NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3379

A SURVEY OF BACKGROUND AND AIRCRAFT NOISE IN COMMUNITIES NEAR AIRPORTS

By K. N. Stevens

Bolt Beranek and Newman, Inc.

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SUMMARY

An extensive survey has been made of background and aircraft noise levels in residential communities in eight cities having major airports. The measurements were made in areas up to a distance of 12 miles from the airports, and the areas were chosen to be under regularly used flight paths. More than 20 such areas were selected at various distances from the airport in each city. Readings of background noise were obtained primarily in the octave bands 75 to 150, 300 to 600, and 1,200 to 2,400 cps, about 25 such readings being taken in each area. Octave-band spectra were obtained from magnetic tape recordings of the noise of about 250 aircraft in flight, representing substantially all commercial types. The results have been analyzed to yield a statistical description of the background noise in many different communities and of aircraft noise spectra at various locations with respect to airports and flight paths.

INTRODUCTION

This report presents the results of a survey of noise levels in residential communities in eight cities having major airports. The major objectives of the survey are twofold:

(1) To determine the statistical properties of the background noise, in the absence of aircraft noise, in typical residential areas in these cities

(2) To determine the statistical properties of the aircraft noise levels in residential areas under regularly used flight paths near airports.

The purpose of the measurements is not to evaluate the detailed acoustical properties of the sources that are responsible for the background and aircraft noise in communities. The purpose is rather to describe, in statistical terms, the noise to which people who live in the communities are exposed.

In each of the eight cities, measurements were made in more than 20 areas, each of which covered about four square blocks. All areas were located within a radius of 12 miles of the airports. Before the areas were selected, a careful study was made of regularly used aircraft flight paths to and from the airport. The areas in which noise measurements were made were chosen to be under these regularly used flight paths.

In this report the procedure that was followed in the measurement of background and aircraft noise is described and the results of the measurements are presented and discussed briefly in the light of the known statistical properties of the sources of background and of aircraft noise and in the light of previously reported measurements.

This report was prepared for the National Opinion Research Center of the University of Chicago as part of a larger study for the National Advisory Committee for Aeronautics on the community aspects of the aircraft noise problem.

BACKGROUND NOISE

Procedure

In order to describe adequately the background noise in a community, it is necessary to measure and to specify several quantities. It is certainly not valid to make one measurement of sound level at one point in the community at one time and then to call this result the "background noise for the community." Ideally, the sound pressure level of the noise should be recorded at all frequencies, at all times through the day and night, and at all points in the community. Such a large-scale measurement program is, however, clearly impractical. In order to obtain useful data without a prohibitively large number of measurements, <u>samples</u> of the noise in frequency, in time, and in space must be taken. If the samples are selected properly, they can provide an adequate description of the background noise in a community.

First it is helpful to examine how space variations in background noise from point to point in a community are accounted for in the measurement procedure. One of the considerations in the original selection of each area was that the background noise at all residences within the area be more or less the same. For example, the residential area may be selected to be the row of houses on either side of a busy street; or, the streets within the area may be very lightly traveled, and most of the noise may originate from a busy street 1/4 mile away. Because the noise was more or less the same throughout most areas, it was usually necessary to make measurements of background noise at only one position within each area. In areas, however, where some nonuniformity in the noise was expected, measurements were made at two or more locations and the results were averaged.

The noise level near a busy street depends, of course, upon the distance the measurements are made from the street. In this survey, all measurements were made near typical residences, regardless of their distance from noisy streets, since the objective was to evaluate the noise to which residents are exposed and not to evaluate the characteristics of the noise sources.

All measurements were made during weekdays in order to obtain a sample of the type of noise that occurs most frequently. Readings were taken during two periods of the day: (1) from 9:30 a.m. to 4:30 p.m. and (2) from 1:00 a.m. to 5:00 a.m. These times were selected because the background noise in most areas remains reasonably stable within each of these periods, and, hence, measurements made over a short interval of time within each period would be fairly representative of measurements for the entire period. Selection of these measuring periods avoids rush hours and evening hours during which the level of traffic is not uniform.

All measurements were made in octave bands of frequency, using a conventional sound-level meter in combination with an octave-band analyzer. Almost all the readings of sound pressure level were taken in three octave bands of frequency: from 75 to 150, 300 to 600, and 1,200 to 2,400 cps. These three octave bands appear to provide an adequate sample of the frequency spectrum since, in most cases, the spectrum of the background noise does not deviate markedly from location to location in a given residential community, or from community to community.

The sound pressure level in each octave band generally fluctuates with time, the fluctuations being as great as 15 decibels in some cases. In order to evaluate these short-time fluctuations in the background noise, the sound pressure level in each of the three octave bands was sampled at regular intervals. Successive readings of sound pressure levels in the 75- to 150-, 300- to 600-, and 1,200- to 2,400-cps bands were taken at regular intervals of 5 seconds. The cycle was repeated until 15 or more readings had been taken in each of the three bands. In some cases as many as 30 readings were taken in each band, if it was judged that this larger number would be required in order to obtain a reasonably stable statistical picture of the distribution in levels.

Each reading was taken to the nearest 5 decibels. The data were recorded as shown in table I. As each reading was taken, an "x" was recorded beside the appropriate decibel range. The data obtained from a sequence of readings were recorded, therefore, as three distributions of levels in three frequency bands.

For each area, at least two data sheets of the type shown in table I were completed - one or more for daytime and one or more for nighttime. In some cases, additional sets of readings were taken during either the daytime or nighttime periods. These additional data served to verify the assumption that the distributions that described the background noise levels remained reasonably stable throughout these periods.

Results

From data sheets of the type shown in table I the objective is to derive a reasonably simple description of the background noise existing at the time the measurements were made. In each frequency band there is, in effect, a distribution curve that indicates how the samples of sound pressure level are distributed along the decibel scale. A distribution that is concentrated at one point along the scale represents a noise with very little fluctuation. If there are large fluctuations, the distribution is broad.

For each of the distributions, the mean sound pressure level has been computed on an intensity basis. In order to perform this computation, the procedure is to (1) convert all decibel readings to relative intensity, (2) compute the mean relative intensity, and (3) convert this mean relative intensity back to decibels. The procedure may be illustrated by using the distribution shown in table I for the 300- to 600-cps band, in which four samples were measured in the range 35 to 40 decibels, eight at 40 to 45 decibels, one at 45 to 50 decibels, and two at 50 to 55 decibels. The intensities corresponding to these ranges of sound pressure level are in the ratio 1:3:10:30 (since 10 decibels represents a tenfold increase in intensity, and 5 decibels represents approximately a threefold increase). If the intensity in the lowest range (35 to 40 decibels) is called unity, the average relative intensity is

$$\frac{4 \times 1 + 8 \times 3 + 1 \times 10 + 2 \times 30}{15} = 6.5$$

which is about 8 decibels above the reference intensity. Thus, the average level computed by this procedure is 46 decibels. The median level, on the other hand, is 42 decibels. The mean computed on an intensity basis is seen to give considerable weight to measurements of high sound pressure level and relatively less weight to measurements of lower sound pressure level. This mean appears to yield a more realistic single measure of the noise exposure experienced by residents in a community.

Computation of the mean levels for each of three frequency bands and for daytime and nighttime measurements yields a total of six numbers that describe the background noise in each area. Curves showing how these mean levels are distributed in the more than 180 areas in the eight cities are given in figures 1(a) to 1(c). Each figure shows two curves which represent the cumulative distribution of levels in a given frequency band for daytime and for nighttime. For example, figure 1(b) shows that, in 50 percent of the areas, the mean background level in the 300- to 600-cps band exceeded 33 decibels at night. In 95 percent of the areas, the level exceeded 22 decibels and the mean level was greater than 46 decibels in only 5 percent of the areas.

From these three pairs of cumulative distribution curves a statistical picture of the noise spectra in the daytime and in the nighttime is shown in figures 2(a) and 2(b). Each curve indicates a spectrum that is exceeded in x percent of the areas, where x is the number that labels the curve. A curve labeled 25 percent, for example, depicts a background noise spectrum that is exceeded in 25 percent of the areas in which measurements were made.

Each noise spectrum is defined by only three points, since most of the measurements were made in only three octave bands of frequency. Some measurements were made in other octave bands, however, and those measurements indicate that the background noise spectrum is usually rather smooth. Joining the points in figures 2(a) and 2(b) by smooth curves and extrapolating the curves below 75 cps and above 2,400 cps is therefore usually justified.

Discussion of Results

Figures 2(a) and 2(b) summarize measurements of background noise in areas that represent a wide variety of residential communities. At one extreme are rural areas in which busy roads are some distance away and in which there is negligible traffic on local roads. At the other extreme are residences that are near very busy highways or city streets, with large numbers of trucks and automobiles. The majority of the areas in which measurements were taken would be designated as urban or suburban.

The average difference between the daytime and the nighttime background noise is about 7 decibels. In some areas, characterized by a large volume of nighttime traffic (e.g., trucks on a state highway), there may be no difference between daytime and nighttime background noise. In other areas, the difference may be 15 decibels or more.

The data in figures 2(a) and (b) show that the average background noise in 90 percent of the areas is within a range of about 22 decibels in both the daytime and the nighttime measuring periods. Measurements of background noise at any instant of time will, however, cover a considerably wider range, since the noise often exhibits large fluctuations.

The difference between the levels in the 75- to 150- and the 300- to 600-cps bands is about 14 decibels on the average. Between the 300- to 600- and 1,200- to 2,400-cps bands, the average difference is about 5 decibels. In the 1,200- to 2,400-cps band, there are often contributions to the noise from rustling leaves, crickets, birds, and so forth. These contributions tend to keep the average background levels in the higher frequency bands above the levels that would be expected if motor traffic were the only source of noise.

AIRCRAFT NOISE

Procedure

All measurements of aircraft noise were made in areas that had been specially selected on the basis of distance from the airport and location with respect to regularly used flight paths to and from ends of airport runways. As far as possible, areas were selected in which only one type of aircraft noise predominated, that is, most of the flights over a given area were either landings or take-offs (not both), and in which the aircraft were operated within certain limits of altitude. It is clear that this ideal situation is only approximated in practice. Over areas designated as "landing" there will be an occasional take-off; over areas close to an airport where altitudes for take-offs and approaches are normally 1000 feet or less, there will be some circling operations at higher altitudes.

Measurements of aircraft noise in a given area were usually made on occasions when the background-noise survey was in progress in the same area. Measurements were not restricted to aircraft that were undergoing operations for which the area was designated, although most of the aircraft were undergoing such operations. Measurements were made for <u>all</u> aircraft that produced noise levels substantially above the background noise. For all measurements the position of the microphone was noted and the distance from the ends of airport runways was later determined from maps.

The noise levels produced by the aircraft were not read directly from an octave-band analyzer. The noise was first recorded on a magnetic tape recorder, together with suitable calibrating signals to permit determination of absolute levels. Each time an aircraft passed overhead, the tape recorder was switched on and a 10- to 30-second sample of the aircraft noise was recorded, including the time before and after the level reached a peak value. For each recording the attenuator settings on the recording instrument were noted. A 400-cps calibrating signal was recorded from time to time, and the attenuator settings were again noted.

After the completion of the survey the tape recordings were analyzed by means of an octave-band analyzer and a graphic level recorder. The graphic level recorder draws on a strip of paper a trace which represents the time variation of sound pressure level in each octave band of frequency. Traces of the calibrating signal were also made on the graphic level recorder, and these served to set the absolute level of the recordings of aircraft noise. The entire measuring system was calibrated at all frequencies, and corrections were applied for nonuniformities in frequency response and for other minor deviations from ideal response.

Analysis of Results

In the analysis of the recordings of aircraft noise, the objective is to obtain a statistical description of the aircraft noise levels in the residential areas around the airport. As noted previously, this total aircraft noise is a composite of (1) noise from aircraft undergoing a specific operation for which the area is designated and (2) noise from aircraft undergoing other operations in that area. The noise is controlled largely by aircraft of the first type, since they are in the majority. The statistical description of the aircraft noise that is presented in the following discussion does not include data on the frequency of occurrence of the aircraft. The measurements in the present survey yield information only on the levels of the aircraft noise, without regard for the number of times the aircraft pass overhead.

Since only a limited time was available for the survey, it was not possible to make large numbers of measurements of aircraft noise in each area. Thus, a valid statistical description of the aircraft noise levels in a given area could not be obtained from measurements in that area alone. Such data could be gathered only if a period of weeks and even months was spent making measurements at each airport center.

From the data at hand, valid statistical descriptions of the aircraft noise can be obtained only if the data from different airport centers are combined. Such a combination of data is possible if it is assumed that the statistical characteristics of the aircraft noise levels in an area a given number of miles from the end of a runway (measured along the flight path) are independent of the particular airport center or city in which the area is located. A distinction is made, however, between areas designated as "landing" and those designated as "take-off." The assumption implies that differences in flight regulations, circling patterns, and so forth, at different airports do not materially modify the statistical description of aircraft noise levels in areas that are the same distance from airport runways but in different airport centers. In effect, the assumption implies that the aircraft noise levels are determined by only two independent variables: (1) distance from the end of the runway, measured along the flight path, and (2) designation of the area as landing or take-off.

The validity of this assumption cannot be verified with confidence from the limited data at hand. However, general observations of aircraft operations in various airport centers indicate that the assumption is not unreasonable. The analysis of the data will proceed on this basis.

In the analysis of the results, the discussion is restricted primarily to the peak levels as the aircraft passes over the measuring location. The time characteristics of the noise are, of course, dependent upon the altitude of the aircraft. If the aircraft is only a few hundred feet high, the peak will be sharp, as illustrated in the trace shown in figure 3(a). This trace was recorded by the graphic level recorder and represents the sound pressure level in the 300- to 600-cps frequency band at a distance of 1.5 miles from the end of the runway as the aircraft takes off. When the aircraft is at a higher altitude, a flatter trace is obtained, since the relative distance between the aircraft and the microphone changes less rapidly. Figure 3(b) shows a trace taken at an area 4.3 miles from the end of a runway.

