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Report 2759 R
Project 11150

SOUND EXPOSURE LEVEL VERSUS DISTANCE CURVES FOR CIVIL AIRCRAFT

Dwight E. Bishop
John F. Mills
Jane M. Beckmann

February 1976

Submitted to:
Mr. Damon Gray
Office of Noise Abatement
Environmental Protection Agency
Washington, D.C. 20460

Reference: EPA Contract 68-01-2265

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SOUND EXPOSURE LEVEL VERSUS DISTANCE CURVES FOR CIVIL AIRCRAFT

I. INTRODUCTION

This report provides sound exposure level (SEL) data for civil aircraft in a form useful for day/night average level (L_{dn}) calculations. The SEL data are presented in tabular form in this report; the report also briefly summarizes the data sources and technical analyses used in developing the noise data.

Noise data are included for all major current civil transport and business jet aircraft and for most general aviation aircraft. Data are also provided for possible retrofit of low bypass ratio (LBPR) turbofan aircraft with acoustically lined nacelles. As in the companion report which presents effective perceived noise level versus distance curves for civil aircraft[17]*, the correlation of noise level data with aircraft operations (in terms of aircraft speed and engine operating parameters) varies in detail--from specific curves for different engine parameters and speeds for major civil transport aircraft, to generalized noise curves for rather broad categories of propeller aircraft.

Section II presents the noise data. Section III describes the source of noise data, outlines analysis methods, and discusses some of the technical problems involved in developing the noise curves.

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*References are listed together at the end of the report.

II. NOISE DATA PRESENTATION

The day/night average level (L_{dn}) procedures for calculating the noise environment in the vicinity of an airport[10] utilize the SEL as a basic noise event descriptor for moving aircraft*. In the procedures, noise information is needed at varying distances from the aircraft. Thus the general input requirement is for a set of SEL values tabulated at various distances, typically from 200 ft. to 25,000 ft. or greater. The L_{dn} model assumes that, for a given aircraft, an SEL can be defined from the knowledge of the type of aircraft, basic engine operating parameters, air speed and atmospheric propagation conditions. Two sets of noise vs. distance curves are used:

a) air-to-ground propagation;
b) ground-to-ground propagation.

In the program, algorithms are provided for the transition between air-to-ground and ground-to-ground curves. The air-to-ground propagation curves assume atmospheric absorption in accordance with SAE ARP 866 [3]. The ground-to-ground propagation curves assume similar atmospheric absorption plus excess ground attenuation[1].

The noise level vs. distance curves data given in this report are developed for standard day conditions (59°F and 70% relative humidity.) Data provided for these conditions generally provide

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*The L_{dn} calculation procedures follow closely those for calculating noise exposure forecast (NEF) contours as described in References 1 and 2.

rather conservative estimates of noise levels for the range of temperatures and humidity often encountered in civil airports in this country.

Noise data for both air-to-ground and ground-to-ground propagation are presented in tabular form in Table II. Table I provides a guide to a selection of noise information for both general aircraft classifications and specific aircraft types.

For the turbojet and turbofan aircraft, noise curves are referenced in terms of an aircraft engine operating parameter, typically referred net thrust. The thrust values to use for a particular takeoff or landing profile, taking into account specific operating procedures, operating weights, air speeds, flap settings, etc., can be determined from the calculation procedure and aircraft data provided in Reference 4.

For most aircraft included in this report, noise data are tabulated for typical takeoff and approach thrust settings. However, for the two, three and four engine low bypass ratio turbofan transport aircraft, a more complete set of curves is provided. For these aircraft typical approach and takeoff curves are also indicated for use when more detailed information about specific engine operating parameters is not known.

In utilizing the data in L_{dn} computations, an additional correction is to be applied to the noise data. The SEL values are to be adjusted for aircraft altitude on the basis of an acoustic impedance correction, $\Delta_{\rho c}$:

$$\Delta_{\rho c} = 10 \log \frac{\rho c}{\rho_o c_o} = 10 \log \left(\frac{\rho}{\rho_o}\right)\sqrt{\frac{T}{T_o}}$$

where:

ρ = air density at aircraft altitude
c = speed of sound at aircraft altitude
T = absolute temperature at aircraft altitude

and subscript "o" refers to sea level standard day unless otherwise specified.

TABLE I

INDEX TO AIRCRAFT SEL VERSUS DISTANCE CURVES

General Aircraft Type	Specific Aircraft Type	Aircraft Engine Type	Refer to Table
4-Engine LBPR Turbofan Transport	Boeing 707 Series Douglas DC-8 Series	JT3D Series JT3D Series	II-1
4-Engine LBPR Turbofan Transport with Retrofit Nacelles	Boeing 707 Series Douglas DC-8 Series	JT3D Series JT3D Series	II-2
3-Engine LBPR Turbofan Transport	Boeing 727 Series	JT8D	II-3
3-Engine LBPR Turbofan Transport with Retrofit Nacelles	Boeing 727 Series	JT8D Series	II-4
2-Engine LBPR Turbofan Transport	Boeing 737 Douglas DC-9	JT8D Series JT8D Series	II-5
2-Engine LBPR Turbofan Transport with Retrofit Nacelles	Boeing 737 Douglas DC-9	JT8D Series JT8D Series	II-6
4-Engine HBPR Transport	Boeing 747-100A Boeing 747-100D,-200B	JT9D-3A JT9D-3A,-7	II-7
3-Engine HBPR Transport	Douglas DC-10-10,-30 Douglas DC-10-40	CF6-6D JT9D-20	II-8
Business Jets	Cessna Citation	(2) JT15D-1 Turbofans	II-9
	Commodore Jet Commander 1121	(2) CJ610-5 Turbojets	"
	Dassault Fan Jet Falcon 20	(2) CF700-2 Turbofans	"
	Gates Learjet 24/25	(2) CJ610-6 Turbojets	II-10
	Gates Learjet 35/36	(2) TFE731-2 Turbofans	"
	Grumman Gulfstream II	(2) Spey 511-8 Turbojets	II-11
	Lockheed Jetstar 1	(4) JT 12A-6A Turbojets	"
	North American Sabre 80	(2) CJ700-2D-2 Turbofans	"
	North American Sabre 60	(2) JT 12A-8 Turbojets	II-12
	Composite Aircraft	Note 1	"
4-Engine Turboprop Transport	Lockheed Hercules 382E, 382G, C130H	Allison T56-15 Series	II-13
	Lockheed Electra, Hercules	Allison T56-7 & earlier	"
2-Engine Turboprop Transport	Fairchild F-27, HS-748	Rolls Royce Dart Series	II-14
	DeHavilland DHC-6 Twin Otter	PT6 Series	"
4-Engine Piston Transport	DC-6, DC-7, Constellation		II-15
2-Engine Piston Transport (>12,500 lbs max. gross weight)	Convair 340, 440, DC-3		"
2-Engine Piston Aircraft (<12,500 lbs max. gross weight)	Cessna 310, Cessna 337, Piper Aztec, Beech Queen Air		II-16
1-Engine Piston Aircraft Composite	Cessna 182 Piper Cherokee Beech Bonanza	Note 2	"

Note 1 - The composite business jet noise is based upon the noise characteristics of three types of business jet engines (straight turbojets, turbofans and small turbofans [Cessna Citation]). The composite characteristics assume a ratio of operations of 70% turbojet, 16% larger turbofans and 14% smaller turbofans.

Note 2 - The composite single engine aircraft assume 80% operations of aircraft having engines of less than 200 HP and 20% operations of aircraft having engines of 200 to 600 HP.

TABLE II-1

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft: Four Engine LBPR Turbofan Transport Aircraft - 707 & DC-8 with JT3D Series Engines (Note: Subtract 2 dB for DC-8-63 Aircraft)

Operation:			Approach								Takeoff	
Airspeed:	160 Kt		160 Kt		160 Kt		160 Kt		160 Kt		160 Kt	
Power:	Fn = 4000 lbs		Fn = 6000 lbs		Fn = 8000 lbs		Fn = 10000 lbs		Fn = 12000 lbs		Fn = 15000 lbs	
	SEL, dB		SEL, dB		SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	111.0	106.0	113.0	108.0	115.0	110.0	117.0	112.0	119.0	114.0	121.0	116.0
250	109.6	104.6	111.6	106.6	113.6	108.6	115.6	110.6	117.6	112.6	119.6	114.6
315	108.1	103.1	110.1	105.1	112.1	107.1	114.1	109.1	116.1	111.1	118.1	113.1
400	106.5	101.5	108.5	103.5	110.5	105.5	112.5	107.5	114.5	109.5	116.5	111.5
500	104.8	99.8	106.9	101.9	108.9	103.9	111.0	106.0	113.0	108.0	115.0	110.0
630	102.9	97.9	105.2	100.2	107.3	102.3	109.3	104.3	111.3	106.3	113.3	108.3
800	101.0	96.0	103.2	98.2	105.5	100.5	107.6	102.6	109.6	104.6	111.8	106.8
1000	99.0	94.0	101.5	96.5	104.0	99.0	106.0	101.0	108.0	103.0	110.0	104.9
1250	96.7	91.7	99.3	94.3	102.0	97.0	104.1	99.1	106.2	101.1	108.2	103.0
1600	94.1	89.1	97.0	92.0	99.8	94.8	102.0	96.9	104.1	98.9	106.2	100.8
2000	91.5	86.4	94.5	89.4	97.5	92.4	100.0	94.8	102.0	96.7	104.5	98.9
2500	89.0	83.8	92.0	86.8	95.0	89.7	97.5	92.0	99.9	94.3	102.6	96.6
3150	86.3	80.8	89.1	83.6	92.3	86.6	95.0	89.1	97.3	91.2	100.6	94.1
4000	83.5	77.5	86.5	80.5	89.5	83.3	92.5	86.0	95.0	88.3	98.5	91.1
5000	80.6	73.8	83.6	76.8	86.7	79.6	89.5	82.2	92.4	84.8	96.2	87.4
6300	77.6	69.8	80.6	72.8	83.7	75.6	86.7	78.3	89.7	81.0	93.6	83.6
8000	74.4	65.4	77.3	68.3	80.5	71.2	83.4	73.8	86.8	76.9	90.8	79.6
10000	71.5	61.3	74.5	64.3	77.5	67.0	80.5	69.7	84.0	72.9	88.0	75.6
12500	68.3	56.9	71.5	60.1	74.4	62.6	77.3	65.1	81.0	68.4	85.2	71.5
16000	65.0	52.1	68.0	55.1	71.0	57.6	74.0	60.1	77.5	63.0	82.0	66.6
20000	61.7	47.0	64.8	50.1	67.8	52.4	70.6	54.5	74.3	57.6	79.0	61.7
25000	58.5	41.8	61.5	44.8	64.5	47.0	67.5	49.3	71.5	52.5	76.0	56.5

