EPA
United States
Environmental Protection
Agency

EPA 550/9-82-338

NOISE EXPOSURE AROUND JOINT-USE AIRPORTS

DECEMBER 1980

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF NOISE ABATEMENT AND CONTROL
WASHINGTON D.C. 20460

N-96-01
II-A-210

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA 550/9-82-338	2.	3. Recipient's Accession No.
4. Title and Subtitle NOISE EXPOSURE AROUND JOINT-USE AIRPORTS			5. Report Date DECEMBER 1980
			6.
7. Author(s) Richard Burke - Dwight E. Bishop			8. Performing Organization Rept. No. BBN 4218
9. Performing Organization Name and Address Bolt Beranek and Newman Inc.			10. Project/Task/Work Unit No. 09398
			11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address U.S. Environmental Protection Agency Office of Noise Abatement and Control Washington, D.C. 20460			13. Type of Report & Period Covered Final
			14. EPA ONA

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This report describes a study of present and future exposures of people to noise from airports used by both civilians and military aircraft and predicts how exposure around these airports will be affected by increasingly stringent aircraft noise regulations in the absence of similar regulation of military aircraft.

17. Document Analysis a. Descriptors

Noise Control
Noise Exposure Around Airports
Airport Noise Exposure
Joint-Use Airports and Noise Exposure

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement: Unlimited	19. Security Class (This Report) Unclassified	21. No. of Pages
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

BBN Report 4218
Project 09398

EPA 550/9-82-338

NOISE EXPOSURE AROUND JOINT-USE AIRPORTS

Richard Burke
Dwight E. Bishop

December 1980

Prepared for:

U.S. Environmental Protection Agency

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

1.0 INTRODUCTION

This report describes a study of present and future exposure of people to noise from airports in the U.S. which are used by both civilian and military-based aircraft. The purpose of the study is to predict how noise exposure around these joint-use airports will be affected by increasingly stringent civil aircraft noise regulations in the absence of similar regulation of military aircraft. Of special interest is to find a point, if any, at which further reductions in noise exposure require abatement of military aircraft noise.

Joint-use airports are defined for this study as airports that have civil operations and based military aircraft. Airports with only transient military operations from non-based aircraft are excluded from the analysis.

In this report, noise exposures are computed for all civil aircraft operations, for the based military operations, and for the combination of the two. Noise exposures are given in terms of the land area and population exposed to day-night levels (DNL) exceeding 55, 60, 65, 70, and 75 dB. Exposures are computed for five stages of regulation: one baseline stage representing current (calendar year 1978) conditions and four other stages in which the jets and the large props in the civil aircraft fleet become progressively less noisy by means of source noise control. Noise levels for military aircraft and for small civil props are held constant throughout the analysis.

This study complements and provides an essential connection between other studies EPA has performed in the past and plans for the future on the subject of aircraft noise exposure. These include a recent study of the noise exposure to the year 2000 due to the main civil air carrier operations.[1] Military and general aviation aircraft were excluded from this analysis. Exposure to noise solely from general aviation operations is the subject of a separate EPA sponsored study, while noise exposure from military operations alone is the subject of continued studies by the Air Force and other branches of the Department of Defense. It is hoped that the present study will help provide a useful link between these other areas of investigation.

As described in the sections below, the methods which were used to obtain noise exposure values for joint-use airports involve many steps. Briefly, the steps include the following:

1. Identify joint-use airports in the U.S.

2. Categorize these airports by:

   - number and type of military and civilian aircraft
   - runway and flight path configurations
   - surrounding population densities

3. Define average airports representative of the categories defined above.

4. Examine the reduction in noise exposure contours around these average airports resulting from the implementation of various FAA civil aircraft noise regulations.

5. Use these results for average airports to estimate the nationwide noise exposure around joint-use airports, and the total reductions in exposure expected

to result from civil noise regulations. Evaluate the significance of military aircraft noise in light of these results.

The remainder of this report is organized in three sections. Section 2 provides a description of present joint-use airport characteristics, including number and types of aircraft, runway configurations, flight tracks and profiles, and neighboring population densities. Section 3 defines the average airports (AVports) which are used in the noise analysis and the method of scaling these results to estimate nationwide impacts. It also describes the aircraft noise regulations under study, the computer program used to generate the noise contours and the regulatory stages which were investigated. Section 4 presents the results, including estimated nationwide noise exposure impacts around joint-use airports for military aircraft alone, civil aircraft alone, and for the combination of both under various regulatory conditions. Interpretive conclusions are presented at the end of this section.

2.0 EXISTING JOINT USE AIRPORTS

In this section, joint-use airports are identified and grouped into similar classes for analysis purposes. The military and civil aircraft that use joint-use airports are described, and appropriate mixes of these aircraft are found which represent average operations for each class. The flight patterns and profiles typical of each type of aircraft are discussed and modeled. Finally, the population characteristics around joint-use airports are evaluated for each class.

2.1 Airport Identification

The majority of joint-use airports which fall within the scope of this study consist of civil airports that have Air National Guard or Air Force Reserve squadrons stationed at the air field. In addition, there are a few situations in which military and civil airports are located next to each other and their aircraft use the same or adjacent runways such as Hickam Air Force Base and Honolulu International Airport in Honolulu, Hawaii. Also, there are a few military airports which have a considerable number of civil operations.

Air Force Reserve and Air National Guard squadrons are stationed at a total of 108 air fields which include 36 Air Force or Air National Guard military fields, three Naval Air Stations, and 69 civil air fields. Table 2-1 lists 66 of the civil air fields for which aircraft operation data is available. The number of average daily operations during calendar year 1978 is given for air carrier, general aviation, and military aircraft. Typically one squadron and one predominant type military aircraft are stationed at each joint-use airport. The predominant aircraft for each airport are also shown in Table 2-1.

TABLE 2-1

AVERAGE DAILY OPERATIONS AND STATIONED MILITARY AIRCRAFT AT JOINT-USE AIRPORTS IN 1978[2]

AVERAGE DAILY OPERATIONS

Joint Use Airport (Alphabetically by State)		Air Carrier	General Aviation	Military	Total	Dominant Stationed Military Aircraft
Birmingham	AL	122	399	41	562	RF-4C
Montgomery	AL	35	214	51	300	RF-4C
Anchorage	AK	167	472	6	645	C-130
Phoenix	AZ	283	805	23	1111	KC-135
Tuscon	AZ	98	637	71	806	A-7D
Ft. Smith	AR	36	143	24	203	F-100D
Fresno	CA	55	604	51	710	F-106
Hayward	CA	0	998	6	1004	HC-130
Ontario	CA	90	376	28	494	O2-A
Van Nuys	CA	0	1638	9	1647	C-130
Hartford	CT	173	217	28	418	F-100D
Wilmington	DE	8	470	45	523	C-130
Jacksonville	FL	103	181	85	369	F-106
Savannah	GA	30	313	36	379	C-130
Honolulu	HI	332	611	96	1039	F-4
Boise	ID	59	531	72	662	RF-4C
Chicago	IL	1655	417	12	2089	KC-135
Peoria	IL	55	315	25	395	O-2A
Springfield	IL	41	314	33	388	F-4C
Ft. Wayne	IN	39	336	18	393	F-4C
Terre Haute	IN	0	282	20	302	F-100D
Des Moines	IA	95	481	19	595	A-7D
Sioux City	IA	39	212	24	275	A-7D
Louisville	KY	163	180	19	362	RF-4C
Bangor	ME	29	162	62	253	KC-135
Baltimore	MD	200	397	12	609	C-7A
Westfield	MA	0	462	38	500	F-100D
Battle Creek	MI	6	159	17	182	O-2A
Duluth	MN	36	117	69	222	RF-4C

TABLE 2-1 (CONTINUED)
AVERAGE DAILY OPERATIONS AND STATIONED
MILITARY AIRCRAFT AT JOINT-USE AIRPORTS IN 1978[2]

Joint Use Airport (Alphabetically by State)		Air Carrier	General Aviation	Military	Total	Dominant Stationed Military Aircraft
Minneapolis	MN	352	353	18	723	C-130A
Jackson	MS	71	128	72	271	C-130
Meridian	MS	13	77	42	132	RF-4C
St. Joseph	MO	0	180	22	202	C-130
St. Louis	MO	528	380	25	933	F-4C
Great Falls	MT	27	220	31	278	F-106
Lincoln	NE	54	407	70	531	RF-4C
Reno	NV	106	410	19	535	RF-4C
Atlantic City	NJ	4	257	103	364	F-106
Schenectedy	NY	79	277	28	384	C-130
Niagara Falls	NY	1	366	85	452	F-101
Suffolk County	NY	0	257	30	287	HC-130
Syracuse	NY	87	374	52	513	A-37B
White Plains	NY	5	486	10	501	O-2A
Charlotte	NC	184	406	14	604	C-130
Fargo	ND	29	199	32	260	F-4C/D
Mansfield	OH	0	200	23	223	A-7D
Toledo	OH	45	246	13	304	F-100D
Youngstown	OH	23	278	20	321	A-37B
Oklahoma City	OK	142	445	23	461	C-130
Tulsa	OK	143	430	26	590	A-7D
Portland	OR	226	399	69	631	F-101
Harrisburg	PA	0	307	29	336	EC-130E

TABLE 2-1 (CONTINUED)
AVERAGE DAILY OPERATIONS AND STATIONED
MILITARY AIRCRAFT AT JOINT-USE AIRPORTS IN 1978[2]

AVERAGE DAILY OPERATIONS

Joint Use Airport (Alphabetically by State)		Air Carrier	General Aviation	Military	Total	Dominant Stationed Military Aircraft
Pittsburgh	PA	541	352	29	922	KC-135
San Juan	PR	129	393	15	537	A-7D
Providence	RI	60	572	32	664	C-130
Sioux Falls	SD	65	295	22	323	A-7D
Knoxville	TN	67	286	22	375	KC-135
Memphis	TN	413	533	11	957	C-130
Nashville	TN	176	425	22	623	C-130
Salt Lake City	UT	211	480	28	719	KC-135
Burlington	VT	31	227	53	311	EB-57
Richmond	VA	87	290	72	449	F-105D
Charlston	WV	45	245	21	311	C-130
Madison	WI	62	505	64	631	O-2A
Milwaukee	WI	201	456	20	677	KC-135
Cheyenne	WY	20	195	37	252	C-130

The table shows that joint-use airports encompass a wide range of aircraft mixes. Nine of the airports had no air carrier operations in 1978, while one of them (Chicago O'Hare) had an average of more than one every minute of the year.

Although they are quieter, and, therefore, have less impact than air carrier aircraft, general aviation aircraft represent a significant fraction of all joint-use airport operations. The percent of an airport's operations represented by general aviation aircraft increases as the number of air carriers decreases. At airports with more than 500 daily air carrier operations, about one-third of all operations are general aviation, whereas at airports with less than ten daily air carrier operations, about nine-tenths of all operations are general aviation. In spite of this, greater variety of aircraft, including those driven by single- and twin-piston engines, are found at the larger airports. It is clear that a proper description of nationwide operations at joint-use airports is a complex task.

In order to correctly take into account these variations in aircraft mix and number of operations, the joint-use airports are classified in five classes, as shown in Table 2-2. These classes are defined so as to maximize the similarity of aircraft mixes among airports of the same class, and also to group together airports with similar numbers of air carrier operations, since these are usually the dominant factor in determining total airport noise impact.

Before these classes were established, it was decided to eliminate from consideration those airports whose sole military based aircraft is the O-2A twin piston engine aircraft. This aircraft is

TABLE 2-2
CLASSIFICATION OF JOINT-USE AIRPORTS

Airport Code	Town		1978 daily Air Carrier Operations[3]
Class A (0 Air Carrier Operations)			AVG=0
BAF	Westfield	MA	0
FOK	Suffolk County	NY	0
HUF	Terre Haute	IN	0
HWD	Hayward	CA	0
MDT	Harrisburg	PA	0
MFD	Mansfield	OH	0
SCH	Schenectady	NY	0
STJ	St. Joseph	MO	0
VNY	Van Nuys	CA	0
Class B (1-39 Air Carrier Operations)			AVG=25
ACY	Atlantic City	NJ	4
BGR	Bangor	ME	29
BTV	Burlington	VT	31
CYS	Cheyenne	WY	20
DLH	Duluth	MN	36
FAR	Fargo	ND	29
FSM	Ft. Smith	AR	36
FWA	Ft. Wayne	IN	39
GTF	Great Falls	MT	27
IAG	Niagara Falls	NY	1
ILG	Wilmington	DE	8
MEI	Meridian	MS	13
MGM	Montgomery	AL	35
SAV	Savannah	GA	30
SUX	Sioux City	IA	39
YNG	Youngstown	OH	23
Class C (40-99 Air Carrier Operations)			AVG=66
BOI	Boise	ID	59
CRW	Charleston	WV	45
DSM	Des Moines	IA	95
FAT	Fresno	CA	55
FSD	Sioux Falls	SD	65
JAN	Jackson	MS	71
LNK	Lincoln	NE	54
PVD	Providence	RI	60
RIC	Richmond	VA	87

TABLE 2-2
CLASSIFICATION OF JOINT USE AIRPORTS
(CONTINUED)

Airport Code	Town		Air Carrier Operations[3]
Class C (40-99 Air Carrier Operations (Continued))			
SPI	Springfield,	IL	41
SYR	Syracuse	NY	87
TOL	Toledo	OH	45
TUS	Tuscon	AZ	98
TYS	Knoxville	TN	67
Class D (100 or more Air Carrier Operations)			AVG=299
BAL	Baltimore	MD	200
BDL	Hartford	CT	173
BHM	Birmingham	AL	122
BNA	Nashville	TN	176
CLT	Charlotte	NC	184
JAX	Jacksonville	FL	103
MEM	Memphis	TN	413
MKE	Milwaukee	WI	201
MSP	Minneapolis	MN	352
OKC	Oklahoma City	OK	142
ORD	Chicago	IL	1655
PDX	Portland	OR	226
PHX	Phoenix	AZ	283
PIT	Pittsburgh	PA	541
RNO	Reno	NV	106
SDF	Louisville	KY	103
SJU	San Juan	PR	129
SLC	Salt Lake City	UT	211
STL	St. Louis	MO	528
TUL	Tulsa	OK	134
Class E (Special Airports)			AVG=250
ANC	Anchorage	AK	167
HNL	Honolulu	HI	332

small enough in size that its effect on an airport's noise exposure levels may be considered negligible, especially considering the fact that the O-2A represents ten percent or less of the operations at these airports. The airports deleted for this reason are the following:

BTL	Battle Creek	MI
HPN	White Plains	NY
ONT	Ontario	CA
PIA	Peoria	IL
MSN	Madison	WI

Considering the classification of the remaining airports, the first class (A) includes those airports which have no air carrier operations. These airports are likely to be most affected by the presence of military aircraft and the least changed by the ongoing imposition of civil regulations.

The second class (B) covers those airports which have an average of 1-39 daily air carrier operations. These airports tend to have very few large turboprops or large commercial jets. Rather, they are dominated by the small turboprops and the two- and three-engine narrow-body jets, such as the DC-9 and the B-737.

The third class (C) comprises those airports which have 40-99 daily air carrier operations. Nearly half of these airports have long range aircraft such as the DC-8 and B-707, but the predominant aircraft are again the two- and three-engine narrow-bodies.

The fourth class (D) airports include the bulk of the large commercial airports in the study, those with 100 daily air carrier operations or more. Nearly all of these airports are serviced by the two-, three-, and four-engine jet airliners, and most of them are serviced by the small turboprops and twin piston aircraft, as well.

The fifth class (E) consists of airports which have a large number of aircraft embarking on long range trips. These long trips require aircraft to carry more fuel. The heavier load significantly changes their takeoff profiles, and therefore, their noise impacts are different. To identify cases where long range profiles are used in significant numbers, a detailed analysis of trip length information was made of airports at which 15 percent or more of total operations involve long range aircraft (three-engine wide bodies and all four-engine jets). The results of this analysis are shown in Table 2-3.

Assuming that a long range trip corresponds to a travel time of four or more hours, the table shows that there are only two airports where long range trips represent five percent or more of average daily takeoffs: ANC (Anchorage) with 12 percent and HNL (Honolulu), with 27 percent. These two airports were considered to constitute Airport Class E. For modeling purposes, profiles are developed for both short trip and long trip operations of the long range aircraft operating at these two airports, whereas only the short trip profile is used for Airport Classes A-D.

Table 2-4 is a summary table, showing the number of airports and the average number of daily military, air carrier, and general aviation operations in each class. The next two sections of this text describe the types of aircraft which make up these operations.

TABLE 2-3
PERCENT OF AVERAGE DAILY TAKEOFFS MADE
BY LONG RANGE AIRCRAFT, BY TRIP LENGTH*

Airport		Avg. Daily Takeoffs	Trip Length (Hrs.) <3	3-4	4-5	>5	"Long Range" Trips >4 Hrs.
ANC	Anchorage	108	0	4.9	0	11.6	11.6
BDL	Hartford	178	3.8	0	0	0.6	0.6
HNL	Honolulu	235	0	0	18.0	8.8	26.9
MSP	Minn./St. Paul	215	8.5	1.9	0	0	0
ORD	Chicago	931	13.1	7.4	0.1	1.5	1.6
PDX	Portland	155	6.5	3.9	2.6	0	2.6
PHX	Phoenix	145	10.2	4.1	0.7	3.4	4.1
SJU	San Juan	207	3.7	5.3	0.1	0.7	0.8
STL	St. Louis	302	7.2	2.9	0	0	0

* Based on national and international arrival time information given in References 5 and 6, respectively. Number of takeoffs assumed equal to number of arrivals. Long range aircraft include three-engine wide-body jets and all four-engine jets (categories 1-3 in Section 2.3 below).

TABLE 2-4
AVERAGE DAILY OPERATIONS

	Airport Class				
	A	B	C	D	E
	Number of Airports				
	9	16	14	20	2
Aircraft Type	Average Daily Operations				
Military	20	46	44	27	51
Air Carrier	0	25	66	299	250
General Aviation	488	238	380	389	542

2.2 Military Aircraft

Table 2-5 gives a brief description of the various types of military aircraft found at joint-use airports. They range from the small O-2A two-engine aircraft, discussed above, which is stationed at five bases, to the large KC-135A aircraft powered with four turbojet engines, stationed at eight bases. The most common aircraft is the C-130 "Hercules", which is stationed at 22, or about one-third of the bases.

To model the effect of these aircraft at joint-use airports, the aircraft are arranged in groups which have similar noise characteristics and a representative aircraft is chosen to model each group (see Table 2-6). Proceeding from the noisiest to the quietest, at the head of the list is the KC-135 refueling tanker. This aircraft is in a noise category all by itself due to the size of its four powerful turbojet engines which are required to lift its tremendous gross weight, about 300,000 pounds.

Next, in terms of noise, are the various one and two engine turbojets. This category includes the F-4, F-100, F-101, F-105, and F-106 fighters and fighter-bombers, powered by Pratt and Whitney engines. It was also decided to include in this category the A-7D Corsair and the A-37B trainer, which are light attack aircraft powered by Allison turbofan and GE turbojet engines, respectively, and the EB-57 electronic countermeasure aircraft, powered by two turbojets. Since the F-4 is found at more joint-use airports than any other aircraft in the group, this aircraft is used to represent the noise and performance characteristics of the group as a whole.

TABLE 2-5
CHARACTERISTICS OF MILITARY AIRCRAFT STATIONED AT JOINT USE AIRFIELDS*

Aircraft Name		Mission	Engine No.	Engine Type	G.Wt. 1000 lb.	Joint Use Air-fields
KC-135	Stratotanker	Refueling tanker	4	P&W J57 turbojet	297	8
C-130	Hercules	Transport	4	Allison T56 turboprop	175	22
F-4	Phantom II	Fighter-bomber	2	P&W J79 turbojet	57	13
F-105	Thunderchief	Fighter-bomber	1	P&W J57 turbojet	53	2
F-101	Voodoo	Intercepter fighter	2	P&W J57 turbojet	47	2
EB-57	Canberra	Electronic Counter-measure	2	P&W J57 turbojet	46	2
A-7D	Corsair II	Light attack	1	Allison TF41 turbofan	42	8
F-106	Delta Dart	Intercepter fighter	1	P&W J57 turbojet	35	4
F-100	Super Sabre	Fighter-bomber	1	P&W J57 turbojet	35	5
C-7	Caribou	Transport	2	P&W R200 piston	29	1
HH-3	Jolly Green Giant	Rescue helicopter	2	GE T58 turboshaft	22	2
A-37B	Dragonfly	Light attack trainer	2	GE J85 turbojet	14	3
HH-1H	Iroquois	Rescue helicopter	1	Lycoming turboshaft	10	1
02-A	Skymaster	Recon-naissance	2	Cont. 10-360 piston	5	5

*Arranged in order by maximum gross takeoff weight. Data includes Air Force Reserve and Air National Guard Squadrons from Ref. 2.