The measurements of aircraft noise levels are summarized in figures 4 and 5. Data are given only in the frequency bands from 75 to 2,400 cps. The contribution of levels below 75 cps and above 2,400 cps is probably not important in the evaluation of the effects of the noise on people for the types of noise spectra measured in this survey.

The construction of these figures may be explained by examining one - say figure 4(c) - which gives the sound pressure levels in the 300- to 600-cps band for take-off areas. Each point on the graph represents a measurement of noise from a separate aircraft. From the recording of this aircraft, the peak level in decibels is obtained by the procedure described previously. From the known position of the microphone, the distance from the end of the runway, measured along the flight path, is obtained. These two numbers - the peak level in decibels and the distance in miles - determine a point in figure 4(c).

There is a considerable spread in the levels of aircraft noise measured a given distance from the airport. This spread is attributable to a number of factors, of which the following are the most important:

(1) The measurements represent noise from different types of aircraft, from DC-3's to DC-6B's and Super Constellations.

(2) The position of the flight path relative to the measuring microphone may change appreciably from one measurement to the next. For some

measurements, the aircraft passes directly overhead; for other measurements, the aircraft passes at an oblique angle.

(3) The atmospheric conditions, in particular, the wind and temperature gradients and turbulence, vary from day to day and from hour to hour.

(4) At a given distance from the airport, pilots may use different engine power settings, with consequent differences in radiated noise.

In order to examine the distribution of levels at a given distance in more detail, study the group of measurements in the range 3 to 5 miles from the end of the runway. About 44 measurements are clustered in this distance group, which can be represented by an average distance of about 4 miles. In figure 6 a cumulative distribution curve is plotted, showing the percentage of measurements in this distance group that are less than the level designated by the abscissa. This cumulative distribution forms a smooth curve. This curve shows that 25 percent of the measurements are less than 57 decibels, 50 percent are less than 64 decibels, 75 percent are less than 69 decibels, and 90 percent are less than 75 decibels. Hence, in figure 4(c) four points are plotted at a distance of 4 miles, representing each of these four percentage levels.

Similar cumulative distribution curves are drawn for other distance groups, and hence four points are plotted in figure 4(c) for each of these groups. By joining the points in the manner shown in figure 4(c), four curves are obtained which indicate how the sound pressure level decreases with distance from the end of the runway. Ninety percent of all measurements fall below the upper curve, 75 percent fall below the next curve, and so forth. The same procedure is followed for other octave bands of frequency.

The data in figures 4 and 5 are replotted in a different form in figures 7(a) to 7(d). In each figure noise spectra are shown for several distance groups. The spectra shown depict levels that are exceeded in 10, 25, 50, and 75 percent (figs. 7(a) to 7(d), respectively) of the measurements made in the survey. The smooth curves indicate the spectra for take-off areas.

Data for both landings and take-offs are plotted in figures 7(a) to 7(d). There is apparently no significant difference in the noise levels for landings and for take-offs for areas that are the same distance from the ends of runways.

Discussion of Results

The data shown in figures 4, 5, and 7 represent a composite of measurements on about 250 aircraft. The composite plots show the distribution of sound pressure levels to which residents who live under regularly used flight paths are exposed. In general, for a given distance from the airport, the greatest sound pressure levels are measured when large aircraft, such as DC-6's and Super Constellations, follow flight paths that are directly over measuring locations. The lower sound pressure levels are measured for smaller aircraft, such as DC-3's, or for aircraft which deviate considerably from the flight paths that are usually followed in take-offs and landings.

At high frequencies (e.g., in the 1,200- to 2,400-cps band) the measurements of aircraft noise at the most distant areas are usually limited by background noise. A comparison of the measurements of aircraft noise from 7 to 10 miles, in figures 4(e) and 5(e), with the measurements of background noise, in figure 2(a), indicates approximately the same distribution of levels for the two cases.

If certain assumptions are made concerning the flight paths and the type of operation of the aircraft, it is possible to predict the expected noise levels on the ground as aircraft pass overhead. In figure 8 an idealized aircraft flight path is shown. Point A represents the take-off point, or the touch-down point for landings. Assume that the aircraft flies in a straight path with no turns and with a steady climb on a 20:1 flight path and that measurements are made directly under the flight path. Further, assume that the noise power radiated by the aircraft is independent of the altitude of the aircraft and that the noise characteristics of all aircraft are the same. In this idealized situation the peak sound pressure level measured on the ground would decrease 6 decibels for each doubling of the distance from point A. This conclusion is based on the assumption of geometrical spreading of sound from the source.

In plotting the levels for take-offs in figure 4, distances are measured from the end of the runway (shown as B in fig. 8) and not from the take-off point. For runways of average length, there is a difference of about 1 mile between these two distances. When a correction is made for this difference, the rate of decrease in level with distance from the end of the runway is somewhat less than 6 decibels per doubling of distance, especially for small distances. The actual computed shape of the curve showing the decrease in level with distance in this idealized situation is plotted in figure 9. Figure 9 also shows the distribution of measured levels for take-offs in the 300- to 600-cps band, from figure 4(c).

The dashed line in figure 9 is the computed level that would be produced by an aircraft radiating 20,000 watts of sound power. This is approximately the over-all power of the noise radiated from a large four-engine aircraft with all engines operating at take-off power. The power in the 300- to 600-cps band is about one-sixth of the over-all power (i.e., about 8 decibels lower). The dashed line in figure 9 represents, in effect, the highest sound pressure levels that would be measured on the ground, under the ideal conditions just described. There are appreciable deviations from this computed curve and from similar computed curves for other frequency bands. Some of the more important reasons for the deviations are listed as follows:

(1) The measurements represent commercial transports of all types, and these different types produce different noise power. For example, the sound pressure levels measured directly underneath a DC-3 are about 8 decibels below the levels underneath a DC-6 at the same altitude.

(2) For take-offs, the power settings of the engines are usually less as the aircraft gains altitude, with consequent reduction of several decibels in noise power radiated. For landings, however, the power settings are probably not changed appreciably.

(3) For the more distant areas, the sound must propagate through greater distances, with resultant additional attenuation in excess of that predicted from the assumption of the inverse square law. The additional attenuation is usually greater for high frequencies than for low frequencies. This is emphasized in figures 7(a) to 7(d), which show a more sloping spectrum for the distant areas than for the close areas.

(4) As the distance from the airport increases, the aircraft begin to deviate from straight flight paths. For the distant areas, only a few aircraft will pass directly over the measuring location. Consequently, the average propagation distance of the sound from the aircraft to the measuring microphone is greater than the altitude of the aircraft.

(5) The assumption of a steady climb on a 20:1 flight path is only approximate. There may be considerable deviations from this average rate.

(6) In a few cases, especially in the higher frequency bands and for large distances from the airport, the sound pressure level of the aircraft noise is comparable with that of the background noise. For these cases the measurements do not reflect the levels of the noise that is propagated from the aircraft.

All of the effects listed above contribute to the data summarized in figure 7 and no attempt is made in this report to evaluate the separate contribution of each factor.

CONCLUDING REMARKS

The results of a survey of measurements of background and aircraft noise in communities near eight commercial airports show that there is a range of more than 20 decibels in the average background noise in the 180 areas included in the survey. On the average, the levels of background noise in the daytime are 7 decibels above the corresponding nighttime levels. The octave-band spectrum of the background noise slopes downward with increasing frequency, the slope being greater at low frequencies (below the 300- to 600-cps band) than at high frequencies.

As the distance from the ends of airport runways is increased from 1 to 10 miles, the aircraft noise levels measured on the ground decrease by 20 decibels or more at low frequencies and by more than 30 decibels at high frequencies. There are no systematic differences between the levels from aircraft take-offs and landings in areas that are a given distance from the ends of runways. Measurements of the noise levels of aircraft passing close to a given area near an airport exhibit a spread of 20 decibels or more. This spread is attributable to variations in type of aircraft, power settings, meteorological conditions, and aircraft flight paths.

Bolt Beranek and Newman, Inc.,
Cambridge, Mass., July 16, 1954.