TABLE II-2

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft: Four Engine LBPR Turbofan Transport Aircraft - 707 & DC-8 with JT3D Series Engines with Retrofit Lined Nacelles

Operation:	Approach										Takeoff	
Airspeed:	160 Kt		160 Kt		160 Kt		160 Kt		160 Kt		160 Kt	
Power:	Fn = 4000 lbs		Fn = 6000 lbs		Fn = 8000 lbs		Fn = 10000 lbs		Fn = 12000 lbs		Fn = 15000 lbs	
Distance ft.	SEL, Air to Ground	dB Ground to Ground	SEL, Air to Ground	dB Ground to Ground	SEL, Air to Ground	dB Ground to Ground	SEL, Air to Ground	dB Ground to Ground	SEL, Air to Ground	dB Ground to Ground	SEL, Air to Ground	dB Ground to Ground
200	102.0	97.0	105.0	100.0	108.0	103.0	111.0	106.0	114.5	109.5	118.0	115.0
250	100.5	95.5	103.5	98.5	106.7	101.7	109.8	104.8	113.2	118.2	116.9	111.9
315	99.0	94.0	102.0	97.0	105.3	100.3	108.5	103.5	111.8	106.8	115.8	110.8
400	97.3	92.3	100.5	95.5	103.8	98.8	107.0	102.0	110.3	105.3	114.5	109.5
500	95.8	90.8	99.0	94.0	102.4	97.4	105.8	100.8	108.9	103.9	113.2	108.2
630	94.0	89.0	97.3	92.3	100.8	95.8	104.2	99.2	107.5	102.4	112.0	106.9
800	92.2	87.1	95.6	90.5	99.2	94.1	102.5	97.4	105.9	100.7	110.4	105.2
1000	90.5	85.3	94.0	88.8	97.5	92.3	101.0	95.8	104.5	99.3	109.0	103.8
1250	88.5	83.2	92.1	86.8	95.7	90.4	99.2	93.9	102.7	97.4	107.5	102.2
1600	86.4	81.1	90.0	84.7	93.5	88.2	98.0	92.6	100.7	95.3	105.7	100.2
2000	84.5	79.0	88.0	82.5	91.5	85.9	95.0	89.3	99.0	93.3	104.0	98.3
2500	82.4	76.6	86.0	80.2	89.4	83.6	93.0	87.1	97.0	91.1	102.0	96.0
3150	80.2	73.9	83.8	77.5	87.2	80.9	90.8	84.4	94.8	88.4	99.9	93.4
4000	78.0	71.0	81.5	74.5	85.0	77.9	87.5	80.4	92.5	85.3	97.5	90.2
5000	75.7	67.7	79.1	71.1	82.7	74.6	86.1	77.9	90.2	81.8	95.4	86.9
6300	73.2	63.9	76.6	67.5	80.2	70.8	83.8	74.3	87.9	78.3	93.0	83.3
8000	70.6	60.6	74.0	64.0	77.5	67.4	81.0	70.8	85.3	75.0	90.5	80.1
10000	68.0	57.2	71.5	60.7	75.0	64.1	78.5	67.4	83.0	71.7	88.0	76.6
12500	65.0	53.0	68.6	56.6	72.4	60.3	76.0	63.8	80.2	67.9	85.2	72.8
16000	61.6	48.2	65.0	51.6	69.2	55.7	73.0	59.4	77.1	63.4	82.1	68.3
20000	58.3	43.3	62.0	47.0	66.2	51.0	70.1	54.8	74.1	58.3	79.1	63.4
25000	55.0	38.1	59.0	42.1	63.0	45.9	67.0	49.7	71.0	53.5	76.0	58.3

TABLE II-3

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft: Three Engine LBPR Turbofan Aircraft - 727 with JT8D Series Engines

Operation:		Approach						Takeoff	
Airspeed:	160 Kt		160 Kt		160 Kt		160 Kt		160 Kt
Power:	Fn = 4000 lbs		Fn = 6000 lbs		Fn = 8000 lbs		Fn = 10000 lbs		Fn = 12000 lbs
	SEL, dB		SEL, dB		SEL, dB		SEL, dB		SEL, dB
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	104.0	99.0	107.0	102.0	110.0	105.0	113.5	108.5	117.0	112.0
250	102.6	97.6	105.6	100.6	108.5	103.5	112.2	107.2	116.0	111.0
315	101.1	96.1	104.0	99.0	107.0	102.0	110.8	105.8	114.8	109.8
400	99.5	94.5	102.5	97.5	105.5	100.5	109.5	104.5	113.5	108.5
500	97.9	92.9	101.0	96.0	104.2	99.2	108.0	103.0	112.2	107.1
630	96.1	91.0	99.3	94.2	102.7	97.7	106.6	101.6	110.9	105.8
800	94.2	89.2	97.7	92.7	101.0	96.0	105.0	100.0	109.4	104.3
1000	92.5	87.5	96.0	91.0	99.5	94.5	103.5	98.4	108.0	102.9
1250	90.4	85.4	93.9	88.9	97.6	92.5	101.7	96.6	106.2	101.0
1600	88.0	82.9	91.6	86.5	95.5	90.3	99.8	94.6	104.3	99.0
2000	86.0	80.9	89.5	84.4	93.5	88.3	98.0	92.6	102.5	97.0
2500	83.2	78.0	87.0	81.8	91.2	85.8	95.8	90.2	100.7	94.9
3150	80.7	75.1	84.6	79.0	89.0	83.1	93.6	87.5	98.7	92.3
4000	77.8	71.9	82.0	76.1	86.5	80.2	91.5	84.7	96.5	89.3
5000	75.0	68.4	79.4	72.8	84.0	76.8	89.1	81.2	94.1	85.6
6300	72.0	64.4	76.8	69.2	81.4	73.0	86.7	77.5	91.7	81.7
8000	68.9	60.4	73.8	65.3	78.7	69.4	84.0	73.8	89.1	78.1
10000	66.0	56.6	71.0	61.6	76.0	65.7	81.5	70.3	86.8	74.7
12500	63.0	52.3	68.0	57.3	73.0	61.4	78.5	65.9	83.8	70.3
16000	59.5	47.2	64.5	52.2	69.5	56.2	75.2	60.9	80.4	65.1
20000	56.2	42.2	61.3	47.3	66.3	51.2	72.0	55.7	77.3	59.9
25000	53.0	37.0	56.0	42.0	63.0	45.8	68.5	50.0	74.0	54.3

TABLE II-4

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft: Three Engine LBPR Turbofan Aircraft - 727 with JT8D Series Engines with Retrofit Lined Nacelles

Operation:	Landing								Takeoff	
Airspeed:	160 Kt.		160 Kt.		160 Kt.		160 Kt.		160 Kt.	
Power:	Fn = 4000 lbs.		Fn = 6000 lbs.		Fn = 8000 lbs.		Fn = 10000 lbs.		Fn = 12000 lbs.	
	SEL, dB		SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	98.5	93.5	102.0	97.0	106.5	101.5	111.5	106.5	116.5	111.5
250	97.2	92.2	100.7	95.7	105.2	100.2	110.2	105.2	115.3	110.3
315	95.8	90.8	99.3	94.3	103.8	98.8	108.8	103.8	114.2	109.2
400	94.5	89.5	98.0	93.0	102.5	97.5	107.5	102.5	113.0	108.0
500	93.1	88.1	96.8	91.8	101.2	96.2	106.3	101.3	111.8	106.7
630	91.8	86.8	95.5	90.5	100.0	95.0	105.0	100.0	110.5	105.4
800	90.4	85.4	94.2	89.2	98.8	93.8	103.8	98.8	109.2	104.1
1000	89.0	83.9	93.0	87.9	97.5	92.5	102.5	97.4	108.0	102.9
1250	87.3	82.1	91.3	86.1	95.8	90.7	101.0	95.9	106.2	101.0
1600	85.3	80.0	89.7	84.4	94.2	89.0	99.5	94.3	104.3	99.0
2000	83.5	78.0	88.0	82.5	92.5	87.3	98.0	92.6	102.5	97.0
2500	81.1	75.4	85.7	80.0	90.3	84.9	95.8	90.2	100.7	94.9
3150	78.6	72.3	83.3	77.0	88.2	82.3	93.6	87.5	98.7	92.3
4000	76.0	69.0	81.0	74.0	86.0	79.7	91.5	84.7	96.5	89.3
5000	73.3	65.3	78.7	70.7	83.7	76.5	89.1	81.2	94.1	85.6
6300	70.7	61.7	76.0	67.0	81.2	72.8	86.7	77.5	91.7	81.7
8000	67.8	57.8	73.1	63.1	78.5	69.2	84.0	73.8	89.1	78.1
10000	65.0	53.8	70.5	59.3	76.0	65.7	81.5	70.3	86.5	74.1
12500	62.0	49.6	67.3	54.9	73.0	61.4	78.5	65.9	83.7	70.2
16000	58.5	44.5	64.0	50.0	69.5	56.2	75.2	60.9	80.4	65.1
20000	55.2	39.5	60.8	45.1	66.3	51.2	72.0	55.7	77.3	59.9
25000	52.0	34.3	57.5	39.8	63.0	45.8	68.5	50.0	74.0	54.3

TABLE II-5

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft: Two Engine LBPR Turbofan Aircraft - 737 & DC-9 with JT8D Series Engines