TABLE 2-6
CATEGORIES OF MILITARY AIRCRAFT

Aircraft Category	Characteristics	Engine	Aircraft*	Designation
I	Heavy Tanker	Turbojet	Stratotanker	KC-135
II	Fighter	Turbojet and Turbofan	Corsair II	A-7D
			Dragonfly	A-37B
			Phantom II	F-4
			Super Sabre	F-100
			Voodoo	F-101
			Thunderchief	F-105
			Delta Dart	F-106
			Canberra	EB-57
III	Transport and Helicopter	Turboprop	Hercules Transport	C-130
			Jolly Green Giant Helicopter	HH-3

*The aircraft chosen to represent each aircraft category in the noise exposure model is underlined.

After these two groups, two different aircraft types remain: transports and helicopters. The primary aircraft in this category is the C-130 Hercules transport, powered by four Allison turboprop engines. A similar but somewhat less noisy light transport is also included, the C-7 Caribou, powered by two Pratt and Whitney piston engines. Two turbo-powered helicopters, the HH-3 Jolly Green Giant and the HH-1H Iroquois, complete the group. Since the C-130 is the dominant aircraft at 22 joint-use airports and the other three types of aircraft are only found at four airports, the noise and performance characteristics of the C-130 are used to apply to all aircraft in this group.

Military aircraft represent from 0.5 to 32 percent of operations at joint-use airports. This percentage tends to decrease as the number of air carrier operations increase. A breakdown of operations at each airport class by military aircraft category, time of operation, and itinerant or local operation, is shown in Table 2-7. Here, local operations represent practice pattern flights such as touch-and-go landings. These operations have a somewhat greater impact than straight-in and straight-out itinerant operations because they impact land areas close to the airport at relatively low altitudes during level flight as well as during takeoff and landing.

2.3 Civil Aircraft

Two types of civil aircraft are treated in this section, air carriers and general aviation. According to the Official Airline Guide,[5] there are over 40 different types of aircraft utilized in air carrier operations at joint-use airports at the present time. They range from the largest airliner in the world, the Boeing 747 Jumbo Jet, which has a gross weight of up to 800,000

TABLE 2-7
NUMBER OF DAILY MILITARY OPERATIONS
IN EACH AIRCRAFT CATEGORY, BY AIRPORT CLASS
AND TIME OF OPERATION

Airport Class	Time of Operation	Itinerant I	Itinerant II	Itinerant III	Local I	Local II	Local III
		Military Aircraft Category					
A	Day	0.0	4.03	6.31	0.0	2.28	7.41
	Nt.	0.0	0.08	0.13	0.	0.05	0.15
B	Day	1.28	14.70	3.49	2.51	19.11	3.73
	Nt.	0.03	0.30	0.07	0.05	0.39	0.08
C	Day	0.84	16.94	2.52	0.70	16.31	6.23
	Nt.	0.02	0.35	0.05	0.01	0.33	0.13
D	Day	3.63	10.17	4.29	1.11	5.29	2.19
	Nt.	0.07	0.21	0.09	0.02	0.11	0.04
E	Day	0.0	39.69	2.45	0.0	7.48	0.49
	Nt.	0.0	0.81	0.05	0.0	0.02	0.01

pounds, to one of the smallest, the Piper Cherokee, which weighs less than 2000 pounds. To specify the noise and performance characteristics of each aircraft in the noise exposure model would be an exhaustive task; therefore, they are combined into 13 categories which have similar noise producing characteristics, and a representative aircraft is chosen to represent each group in the model.

The 13 categories are listed in Table 2-8 along with the aircraft which are included in each category and the code or codes by which each aircraft is designated in the Official Airline Guide.[5] The first six categories are simply a standard classification of jet airliners by number of engines (two, three, or four) and size of aircraft (wide-body or narrow-body). The next four categories, (seven to ten) are turboprop business jets arranged by engine type (Dart and Other, Allison, or PT6). The PT6 engine category is further broken down by takeoff weight (under 12,500 pounds and over 12,500 pounds). The next two categories (11 and 12) include all light aircraft powered by twin- and single-piston engines, respectively. The final category (13) includes two models of aircraft approaching obsolescence which do not fit well into the other categories, the Lockheed Electra and Constellation. Representative aircraft are chosen for each category on the basis of data availability and the relative importance of the aircraft in the group.

The percent of operations in each category was derived for each airport class by examining the Official Airline Guide's North American Edition[5] and Worldwide Edition[6]. The number and time of arrival of each type of aircraft was tabulated for each airport. These values were then grouped into the thirteen air carrier categories, two time periods (day and night), and the five

TABLE 2-8
CATEGORIES OF AIR CARRIER AIRCRAFT

Aircraft Category	No. of Engines	Characteristics	Aircraft*	Airline Guide Code[5]
1	4	Wide Body	Boeing 747	747,74L
2	4	Narrow Body	Boeing 707	707,70M
			Boeing 720	B72
			McDonnell-Douglas DC8	DC8, D8S
3	3	Wide Body	McDonnell-Douglas DC10	D10
			Lockheed L1011	L10
4	3	Narrow Body	Boeing 727	727,72M,72S
5	2	Wide Body	AirBus A300B	AB3
6	2	Narrow Body	Boeing 737	737,73M,73S
			British Aerospace Corporation BAC111	B11
			McDonnell-Douglas DC9	DC9,D9S,D95
7	2	Turboprop Dart Engine	McDonnell-Douglas DC3	DC3
			Fokker F-227	FK7
			Fokker-All Types	FKF
			Hawker-Siddeley 748	HS7
			Grumman Gulf-stream 1 G159	GRS
			Namco YS11	YS1
8	2	Turboprop Allison Engine	Convair-All	CVR
9	2	Turboprop >12,500 lb PT6 Engine	Nord 262	ND2
			Short-Harland SD3-30	SH3
			Nord 298	298

TABLE 2-8 (CONTINUED)
CATEGORIES OF AIR CARRIER AIRCRAFT

Aircraft Category	No. of Engines	Characteristics	Aircraft*	Airline Guide Code[5]
10	2	Turboprop <12,500 lb PT6 Engine	Beech 99	BE9
			Beech-All Types	BEC
			Beech-All Turbo	BET
			DeHavilland Canada	DHC
			DeHavilland Twin Otter	DHT
			Baneirante	EMB
			Handley-Page Jetstream	HPJ
			Swearington-Metro	SWM
11	2	Piston	Beech Twin Bonanza	BEO
			Beech Queen Air 80	BEQ
			Beech T-18	BET
			Cessna 402	CN4
			Cessna All Types	CNA
			DeHaviland Heron	DHH
			DeHaviland R400	DHR
			Grumman G 21A	GRG
			Piper Chieftan	PAF
			Piper-All Types	PAG
			Piper Navajo	PAN
			Piper Seneca	PAS
			Piper Aztec	PAZ
			Props-All Types	PRP
			Ted Smith Aerostar 601	TS6

TABLE 2-8 (CONTINUED)
CATEGORIES OF AIR CARRIER AIRCRAFT

Aircraft Category	No. of Engines	Characteristics	Aircraft*	Airline Guide Code[5]
12	1	Piston	Cessna 207	CNT
			Piper Cherokee	PAC
			Props-Single Engine	(none)
13	4	Miscellaneous	Lockheed Electra	LOE
	2		Lockheed Constellation	L07

* The aircraft chosen to represent each aircraft category in the noise exposure model is underlined.

airport classes. The percentage of all operations in each class was then computed, as shown in Table 2-9. When combined with the average number of daily air carrier operations listed in Table 2-2, these values will determine the number of air carriers of each type to be used in the AVport analysis.

General aviation operations at joint-use airports also comprise a wide range of aircraft types. Since these aircraft are less noisy and therefore have less impact on the surrounding population than air carriers, it is not necessary to model the detailed differences between types. Instead, three general aviation categories are defined. These are busness jets, twin-engine piston aircraft, and single-engine piston aircraft. A composite aircraft, representing the wide variety of aircraft types in each group, was developed for each category for modeling purposes.

The percent of aircraft in each of these three categories is derived from a brief telephone survey of tower operators at AVport A airports. The survey showed that approximately 13% of all operations are busness jets, 30% are twins, and 57% are single propeller aircraft. There are no published data to indicate how these percentages further divide into local and itinerant operations, so this breakdown is determined as follows. According to Table 2-6, approximately 50% of all general aviation operations are local operations and 50% are itinerant operations. If aircraft in each category flew the same portion of local flights as itinerant flights, the percentage breakdown would be 13% jets, 30% twins, and 57% single props for both local and itinerant operations. However, although definitive estimates are not available, it is expected that the single engine props represent a greater proportion of local operations than they do itinerant operations, and

TABLE 2-9
PERCENT OF OPERATIONS IN EACH AIRPORT CLASS, BY AIR CARRIER AIRCRAFT CATEGORY AND TIME OF OPERATION*

		Air Carrier Aircraft Category													
		Jets						Large Props			Small Props			LgPrp	
Air-port Class	Time	747 1	707 2	DC10 3	727 4	A300 5	DC9 6	HS7 7	CVR 8	SD3 9	DHC 10	PRP2 11	PRP1 12	LOE 13	Total
B	Day	0	1.56	0.78	14.71	0	32.54	1.12	11.47	1.12	21.34	3.01	0.28	0	87.93
	Nt.	0	0	0	3.06	0	5.07	0	1.17	0	2.39	0.39	0	0	12.08
C	Day	0	2.26	0	25.17	0	39.79	6.30	4.70	2.87	5.77	3.73	0	0	90.59
	Nt.	0	0.30	0	3.23	0	4.39	0.69	0.19	0	0.17	0.41	0	0	9.38
D	Day	0.31	4.99	3.74	32.59	0.0004	30.27	2.87	2.09	0.65	8.83	5.49	0.07	0.01	91.91
	Nt.	0.26	0.62	0.86	3.50	0	2.38	0.05	0.10	0.02	0.06	0.19	0.02	0	8.06
E	Day	7.13	1.90	7.00	10.57	0	31.40	1.41	0	0.58	18.34	14.04	0	1.04	93.41
	Nt.	1.58	0.57	1.41	0.52	0	1.70	0	0	0	0.81	0	0	0	6.59

*Data based on arrival information listed in Reference 5. Total day and night percentages may not add up to 100 percent due to rounding.

business jets and twin props represent a smaller portion of local operations than itinerant operations. With these assumptions, the following distribution of aircraft is assumed for our study:

General Aviation Category	Aircraft	Percent of Operations Itinerant	Local
1	Business Jets	15%	10%
2	Twin Props	35%	25%
3	Single Props	50%	65%
	Total	100%	100%

The above distribution is assumed to apply to general aviation aircraft in all airport classes, and is in reasonable agreement with flight data from other sources.[9] The number of nighttime operations by general aviation aircraft was found, in the telephone survey, to be approximately 1% of all itinerant operations. This value is assumed to apply to each airport class. It is assumed that there are no nighttime local operations. By applying the distribution values discussed above to the average daily operations of general aviation aircraft shown in Table 2-4, the average number of operations in each aircraft category are obtained, as shown in Table 2-10.

2.4 Runway, Flight Track and Profile Characteristics

In this section, average runway, flight track, and flight profile characteristics are formulated for aircraft in each airport class. A variety of runway configurations and flight patterns are found at the joint-use airports under study. Runway lengths vary from 3,500 feet to 13,000 feet. Practice flight patterns differ greatly from airport to airport, reflecting differences in surrounding terrain, local wind conditions, and locations of noise-sensitive

TABLE 2 - 10

AVERAGE NUMBER OF GENERAL AVIATION OPERATIONS IN
EACH AIRCRAFT CATEGORY, BY AIRPORT CLASS AND TIME OF OPERATION (1)

Airport Class	Time of Operation	General Aviation Aircraft Category: Itinerant			Local			Total(2)
		Bus.Jet	Lg. Prop.	Sm.Prop.	Bus.Jet	Lg.Prop	Sm.Prop.	
A	Day	38.3	89.4	127.8	23.0	57.5	149.4	485.4
	Night	0.4	0.9	1.3	0	0	0	2.6
B	Day	19.9	46.4	66.3	10.4	26.0	67.6	236.6
	Night	0.2	0.5	0.7	0	0	0	1.4
C	Day	36.6	85.4	122.0	13.4	33.4	86.8	377.5
	Night	0.4	0.9	1.2	0	0	0	2.5
D	Day	51.4	119.1	170.2	4.5	11.3	29.4	385.6
	Night	0.5	1.2	1.7	0	0	0	3.4
E	Day	49.5	115.4	164.8	20.9	52.3	135.9	538.7
	Night	0.5	1.2	1.7	0	0	0	3.3

(1) Values based on percent distributions discussed in text and on average totals given in Table 2-4.

(2) Numbers may not add to totals due to rounding.

population areas. Takeoff and approach profiles are also influenced by differences in these conditions to some degree, as well as by differences in aircraft weights, pilot habits, airline recommendations, and other features of the particular aircraft being flown.

Runways and Flight Tracks

The number and orientation of runways at the various joint-use airports cannot be "averaged" in a simple way. No single configuration could be said to model the variety of conditions that exist. Nevertheless, the model which is described below may be expected to produce a noise contour of similar size as contours from actual configurations.

In the model, there is only one large runway. Flight tracks for military aircraft are assumed to follow those of air carrier aircraft, while general aviation aircraft are assigned separate flight tracks.

Flight tracks for military and air carrier aircraft are shown in Figure 2-1 for AVports A, B, and C, and in Figure 2-2 for AVports D and E. A single local pattern flight track is shown for military aircraft traveling in a counterclockwise direction. All local military operations are assumed to follow this path. Itinerant aircraft are assumed to approach and depart the single runway in both directions. Three approach paths and three departure paths are defined in each direction, one which goes straight out from the runway, and two others which branch to the right and left. The approach and departure angles, turn radii, and percent distribution values for these itinerant flights are derived from

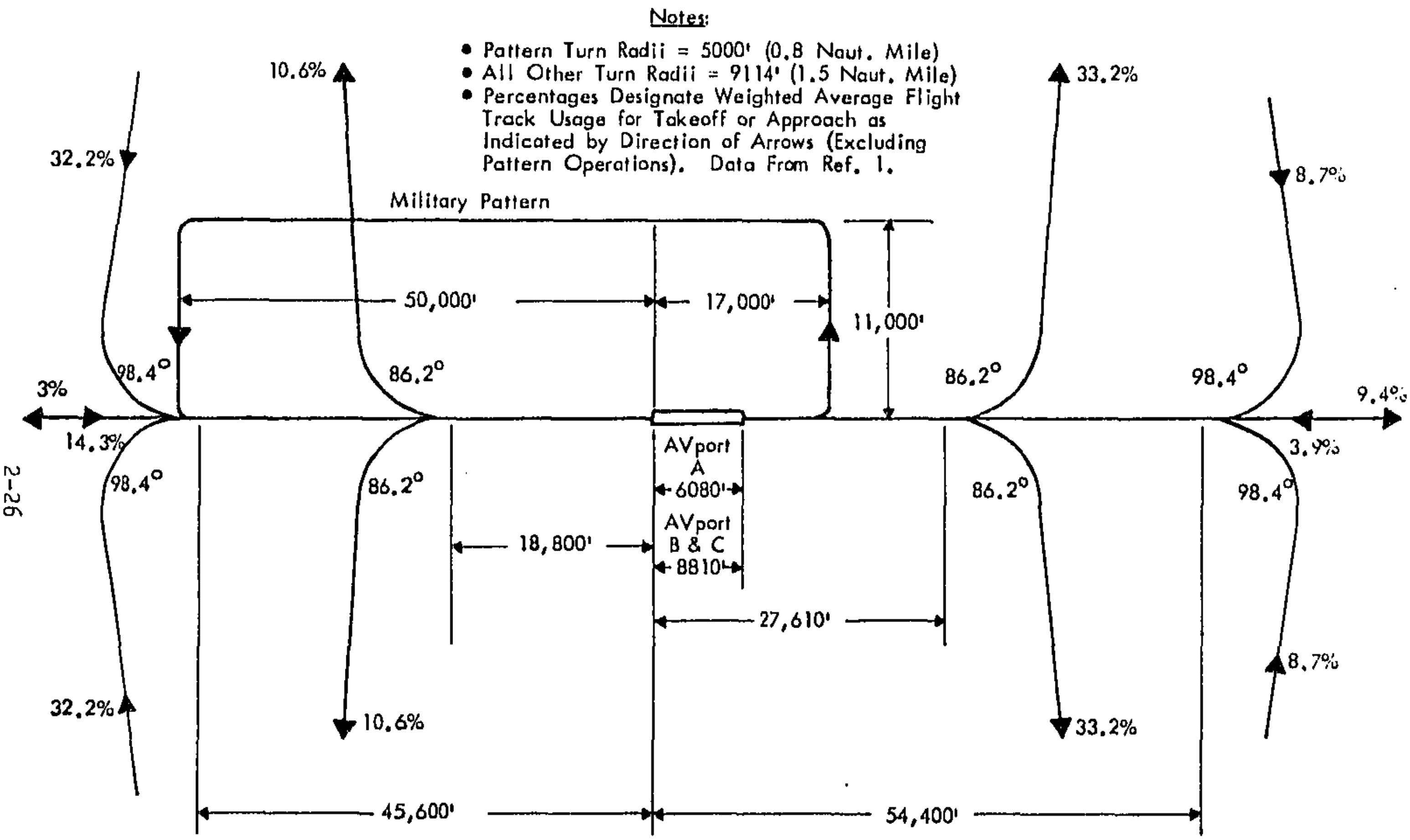

FIGURE 2-1. MILITARY AND AIR CARRIER FLIGHT TRACKS FOR AVPORTS A, B, AND C

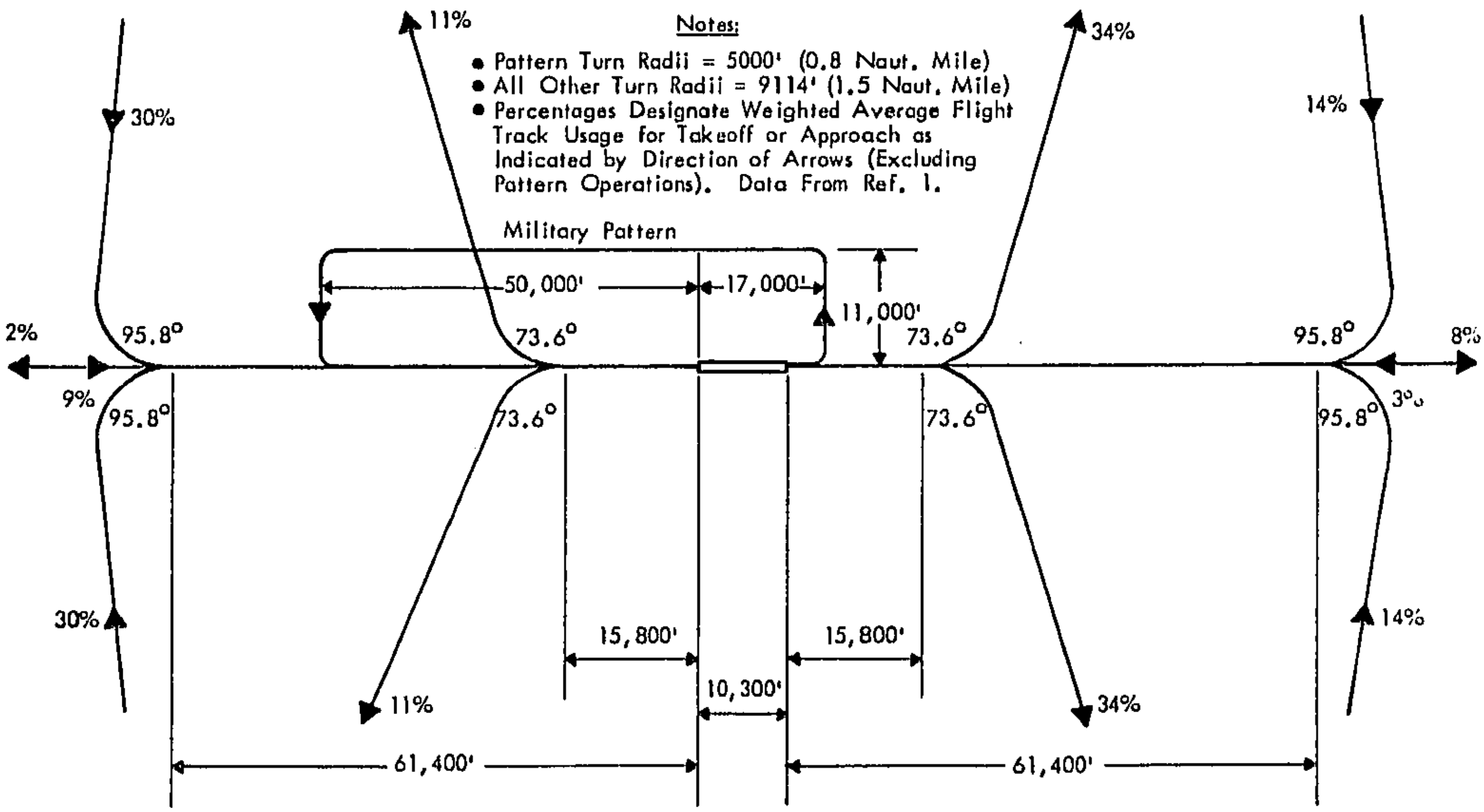

FIGURE 2-2. MILITARY AND AIR CARRIER FLIGHT TRACKS FOR AVPORTS D AND E

Reference 1, in which a survey was made of airport flight tracks. In that study, two flight track configurations were developed whose runway lengths closely match the average runway lengths of AVports A, B, and C and AVports D and E, respectively. All military and air carrier aircraft are assumed to follow the flight track distributions shown in the two figures.

