3. CONFERENCE SCOPE AND NOISE CONCEPTS

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SUMMARY

The scope and objectives of the conference are indicated. In addition, some guidelines and definitions for the presentation of the subject matter of subsequent papers are provided.

INTRODUCTION

The scope of the conference and its objectives can be described with the aid of figure 1. The focal point for all discussions will be the airport noise problem for large commercial jet airplanes. Emphasis is on the technical aspects of the problem, rather than on the political, legal, or regulatory aspects. Attention will be given to the minimization of noise during landing approach, ground operations, and climbout. There will be no direct references to helicopters, V/STOL aircraft, military aircraft, and general aviation, although the material presented will have some obvious application to those vehicles. Likewise, no direct reference will be made to the sonic-boom problem nor to land-use planning. In addition to indicating the scope and objectives of the conference, the purpose of this paper is to provide some guidelines and definitions for the presents-tion of the subject matter of subsequent papers.

NOISE-REDUCTION METHODS

At the present time the optimum approach to noise alleviation has not been defined. However, such methods as noise reduction at the source through proper component design, operational procedures to minimize noise exposures, and the application of duct treatment technology are all known to be beneficial and will be discussed in several of the conference papers.

One of the main conclusions of the International Conference on the Reduction of Noise and Disturbance Caused by Civil Aircraft, held at Lancaster House, London, November 22-30, 1966, was that future airplanes needed to have more acceptable noise characteristics than those currently in service. The ability to control noise at the source was considered necessary not only to produce noise reductions but also to make possible predictions of noise as a basis for effective community planning.

ENGINE CONSIDERATIONS

The most significant factor in noise alleviation at the source has been the development of the fan jet or bypass engine. Two fan jet engines are illustrated in figure **2.** The illustration labeled "Current" represents a type of fan jet engine that is in common commercial airplane usage and which is also involved in some of the noise-reduction studies to be described. The second illustration represents a higher bypass-ratio engine of the type being developed for large future commercial airplanes. These future engines are characterized by large-diameter fan sections and large fan exits.

The data of figure 3 illustrate the noise-reduction potential for the proposed type of engine. Relative perceived noise levels are shown as a function of bypass ratio for the current operational engines and for those proposed for future airplanes. Data are for a 200-foot sideline-observer location and for equal-rated thrust. Perceived noise level is defined more exactly subsequently; however, it is noted to be a unit of subjective noisiness and, hence, lower values are desired. The current family of turbojets constitute the reference point in this figure and, of course, for them the bypass ratio is 0. The current fan jets are represented by the middle shaded area, and the bypass ratios are noted to be relatively small. Much study and development work has led to consideration of bypass ratios of the order of **4** and above for purposes of noise reduction. The noise-reduction potential for the future engines is represented by the bottom boundary of the long shaded region and this bottom boundary is largely defined by the jet-mixing noise. Because noise from the rotating machinery and internal equipment for these high-bypass-ratio engines tends to be relatively more intense, the long shaded region has considerable depth. Much of the present-day research is aimed at reducing the levels of the interior noise components represented by this shaded region so that the full noise-reduction potential of such engines may be realized.

Two general philosophies of internal noise reduction for fan engines are illustrated by the drawings in figure **4.** The fact that the inner components, such as the fan, compressor, and turbine, are significant in noise production leads to the first philosophy that proper design of such components can be effective in optimizing the noise charscteristics of the engine. The second philosophy of design, as represented by the bottom drawing, is based on the concept of minimum interference with the interior components of the engine and involves only the application of noise-reduction materials external to the engine in the vicinity of the engine nacelle.

The component-design approach is judged to be most attractive for future engine developments rather than for modification of existing engines. The concept of applying acoustic treatment in the nacelle external to the engine is attractive €or retrofitting existing nacelles as well as for incorporation into new engine designs.

ENGINE NOISE SPECTRA

The characteristic noise spectra for engines of interest for commercial applications can be discussed with the aid of figure 5. This figure contains schematic representations of the two types of noise present in all engine spectra, that is, broadband noise and tones. The broadband noise, which is characterized by random-type time histories, may come from the mixing of the exhaust jets with the outside air and from the interactions of the airflows with both the stationary and rotating parts of the engine. The tones, on the other hand, have periodic time histories and are associated with only the rotating components of the engine. It is significant that for the turbojet engine, the broadband noise dominates; for the current fan jet engines, both the broadband and the tone noises are important; and, for some future fan jet engines, the tones may dominate the noise spectrum.

