



AEROSPACE INFORMATION REPORT

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HELICOPTER AND V/STOL AIRCRAFT NOISE MEASUREMENT PROBLEMS

1. PURPOSE

The noise signatures of vertical and short takeoff and landing (V/STOL) aircraft can differ substantially from those of conventional takeoff and landing (CTOL) aircraft for which measurement procedures have been standardized. It is the purpose of this document, therefore, to review the more important factors associated with the measurement of external noise of V/STOL aircraft and to provide general guidance for the acquisition and analysis of such data. In this document, the term V/STOL aircraft is understood to include all aircraft which may operate in:

- a. The VTOL mode, exclusively, where the aircraft takes off and lands vertically and horizontal transition is made in the air.
- b. The STOL mode, exclusively, where the aircraft takes off and lands with a relatively short ground roll and is capable of steep climbout and approach angles.
- c. The VTOL, STOL or CTOL mode.

These aircraft, therefore, include helicopters, tilt rotor configurations, propeller and prop-fan aircraft, combination lift-fan and cruise engine configurations, and various types of externally and internally blown flap installations.

2. PROBLEM AREAS

- 2.1 Because of the wide variety of aircraft which must be considered, the acoustic frequency range of interest must be extended well below that presently considered for CTOL aircraft which are for the most part powered by turbojet or turbofan engines. For example, the rotor-rotational noise on large helicopters has maximum energy at infrasonic frequencies with the fundamental in the range of 10 to 20 Hz, but can still be perceived aurally as repetitive impulses.
- 2.2 It is well known that the shape of the annoyance response curve, reference SAE ARP 865A, is most heavily weighted in the frequency range from 3 to 4 kHz. It has also been shown that the preferred octaves with 63, 125 and 250 Hz geometric mean frequencies, are the most important from an aircraft detection standpoint. However, it is the distinctly separable acoustical "events" taking place 10 to 20 times per second in rotorcraft that appear to elicit significant subjective reaction. It is therefore considered necessary to measure the fundamental and lower order harmonics of the rotational noise, as well as the higher harmonics, to provide data for correlation with observed subjective reactions and analytical noise prediction methods. Information that can be lost by a noise measurement system that does not have adequate low frequency capability, e.g., suppression of high crest factors, is shown by Figure 1.

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- 2.3 An aspect of the noise measurement problem associated with some types of rotor and propeller aircraft relates to the impulsive and impact characteristics of the noise signatures. Impulsive noise is characterized by pulses of extremely short duration and extremely short rise time to their maximum levels. Rotors emit high amplitude, modulated and repetitive impulse noise at relatively low frequencies as well as at high frequencies. Propellers have similar characteristics but at higher associated frequencies. Thus, to "capture" peak amplitudes accurately, the acoustical data acquisition systems must have very wide frequency response and high crest factor capability. Experience indicates that power measuring systems such as rms type analyzing circuits and graphic level recorders are not suited to analyze and present such data. Spectral displays lose relative phasing information, which an amplitude-time histogram preserves, however. A systematic approach is needed to develop common descriptors and instrument systems for waveform characteristics related to subjective response.
- 2.4 Another problem area related to V/STOL aircraft noise measurements is the probable, eventual standardization of noise measurement distances. For example, distances as short as 150 to 200 feet (45 to 61 m) have been used to establish baseline measurement perimeters for CTOL transport aircraft to assure that data are reasonably representative of the acoustic far field. For conventional turbofan aircraft such as the 707 or DC-9, for example, these distances may be satisfactory. However, for some types of V/STOL aircraft, such as those which might employ large tilting rotor-props at the wing tips, a 200 foot (61 m) distance may still be in the acoustic near field because of the physical separation of the various noise sources and the long wavelengths associated with low frequency noise. Delineation of the boundary between the near and far fields may also be difficult for aircraft with large, distributed, line noise sources such as internally blown flap systems. This situation should be thoroughly investigated before any attempt at standardization of noise measurement distances is made, since it has an important bearing on the ability to correlate predicted noise levels with field measurements. Present experience with CTOL aircraft has shown that nominal boundary between the near and far fields is within about two major noise source dimensions or two wave lengths of the lowest frequency of interest, whichever is greater. Whether these criteria are valid for a large, distributed line source should be verified.
- 2.5 The one feature of V/STOL aircraft that, perhaps more than any other, differentiates them from CTOL aircraft, is the use, in general, of some form of powered lift augmentation. This distinction holds true whether one considers helicopters (as a class), configurations with blown flap systems, tilt cruise engines or the use of lift fans, etc. For some configurations, such as helicopters or aircraft employing tilt cruise engines, the power system which is used to provide lift is also used to provide cruise thrust. In others, such as those employing lift engines and independent cruise engines, the lift engines are used only for takeoff and landing and are shut-down for cruise conditions. Since concern is with the total noise picture, measured noise levels must be the sum at the point of measurement of all the noise sources on the aircraft. However, at measurement points close to the V/STOL port, each of the sources may be changing its noise characteristics independently of the other sources on the aircraft. This independent modulation of power (and noise) is an additional variable in the description of community noise. Although the goal of the operator will be that the aircraft is always operated in its most efficient and economical mode, the socio-economic makeup of a community adjacent to a V/STOL port or its topography may require the imposition of certain operational noise constraints. Thus, it is conceivable that on a given route a V/STOL aircraft might operate as a CTOL at one airport, as a STOL at another and as a VTOL at a third. Therefore, a meaningful noise estimation procedure and measurement program will require that the temporal characteristics of each of the noise sources be taken into account for all potential terminal area and low altitude cruise modes of operation.
- 2.6 Processing of acoustic data involving very low frequency and/or repetitive impulse or impact noise should be approached with caution, particularly where the end product of the data reduction process is to be a subjective rating number such as Effective Perceived Noise Level (EPNL). The EPNL rating scheme was developed on the basis of broad band noise corrected for discrete tones and duration. In addition, the lowest one-third octave band center frequency considered is 50 Hz. The difficulty of objectively quantifying subjective response to repetitive impulse noise, such as helicopter rotor blade slap, is reflected by the fact that no criteria for acceptability have been agreed on. Similarly, with respect to noise resulting from relatively high propeller tip speeds, i.e., at Mach numbers greater than approximately 0.8, the effect of many harmonically related tones has not been evaluated, although it is known that the harmonic relationships significantly affect annoyance. The establishment of criteria in this area is mandatory before progress can be made towards designing propeller/rotor V/STOL aircraft that will have acceptable community noise levels.