A separate set of flight tracks is defined for general aviation aircraft. These flight tracks are shown in Figure 2-3. Again, three departure paths and three approach paths are defined for all itinerant general aviation operations. In addition, a single rectangular flight pattern is defined for all local operations.

The sensitivity of the contour areas to changes in the percent distribution of operations along the various flight tracks was examined in four test runs. Two of these involved air carrier operations at AVport D, and two involved general aviation operations at AVport A. The first air carrier test run considered the case in which no turns were made. All aircraft were assumed to follow straight-in and straight-out approaches and departures. The second air carrier run considered the case in which no aircraft made straight-in and straight-out approaches and departures; rather, all aircraft made turns either to the right or to the left. The results of this test evaluation are shown in Table 2-11.

In the first test involving changes in general aviation flight tracks, the departure path which makes a 45° angle turn to the left was changed to make a 45° angle to the right. In the second test, operations were assumed to travel in both directions at a ratio of 2:1. These results are also shown in Table 2-11.

Note: Percentages Indicate Portion of All Approaches or All Departures Using That Track. Turning Radii = 900' for 90° Turns, 1000' for 45° Turns. Data From Ref. 8.

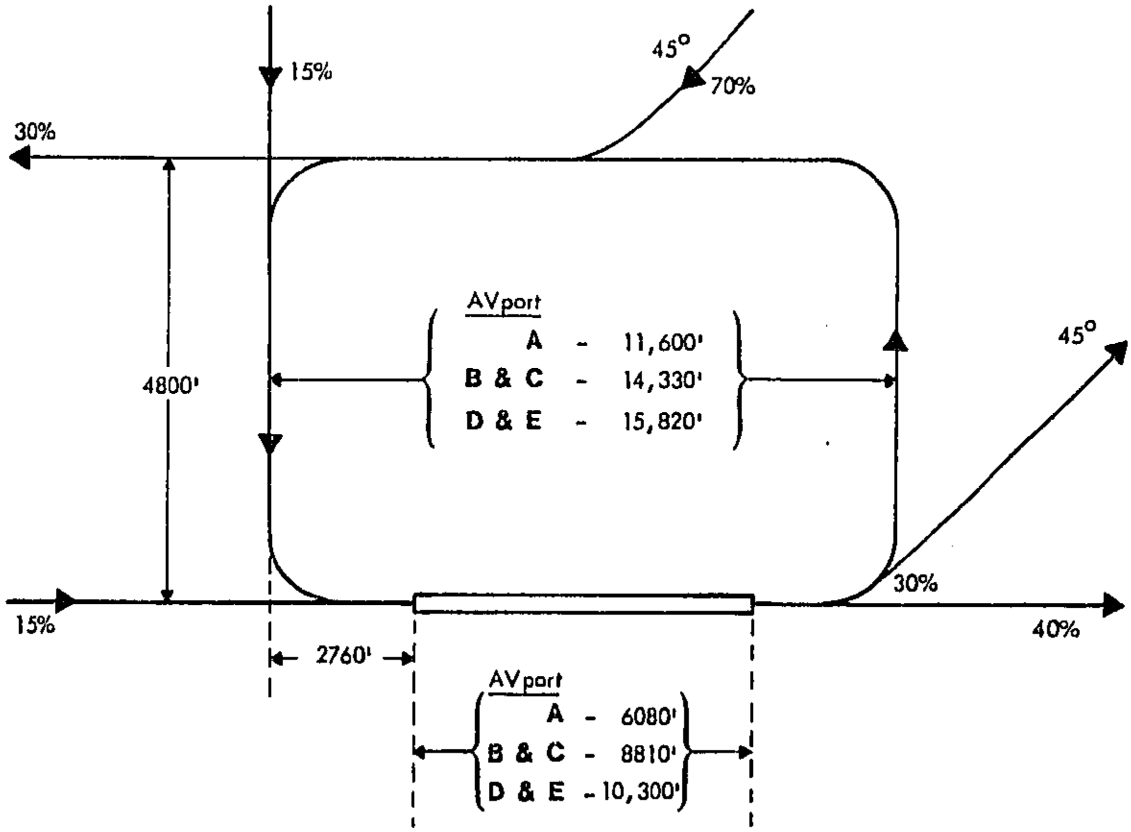

FIGURE 2-3. FLIGHT TRACKS FOR GENERAL AVIATION OPERATIONS

TABLE 2-11
SENSITIVITY OF CONTOUR AREAS AND POPULATION TO CHANGES IN AIR CARRIER AND GENERAL AVIATION FLIGHT TRACK DISTRIBUTION

	DNL Contour	Air Carriers Alone: Straight In-Out Only	Air Carriers Alone: Turn In-Out Only	General Aviation Alone: 1/3 Opposite Direction	General Aviation Alone: Change 1 T/O Track
AREA			Percent Change from Baseline (%).		
	75	0.0	0.0	1.3	0.0
	70	0.0	0.3	3.2	-0.6
	65	4.7	0.2	-2.5	-3.9
	60	12.8	2.4	11.3	3.0
	55	5.3	4.0	7.7	5.2
POPULATION					
	75	-8.8	0.0	66.7	0.0
	70	-7.1	0.0	51.4	0.0
	65	-1.6	0.7	15.4	-5.8
	60	7.9	2.2	24.8	0.4
	55	-0.9	5.0	28.0	-5.3
AREA			Equivalent Noise Level Change from Baseline*(dB)		
	75	0.0	0.0	0.1	0.0
	70	0.0	0.0	0.2	0.0
	65	0.3	0.0	-0.2	-0.3
	60	0.8	0.2	0.7	0.2
	55	0.3	0.3	0.5	0.4
POPULATION					
	75	-0.6	0.0	2.9	0.0
	70	-0.5	0.0	2.4	0.0
	65	-0.1	0.0	0.8	-0.3
	60	0.5	0.1	1.3	0.0
	55	-0.1	0.3	1.4	-0.3

* Changes in noise level which would yield the same changes in area and population as the indicated changes in flight track distribution.

The results of the sensitivity analysis show that the contour areas change very little if flight tracks are shifted, or aircraft are operated in a differend direction. The maximum change in area is 12.8% for air carrier changes and 11.3% for general aviation changes. The increase in noise level which would be required to achieve these changes is less than 1 dB. Since the uncertainty in aircraft noise levels and other features of our model is of this magnitude or greater, it may be concluded that the sensitivity of the results to assumptions of flight path and direction is sufficiently low. The maximum change in population within any one contour is 8.8% for air carriers and 66.7% for general aviation, corresponding to changes in noise levels of 0.6 dB and 2.9 dB, respectively. The unusually high value for general aviation is due to the fact that population densities vary greatest at close distances from the airport. Therefore, for airports with a small number of quiet aircraft operations, such as AVport A, small changes in flight patterns may yield large percentage changes in the population within various contours. Since these contours will be overshadowed by military operations in the case of AVport A, and by military <u>and</u> air carrier operations in the case of the other AVports, the values shown are not indicative of the sensitivity of the model in its actual operating modes.

Profiles

Profile and performance data for military aircraft was gathered from BBN files. The flight procedures used to model civil aircraft at joint-use airports are based on the Airline Transport Association (ATA) Flight Procedures revised in December 1976. The takeoff profile and performance information associated with these procedures are illustrated in Appendix A. The average gross weights used for the jet airliners (Categories 1-6) are shown in

Table 2-12. Note that two gross weights are defined for Categories 1-3, corresponding to short range and long range operations. The long range aircraft are only used in AVport E (see Section 2.1).

Approach profiles for civil aircraft are assumed to be 3° for all 3 military categories, air carrier categories 1 through 10 and 13, and general aviation category 1. A 4.5° approach glide slope is assumed for air carrier categories 11 and 12 and general aviation categories 2 and 3. Full flaps are assumed for all aircraft landings.

2.5 Population Characteristics

In this section, population density values are calculated for each AVport class as a function of distance from the airport. The population around airports varies in a characteristic way. Within the first one or two miles of the center of the airport, the population density is typically very small since the area underneath the approach and departure paths must be free from buildings, and other areas close to the airport runways are put to non-residential use. As one moves further from the airport center, the population density increases until, at a point between three and five miles from the airport center, the maximum population density is usually reached. This distance represents the distance between the airport and the center of the nearest town. After this point, the population density decreases more or less uniformly until a point is reached at which the airport noise is no longer impacting the population.

The variation of population density with distance from the airport center is shown for each airport class in Figure 2-4. In the

TABLE 2-12
AVERAGE GROSS WEIGHTS USED IN THE MODEL FOR JET AIR CARRIERS

Air Carrier Category*	Representative Aircraft	Average Gross Weight (1000 lb)
1 L	747	720
S		640
2 L	707	300
S		230
3 L	DC-10	440
S		370
4	727	156
5	A300	302
6	DC-9	92

* L indicates long range (4 or more hours travel time).
S indicates short range (less than 4 hours travel time).

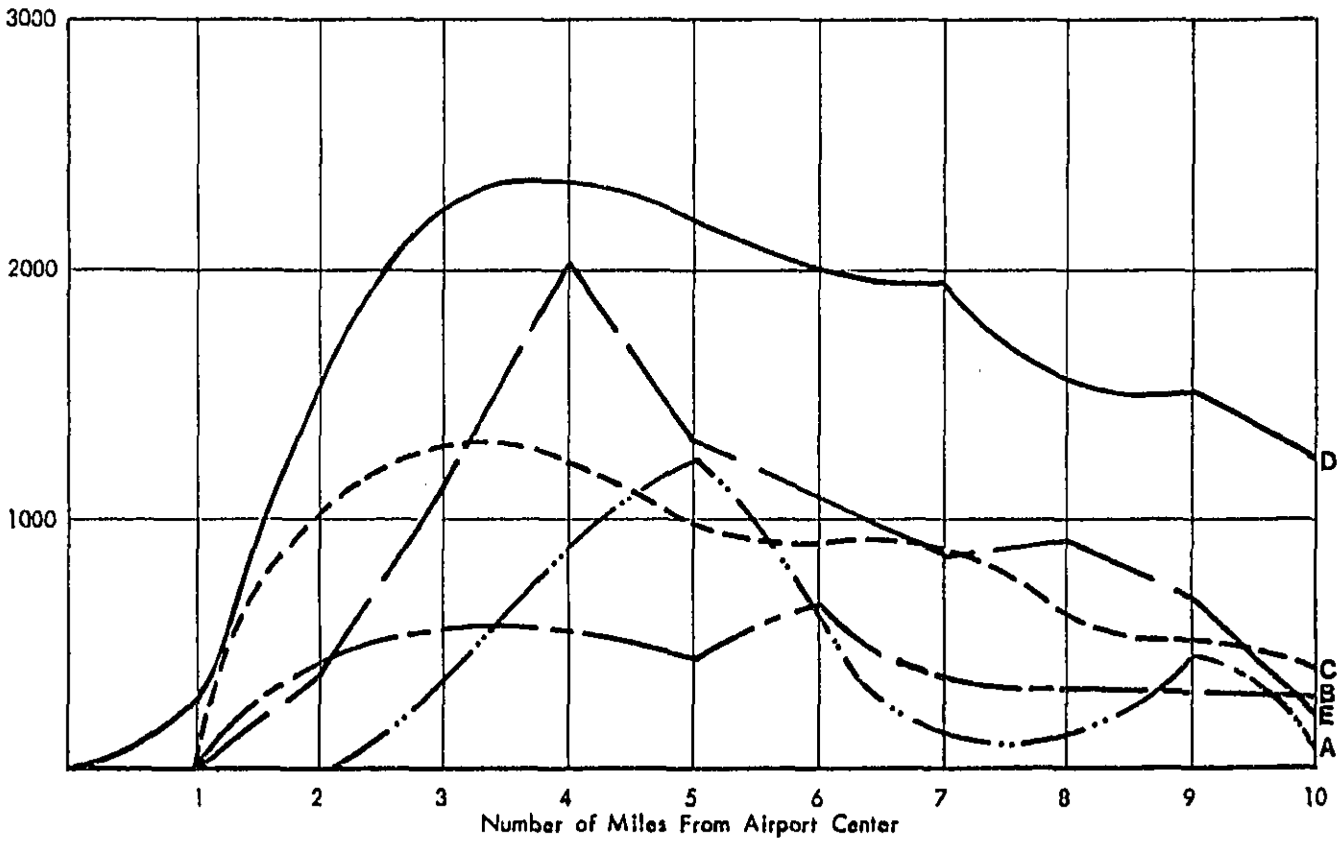

FIGURE 2-4. POPULATION DENSITY AROUND AIRPORTS AS A FUNCTION OF DISTANCE FROM CENTER OF RUNWAY, BY AIRPORT CLASS[4]

model of population impacts, an average population value is assigned to the center of each one-mile-wide band around the airport. Grid points falling between the centers of the specified one-mile-wide bands are assigned population density values which are proportionate to their position relative to the centers of the two bands. In this way a smooth transition is made between the different population density values. Population densities in each one mile band are shown in Table 2-13.

TABLE 2-13

POPULATION DENSITY AROUND AIRPORTS,
BY CLASS AND RADIAL DISTANCE FROM RUNWAY (PEOPLE PER SQUARE MILE) [4]

AIRPORT CLASS	DISTANCE OF OUTER EDGE OF ONE-MILE-WIDE BAND FROM CENTER OF RUNWAY (MILES)									
	1	2	3	4	5	6	7	8	9	10
A	0	0	380	910	1,240	610	120	130	470	70
B	0	430	550	560	430	670	360	320	300	290
C	0	1,030	1,300	1,230	980	910	890	620	520	400
D	280	1,540	2,260	2,350	2,210	2,030	1,960	1,550	1,520	1,250
E	0	1,380	1,145	2,025	1,325	1,100	895	935	715	225

3.0 NOISE EXPOSURE COMPUTATION METHOD

In this section, three portions of the noise exposure computation method are described. These elements are (1) define noise regulation scenarios (Section 3.1), (2) run the computer model of noise exposure (Section 3.2), (3) scale the results to a nationwide basis (Section 3.3).

3.1 Noise Regulation Scenarios

The noise impacts around joint use airports are analyzed under five noise regulation scenarios or stages. At each stage, only civil aircraft noise levels are changed. The analysis year, population densities, fleet size, aircraft mix, flight paths and flight procedures remain the same, as described in Section 2. Under these conditions, the analysis does not predict actual noise exposures in the future, but rather it helps one visualize the relative importance of military aircraft noise under successively strict civil noise regulation conditions.

The five scenarios described in this section are termed as follows:

Baseline	Stage 1
69 FAR 36	Stage 2
75 FAR 36	Stage 3
80 FAR 36	Stage 4
85 FAR 36	Stage 5

Stage 1

Aircraft noise levels in this baseline scenario are based on typical equipment in use at the current time (calendar 1978 is the analysis year). Although this is termed the baseline case, most current civil aircraft also conform to the Stage 2 noise regulations. Therefore, there is not much difference between Stages 1 and 2. Since only one aircraft type is used to model each category, a number of older, noiser aircraft in use are ignored, such as the "blow indoors" version of the Boeing 747.

The noise limits for Stages 2-5 are shown in Figures 3-1 (Takeoff), 3-2 (Sideline), and 3-3 (Approach) in terms of EPNL as a function of maximum aircraft weight.

Stage 2

The 69 FAR 36, or Stage 2 FAA noise regulations are met by all aircraft except the Boeing 707 and 727, and the McDonnell-Douglas DC-9. These three aircraft are altered to meet Stage 2 levels by assuming they are fitted with quiet nacelles.

Stage 3

For all aircraft used in Stage 2 which exceed the 75 FAR 36 or Stage 3 FAA noise rules, a noise reduction was applied as follows. First, the differences between the aircraft's takeoff, sideline, and approach noise levels and the corresponding Stage 3 limits at these points, were determined. The largest of these differences was then applied to the aircraft's noise versus distance curves. As a result, the modified aircraft meet the limits at two of the three points with some margin, and meet one of the limits with no margin. Although this method of deriving noise levels for aircraft under strict noise control involves simplifying assumptions, such as the assumption that no tradeoffs are