Operation:			Approach						Takeoff	
Airspeed:	160 Kt		160 Kt		160 Kt		160 Kt		160 Kt	
Power:	Fn = 4000 lbs		Fn = 6000 lbs		Fn = 8000 lbs		Fn = 10000 lbs		Fn = 12000 lbs	
	SEL, dB		SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	102.0	97.0	105.0	100.0	108.0	103.0	111.5	110.5	115.0	110.0
250	100.6	95.6	103.6	98.6	106.5	101.5	110.2	109.2	114.0	109.0
315	99.1	94.1	102.0	97.0	105.0	100.0	108.8	103.8	112.8	107.8
400	97.5	92.5	100.5	95.5	103.5	98.5	107.5	102.5	111.5	106.5
500	95.9	90.9	99.0	94.0	102.2	97.0	106.0	101.0	110.2	105.1
630	94.1	89.0	97.3	92.2	100.7	95.7	104.6	99.6	108.9	103.8
800	92.2	87.2	95.7	90.7	99.0	94.0	103.0	98.0	107.4	102.3
1000	90.5	85.5	94.0	89.0	97.5	92.5	101.5	96.4	106.0	100.9
1250	88.4	83.4	91.9	86.9	95.6	90.5	99.7	94.6	104.2	99.0
1600	86.0	80.9	89.6	84.5	93.5	88.3	97.8	92.6	102.3	97.0
2000	84.0	78.9	87.5	82.4	91.5	86.3	96.0	90.6	100.5	95.0
2500	81.2	76.0	85.0	79.8	89.2	83.8	93.8	88.2	98.7	92.9
3150	78.7	73.1	82.6	77.0	87.0	81.1	91.6	85.5	96.7	90.3
4000	76.0	70.1	80.0	74.1	84.5	78.2	89.5	82.7	94.5	87.3
5000	73.0	66.4	77.4	70.8	82.0	74.8	87.1	79.2	92.1	83.6
6300	70.0	62.4	74.8	67.2	79.4	71.0	84.7	75.5	89.7	79.7
8000	66.9	58.4	71.8	63.3	76.7	67.4	82.0	71.8	87.1	76.1
10000	64.0	54.6	69.0	59.6	74.0	63.7	79.5	68.3	84.5	72.4
12500	61.0	50.3	66.0	55.3	71.0	59.4	76.5	63.9	81.8	68.3
16000	57.5	45.2	62.5	50.2	67.5	54.2	73.2	58.9	78.4	63.1
20000	54.2	40.2	59.3	45.3	64.3	49.2	70.0	53.7	75.3	57.9
25000	51.0	35.0	56.0	40.0	61.0	43.8	66.5	48.0	72.0	52.3

TABLE II-6

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft: Three Engine LBPR Turbofan Aircraft - 737 with JT8D Series Engines with Retrofit Lined Nacelles

Operation:	Landing								Takeoff	
Airspeed:	160 Kt.		160 Kt.		160 Kt.		160 Kt.		160 Kt.	
Power:	Fn = 4000 lbs. SEL, dB		Fn = 6000 lbs. SEL, dB		Fn = 8000 lbs. SEL, dB		Fn = 10000 lbs. SEL, dB		Fn = 12000 lbs. SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	96.5	91.5	100.0	95.0	104.5	99.5	109.5	104.5	114.5	109.5
250	95.2	90.2	98.7	93.7	103.2	98.2	108.2	103.2	113.3	108.3
315	93.8	88.8	97.3	92.3	101.8	96.8	106.8	101.8	112.2	107.2
400	92.5	87.5	96.0	91.0	100.5	95.5	105.5	100.5	111.0	106.0
500	91.1	86.1	94.8	89.8	99.2	94.2	104.3	99.3	109.8	104.7
630	89.8	84.8	93.5	88.5	98.0	93.0	103.0	98.0	108.5	103.4
800	88.4	83.4	92.2	87.2	96.8	91.8	101.8	96.8	107.2	102.1
1000	87.0	81.9	91.0	85.9	95.5	90.5	100.5	95.4	106.0	100.9
1250	85.3	80.1	89.3	84.1	93.8	88.7	99.0	93.9	104.2	99.0
1600	83.3	78.0	87.7	82.4	92.2	87.0	97.5	92.3	102.3	97.0
2000	81.5	76.0	86.0	80.5	90.5	85.3	96.0	90.6	100.5	95.0
2500	79.1	73.4	83.7	78.0	88.3	82.9	93.8	88.2	98.7	92.9
3150	76.6	70.3	81.3	75.0	86.2	80.3	91.6	85.7	96.7	90.3
4000	74.0	67.0	79.0	72.0	84.0	77.7	89.5	82.7	94.5	87.3
5000	71.3	63.3	76.7	68.7	81.7	74.5	87.1	79.2	92.1	83.6
6300	68.7	59.7	74.0	65.0	79.2	70.8	84.7	75.5	89.7	79.7
8000	65.8	55.8	71.1	61.1	76.5	67.2	82.0	71.8	87.1	76.1
10000	63.0	51.8	68.5	57.3	74.0	63.7	79.5	68.3	84.5	72.1
12500	60.0	47.6	65.3	52.9	71.0	59.4	76.5	63.9	81.7	68.2
16000	56.5	42.5	62.0	48.0	67.5	54.2	73.2	58.9	78.4	63.1
20000	53.2	37.5	58.8	43.1	64.3	49.2	70.0	53.7	75.3	57.9
25000	50.0	32.3	55.5	37.8	61.0	43.8	66.5	48.0	72.0	52.3

TABLE II-7

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Four Engine HBPR Turbofan Transport Aircraft

Aircraft:	Boeing 747-100A Blow-in-Door Nacelles JT9D Engines		Boeing 747-100A Blow-in-Door Nacelles JT9D Engines		Boeing 747-100D Fixed Lip Nacelles JT9D Engines		Boeing 747-100D Fixed Lip Nacelles JT9D Engines	
Operation:	Takeoff		Approach		Takeoff		Approach	
Airspeed:	160 Kt		160 Kt		160 Kt		160 Kt	
Power:	N_1 = 3300		N_1 = 2400		N_1 = 3350		N_1 = 2400	
	SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	118.0	113.0	111.5	106.5	115.0	110.0	106.5	101.5
250	117.0	112.0	110.3	105.3	114.0	109.0	105.1	100.1
315	115.8	110.8	109.0	104.0	112.8	107.8	103.5	98.5
400	114.5	109.5	107.5	102.5	111.5	106.5	102.0	97.0
500	113.2	108.2	106.2	101.2	110.2	105.1	100.4	95.4
630	111.9	106.9	104.7	99.7	109.0	103.9	98.9	93.8
800	110.3	105.2	103.1	98.1	107.5	102.4	97.1	92.1
1000	109.0	103.9	101.5	96.4	106.0	100.8	95.5	90.4
1250	107.4	102.2	99.9	94.9	104.5	99.3	93.7	88.6
1600	105.3	100.0	98.0	93.0	103.0	97.5	91.6	86.4
2000	103.5	98.1	96.0	91.0	101.3	95.7	89.8	84.5
2500	101.7	96.0	93.7	88.5	99.6	93.6	87.9	82.4
3150	99.7	93.5	91.2	85.9	97.8	91.3	85.8	79.9
4000	97.5	90.4	88.5	83.0	96.0	88.6	83.5	76.8
5000	95.0	86.7	85.7	79.8	94.0	85.4	81.3	73.7
6300	92.2	82.6	82.6	76.1	91.7	81.7	79.0	70.2
8000	89.5	78.9	79.5	72.2	89.1	78.2	76.5	67.0
10000	87.0	75.3	76.5	68.1	87.0	75.0	74.0	63.6
12500	84.5	71.6	73.4	63.4	84.5	71.2	71.2	59.6
16000	81.5	67.0	69.9	57.9	81.5	66.7	68.1	55.2
20000	78.9	62.6	66.5	52.4	78.9	62.2	65.1	50.5
25000	76.0	57.7	63.5	47.1	76.0	57.1	62.0	45.5

TABLE II-8

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft: Three Engine HBPR Turbofan Transport Aircraft

	DC-10-10 CF6 Series Engines		DC-10-10 CF6 Series Engines (50° Flaps)		DC-10-10 CF6 Series Engines (35° Flaps)		DC-10-40 JT9D Series Engines		DC-10-40 JT9D Series Engines	
Operation:	Takeoff		Approach		Approach		Takeoff		Approach	
Airspeed:	160 Kt		160 Kt		160 Kt		160 Kt		160 Kt	
Power:	N_1 = 3420		N_1 = 2600		N_1 = 2300		N_1 = 3350		N_1 = 2400	
	SEL, dB		SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	109.0	104.0	105.5	100.5	102.0	97.0	110.0	105.0	104.5	99.5
250	108.0	103.0	104.0	99.0	100.5	95.5	109.0	104.0	103.0	98.0
315	106.8	101.8	102.5	97.5	99.0	94.0	107.8	102.8	101.5	96.5
400	105.5	100.5	101.0	96.0	97.5	92.5	106.5	101.5	100.0	95.0
500	104.2	99.1	99.4	94.4	95.9	90.9	105.2	100.1	98.4	93.4
630	103.0	97.9	97.7	92.7	94.2	89.2	104.0	98.9	96.7	91.7
800	101.5	96.4	96.0	91.0	92.5	87.5	102.5	97.4	95.0	90.0
1000	100.0	94.8	94.5	89.4	91.0	85.9	101.0	95.8	93.5	88.4
1250	98.6	93.3	92.6	87.5	89.1	84.0	99.6	94.3	91.6	86.5
1600	97.0	91.5	90.5	85.4	87.0	81.8	98.0	92.5	89.5	84.4
2000	95.3	89.7	88.8	83.5	85.3	80.0	96.3	90.7	87.8	82.5
2500	93.7	87.7	86.8	81.3	83.3	77.8	94.7	88.7	85.8	80.3
3150	91.9	85.4	84.7	78.8	81.2	75.3	92.9	86.4	83.7	77.8
4000	90.0	82.6	82.5	75.8	79.0	72.3	91.0	83.6	81.5	74.8
5000	88.0	79.4	80.2	72.6	76.7	69.1	89.0	80.4	79.2	71.6
6300	85.8	75.8	78.0	69.2	74.5	65.7	86.8	76.8	77.0	68.2
8000	83.3	72.4	75.4	65.9	71.9	62.4	84.3	73.4	74.4	64.9
10000	81.0	69.0	73.0	62.6	69.5	59.1	82.0	70.0	72.0	61.6
12500	78.5	65.2	70.3	58.7	66.8	55.2	79.5	65.9	69.1	57.5
16000	75.5	60.7	67.2	54.3	63.8	50.9	76.5	61.7	66.2	53.3
20000	72.9	56.2	64.2	49.6	60.7	46.1	73.9	57.2	63.2	48.6
25000	70.0	51.1	61.0	44.5	57.5	41.0	71.0	52.1	60.0	43.5

