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Aircraft Engine Emissions Estimator

GLENN D. SEITCHEK

AIR FORCE ENGINEERING AND SEVICES CENTER
HQ AFESC/RDVS
TYNDALL AFB FL 32403-6001

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FINAL REPORT

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The objective of this effort is to revise the Aircraft Emission Estimation Techniques (ACEE) Handbook to reflect changes in the Air Force aircraft inventory that have occurred since 1975. A complete listing of current Air Force aircraft and their associated engines is included. Emission factors for most of these engines are provided, along with examples for calculating emissions from aircraft operations, and analyzing their impact. This report supersedes CEEDO-TR-78-33, "Aircraft Emission Estimation Techniques (ACEE)."

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PREFACE

This final report was prepared by the Air Force Engineering and Services Center, Tyndall AFB, Florida 32403. This work was accomplished under Job Order Number 20543048. Maj Richard Padgett and 1Lt Glenn Seitchek were the project officers.

The methodology presented in this report was developed to enable base-level environmental personnel to calculate annual aircraft emissions and estimate the contribution of aircraft operations to the total air pollution concentrations near a base. Much of the information required to perform the air quality analysis is contained in the Air Quality Assessment Model. The model was developed by the Air Force to predict air pollutant concentrations in the vicinity of airports and is a source of information for this handbook. The results and recommendations do not represent Air Force policy but can be used by base personnel to estimate the impact of aircraft operations on local air quality.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This report has been reviewed and is approved for publication.

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SECTION I

INTRODUCTION

The Aircraft Emissions Estimator is a screening methodology to indicate significant air quality impact from USAF aircraft. This report contains data and guidance to perform these analyses. Annual and maximum 1-hour base aircraft operations are required prior to performing an analysis. Some guidelines to assist environmental personnel with interpreting the results are included.

This air quality analysis is not site-specific. It can be performed by environmental personnel at any Air Force base, for any base. This report will allow base personnel to conduct preliminary air quality impact analysis of beddowns and mission changes at the base. If an aircraft air pollution problem is indicated, the base should request assistance in performing a more detailed air pollution analysis (e.g., air quality assessment model). By screening aircraft air quality impacts at the base level, Air Force manpower and resources can be more effectively used.

This handbook supersedes CEEDO-TR-78-33, "Aircraft Emission Estimation Techniques (ACEE)."

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SECTION II

BACKGROUND

The preliminary assessment of USAF impact on the air quality is usually performed at base level. This analysis is often an update of the aircraft emissions inventory. When total aircraft emissions are computed, they are compared with the total base emissions inventory. A crude air-quality analysis might be performed using a "Q" or box dispersion model. The results of such models are inaccurate and very conservative.

The base environmental personnel are usually required to make quick impact analysis of the direct aircraft impact on air quality. Since aircraft are the only sources being investigated, a complex analysis of all base emission sources (i.e., AQAM) is not required. In addition, the base does not have the resources to spend on complex dispersion evaluations. The base personnel only need the annual aircraft emissions and "worst-case" downfield pollution concentrations to estimate the impact of aircraft on air quality. This estimate gives base personnel an indication of a possible air pollution problem. If the estimate indicates a possible problem, a more detailed air quality analysis will be required.

A simple analytical method is needed to determine emissions from aircraft and the impact of these emissions on air quality. The procedure must contain all the data required to make aircraft emission and air quality impact analysis and provide guidelines to interpret the results with respect to federal, state, and local standards.

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SECTION III

METHODOLOGY

A. AIRCRAFT ENGINE EMISSIONS FACTORS

Accurate emissions data are required for analysis of the air pollution emissions from aircraft engines. For this reason, the Air Force conducted a 3-year engine emission survey from 1975 through 1977 (Reference 1). The most common Air Force engines were sampled using advance turbine engine emission measurement techniques. These emissions data are still the most current and accurate available.

Table 3 contains emissions indices for common Air Force aircraft engines. Careful attention should be given to the references from which the emissions data were obtained. The Scott Environmental Technology emissions measurement data are accurate to $\pm$ 15 percent of the reported data (Reference 1). All other emissions data are extracted from other reports; no specific accuracy limits can be assigned to these emissions indices.

Carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NOx) emissions were measured using procedures described in the SAE Aerospace Recommended Practice 1265. The particulate (PART) emissions were derived from SAE Smoke Numbers. The Smoke Numbers were converted to mass per unit volume (Reference 2). The particulate mass rates in Table 3 were calculated using the mass per unit volume results, engine operating characteristics and mass balance. Sulfur oxides (SOx) were calculated using the average percentage of sulfur in the fuel and assuming complete oxidation of fuel sulfur to sulfur dioxide (Reference 3).

Afterburning engines in Table 3 (except the J-85) use extrapolated data based on J-79 afterburner emissions data and the actual engine afterburner fuel flow rates (Reference 4).

The aircraft engine emissions factors in Table 3 are expressed in units of pollutant mass per 100 mass units of fuel consumed, e.g., pounds per thousand pounds or grams per kilogram (Figure 1). The emissions factors and fuel flows are given for each engine mode. The engine thrust modes listed are the primary modes used by an aircraft during Landing and Takeoff (LTO) and Touch and Go (TGO) cycles.

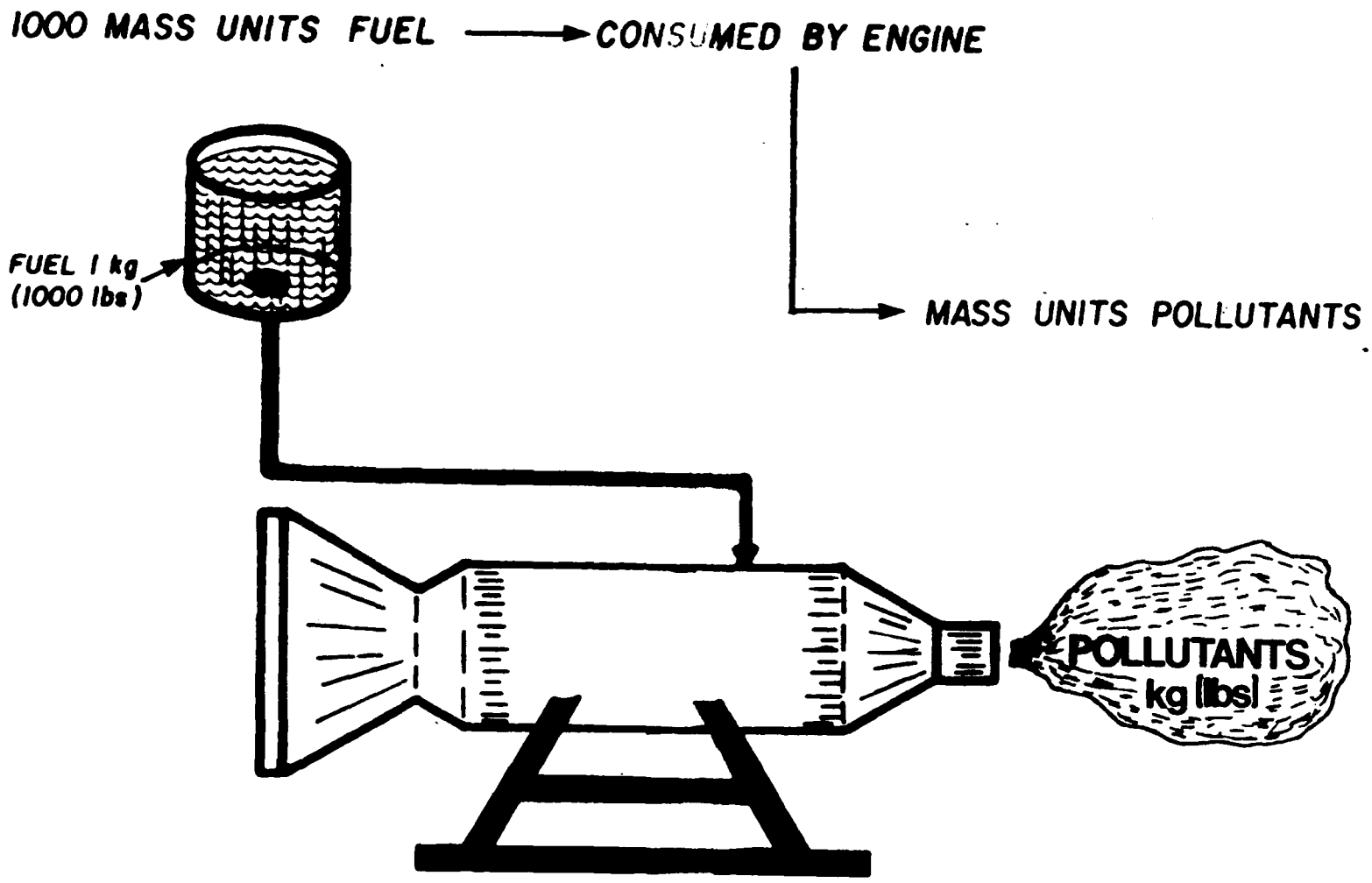

Figure 1. Emissions Factors

Emissions calculations are not limited to LTO and TGO cycles. Others, such as flyby and box patterns can be determined by knowing which modes are used during the pattern and the time spent in each mode. The emissions factors discussed in the next paragraph must be used for this calculation.