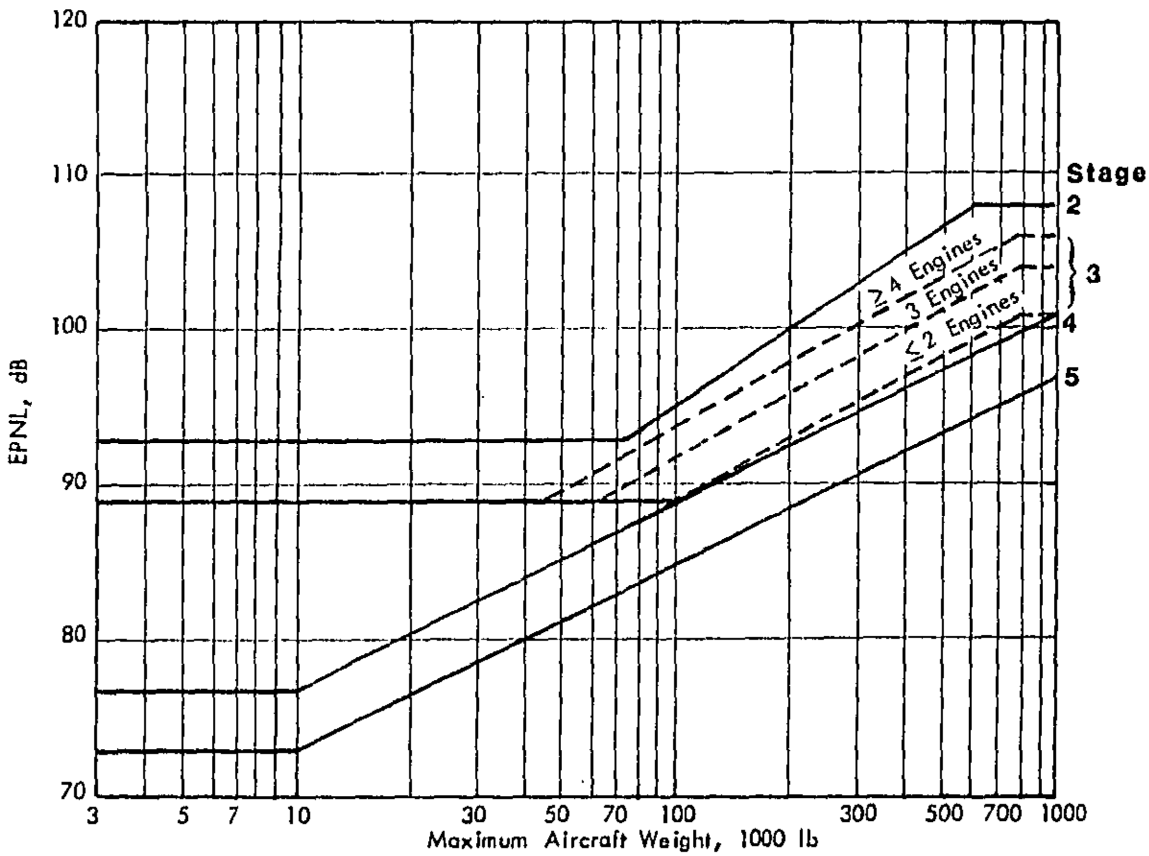

FIGURE 3-1. TAKEOFF NOISE LIMITS FOR STAGES 2-5

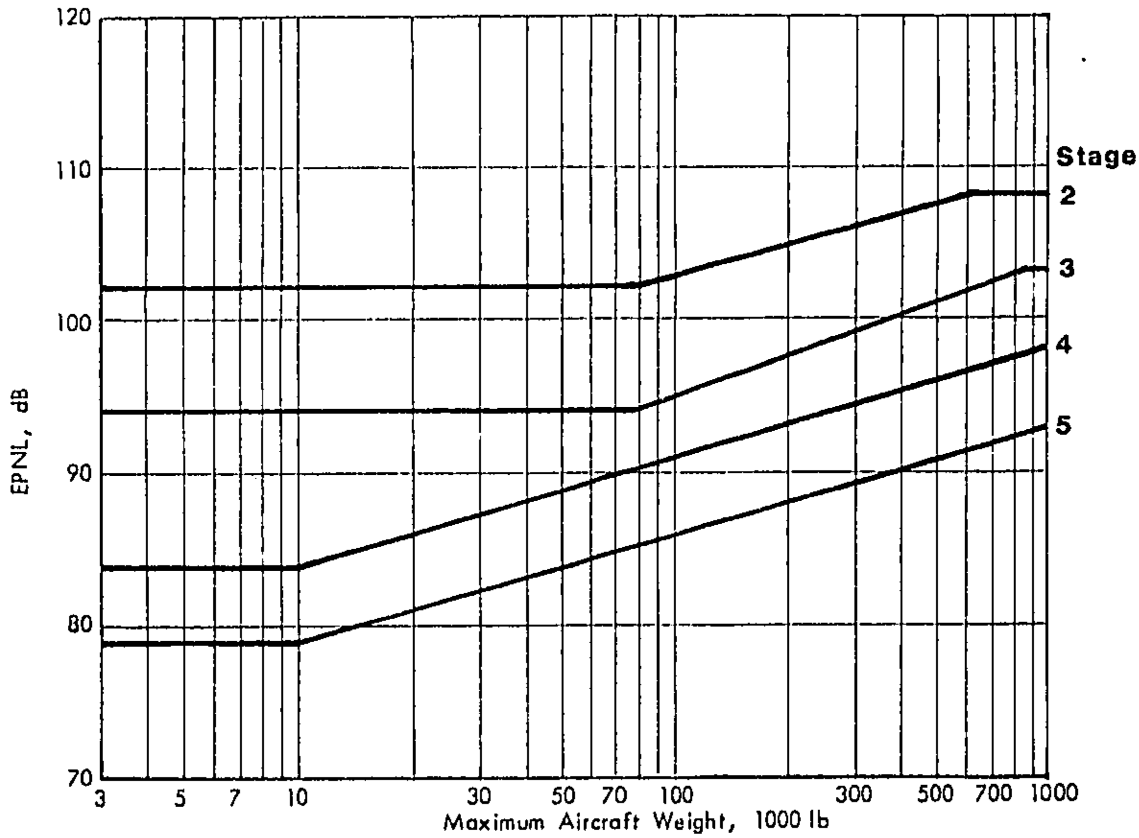

FIGURE 3-2. SIDELINE NOISE LIMITS FOR STAGES 2-5

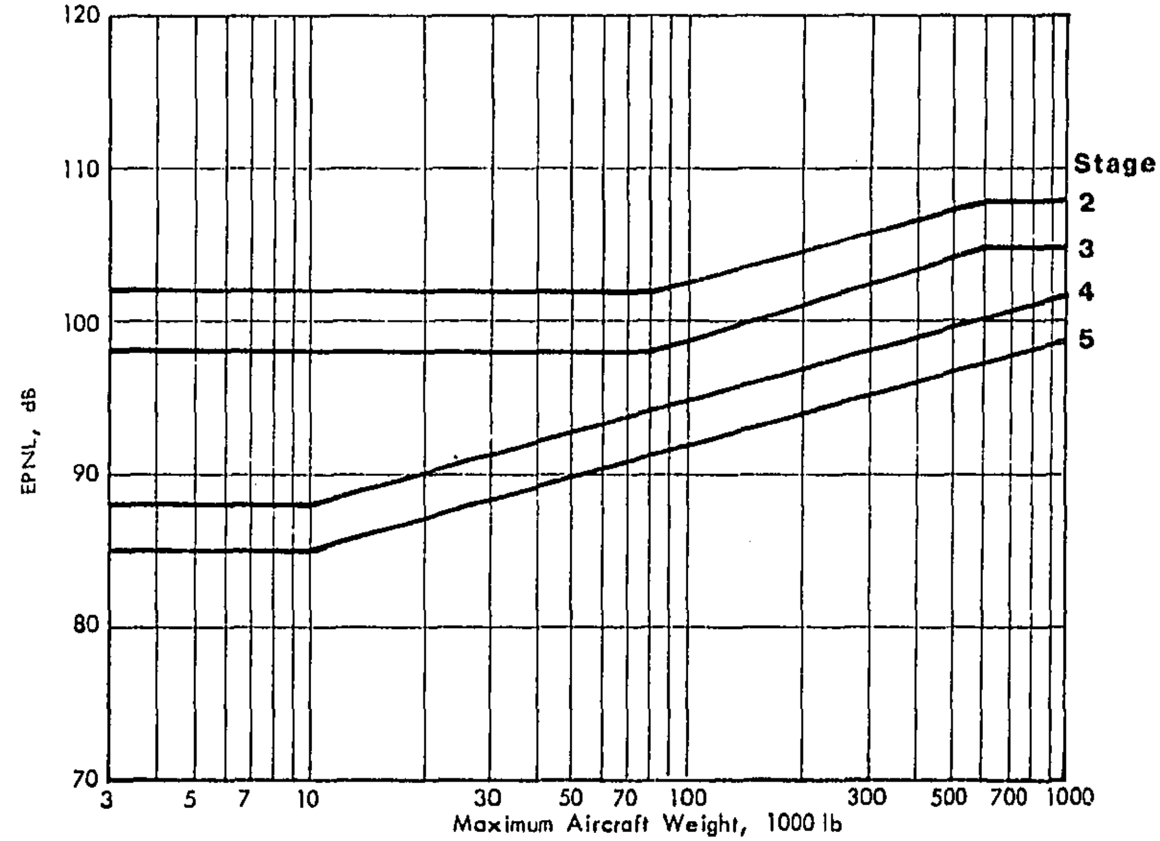

FIGURE 3-3. APPROACH NOISE LIMITS FOR STAGES 2-5

made among the three measurement points in order to reach compliance, it is straightforward, appears to give reasonable results, and is appropriate for the purposes of this study.

As Table 3-1 shows, noise reductions are applied to aircraft in categories 2, 4, 5, and 6 in order for them to meet Stage 3 regulations.

Stage 4

The 80 FAR 36 noise limits were proposed by the EPA to the Federal Aviation Administration (FAA) in 1976 and were published as an FAA Notice of Proposed Rulemaking 76-22. As Table 3-1 shows, a noise reduction is required of all aircraft categories except the light turboprops, twin props, and single props, in order to meet the Stage 4 regulatory limits. These limits refer to the quietest available technology.

Stage 5

The 85 FAR 36 limits were also proposed by the EPA to the FAA. Again, all categories except light props, twin props, and single props are affected. These limits refer to quiet future technology.

3.2 Computer Program (NOISEMAP)

The NOISEMAP computer program is a comprehensive set of computer routines for calculating noise exposure contours for airport operations developed by Bolt Beranek and Newman. The program permits calculation of the noise environment in terms of day-night level (DNL), noise exposure forecast (NEF) or community noise equivalent

TABLE 3-1

REDUCTION IN EPNL FROM PREPRESENTATIVE AIRCRAFT NOISE LEVELS TO MEET NOISE LIMITS OF SCENARIOS*

Civil Aircraft Category	Representative Aircraft	Scenarios Where Aircraft Are Used	Noise Reduction Applied To Representative Aircraft to To Meet Noise Limits, dB		
			Scenario 3	Scenario 4	Scenario 5
Air Carrier Aircraft					
1	747	1-5	0	-7.8	-11.8
2	707	1	---	---	---
	707QN	2-4	-9.5	-14.3	-19.3
3	DC-10	1-5	0	-5.3	- 8.3
4	727	1	---	---	---
	727QN	2-5	-5.2	-8.2	-12.5
5	AB300	1-2	---	---	---
	DC-10	3-5	-1.7	-4.6	- 7.6
6	DC-9	1	---	---	---
	DC-9QN	2-5	-6.0	-6.1	-11.1
7	MS748	1-2	---	---	---
	CV580	3-5	0	-3.9	- 7.9
8	CV580	1-5	0	-3.9	- 7.9
9	SD3-30	1-5	0	-7.0	-11.0
10	DHC-6	1-5	0	0	0
11	Twn Composite	1-5	0	0	0
12	Sgl Composite	1-5	0	0	0
13	Electra	1-5	0	-3.6	- 7.0
General Aviation					
G1	Bus Jet Composite	1-2	---	---	---
	Lear 35/36	3-5	0	-2.6	- 6.1
G2	Twn Composite	1-5	0	0	0
G3	Sgl Composite	1-5	0	0	0

* Noise reduction values shown enable aircraft to meet all three limits in given scenario (takeoff, sideline, and approach). No noise reduction is needed to meet Scenario 2 limits. Symbols are defined as follows:

- --- Aircraft not used in this scenario.
- 0 No noise reduction required to meet limits.
- QN Quiet nacelle engine noise treatment.

levels (CNEL). With simple modification of input data, NOISEMAP also can develop noise level contours, typically in terms of effective perceived noise level (EPNL) or sound exposure level (SEL), for individual aircraft operations.

The program and underlying technical concepts are very well documented in technical reports.[10,11] A thorough revision of the program operator's manual reflecting the latest program changes and extensions is provided in Reference 12.

Basic noise information for military aircraft modeled in the program are documented in reports prepared for the U. S. Air Force Aerospace Medical Research Laboratory.[13] Basic noise and performance characteristics for major civil aircraft modeled in NOISEMAP were collected and described in several reports prepared for the EPA.[14,15] The civil aircraft noise and performance data used in this report includes the latest reviewed and updated information.

3.3 Method of Scaling Results

Day-night level contours were computed for each AVport for the following groupings of aircraft:

(a) Military operations, separately for the KC-135, F-4, and C-130 aircraft.
(b) Civil operations, separately for civil jets, large props and small props, and totals.
(c) All operations, separately for the KC-135, F-4, and C-130 aircraft.

For each AVport, groupings (b) and (c) were analyzed for each of the five stages. Grouping (a) contours do not change with regulatory stage and therefore were only analyzed once.

Once contours were obtained for the average airport (AVport) in each class, the next step was to find the total contour area for all the individual airports within each class. Since each airport has its own unique mix of civil jets and props, general aviation and military aircraft, a simplifying analytical technique was used to estimate airport contours. This technique is based on the premise that the primary contributors to joint use airport noise contours are the dominant military aircraft and civil jets. In the analysis discussed below it has been assumed that the military aircraft is the dominant contributor and the civil jets are secondary. The analysis can be performed for the reverse situation, yielding similar results. It can also be extended to include three varieties of aircraft if necessary. Although only contour area estimates are described in the equations below, the same analysis applies to our estimates of exposed population.

The basic assumption in the analysis is that the contour area for the operations of any major class of aircraft, and, indeed, for the airport as a whole, will follow the general expression

$$\log(\text{contour area}) = a + b \log(\text{number of operations}) \quad (3.1)$$

or

$$\text{contour area} = 10^{a} \cdot (\text{number of operations})^{b} \quad (3.2)$$

For a given airport, one can compute the contour areas for different aircraft types and in general one will find that the values of

$\underline{b}$ will not differ markedly between the aircraft classes except for very small contour areas. If one plots the contour areas for different day-night level values for a given aircraft type, the plot can be interpreted in terms of showing the variation in day-night level as the number of operations are varied.

Now consider the case where the total airport contour is largely, but not completely, dominated by the operations of two classes of aircraft, civil jets and a particular military aircraft. Let A(M), A(J), and A(T) represent the area within a given DNL contour for a specified AVport for operations of M, J, and T types of aircraft, where (M) denotes military operations, either KC-135, F-4, or C-130 aircraft, (J) denotes civil jet operations only, and (T) denotes all operations at the airport (civil jet, civil propeller and military). Then let N(M), N(J), and N(T) represent the average daily number of operations of the M, J, and T types of aircraft.

Let subscript $\underline{i}$ denote the ith airport within a given class of airports, and subscript $\underline{o}$ denote the AVport within that class of airports for which contour areas were calculated.

From the contour area calculations, $A(T)_o$, $A(J)_o$ and $A(M)_o$ are known for DNL values of 55, 60, 65, 70 and 75 dB. From plots of $A(J)_o$ and $A(M)_o$ versus DNL, best fit regression lines can be calculated to determine:

$$\log(A(M)_o) = a_M + b_M \cdot \log(N(M)_o) \qquad (3.3)$$

and

$$\log(A(J)_o) = a_J + b_J \cdot \log(N(J)_o) \qquad (3.4)$$

Because of the relatively small areas calculated for the 75 dB contours, these values were usually not used in determining regression line fits. The regression lines determined from the other four points were used to derive areas and populations for all contour values from 55 to 75 dB.

Assuming that $A(M)_o$ is greater than $A(J)_o$, one can determine the trading relationship between numbers of civil and military aircraft operations for contour area. The number of civil jet operations $x(J)_o$ needed to generate a given military contour area is given by:

$$\log(A(M)_o) = a_J + b_J \log(x(J)_o) \qquad (3.5)$$

therefore,

$$\log(x(J)_o) = \frac{\log(A(M)_o) - a_J}{b_J} \qquad (3.6)$$

or,

$$x(J)_o = (A(M)_o \cdot 10^{a_J})^{1/b_J} \qquad (3.7)$$

Now form the ratio r_{CM} where

$$r_{CM} = \frac{N(M)_o}{x(J)_o} \qquad (3.8)$$

The ratio r_{CM} establishes the trading relationship between numbers of civil and military aircraft, and allows one to express the civil operations in terms of an equivalent number of military operations. For each airport in a given class, the civil contribution, in terms of military operations can then be added to the military contribution, also in terms of military operations, to obtain a total equivalent number of military operations. At this point, note that operations from air carrier and general aviation aircraft may contribute to the contour area. Assuming that these contributions are small and fixed, a final working expression can be developed allowing one to estimate contour areas as the number of civil and military operations are varied. Set

$$\log(A(T)_o) = a_o + b_M \log\,[N(M)_o + r_{CM}(N(J)_o)] \qquad (3.9)$$

and solve for a_o:

$$a_o = \log(A(T)_o) - b_M \log[N(M)_o + r_{CM}(N(J)_o)] \qquad (3.10)$$

Thus, for the ith airport in the oth AVport class, regardless of the number of civil jet or military operations, its total contour area is approximated by:

$$\log(A(T)_i) = a_o + b_M \log[N(M)_i + r_{CM}(N(J)_i)] \qquad (3.11)$$

or

$$A(T)_i = 10^{a_o}\,[N(M)_i + r_{CM}(N(J)_i)]^{b_M} \qquad (3.12)$$

The combined contour area of all k airports in a given class for combined military and civil operations, $\overline{A}$, is given by:

$$\overline{A} = \sum_i^k A(T)_i \qquad (3.13)$$

or

$$\overline{A} = 10^{a_o} \sum_i^k (N(M)_i) + r_{CM}(N(J)_i))^{b_M} \qquad (3.14)$$

Values of A were calculated and summed over the five airport classes, yielding total contour areas for the following aircraft groupings:

(a) Military operations alone (separately for the KC-135, F-4, and C-130 aircraft, and totals)
(b) Civil operations alone (totals only)
(c) All operations (separately for the KC-135, F-4, and C-130 aircraft, and totals).

Similar information was obtained for exposed population estimates. Item (a) was estimated for the Stage 1 65 dB contour only. The remaining items were estimated for the 55, 60, 65, 70 and 75 contours at all five regulatory stages.

4.0 RESULTS

In this section the results of the noise contour analysis are presented. The reduction in noise contour area resulting from various stages of civil noise regulation are presented in Section 4.1. The reduction in the number of people exposed to these noise levels are shown in Section 4.2. The classes of airports which benefit most -- and least -- from civil noise regulations are noted in Section 4.3. Overall conclusions which can be drawn from the study are presented in Section 4.4.

4.1 Reduction in Impacted Area

Table 4-1 lists the total national area estimated to be impacted by noise of various levels around joint use airports. The areas which would be impacted if only civil aircraft were operating at these airports are shown under the "Civil Alone" column heading. The areas which would be impacted if only military aircraft were operating are shown in a row at the bottom of the table for the DNL 65 dB contour for each of the three aircraft types - KC-135, F-4, and C-130 - and for the totals. The areas impacted by all civil and military aircraft are shown under the "Civil and Military" column headings. The total values are shown as well as the portions dominated by the three military aircraft types.

To illustrate the results, let us take an example from the table. The total amount of area exposed to a DNL of 65 dB or more from all aircraft operations at the 7 airports where the KC-135 is the dominant military aircraft is 188 square miles under Stage 1 regulations and 142 square miles under Stage 5 regulations. This is a reduction of 24 percent. The effect of Stage 5 regulations on the 35 airports dominated by F4-type aircraft is a reduction in the 65

TABLE 4-1

NATIONAL AREA WITHIN DNL CONTOURS

AT JOINT USE AIRPORTS BY

REGULATORY STAGE AND AIRCRAFT GROUP

DNL of Contour (dB)	Regulatory Stage	Area Within Contour (Sq. Mi.)				
			Civil and Military			
		Civil Alone	Total*	KC135	F4	C130
55	1	1674	3087	740	1906	441
	2	1672	3066	740	1896	430
	3	815	2441	614	1637	189
	4	514	2301	569	1564	167
	5	301	2166	551	1531	85
60	1	851	1584	373	990	222
	2	848	1578	373	990	215
	3	417	1277	311	870	96
	4	257	1208	291	834	82
	5	137	1131	279	815	37
65	1	432	813	188	514	111
	2	419	807	187	513	107
	3	213	669	158	462	49
	4	129	634	149	445	40
	5	62	594	142	437	16
70	1	220	418	95	267	56
	2	206	413	94	265	54
	3	109	350	80	245	25
	4	65	333	76	237	20
	5	28	311	72	233	6
75	1	122	215	48	139	28
	2	101	211	47	137	27
	3	56	183	41	129	13
	4	33	174	39	126	10
	5	13	163	37	124	3
			Military Alone			
65	1-5	-	580	140	430	10

*Subtotals may not add to totals due to rounding.

dB contour area of 15 percent. The effect at the 19 C-130-dominated airports is a reduction of 36 percent. The total average reduction is 27 percent. Thus, the dominant type of military aircraft at an airport has a clear influence on the effectiveness of civil aircraft noise regulations in reducing the area within noise contours when both civil and military operations are considered.

The reduction in area exposed to 65 dB DNL from civil aircraft operations is illustrated in Figure 4-1 for each of the five regulatory stages. From a baseline (Stage 1) area of 432 square miles, the reduction is 3 percent for Stage 2, 51 percent for Stage 3, 70 percent for Stage 4, and 86 percent for Stage 5. A similar chart in Figure 4-2 shows the area exposed to 65 dB DNL from all aircraft operations. The areas contributed by airports in each of the three military aircraft classes are also illustrated in the figure.

The relationship between noise exposure area and noise exposure level is illustrated in Figure 4-3 for civilian operations and in Figure 4-4 for military and civilian operations. The relationship between the noise level L and area A for both figures is seen to be roughly

$$L = a + b \log A, \text{ dB} \qquad (4.1)$$

as assumed in Section 3.3, where a is a constant and b is the slope of the line ranging from about -17 to -18.