TABLE II-9

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Business Jet Aircraft

Aircraft:	Cessna Citation Two JT15 D-1 Turbofan Eng.		Cessna Citation Two JT 15 D-1 Turbofan Eng.		Commodore Jet Commander 1121 Two CJ610-5 Turbojet Eng.		Commodore Jet Commander 1121 Two CJ 610-5 Turbojet Eng.		Dassault Fan Jet Falcon, Two CJ700-2B Turbofan Eng.		Dassault Fan Jet Falcon, Two CJ700-2B Turbofan Eng.	
Operation:	Takeoff		Approach		Takeoff		Approach		Takeoff		Approach	
Airspeed:	115 Kt		115 Kt		145 Kt		140 Kt		140 Kt		140 Kt	
Power:	Fn = 1550 lbs.		Fn = 510 lbs.		Fn = 2470 lbs.		Fn = 1170 lbs.					
	SEL, dB		SEL, dB		SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	97.2	92.2	86.9	81.9	121.6	116.6	108.0	103.0	107.0	102.0	100.4	95.4
250	96.0	91.0	85.7	80.7	120.4	115.4	106.9	101.9	105.5	100.5	99.1	95.4
315	94.9	89.9	84.5	79.5	119.1	114.1	105.7	100.7	103.9	98.9	97.6	92.6
400	93.7	88.7	83.2	78.2	117.7	112.7	104.5	99.5	102.3	97.3	96.1	91.1
500	92.5	87.4	81.9	76.9	116.3	111.3	103.3	98.3	100.7	95.7	94.5	89.5
630	91.2	86.1	80.6	75.5	114.9	109.9	102.0	97.0	99.1	94.1	92.7	87.7
800	89.9	84.8	79.2	74.1	113.3	108.3	100.7	95.6	97.5	92.5	90.8	85.8
1000	88.5	83.3	77.8	72.6	111.7	106.7	99.3	94.2	95.9	90.8	88.8	83.8
1250	87.1	81.7	76.3	71.0	110.0	104.9	97.8	92.7	94.2	89.1	86.7	81.6
1600	85.5	80.1	74.7	69.3	108.2	103.1	96.2	91.1	92.5	87.2	84.5	79.2
2000	83.9	78.3	73.1	67.6	106.3	101.1	94.5	89.3	90.7	85.3	82.3	76.8
2500	82.2	76.2	71.5	65.4	104.2	98.8	92.7	87.3	88.7	83.1	80.0	74.4
3150	80.4	73.7	69.7	62.9	102.0	96.3	90.7	85.1	86.6	80.6	77.9	71.8
4000	78.5	70.8	67.9	60.2	99.7	93.3	88.6	82.5	84.4	77.6	75.7	69.1
5000	76.4	67.4	66.0	57.0	97.1	89.8	86.4	79.4	82.0	74.1	73.5	66.0
6300	74.2	64.0	63.9	53.5	94.4	85.8	83.9	76.0	79.4	70.1	71.2	62.6
8000	71.8	60.3	61.8	50.5	91.4	82.1	81.2	72.7	76.5	66.4	68.8	59.4
10000	69.3	56.7	59.5	47.2	88.2	77.9	78.4	69.1	73.6	62.2	66.2	55.8
12500	66.5	52.6	57.1	43.5	84.7	73.3	75.3	65.0	70.5	57.5	63.6	51.7
16000	63.5	48.1	54.5	39.5	81.0	68.1	71.9	60.5	67.2	52.3	60.8	47.2
20000	60.3	43.0	51.7	35.2	76.9	62.2	68.4	55.4	63.7	46.6	57.8	42.2
25000	56.9	37.5	48.6	30.4	72.4	55.7	64.6	49.7	60.0	40.4	54.7	36.7

TABLE II-10

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Business Jet Aircraft

Aircraft:	Gates Learjet 24 & 25 Two CJ610-6 Turbojet Eng.		Gates Learjet 24 & 25 Two CJ610-6 Turbojet Eng.		Gates Learjet 35 & 36 Two TFE 731-2 Turbofan Eng.		Gates Learjet 35 & 36 Two TFE 731-2 Turbofan Eng.	
Operation:	Takeoff		Approach		Takeoff		Approach	
Airspeed:	155 Kt		150 Kt		160 Kt		150 Kt	
Power:	Fn = 2500 lbs.		Fn = 1050 lbs		Fn = 2630 lbs		Fn = 997 lbs	
	SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	121.6	116.6	105.9	100.9	107.2	102.2	90.8	85.8
250	120.4	115.4	104.8	99.8	105.9	100.9	89.6	84.6
315	119.1	114.1	103.6	98.6	104.5	99.5	88.4	83.4
400	117.1	112.1	102.4	97.4	103.1	98.1	87.1	82.1
500	116.3	111.3	101.2	96.2	101.7	96.7	85.7	80.7
630	114.9	109.9	99.9	94.9	100.2	95.1	84.3	79.3
800	113.3	108.3	98.6	93.5	98.6	93.6	82.8	77.8
1000	111.7	106.7	97.2	92.1	97.0	91.9	81.3	76.1
1250	110.0	104.9	95.7	90.6	95.3	90.2	79.7	74.4
1600	108.2	103.1	94.1	89.0	93.6	88.3	77.9	72.6
2000	106.3	101.1	92.4	87.2	91.7	86.3	76.2	70.7
2500	104.2	98.8	90.6	85.2	89.7	84.0	74.3	68.5
3150	102.0	96.3	88.6	83.0	87.6	81.4	72.4	66.1
4000	99.7	93.3	86.5	80.4	85.4	78.4	70.4	63.3
5000	97.1	89.8	84.3	77.3	82.9	74.8	68.4	60.2
6300	94.4	85.8	81.8	73.9	80.3	70.7	66.2	56.7
8000	91.4	82.1	79.1	70.6	77.5	66.9	64.0	53.5
10000	88.2	77.9	76.3	67.0	74.5	62.7	61.6	50.1
12500	84.7	73.3	73.2	62.9	71.3	58.0	59.2	46.2
16000	81.0	68.1	69.8	58.4	67.8	52.8	56.6	42.0
20000	76.9	62.2	66.3	53.3	64.0	47.0	53.9	37.5
25000	72.4	55.7	62.5	47.6	60.0	40.7	51.1	32.5

TABLE II-11

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Business Jet Aircraft

Aircraft:	Grumman Gulfstream II Two SPEY 511-8 Turbojet Eng.		Grumman Gulfstream II Two SPEY 511-8 Turbojet Eng.		Lockheed Jetstar I/C-140 Four JT 12A-6A Turbojet Eng.		Lockheed Jetstar I/C-140 Four JT 12A-6A Turbojet Eng.		North American Sabre 80 Two CF700-2D-2 Turbofan Eng.		North American Sabre 80 Two CF700-2D-2 Turbofan Eng.	
Operation:	Takeoff		Approach		Takeoff		Approach		Takeoff		Approach	
Airspeed:	175 kt		155 kt		145 Kt		135 Kt		140 kt.		140 kt.	
Power:	Fn = 9300 lbs.		Fn = 3200 lbs.		Fn = 2800 lbs.		Fn = 1270 lbs.		Fn = 3450 lbs.		Fn = 865 lbs.	
	SEL, dB		SEL, dB		SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	120.1	115.1	99.6	94.6	121.1	116.1	108.3	103.3	112.0	107.0	96.5	91.5
250	119.0	114.0	98.5	93.5	119.9	114.9	107.2	102.2	110.5	105.5	95.2	90.2
315	117.9	112.9	97.3	92.3	118.7	113.7	106.0	101.0	108.9	103.9	93.7	88.7
400	116.8	111.8	96.1	91.1	117.4	112.4	104.8	99.8	107.3	102.3	92.2	87.2
500	115.6	110.6	94.9	89.9	116.1	111.1	103.6	98.6	105.7	100.7	90.6	85.6
630	114.5	109.4	93.7	88.7	114.7	109.7	102.3	97.3	104.1	99.1	88.8	83.8
800	113.3	108.1	92.4	87.3	113.2	108.2	100.9	95.9	102.5	97.5	86.9	81.9
1000	112.0	106.7	91.1	85.9	111.7	106.6	99.5	94.5	100.9	95.8	84.9	79.9
1250	110.7	105.3	89.6	84.4	110.1	104.9	98.0	92.9	99.2	94.1	82.8	77.7
1600	109.3	103.7	88.2	82.9	108.3	103.1	96.3	91.2	97.5	92.2	80.6	75.3
2000	107.8	102.0	86.6	81.2	106.5	101.2	94.5	89.4	95.7	90.3	78.4	72.9
2500	106.3	100.0	85.0	79.3	104.5	98.9	92.6	87.4	93.7	88.1	76.1	70.5
3150	104.6	97.6	83.2	77.1	102.4	96.3	90.5	85.1	91.6	85.6	74.0	67.9
4000	102.8	94.8	81.3	74.5	100.1	93.3	88.1	82.5	89.4	82.6	71.8	65.2
5000	100.9	91.5	79.3	71.5	97.6	89.7	85.6	79.5	87.0	79.1	69.6	62.1
6300	98.9	87.9	77.1	68.2	95.0	85.7	82.8	76.1	84.4	75.1	67.3	58.7
8000	96.6	84.9	74.8	65.2	92.1	81.9	79.8	72.5	81.6	71.4	64.9	55.5
10000	94.2	81.5	72.3	61.9	89.0	77.7	76.6	68.5	78.6	67.2	62.3	51.9
12500	91.6	77.7	69.6	58.1	85.8	73.1	73.6	64.2	75.5	62.5	59.7	47.8
16000	88.8	73.4	66.7	53.9	82.2	67.8	69.7	59.1	72.2	57.3	56.9	43.3
20000	85.8	68.6	63.6	49.2	78.4	62.1	66.2	53.7	68.7	51.6	53.9	38.3
25000	82.5	63.3	60.3	44.0	74.3	55.7	62.5	47.9	65.0	45.4	50.8	32.8

