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GENERAL DESCRIPTION OF A METHOD FOR DESK CALCULATION OF DAY-NIGHT LEVELS (L_{dn}) RESULTING FROM CIVIL AIRCRAFT OPERATIONS

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GENERAL DESCRIPTION OF A METHOD FOR DESK CALCULATION OF DAY-NIGHT LEVELS (L_{dn}) RESULTING FROM CIVIL AIRCRAFT OPERATIONS

I. INTRODUCTION

This memo outlines a basic method for estimating day-night (L_{dn}) values at a particular land area resulting from aircraft operations. The method is illustrated in Section IV by means of several examples.

Desk calculations will provide the L_{dn} value at defined ground locations for noise resulting from aircraft takeoffs or landings from an airport. The calculations utilize noise charts which will provide noise information for most civil aircraft currently operating in the country for a variety of takeoff and landing operations (including noise abatement procedures). The handbook will provide information for estimating L_{dn} values for both:

(a) preliminary assessment where detailed information and aircraft operation is not available and

(b) detailed assessment when accurate information on aircraft operations and flight paths is known.

Naturally, the later assessment requires much more extensive information on aircraft operations and may be much more time consuming to calculate.

The method has been developed for desk calculations of L_{dn} values for relatively small land areas. It is not intended for developing noise exposure contours around an entire airport. Desk calculations will generally be much too time consuming to develop full sets of contours. When noise contours over a considerable area are needed, several computer programs are currently available and should be used. The basic noise information which is to be provided in the handbook is identical to that used in some of the current computer programs for calculating L_{dn} contours.

The basic steps in calculating L_{dn} values are relatively simple and straightforward. However, since the number of calculations multiply by the number of types of aircraft and the kinds of operations involved, the calculations can be quite lengthy when calculating noise exposure near an airport where the noise is due to operations on several runways by a variety of different types of aircraft.

II. BASIC L_{DN} CONCEPTS

The day-night average level may be defined as a measure of the noise environment at a prescribed position over a 24-hour period. It is equivalent in total sound energy to the level of a continuous A-weighted sound level, with a 10 dB weighting applied to the nightime level. For airport operations, the L_{dn} may be calculated by taking into account the noise exposure contribution of each significant noise event (for example, the noise events occuring during each takeoff and landing operation) occuring over the 24-hour period. A special weighting is applied to the noise events during nightime (between 10 pm and 7 am). The noise exposure contributions of each event are then summed up (on an energy basis) to obtain the L_{dn} value.

The noise exposure contribution for each aircraft operation is described in terms of the sound exposure level (SEL). The SEL is the A-weighted sound level integrated over the time of the noise event referred to a reference duration of one second. Hence, the SEL gives the equivalent level of a continuous signal of one second duration for the event.

Where a large variety of aircraft may contribute to the noise environment, calculations are simplified by classifying the aircraft by types. This type classification is based primarily on the aircraft noise characteristics and their takeoff and landing performance capabilities. Thus, in calculating L_{dn} values, one determines the number of significance operations for each class of aircraft occuring in the daytime and nightime periods. From this information, the L_{dn} value can be calculated as will be described in the following sections of this memo.

Near an airport, the L_{dn} contributions by aircraft noise will generally be much greater than that contributed by other sources hence, the L_{dn} value due to aircraft will be essentially equal to the L_{dn} value for the site. At distances further from the airport, or near other major noise sources, the L_{dn} values resulting from aircraft operations may not fully account for the noise exposure at the site. In such situations, the L_{dn} contributions resulting from other sources (motor vehicle traffic for example) must be taken into account to determine the total L_{dn} for that site.

III. OUTLINE OF METHOD

The basic problem to be solved is illustrated in Figure 1 for the simple case of land parcel exposed to noise from takeoffs of a single type of aircraft. To solve this problem, certain basic *operational information* must be obtained. This information consists of:

(A) Type of aircraft (charts will be provided for selection of aircraft types)

(B) Mode of operation, takeoff or landing (several sets of landing and takeoff charts may be provided when detailed operating characteristics are to be taken into account. For the simplified calculation method, single sets of takeoff and approach noise charts will be used for each aircraft.)

(C) The number of operations per daytime and per nighttime period. (For most purpose the average number of daily operations averaged over a yearly period should be used. For more detailed investigations, one may wish to consider the number of operations occuring over a shorter period. For example, when pronounced changes in aircraft operations occurs for different seasons of the year, one might wish to calculate separate L_{dn} values for the seasons.)

(D) Aircraft flight track over the ground (The path of the aircraft projected on the ground is called the track) The track must be located to determine actual distances from the land parcel to the aircraft in flight.

The next step is to determine the distances D_1 and D_2 as shown in Figure 2. For takeoffs, D_1 is the distance along the flight track from the start of the takeoff to a perpendicular drawn from the flight track through the land parcel. For landing, D_1 is the distance along the flight track from the landing threshold* to the perpendicular drawn from the flight track through the land parcel. Knowledge of D_1 and of the aircraft takeoff or landing profile permits one to determine h, the aircraft height above ground (see Figure 2), as the aircraft passes near the ground position.

The next major step is to select the proper *noise chart*. Selection of the *noise chart* is determined by:

- Aircraft type operation
- distance D_1**

* For many runways, the landing threshold coincides with the beginning of the runway. However, "delayed" landing thresholds are used at a number of airports, where the landing threshold is displaced along the runway.

**Several charts may be needed to cover the entire range of D_1 distances that may be of interest.

Figure 3 shows a simplified noise chart. The noise charts have a number of curves. Each curve depicts the sound exposure level as a function of the distance from the land parcel to the flight track centerline, (D_2), for a specified value of D_1. Each chart typically shows curves for a number of D_1 distances.

As shown in Figure 3, the desired SEL value is determined by first establishing the D_2 distance along the x axis. A perpendicular is then drawn on the graph to intercept the proper D_1 value. The appropriate D_1 distance is established by interpolation between the bracketing D_1 curves. From this intersection, a line is drawn horizontally to intersect the Y-axis. This intersection determines the proper SEL value.

The SEL value must now be adjusted to determine the L_{dn} contributed by this particular aircraft operation. This adjustment is based on the number of time the operation occurs. This adjustment value "K" is given by the chart shown in Figure 4.*

L_{dn} is simply the sum of the SEL value and the K value from Figure 4.

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* This figure provides a graphical solution of:

$$K = 10 \log (N_D + 10\ N_N) - 49.4 \quad \text{(dB)}$$

The above step completes the process for obtaining an L_{dn} value for a single aircraft operation by one class of aircraft. This process must then be repeated for each major aircraft type and mode of operation. Repitition then results in a set of L_{dn} values. The total aircraft noise environment is then the energy summation of these "partial" L_{dn} values.

