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THE NOISINESS OF LOW FREQUENCY BANDS OF NOISE

By

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February 1975

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16. Abstract

A study was performed to examine the relative noisiness of low frequency 1/3-octave bands of noise. The frequency range investigated was bounded by the bands centered at 25 and 200 Hz, with intensities ranging from 50 to 95 dB (SPL). Thirty-two subjects used a method of adjustment technique, producing comparison band intensities as noisy as 100 and 200 Hz standard bands at 60 and 72 dB. The work resulted in contours of equal noisiness for 1/3-octave bands, ranging in intensity from approximately 58 to 86 dB (SPL). These contours were compared with the standard equal noisiness contours; in the region of overlap, between 50 and 200 Hz, the agreement was good.

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THE NOISINESS OF LOW FREQUENCY BANDS OF NOISE

By Ben William Lawton

There are increasing numbers of low frequency noise sources, affecting people in varied environments. One practical example of such a low frequency noise source is the short takeoff and landing (STOL) aircraft. Jet-powered STOL aircraft will have integrated lift-propulsion systems which will permit shorter takeoff and landing distances than necessary for conventional jet transports. The use of such lift-propulsion systems has been shown to increase the jet exhaust noise, with maximum noise components below 300 Hz, and in some cases, below 50 Hz. This fact is illustrated in figure 1 which shows takeoff 1/3-octave band spectra for a two-engine commercial jet and a comparable simulated STOL jet (from ref. 1). In the figure, the horizontal axis is 1/3-octave band center frequency in Hertz (Hz); the vertical scale is band sound pressure level in dB. The two spectra are essentially the same above the 80 Hz 1/3-octave band; below this frequency, the simulated STOL spectra has components much higher in band SPL than the conventional jet.

The noise of such STOL aircraft will be quantified using perceived noise level (PNL). However, this unit does not consider some of the major bands below 50 Hz. As STOL aircraft and larger conventional jet transports come into commercial service, PNL will become an increasingly inaccurate subjective rating unit and this inaccuracy may be of some considerable importance.

Throughout the development of PNL, relatively little attention was devoted to the frequency bands below 150 Hz. The major effort has been to account for the subjectively more annoying higher frequencies, in the kiloHertz range. Recently, there has been renewed interest in the shape of equal noisiness, or noy, contours used in the calculation of PNL. Several researchers report subjective experiments resulting in modified noy contours for 1/3-octave bands. These contours are shown in figure 2, where the low frequency region is of interest here.

The horizontal axis is frequency in Hz; the vertical axis is sound pressure level in dB, measured relative to the 1 kHz, 1/3-octave band. The heavy line represents the standard noy contour of Kryter and Pearsons, used in the calculation of PNL (ref. 2). The two dashed lines represent studies by Wells (ref. 3) and Ollerhead (ref. 4). Below approximately 100 Hz, both of these dashed contours fall under standard noy contour, indicating slightly more noisiness for a given SPL in the low frequency range. The shaded area represents another study of Ollerhead (ref. 5), which indicates the opposite trend. Here, a given band SPL indicates much less noisiness than the standard noy contours.

The curves of this figure show essentially opposite trends, indicating both more and less noisiness for a given band SPL below approximately 100 Hz. The research reported here was aimed at clarifying or resolving this discrepancy in the low frequency noy curve shape.

The current subjective response to noise study examined the relative noisiness of certain low frequency 1/3-octave bands of noise. The frequency range investigated was bounded by the bands centered at 25 Hz and 200 Hz, with band intensities ranging from 50 dB to 95 dB SPL. Figure 3 shows the frequency/intensity region available to the human subjects who particiapted in the study. The horizontal axis is frequency in Hz; the vertical axis is sound pressure level in dB. The frequency/intensity region of the present research is shown as the boxed-in area. For comparison, the threshold of hearing for 1/3-octave bands (ref. 6) is shown at the bottom of the figure. The commonly accepted lower limit for physiological reaction to noise is also shown at the top of the figure.

Thirty-two human subjects, sixteen males and sixteen females, performed a method of adjustment experiment. The subjects were given the following definition of noisiness, taken from Kryter's book, <u>The Effects of Noise on Man</u>: (ref. 7)

> "The subjective impression of the unwantedness of a not unexpected, nonpain or fear-provoking sound as part of one's environment is defined as the attribute of perceived noisiness." Noisiness means the same thing as "unwantedness," "unacceptableness," or "objectionableness."