TABLE II-12

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Business Jet Aircraft

Aircraft:	North American Sabre 60 Two JT12A-8 Turbojet Eng.		North American Sabre 60 Two JT12A-8 Turbojet Eng.		Composite* Business Jet		Composite* Business Jet	
Operation:	Takeoff		Approach		Takeoff		Approach	
Airspeed:	145 Kt		135 Kt					
Power:	FN = 2800 lbs.		Fn = 800 lbs.					
	SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	119.1	114.1	103.3	98.3	120.1	115.1	104.4	99.4
250	117.9	112.9	102.2	97.2	118.9	113.9	103.3	98.3
315	116.7	111.7	101.0	96.0	117.6	112.6	102.1	97.1
400	115.4	110.4	99.8	94.8	115.6	110.6	100.9	95.9
500	114.1	109.1	98.6	93.6	114.8	109.8	99.7	94.7
630	112.7	107.7	97.3	92.3	113.4	108.4	98.4	93.4
800	111.2	106.2	95.9	90.9	111.8	106.8	97.1	92.0
1000	109.7	104.6	94.5	89.5	110.2	105.2	95.7	90.6
1250	108.1	102.9	93.0	87.9	108.5	103.4	94.2	89.1
1600	106.3	101.1	91.3	86.2	106.7	101.6	92.6	87.5
2000	104.5	99.2	89.5	84.4	104.8	99.6	90.9	85.7
2500	102.5	96.9	87.6	82.4	102.7	97.3	89.1	83.7
3150	100.4	94.3	85.5	80.1	100.5	94.8	87.1	81.5
4000	98.1	91.3	83.1	77.5	98.2	91.8	85.0	78.9
5000	95.6	87.7	80.6	74.5	95.6	88.3	82.8	75.8
6300	93.0	83.7	77.8	71.1	92.9	84.3	80.3	72.8
8000	90.1	79.9	74.8	67.5	89.9	80.6	77.6	69.1
10000	87.0	75.7	71.6	63.5	86.7	76.4	74.8	65.5
12500	83.8	71.1	68.6	59.2	83.2	71.8	71.7	61.4
16000	80.2	65.8	64.7	54.1	79.5	66.6	68.3	56.9
20000	76.2	60.1	61.2	48.7	75.4	60.7	64.9	51.8
25000	72.3	53.1	57.5	42.9	71.0	59.2	61.1	46.1

*The composite business jet noise is based upon the noise characteristics of three types of business jet engines (straight turbojets, turbofans and small turbofans [Cessna Citation]). The composite characteristics assume a ratio of operations of 70% turbojet, 16% larger turbofans and 14% smaller turbofans.

TABLE 11-13

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft:	4-Engine Turboprop Transport Lockheed Hercules, 382E, 382G, C130H				4-Engine Turboprop Transport Lockheed Electra Lockheed Hercules 382B, C130E			
Operation:	Takeoff		Approach		Takeoff		Approach	
Airspeed:	145 Kt		140 Kt		145 Kt		140 Kt	
Power:								
	SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	104.1	99.1	98.4	93.4	99.1	94.1	96.4	91.4
250	103.0	98.0	97.3	92.3	98.0	93.0	95.3	90.3
315	101.8	96.8	96.1	91.1	96.8	91.8	94.1	89.1
400	100.7	95.7	94.9	89.9	95.7	90.7	92.9	87.9
500	99.5	94.5	93.7	88.6	94.5	89.5	91.7	86.6
630	98.3	93.2	92.4	87.3	93.3	88.2	90.4	85.3
800	97.1	91.9	91.1	86.0	92.1	86.9	89.1	84.0
1000	95.8	90.5	89.7	84.5	90.8	85.5	87.7	82.5
1250	94.4	89.0	88.2	82.9	89.4	84.0	86.2	80.9
1600	93.0	87.4	86.7	81.3	88.0	82.4	84.7	79.3
2000	91.5	85.6	85.1	79.5	86.5	80.6	83.1	77.5
2500	89.9	83.7	83.5	77.5	84.9	78.7	81.5	75.5
3150	88.2	81.5	81.7	75.3	83.2	76.5	79.7	73.3
4000	86.5	79.0	79.8	72.7	81.5	74.0	77.8	70.7
5000	84.6	76.1	77.8	69.7	79.5	71.1	75.8	67.7
6300	82.6	73.0	75.7	66.4	77.6	68.0	73.7	64.4
8000	80.5	69.8	73.4	63.3	75.5	64.8	71.4	61.3
10000	78.3	66.4	71.1	59.8	73.3	61.4	69.1	57.8
12500	76.0	62.6	68.6	55.9	71.0	57.6	66.6	53.9
16000	73.7	58.1	66.0	51.6	68.7	53.1	64.0	49.6
20000	71.2	53.6	63.4	46.8	66.2	48.6	61.4	44.8
25000	68.7	48.7	60.5	41.8	63.7	43.7	58.5	39.8

TABLE II-14

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft:	2-Engine Turboprop Transport with Dart Engines F-27, HS-748				2-Engine Turboprop Aircraft with PT 6 Engines DHC-6 Twin Otter			
Operation:	Takeoff		Approach		Takeoff		Approach	
Airspeed:	140 Kt		120 Kt		70 Kt		65 Kt	
Power:								
	SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	101.7	96.7	99.6	94.6	94.8	89.8	91.8	86.8
250	100.6	95.6	98.2	93.2	93.6	88.6	90.5	85.5
315	99.6	94.6	96.8	91.8	92.4	87.4	89.1	84.1
400	98.5	93.5	95.2	90.2	91.1	86.1	87.7	82.7
500	97.4	92.4	93.6	88.6	89.8	84.7	86.3	81.2
630	96.3	91.1	91.7	86.7	88.4	83.3	84.7	79.7
800	95.1	90.0	89.8	84.7	86.9	81.7	83.0	78.0
1000	94.0	88.7	87.7	82.6	85.4	80.1	81.3	76.2
1250	92.8	87.3	85.5	80.3	83.8	78.3	79.4	74.3
1600	91.5	85.7	83.2	77.7	82.1	76.4	77.4	72.3
2000	90.3	84.2	80.8	75.0	80.4	74.3	75.3	70.1
2500	89.0	81.7	78.5	72.4	78.5	72.0	73.1	67.8
3150	87.6	78.8	76.4	69.2	76.6	69.5	70.7	65.2
4000	86.1	75.4	74.3	66.0	74.7	66.6	68.2	62.3
5000	84.6	71.8	72.3	63.0	72.7	63.4	65.2	59.0
6300	82.9	68.8	70.3	59.9	70.8	59.8	62.8	55.3
8000	81.1	65.6	68.3	56.6	68.8	56.4	60.1	51.6
10000	79.1	62.8	66.3	53.1	66.8	52.7	57.3	47.6
12500	77.0	60.0	64.2	49.1	64.7	48.7	54.5	43.2
16000	74.6	56.9	62.1	45.1	62.6	44.5	51.7	38.4
20000	72.1	53.4	59.9	40.8	60.4	40.2	49.0	33.3
25000	69.3	49.5	57.7	36.5	57.9	35.9	46.1	27.8

TABLE II-15

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft:	4-Engine Piston Transport				2-Engine Piston Transport (>12,500 lbs. Max. Gross Wt.)			
Operation:	Takeoff		Approach		Takeoff		Approach	
Airspeed:	140 Kt.		120 Kt.		140 Kt.		120 Kt.	
Power:								
	SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	106.6	101.6	96.4	91.4	103.6	98.6	93.4	88.4
250	105.5	100.5	95.3	90.3	102.5	97.5	92.3	87.3
315	104.4	99.4	94.2	89.2	101.4	96.4	91.2	86.2
400	103.2	98.2	93.1	88.1	100.2	95.2	90.1	85.1
500	102.0	97.0	92.0	87.0	99.0	94.0	89.0	84.0
630	100.8	95.6	90.8	85.6	97.8	92.6	87.8	82.6
800	99.5	94.2	89.6	84.2	96.5	91.2	86.6	81.2
1000	98.2	92.6	88.4	82.7	95.2	89.6	85.4	79.7
1250	96.8	91.0	87.1	81.1	93.8	88.0	84.1	78.1
1600	95.4	89.2	85.8	79.4	92.4	86.2	82.8	76.4
2000	94.0	87.3	83.4	77.6	91.0	84.3	81.4	74.6
2500	92.5	85.2	82.9	75.5	89.5	82.2	79.9	72.5
3150	90.9	82.8	81.4	73.0	87.9	79.8	78.4	70.0
4000	89.3	80.0	79.9	70.3	86.3	77.0	76.9	67.3
5000	87.6	76.8	78.2	67.2	84.6	73.9	75.2	64.2
6300	85.9	73.6	76.5	64.1	82.9	70.6	73.5	61.1
8000	84.0	70.5	74.7	60.8	81.0	67.5	71.7	57.8
10000	82.0	67.4	72.8	57.7	79.0	64.4	69.8	54.7
12500	79.9	64.9	70.7	54.2	76.9	61.9	67.7	51.2
16000	77.7	60.1	68.5	50.5	74.7	57.1	65.5	47.5
20000	75.2	56.0	66.2	46.5	72.2	53.0	63.2	43.5
25000	72.6	51.6	63.6	42.3	69.6	48.6	60.6	39.3