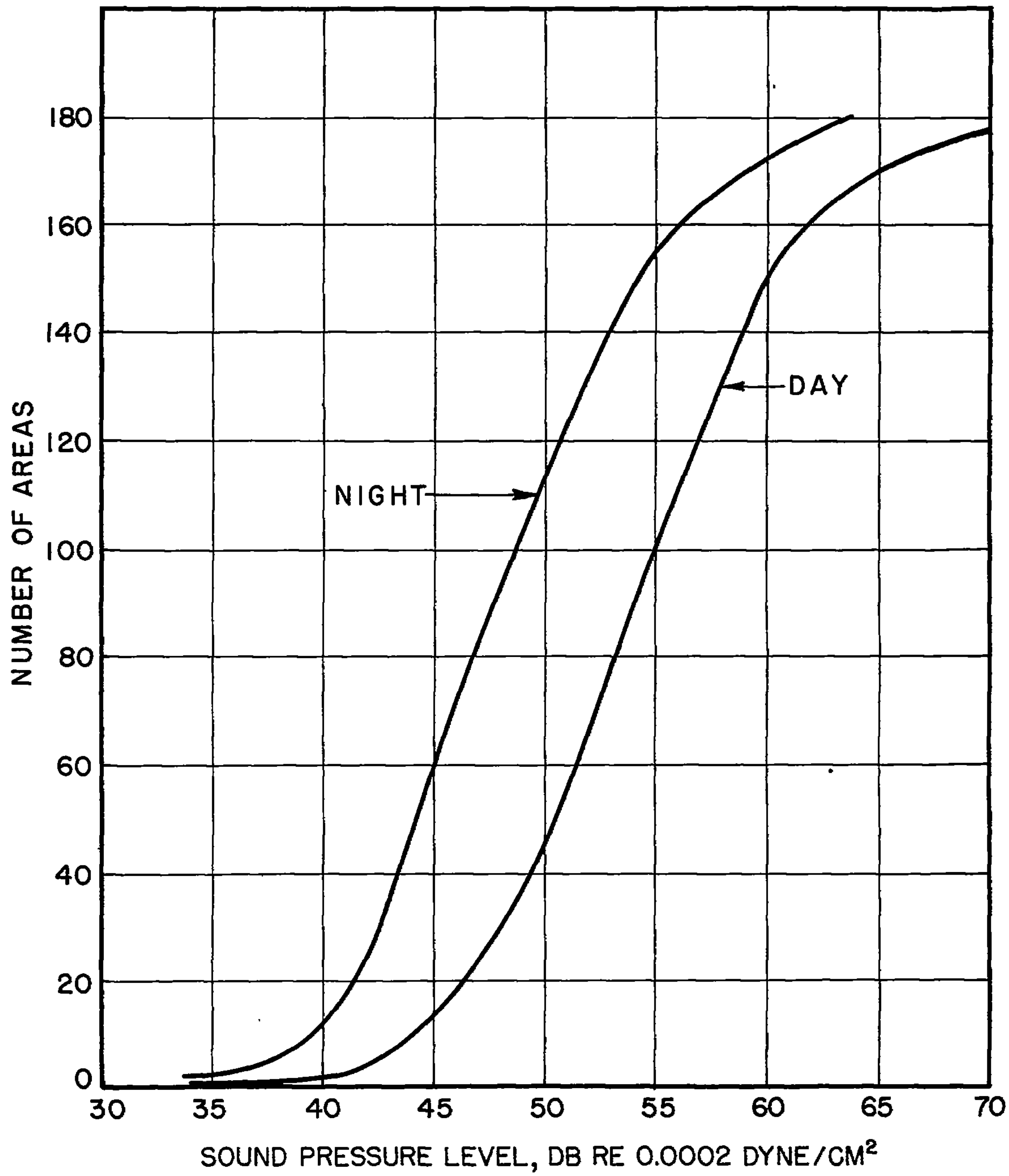
TABLE I

TABLE ILLUSTRATING MEASUREMENT PROCEDURE

FOR BACKGROUND NOISE

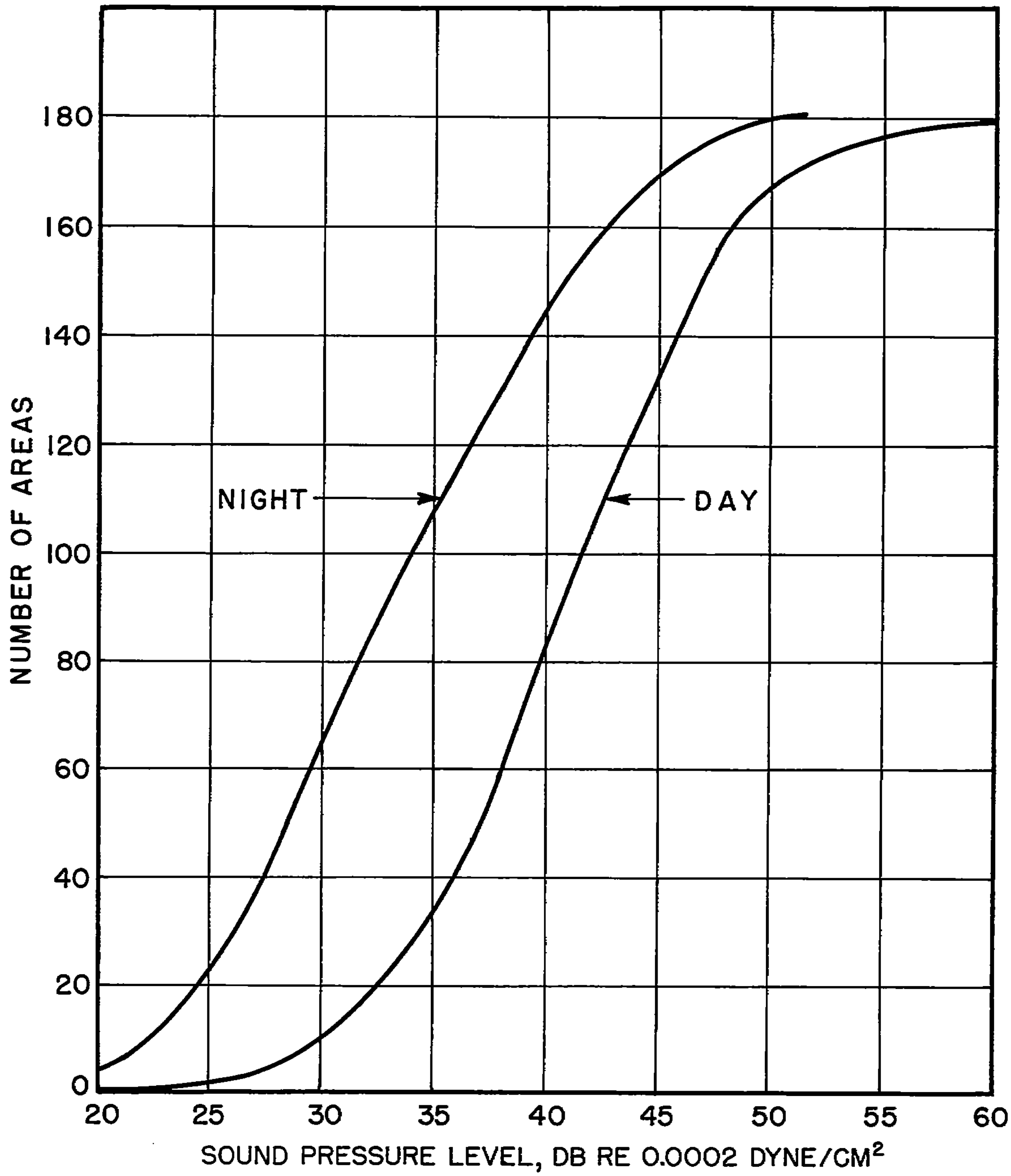
[Each x indicates one reading obtained in particular decibel range]

Frequency band, cps	Background noise level, db	Mean noise level, db
75 to 150	40 to 45 45 to 50 xxx 50 to 55 xxxxxxxx 55 to 60 xxxx 60 to 65 65 to 70	54
300 to 600	30 to 35 35 to 40 xxxx 40 to 45 xxxxxxxx 45 to 50 x 50 to 55 xx 55 to 60	46
1200 to 2400	25 to 30 30 to 35 xx 35 to 40 xxxxxxxxx 40 to 45 xx 45 to 50 xx 50 to 55	41



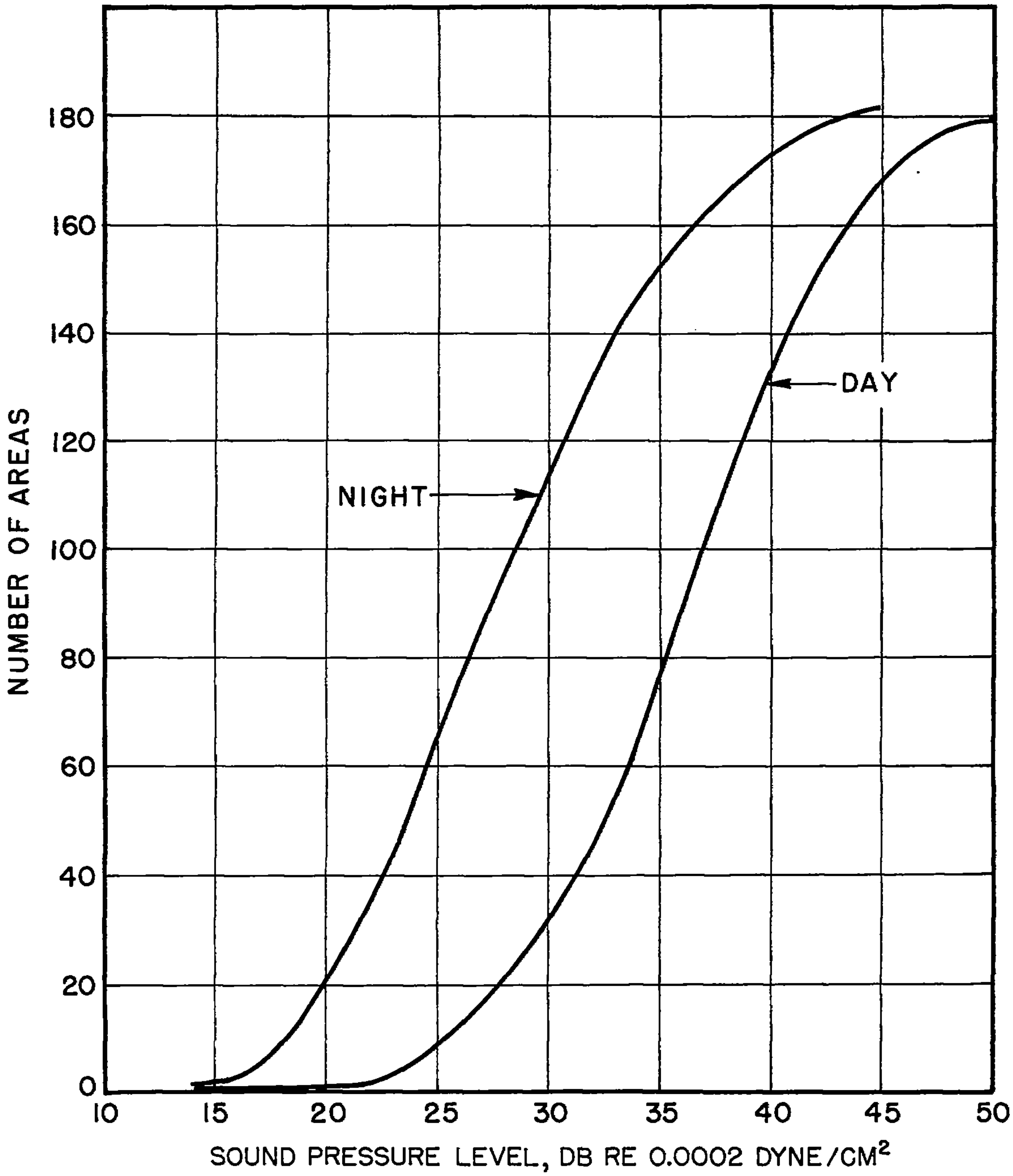
(a) 75- to 150-cps band.

Figure 1.- Cumulative distribution of background noise levels. RE indicates "referred to a level of."



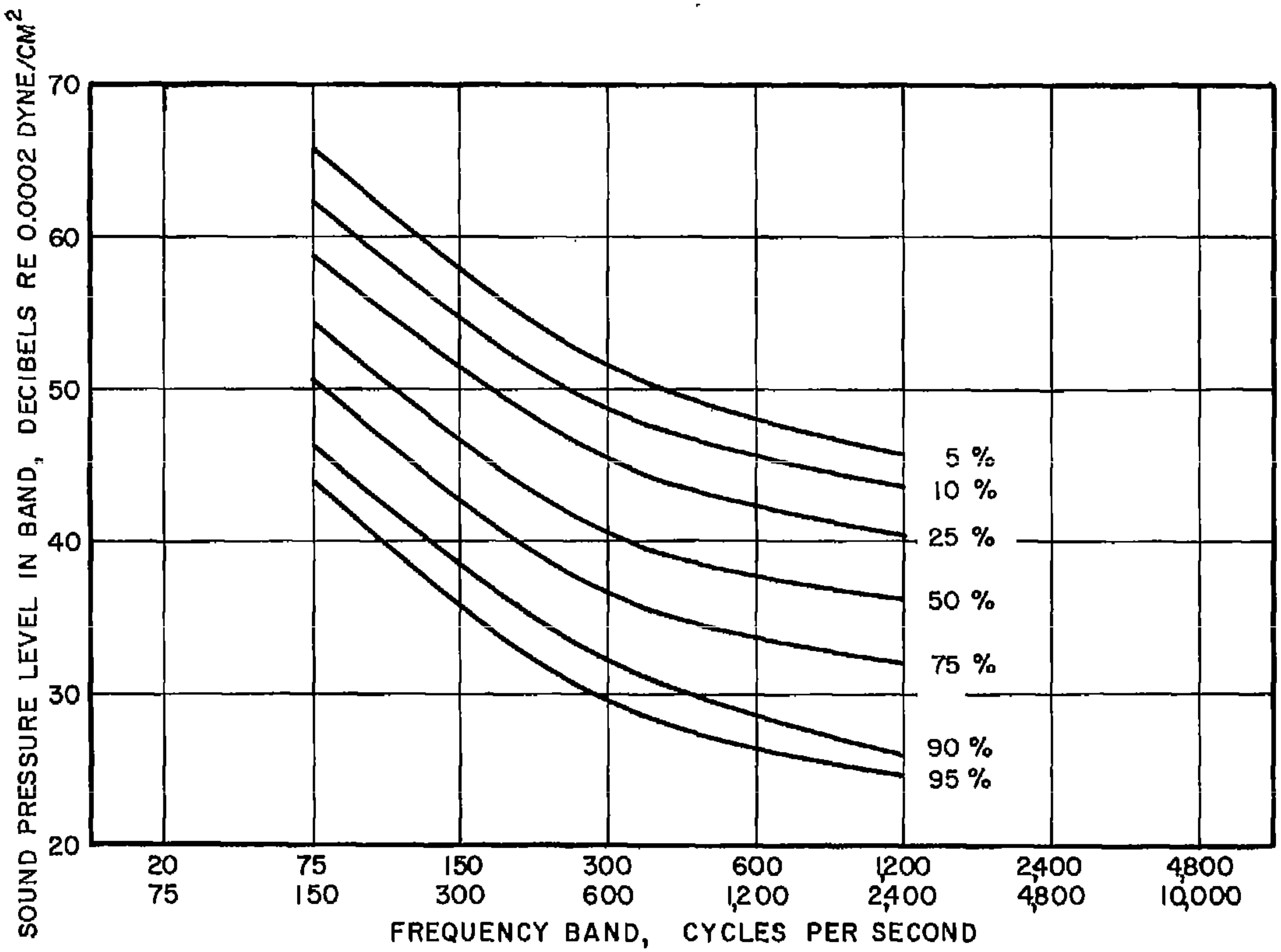
(b) 300- to 600-cps band.

Figure 1.- Continued.



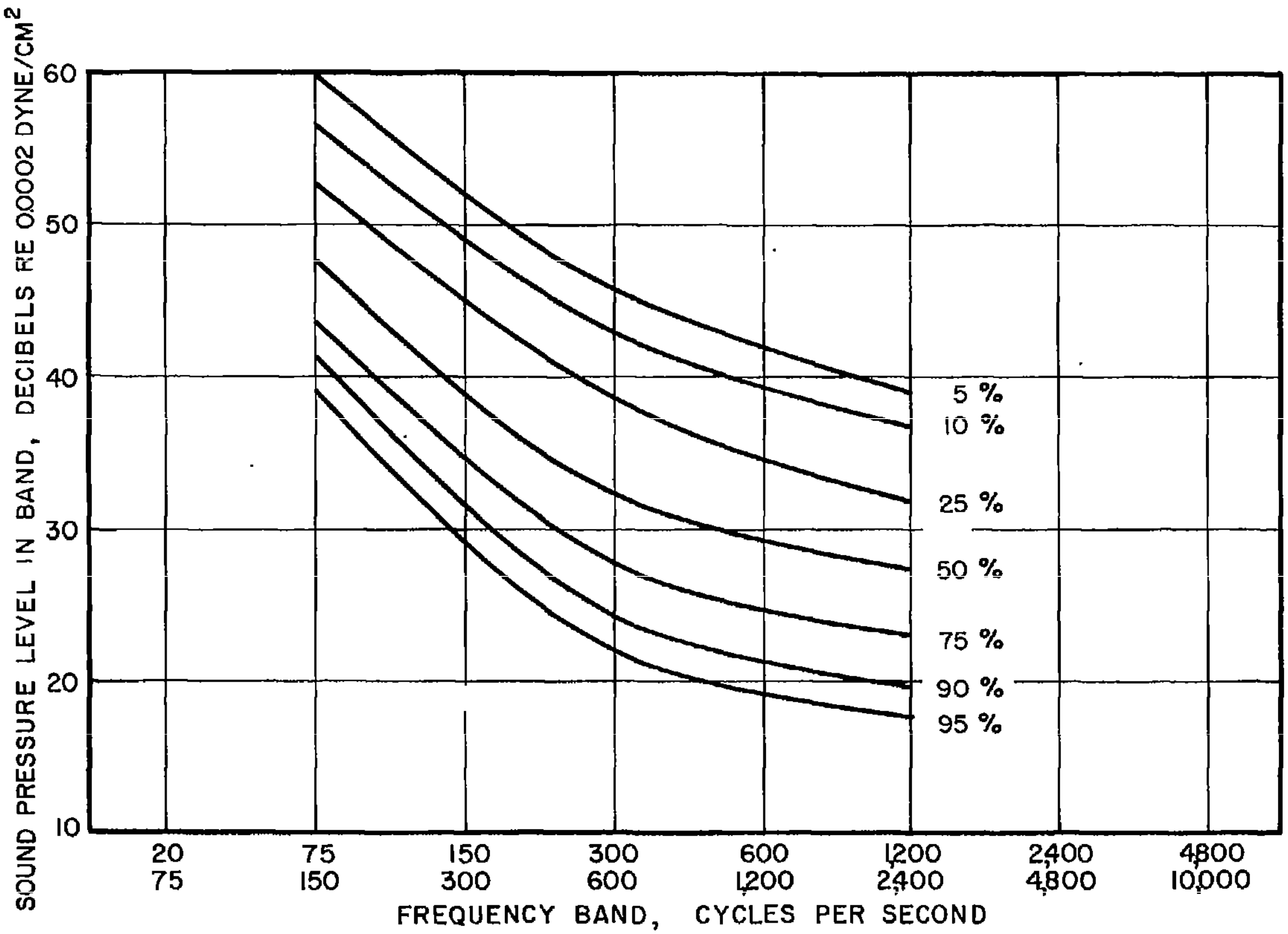
(c) 1,200- to 2,400-cps band.