Using the method of adjustment and this definition, the subjects were to produce comparison band intensities subjectively equal in noisiness to standard bands at 100 Hz and 200 Hz, both at 60 dB and 73 dB SPL. Figure 4 gives an overview of the experimental design. Each of the eight comparison band frequencies was paired with each of the two standard band frequencies. Thus each subject performed sixteen adjustments.

The subjects were tested individually in a small anechoic chamber located at the Institute of Sound and Vibration Research at the University of Southampton. The chamber had a volume of 34.5 cubic meters, and was used as a pressure chamber for this experiment. The comparison and standard band stimuli were presented to the subjects using a specially constructed loudspeaker. The stimuli had a duration of 5 seconds, alternating between the fixed standard and adjustable comparison bands for as long as the subject required to make the noisiness balance adjustment. Figure 5 presents a representative time history of an adjustment. The horizontal scale is time in seconds; the vertical scale is band sound pressure level for the standard and comparison bands. The figure shows how a subject might make the required noisiness balance over a few repetitions of the standard/comparison pairs. The data obtained from the adjustment would be the band SPL of the comparison when adjusted to be subjectively equal in noisiness to the fixed standard.

Analysis of variance of the data showed none of the counter-balanced presentation conditions to be significant. Therefore, the adjustments of all subjects were meaned over standard band frequency and level. Looking at these results in some detail in the next figures, the mean adjustments are shown with the appropriate portions of the Kryter and Pearsons noy contours. For these figures, the horizontal axis is 1/3-octave band center frequency in Hz; the vertical axis is band SPL in dB. The adjustment means are presented as open symbols; the Kryter-Pearsons noy value contours are shown as the solid lines.

Referring to figure 6 showing the adjustments to the 100 Hz standards, tests were performed to compare the present values to the Kryter-Pearsons noy values. The absolute dB differences between the two sets of points were found to be significant for the lower sets, that is, the present data represented by the circles were found to be displaced upward in dB from the 1.8 noy contour. Also, linear regressions were performed on the sets of points within the region of overlap, between 50 and 200 Hz. For instance, a least squares fit was made for the data circles and the 1.8 noy contour. The slopes of these two lines were tested statistically. These tests revealed no statistically significant differences between the slopes of the present data and the reference noy values.

Referring now to figure 7 showing the adjustments to the 200 Hz standard, similar tests were performed. The statistical procedures showed a significant displacement of the data represented by the diamonds, the adjustments to the 200 Hz standard at 73 dB. Regressions were also performed and the slopes tested: in both cases the slopes were not significantly different. The results of the statistical tests, comparing the present results with the reference noy values, revealed some displacement along the dB scale for two of the present study contours, but agreement of regression line slopes. Therefore, in general, the agreement between the results of the present study and the Kryter-Pearsons noy values can be considered reasonably good.

In summary, the present results are shown in figure 8, compared with the appropriate noy contours. Here the horizontal axis is 1/3-octave band center frequency in Hz and the vertical axis is band SPL in dB. The solid curves represent the equal noisiness contours of Kryter and Pearsons. The broken lines in the lower frequency region are the results of the present study. These results generally follow an eyeball extension of the Kryter-Pearsons curves. On the basis of the small amount of data presented here, it should be possible to extend the equal noisiness contours to lower frequencies. More experimentation is required to confirm the slopes of the curves and to establish the spacings, or growth of noisiness. Noy values for these low frequency bands would be useful when computing the perceived noise level, or any related units, for new aircraft, or any other noise sources containing 1/3-octave band components below 50 Hz.