4.2 Reduction in Exposed Population

The number of people estimated to be exposed to various levels of noise from joint use airport operations are shown in Table 4-2. The population which would be exposed if only civil aircraft were operating are shown under the "Civil Alone" column heading. The

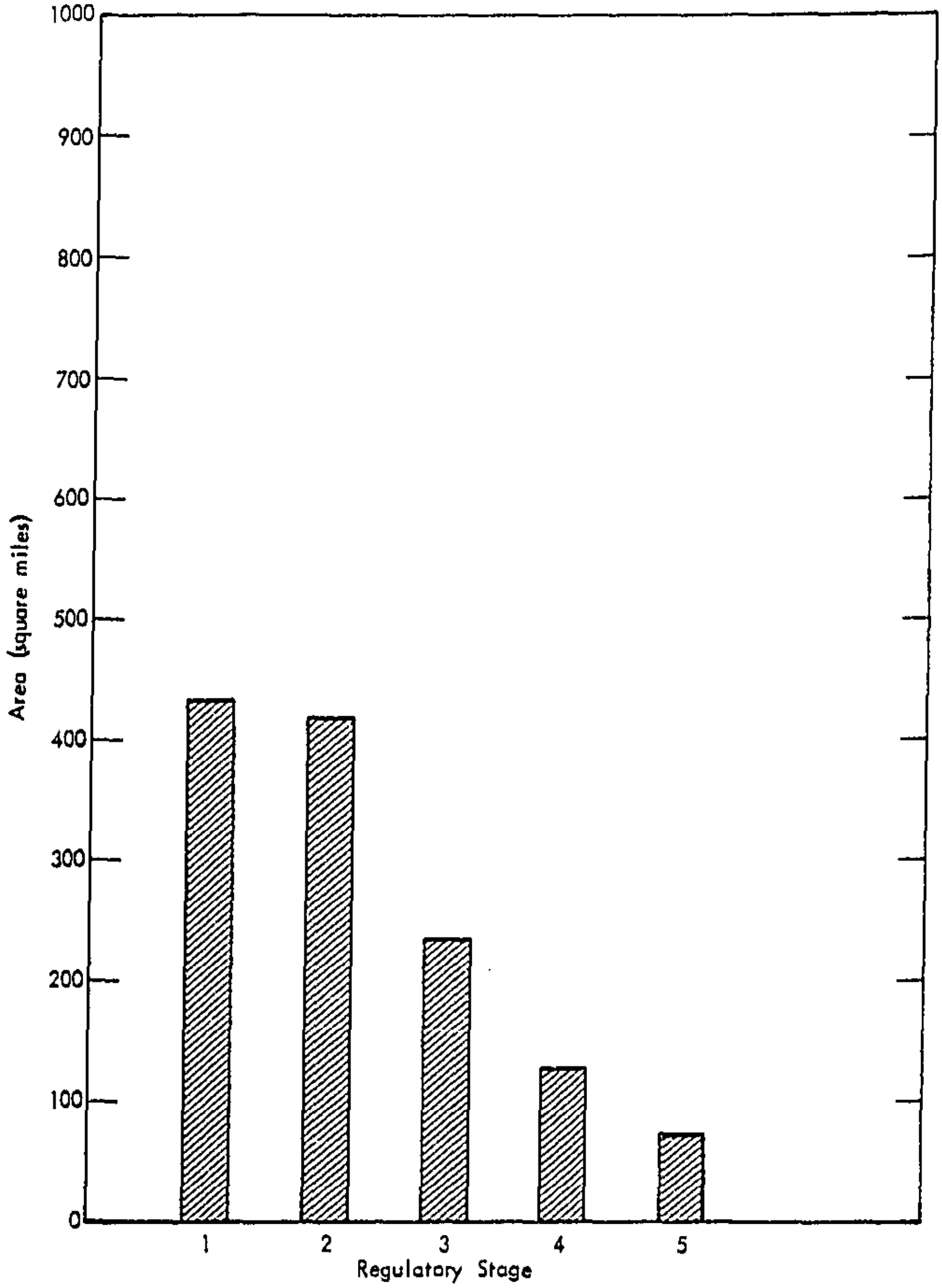

FIGURE 4-1. NATIONAL AREA WITHIN 65 dB DNL CONTOUR FROM CIVIL OPERATIONS AT JOINT USE AIRPORTS

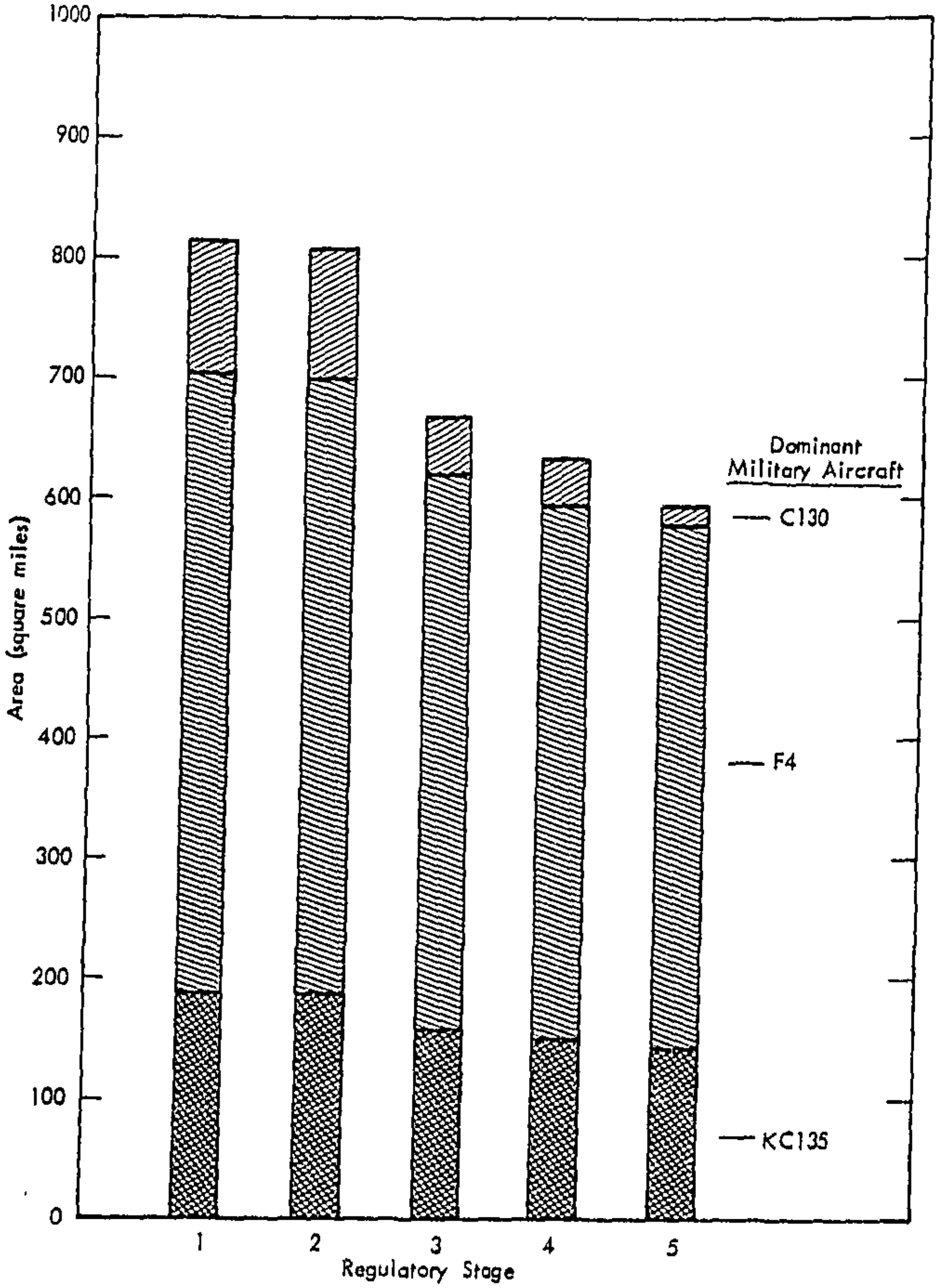

FIGURE 4-2. NATIONAL AREA WITHIN 65 dB DNL CONTOUR FOR CIVIL AND MILITARY OPERATIONS AT JOINT USE AIRPORTS

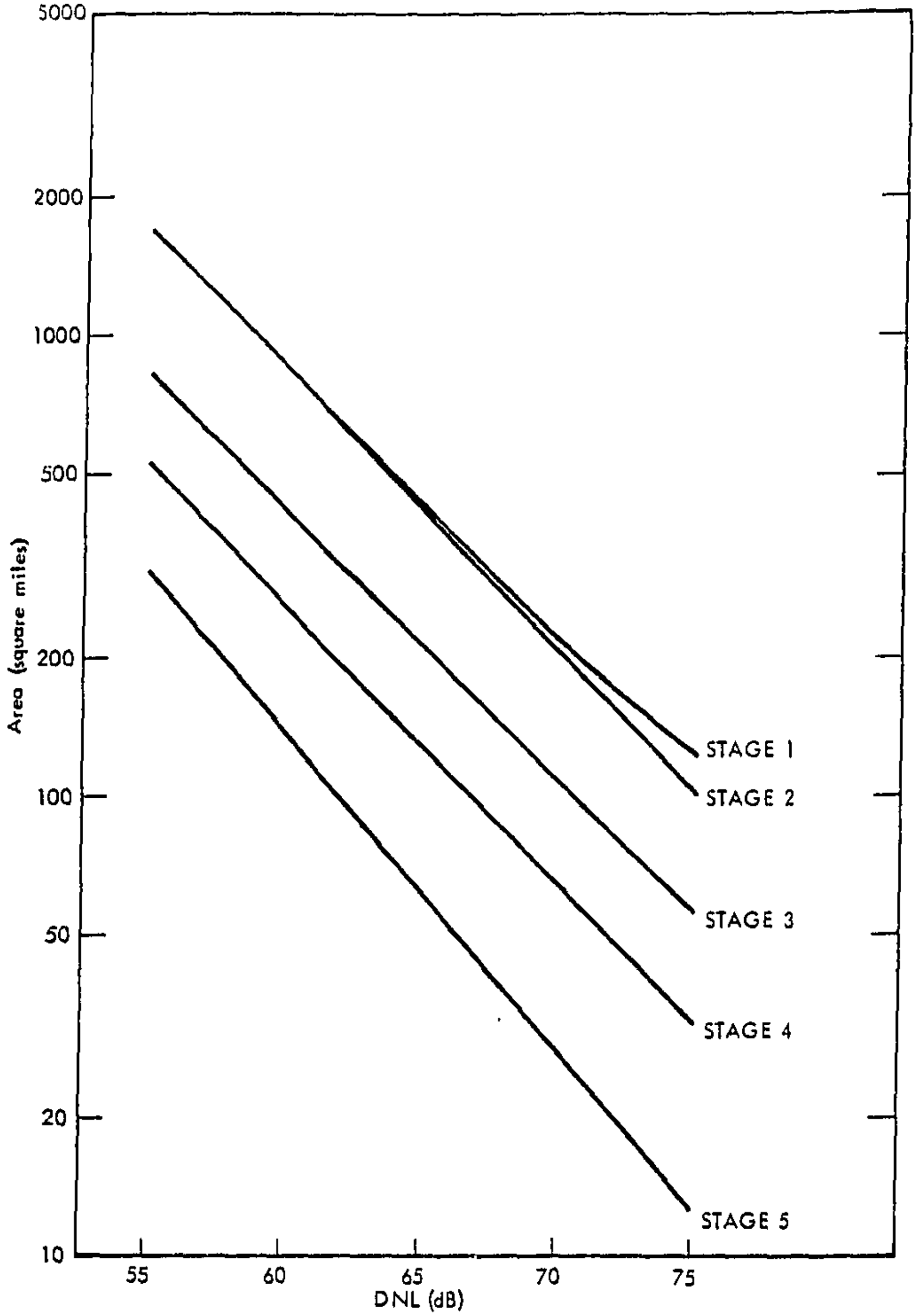

FIGURE 4-3. IMPACTED AREA AS A FUNCTION OF DNL AND REGULATORY STAGE FOR CIVIL OPERATIONS AT JOINT USE AIRPORTS

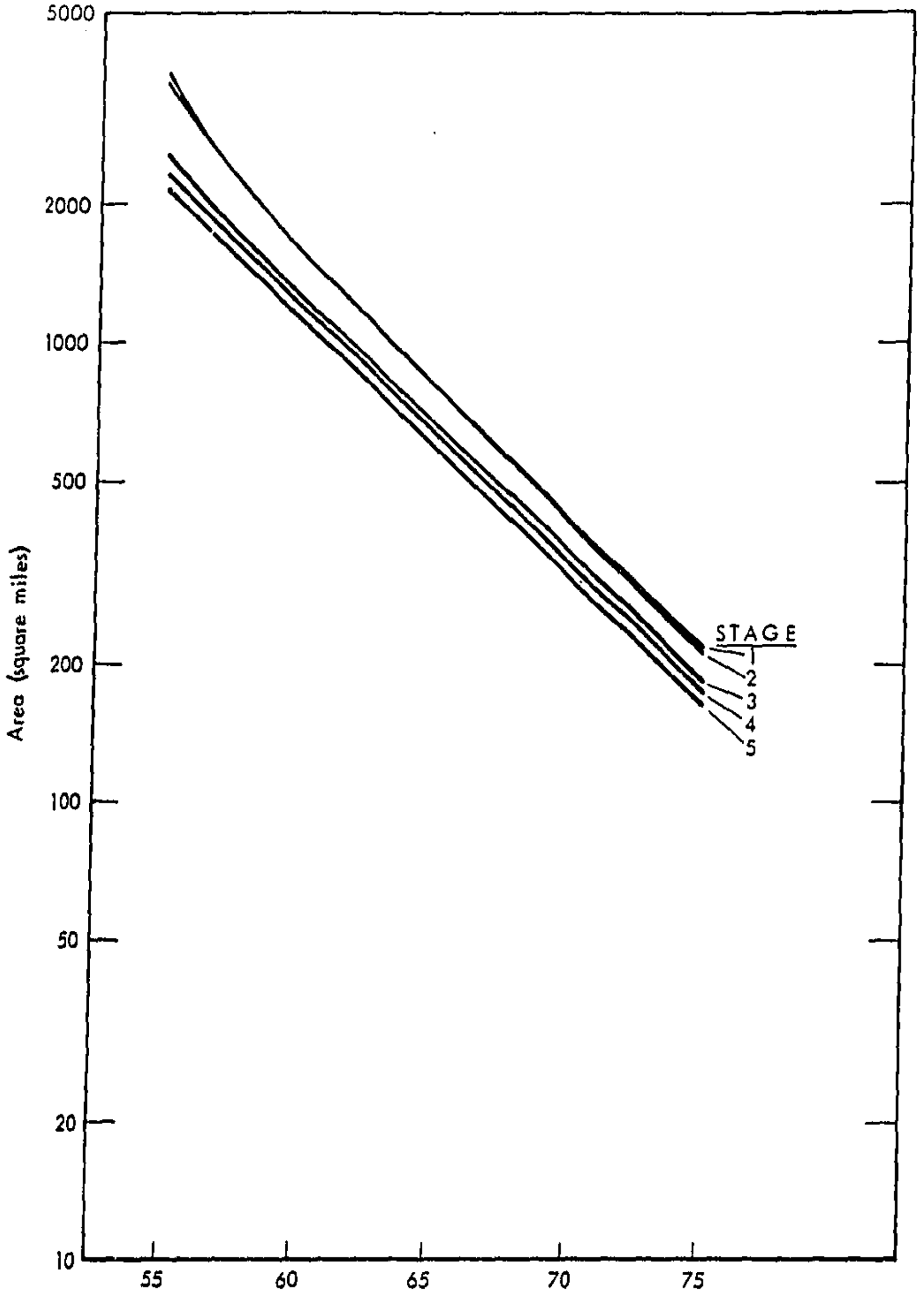

FIGURE 4-4. IMPACTED AREA AS A FUNCTION OF DNL AND REGULATORY STAGE FOR CIVIL AND MILITARY OPERATIONS AT JOINT USE AIRPORTS

TABLE 4-2

NATIONAL POPULATION WITHIN DNL CONTOURS

AT JOINT USE AIRPORTS BY

REGULATORY STAGE AND AIRCRAFT GROUP

DNL of Contour (dB)	Regulatory Stage	Population Within Contour (1000)				
			Civil and Military			
		Civil Alone	Total*	KC135	F4	C130
55	1	1983	3286	979	1798	509
	2	1976	3284	979	1798	507
	3	1152	2614	808	1517	289
	4	723	2383	753	1446	185
	5	407	2219	709	1400	110
60	1	1008	1672	496	920	256
	2	1001	1669	496	919	254
	3	595	1348	412	787	148
	4	352	1219	379	751	89
	5	188	1134	357	727	50
65	1	512	943	251	562	129
	2	502	939	251	562	126
	3	309	696	210	410	77
	4	173	625	191	391	43
	5	87	581	180	378	23
70	1	261	435	127	242	65
	2	252	432	127	242	63
	3	161	361	107	214	40
	4	80	321	96	204	21
	5	40	299	91	197	10
75	1	133	222	65	125	33
	2	126	220	64	124	31
	3	84	187	55	111	21
	4	42	166	48	107	10
	5	19	154	46	103	5
			Military Alone			
65	1-5	-	540	165	370	1

*Subtotals may not add to totals due to rounding.

population exposed to the 65 dB contour from military operations alone are shown in the bottom row of the table. The population exposed to all civil and military aircraft are shown under the "Civil and Military" column heading. The total values are broken down by dominating military aircraft -- KC-135, F-4, or C-130 -- in the last three columns.

The effect of regulations on population exposure for the three airport groups varies in a similar way as the area exposure estimates. The population exposed to 65 dB DNL or greater is reduced from Stage 1 to Stage 5 by 28 percent at KC-135-dominated airports, by 33 percent at F-4-dominated airports, and by 83 percent at C-130-dominated airports. The total average reduction is 38 percent.

Figure 4-5 illustrates the effects of the regulatory stages on the population exposed to 65 dB DNL or more from civil aircraft operations alone. From a baseline (Stage 1) population of 512,000, Stage 2 reduces the exposed population by 2 percent, Stage 3 by 40 percent, Stage 4 by 66 percent, and Stage 5 by 83 percent. Figure 4-6 illustrates the same effects for all operations. From a baseline population exposed to 65 dB DNL of 943,000, Stage 2 reduces the exposed population by 0.4 percent, Stage 3 by 26 percent, Stage 4 by 34 percent, and Stage 5 by 38 percent.

The relationship between noise exposed population and noise exposure level is illustrated in Figure 4-7 for civil operations and Figure 4-8 for all operations. The relationship between noise level L and population exposed P is seen to be approximately