Since the L_{dn} values are expressed in decibels, they cannot be added together by ordinary arithmetic. Instead "decibel addition" is involved. A chart for adding sound levels quite accurately by "decibel addition" is given in Figure 5. This chart can be used to an accuracy of 0.1 dB, but most applications will not require (nor justify) this degree of precision. A more practical addition procedure for quickly estimating the sum of two or more decibel levels is given in the top of Table 1. The use of this table will yield a sum that has an accuracy within 1 dB. An accuracy within 1/2 dB can be obtained by using the lower half of Table 1. This degree of accuracy in comparing L_{dn} values will generally be adequate for most calculations.

When a number of L_{dn} values are to be added,* they should be added two at a time, starting with the lower valued levels and continuing the addition procedure of two at a time until only

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* The availability of scientific calculators have 10^X and log $_{10}X$ functions makes decibel addition very easy, and precise.

one value remains. To illustrate, suppose it is desired to add the following five levels, using the summation procedure of the upper portion of Table 1:

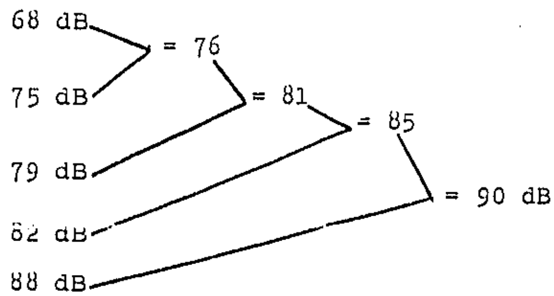


Table 2 provides a summary of the basic calculation steps described above. Figure 6 provides a sample chart for calculating the L_{dn} values.

IV. EXAMPLES

The following two examples illustrate the procedure, the first for a single aircraft operation and the second for multiple aircraft operations. Calculations for these examples are given in Figure 7.

Example 1 -

Consider a site exposed to noise from takeoffs of turbofan transport aircraft with the aircraft departing along a curved flight path essentially as shown in Figure 2. There are twelve operations during daytime hours (between 7 am and 10 pm) and two nighttime operations (between 10 pm and 7 am). Measurement of the flight track on a map shows that the distance D_1 is 22,000 feet and the distance D_2 is 4,000 feet.

Entering the takeoff chart of Figure 3 which covers the D_1 distance values from 20,000 to 40,000 feet and using distance D_2 value of 4,000 feet one obtains the SEL value of 102.5 dB. Note that a curve for D_1 equal to 22,000 feet is located two-fifths of the distance between the D_1 curves for 20,000 and 25,000 feet.

The interpolation here can be done by inspection or by calculation:

At D_2 = 4000 ft, the SEL for D_1 = 20,000 ft is 104 dB; for D_1 = 25,000 ft, the SEL is 100 dB.

Thus, the SEL for a D_1 of 22,000 ft is:

$$104 + \frac{22{,}000-20{,}000}{25{,}000-20{,}000} \cdot (-4)$$

$$= 104 - \frac{2}{5}(4) = 104 - 1.5 = 102.5$$

From Figure 4, the "K" value for N_D equal to 12 and N_N equal to 2 is -34.5 dB. Therefore, as shown by the calculation in Figure 7, the L_{dn} is 68 dB.

<u>Example 2</u> -

Consider the same site as in Example 1. The airport is considering a change in aircraft departure paths, such that a large proportion of aircraft would make a "straight-out" departure as sketched in Figure 8. The total number of departures is unchanged. What will be the change in noise exposure at the site as a result of this change in operations? The needed operational information is tabulated in Figure 7. Eight daytime flights have been changed from flight path A to flight path B (see Figure 6). The two night operations have been split between the two paths.

The distances D_1 and D_2 are tabulated in Figure 7. The SEL values from Figure 3 are also tabulated. The new flight path results in an SEL that is 2.5 dB lower than that for flight path A.

The addition of "K" values obtained from Figure 4 results in L_{dn} values of 64.5 dB and 63.0 dB. "Adding" the two L_{dn} values by means of Table 1-B results in a total L_{dn} of 67 dB. (More precise calculations yield 66.8 dB.)

> 64.5 - 63.0 = 1.5 dB. By Table 1-B, 2.5 dB should then be added to 64.5 dB
>
> 64.5 + 2.5 = 67.0 dB

Thus, the change in flight paths has resulted in a decrease in noise exposure at the site by 1 dB.

TABLE 1

RULES FOR COMBINING SOUND LEVELS BY "DECIBEL ADDITION"

A. For noise levels known or desired to an accuracy of ± 1 decibel:

When two decibel values differ by	Add the following amount to the higher value
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 9 dB	1 dB
10 dB or more	0 dB

B. For noise levels known or desired to an accuracy of ± ½ decibel:

When two decibel values differ by	Add the following amount to the higher value
0 or ½ dB	3 dB
1 or 1½ dB	2½ dB
2 to 3 dB	2 dB
3½ to 4½ dB	1½ dB
5 to 7 dB	1 dB
7½ to 12 dB	½ dB
13 dB or more	0 dB

(For greater accuracy, refer to chart in Figure 5)

TABLE 2. DAY-NIGHT LEVEL CALCULATION SUMMARY

1. Obtain operational input information:
   - Aircraft type
   - Mode of operations: takeoff or landing
   - Number of operations for :
     - Daytime (N_d)
     - Nightime (N_n)
   - Flight track location in the ground