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CONVENTIONAL AND SIMULATED STOL JET TAKEOFF NOISE SPECTRA

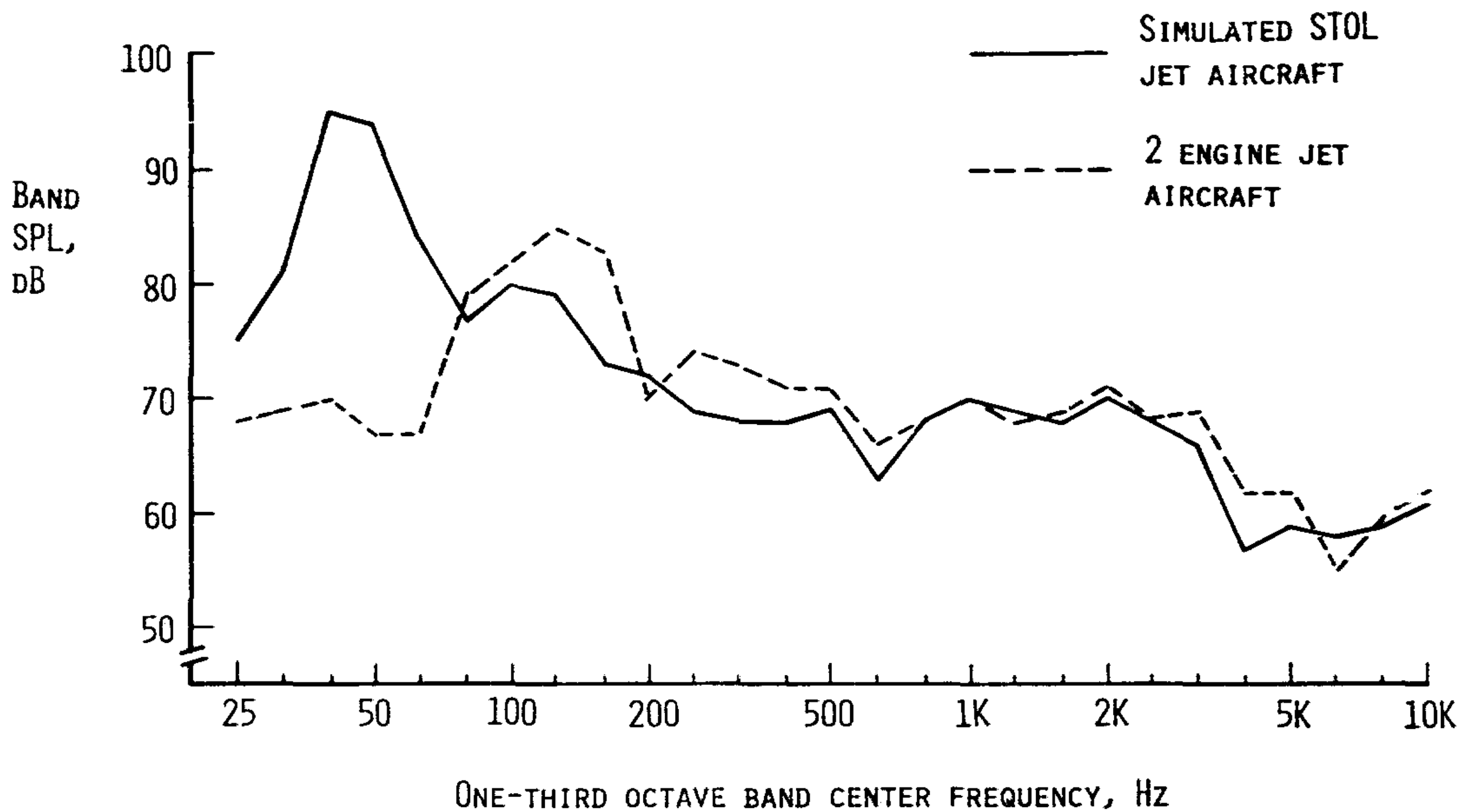

FIGURE 1