$$L = a + b \log P, \text{ dB} \qquad (4.2)$$

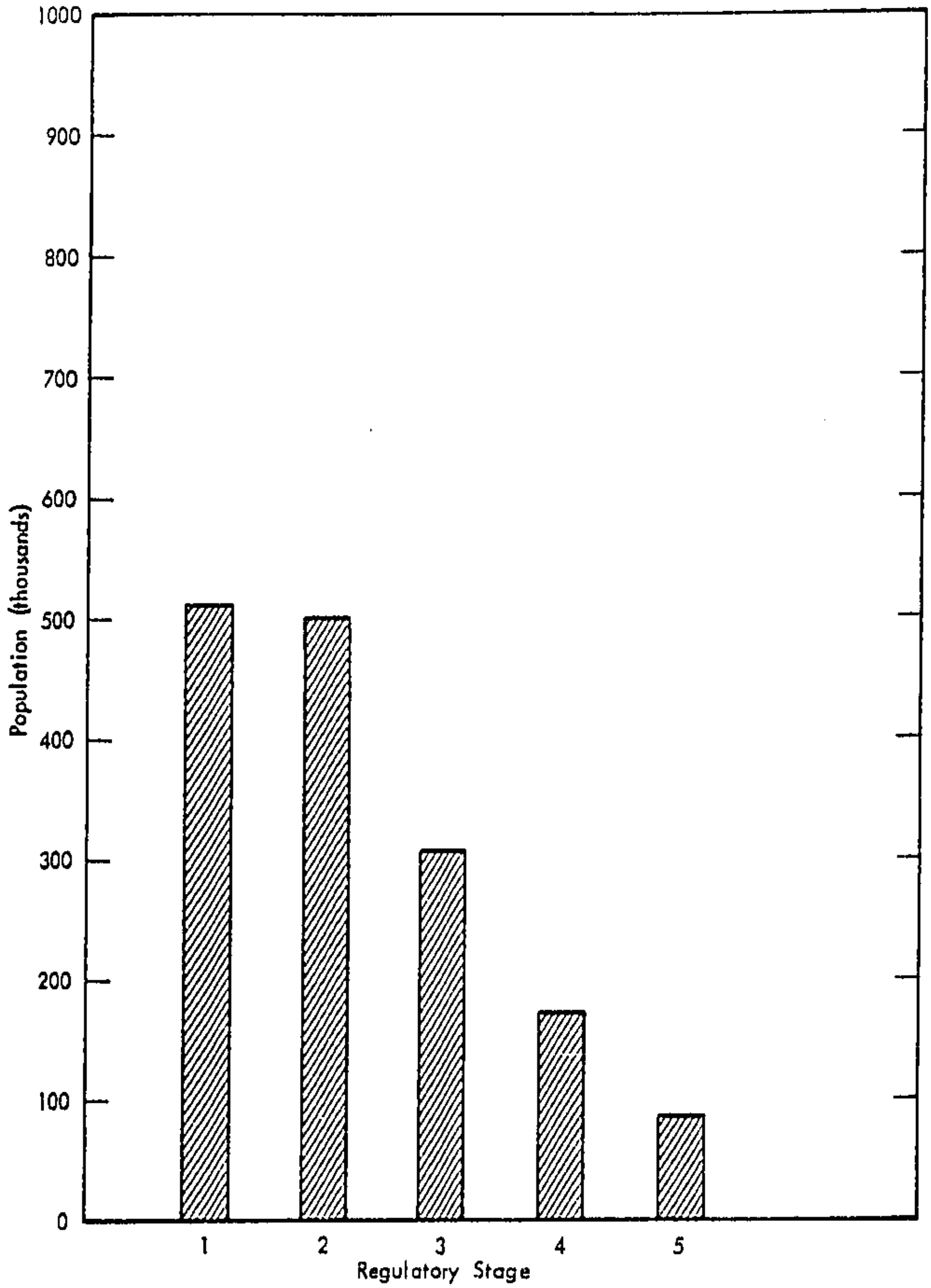

FIGURE 4-5. NATIONAL POPULATION EXPOSED TO 65 dB DNL OR GREATER FROM CIVIL OPERATIONS AT JOINT USE AIRPORTS

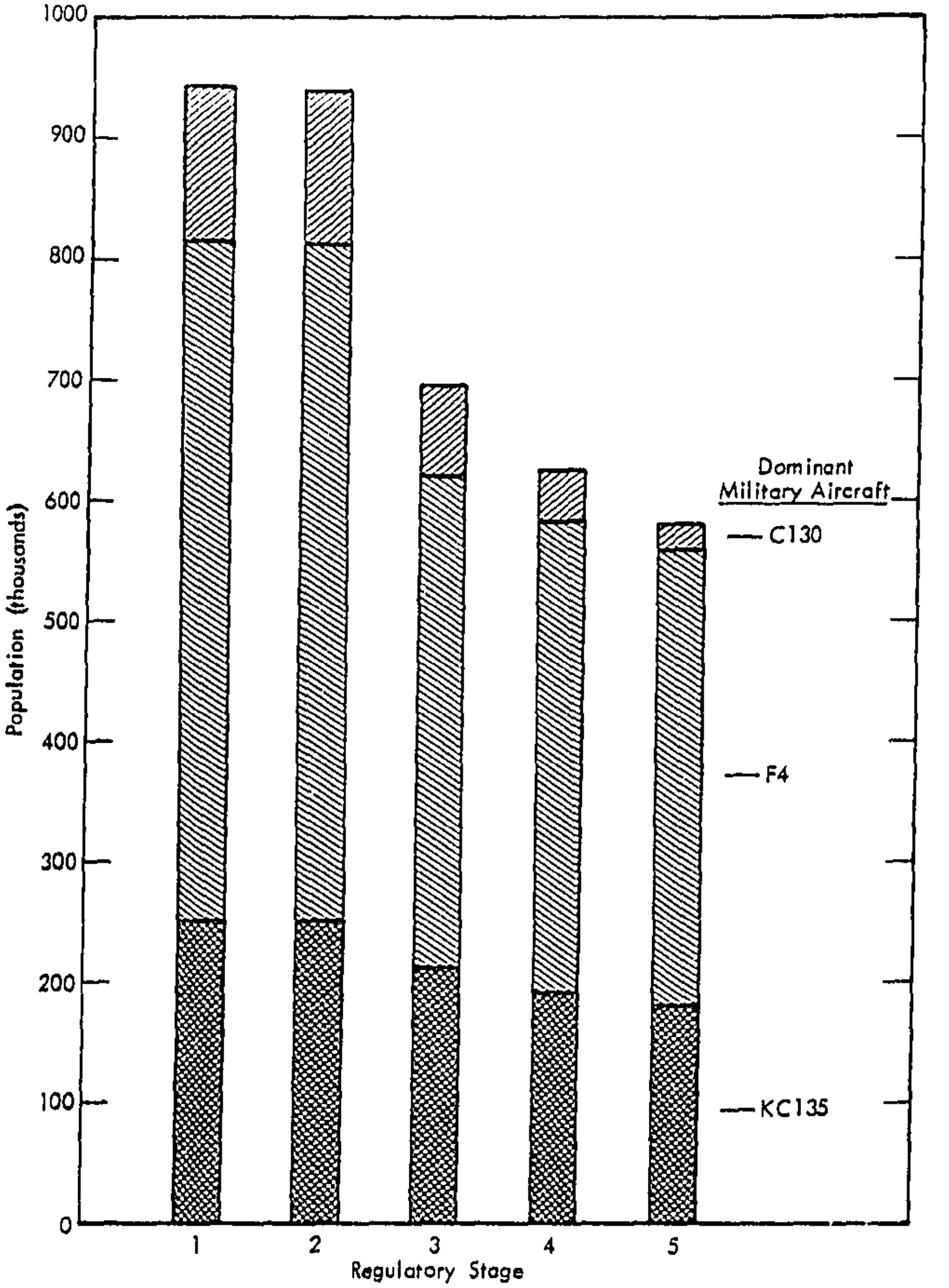

FIGURE 4-6. NATIONAL POPULATION EXPOSED TO 65 dB DNL OR GREATER FROM CIVIL AND MILITARY OPERATIONS AT JOINT USE AIRPORTS

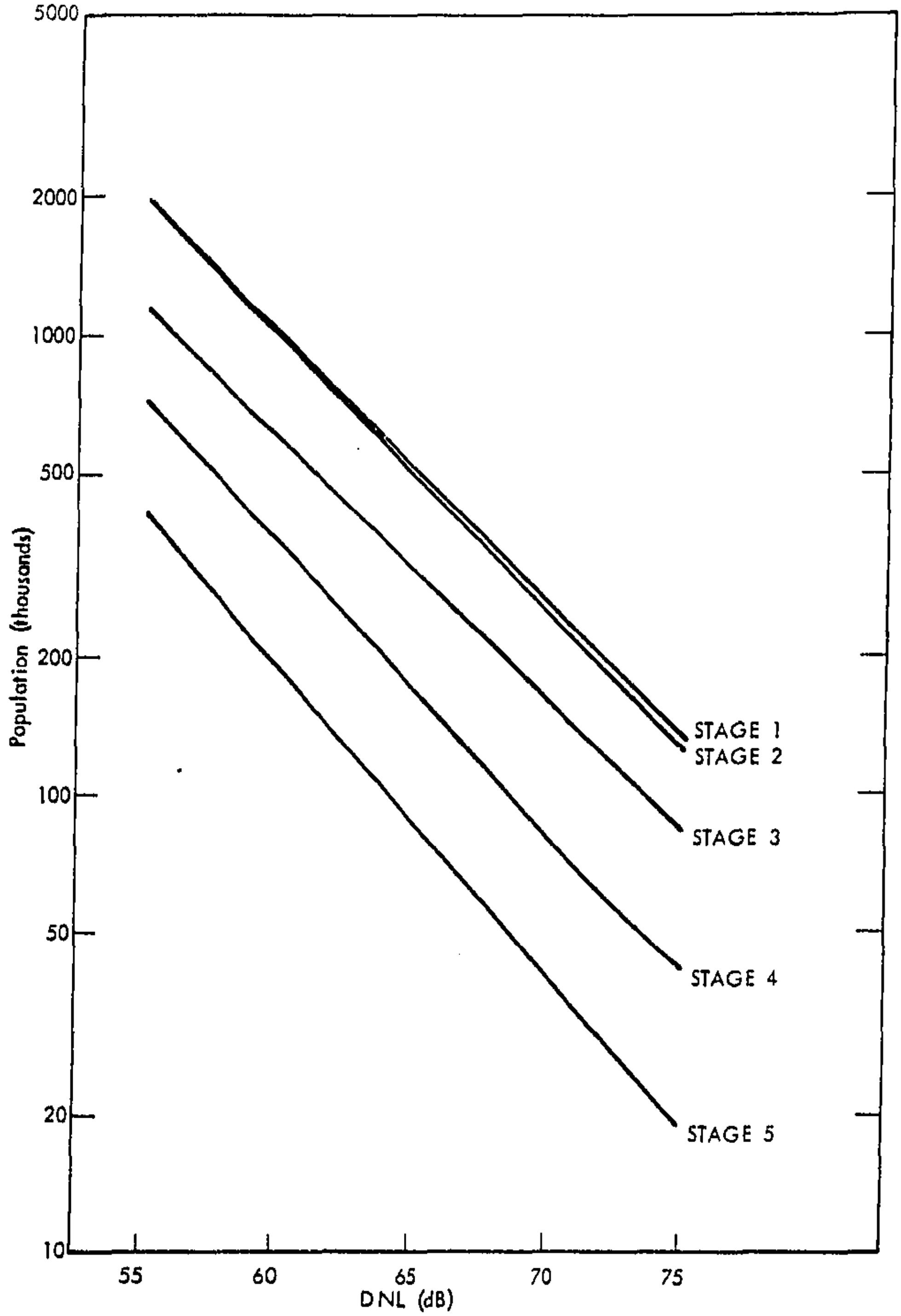

FIGURE 4-7. NATIONAL POPULATION EXPOSURE AS A FUNCTION OF DNL FOR CIVIL OPERATIONS AT JOINT USE AIRPORTS

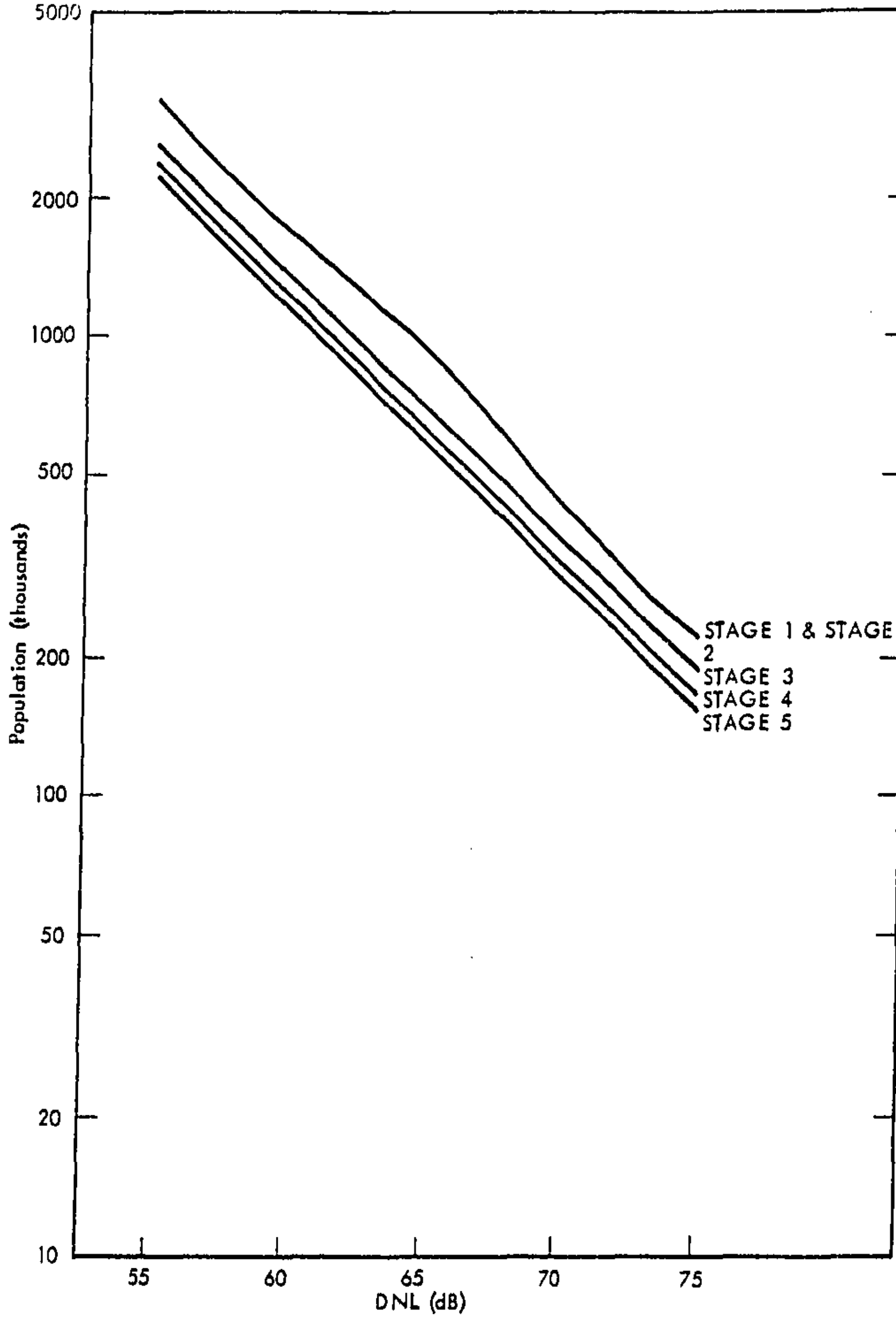

FIGURE 4-8. NATIONAL POPULATION EXPOSURE AS A FUNCTION OF DNL FOR CIVIL AND MILITARY OPERATIONS AT JOINT USE AIRPORTS

where a is a constant and b is approximately -17. This equation applies to both total operations and to civil operations alone.

It is interesting to note at this point that these estimates of the noise exposed population around joint use airports are an appreciable fraction of that estimated in other studies for strictly air carrier airports, as shown below.

	Number of People Exposed to DNL or Higher (millions)	
DNL (dB)	Joint Use Airports (Stage 1)	Air Carrier Airports (Ref. 10)
55	3.3	24.3
65	0.9	4.7
75	0.2	0.3

4.3 Effects on Different Airport Classes

Civil aircraft noise regulations affect different sized joint use airports in different ways. Table 4-3 shows the changes in 65 dB DNL contour areas which are estimated to occur between the baseline (Stage 1) and the most stringent (Stage 5) civil aircraft regulations presently contemplated. Similar results are observed for other DNL contour values and for population exposure estimates. The sample table shows the total area in square miles presently exposed to 65 dB or greater for airports in each of the five airport classes. Recall that the size of airports increases from A to D, with E being a special subset of class D airports. As expected, the exposure area increases somewhat proportionally to airport size.

TABLE 4-3

REDUCTION OF AREA WITHIN THE 65 dB DNL CONTOUR
BY AIRPORT CLASS AND DOMINANT MILITARY AIRCRAFT

Airport Class	No. of Airports	Total Area Within 65 dB DNL Contour Stage 1 (Sq.Mi.)	Percent Reduction from Stage 1 to Stage 5 (%)			
			Total*	KC-135	F-4	C-130
A	9	61	50	--	12	91
B	16	197	8	2	3	84
C	14	179	17	14	11	84
D	20	350	39	31	31	83
E	2	25	18	--	18	83
Total*	61	813	27	25	15	86

*Subtotals may not add to totals due to rounding. A dash(--) indicates these aircraft are not based at airports in the given class.

With one exception, the reduction in area which can be achieved with civil aircraft noise regulations also increases with airport size, whether the reduction is measured in terms of percent or absolute value. The exception is Airport Class A, where the C130 is the predominant military aircraft and there are no air carrier jet operations. For airports in this class the noise from business jets are greatly reduced between Stage 1 and Stage 5. In the absence of other noisy aircraft, this reduction has a great effect on the overall Class A airport contours.

As the table shows, effects on KC-135 and F-4 dominated airports are relatively similar in terms of percent reduction of contour area. The effects on C-130 dominated airports are much larger, irregardless of airport class.

The conclusions from this brief analysis are that civil aircraft noise regulations have their greatest effect on large size joint use airports, and that small airports without air carriers or military jets but with a significant number of business jets will also be benefited by very strict civil noise regulations.

4.4 Conclusions

Table 4-4 summarizes the some of the noise exposure results which are discussed in the previous sections. Noise exposure areas and population figures are shown for three DNL contour values -- 55, 65, and 75 dB -- and for three regulatory stages -- Stage 1, Stage 3, and Stage 5. From this table and from the results discussed above, the following conclusions may be drawn:

TABLE 4-4

SUMMARY OF JOINT USE AIRPORT
NOISE EXPOSURE ESTIMATE

DNL Contour (dB)	Civil Stage 1	Military Stage 1	Civil and Military Stage 1	Civil and Military Stage 3	Civil and Military Stage 5
	Area Within Contour (Sq.Mi.)				
55	1700	2000	3100	2400	2200
65	430	580	810	670	590
75	120	160	220	180	160
	Population Within Contour (Millions)				
55	2.0	2.0	3.3	2.6	2.2
65	0.5	0.5	0.9	0.7	0.6
75	0.1	0.1	0.2	0.2	0.2

1. The degree of noise exposure around joint-use airports is an appreciable fraction of the noise exposure found around strictly air carrier airports in the United States.

2. The relative contribution from military and civilian aircraft to the noise exposed areas and populations around joint-use airports is roughly equal in magnitude.

3. The benefits from civil aircraft noise regulations for joint-use airports, as measured, for example, by the successive reduction in area and population exposed to 65 dB DNL relative to the previous stage, are found to be as follows:

   a) a minor reduction between Stages 1 and 2 (0.8% in area, 0.4% in population)
   b) a major reduction between Stages 2 and 3 (17% in area, 26% in population)
   c) a moderate reduction between Stages 3 and 4 (5% in area, 10% in population)
   d) a moderate reduction between Stages 4 and 5 (6% in area, 7% in population)

4. The relationship between noise exposure level and both exposure area and exposed population is approximately given by

$$L = a - 17 \cdot \log x, \text{ dB} \qquad (4.3)$$

where L is the average day-night sound level
x is either the area or population exposed to L or higher
and a is an appropriate constant.

5. Civil aircraft noise regulations have their greatest benefit at the largest joint-use airports (100 or more daily operations--Class D). As these regulations become increasingly strict, major benefits are also observed at small airports with no air carriers (Class A) in cases where business jet operations are significant and the C-130 is the dominant military aircraft.

6. Since they represent 35 of the 61 airports under study, joint-use airports where fighters predominate (F-4 airports) contribute the greatest amount to the national area and population exposure figures (60 to 75 percent). Their contribution is highest at strict stages of civil noise regulation, therefore this military aircraft type deserves the greatest attention as civil aircraft become increasingly quieter. The seven airports where the KC-135 is the dominant military aircraft contribute a rather constant moderate amount to the total figures (25 to 30 percent). The 19 airports where the C-130 and C-7 dominate only contribute a small amount (2 to 15 percent) to the total exposure. This contribution tends to decrease at more strict stages of civil noise regulation.

REFERENCES

1. C. Bartel and L. C. Sutherland, "Noise Exposure of Civil Aircarrier Airplanes Through the Year 2000", Wyle Research Report WR 78-11 for the U.S. Environmental Protection Agency (EPA), February 1979.

2. "Air Force Reserve Flying Wings and Assigned Units", and "The Air National Guard by Major Command Assignment (as of April 1, 1979)", p. 109 and 113, <u>Air Force Magazine</u>, May 1979.

3. "Tower Airport Statistics Handbook, Calendar Year 1978", U.S. Departments of Transportation (DOT), Report No. FAA-AVP-79-2, April 1979.

4. "Population Near Airports - Study for Civil Aeronautics Boards", Federal Aviation Administration (FAA), March 21, 1979.

5. "Official Airline Guide, North American Edition", The Reuben H. Donnelley Corporation, Oak Brook, Illinois, Vol. 4, No. 19, July 1978.

6. "Official Airline Guide, Worldwide Edition", Official Airline Guides Inc., Oak Brook, Illinois, Vol.4, No. 10, December 1979.

7. D. E. Bishop, J. F. Mills, and J. M. Beckmann, "Sound Exposure Level Versus Distance Curves for Civil Aircraft", Bolt Beranek and Newman (BBN) Report 2759R, U.S. EPA, February 1976.

REFERENCES (CONTINUED)

8. D. E. Bishop and A. P. Hays, "Handbook for Developing Noise Exposure Contours for General Aviation Airports", U.S. DOT Report No. FAA-AS75-1, December 1975.

9. National Business Aircraft Association, "Survey of Business Aviation for the Calendar Year 1979", by Price Waterhouse and Co., July 16, 1975.

10. D. E. Bishop, "Community Noise Exposure Resulting from Aircraft Operations: Application Guide for Predictive Procedure", Air Force Report AMRL TR-73-105, Nov. 1974 [AD A004818].

11. R. D. Horonjeff, R. R. Kandukuri and N. H. Reddingius, "Community Noise Exposure Resulting from Aircraft Operations: Computer Program Description", Air Force Report AMRL-TR-73-109, Nov. 1974 [AD A004821].

12. J. M. Beckmann, H. Seidman, "Community Noise Exposure Resulting from Aircraft Operations: NOISEMAP 3.4 Computer Program Operator's Manual", Air Force Report AMRL-TR-78-109, December 1978.

13. "Community Noise Exposure Resulting From Aircraft Operations, Vol. 1-6," Aerospace Medical Research Laboratory Report AMRL-TR-73-110, February 1978.

14. W. J. Galloway, J. F. Mills, A. P. Hays, "Data Base for Predicting Noise from Civil Aircraft: Flight Profile Prediction", BBN Report 2746R, March 1976.

REFERENCES (CONTINUED)

15. D. E. Bishop, J. F. Mills, J. M. Beckmann, "Effective Perceived Noise Level Versus Distance Curves for Civil Aircraft", BBN Report 2747R, Feb. 1976.

APPENDIX A

APPENDIX A
FLIGHT PROCEDURES USED TO MODEL CIVIL AIRCRAFT AT JOINT-USE AIRPORTS

Air Carrier Aircraft Category	Representative Aircraft Type	Takeoff Flight Procedures Used (Figure No.)	Landing Flight Procedures Used (Glide Slope)(2)
1. 4 Eng. Wide	747	A-1,2(1)	3°
2. 4 Eng. Narrow	707	A-3,4(1)	3°
3. 3 Eng. Wide	DC-10	A-5,6(1)	3°
4. 3 Eng. Narrow	727	A-7,8	3°
5. 2 Eng. Wide	A300	A-9	3°
6. 2 Eng. Narrow	DC-9	A-10,11	3°
7. 2 Eng. TP-Dart	HS748	A-12	3°
8. 2 Eng. TP-Allison	CV580	A-12	3°
9. 2 Eng. Hvy. TO-PT6	SD3-30	A-13	3°
10. 2 Eng. Lt. TP-PT6	DHC-6	A-14	4.5°
11. 2 Eng. Piston	Composite	A-15	4.5°
12. 1 Eng. Piston	Composite	A-16	4.5°
13. Misc.	Electra	A-17	3°

General Aviation Aircraft Category			
1. Bus. Jet	Composite	A-18	3°
2. 2 Eng. Piston	Composite	A-15	4.5°
3. 1 Eng. Piston	Composite	A-16	4.5°

(1) Two profiles are defined for each of these aircraft: one representing short range operations and one representing long range operations. Average stage lengths were computed for all flights under four hours for shortrange trips, and over four hours for long range trips. The aircraft weights which corresponded to the computed stage lengths were then used to choose the appropriate takeoff profiles.