2. From a flight track map, obtain distances D_1 and D_2 (see Figure 2)

3. Select proper aircraft noise chart, based on:
   - Aircraft type
   - Mode of operation
   - Distance D_1

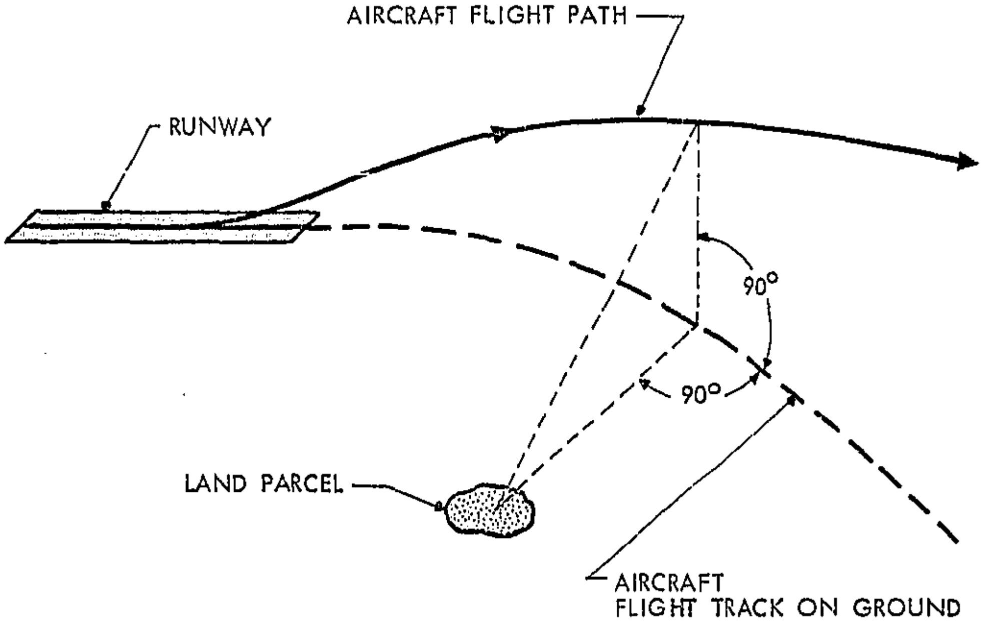
4. From the noise chart, determine the aircraft sound exposure level (SEL) by entering the chart using distances D_1 and D_2.

5. Obtain the "K" value for number of operations from Figure 4, using N_d and N_n.

6. Add SEL and K to obtain L_{dn}.

7. Repeat Steps 1 through 6 for each separate aircraft type and mode of operations that would contribute to the noise exposure at the land parcel.
   Thus, for each aircraft type and mode of operation, i, one will obtain a corresponding L_{dn} (i).

8. "Add" the L_{dn} (i) values on a decibel basis, using Table 1 or Figure 5 to obtain the total aircraft L_{dn}.