COMPARISON OF VARIOUS CONTOURS OF EQUAL NOISINESS

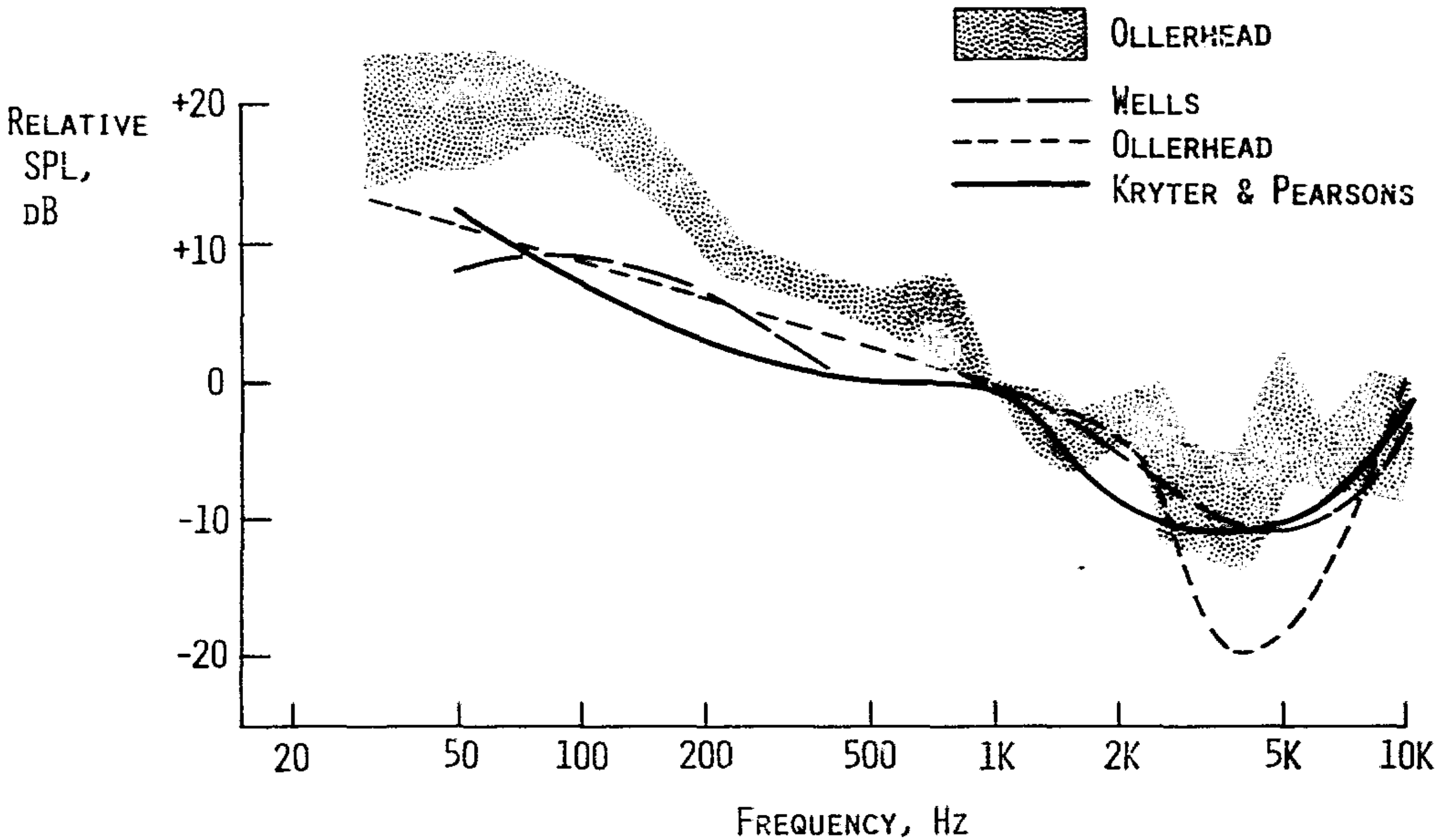

FIGURE 2

FREQUENCY-INTENSITY REGION AVAILABLE TO SUBJECTS
DURING PRESENT RESEARCH