B. CALCULATING EMISSIONS USING EMISSIONS FACTORS

1. Procedure

Emissions (W) can be calculated for any engine mode using the aircraft emissions factors in Table 1. Engine Mode (E), Time in Mode (t), and Number of Engines (N) are the only input parameters required to calculate emissions. The Engine Mode Fuel Flow (F) and Emission Factor (e) are obtained from Table 3. The engine modal emissions are calculated by Equation (1).

$$W = NFte = g \text{ of Pollutants} \qquad (1)$$

Emissions must be calculated for each pollutant type under consideration, and each engine mode must be calculated separately.

Accurate time in mode data is required. Doubling the time in mode will double the amount of emissions.

The times in mode during each phase of the LTO and TGO cycles is recorded, and should be collected for each aircraft. Aircraft should be timed during peak operational periods to get representative data. An average of the time phase should be used as the time spent in that phase. Pilot interviews are less time-consuming, but usually much less accurate. If no data are available, Table 4 can be referenced for example times.

To calculate emissions using the factors, the following steps should be taken:

a. Determine the aircraft in question, then find its associated engine in Table 1. The number of engines (n) are also listed in Table 1.

b. Determine the desired engine mode (E). Table 2 can provide some guidance. The user must know the length of time spent in this mode (t).

c. From Table 3, listed by engine, determine the correct fuel flows (F), and emission factors (e).

d. Calculate pollutants using Equation (1).

$$W = NFte \tag{1}$$

Emissions must be calculated for each pollutant type under consideration, and each engine mode must be considered separately.

e. Calculate total emissions for each pollutant by adding the results from each engine mode.

TABLE 1. USAF AIRCRAFT AND ENGINES

AIRCRAFT	ENGINE	NUMBER OF ENGINES	LTO/TGO CHART
A-7D,K	TF-41-1 (ALLISON)	1	A-1
A-10A	TF-34-100(GE)	2	A-1
AC-130A	T56-9 (ALLISON)	4	
AC-130H	T56-15 (ALLISON)	4	
B-1A	F 101-100 (GE)	4	A-19
B-1B	F-101-102 (GE)	4	
B-52D	J-57-19W (P&W) or J-57-43WB (P&W)	8	A-2
B-52H	TF 33-3 (P&W)	8	A-3
C-5A,B	TF 39-1 (GE)	4	A-4
C-9A	JT8D-9 (P&W)	2	A-5
C-12A	PT6A-41 (P&W)	2	
C-21A	TFE731-2 (GARRETT)	2	
C-130A	T 56-9 (ALLISON)	4	A-6
C-130B	T 56-7 (ALLISON)	4	A-6
C-130D	T 56-9 (ALLISON)	4	A-6
C-130E	T 56-7 (ALLISON)	4	A-6
C-130H	T 56-15 (ALLISON)	4	A-6
C-135A	J 57-59W (P&W)	4	
C-135 B,C	J 57-43 WB (P&W)	4	A-7
C-140A	J60-5A/B (P&W)	4	
C-141A,B	TF 33-7 (P&W)	4	A-8
CT-39A	J60-3A (P&W)	2	

TABLE 1. USAF AIRCRAFT AND ENGINES (CONTINUED)

AIRCRAFT	ENGINE	NUMBER OF ENGINES	LTO/TGO CHART
DC-130A	T56-9 (ALLISON)	4	
E-3A	TF33-100A (P&W)	4	
E-4A,B	F103-100 (GE)	4	
EC-130E	T 56-7 (ALLISON) or T 56-15 (ALLISON)	4	
EC-130H	T 56-15 (ALLISON)	4	
EC-135A	J 57-59W (P&W)	4	
EC-135B	TF 33-5 (P&W)	4	
EC-135C	TF 33-9 (P&W)	4	
EC-135E	TF 33-102 (P&W)	4	
EC-135G	J57-59W (P&W)	4	
EC-135H	TF 33-102 (P&W)	4	
EC-135J	TF 33-9 (P&W)	4	
EC-135K	TF 33-102 (P&W)	4	
EC-135L	J 57-59W (P&W)	4	
EC-135N	J57-43WB(P&W)	4	
EC-135P	TF 33-102 (P&W)	4	
F-4C,D	J 79-15 (GE)	2	A-10
F-4E,G	J 79-17 (GE)	2	A-10
F-5B	J 85-13 (GE)	2	A-11
F-5E,F	J 85-21 (GE)	2	A-11
F-15A,B,C,D	F100-100 (P&W)	2	A-13
F-16A,B	F100-200 (P&W)	1	A-13

TABLE 1. USAF AIRCRAFT AND ENGINES (CONTINUED)

AIRCRAFT	ENGINE	NUMBER OF ENGINES	LTO/TGO CHART
F-106A,B	J75-17 (P&W)	1	A-9
F-111A	TF 30-3 (P&W)	2	A-11
F-111D	TF 30-9 (P&W)	2	A-12
F-111E	TF 30-3 (P&W)	2	A-12
F-111F	TF 30-100 (P&W)	2	A-12
FB-111A	TF 30-7 (P&W)	2	
HC-130H,N,P	T56-15 (ALLISON)	4	
KC-10A	F103-100 (GE)	3	
KC-135A,D	J57-59W (P&W)	4	A-7
KC-135E	TF33-102 (P&W)	4	
KC-135Q	J57-59W (P&W)	4	
KC-135R	F108-100 (GE)	4	
MC-130E	T56-15 (ALLISON)	4	
NC-135A/ NNC-135A	J57-43WB (P&W)	4	
NC-131H	501-D13H (ALLISON)	2	
NC-39A	J60-3A (P&W)	2	
NC-141A	TF33-7 (P&W)	4	
NF-106B	J75-17 (P&W)	1	
O-2A,B	IO-360D (CONT)	2	A-14
OA-37B	J85-17A (GE)	2	
OV-10A	T76-10/418 (GARRETT) or T76-12/419 (GARRETT)	2	A-15
RC-135M,S	TF33-5 (P&W)	4	

TABLE 1. USAF AIRCRAFT AND ENGINES (CONTINUED)

AIRCRAFT	ENGINE	NUMBER OF ENGINES	LTO/TGO CHART
RC-135T	TF33-102 (P&W)	4	
RC-135 U,V	TF 33-9 (P&W)	4	
RC-135W	TF33-5 (P&W)	4	
RF-4C	J79-15 (GE)	2	
SR-71A	J58 (P&W)	2	
T-33A	J33-35 (ALLISON)	1	A-16
T-37B	J69-25 (TCAE)	2	A-17
T-38A,B	J85-5 (GE)	2	A-17
T-39A,B	J60-3A (P&W)	2	A-18
T-41A	0300D (CONT)	1	A-18
T-41B	I0300D (CONT)	1	A-18
T-41C	I0360D (CONT)	1	A-18
T-43A	JT8D-9 (P&W)	2	
T-46A	F109-100 (GARRETT)	2	
TR-1A,B	J75-13 (P&W)	1	
U-2	J75-13 (P&W)	1	
UC-123K	R2800-99W (P&W) and J85-17 (GE)	2 2	
UV-18B	PT6A-27 (P&W)	2	
VC-131D	R2800-103W (P&W)	4	
VC-137B,C	JT3D-3B	4	
VC-140B	J60-5A/B (P&W)	4	
WC-130E	T56-7 (ALLISON) or T56-15 (ALLISON)	4	

TABLE 1. USAF AIRCRAFT AND ENGINES (CONCLUDED)

AIRCRAFT	ENGINE	NUMBER OF ENGINES	LTO/TGO CHART
WC-130H	T56-15 (ALLISON)	4	
WC-135B	TF 33-5 (P&W)	4	

ALLISON (AL) - ALLISON

CONT - CONTINENTAL

GARRETT (GA) - GARRETT

GE - GENERAL ELECTRIC

P&W - PRATT & WHITNEY

TCAE - TELEDYNE CAE

TABLE 2. OPERATIONAL MODES IN THE ARRIVAL DEPARTURE PATH

Operational Mode	Engine Thrust Setting
Start up	Idle
Outbound taxi	Idle
Engine check	Military[1]
Runway roll	Afterburner[2] (Except F-15)
Climbout 1	Afterburner[2]
Climbout 2	Military
Approach 1	Idle
Approach 2	Idle
Landing on Runway	Idle
Inbound Taxi	Idle
Idle at shutdown	Idle

[1]Military setting use for runway roll on F-15 aircraft.

[2]When an aircraft engine does not have or does not use an afterburner, substitute military.

