Appendix J

Measuring Aircraft Noise

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MEASURING AIRCRAFT NOISE

Basic Noise Measures

There are several attributes associated with sound: it may be loud or faint; it may be high-pitched or low, discordant or pleasing, etc. These various characteristics must be quantified in order to arrive at an engineering description of any given sound and to have a means for comparing two sounds separated in space and time.

The word noise is in wide use in many fields of technology today, but if we limit our discussion to its use in relation to sound, one may define noise loosely as unwanted sound. For our purposes, an acceptable definition of sound is that it is a physical disturbance of the atmosphere that can be detected by the human ear. A simple source of sound familiar to all of us is the tuning fork. When it is struck, it vibrates in a to-and-fro motion setting the air in motion in the same manner. The resulting disturbance of the air travels outward from the tuning fork and upon entering the ear canal of the listener produces an auditory sensation, or sound.

We are concerned in defining the impact of aircraft noise on people, on communities and on land uses. Before discussing these aspects, it is useful to discuss some of the properties of sound and develop some of the quantitative scales that are used in the measurement of sound.

Decibel Scale

The pressure fluctuations in the quiescent atmosphere, which are detected as sound, are generally very small, but nonetheless here is a large difference in pressure between the faintest audible sound (e.g., rustling leaves) and the loudest sounds (jet engines, rockets). The ratio is on the order of a million billion. Although the human ear can distinguish the difference in loudness between these different sources, the differences in perceived loudness are much smaller than in the actual measured differences in pressure.

It is possible to construct a scale for measuring the pressure fluctuations (sound pressure) which corresponds fairly well with the properties of the human ear as far as loudness perception is concerned. This scale is called the “decibel scale” and quantity that it measures is called sound pressure level. The zero on this scale corresponds roughly to the quietest sound an average person can hear. A sound level of 120 on this scale corresponds to the point where the noise becomes painful.

Frequency Spectrum

Apart from the loudness of a sound, there is the characteristic of pitch. While the size of pressure fluctuations in the air determines the loudness of the sound, the pitch is related to how often such fluctuations repeat. For audible sounds this repetition may vary from about 20 times per second to around 16,000 times per second. If a given sound consists of fluctuations that repeat 440 times per second, we say that the sound has a frequency of 440 Hertz (Hz), where one hertz is equivalent to one frequency per second.

There are various kinds of sounds. The sound produced by the simple tuning fork is known as a pure tone and is usually composed of a single frequency. An example of a more complex sound is a musical note such as Middle C on the piano. This kind of sound has a fundamental frequency (256Hz) plus several overtones or harmonics. In practice one encounters sounds that are much more complex, such as speech, music and the wide range of sounds classified as noise. Each of these sounds contains energy extending over a rather wide frequency range. This includes, of course, most aircraft noise, as well as the noise produced by most motor vehicles. One can identify the pure tone with the whine of a jet engine compressor or fan, and the broadband noise with the roar of the exhaust of a turbojet engine.

A-Weighted Sound Level

To complicate matters, the human ear is more sensitive to sound energy at higher frequencies than at lower frequencies, and further, the ear's sensitivity to sounds of different frequencies changes with the level (loudness) of the sound. In problems involving people's reaction to noise, one needs a way of accounting for the ears varying sensitivity to noises that vary in frequency and in level. Much effort has gone into studies to develop improved methods of relating physical measurements to the subjective response of human listeners. One early approach for improving the correlation between measured pressures and subjective human response was the introduction of frequency weighing networks on sound level meters.

The weighting network that is in the widest use today is the A-weighting network. The network discriminates against the lower frequencies, to which the ear is less sensitive, according to a relationship approximating a person's subjective reaction in terms of loudness at moderate sound levels. Noise levels with the A-weighting network are identified as the "A-weighted sound pressure level of 77 decibels," or more simply as the "A level of 77dB," or shorter yet, as 77dBA." The A-weighting is widely used throughout the world to measure community and industrial noise. It is also widely used to measure motor vehicle and traffic noise. Table A-1 lists the approximately A-level of some sounds.

Day-Night Average Sound Level (DNL)

The Day-Night average sound level, abbreviated as DNL and symbolized as Ldn, is the 24-hour sound level, in decibels, for the period from midnight to midnight, obtained after the addition of 10 decibels to sound levels from 10 p.m. to 7 a.m. DNL was developed in 1973-74 for the Environmental Protection Agency. DNL is a measurable quantity and can e measured directly at a specific location using portable monitoring equipment. It is widely used for estimating noise impacts at both civil and military airports. DNL may be used for quantifying other noise sources, such as auto traffic, and for comparing them to airport generated noise. A noise contour is a continuous line on a map of the airport vicinity that connects all the points of the same noise exposure level. Contour values usually range from less than 55Ldn for lightly impacted areas to more than 75Ldn for heavily impacts areas. The contours are then drafted on a map of the airport environs. Chapter 3 contains Exhibit 3-6 which illustrates the compatible land uses associates with the various DNL levels.