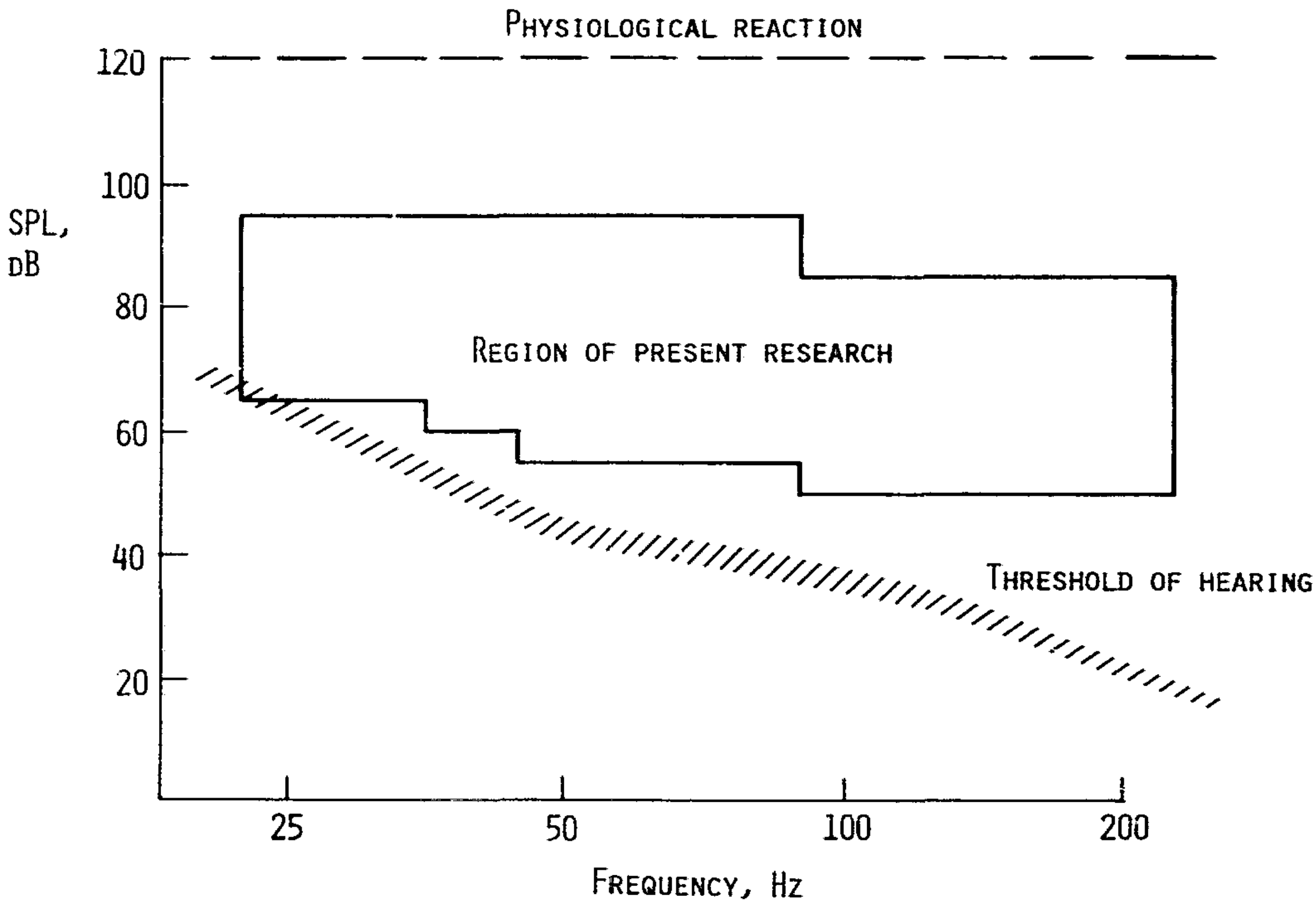

FIGURE 3

ONE-THIRD OCTAVE BANDS USED AS STIMULI

VARIABLE COMPARISON BAND CENTER FREQUENCY, Hz

FIXED STANDARD BAND CENTER FREQUENCY, Hz	