TABLE II-16

TABULATION OF SEL VALUES FOR DIFFERENT AIRCRAFT

Aircraft:	2-Engine Piston Aircraft (<12,500 lbs. Max. Gross Wt.)				1-Engine Piston Aircraft Composite*			
Operation:	Takeoff		Approach		Takeoff		Approach	
Airspeed:	110 Kt.		90 Kt.		110 Kt.		90 Kt.	
Power:								
	SEL, dB		SEL, dB		SEL, dB		SEL, dB	
Distance, ft.	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground	Air to Ground	Ground to Ground
200	93.3	88.3	86.9	81.9	91.3	86.3	79.3	74.3
250	92.2	87.2	85.7	80.7	90.2	84.2	78.1	72.3
315	91.1	86.1	84.6	79.6	89.1	82.1	77.0	70.0
400	90.1	85.0	83.4	78.4	88.1	80.0	75.8	67.8
500	89.0	83.9	82.2	77.2	87.0	77.9	74.6	65.6
630	87.6	82.6	81.0	75.8	85.9	75.6	73.4	63.2
800	86.7	81.3	79.7	74.4	84.7	74.3	72.1	61.8
1000	85.5	79.9	78.4	72.9	83.5	72.9	70.8	60.3
1250	84.3	78.4	77.1	71.2	82.3	71.4	69.5	63.6
1600	83.0	76.7	75.7	69.4	81.0	69.7	68.1	56.8
2000	81.7	75.0	74.3	67.5	79.7	68.0	66.7	54.9
2500	80.3	72.9	72.8	65.3	78.3	65.9	65.2	52.7
3150	78.9	70.5	71.2	62.8	76.9	63.5	63.6	50.2
4000	77.4	67.3	69.6	59.9	75.4	60.6	62.0	47.3
5000	75.8	64.4	68.0	56.6	73.8	57.4	60.4	44.0
6300	74.1	61.1	66.3	53.1	72.1	53 7	58.7	40.5
8000	72.3	58.3	64.5	50.2	70.3	51.3	56.9	37.6
10000	70.3	55.4	62.6	47.0	68.3	48.4	55.0	34.4
12500	68.2	52.1	60.6	43.6	66.2	45.1	53.0	31.0
16000	65.9	48.5	58.4	39.9	63.9	41.5	50.8	27.3
20000	63.4	44.5	56.1	36.1	61.4	37.5	48.5	23.5
25000	60.7	40.2	53.6	32.1	58.7	33.2	46.0	19.5

*The composite single engine aircraft assumes 80% operations of aircraft having engines of less than 200 HP and 20% operations of aircraft having engines of 200 to 600 HP.

III. TECHNICAL BACKGROUND

A. Basic SEL Definition

The sound exposure level (SEL), in dB, as defined in Reference 18 is the level of the time-integrated mean square A-weighted sound pressure for an event, with a reference time of one second:

$$SEL = 10 \log \int_{-\infty}^{\infty} 10^{\frac{AL}{10}} dt$$

For purposes of aircraft noise evaluation, SEL is usually computed from A-levels sampled at discrete intervals of 0.5 seconds or less. Thus the working expression for SEL becomes:

$$SEL = 10 \log \sum_{k=0}^{k=\frac{d}{\Delta t}} 10^{\frac{AL(k)}{10}} + 10 \log \Delta t$$

where d is the time interval during which AL(k) is within 10 dB of the maximum A-level, and Δt is the time interval between noise level samples.

The SEL is identical to the single event noise exposure level (SENEL), in dB, as defined in Reference 19 except that the SENEL is defined in terms of integration (summation) from a threshold noise level approximately 30 dB below the maximum level, while, in this report, SEL is defined in terms of integration over noise levels within 10 dB or more of the maximum value. Integration over only the upper 10 dB yields acceptable values that typically differ by 0.3 dB or less from values based on integration over 30 dB.

A tone-corrected sound exposure level (SELT), in dB, can also be defined for a noise event as follows:

$$SELT = 10 \log \int_{-\infty}^{\infty} 10^{\frac{ALT}{10}} dt$$

For purposes of aircraft noise evaluation, SELT can be computed from tone-corrected A-levels sampled at discrete time intervals of 0.5 seconds or less, as follows:

$$SELT = 10 \log \sum_{k=0}^{k=\frac{d}{\Delta t}} 10^{\frac{ALT(k)}{10}} + 10 \log \Delta t$$

where d is the time interval during which ALT (k) is within 10 dB of ALTM, and Δt is the time interval between noise level samples.

The tone correction applied to the A-level in the above expressions is that used in calculating the tone-corrected perceived noise level. Thus the calculation of the SELT is similar to the calculation of the effective perceived noise level, except for the use of the A-weighting network, and reference to a one second duration in SELT computations.

B. General Approach

For L_{dn} calculations, SEL values are needed over a wide range of distances. The field noise data for any particular aircraft and operating condition are typically available only at one or, at most, a few distances. Thus, to generate curves, there is need for both:

a) accurate noise levels measurements at one or more distances;

b) an analytic model for generating SEL values as a function of distance.

Analytic models of varying complexity can be developed for predicting aircraft noise. The more complex models often require more complete noise information than is generally available from most field measurements. The basic approach for this study has been to utilize a relatively simple analytic model to generate sets of SEL curves from selected noise data. Where available, noise data from different sources have been used, particularly in developing the noise curves for major transport aircraft. The resulting noise vs. distance curves have then been compared with noise curves from other studies. Engineering judgment has been used to select what is believed to be the most representative set of curves. Because the amount of noise data and the number of checkpoints varies considerably with the type of aircraft, the degree of cross checking and comparison varies considerably among the different aircraft.

Because the SEL is a relatively new noise measure, many available sources of noise data do not report SEL values even where complete spectrum information and EPNL values are reported. Thus, in general, at this time there are greater uncertainties in the SEL curves, as compared to EPNL or perceived noise level curves.

C. Analytical Noise Model

The model assumed for developing SEL values at the different distances assumes that the SEL at any distance is equal to the maximum A-level, ALM, plus a "duration factor," D:

$$SEL = ALM + D$$

If the quantities in the above equation are known at one distance, x_o, and the ALM can be estimated for another distance, x, the duration adjustment, ΔD, is assumed to be simply 10 times the logarithm of the ratio of the two distances:

$$\Delta D = 10 \log \frac{x}{x_o}$$

The working equations can be developed in more complete form with reference to Figure 1. For simplicity of discussion we assume level flight noise data has been obtained at position P (see Figure 1) with all data adjusted to standard day conditions and the desired aircraft altitude and reference air speed.* At P, the distance of closest approach, x_o, is known. Also, corrected values of the sound exposure level, SEL_{x_o}, and the one-third octave band spectra at the time of ALM, SPL_{ix_o}, are

*Reference 6 outlines the calculation steps for correcting level flight data to reference conditions.

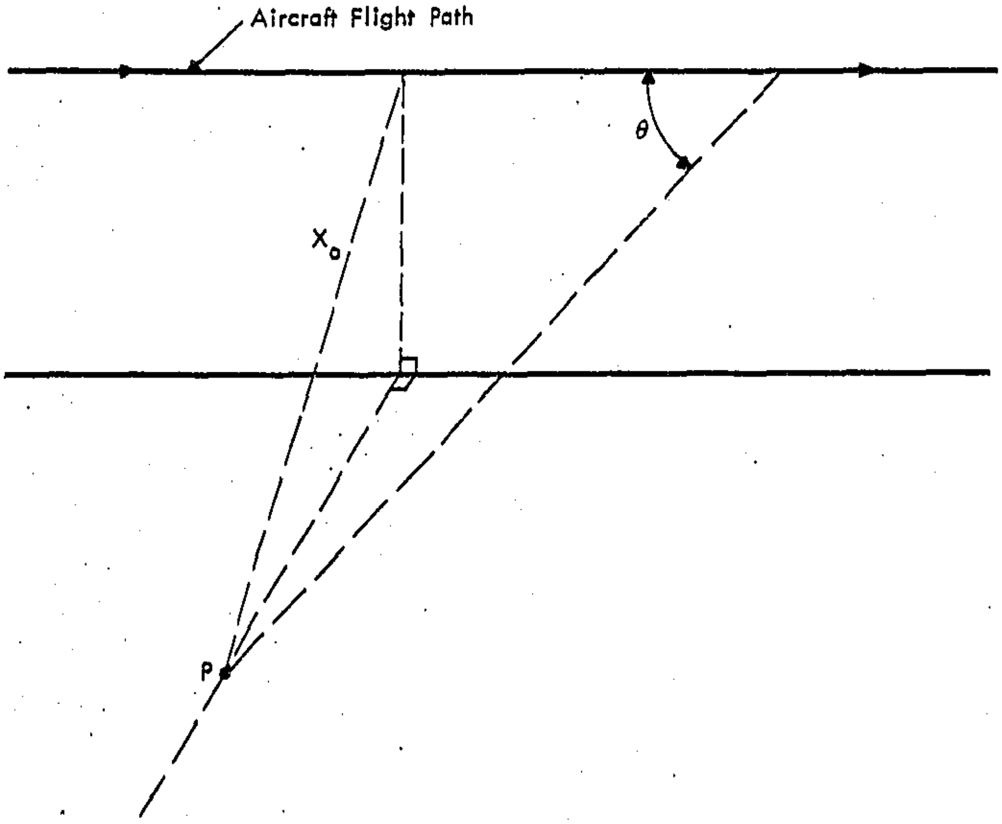

FIGURE 1. SIMPLIFIED LEVEL FLIGHT GEOMETRY FOR CALCULATING SEL VALUES AT VARYING DISTANCES

known. The angle of radiation from the aircraft that produced SPL_{ix_o}, θ, is also known*.

At any distance x, it is assumed that the ALM at x can be calculated from the corresponding one-third octave band levels:

$$SPL_{ix} = SPL_{ix_o} - \frac{\alpha_i}{\sin\theta}(x-x_o) - 20 \log \frac{x}{x_o} \qquad (1)$$

where α_i are the one-third octave band atmospheric absorption coefficients at standard day conditions.

With ALM_x known, SEL_x is given by:

$$SEL_x = SEL_{x_o} + AL_x - AL_{x_o} + 10 \log \frac{x}{x_o} \qquad (2)$$

This model, then, requires knowledge of the one-third octave band spectrum observed at the time of the maximum A-level, and the angle of radiation, either known or assumed. In applying the model to available data, values of θ were often not known, and estimates of θ were then used.

D. Sources of Noise Data

A number of sources of noise data have been used in developing SEL versus distance curves. The sources of data, with reference to the general type of measurement condition, can be classified as (a) controlled tests and (b) airport measurements (uncontrolled). The use of the word "controlled" implies

*For most of the data utilized in this study, the θ and accompanying noise spectra were based upon PNLTM or PNLM, rather than ALM. As discussed in Reference 6, use of the PNLTM spectra can lead to underestimation of SEL values at larger distances for some aircraft. However, for most aircraft, it is believed that this error is small compared to other uncertainties.

control, and/or knowledge of aircraft performance and engine operating parameters. The quality of the noise data in terms of accuracy of the acoustic measurements often is not significantly different between the controlled or airport tests, but aircraft information is less detailed in the latter.