TABLE 3. ENGINE EMISSIONSDATA

ENGINE	ENGINE MODE	FUEL FLOW KG/S	1000 LB/HR	POLLUTANT EMISSION RATE (G/KG FUEL OR LBS/1000 LBS FUEL) CO	HC	NOX	PART
501-D13H	IDLE						
(AL)	APPROACH			NO DATA AVAILABLE			
	INTERMED						
	MILITARY						
F100-100	IDLE	0.18A	1.42A	24.0A	3.2A	3.3A	0.12N
(P&W)	APPROACH	0.38D	3.00D	5.8C	1.9C	6.7C	0.27P
	INTERMED	0.64A	5.11A	1.6A	0.1A	9.8A	0.47N
	MILITARY	1.30A	10.32A	0.9A	0.1A	27.0A	0.34N
	AB	5.8E	46.01E	4.0F	0.01F	3.1F	0.15F
F100-200	IDLE	0.13V	1.04V				
(P&W)	APPROACH			USE F100-100			
	INTERMED						
	MILITARY	1.33V	10.58V				
	AB	6.52V	51.73V				
F101-100	IDLE	0.06V	0.44V	120.1X	25.2X	7.3X	0.09X
(GE)	APPROACH						
	INTERMED						
	MILITARY	1.26V	9.98V	7.6X	0.4X	2.3X	0.02X
	AB	8.41V	66.73V	16.7X	0.1X	4.6X	0.05X
F101-102	IDLE	0.06V	0.44V				
(GE)	APPROACH			USE F101-100			
	INTERMED						
	MILITARY	1.26V	9.98V				
	AB	8.41V	66.73V				

TABLE 3. ENGINE EMISSIONSDATA (CONTINUED)

ENGINE	ENGINE MODE	FUEL FLOW KG/S	1000 LB/HR	POLLUTANT EMISSION RATE (G/KG FUEL OR LBS/1000 LBS FUEL) CO	HC	NOX	PART
F103-100	IDLE	0.19V	1.49V	80.4T	45.9T	2.6T	
(GE)	APPROACH	1.42V	11.24V	5.4T	1.4T	10.1T	
	INTERMED						
	MILITARY	2.63V	20.91V	0.2T	1.0T	34.0T	
F108-100	IDLE	0.13W		24.7W	1.17W	4.12W	
(GE)	APPROACH	0.34W		3.4W	0.10W	8.62W	
	INTERMED	0.93W		0.9W	0.04W	17.18W	
	MILITARY	1.12W		0.9W	0.04W	21.05W	
F109-100	IDLE						
(GA	APPROACH			NO DATA AVAILABLE			
	INTERMED						
	MILITARY						
IO300D	IDLE						
(CONT)	APPROACH			NO DATA AVAILABLE			
	INTERMED						
	MILITARY						
IO360D	IDLE	0.01M	0.03M	848.0M	145.0M	1.1M	60.0M
(CONT)	APPROACH	0.01M	0.06M	945.9M	23.6M	5.5M	40.9M
	APPROACH	0.01M	0.04M	879.0M	70.6M	2.5M	55.0G
	INTERMED	0.01M	0.07M	972.0M	17.4M	6.6M	40.0M
	MILITARY	0.01	0.09M	1030.0M	22.5M	5.3M	20.0M

TABLE 3. ENGINE EMISSIONSDATA (CONTINUED)

ENGINE	ENGINE MODE	FUEL FLOW KG/S	1000 LB/HR	POLLUTANT EMISSION RATE (G/KG FUEL OR LBS/1000 LBS FUEL) CO	HC	NOX	PART
J33-35	IDLE	0.15A	1.20A	127.0A	19.5A	1.5A	0.73N
(AL)	APPROACH	0.25H	2.00H	84.6C	6.5C	1.9C	0.57P
	INTERMED	0.60A	4.75A	49.1A	1.3A	2.7A	0.02N
	MILITARY	0.70A	5.52A	31.3A	0.5A	3.6A	0.02N
J57-19W	IDLE	0.12A	0.95A	79.0A	77.0A	2.2A	0.16N
(P&W)	APPROACH	0.42I	3.38I	7.9C	1.4C	5.8C	0.93P
	INTERMED	0.82A	6.50A	2.4A	0.2A	9.5A	1.92N
	MILITARY	0.94A	7.47A	1.9A	0.1A	11.0A	1.72N
	WATER AUG	1.53J	12.13J	21.1J	2.2J	2.7J	1.89J
J57-43WB	IDLE	0.12A	0.99A	78.0A	75.0A	2.2A	0.14N
(P&W)	APPROACH	0.23K	1.85K	9.7C	1.8C	5.3C	0.52P
	APPROACH	0.23I	1.85I	24.0C	9.2C	3.6C	0.293P
	INTERMED	0.84A	6.69A	2.3A	0.1A	9.9A	1.23N
	MILITARY	0.98A	7.78A	1.5A	0.1A	11.0A	1.74N
	WATER AUG	1.53J	12.13J	21.1J	2.2J	2.7J	22.5R
J57-59W	IDLE	0.16J	1.25J	65.0J	52.9J	2.4J	0.13R
(P&W)	APPROACH	0.23K	1.85K	32.5B	14.2B	3.3B	0.22S
	INTERMED	0.49J	3.87J	8.9J	1.1J	6.1J	0.60R
	MILITARY	1.00J	7.90J	2.4J	0.2J	11.3J	0.84R
	WATER AUG	1.53J	12.13J	21.1J	2.2J	2.7J	22.5R
J58	IDLE		CLASSIFIED				
(P&W)	APPROACH						
	INTERMED						
	MILITARY						

TABLE 3. ENGINE EMISSIONS DATA (CONTINUED)

ENGINE	ENGINE MODE	FUEL FLOW KG/S	1000 LB/HR	POLLUTANT EMISSION RATE (G/KG FUEL OR LBS/1000 LBS FUEL) CO	HC	NOX	PART
J60-03A	IDLE	0.07V	0.58V	70.0A	9.2A	1.5A	0.02N
(P&W)	APPROACH	0.07C	0.52C	50.5C	5.6C	1.7C	0.02P
	INTERMED	0.18A	1.43A	5.8A	0.2A	4.0A	0.23N
	MILITARY	0.43V	2.88V	4.0A	0.1A	4.6A	0.17N
J60-05A/B	IDLE	0.06A	0.46A	70.0A	9.2A	1.5A	0.02N
(P&W)	APPROACH	0.07C	0.52C	50.5L	5.6L	1.7L	0.02P
	INTERMED	0.18A	1.43A	5.8A	0.2A	4.0A	0.23N
	MILITARY	0.31A	2.47A	4.0A	0.1A	4.6A	0.17N
J69-25	IDLE	0.029A	0.231A	129.0A	19.0A	1.5A	0.55N
(TCAE)	APPROACH	0.04A	0.288A	106.9A	11.1A	1.7A	0.28N
	INTERMED	0.09A	0.70A	50.0A	1.3A	2.7A	0.02N
	MILITARY	0.14A	1.10A	32.0A	0.5A	3.6A	0.02N
J75-13	IDLE		CLASSIFIED				
(P&W)	APPROACH						
	INTERMED						
	MILITARY						
J75-17	IDLE	0.20A	1.55A	86.0A	72.0A	2.3A	0.23N
(P&W)	APPROACH	0.44K	3.50K	17.5C	5.2C	4.3C	0.44P
	MILITARY	1.63A	12.94A	1.3A	0.1A	12.0A	1.08N
	AB	6.77A	53.70A	4.0F	0.01F	3.1F	0.15F
J75-19W	IDLE	0.20A	1.58A	62.0A	38.0A	2.6	0.23N
(P&W)	APPROACH	0.22K	3.50K	17.5C	5.2C	4.3C	0.44F
	INTERMED	1.09A	8.64A	1.9A	0.3A	3.0A	1.04N
	MILITARY	1.71A	13.60A	1.5A	0.3A	10.0A	1.04N
	AB	4.54A	36.01A	4.0F	0.01F	3.1F	0.15F

TABLE 3. ENGINE EMISSIONS DATA (CONTINUED)

ENGINE	ENGINE MODE	FUEL FLOW KG/S	1000 LB/HR	POLLUTANT EMISSION RATE (G/KG FUEL OR LBS/1000 LBS FUEL) CO	HC	NOX	PART
J79-15	IDLE	0.14A	1.13A	57.0A	12.0A	2.5A	0.5N
(GE)	APPROACH	0.44D	3.50D	9.4C	1.1C	4.8C	1.8P
	INTERMED	0.68A	5.36A	4.6A	0.3A	5.6A	2.8N
	MILITARY	1.12A	8.93A	2.2A	0.2A	8.9A	2.2N
	AB	4.06A	32.24A	4.0F	0.01F	3.1F	0.15F
J79-17	IDLE	0.13L	1.06L	66.0	23.1L	2.7L	0.18L
(GE)	APPROACH	0.44D	3.50D	15.4L	0.5L	4.5L	0.51L
	INTERMED	0.88L	7.00L	7.8L	0.1L	5.8L	0.72L
	MILITARY	1.24L	9.82L	5.2L	0.1L	10.6L	0.92L
	AB	4.40F	34.95F	4.0F	0.01F	3.1F	0.15F
J85-05	IDLE	0.06A	0.45A	178.0A	30.0A	1.3A	0.003N
(GE	APPROACH	0.13D	1.00D	73.6C	6.4C	1.8C	0.007P
	APPROACH	0.18H	1.46H	43.0C	3.5C	2.3C	0.011P
	INTERMED	0.28A	1.46A	43.0A	3.5A	2.3A	0.011A
	MILITARY	0.33A	2.63A	29.0A	0.8A	2.6A	0.018A
	AB	1.05A	8.32A	26.0F	0.07F	2.0F	0.008F
J85-13	IDLE	0.07V	0.55V				
(GE	APPROACH			USE J85-5			
	INTERMED						
	MILITARY	0.35V	2.80V				
	AB	1.13V	8.98V				
J85-17A	IDLE	0.07V	0.58V				
(GE)	APPROACH			USE J85-5			
	INTERMED						
	MILITARY	0.48V	3.81V				