25	31.5	40	50	63	80	100	200
100								
200								

FIGURE 4

REPRESENTATIVE TIME HISTORY OF AN ADJUSTMENT

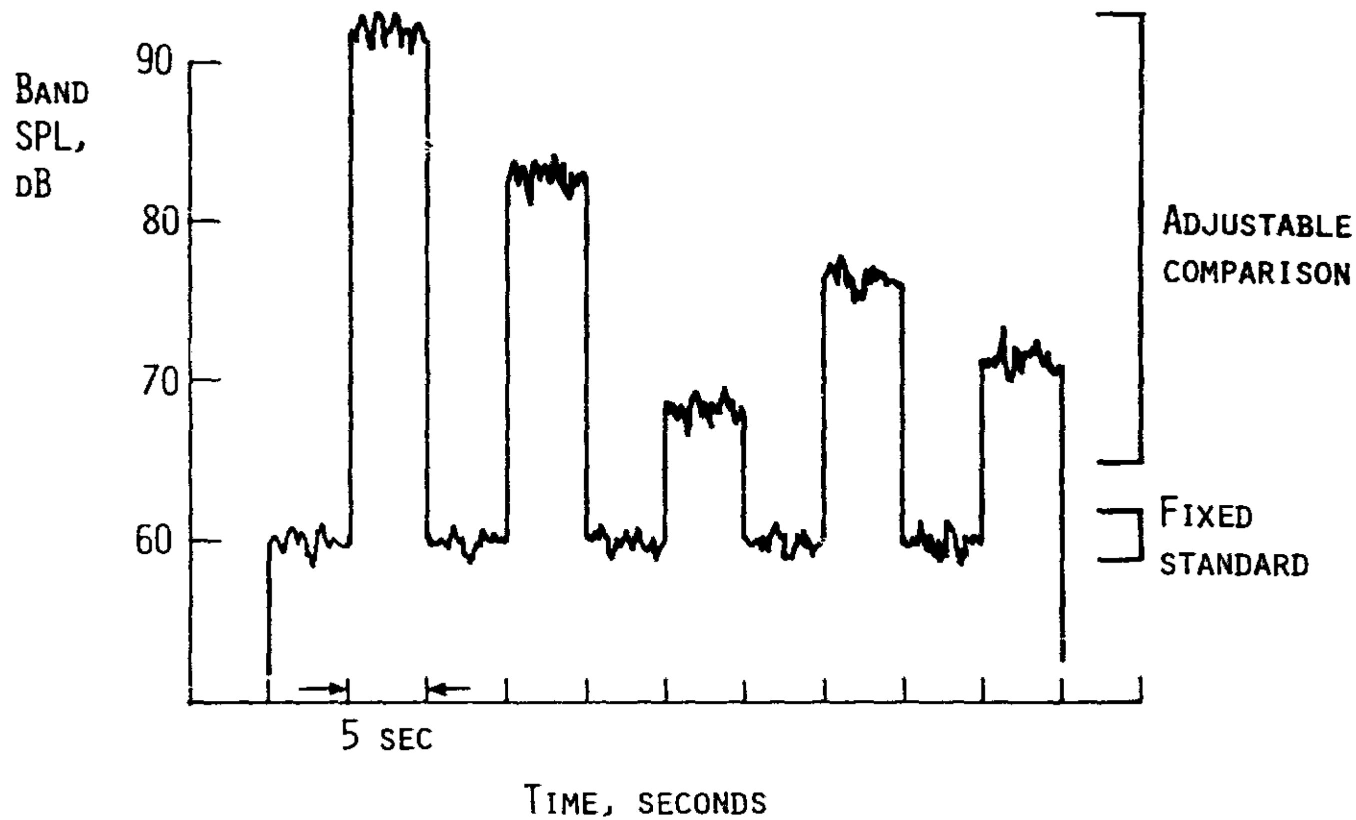

FIGURE 5