Figure 1.- Concluded.



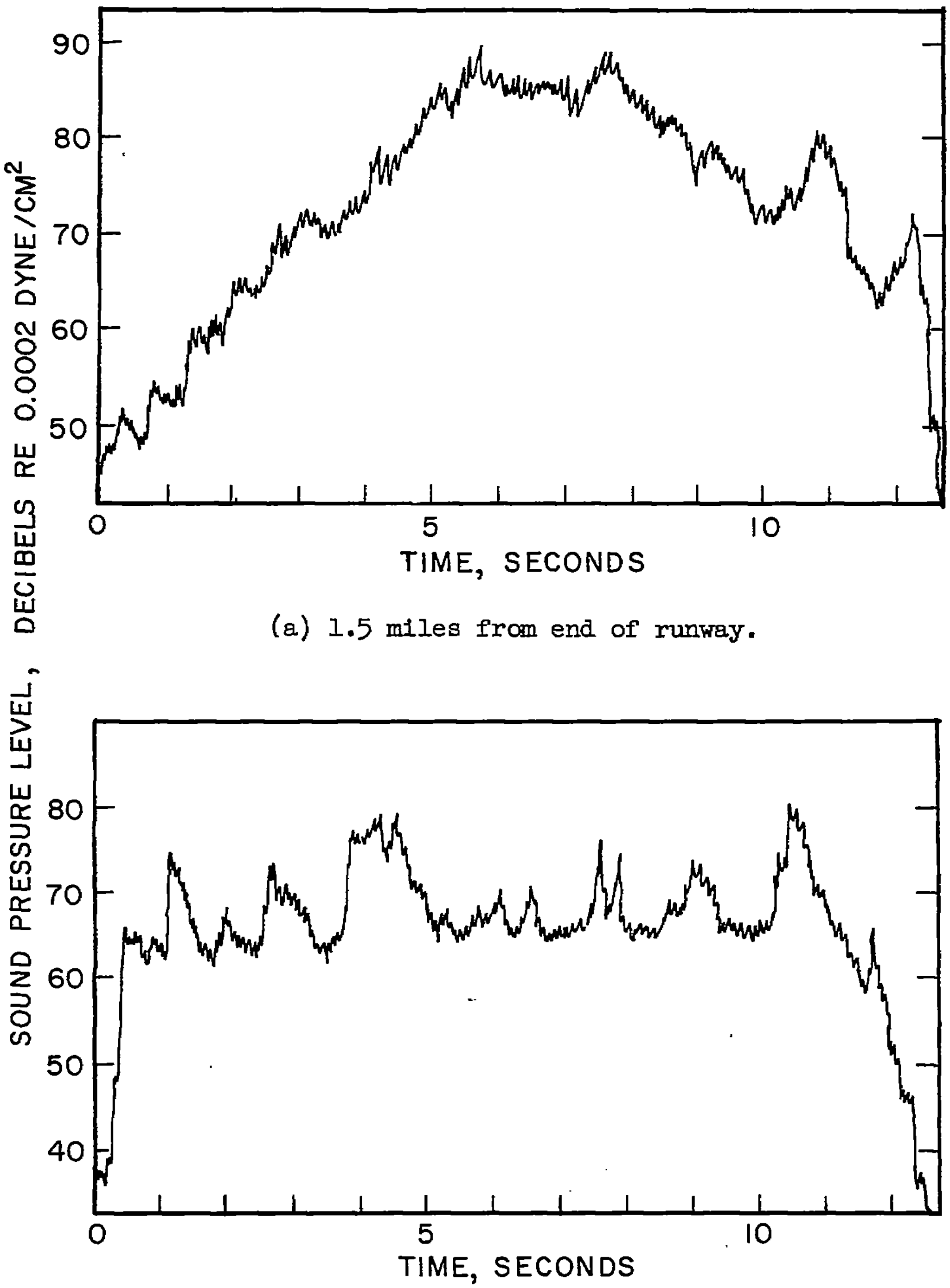
(a) Daytime.

Figure 2.- Measurements of background noise. RE indicates "referred to a level of."



(b) Nighttime.

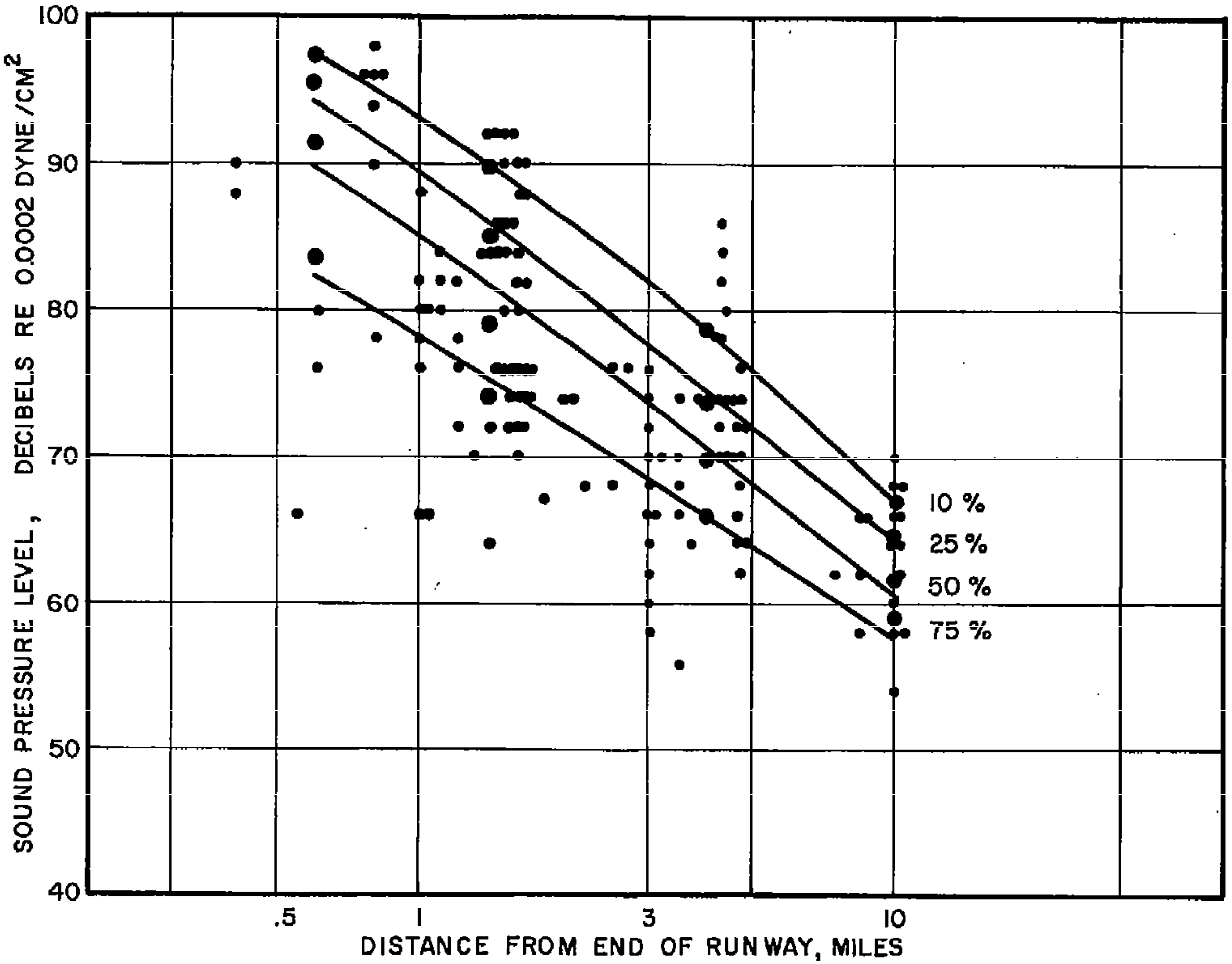
Figure 2.- Concluded.



(a) 1.5 miles from end of runway.

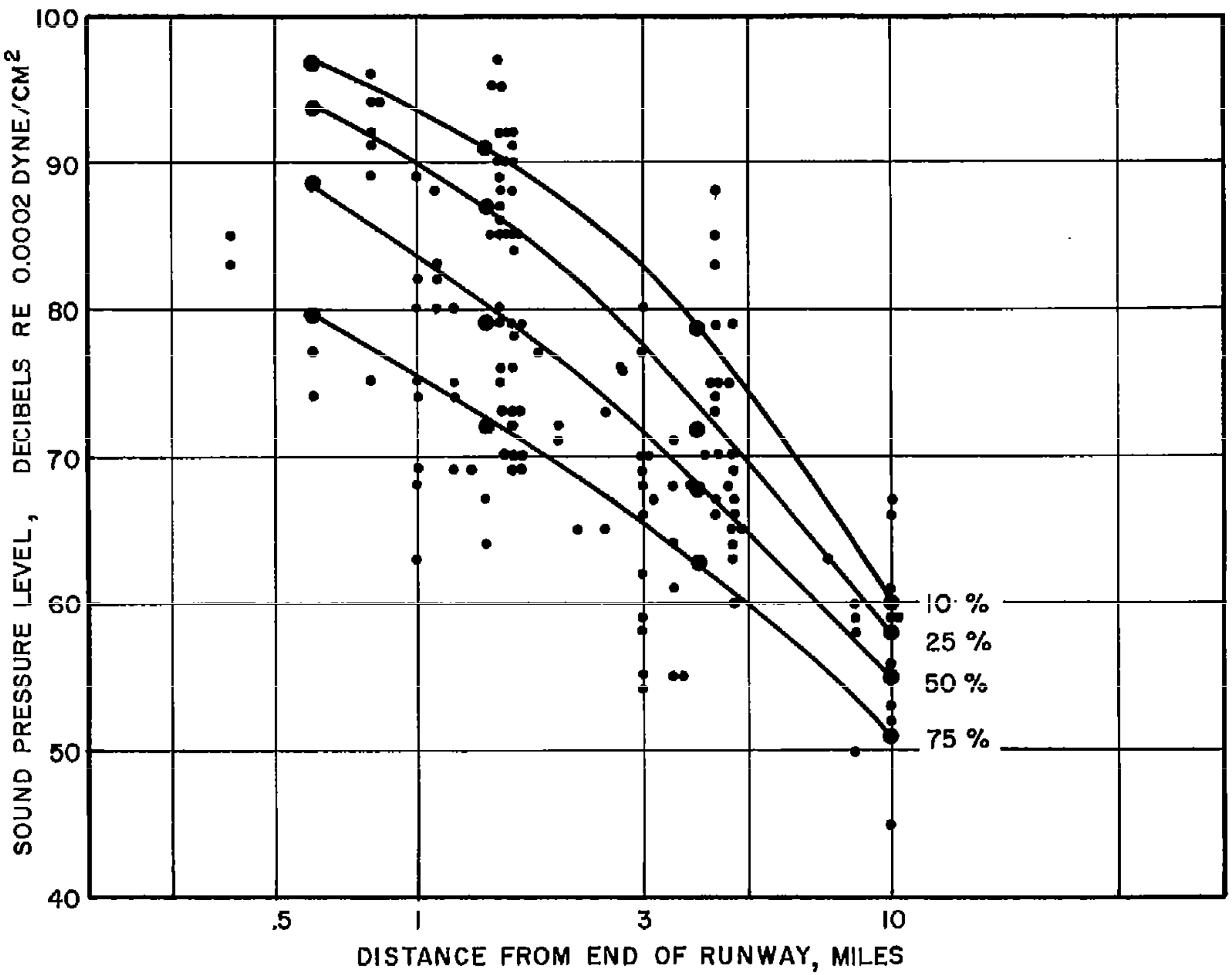
(b) 4.3 miles from end of runway.

Figure 3.- Typical variations of take-off noise in 300- to 600-cps band traced by graphic level recorder. RE indicates "referred to a level of."