TABLE 3. ENGINE EMISSIONS DATA (CONTINUED)

ENGINE	ENGINE MODE	FUEL FLOW KG/S	1000 LB/HR	POLLUTANT EMISSION RATE (G/KG FUEL OR LBS/1000 LBS FUEL) CO	HC	NOX	PART
J85-21	IDLE	0.07V	0.58V	158.9L	24.3L	1.3L	
(GE)	APPROACH			USE J85-5			
	INTERMED						
	MILITARY	0.44V	3.50V	21.6L	0.2L	5.0L	
	AB	1.37V	10.86V				
JT3D-3B	IDLE	0.14V	1.11V	125.0U	113.1U	1.6U	0.52U
(P&W)	APPROACH	0.52U	4.14U	9.6U	1.9U	5.3U	1.53U
	INTERMED						
	MILITARY	1.21V	9.63V	1.1U	0.4U	13.7U	0.76U
JT8D-09	IDLE	0.18V	1.44V	34.8U	7.3U	3.0U	0.38U
(P&W)	APPROACH	0.43U	3.41U	5.3U	0.5U	9.1U	0.44U
	INTERMED						
	MILITARY	1.09V	8.63V	0.9U	0.1U	22.6U	0.42U
O300D	IDLE						
(CONT)	APPROACH			NO DATA AVAILABLE			
	INTERMED						
	MILITARY						
PT6A-27	IDLE						
(P&W)	APPROACH			NO DATA AVAILABLE			
	INTEMED						
	MILITARY						
PT6A-41	IDLE						
(P&W)	APPROACH			NO DATA AVAILABLE			
	INTEPMED						
	MILITARY						

TABLE 3. ENGINE EMISSIONS DATA (CONTINUED)

ENGINE	ENGINE MODE	FUEL FLOW KG/S	1000 LB/HR	POLLUTANT EMISSION RATE (G/KG FUEL OR LBS/1000 LBS FUEL) CO	HC	NOX	PART
R2800-099	IDLE						
(P&W)	APPROACH			NO DATA AVAILABLE			
	INTERMED						
	MILITARY						
R2800-103	IDLE						
(P&W)	APPROACH			NO DATA AVAILABLE			
	INTERMED						
	MILITARY						
T56-07	IDLE	0.09A	0.72A	32.0A	21.0A	3.9A	0.83N
(AL)	APPROACH	0.10C	0.83C	22.2C	12.4C	4.4C	0.97P
	INTERMED	0.23A	1.85A	2.4A	0.5A	9.2A	0.51N
	MILITARY	0.25A	1.96A	2.1A	0.4A	9.3A	0.50N
T56-09	IDLE	0.10V	0.80V				
(AL)	APPROACH			USE T56-07			
	INTERMED						
	MILITARY	0.24V	1.87V				
T56-15	IDLE	0.10V	0.80V				
(AL	APPROACH			USE T56-07			
	INTERMED						
	MILITARY	0.29V	2.30V				
T56-10/41	IDLE	0.03L	0.25L	23.8L	7.4L	7.4L	0.38L
(GA)	APPROACH	0.06D	0.45D	17.2L	0.8L	9.5L	0.50L
	INTERMED	0.10L	0.80L	5.9L	0.1L	9.9L	0.63L
	MILITARY	0.11L	0.90L	2.3L	0.1L	10.3L	0.71L

TABLE 3. ENGINE EMISSIONS DATA (CONTINUED)

ENGINE	ENGINE MODE	FUEL FLOW KG/S	1000 LB/HR	POLLUTANT EMISSION RATE (G/KG FUEL OR LBS/1000 LBS FUEL) CO	HC	NOX	PART
T76-12/419	IDLE	0.05V	0.39V				
(GA)	APPROACH			USE T76-10/418			
	INTERMED						
	MILITARY	0.05V	0.43V				
TF30-03	IDLE	0.11A	0.85A	72.0A	62.0A	2.3A	0.01N
(P&W)	APPROACH	0.26D	2.10D	9.2C	2.1C	4.8A	0.05N
	INTERMED	0.62A	4.93	1.3A	0.1A	9.4C	0.45P
	MILITARY	0.78A	6.15A	0.8A	0.03A	12.0A	0.40N
	AB	4.84A	38.40A	4.06F	0.01F	3.1F	0.15F
TF30-07	IDLE	0.12A	0.95A	53.0A	30.0A	3.0A	0.02N
(P&W)	APPROACH	0.26D	2.10D	11.5C	3.2C	6.1C	0.12N
	INTERMED	0.72D	5.71A	1.2A	0.2A	14.0A	0.44N
	MILITARY	0.91A	7.26A	0.8A	0.1A	20.0A	0.35N
	AB	4.84D	38.40A	4.0F	0.01F	3.1F	0.15F
TF30-09	IDLE	0.12V	0.96V				
(P&W)	APPROACH			USE TF30-07			
	INTERMED						
	MILITARY	1.10V	8.65V				
	AB	6.87V	54.50V				
TF30-100	IDLE	0.12A	0.95A	48.0A	19.0A	2.9A	0.02N
(P&W)	APPROACH	0.26D	2.10D	9.9C	2.7C	6.3C	0.08P
	INTERMED	0.90A	7.16A	0.7A	0.1A	20.0A	0.32N
	MILITARY	1.14A	9.08A	0.7A	0.1A	28.0A	0.24N
	AB	6.80A	54.00A	4.0F	0.01F	3.1F	0.15F

TABLE 3. ENGINE EMISSIONS DATA (CONTINUED)

ENGINE	ENGINE MODE	FUEL FLOW KG/S	1000 LB/HP	POLLUTANT EMISSION RATE (G/KG FUEL OR LBS/1000 LBS FUEL) CO	HC	NOX	PART
TF33-003	IDLE	0.11A	0.90A	107.0A	84.0A	1.8A	0.23N
(P&W)	APPROACH	0.48I	3.80C	6.3C	2.6C	5.8C	0.99P
	INTERMED	0.79A	6.24A	2.3A	0.7A	8.5A	1.88A
	MILITARY	0.94A	7.44A	1.7A	0.6A	10.0A	1.73A
TF33-005	IDLE	0.14V	1.12V				
(P&W)	APPROACH			USE TF33-102			
	INTERMED						
	MILITARY	1.21V	9.63V				
TF33-007	IDLE	0.13A	1.07A	93.0A	77.0A	1.8A	0.11N
(P&W)	APPROACH	0.32C	2.50C	13.7C	3.6C	3.8C	0.39C
	INTERMED	0.91A	7.23A	1.3A	0.1A	9.4A	1.30N
	MILITARY	1.10A	8.71A	0.8A	0.03A	12.0A	0.91N
TF33-009	IDLE	0.15V	1.18V				
(P&W)	APPROACH			USE TF33-102			
	INTERMED						
	MILITARY	1.21V	9.63V				
TF33-100A	IDLE	0.15V	1.20V				
(P&W)	APPROACH			USE TF33-007			
	INTERMED						
	MILITARY	1.48V	11.76V				
TF33-102	IDLE	0.14V	1.11V	125.0U	113.1U	1.6U	0.5U
(P&W)	APPROACH		4.14V	9.8U	1.9U	5.3U	1.3U
	INTERMED		8.96U	1.7U	0.5U	10.7U	0.9U
	MILITARY	1.21V	9.63V	1.1U	0.4U	13.7U	0.8U

TABLE 3. ENGINE EMISSIONS DATA (CONCLUDED)

ENGINE	ENGINE MODE	FUEL FLOW KG/S	1000 LB/HR	POLLUTANT EMISSION RATE (G/KG FUEL OR LBS/1000 LBS FUEL) CO	HC	NOX	PART
TF33-102A	IDLE	0.14V	1.11V	125.0U	113.1U	1.6U	0.5U
(P&W)	APPROACH		4.14U	9.6U	1.9U	5.3U	1.9U
	INTERMED		8.96U	1.7U	0.5U	10.7U	0.9U
	MILITARY	1.21V	9.63V	1.1U	0.4U	13.7U	0.8U
TF34-100	IDLE		0.39A	106.7A	34.3A	2.1A	
(GE)	APPROACH		0.92A	16.3A	1.9A	5.7A	
	INTERMED		0.46A	78.0A	20.3A	2.6A	
	MILITARY		2.71A	2.2A	0.1A	10.7A	
TF39-01	IDLE	0.14A	1.13A	67.0A	23.0A	3.0A	0.015N
(GE)	APPROACH	0.19G	1.50G	39.2C	13.2C	3.9C	0.016P
	INTERMED	1.52A	12.02	0.7A	0.2A	28.0A	0.030N
	MILITARY	1.60A	12.69A	0.7A	0.2A	28.0A	0.025N
TF41-01	IDLE	0.13A	1.01A	119.0A	92.0A	1.5A	0.15N
(AL)	APPROACH	0.44D	3.50D	10.2C	2.2C	6.8C	0.36P
	INTERMED	0.74A	5.83A	3.7A	0.4A	12.0A	0.52N
	MILITARY	1.06A	8.42A	1.8A	0.2A	21.0A	0.67N
TFE731-2	IDLE						
(GA)	APPROACH			NO DATA AVAILABLE			
	INTERMED						
	MILITARY						

* A-X represents the reference list for this table.