COMPARISON OF REFERENCE NOY CONTOURS AND MEAN ADJUSTMENTS
FROM PRESENT STUDY

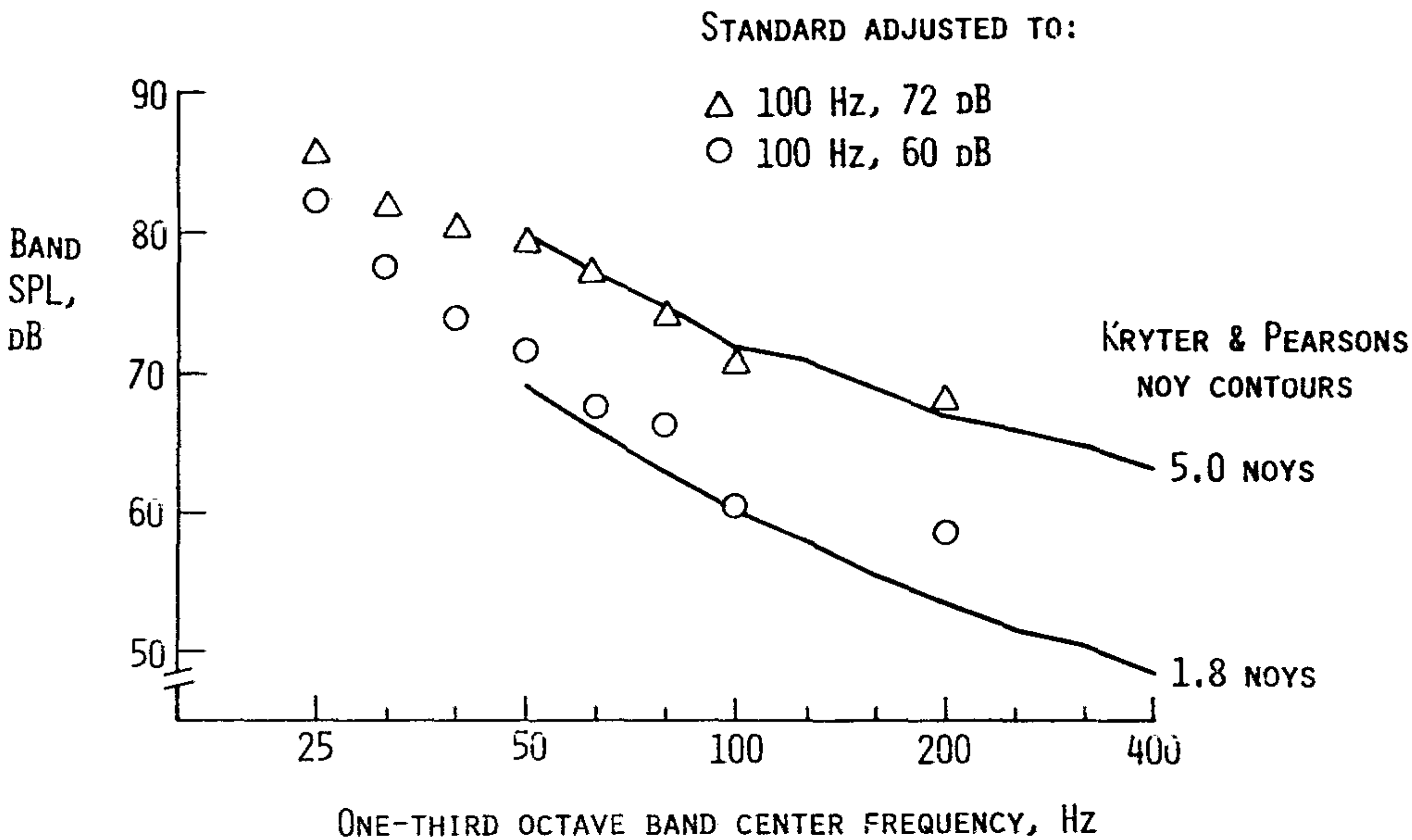

FIGURE 6

COMPARISON OF REFERENCE NOY CONTOURS AND MEAN ADJUSTMENTS FROM PRESENT STUDY