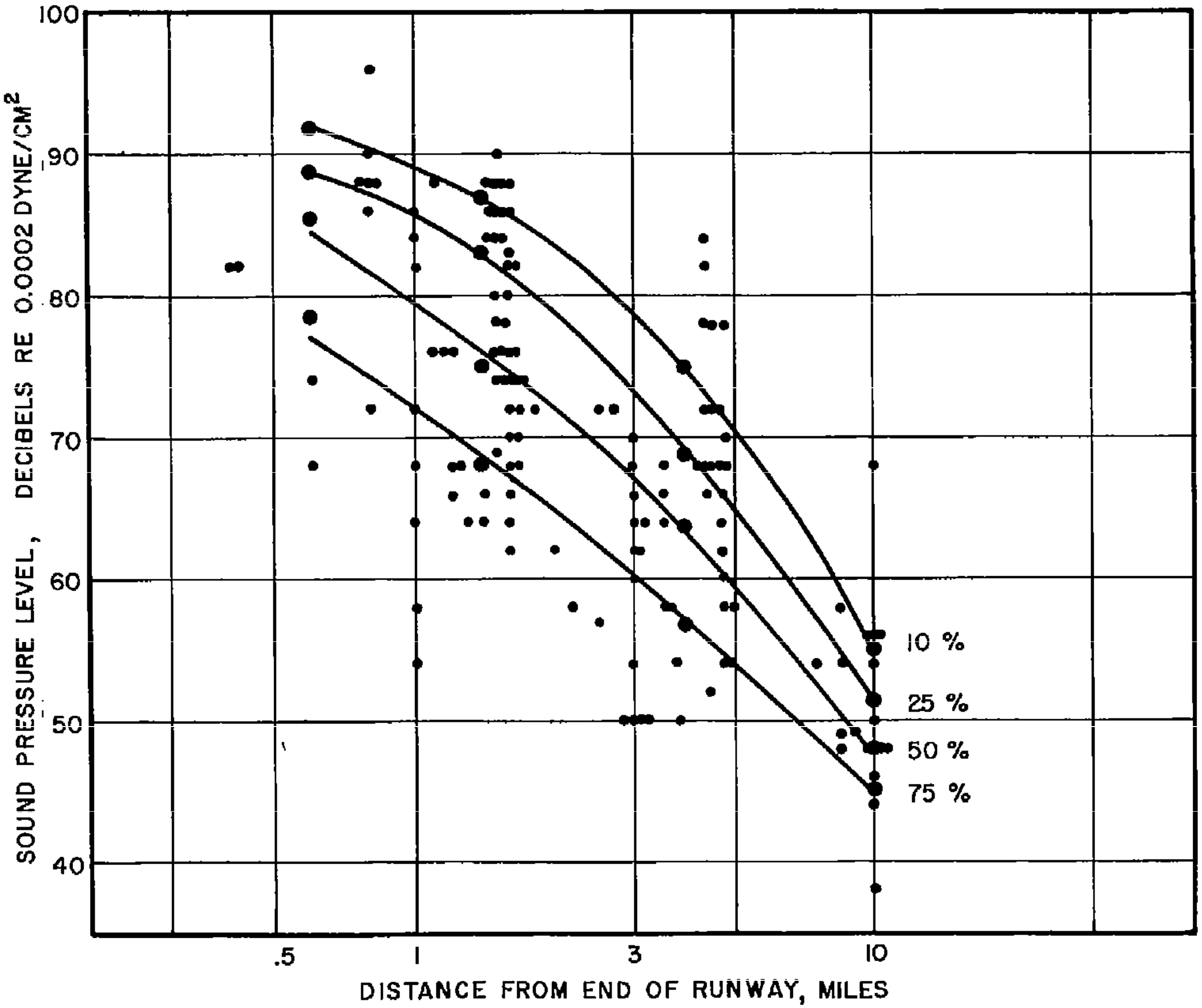
(a) 75- to 150-cps band.

Figure 4.- Measurements of aircraft noise levels over take-off areas. RE indicates "referred to a level of."



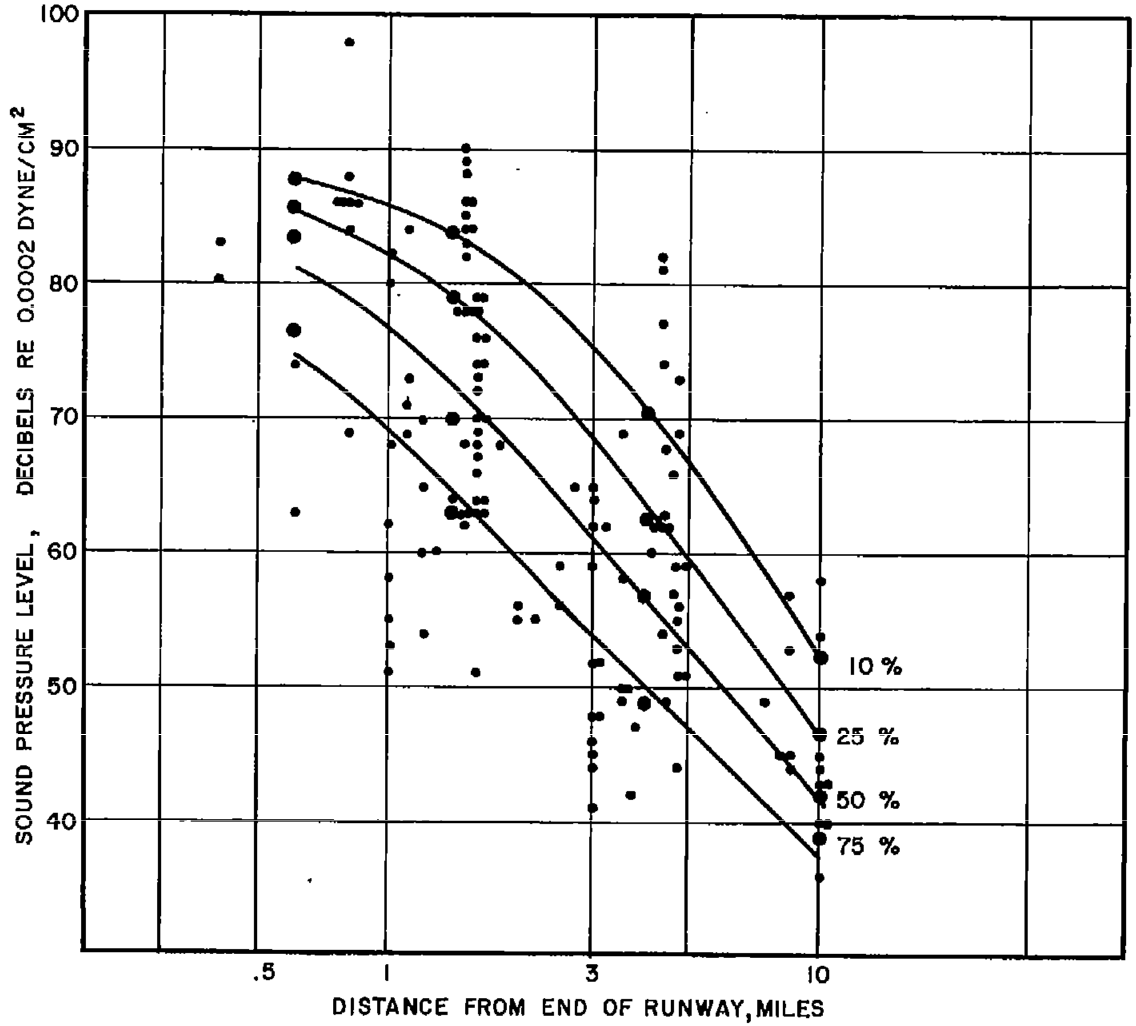
(b) 150- to 300-cps band.

Figure 4.- Continued.



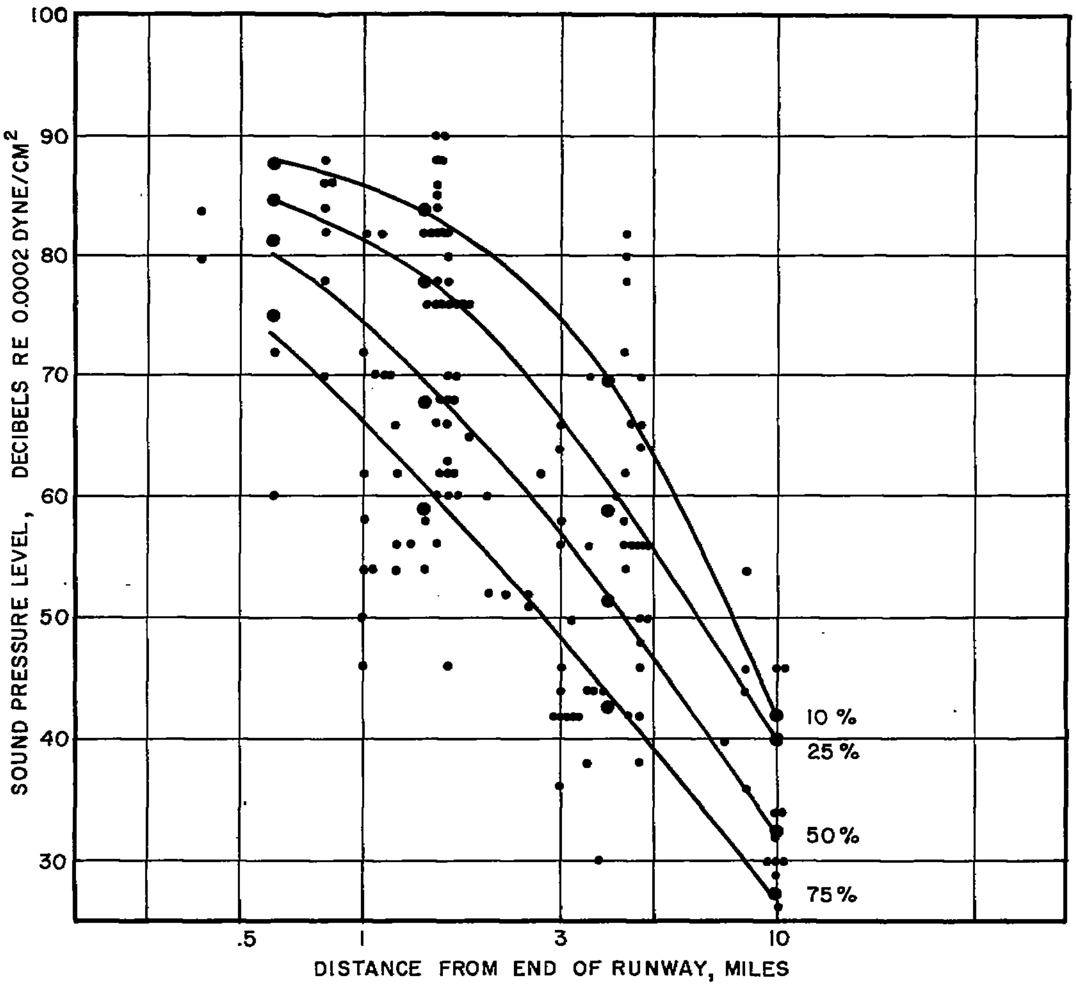
(c) 300- to 600-cps band.

Figure 4.- Continued.



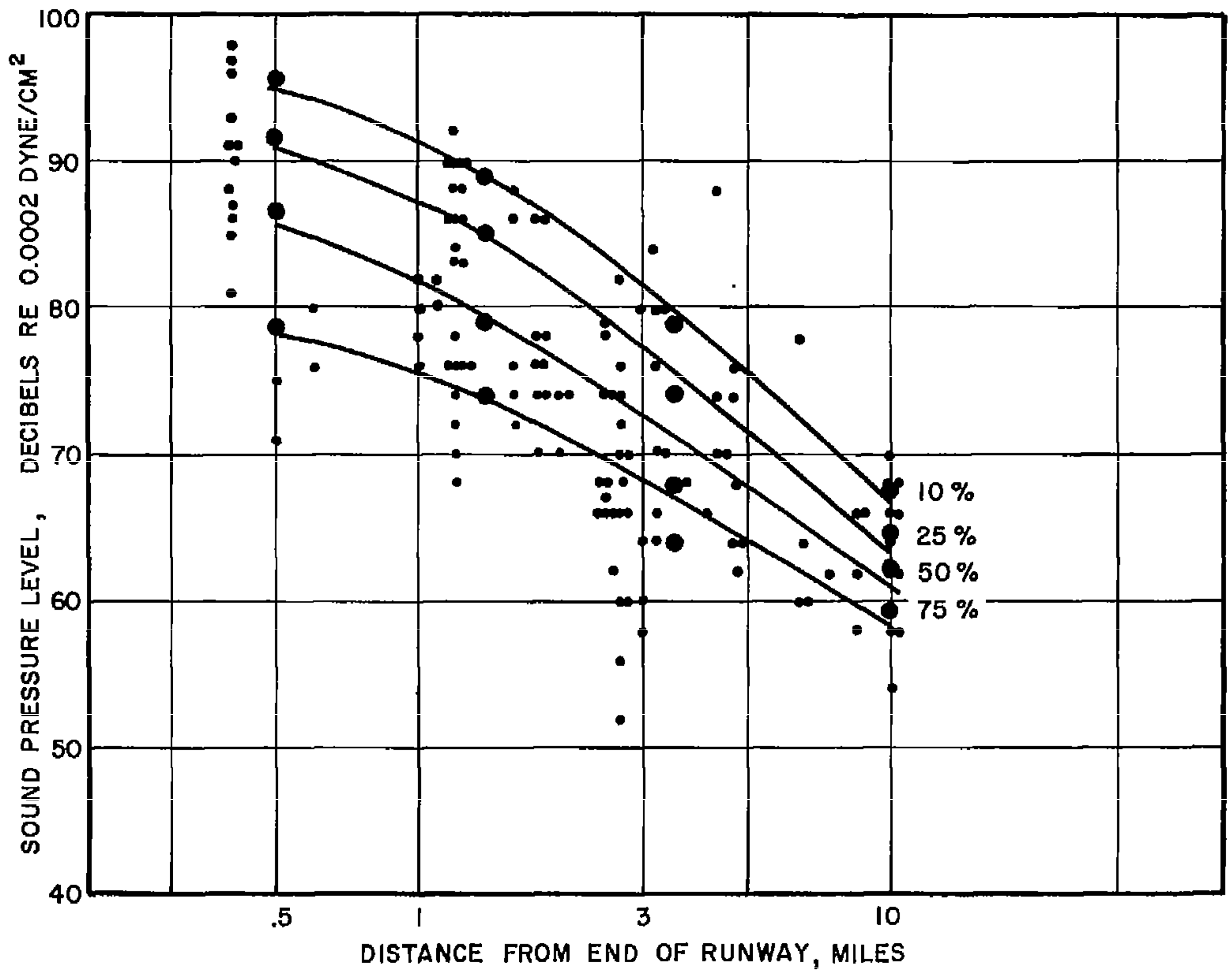
(d) 600- to 1,200-cps band.

Figure 4.- Continued.