Subsequent papers show the tone content of the noise to be especially significant from a subjective standpoint. Hence, the proper measurement of the significant components of the noise spectrum is important. The rest of this paper is devoted mainly to descriptions of concepts of measurement and subjective evaluation of noise and to definitions of important quantities. This review of these quantities and concepts should be helpful in understanding some of the subsequent papers.

One of the useful variables in the analyses of aircraft noise data is the characteristic bandwidth of the analysis equipment. The data of figure 6 illustrate the results that are obtained from analyses of different filter bandwidths for a relatively simple broadband spectrum with one tone. The analyses of such a spectrum with commercially available analyzers such as, for instance, 1/10-octave, 1/3-octave, and full-octave filter systems would give the spectra indicated in the figure. All the spectrum lines are representations of the same noise; that is, the overall noise level is the same for each. The full-octave band spectrum, for instance, has higher band levels than the 1/3-octave band spectrum in the region of the broadband components because of the wider filter bandwidth. The levels of the bands containing the tone are nearly the same irrespective of bandwidth since the tone is relatively strong. One of the important subjective response considerations in spectra with tones is the amount by which the tone protrudes above the broadband noise; hence, the definition of such a factor must take into account the bandwidth which has been used. Since the choice of bandwidth is a matter of judgment, various bandwidth values are used. Wider bandwidths generally lead to simplified procedures whereas narrow bandwidths lead to a more detailed physical description of the data.

Noise levels (a term used interchangeably with sound pressure levels) are expressed in decibels, referred to the conventional value of 0.0002 dyne/cm^2. A decibel is a logarithmic unit and represents the smallest perceptible change in amplitude of a sound. A 6-dB change represents a factor of 2 in sound pressure or a factor of 4 in sound power.

PERCEIVED-NOISINESS CONCEPTS

One of the subjective measurements of noise that has received wide acceptance and which will be referred to in several of the conference papers is that of perceived noisiness. Although this concept will be treated in detail in some of the subsequent papers, a brief discussion here of the basic concepts may be helpful in the understanding of some of the other subject matter to be presented.

Figure 7 indicates the nature of the reaction of people to noise. Shown in the figure is an example of a 1/3-octave band noise spectrum for which each of the frequency bands is judged by human subjects to be equally noisy. It can be seen that a high-frequency band having relatively low band levels is considered to be as noisy as a lower frequency band having higher band levels. The curve labeled "Equal-noisiness contour" is one of a family of curves used to define weighting functions in the calculation of perceived noise levels.

Perceived noise level is noted to be a function of the sound pressure level plus a spectrum shape factor derived from curves such as the one just described; that is -

$$\begin{array}{c}\text{PERCEIVED NOISE}\\\text{LEVEL (PNL)}\end{array} = \begin{array}{c}\text{SOUND PRESSURE}\\\text{LEVEL (SPL)}\end{array} + \begin{array}{c}\text{SPECTRUM SHAPE}\\\text{FACTOR}\end{array}$$

The significance of the spectrum shape factor is further illustrated by the data presented in figure **8.** The two broadband noise spectra are judged to be equally noisy even though the overall noise level associated with the solid curve is 10 dB higher. The much higher noise levels of the solid-curve spectrum at low frequencies compensate for the slightly higher levels of the dashed-curve spectrum at high frequencies.

The concept of effective perceived noise level involves the modification of the perceived noise level to include both a tone weighting factor and a duration weighting factor; that is -

$$\begin{array}{c}\text{EFFECTIVE}\\\text{PERCEIVED NOISE}\\\text{LEVEL (EPNL)}\end{array} = \text{PNL} + \begin{array}{c}\text{TONE}\\\text{FACTOR}\end{array} + \begin{array}{c}\text{DURATION}\\\text{FACTOR}\end{array}$$

The nature of the tone weighting factor can be represented by the spectra of figure 9. These spectra are judged to be equally noisy; that is, the solid-curve basic octave-band spectrum with a tone superposed is equivalent to the dashed-curve octave-band spectrum for which the overall noise level is 7 dB higher. This is just an example; the actual tone weighting factor varies both as a function of the tone amplitude and its frequency.

The nature of the duration weighting factor is illustrated by the sketches in figure 10. Shown schematically in the figure are two perceived-noise-level time histories of flyover noise, one of which has a duration twice that of the other as measured at levels 10 PNdB down from the peak values. Some experiments have indicated that these two flyover-noise situations would be equally acceptable if the peak perceived noise level of the longer one was 3 PNdB lower. This value of 3 PNdB may be considered as an order of magnitude of the duration correction since it may vary for different types of noises.