(2) Full flaps are assumed for all aircraft landings.

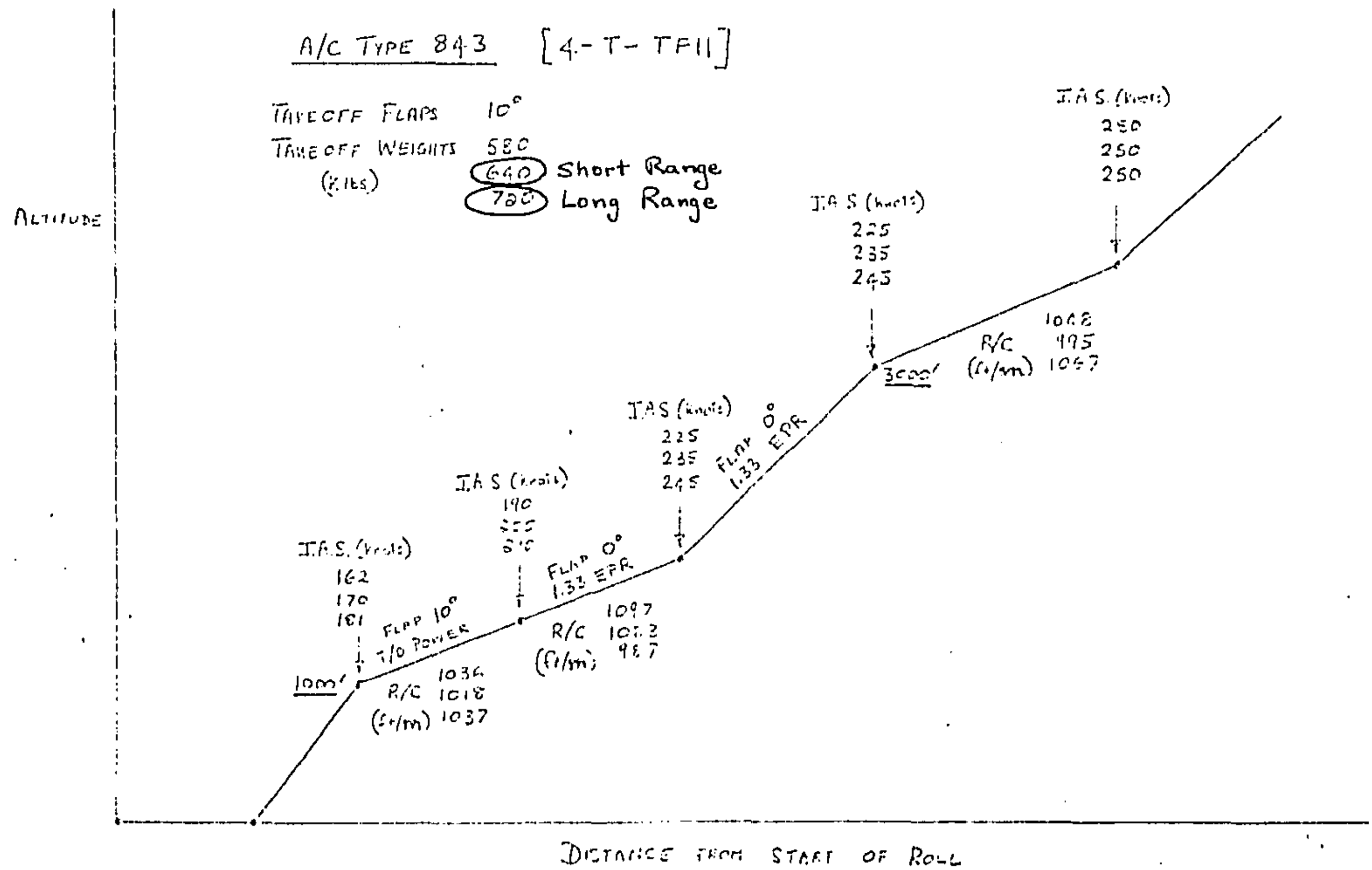

FIGURE A-1. TAKEOFF CHARACTERISTICS FOR 4-ENGINE HBPR TURBOFAN

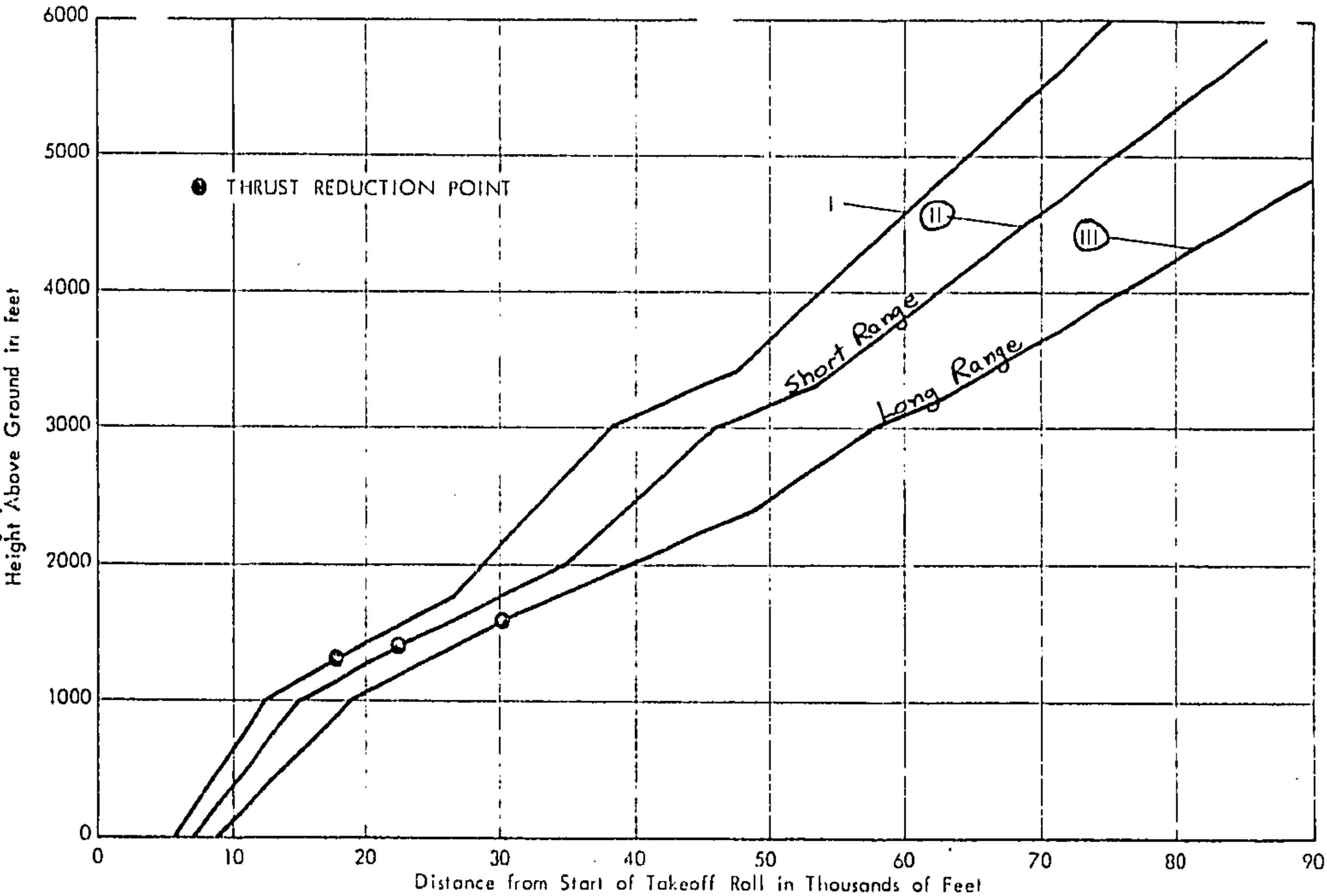

FIGURE A-2. ATA TAKEOFF PROFILES FOR 4-ENGINE HBPR TURBOFAN TRANSPORT AIRCRAFT - 747 SERIES (4-T-TFH) - REVISED PROCEDURES ADOPTED DECEMBER 1976

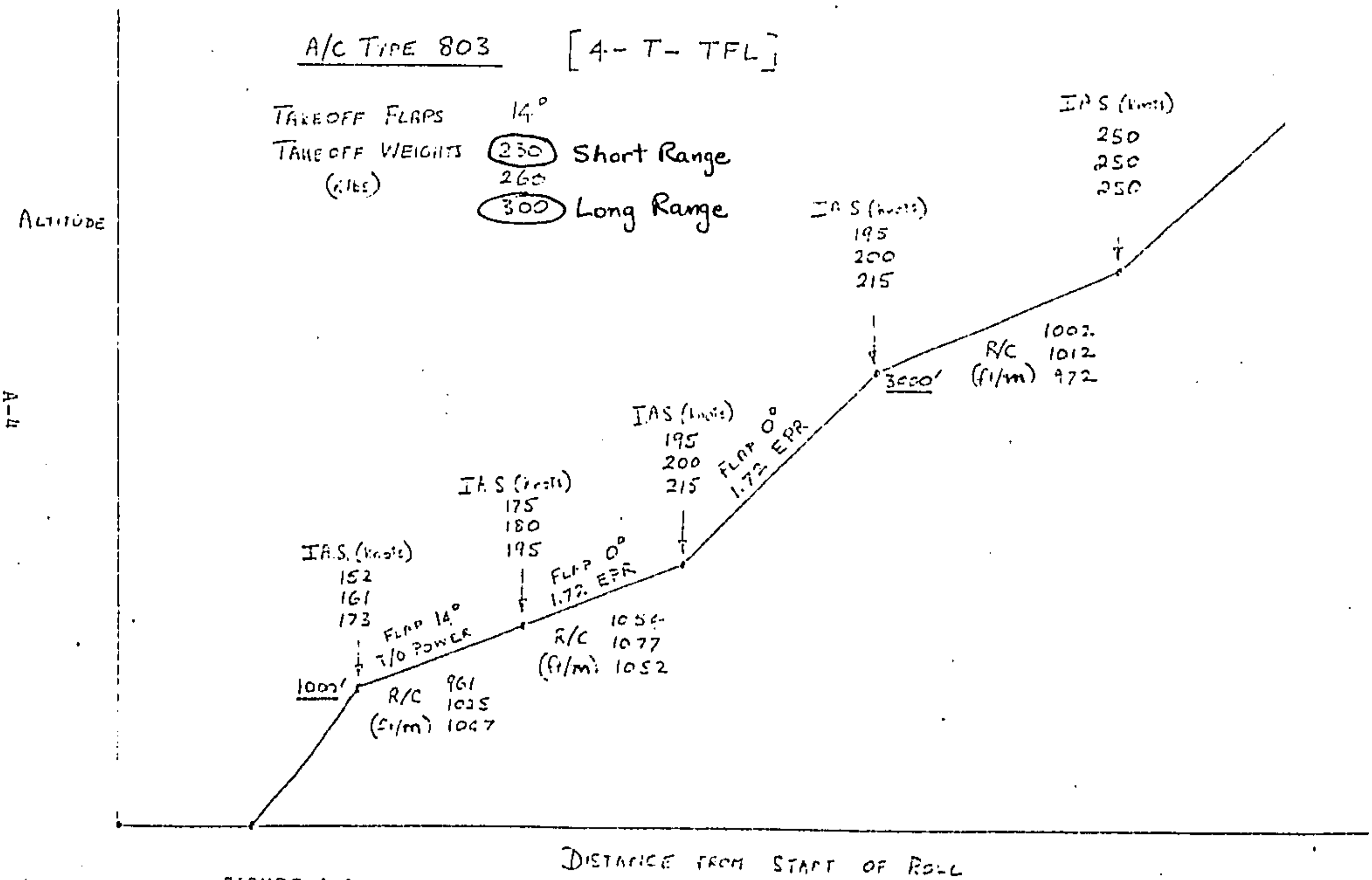

FIGURE A-3. TAKEOFF CHARACTERISTICS FOR 4-ENGINE LBPR TURNOFAN

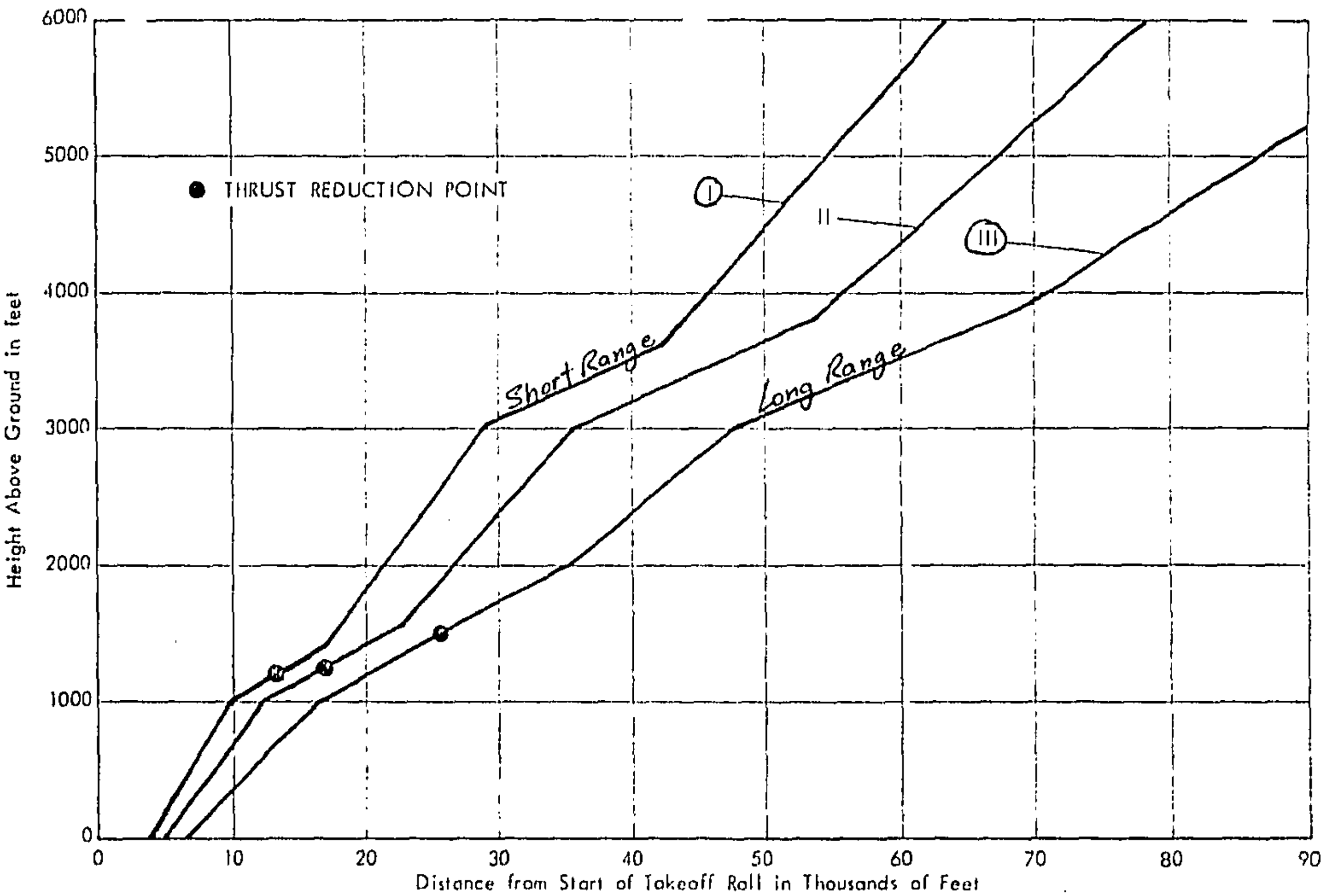

FIGURE A-4. ATA TAKEOFF PROFILES FOR 4-ENGINE LBPR TURBOFAN TRANSPORT AIRCRAFT - DC-8, 707 SERIES (4-T-TFL) - REVISED PROCEDURES ADOPTED DECEMBER 1976