PROBLEM: TO FIND DAY-NIGHT LEVEL (L_{DN}) FOR LAND PARCEL DUE TO AIRCRAFT OPERATIONS FROM AIRPORT

FIGURE 1. BASIC SITUATION FOR CALCULATION OF DAY-NIGHT AVERAGE LEVELS DUE TO AIRCRAFT

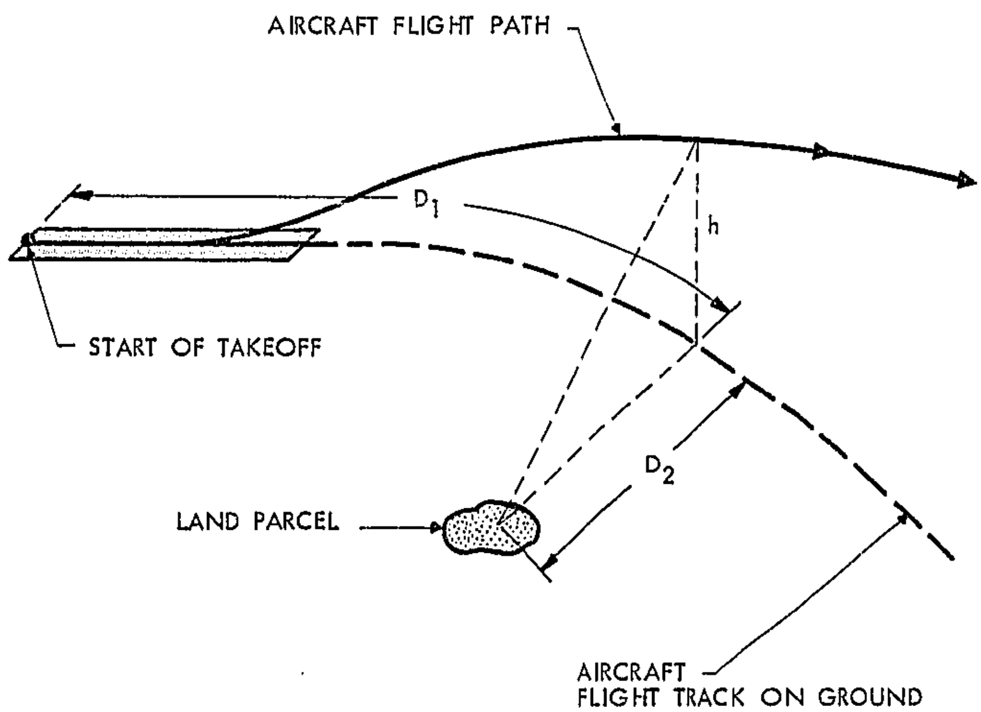


FIGURE 2. DEFINITION OF DISTANCES D_1 AND D_2 FOR AN AIRCRAFT TAKEOFF

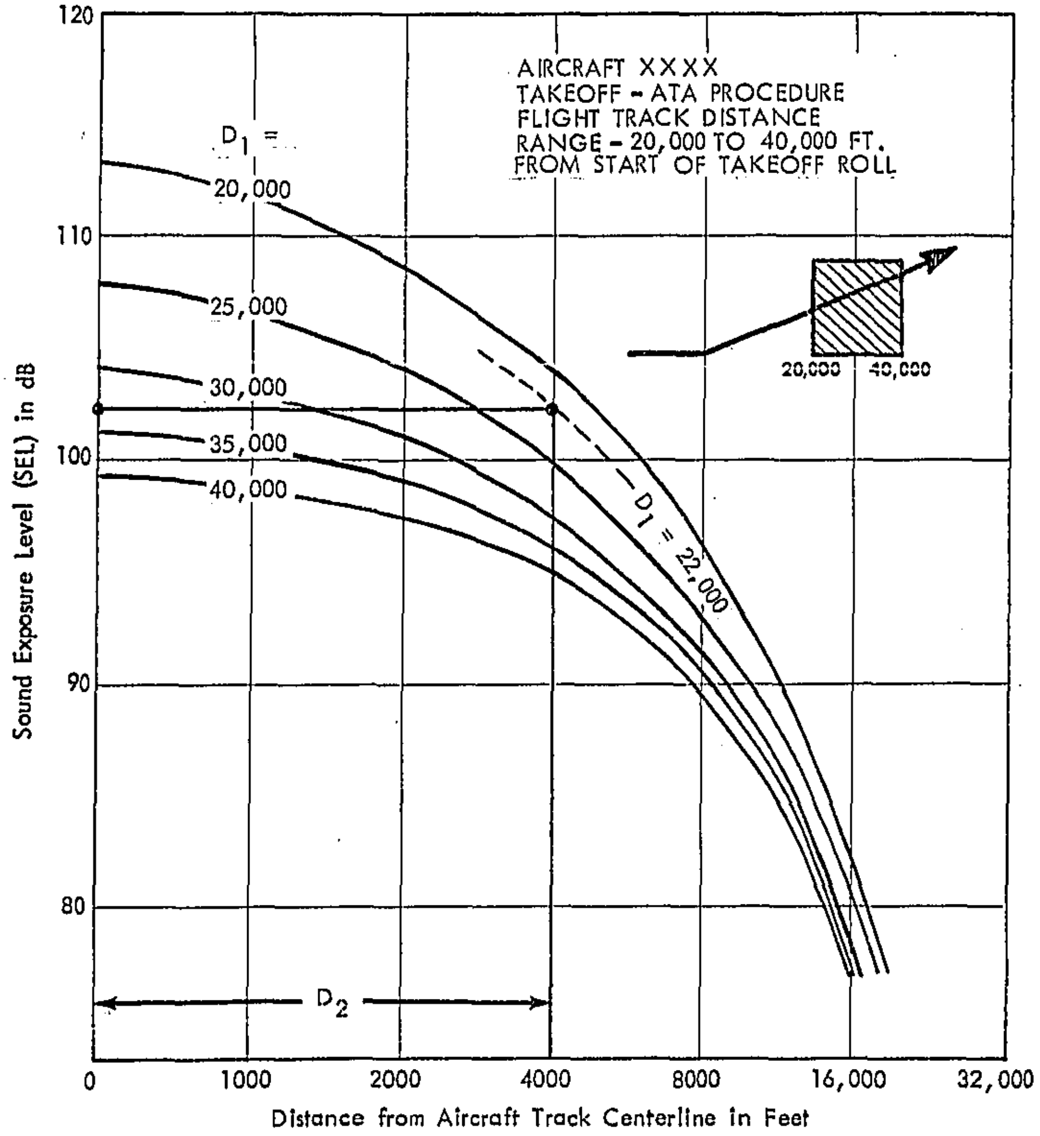


FIGURE 3. SAMPLE AIRCRAFT NOISE CHART SHOWING DETERMINATION OF SEL FOR GIVEN DISTANCES D_1 AND D_2

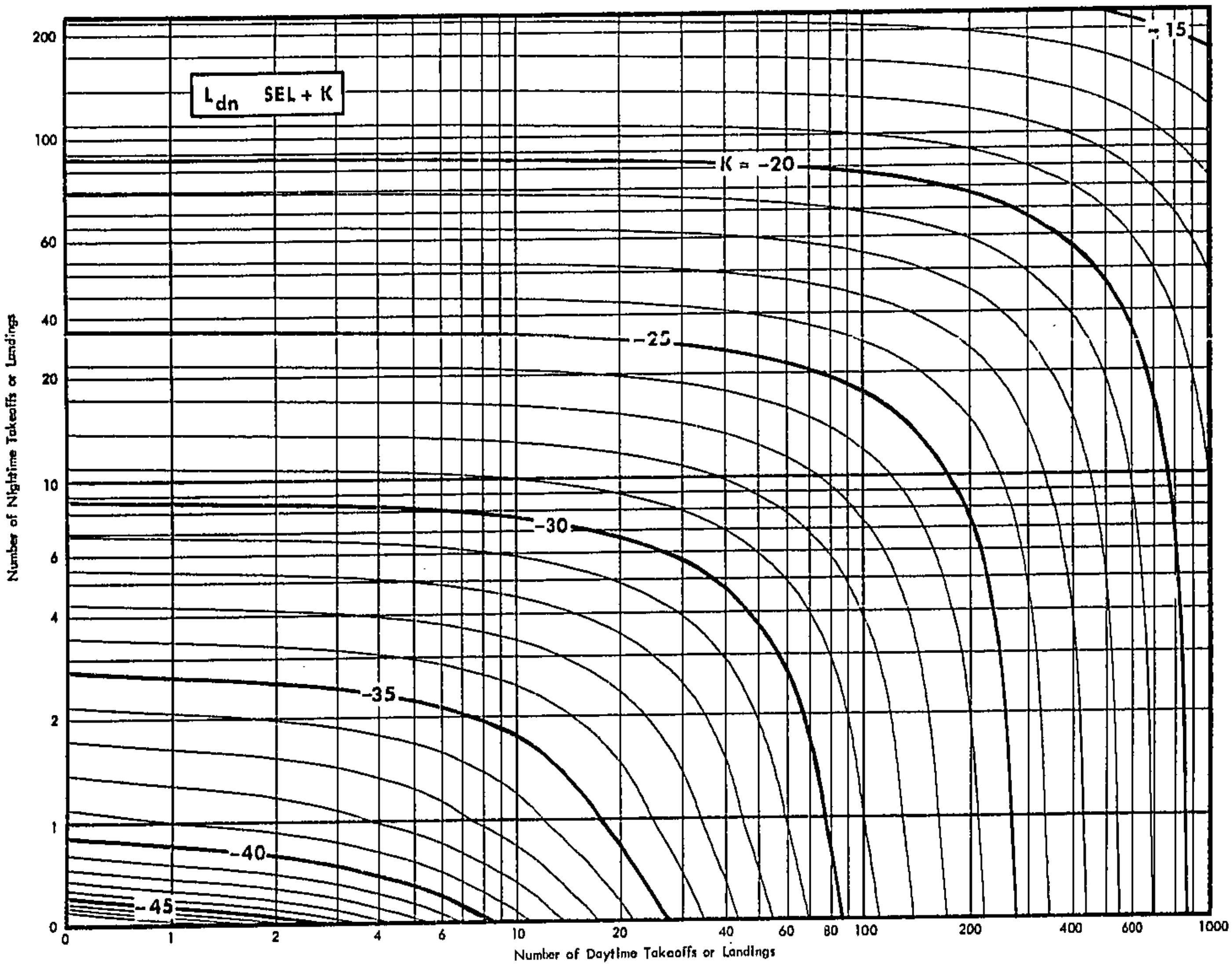


FIGURE 4. CHART FOR DETERMINING THE ADJUSTMENT "K" FOR NUMBER OF AIRCRAFT OPERATIONS DURING DAY AND NIGHT PERIODS