CONCLUDING REMARKS

The subject matter of the conference is noted to be divided into five sections:

(1) Nacelle acoustic treatment technology

(2) Nacelle acoustic treatment application

(3) Noise generation and reduction at the source

(4) Operational considerations

(5) Subjective reaction

Much of the information in the first two sections, which relate to the development of acoustic nacelle treatment technology and to its application in aircraft design, has been derived from contractual studies with The Boeing Company and McDonnell Douglas Corporation. Each section consists of a number of NASA and contractor papers and these papers represent progress reports since in most cases the research is still underway. Other contractor participants were Bolt Beranek and Newman, Inc., Conesco Division of Flow Corporation, IIT Research Institute, Lockheed Missiles and Space Company, North Carolina State University, Pratt & Whitney Aircraft, Stanford Research Institute, TRACOR, Inc., and Wyle Laboratories.

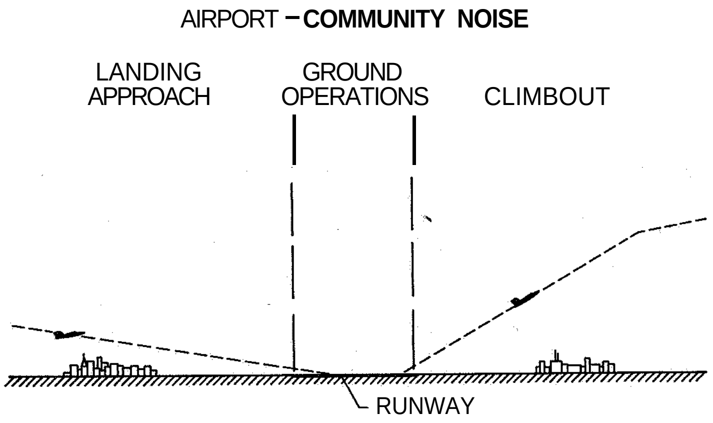

Figure 1

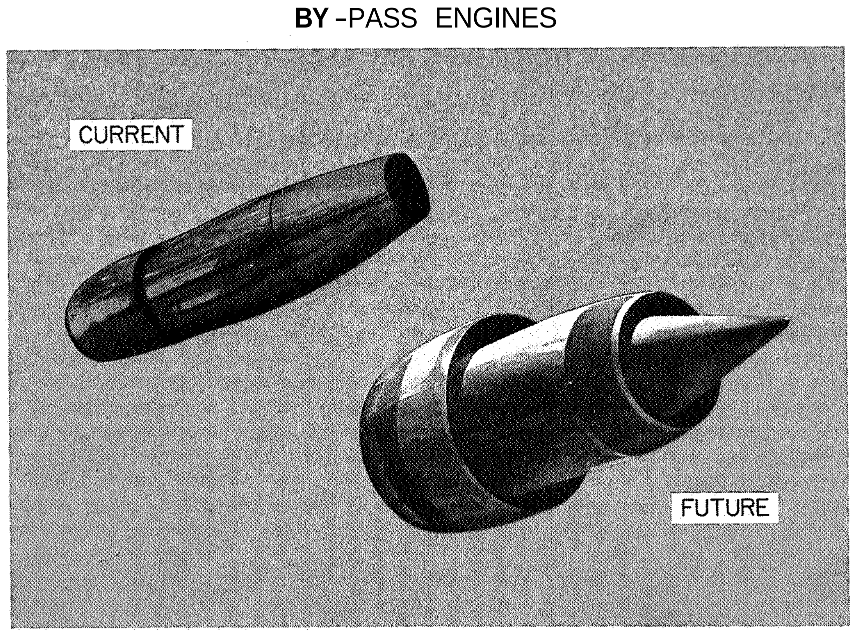

Figure 2

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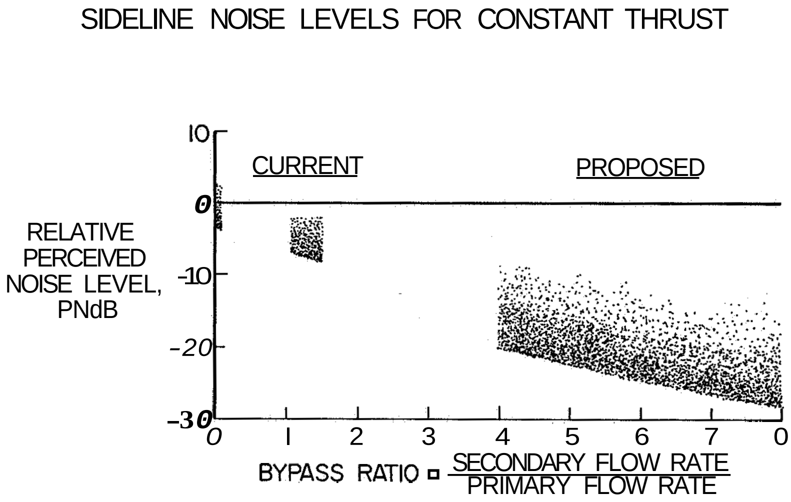