Data from airport measurements serve well in obtaining typical shapes of SEL versus distance curves. However, to peg the SEL curve as a function of known engine parameters, the controlled tests are often most useful.* Table III provides a brief summary of the sources of the data for different major aircraft types. BBN-supplied data includes airport measurements obtained at airports such as Los Angeles International Airport, San Jose Municipal Airport, Orange County Airport and Anchorage, Alaska, among others. The business jet information provided by BBN came largely from certification tests conducted in full accordance with FAR 36, plus other controlled and airport tests. Most propeller aircraft measurements were airport measurements; however, results from some controlled measurements were also utilized.

The data from the aircraft manufacturers includes noise spectra information furnished informally by Boeing and Douglas. The data also includes noise curves and spectral information contained in a number of draft reports prepared for the FAA [7-12] and data reported to NASA [13]. Other sources of information include studies conducted for the FAA [14-16, 22,23].

*Even here, the airport data serves as a check upon controlled tests where data may not have been obtained during realistic aircraft operating conditions.

TABLE III

SUMMARY OF AIRCRAFT NOISE DATA SOURCES

Aircraft Type	BBN	Airframe Manufacturer	Other
4-Engine LBPR (707, DC-8) Transport	Airport	Controlled	Controlled
4-Engine LBPR (707, DC-8) Transport Retrofit	-	Controlled	--
2, 3-Engine LBPR Transport (737, DC-9, 727)	Airport	Controlled	Controlled
4-Engine HBPR (747)	Airport	Controlled	--
3-Engine HBPR (DC-10)	Airport	Controlled	--
Business Jet Aircraft	Controlled*, Airport	--	--
Propeller Aircraft	Airport, Controlled*	--	Controlled

*Controlled includes noise certification tests (FAR 36) as well as other formal aircraft flight test measurements.

As noted earlier, because of the relatively recent introduction of the SEL noise measure, most aircraft noise reports do not provide SEL values even where spectrum and EPNL information may be reported. Thus, even when spectrum data were available to permit the determination of the variation of SEL values with distance (using the analytic model described earlier), the lack of any measured SEL value at the reference condition introduces a potential error in pegging the SEL curve to absolute levels. Where SEL information at reference conditions was lacking but EPNL values were known, differences between EPNL and SEL values were estimated using measured differences between EPNL and SEL values obtained from other measurements. Particularly useful were the EPNL and SEL differences available from data of References 20 and 21.

E. Comparison of Noise Curves

In contrast to the EPNL curves where it is often found that relatively small differences in spectrum shape can result in sizable differences in the EPNL vs. distance curves[17], the shape of the SEL vs. distance curves is quite tolerant of differences in spectrum shape. Thus there is much greater consistency among SEL vs. distance curves derived from noise data from different sources than is the case for the EPNL curves derived from the same information. Part of this greater consistency results from the omission of any tone adjustments in the basic SEL computations.

Another trend of SEL curves, compared with the EPNL curves generated from the same basic data, is that the SEL values will generally show a *slower* rate of decrease with distance than the EPNL values. Figures 2 and 3 illustrate this general characteristic which is observed for most jet-powered

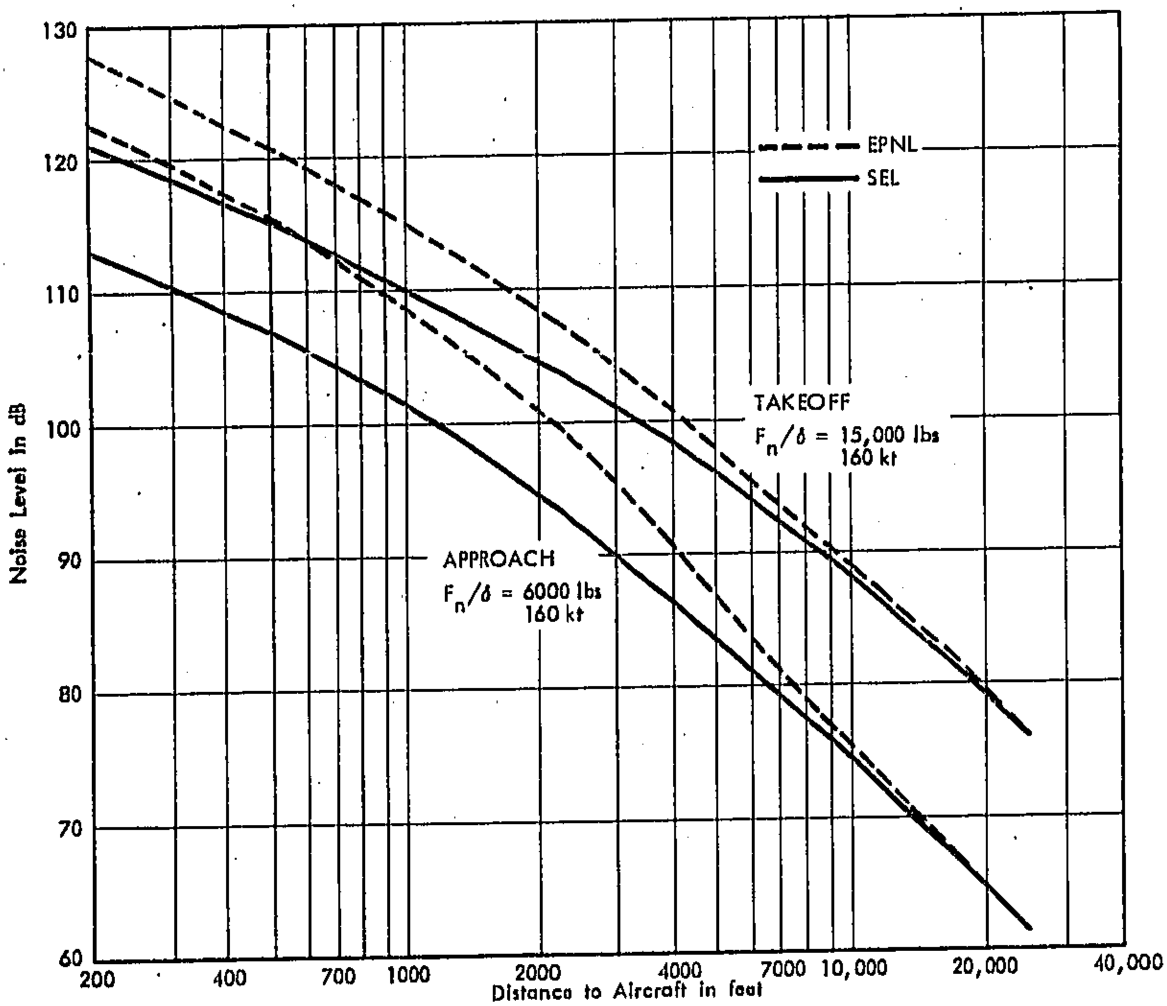

FIGURE 2. COMPARISON OF SEL AND EPNL VARIATIONS WITH DISTANCE - 707 AND DC-8 TRANSPORT AIRCRAFT WITH JT3D SERIES ENGINES

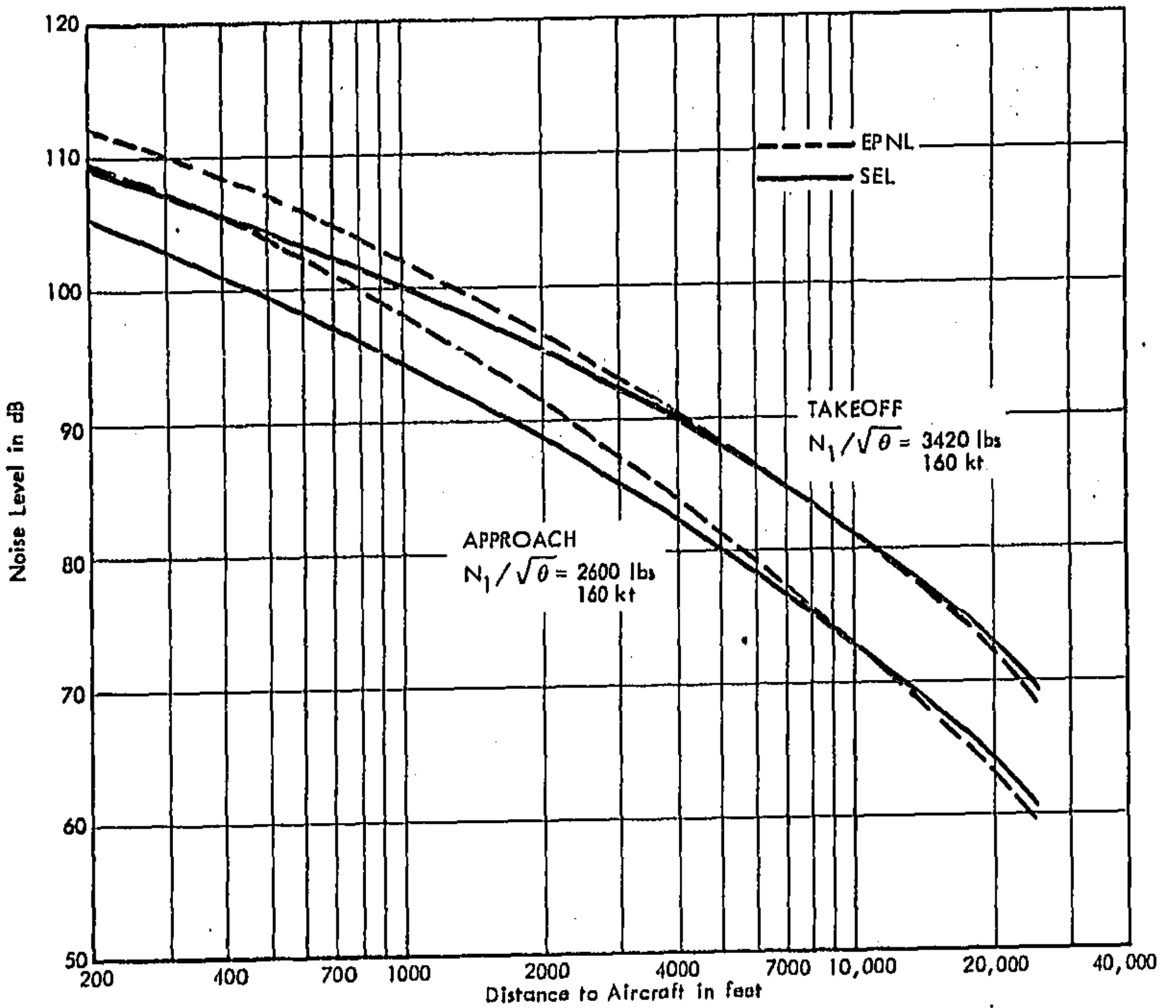

FIGURE 3. COMPARISON OF SEL AND EPNL VARIATIONS WITH DISTANCE - DC10-10 TRANSPORT AIRCRAFT WITH CF6 SERIES ENGINES

aircraft. Figure 2 shows EPNL and SEL curves for typical takeoff and approach thrusts for four-engine LBPR transport aircraft (707 and DC-8 aircraft with JT3D series engines). Figure 3 shows EPNL and SEL curves for typical takeoff and approach thrusts for a three-engine HBPR aircraft (Douglas DC-10-10 with CF6 series engines).