REFERENCE LIST FOR TABLE 3*

A. REFERENCE 1

B. PARTICULATE MASS FLOW CALCULATIONS

C. EMISSIONS CALCULATED BY A POWER CURVE INTERPOLATION

METHOD USING ENGINE MORE FUEL FLOWS AND EMISSION INDICES

D. LT COL MAHLER, HQ TAC/DOV, TRIP REPORT CONTAINING APPROACH AIRCRAFT FUEL FLOWS BY LT P.D. MUSIC (DET 1, ADTC) DATED 15 AUG 77.

E. REFERENCE 12

F. REFERENCE 4

G. REFERENCE 13

H. LT COL ROY W. PETERSON, HQ ATC/DOV, LETTER REPORT CONTAINING AIRCRAFT ENGINE APPROACH MODE FUEL FLOWS DATED 3 AUG 77.

I. CAPT KENNETH HACKER, 1ST GEG SAL, FUEL FLOWS FOR B-52 APPROACH IN LETTER DATED 21 DEC 76.

J. REFERENCE 14

K. TELEPHONE COMMUNICATIONS BETWEEN LT DAVID VAN GASBECK (NGB/DEM) TO LT JOHN HUNT (DET 1 ADTC) ON 2 AUG 77.

L. REFERENCE 15

M. REFERENCE 16

N. A and B

P. B and C

O. C and M

R. B and J

S. C and J

T. REFERENCE 17, p51 (CF6-50C2 ENGINE)

U. REFERENCE 18

V. LETTER FROM WILLIAM J. MEYER, AFLC/LOC/CFP (27 MAR 84)

W. CFM-56-2 COMPLIANCE TEST, CFM INTERNATIONAL, 1 DEC 83 (SOURCE ASD/YZEA)

X. LETTER FROM MAJ GREMS (CEEDO/ECA) TO HQ SAC/DEVQ, 7 JUL 77

TABLE 4. EXAMPLE TIME IN MODE

Aircraft Mode	Light Aircraft	Heavy Aircraft
Startup	6.3	8.5
Outbound Taxi	5.5	7.5
Engine check	1.1	1.2
Runway roll	0.4	0.5
Climbout I	0.4	0.6
Climbout II	0.3	0.7
Approach I	1.9	2.6
Approach II	0.7	1.3
Landing on runway	1.1	1.2
Inbound Taxi	5.5	6.4
Idle at shutdown	0.8	3.3
TOTAL	24.0	33.8

Source: AFWL-TR-74-303 (Reference 6), p28-9

2. Example 1:

Given: T-38 with a 3-minute engine check before take-off.

Find: Amount of carbon monoxide produced by the engine check.

Solution:

a. Engine: J85-5

Number of Engines: N = 2

b. Engine Mode: Military

Time Mode: t (Military) = 3 minutes x 60 s/minute = 180s

c. Fuel Flow: F (Military) = 0.331 kg/s

Emission Factor: e (Military, CO) = 29.0 g CO/kg fuel

d. W = NFte

W (Engine check) = 2 (0.331 Kg/s) (180s) (29.0 g CO/kg fuel)

W (Engine check) = 3455.64 g CO

3. Example 2:

Given: T-38 with a 5-minute (300 sec) startup time, a 15-minute (900 sec) taxi-out time and three 3-minute (180 sec) engine check.

Find: Carbon monoxide emissions for each operation.

Solution:

a. Aircraft: T-38

N = 2

From Table 1: J-85-5 engine

b. From Table 2: E (Startup) = Idle, t = 300 sec

E (Taxi out) = Idle, t = 900 sec

E (Engine check) = Military, t = 180 sec

c. Fuel Flow: F (Idle) = 0.057 kg/s

F (Military) = 0.331 Kg/s

Emission Factor: e (Idle, CO) = 178.0 g CO/kg fuel

e (Military, Co) = 29.0g CO/kg fuel

d. W = NFte

W (Startup, CO) = 2(.057 Kg fuel/s) (300s) (178.0 gCO/kg fuel) = 6087.6 gCO

W (Taxi out, CO)=2(.057) (900) (178.0) = 18262.8 gCO

W (Engine check, CO) = 2(0.331) (180) (29.0) = 3455.6 gCO

e. W (Total, CO) = W (Startup, CO) + W (Taxi out, CO) + W (Engine check, CO) = 6087.6 + 18262.8 + 3455.6 = 27806.0 gCO

C. CALCULATING EMISSIONS USING LTO AND TGO TABLES

1. Procedure

Calculations of pollutant emissions for each phase of the LTO and TGO cycle are time-consuming. To eliminate these calculations, the AQAM Source Inventory was employed (Reference 5). The AQAM Source Inventory uses the emissions indices and aircraft operational data (e.g., climb angle, approach speed) to calculate the amount of pollutants emitted during each individual phase of an LTO or TGO cycle. The same procedures described in Part B are used by the AQAM Source Inventory to calculate total LTO and TGO aircraft emissions. The standard AQAM LTO cycle is illustrated in Figure 2. The TCO cycle differs from the LTO cycle by omitting Phases 1-4 and 7-9, and modifying the runway roll speeds and distances to account for the faster approaches of the TGO cycle. All emissions are calculated to and from 0.914 km (3000 feet) above ground level, because this figure represents the average afternoon mixing depth of the atmosphere, and AQAM stops emission computations at the mixing height (Reference 6).