Figure 3

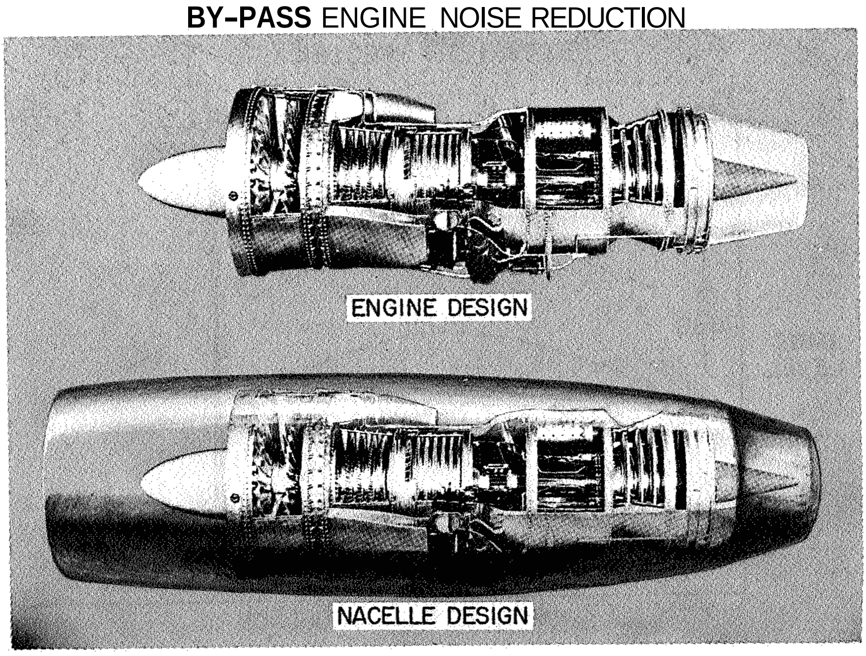

Figure 4 L-68-8538

SCHEMATIC DIAGRAM OF ENGINE NOISE SPECTRA

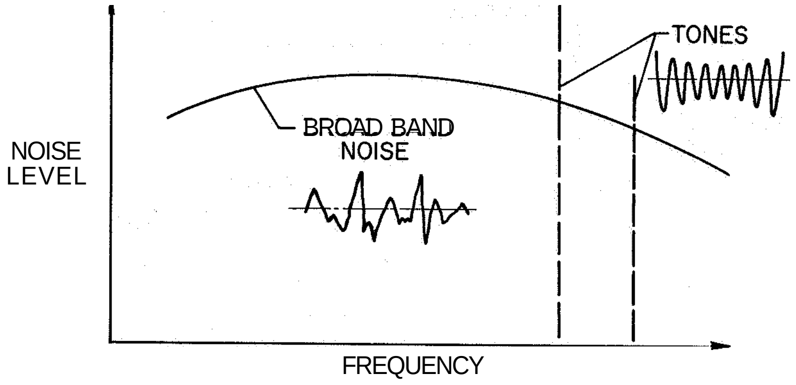

Figure 5

EQUIVALENT SPECTRA

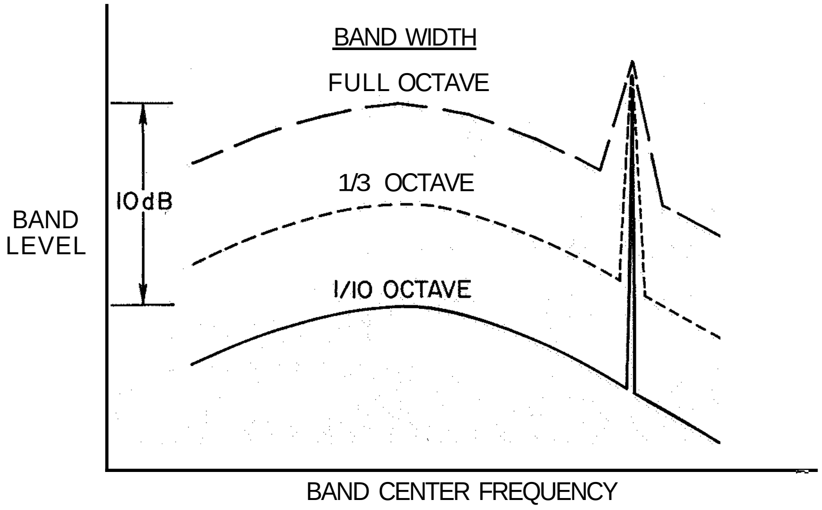

Figure 6

PERCEIVED NOISINESS