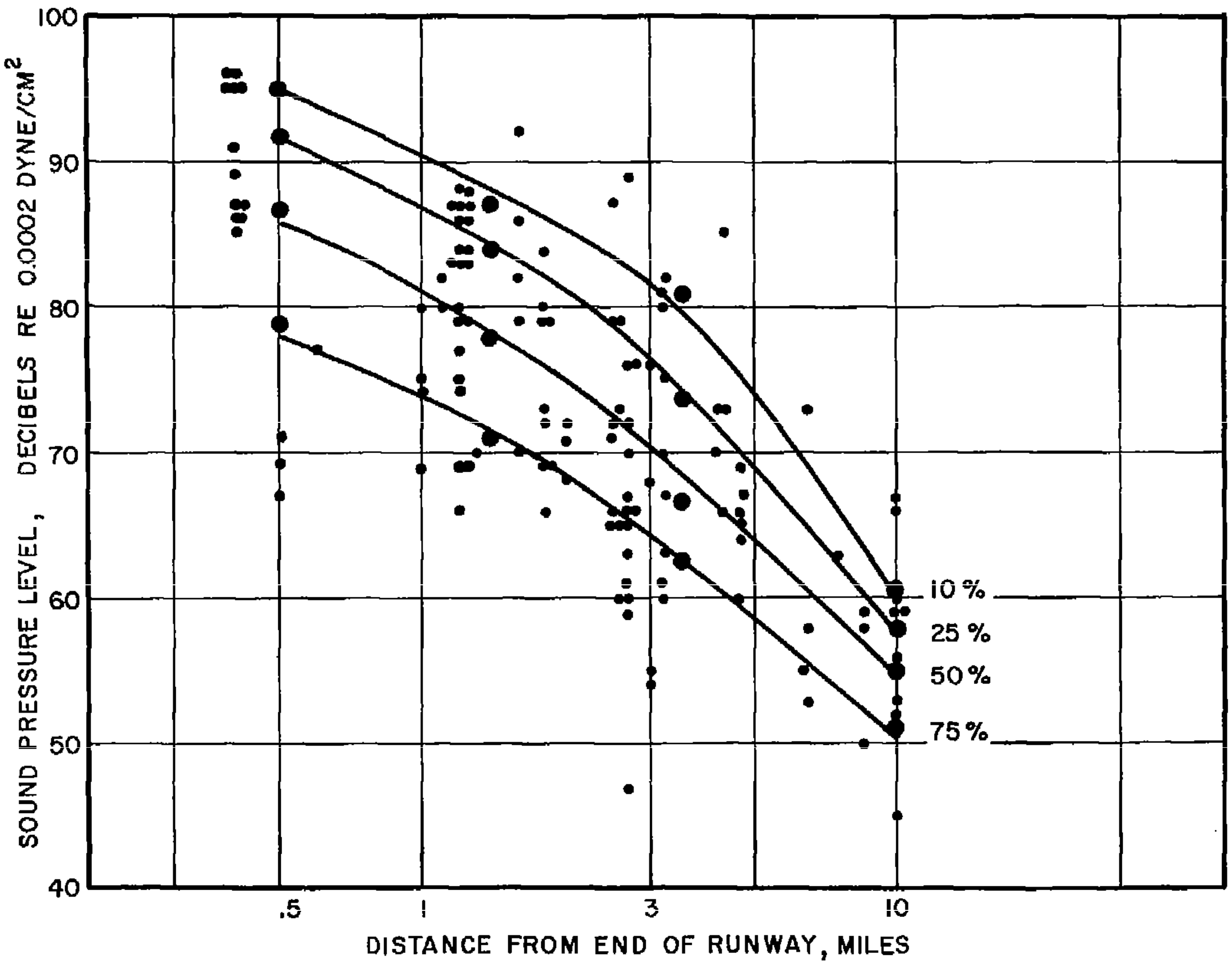
(e) 1,200- to 2,400-cps band.

Figure 4.- Concluded.



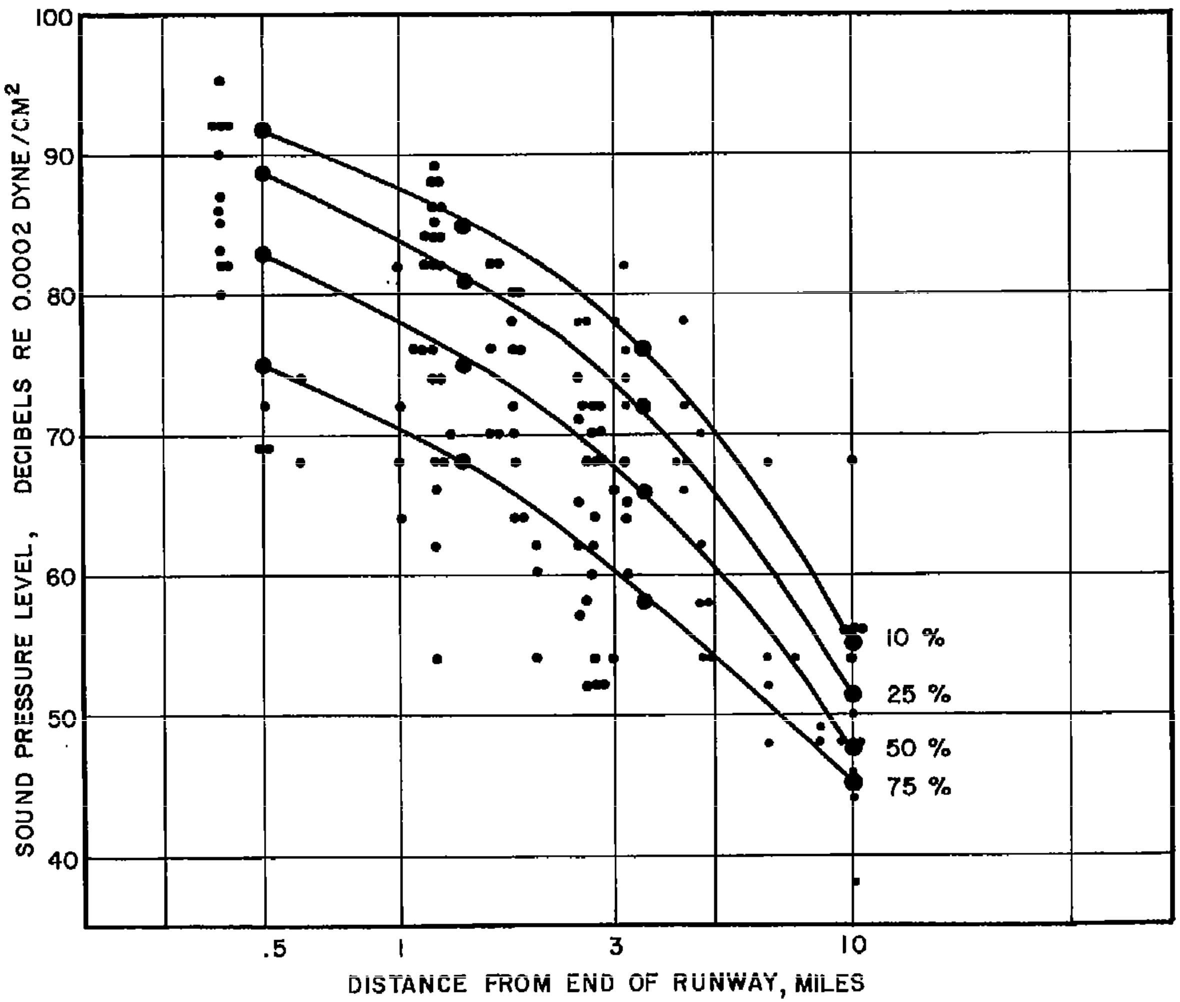
(a) 75- to 150-cps band.

Figure 5.- Measurements of aircraft noise levels over landing areas. RE indicates "referred to a level of."



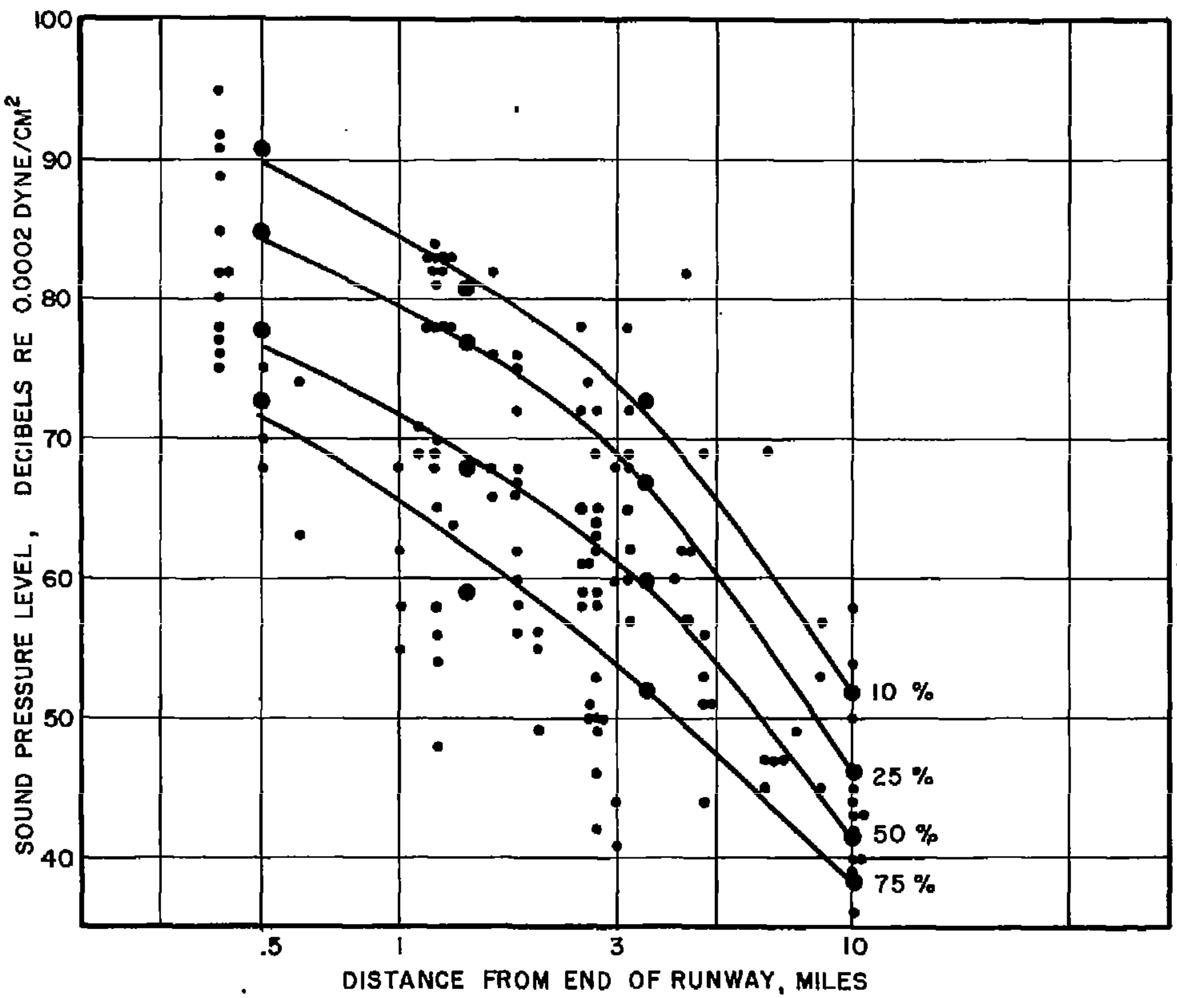
(b) 150- to 300-cps band.

Figure 5.- Continued.



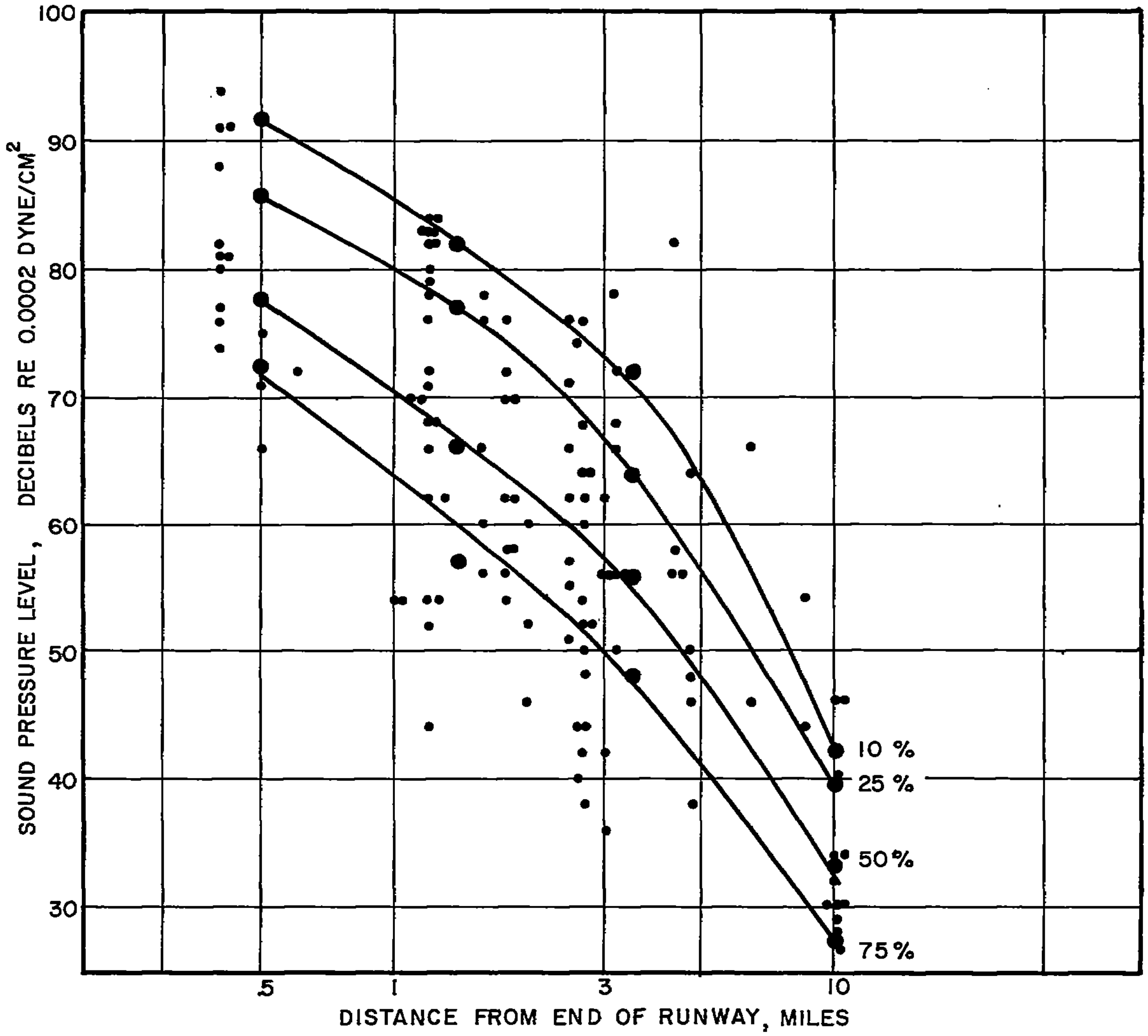
(c) 300- to 600-cps band.