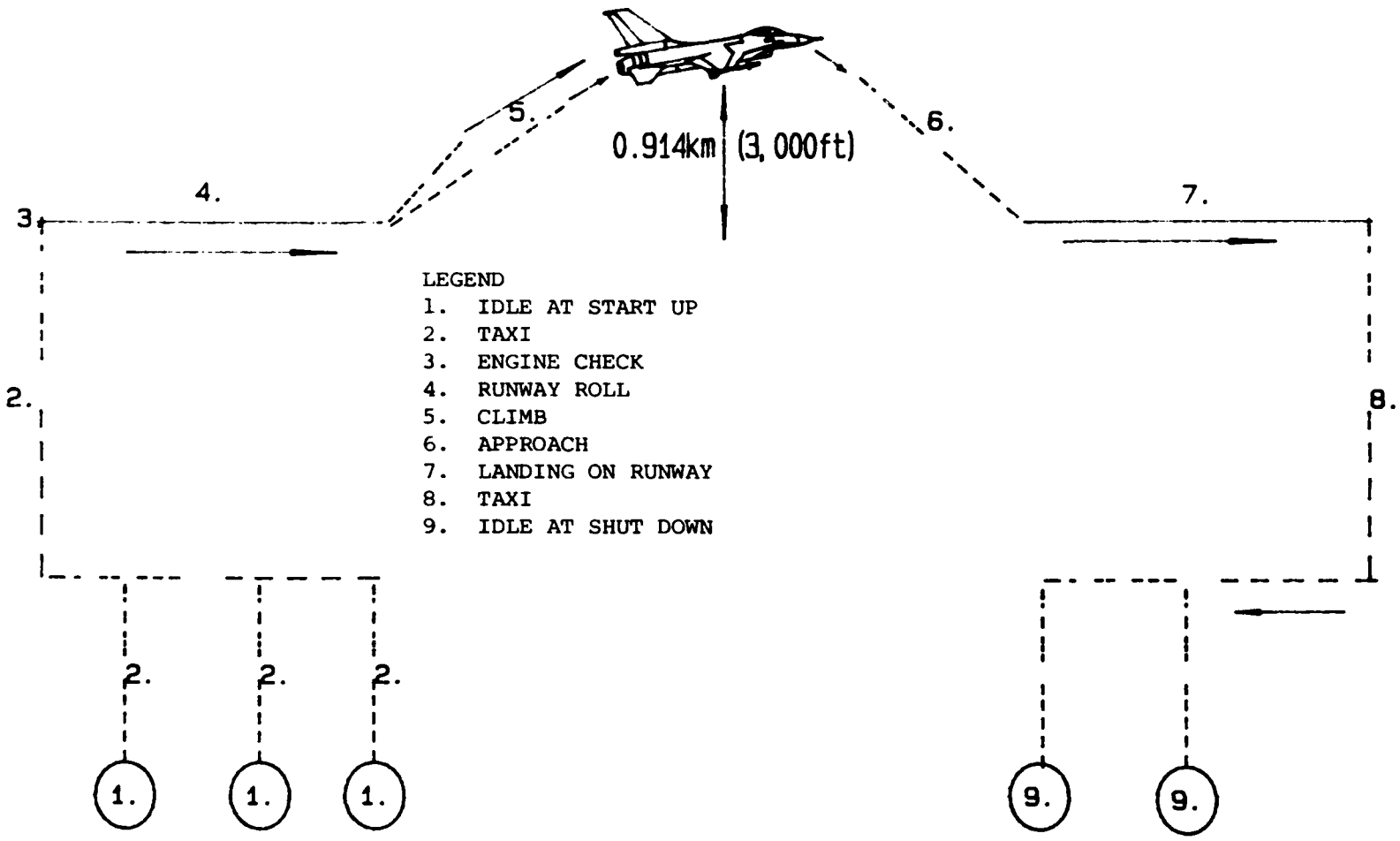

Figure 2. LANDING AND TAKEOFF CYCLE

The AQAM Source Inventory calculates runway roll distances using meteorological conditions and pressure altitude. The parameters used are listed in Table 5. The conditions are based on an annual average of 12 Air Force bases in the continental United States that represent a cross section of all United States Air Force bases.

Taxi distances are assumed to be 4.0 km for both incoming and departing flights. This distance was determined from an Air Force-wide average of taxi distances (Reference 6). The average time in the taxi phase varies with aircraft taxi speeds and operational procedures. Modifications to these taxi times and other LTO and TGO phases is discussed in Part D.

TABLE 5. ANNUAL METEOROLOGICAL CONDITIONS TWELVE AIR FORCE BASES ANNUAL AVERAGES

Meteorological Data	
Average Temperature	17.8°C (64°F)
Pressure Altitude	359.6 m (1180 ft)
Average Windspeed*	3.8 m/s (8.5 mph)

* A headwind to the aircraft's takeoff and landing is used for AQAM Source Inventory calculations.

The AQAM-generated LTO and TGO pollutant emissions are presented in Appendix A. The emissions for each of the five pollutant types are given for the individual LTO phases, and are expressed in metric tons per cycle. The total LTO pollutant emission is the sum of the individual phases. The TGO cycle total emissions are calculated and presented separately from the LTO emissions.

To conduct emissions calculations using the LTO and TGO tables, the following procedure should be used:

a. Identify the aircraft in question.

b. Look in Table 1 to find the appropriate LTO/TGO chart, then find the chart in Appendix A.

c. Determine emissions desired.

2. EXAMPLE 3

Given: T-38 during Standard LTO cycle.

Find: Total NOx emitted.

Solution:

a. T-38

b. LTO/TGO Chart - Appendix A-17

c. W (NOx) = 6.0 E-04 metric tons x 1000 kg/metric ton = 0.6 Kg/LTO

D. LTO MODIFICATIONS

The LTO cycle emissions can be modified to simulate special cases like arming and queuing. The engine thrust mode and time in mode for each special case are required. Using Equation (1), the emissions can be calculated for each engine mode and pollutant. These special case emissions can then be added to the final LTO pollutant total.

1. EXAMPLE 4:

Given: A T-38 at the beginning of the runway develops a 10-minute queue due to heavy aircraft traffic.
Find: Effect of the queue on LTO CO emissions.

Solution:

a. ENGINE = J85-5

N = 2

b. Queue - Idle Power Setting

t = 10 min = 600 sec

c. F (Idle) = 0.057 Kg/s

e (Idle, CO) = 178.0 g CO/KG fuel

4. W (Queue) = NFte

= 2 (0.057) (600) (178.0)

= 12,175 g CO = 12.175 Kg CO

5. From Table A-17:

W (LTO) = 4.0 E-02 metric Tons CO x 1,000 kg/metric ton

= 40.0 Kg CO

W (TOT) = 40.0 + 12.175 = 52.175 Kg CO

Therefore:

CO emissions increased 30 percent during the 10-minute queuing delay.

The time in mode can be calculated for each of the LTO phases. This calculation is important for determining the time of each phase of the standard LTO cycles (Appendix B) and checking emission calculations. Equation (1) can be modified to calculate the time spent in the mode:

$$t(s) = \frac{W(kg) \times 1000 g/kg}{e(g/kg) \times F\ (kg/s) \times N} \qquad (2)$$

The amount of extra time that must be added or subtracted from the standard LTO phase can be determined.

2. EXAMPLE 5:

The average T-38 taxi-out time was estimated to be 10 minutes. How does this compare with the taxi-out phase in the LTO Chart?

Solution:

From Table 1:

F (Idle) = 0.057 kg/s

e (Idle, CO) = 178.0g CO/kg fuel

From Table A-17: W (Taxi-Out, CO) = 1.31 X E-02 metric tons CO x 1000 kg/metric ton = 13.1 kg CO

Time:

$$t\ (\text{Taxi-out}) = \frac{(13.1\ \text{kg CO}) \times (1000\ \text{g/kg})}{(0.057\ \text{Kg Fuel/s}) \times (178.0\ \text{g CO/kg fuel}) \times (2\ \text{engines})}$$

$$t\ (\text{Taxi-Out}) = 645\ \text{s} = 10\ \text{minutes}\ 45\ \text{s}$$

The 10-minute observed time and the 10-minute 45 second LTO taxi-out time are similar. The normal LTO cycle taxi-out emission can be used.

All special modifications to the LTO and TGO emissions (Appendix A) will result in more accurate results. For quick estimates, the tabulated LTO and TGO cycle emissions could be used.

E. ANNUAL EMISSIONS

Aircraft emissions can also be expressed in terms of annual totals. These totals can then be compared with other emission sources on and around the base, to find the aircraft's contribution to the area's total emissions.

The number of annual aircraft operations is required to compute annual emissions. The aircraft data must be in the form of LTOs and TGOs per year. The data can usually be obtained from the base operations sections and are reported monthly. Aircraft types might have to be separated and some data might require manipulation to be reduced into the required format.

The number of annual LTO operations is multiplied by the pollutant emissions from one LTO operation (Equation (3)) to give the annual aircraft pollutant emissions. All emissions of the same pollutant are added to obtain the total aircraft emissions.

Annual Emissions (metric tons) = (LTO pollutant emissions (Metric Tons) x Number of Annual Aircrat LTOs) + (TGO pollutant emissions (metric tons) x Number of annual aircraft TGOs) (3)

The pollution emissions changes can be calculated for operational changes (e.g., decreased engine checks times, decreased arming times) or subtracted from the modified LTO, TGO or flyby circle.

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SECTION IV

SHORT-TERM AIR QUALITY

A. AIR QUALITY

Air-quality analysis is the most important factor in determining the impact of aircraft on the environment. Dispersion and emission analyses are the two main factors in air quality analysis. The dispersion analysis estimates the atmosphere's ability to transport and dilute pollution due to advective winds and eddies caused by atmospheric instability, and is independent of source emissions. The emission analysis determines the total amount of pollutants released into the atmosphere.

The AQAM short-term model quantifies the ambient air quality resulting from atmospheric dispersion and source emissions. It can calculate atmospheric dispersion as a function of windspeed, mixing height, atmospheric stability, and distance from almost any base emission source. Gaussian dispersion models are used by AQAM to predict air quality ground-level concentrations at air bases (References 7 and 8). These concentrations can be compared with US National Primary and Secondary Ambient Air Quality Standards to predict the impact on air quality. The AQAM short-term model, with typical meteorological conditions, is used in this handbook to predict ambient air quality resulting from aircraft operations. Emissions from other base sources (i.e., motor vehicles, boilers) are not included in this handbook, but can be obtained by using other methods, some of which are described in Section VII.

B. METEROLOGICAL CONDITIONS

Meteorological conditions determine the dispersion potential of the atmosphere. Under poor atmospheric dispersion conditions, air pollution problems are most likely to occur. These conditions usually exist during the early morning hours. Calm wind speeds and a stable atmosphere cause very little diluting or transporting of pollutants. The lowest dispersion potential is called the "worst case."

Typical "worst-case" meteorological conditions were used for dispersion and air quality calculations. These conditions are presented in Appendix B. The meteorological data are annual 1-hour averages from 12 USAF bases which represent a good cross section of weather climates in the United States. The morning conditions were chosen because the greatest potential for air pollution problems occur then.