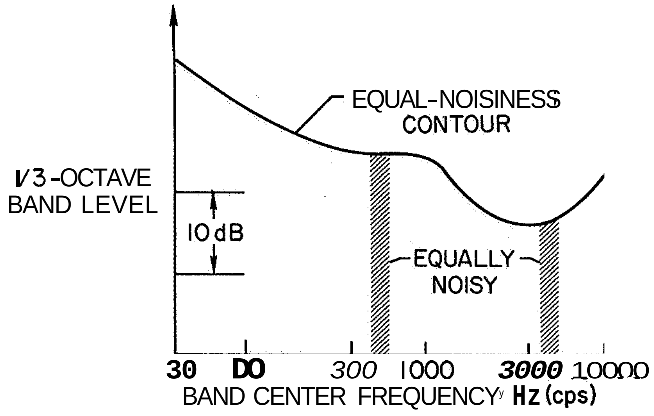

Figure 7

SPECTRUM SHAPES HAVING EQUAL PNL

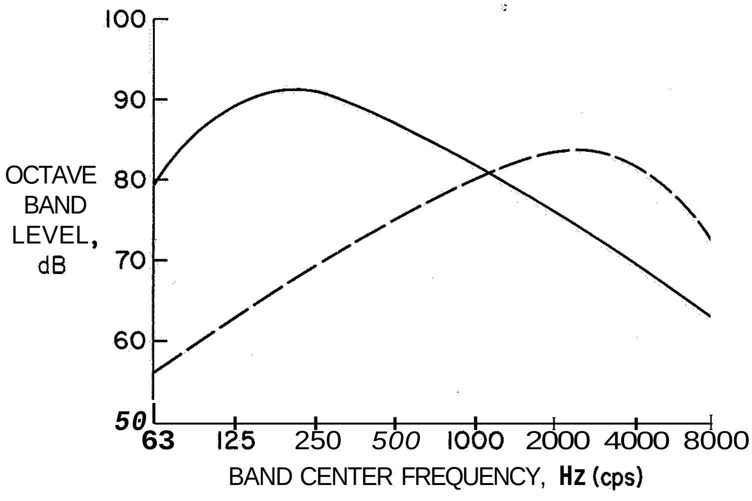

Figure 8

TONE EFFECTS

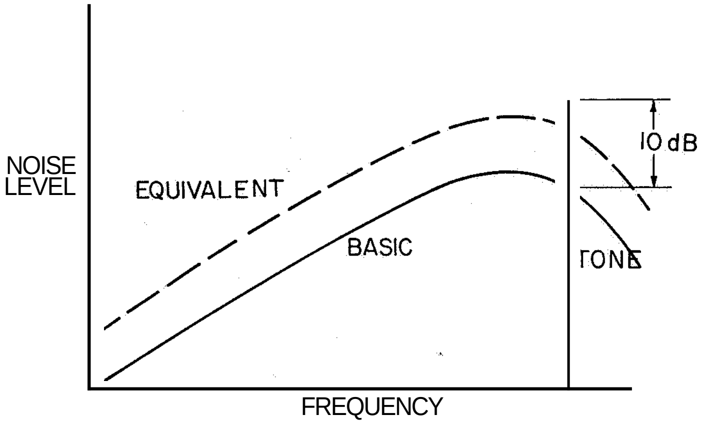

Figure 9

EXAMPLE OF DURATION EFFECTS

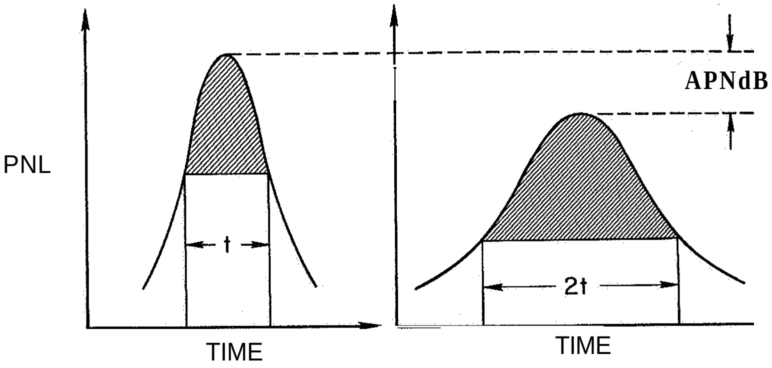

Figure 10