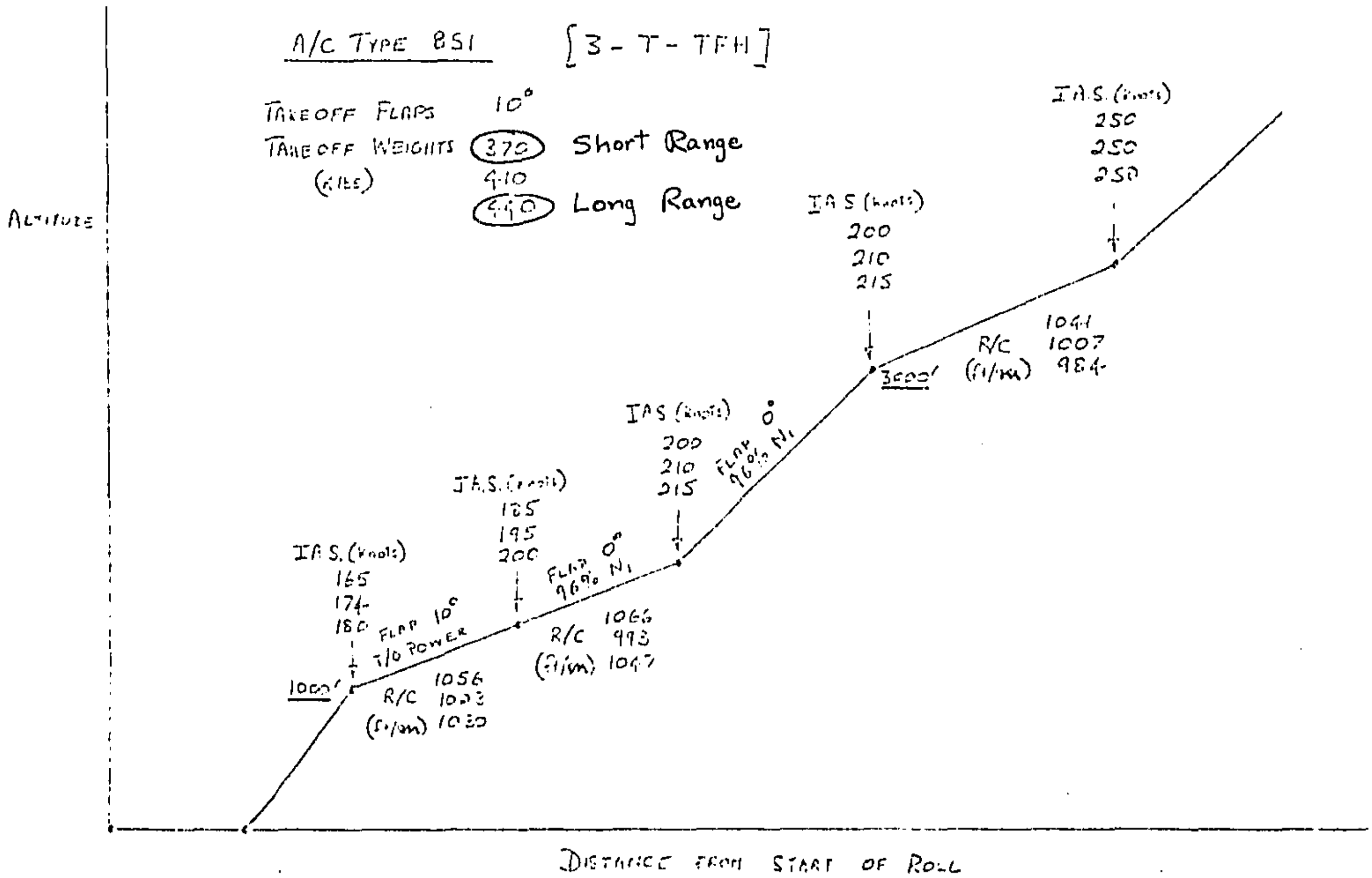

FIGURE A-5. TAKEOFF CHARACTERISTICS FOR 3-ENGINE HBPR TURBOFAN

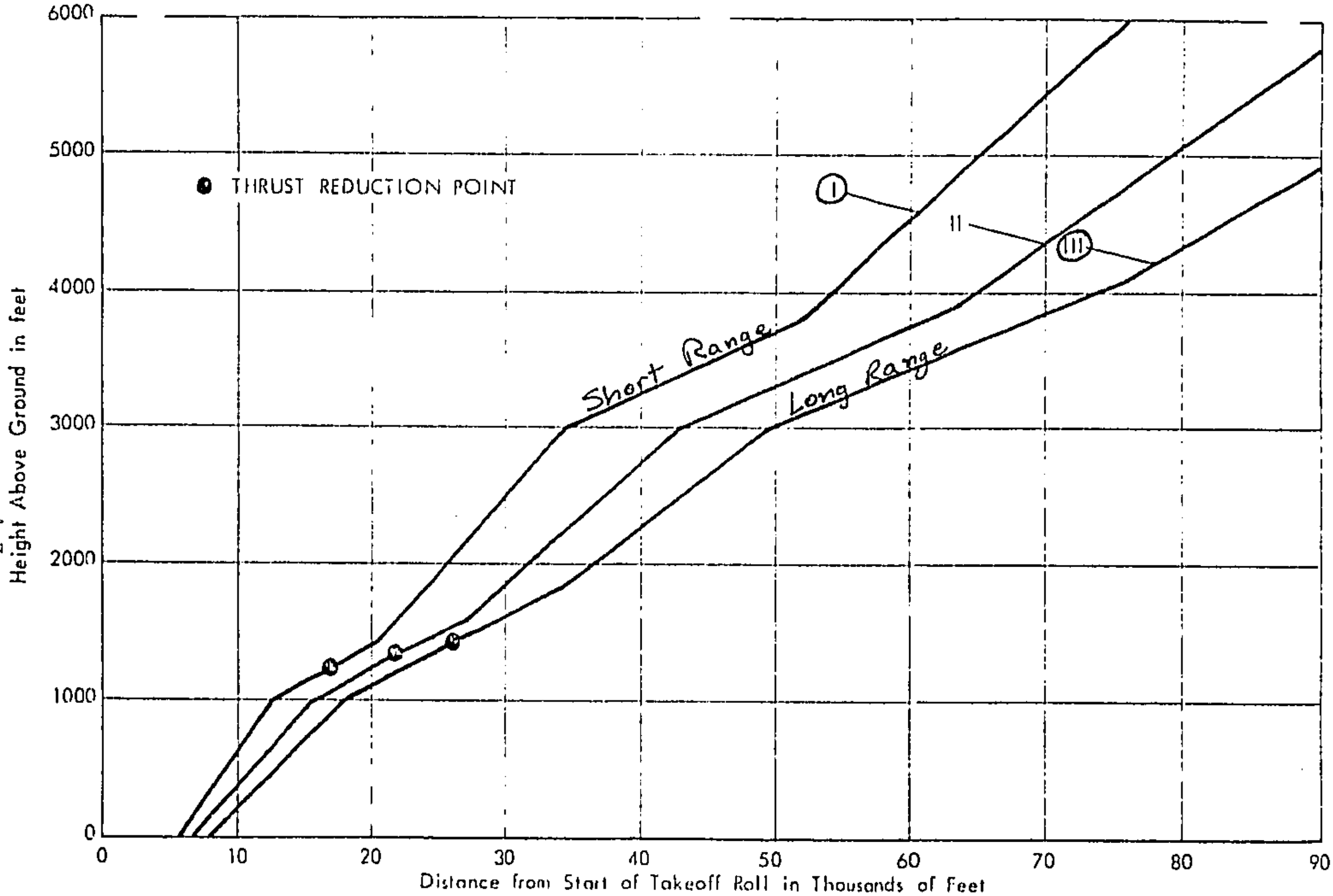

FIGURE A-6. ATA TAKEOFF PROFILES FOR 3-ENGINE HBPR TURBOFAN TRANSPORT - DC-10, L-1011 SERIES (3-T-TFH) - REVISED PROCEDURES ADOPTED DECEMBER 1976

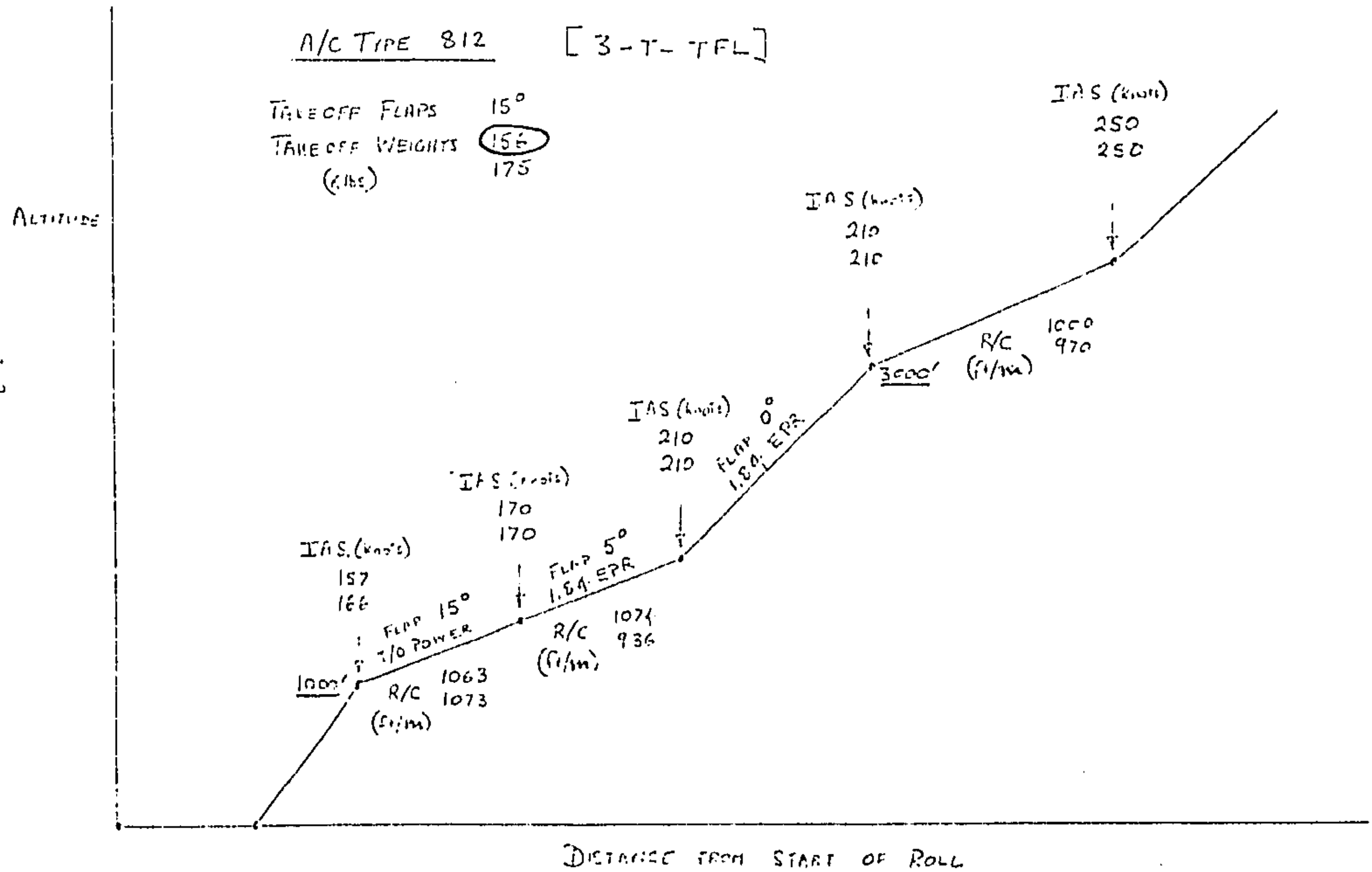

FIGURE A-7. TAKEOFF CHARACTERISTICS FOR 3-ENGING LBPR TURBOFAN

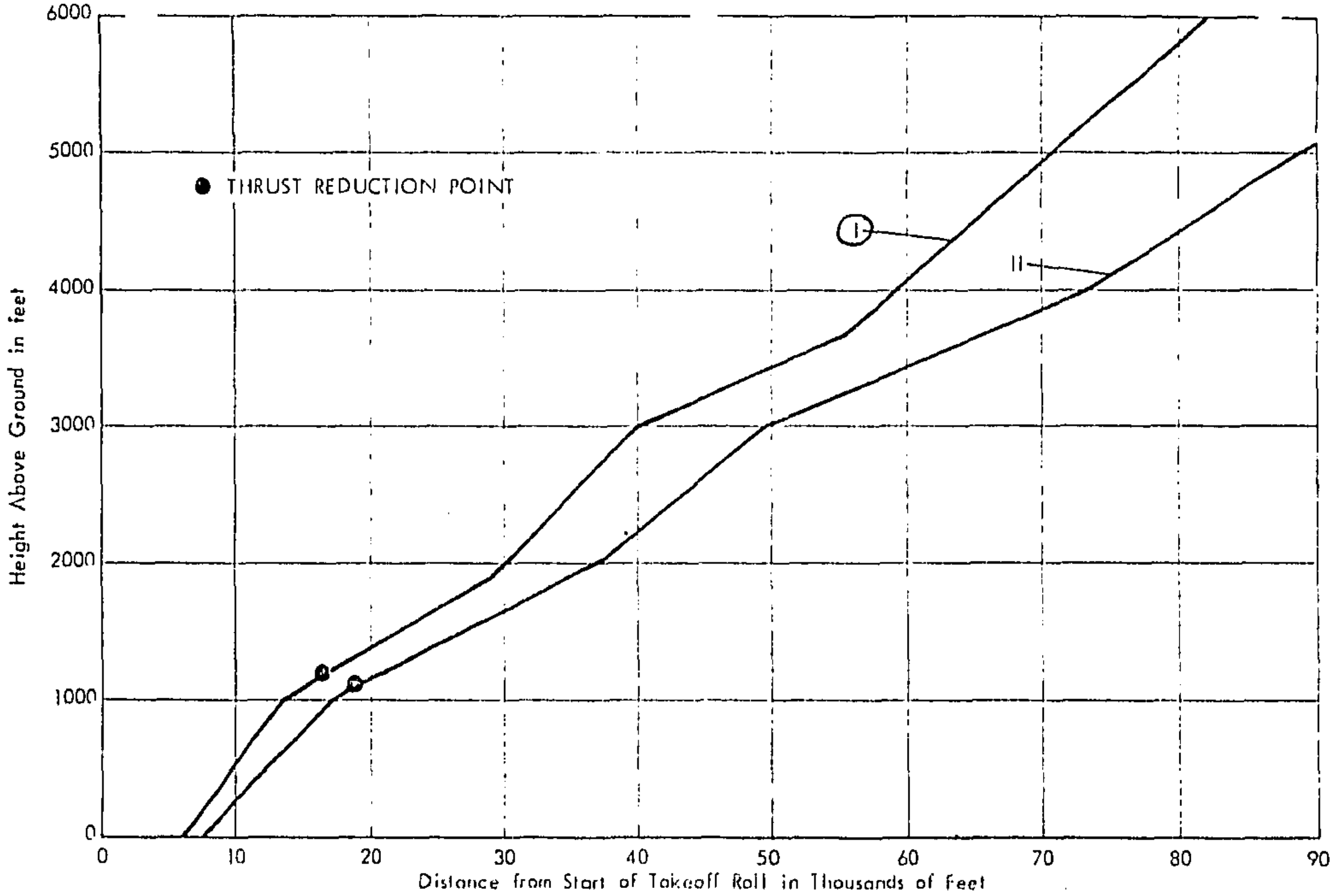

FIGURE A-8. ATA TAKEOFF PROFILES FOR 3-ENGINE LBPR TURBOFAN TRANSPORT AIRCRAFT - 727 SERIES (3-T-TFL) - REVISED PROCEDURES ADOPTED DECEMBER 1976

FIGURE A-9

TAKEOFF PROFILE FOR A300

Distance From Brake Release (feet)	Height (feet)	Speed (kt)	RPM
0	0	0	3360
5,500	0	164	3360
13,167	1,000	164	3360
18,377	1,300	190	3280
19,377	1,345	210	3280
23,217	1,520	210	3280
37,396	3,000	250	3280
54,572	3,850	250	3280
125,000	10,752	250	3280

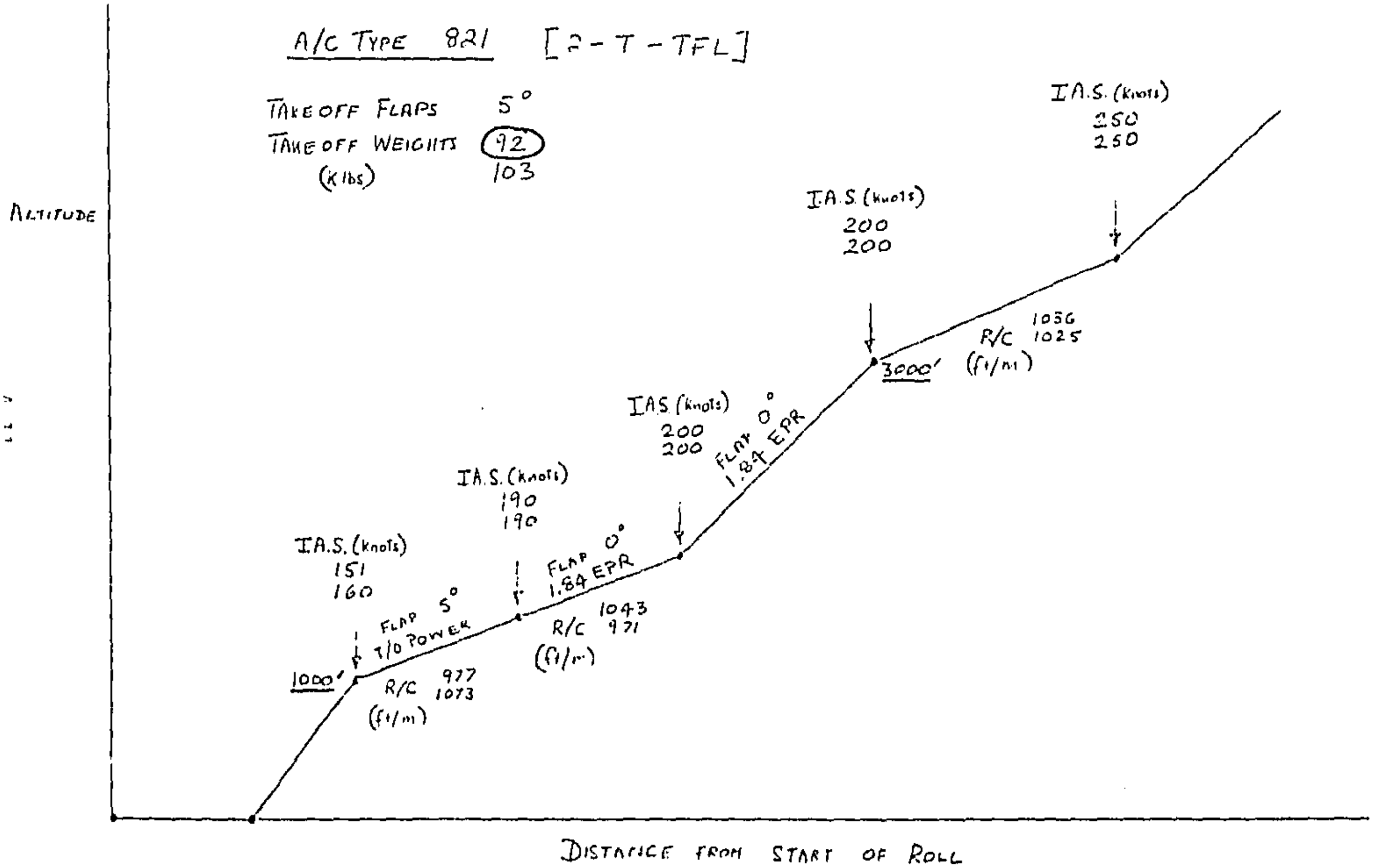

FIGURE A-10. TAKEOFF CHARACTERISTICS FOR 2-ENGINE LBPR TURBOFAN

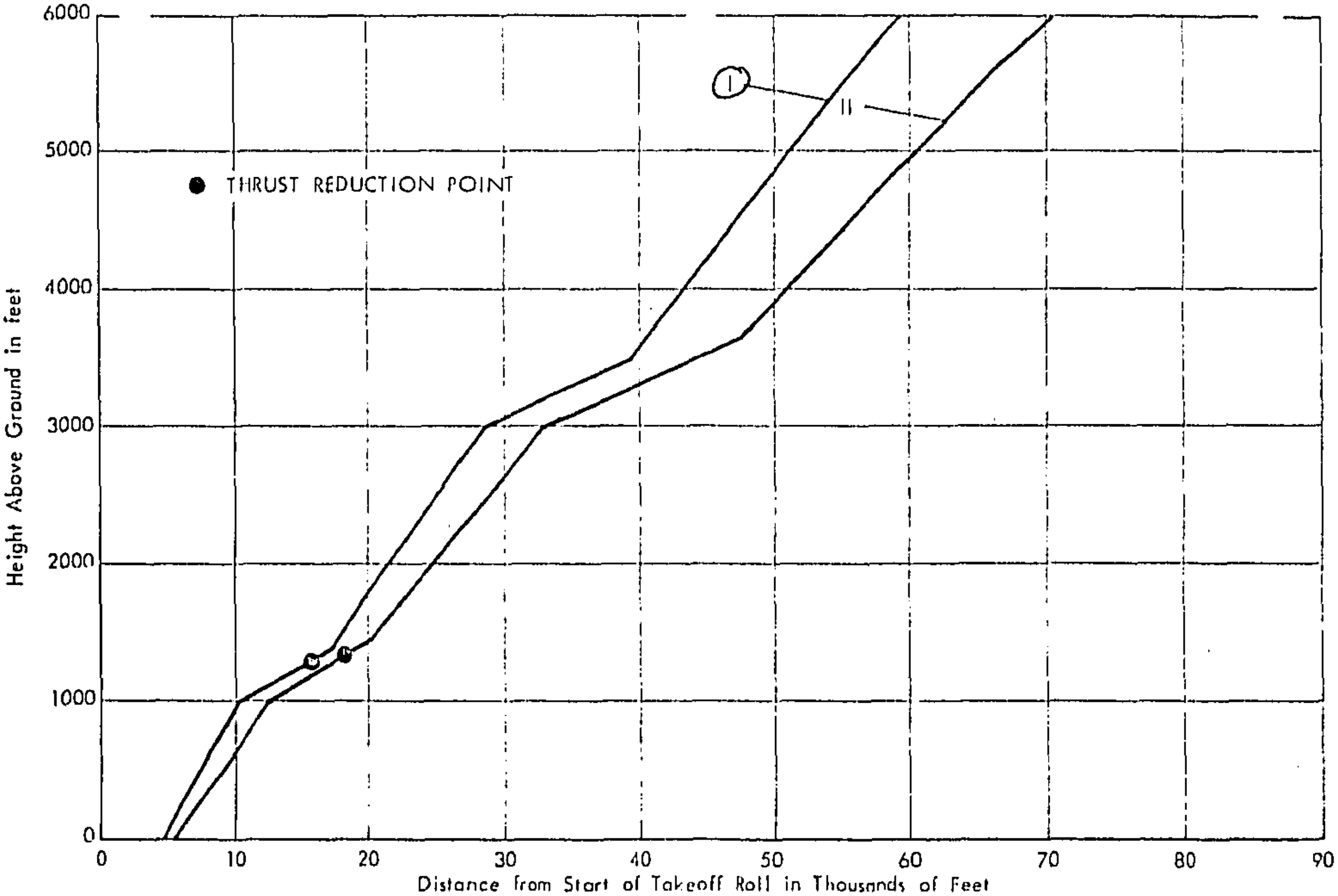

FIGURE A-11. ATA TAKEOFF PROFILES FOR 2-ENGINE LBPR TURBOFAN TRANSPORT AIRCRAFT - DC-9, 737 SERIES (2-T-TFL) - REVISED PROCEDURES ADOPTED DECEMBER 1976

FIGURES A-12 to A-18

Profiles for the aircraft listed in the following figures are based on simplifying assumptions of typical constant speed, climb gradient and power settings. Actual flight procedures vary widely depending on operator preference, weather conditions, load, and other individual aircraft and airport characteristics. Since these types of aircraft are not dominant sources of noise at joint-use airports, this simplification should not adversely affect the accuracy of the noise exposure analysis.

Distance From Brake Release (ft.)	Height (ft.)
Fig A-12 Takeoff Profile for HS748 and CVR580	
0	0
2,662	0
10,000	644
100,000	8,547
Fig A-13 Takeoff Profile for SD3-30	
0	0
3,000	0
20,000	2,000
100,000	10,700
Fig A-14 Takeoff Profile for DHC-6	
0	0
1,948	0
10,000	922
100,000	11,231
Fig A-15 Takeoff Profile for 2 Eng. Piston	
0	0
2,000	0
3,000	100
100,000	11,170
Fig A-16 Takeoff Profile for 1 Eng. Piston	
0	0
720	0
1,650	50
10,000	846
100,000	9,915

FIGURES A-12 to A-18

(Continued)

Distance From Brake Release (ft.)	Height (ft.)
Fig A-17 Takeoff Profile for Electra	
0	0
5,000	0
100,000	7,200
Fig A-18 Takeoff Profile for Bus. Jet	
0	0
3,500	0
39,792	6,261
100,000	17,668