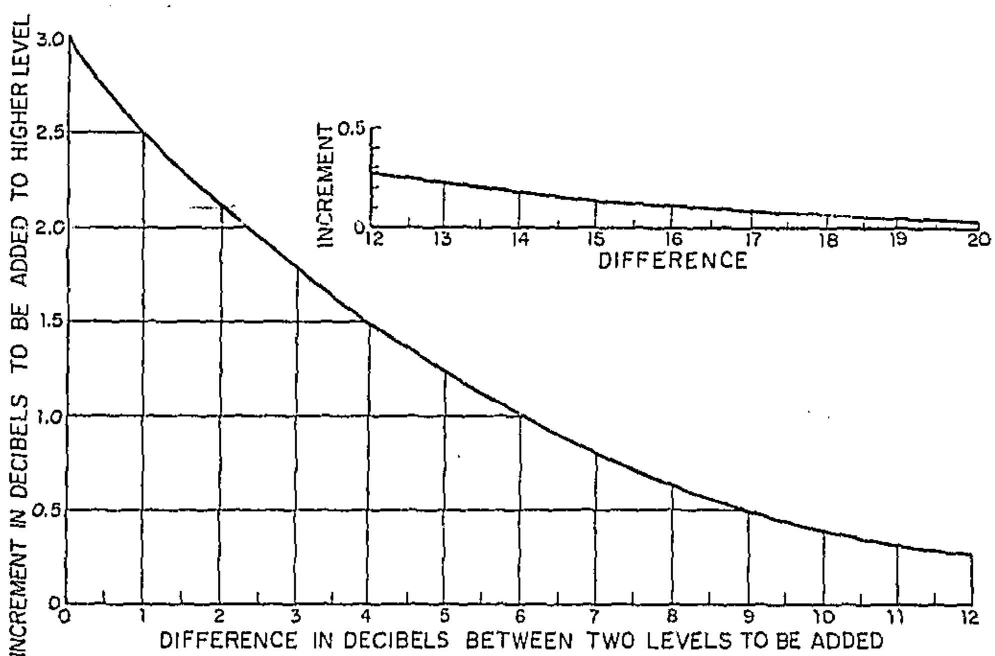


FIGURE 5. CHART FOR COMBINING SOUND LEVELS BY "DECIBEL ADDITION"

AIRCRAFT				
OPERATION				
N_D				
N_N				
D_1				
D_2				
CHART				
SEL				
K				
L_{DN}				

FIGURE 6. L_{DN} CALCULATION CHART

	EXAMPLE 1	EXAMPLE 2		
		Path A	Path B	
AIRCRAFT	xxxx	xxxx	xxxx	
OPERATION	TO	TO	TO	
N_D	12	4	8	
N_N	2	1	1	
D_1	22,000	22,000	20,000	
D_2	4000	4000	6000	
CHART	xxxx - TO	xxxx - TO	xxxx - TO	
SEL	102.5	102.5	100	
K	-34.5	-38	-37	
L_{DN}	68.0	64.5	63.0	