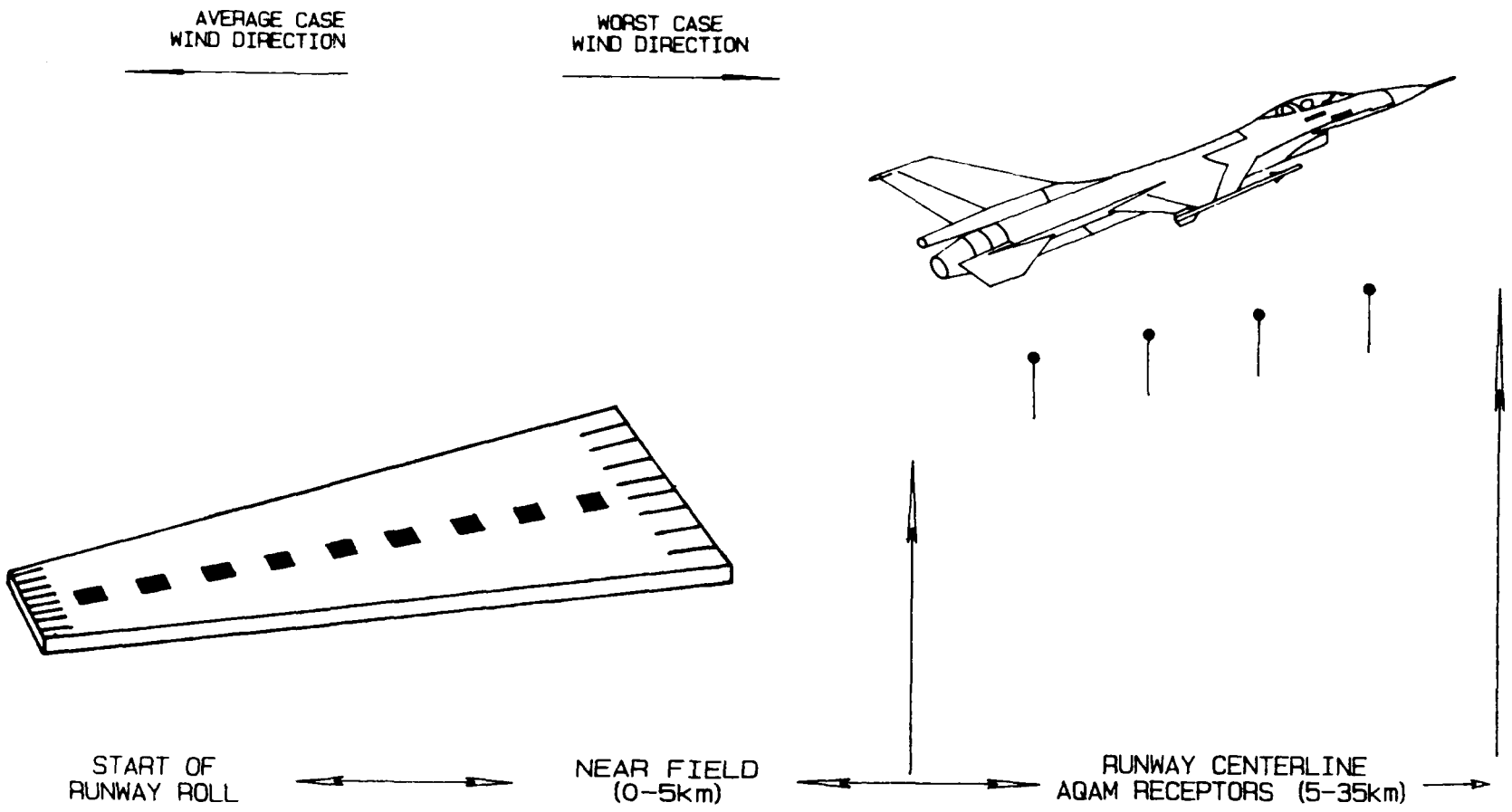
The small tailwind for takeoff gives the maximum downfield pollution concentrations for the "worst case." The tailwind is not typical of normal aircraft takeoff procedures.

C. RUNWAY CENTERLINE CONCENTRATIONS

Downfield centerline pollutant concentrations, which represent the highest ground concentrations, were calculated for many aircraft types, using the AQAM short term program. These calculations are presented in Appendix B. The AQAM short term model simulated downfield ground receptor concentrations resulting from an aircraft takeoff and climb to 914 m (3000 ft) and its approach and landing from the same altitude. The AQAM short-term Gaussian dispersion model calculated the hourly average centerline concentrations resulting from one aircraft LTO and TGO cycle. The pollution concentrations were estimated at points 5 km to 35 km down the runway centerline (Figure 3). The start of runway to 5 km pollutant concentrations were not calculated because of inaccuracies due to near field effects. The takeoff and climbout downfield pollution concentrations were calculated for the typical "worst-case" meteorological conditions.

The AQAM short term program deals only with 1-hour time periods. The number of aircraft taking off during a 1-hour time period is multiplied by the particular pollutant concentration. The result is the 1-hour average pollutant concentration. For environmental assessments, the maximum number of planes taking off during a 1-hour time period should be used. The concentrations of all aircraft takeoffs during the same time period and at the same receptor are summed for the total centerline concentration at the receptor point.

The centerline concentrations calculated assume a straight climbout and represent the highest ambient pollution concentrations. Pollution concentrations will decrease rapidly from either side of the runway centerline. Special fighter climbout procedures are not simulated by the AQAM program; however, the pollution concentration would be lower than the straight climbout now being simulated by AQAM because of the steeper climbout angles used by fighters and trainers.



RUNWAY CENTERLINE CONCENTRATIONS

FIGURE 3.

1. Example 8: Base X has a town lying on the runway centerline 20 km from the start of runway roll. What are the NO_x concentrations resulting from the following 0800-0900 recorded maximum operations?

Solution:

Departures:

T-37 = 14, T-38 = 10

Using Appendix B for a quick estimate:

T-37 NO_x Concentration at 20 km = .01μg/m^3

T-38 NO_x Concentration at 20 km = .02μg/m^3

Mutiply each concentration by the number of departures:

T-37 = .01 μg/m^3 x 14 departures = .14 μg/m^3

T-38 = .02 μg/m^3 x 10 departures = .2 μg/m^3

Adding the concentrations:

Total NO_x at 20 km = .14 μg/m^3 + .2 μg/m^3 = .34 μg/n^3

NOTE: The value 0.00 indicates that the centerline concentrations are less than 0.005 μg/m^3.

SECTION V

DATA ANALYSIS

This handbook is not a final analytical tool. Rather, it is a screening device to determine the possibility of an air quality problem resulting from aircraft operations. Any indication of possible aircraft pollution problems will have to be examined more thoroughly using an analytical model such as AQAM. A more comprehensive air quality examination will either confirm or reject the possibility of an adverse impact of aircraft on the air quality.

A. EMISSIONS ANALYSIS

The annual aircraft emissions can be employed to make crude air-quality analyses. The annual aircraft emissions can be compared with other base or off-base sources to determine aircraft contributors. A survey of most major United States airports indicated that the average aircraft annual emissions did not exceed 2 percent of the total source emissions (Reference 11). The 2 percent aircraft emissions can be used as a guide if the if the base is located in a major urban area. However, this figure is not valid for areas where the base is only major source.

Base aircraft operations resulting in annual emissions in excess of 226,796 kg (226.8 metric tons) of any one pollutant per year should be investigated more closely. The EPA defines this figure as a major source, and the possibility of an aircraft-related air pollution problem could exist if it is exceeded. Any conclusions made concerning aircraft impacts should use the air quality data. Emissions data do not give any information about the dispersion of pollutants in the atmosphere.

B. SHORT-TERM AIR QUALITY ANALYSIS

The downfield ambient air quality can be estimated for 1-hour periods by using this book. The calculated results represent the maximum air pollution concentration from an aircraft takeoff and climbout. The Gaussian dispersion model does not predict reactive pollutant concentrations, like oxidants. However, hydrocarbons and NOx are the main contributors to the formation of oxidants. The downfield hydrocarbons presented in Appendix B are for future reference when hydrocarbon pollution is better understood.

The centerline concentration tables (Appendix B) are based on 1-hour "worst-case" meteorological conditions. The AQAM Short term program uses special 1-hour wind-averaging schemes. An attempt to predict the air quality for more than a 1-hour time period is invalid without special correction factors. The tables assume a "straight-out" climb path.

The 1-hour pollutant concentrations can be compared with the "worst-case" National Ambient Air Quality Standards (NAAQS) to provide a point of reference. The NAAQS are described in terms of annual average concentrations, or concentrations not to exceed more than once per year. The predicted concentrations can be easily compared with NAAQS by using EPA's Pollution Standards Index (PSI). The PSI normalizes all pollutants on a scale of 0-500 according to the short-term NAAQS and health effects. Thus, all pollutants can be compared at the time. The 5 km point is probably the best to use when determining the overall impact of aircraft on air quality. The centerline pollutant concentrations 6 km to 35 km can be used to determine aircraft air quality impact offbase.