F. Composite Business Jet Noise Curves

Tables II-9 to 12, present noise data for specific business jet aircraft. Noise data for a "composite" business jet aircraft are presented in Table II-12 and Figure 4. The noise curves for the composite noise aircraft were established by considering the noise vs distance characteristics for three classes of business jet engines (straight turbojet engines, larger turbofan engines and smaller turbofan engines [specifically those for the Cessna Citation]). The curves assume a ratio of operations of 70% turbojet, 16% larger turbofans and 14% Citation type aircraft. This is representative of the business jet fleet anticipated for the U.S. in the United States at the end of 1976.* Information for adjusting the composite noise characteristics for different fleet characteristics are given in Reference 23.

*At the end of 1974, the business jet fleet was composed of approximately 75% turbojet powered aircraft, 15% larger turbofan powered aircraft and 10% Citation type aircraft.

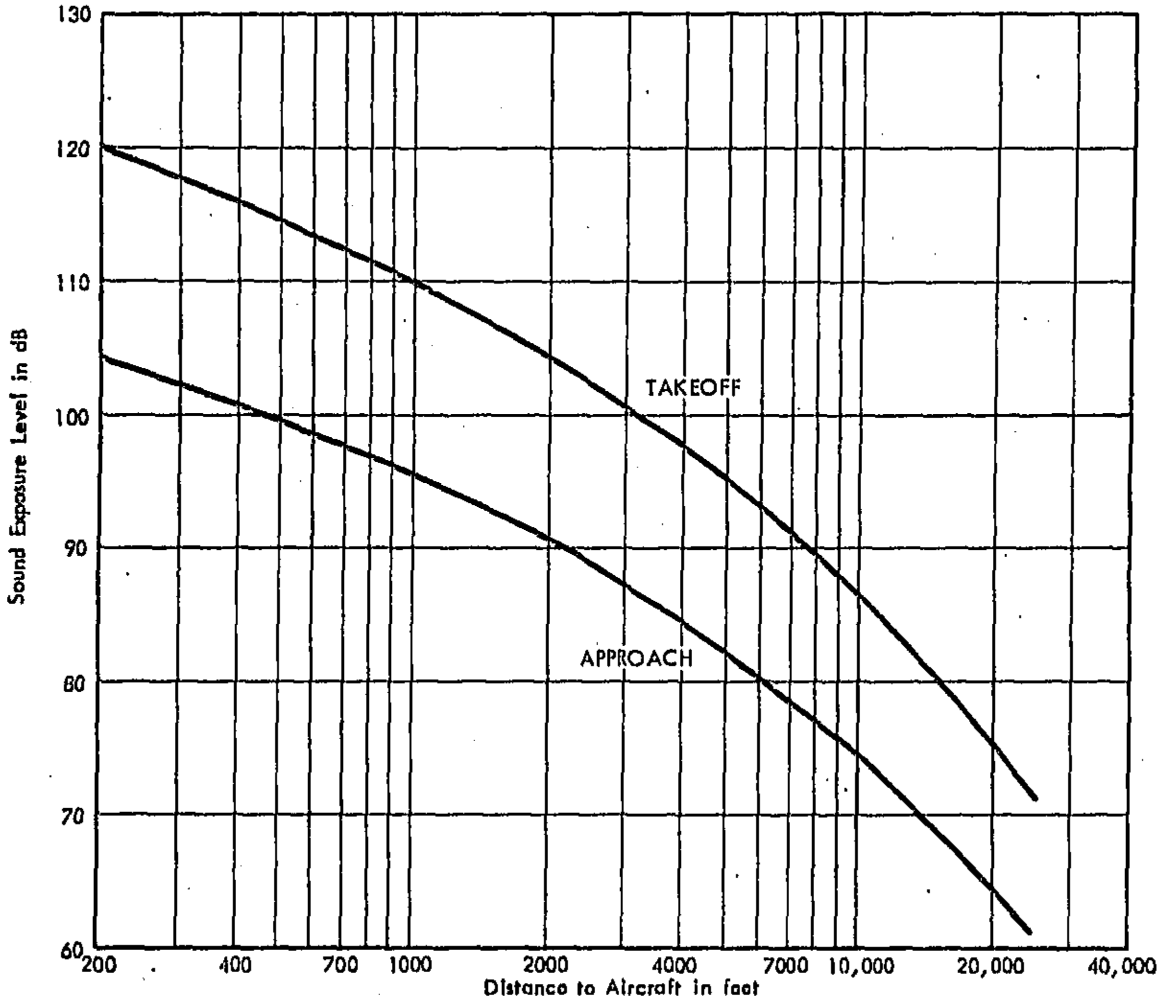

FIGURE 4. SOUND EXPOSURE LEVELS VERSUS DISTANCE - COMPOSITE BUSINESS JET AIRCRAFT

G. Composite Single Engine Propeller Noise Curves

Tables II-16 and Figure 5 present noise data for a composite single engine propeller powered aircraft. This composite curve is based upon review of the noise characteristics of single engine propeller aircraft of varying horsepower and review of the fleet composition in the United States[23]. The composite curve assumes a 80% operations of aircraft having engines of less than 200 HP and 20% of larger operations of aircraft having engines with 200 to 600 HP. For operations of only smaller aircraft (less than 200 HP) the noise curves may be adjusted downward by 1.5 dB for takeoffs and 3 dB for approaches.

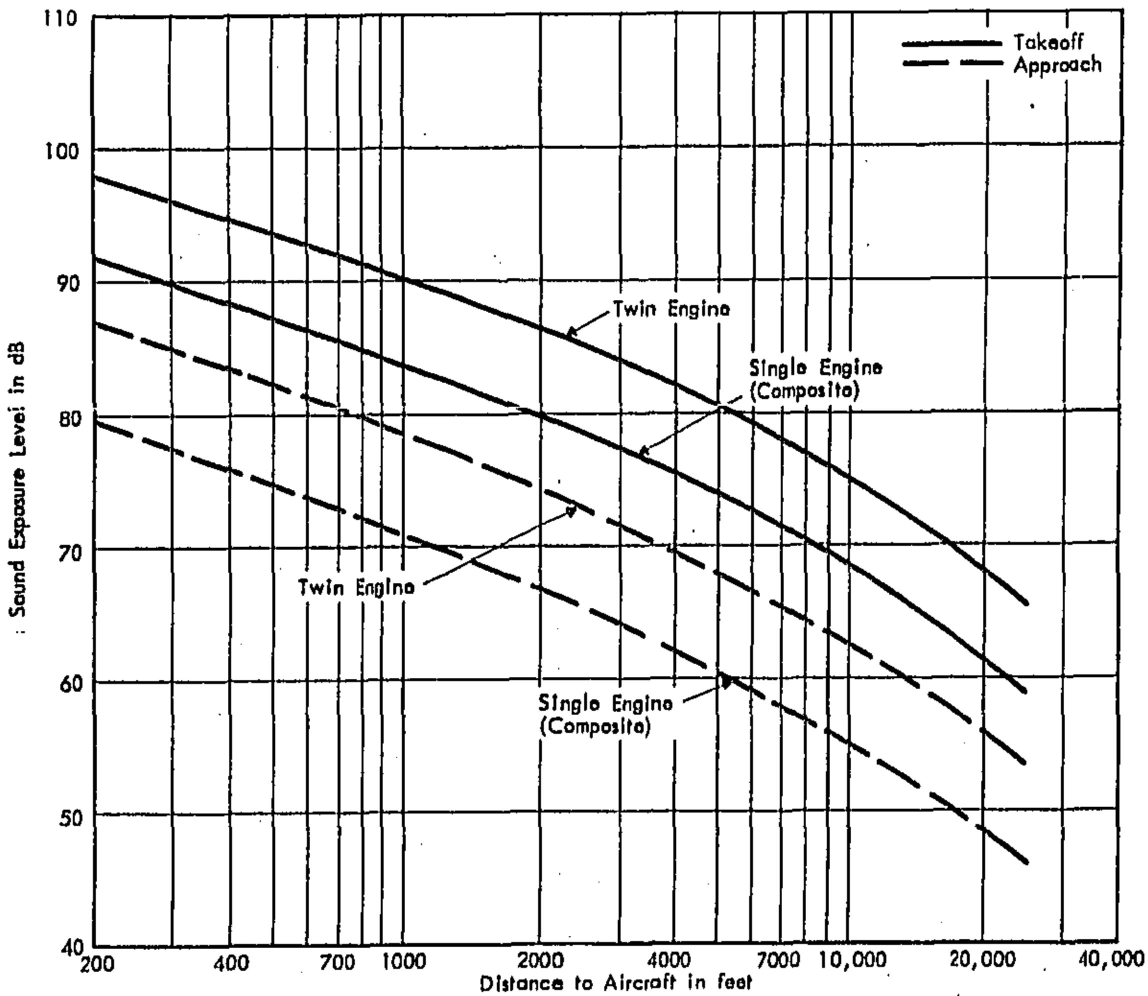

FIGURE 5. SOUND EXPOSURE LEVEL VERSUS DISTANCE - GENERAL AVIATION PROPELLER AIRCRAFT

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