FOR EXAMPLE 2, ADDITION BY MEANS OF TABLE 1 (B) YIELDS AN L_{DN} VALUE OF 67 dB

FIGURE 7. CALCULATIONS FOR EXAMPLES 1 AND 2

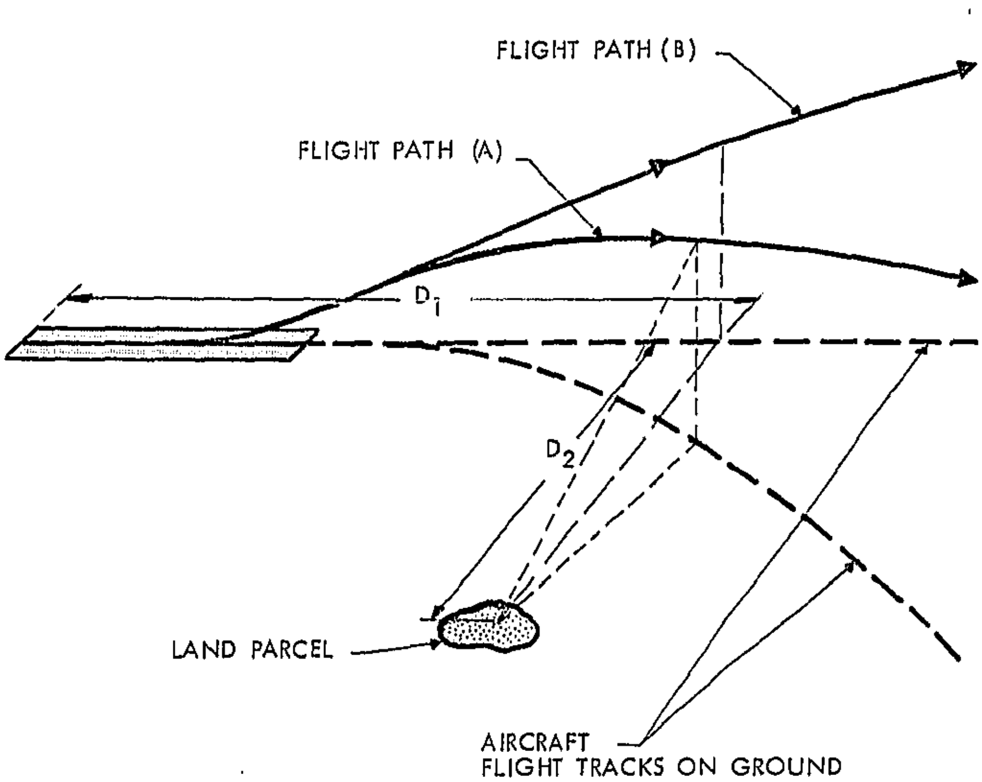
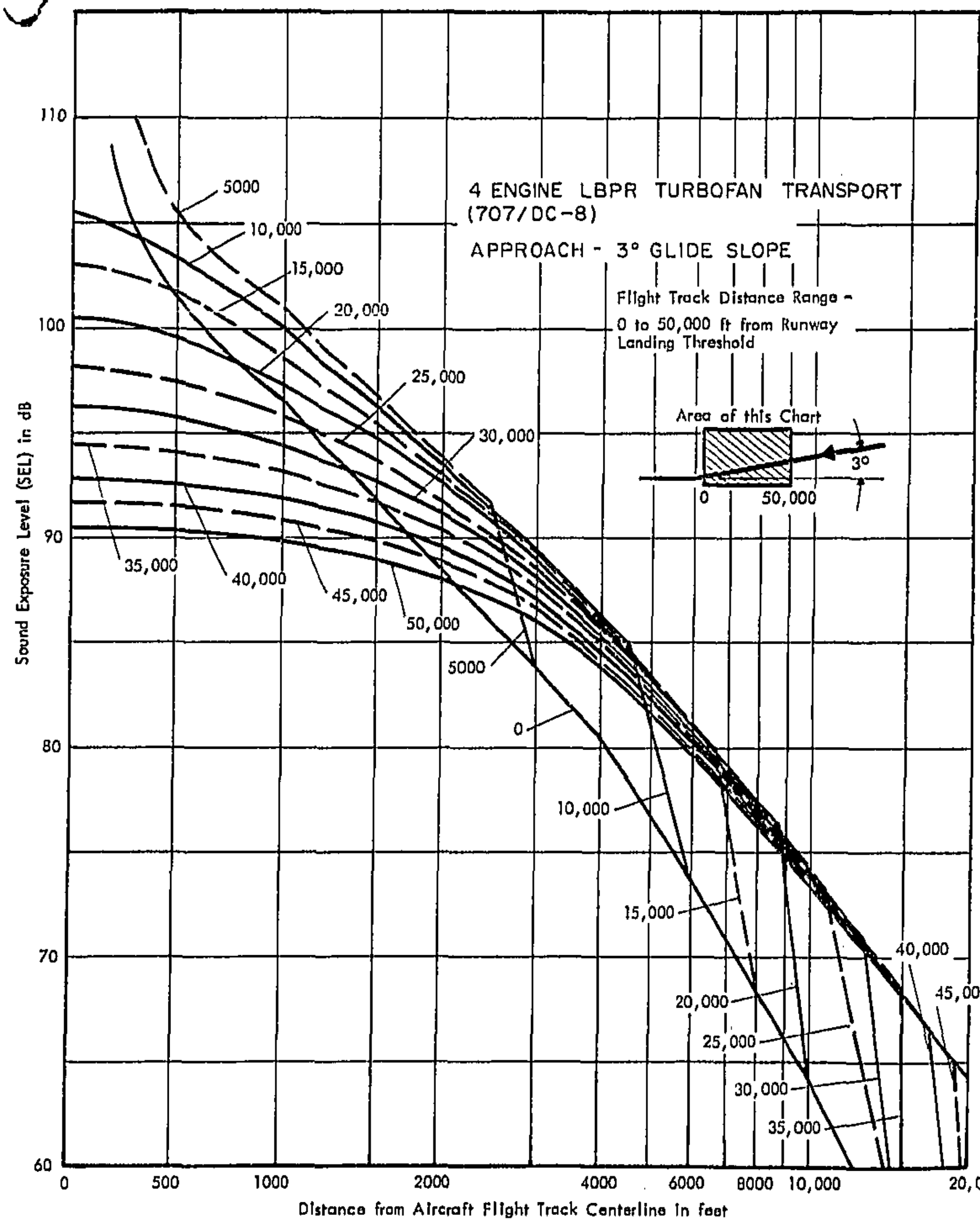
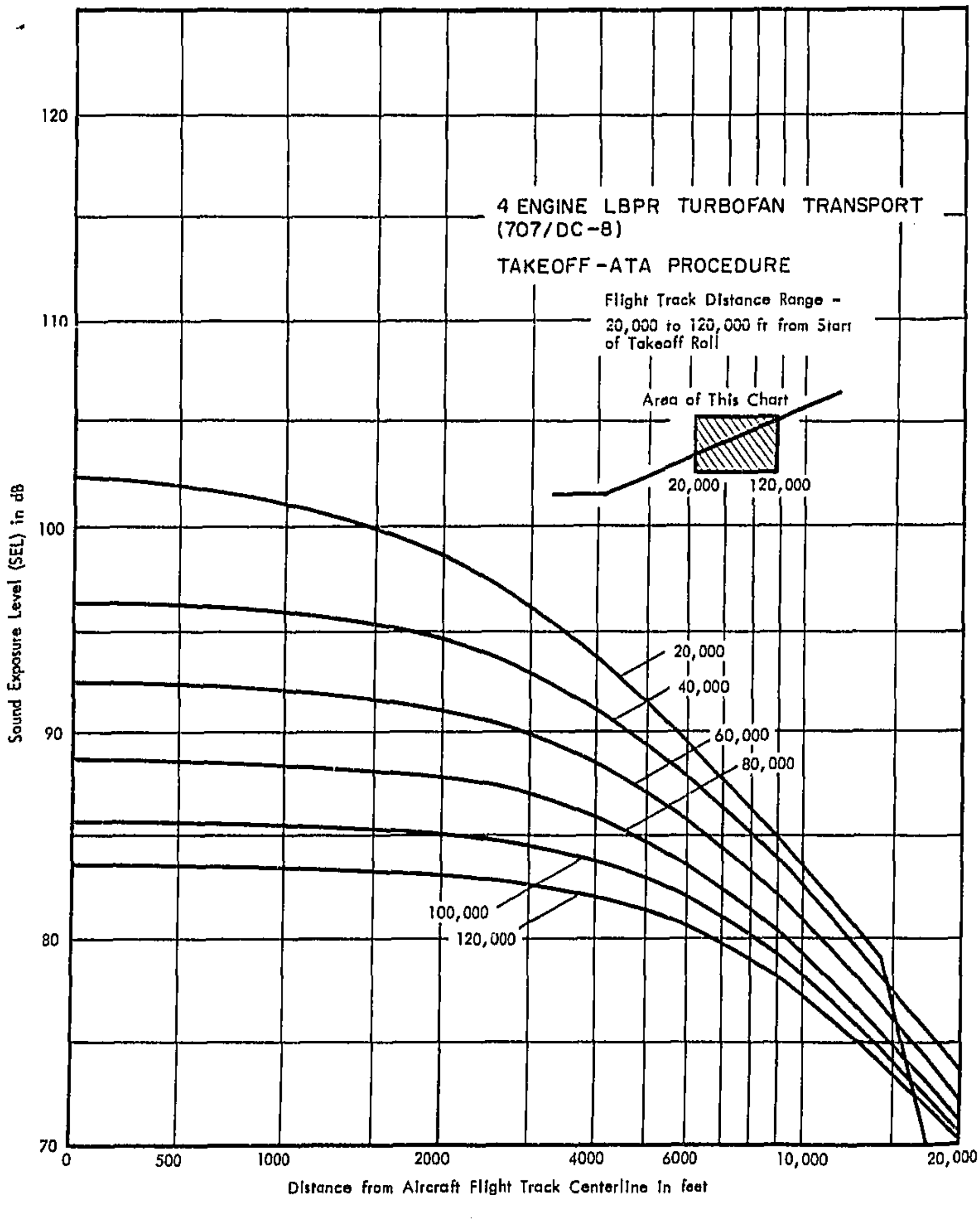


