum reshaped to compensate for air attenuation. The resulting noise cycle is called a synthesized flyover.
 - 1.2.4 A more realistic procedure is to record noise inside of a standard house for listening in the special room. To overcome the difficulty involved in using a standard house the noise may be recorded in the open and then played onto another tape through a filter set which will give it the same attenuation as a standard house and the filtered noise then played back in the special listening room.

- 1.2.5 Headphones have been used for flyover comparisons, but there are many unsolved problems in the use of this method. A microphone can be mounted in one phone unit to monitor the noise while subjects are listening to other phone units. A six cc cavity volume is considered standard for the monitoring phone; however, the volume in the subject's ear-to-phone space will depend on the subject's ear and head shape. The low frequency noise level will depend on the leakage in the depression under the subject's ear adjacent to the jaw bone. In addition to such variables it is difficult to subjectively equate within a matter of a few decibels the level of sound heard via earphones vs. the same sound heard in open air.

In view of the above it is obvious that there is no ideal system for comparing the noises of different flyovers.

1.3 Summary

- 1.3.1 Listening to flyovers in the open for making comparisons of flyover noise is realistic but not usually practical for general use.
- 1.3.2 Listening to stationary power plants for making comparisons is valuable during engine development prior to a new power plant being available for flyover testing. It is not practical for general use.

(With regard to taped noise...)

- 1.3.3 Listening to tapes of flyovers made in free field and played back in a special room at free field levels for making comparisons may be misleading. Therefore, any such comparisons made in the special room should be given a final check by listening to the tapes in free field.
- 1.3.4 Tapes of flyovers played back into headphones may give misleading comparisons. Therefore, any comparisons made using headphones should be given a final check in a special playback room, or if at free field levels in free field.
- 1.3.5 Taped free-field noise attenuated to inside house levels and played in a special room is recommended for comparisons of noise level and quality. (See reference at end of document for standard procedures.)

2. DETERMINATION OF NOISE LEVELS OF AIRCRAFT FLYOVER NOISES USING AN EXPOSURE PROCEDURE RECOMMENDED IN SECTION 1

- 2.1 Introduction - It has been demonstrated that the overall sound pressure levels of various noises do not correlate well with subjective reactions to these noises. A subjective attribute of sound, called loudness, the unit of which is called the phon, has on occasion been used as a measure of the subjective reaction people have to noise, and a number of scales for predicting the loudness of sounds have been proposed.^{4, 5, 13, 15, 16} Unfortunately, these scales are in disagreement with each other and, at best, none of these loudness scales does as well as might be desired in predicting the judged loudness of aircraft noise.^{3, 8, 10}

The Mark VI version of a loudness scale developed by S. S. Stevens is being considered for adoption as a standard for loudness by the American Standards Association.¹⁵ At the same time, the International Organization for Standards is evaluating two different loudness scales and calculation schemes--one by S. S. Stevens (Mark VI) and one by E. Zwicker.¹⁶ The two methods differ considerably in calculation procedures and in obtained results for a given noise.

During the last few years, as a result of the concern of airport neighbors about aircraft noise and the desire of the aircraft industry to be able to predict the reaction of airport neighbors to various aircraft noises, much additional work has been done to develop measures of noise that correlate better with basic subjective responses to the noise.

The Port of New York Authority had a study made which resulted in the proposal of a new scale, called perceived noise level, the unit of which is called the PNdB.^{2, 8} The PNdB scale-weights the various octave bands somewhat differently than most loudness scales, particularly in the higher frequency bands. The PNdB scale was proposed as a scale of the subjective reaction of listeners to the "noisiness" of a sound rather than its loudness. Loudness-calculation procedures, which use the phon as their unit of measurement, give results which differ somewhat for a given aircraft noise from the perceived noise level, PNdB scale.

The International Organization for Standards has proposed a standard procedure for measurement and description of aircraft noise in the vicinity of an airport; the proposed procedure uses the PNdB scale as its basic unit of measurement.²⁰

- 2.2 Relating Community Reaction to Subjective Scales - Much work has been and is being done in an effort to predict community reaction to aircraft noise. In this work, attempts are being made to relate such fundamental measures as noisiness and loudness to community complaints and behavior. The relation of these measures to community reaction is, of course, variable and not very precise, due, no doubt, to fear of crashes, attitudes toward the airlines, previous exposure to aircraft noise and other such factors that influence different people in different ways. An understanding of these factors is obviously important to the public relations departments of airlines and airports. However, the basic evaluation of aircraft noise must be based on the primary relations between acoustic factors and subjective responses that are not colored by fear, anger, or even irritation of people, which depend, to some extent, on non-acoustic factors and may change radically overnight.

It must be emphasized that the engine manufacturer, the airplane manufacturer, and the airline operator, in developing a new power plant and putting it into operation, must do so without the benefit of a demonstration to determine the airport neighbors' reaction to the noise that it will make. The manufacturers will have some noise goals that they are working to in terms of peak PNdB and/or time duration and/or discrete frequency height above the broad band noise. However, the new power plant may have some new noise characteristic that was not contemplated when the goals were written. For example, the radiation pattern may be such as to produce unexpected level variations or the noise may contain some peculiar quality, such as static, cricketing, buzzsaw, etc. Thus, when there are no means available for mathematically rating a noise, subjective means must be used to rate it in comparison with a noise that can be rated mathematically.