Figure 5.- Continued.



(d) 600- to 1,200-cps band.

Figure 5.- Continued.



(e) 1,200- to 2,400-cps band.

Figure 5.- Concluded.

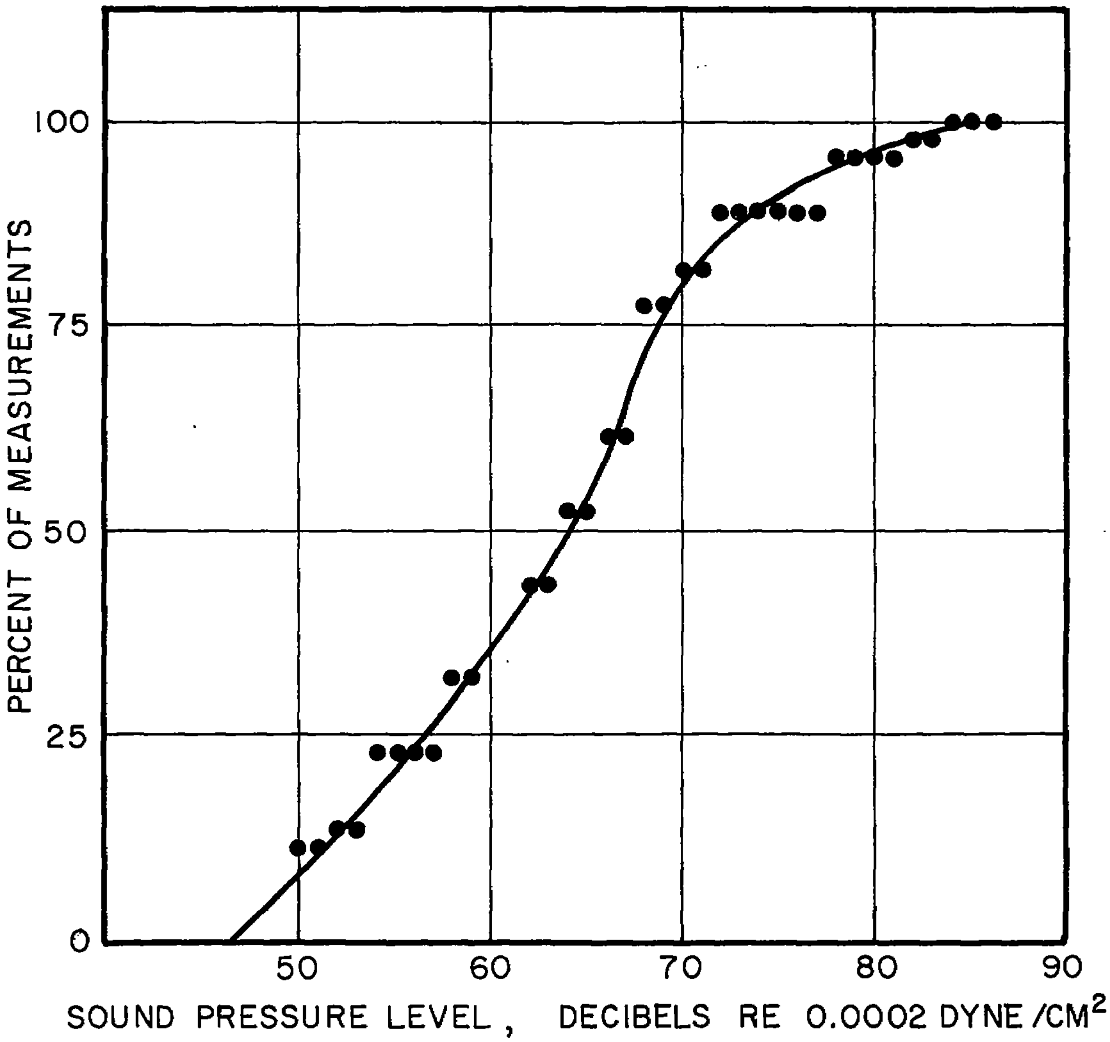
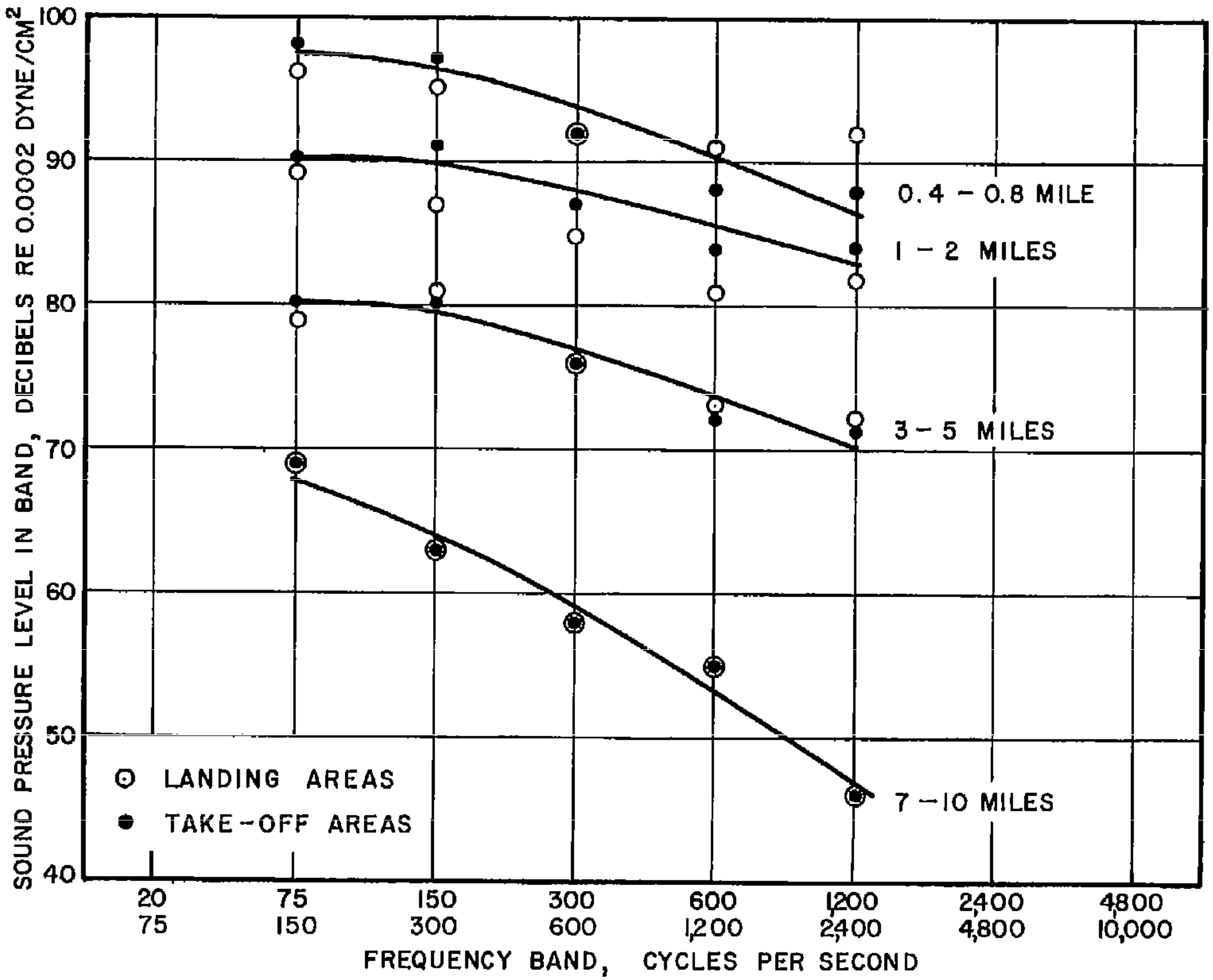
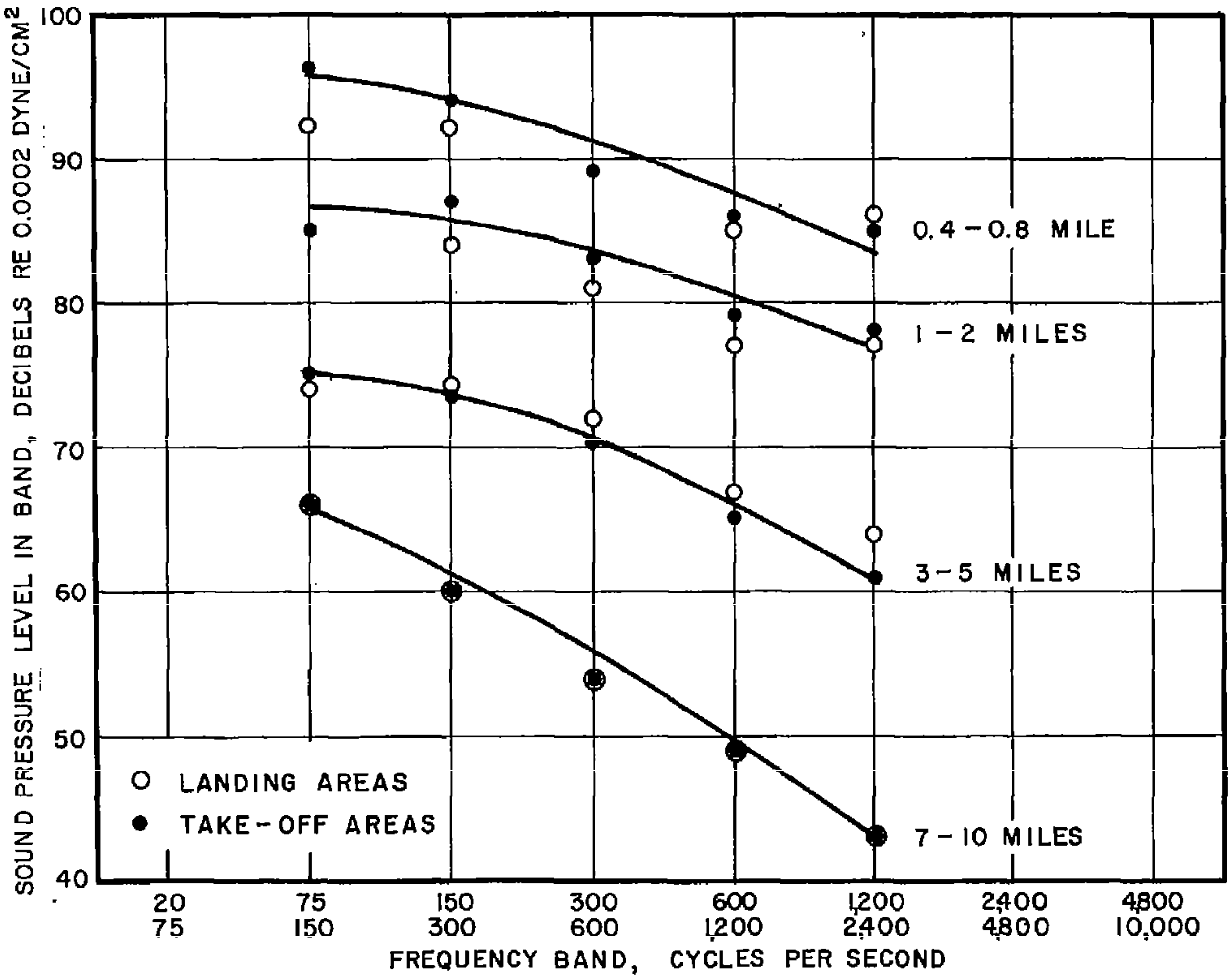


Figure 6.- Cumulative distribution of aircraft noise levels in 300- to 600-cps band. Take-off areas 3 to 5 miles from end of runway. RE indicates "referred to a level of."