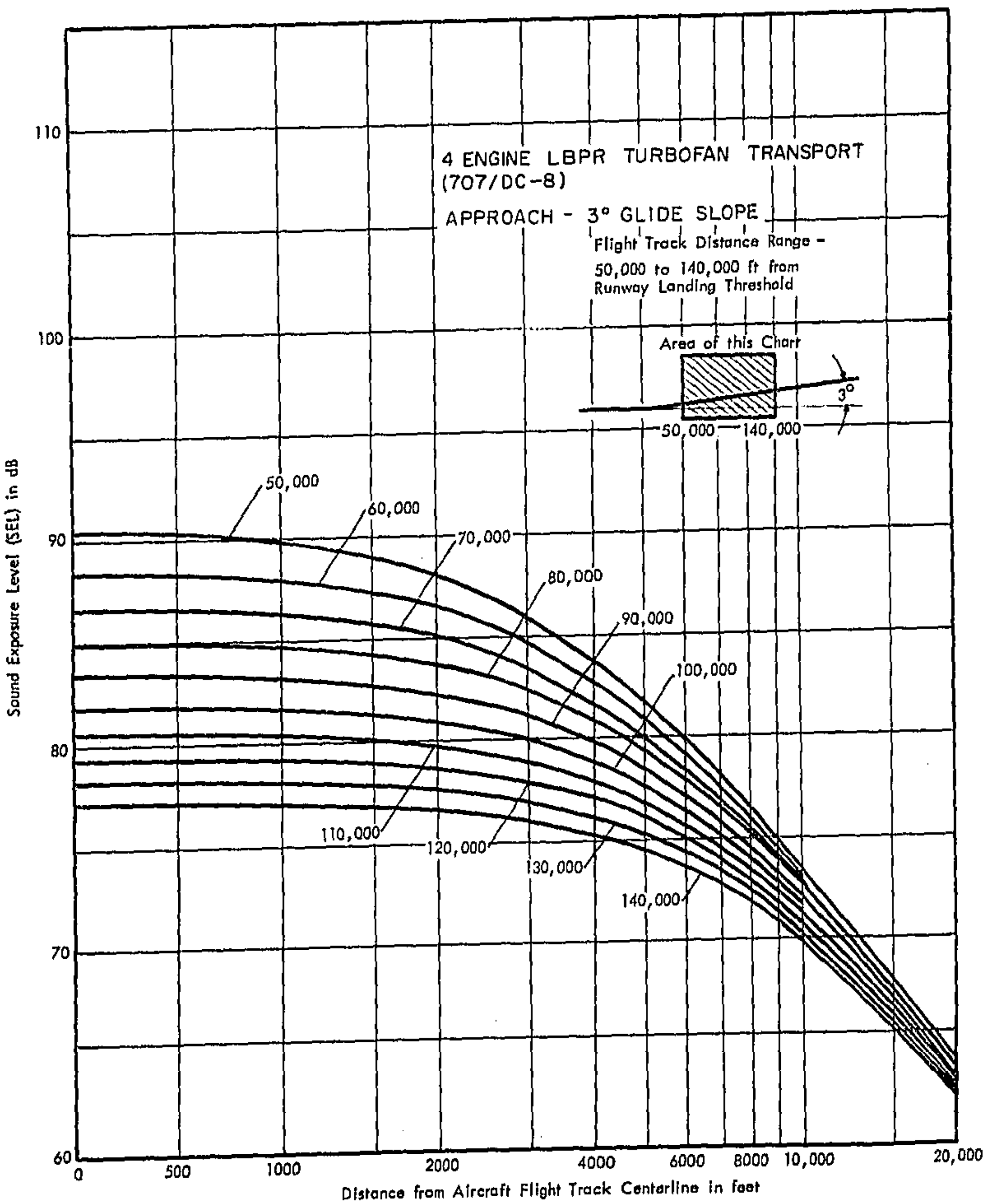
FIGURE 8. FLIGHT PATHS AND DISTANCES FOR EXAMPLE 2