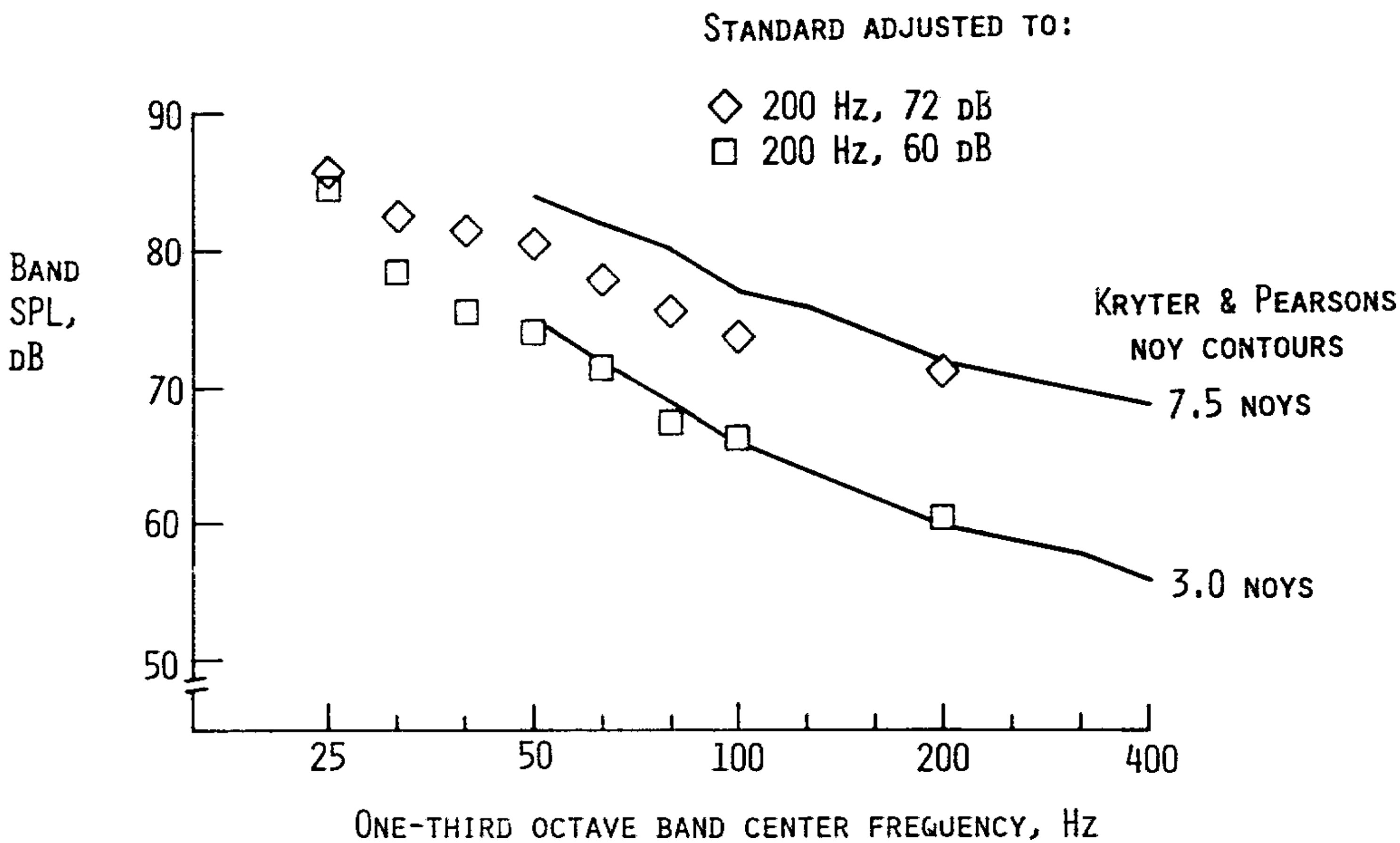

FIGURE 7

THE NOISINESS OF LOW FREQUENCY BANDS OF NOISE

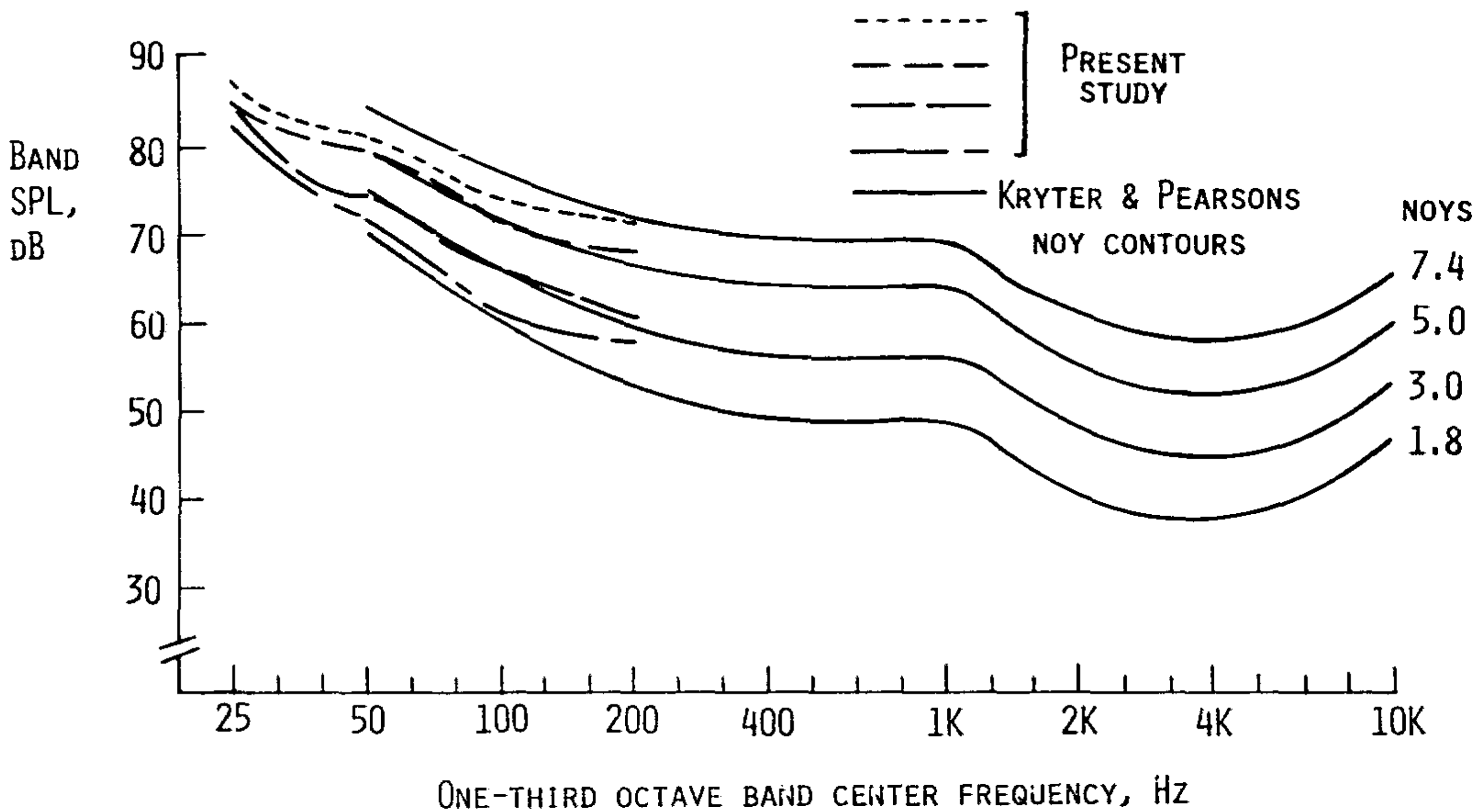

FIGURE 8