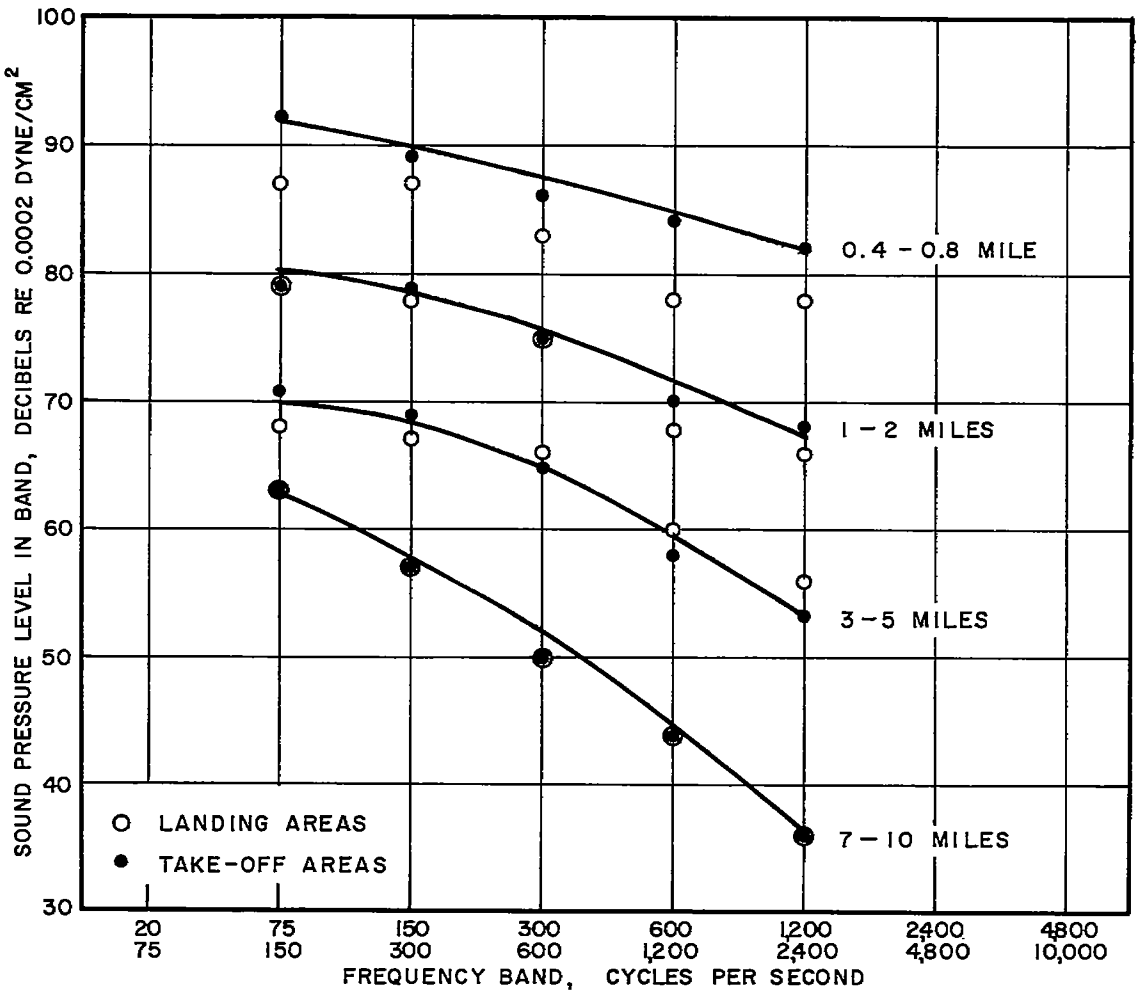
(a) 10 percent of measurements exceed values shown.

Figure 7.- Octave-band spectra of aircraft noise at various distances from end of runway. RE indicates "referred to a level of."



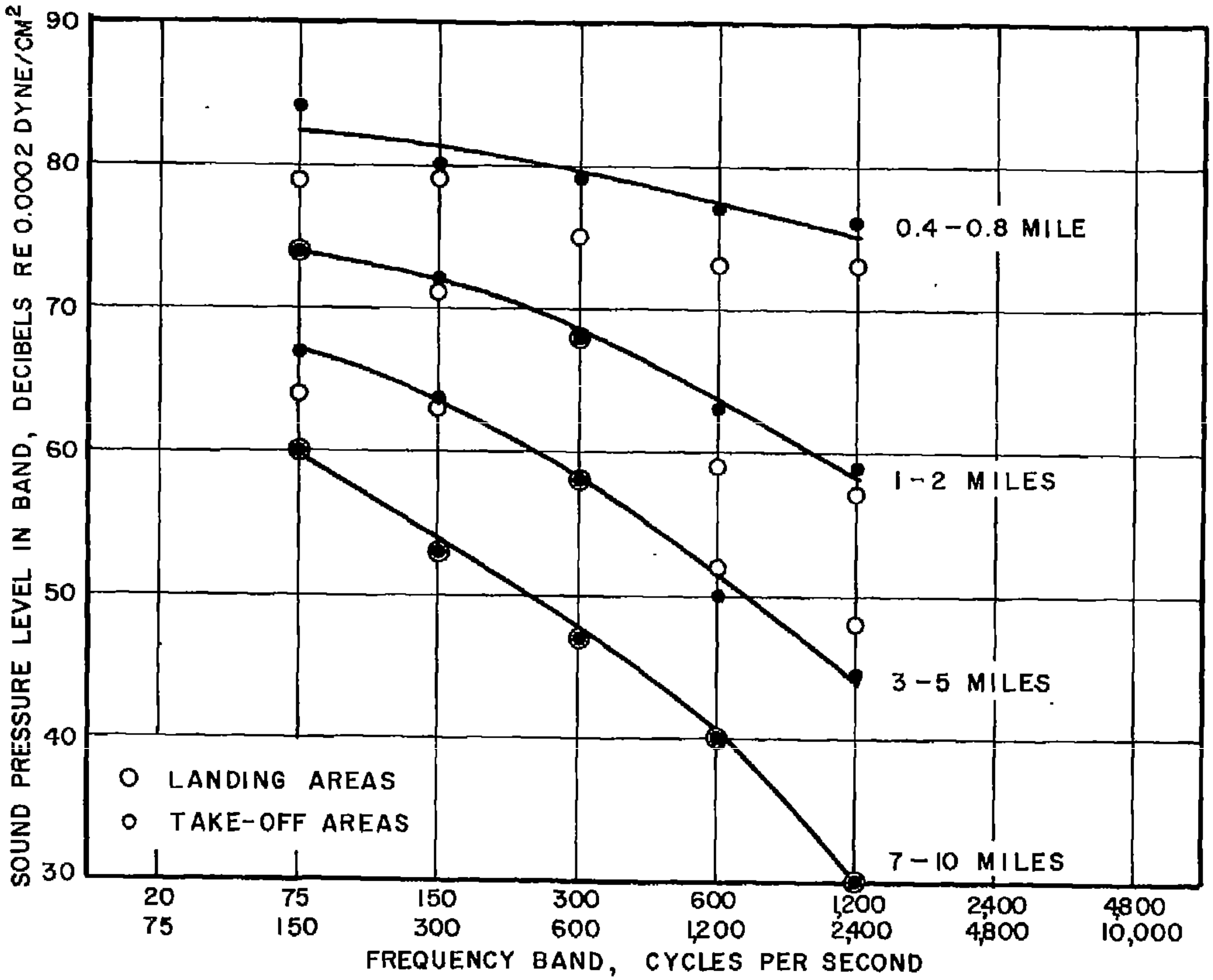
(b) 25 percent of measurements exceed values shown.

Figure 7.- Continued.



(c) 50 percent of measurements exceed values shown.

Figure 7.- Continued.



(d) 75 percent of measurements exceed values shown.

Figure 7.- Concluded.

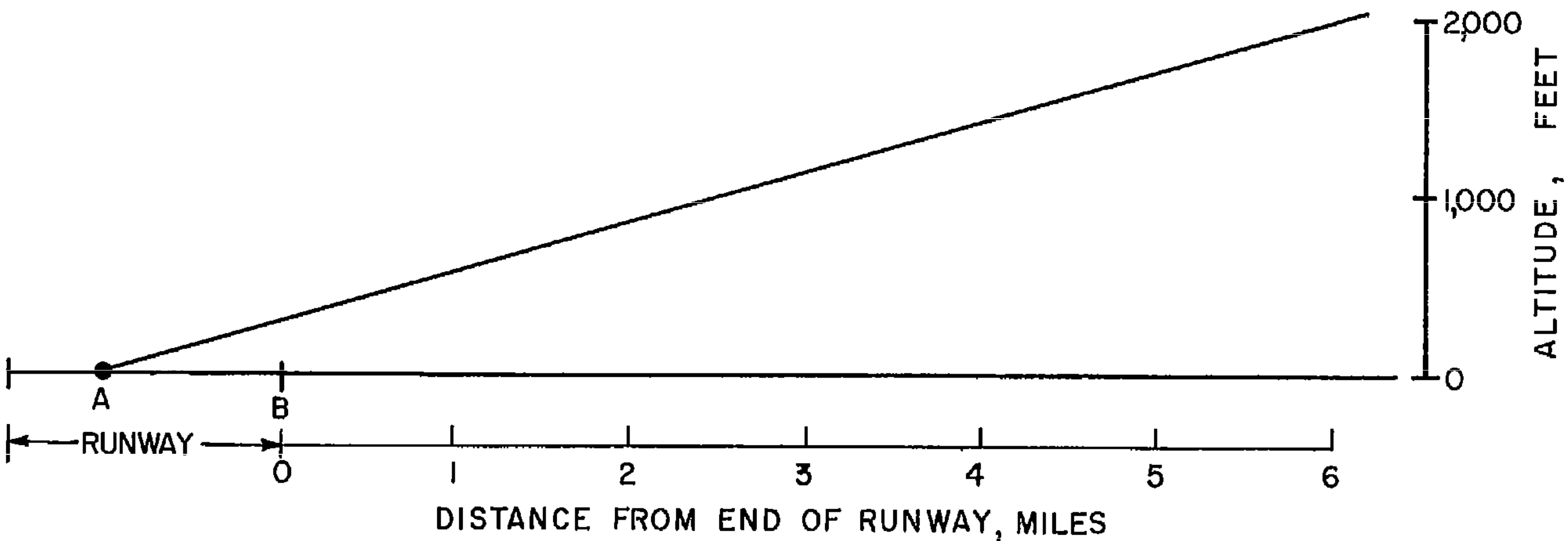


Figure 8.- Idealized flight path for take-offs.

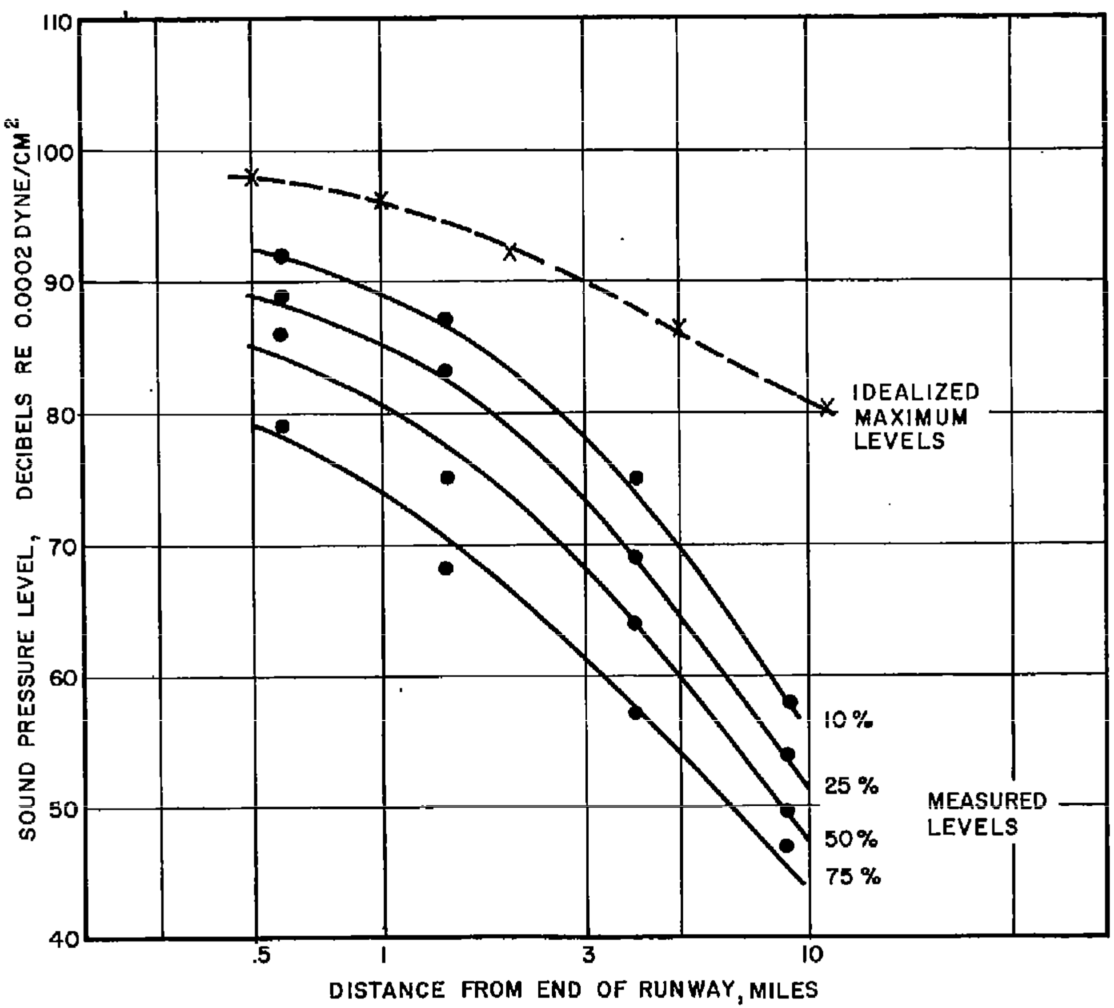


Figure 9.- Comparison of measured levels and idealized maximum levels of aircraft noise over take-off areas. 300- to 600-cps band. RE indicates "referred to a level of."