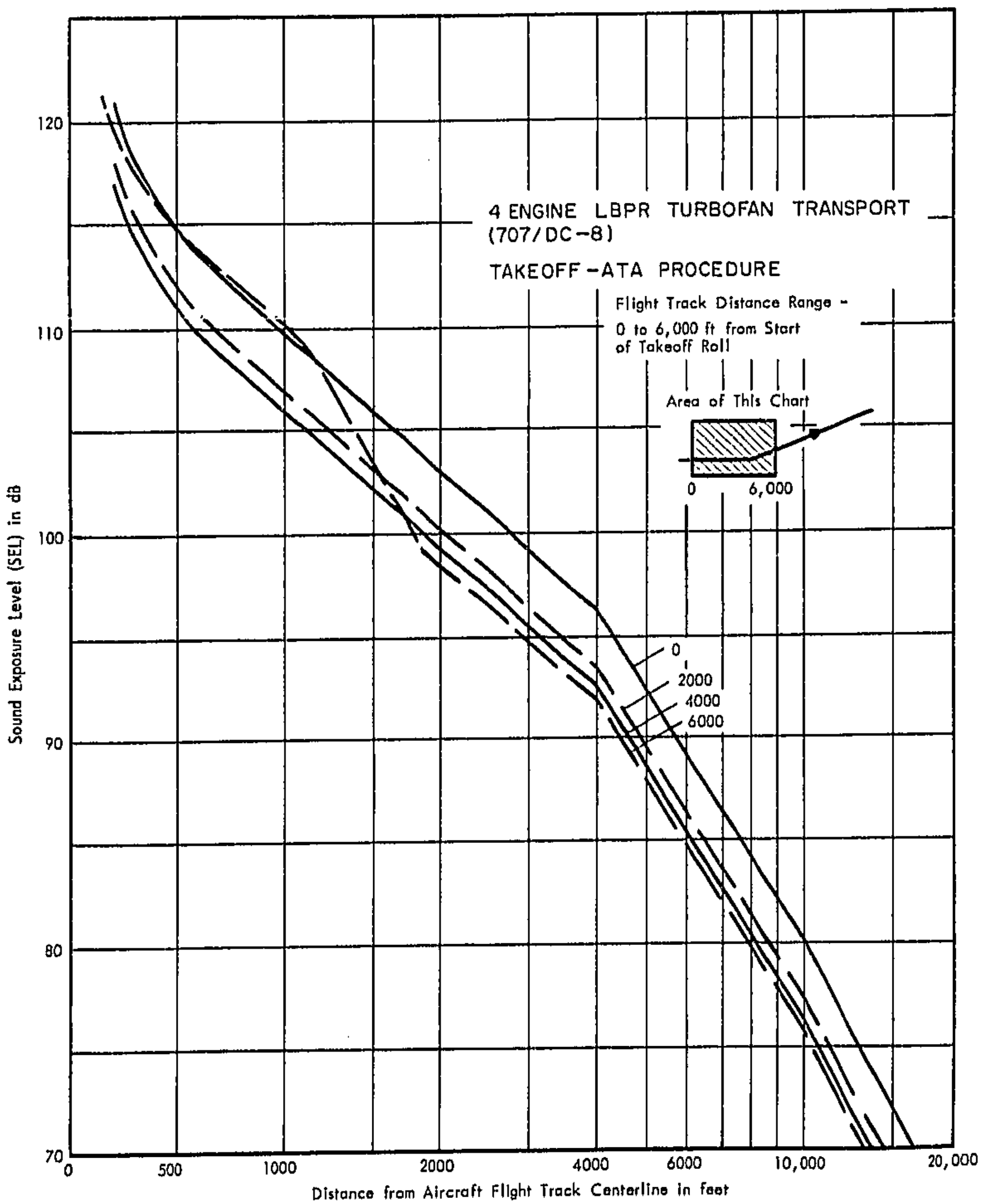


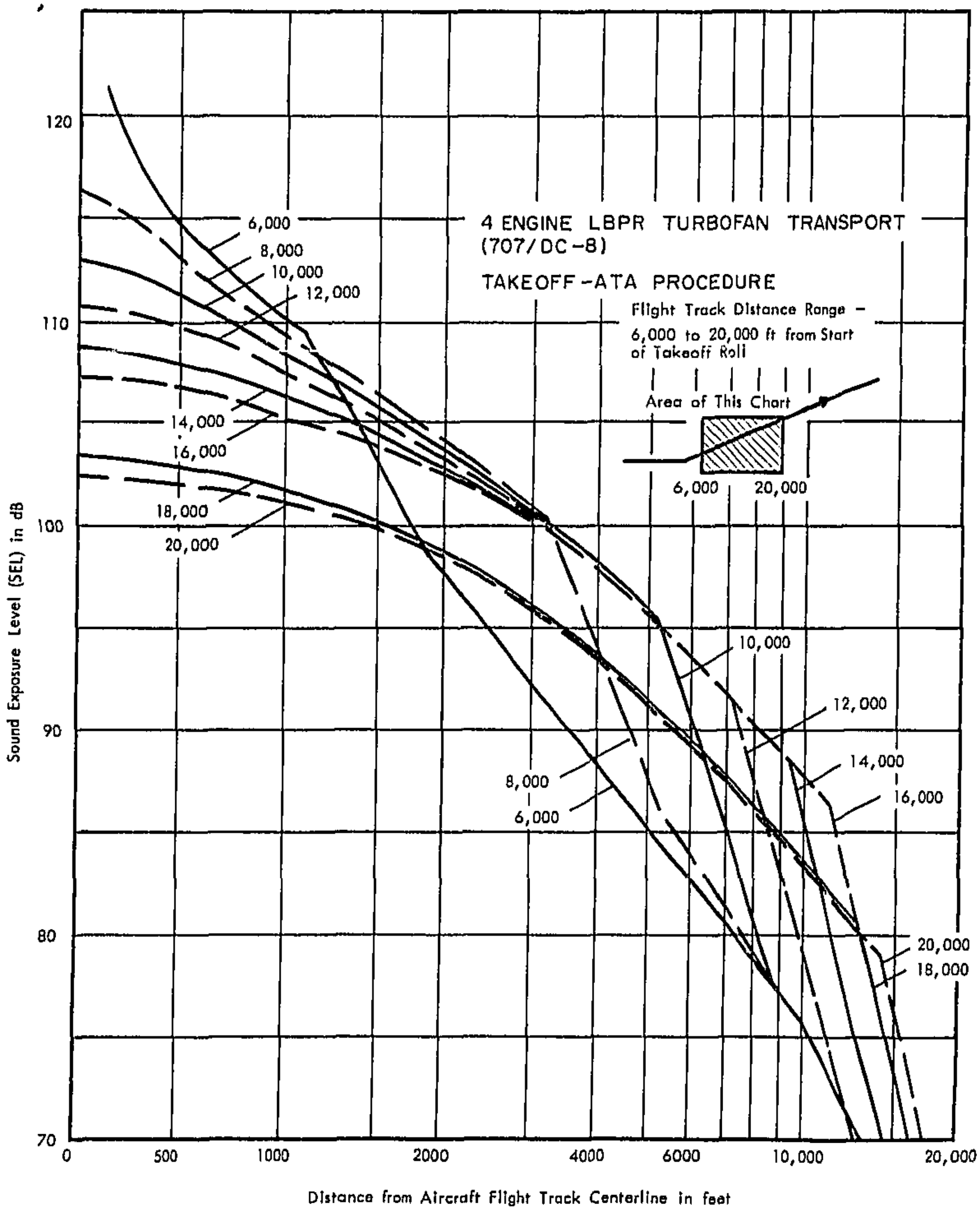
4 ENGINE LBPR TURBOFAN TRANSPORT (707/DC-8)
APPROACH - 3° GLIDE SLOPE
Flight Track Distance Range - 0 to 50,000 ft from Runway Landing Threshold
Area of this Chart
0
50,000
3°
Sound Exposure Level (SEL) in dB
110
100
90
80
70
60
5000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
5000
0
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
0
500
1000
2000
4000
6000
8000
10,000
20,000
Distance from Aircraft Flight Track Centerline in feet



4 ENGINE LBPR TURBOFAN TRANSPORT (707/DC-8)
TAKEOFF-ATA PROCEDURE
Flight Track Distance Range - 20,000 to 120,000 ft from Start of Takeoff Roll
Area of This Chart
20,000
120,000
20,000
40,000
60,000
80,000
100,000
120,000
Sound Exposure Level (SEL) in dB
120
110
100
90
80
70
0
500
1000
2000
4000
6000
10,000
20,000
Distance from Aircraft Flight Track Centerline in feet


4 ENGINE LBPR TURBOFAN TRANSPORT
(707/DC-8)
APPROACH - 3° GLIDE SLOPE
Flight Track Distance Range - 50,000 to 140,000 ft from Runway Landing Threshold
Area of this Chart
3°
50,000
140,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
120,000
130,000
140,000
110
100
90
80
70
60
Sound Exposure Level (SEL) in dB
0
500
1000
2000
4000
6000
8000
10,000
20,000
Distance from Aircraft Flight Track Centerline in feet


4 ENGINE LBPR TURBOFAN TRANSPORT (707/DC-8)
TAKEOFF-ATA PROCEDURE
Flight Track Distance Range - 0 to 6,000 ft from Start of Takeoff Roll
Area of This Chart
0
6,000
0
2000
4000
6000
Sound Exposure Level (SEL) in dB
120
110
100
90
80
70
0
500
1000
2000
4000
6000
10,000
20,000
Distance from Aircraft Flight Track Centerline in feet


4 ENGINE LBPR TURBOFAN TRANSPORT
(707/DC-8)
TAKEOFF-ATA PROCEDURE
Flight Track Distance Range - 6,000 to 20,000 ft from Start of Takeoff Roll
Area of This Chart
6,000
20,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
10,000
12,000
14,000
16,000
8,000
6,000
20,000
18,000
120
110
100
90
80
70
0
500
1000
2000
4000
6000
10,000
20,000
Sound Exposure Level (SEL) in dB
Distance from Aircraft Flight Track Centerline in feet