Any pollutant concentration exceeding 50 percent of the 1-hour NAAQS* should be examined more closely using AQAM or other techniques. An AQAM analysis would use specific meteorological conditions for the base. AQAM simulates all specific base aircraft operations and gives a much more detailed analysis of pollutant concentrations. If aircraft air pollution concentrations are below 50 percent of the "worst-case" 1-hour standards, the base aircraft operations have little adverse effect on air quality and further analysis is not required.

C. COMPARISON WITH STANDARDS

Pollution concentration calculated with this handbook represent the "worst-case," and can be compared with the National Primary standards. These "worst-case" concentrations can be directly compared to "not to exceed more than once a year" standards. A power law is required to convert 1-hour averages to 24- or 8-hour average concentrations. The following power law is used in the "Workbook of Atmospheric Dispersion Estimates" (Reference 9):

$$X_b = X_k \left(\frac{t_k}{t_b} \right)^p \qquad (3)$$

X_b - Desired concentration for sampling time, t_b
X_k - Concentration for shorter sampling time, t_k
p - Between 0.17 and 0.2

The Pollution Standards Index (PSI) and EPA Report 450/2-76-013 (Reference 10) can facilitate evaluating effects of aircraft on air quality. Every pollutant can be normalized using the PSI scale, and therefore, can be compared directly. Problem pollutants can be identified directly.

*Special attention should be given to state and local air pollution standards where applicable.

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SECTION VI

EXAMPLE APPLICATION

Super Air Force Base is a UPT training base. An environmental assessment must be made for increased number of training missions to be flown the next fiscal year. The downfield pollution concentrations must also be determined for Home City. Home City is citing the base for its Carbon Monoxide (CO) concentrations during the morning missions.

The increase in aircraft operations is as follows:

	Increased LTOs (per year)	Increased TGOs (per year)
T-37	1,500	250
T-38	1,000	200

These increased T-38 LTOs will result in a 5-minute queue delay before takeoff.

A. STEP 1 - CURRENT AIRCRAFT OPERATIONS

From base operations, the following operational data were collected for the current fiscal year.

	LTOs (per year)	TGOs (per year)
T-37	15,000	2895
T-38	16,525	2982

B. STEP 2 - MODIFY EMISSIONS FOR THE QUEUING

Since every item in the LTO cycle compared favorably with the time in mode, the LTO cycle in Appendix A is used. The only emissions that have to be added are the queue time.

1. Engine - J85-5

   N = 2

2. Engine Mode -Idle

   t = 5 min = 300s

3. F(Idle) = 0.057 Kg/s

4. $W = N\ Ft$

$W\ (CO) = 2\ (0.57)\ (300)\ (178.0) = 6087.6g = 6.1 \times 10^{-3}$ Metric Tons

$W\ (HC) = 2\ (0.057)\ (300)\ (30.0) = 1026.0g - 1.0 \times 10^{-3}$ Metric Tons

$W\ (NOx) = 2\ (0.057)\ (300)\ (1.3) = 44.46g = 4.45 \times 10^{-5}$ Metric Tons

$W\ (PM) = 2\ (0.057)\ (300)\ (0.003) = .1026g = 1.0 \times 10^{-5}$ Metric Tons

$W\ (SOx) = 2\ (0.057)\ (300)\ (1.0) = 34.2g = 3.4 \times 10^{-5}$ Metric Tons

5. From Table A-17

$W\ (CO) = 4.0 \times 10^{-2}$ Metric Tons

$W\ (HC) = 6.1 \times 10^{-3}$ Metric Tons

$W\ (NOx) = 6.0 \times 10^{-4}$ Metric Tons

$W\ (PM) = 2.3 \times 10^{-6}$ Metric Tons

$W\ (SOx) = 3.5 \times 10^{-4}$ Metric Tons

6. Modified LTO Emissions

$W\ (CO) = 4.0 \times 10^{-2} + 6.1 \times 10^{-3} = 4.6 \times 10^{-2}$ Metric Tons

$W\ (HC) = 6.1 \times 10^{-3} + 1.0 \times 10^{-3} = 7.1 \times 10^{-3}$ Metric Tons

$W\ (NOx) = 6.0 \times 10^{-4} + 4.45 \times 10^{-5} = 6.4 \times 10^{-4}$ Metric Tons

$W\ (PM) = 2.3 \times 10^{-6} + 1.0 \times 10^{-7} = 2.4 \times 10^{-6}$ Metric Tons

$W\ (SOx) = 3.5 \times 10^{-4} + 3.4 \times 10^{-5} = 3.8 \times 10^{-4}$ Metric Tons

C. STEP 3 - Calculate Annual Pollutant Emissions

Calculate the annual pollutant emissions by multiplying the total number of annual LTOs and TGOs by the emissions from one operation.

1. T-38

a. LTO (Emissions from Step 2)

$W(CO) = (16525 + 1000) \times 4.6 \times 10^{-2} = 806.15$ Metric Tons
$W(HC) = (16525 + 1000) \times 7.1 \times 10^{-3} = 124.43$ Metric Tons
$W(NOx) = (16525 + 1000) \times 6.4 \times 10^{-4} = 11.22$ Metric Tons
$W(PM) = (16525 + 1000) \times 2.4 \times 10^{-6} = 0.04$ Metric Tons
$W(SOx) = (16525 + 1000) \times 3.8 \times 10^{-4} = 6.66$ Metric Tons

b. TGO (Emissions from Table A-17)

$W(CO) = (2982 + 200) \times 3.9 \times 10^{-3} = 12.41$ Metric Tons
$W(HC) = (2982 + 200) \times 2.1 \times 10^{-4} = 0.67$ Metric Tons
$W(Nox) = (2982 + 200) \times 2.5 \times 10^{-4} = 0.80$ Metric Tons
$W(PM) = (2982 + 200) \times 1.3 \times 10^{-6} = 4.14 \times 10^{-3}$ Metric Tons
$W(SOx) = (2982 + 200) \times 1.1 \times 10^{-4} = 0.35$ Metric Tons

2. T-37

a. LTO (Emissions from Table A-17)

$W(CO) = (15000 + 1500) \times 1.5 \times 10^{-2} = 247.5$ Metric Tons
$W(HC) = (15000 + 1500) \times 2.0 \times 10^{-3} = 33.0$ Metric Tons
$W(NOx) = (15000 + 1500) \times 3.0 \times 10^{-4} = 4.95$ Metric Tons
$W(PM) = (15000 + 1500) \times 5.6 \times 10^{-5} = 0.92$ Metric Tons
$W(SOx) = (15000 + 1500) \times 1.4 \times 10^{-4} = 2.31$ Metric Tons

b. TGO (Emissions from Table A-17)

$W(CO) = (2895 + 250) \times 2.1 \times 10^{-3} = 6.60$ Metric Tons
$W(HC) = (2895 + 250) \times 1.4 \times 10^{-4} = 0.44$ Metric Tons
$W(NOx) = (2895 + 250) \times 1.1 \times 10^{-4} = 0.35$ Metric Tons
$W(PM) = (2895 + 250) \times 3.8 \times 10^{-6} = 1.20 \times 10^{-2}$ Metric Tons
$W(SOx) = (2895 + 250) \times 3.8 \times 10^{-5} = 0.12$ Metric Tons

3. TOTAL PROJECTED EMISSIONS

W(CO) = 806.15 + 12.41 + 247.5 + 6.60 = 1072.66 Metric Tons
W(HC) = 124.43 + 0.67 + 33.0 + 0.44 = 158.54 Metric Tons
W(NOx) = 11.22 + 0.80 + 4.95 + 0.35 = 17.32 Metric Tons
W(PM) = 0.04 + 4.14 x 10^{-3} + 0.92 + 1.20 x 10^{-2} = 0.98 Metric Tons
W(SOx)= 6.66 + 0.35 + 2.31 + 0.12 = 9.44 Metric Tons

Annual Emissions of Carbon Monoxide exceed 226.8 metric tons. Therefore, additional analysis would be required, and could include a comparison with base, local, and regional emission inventions.

D. STEP 4-AIR QUALITY ANALYSIS

A check of aircraft operations records shows that the maximum number of LTOs during a 1 hour period is 22, and includes 10 T-37s and 12 T-38s. Home City is located 15 km downfield from the start of runway roll.

The information in Appendix B indicates that CO concentrations, 30km downfield are:

T-37 - 0.66 ug/m^3
T-38 - 1.80 ug/m^3

Multiplying by the number of LTOs =

T-37 - 0.66 ug/m^3 x 10 = 6.6 ug/m^3

T-38 - 1.80 ug/m^3 x 12 = 21.6 ug/m^3

Therefore:

Total CO at 15 km = 6.6 ug/m^3 + 21.6 ug/m^3 = 28.2 ug/m^3

The 17 km "worst-case" CO concentration is 28.2 ug/m^3 or 0.028mg/m^3. The primary and secondary NAAQs for CO are 40mg/m^3 maximum 1 hour concentrations not to be exceeded more than once per year. The computation is far less than the primary and secondary NAAQS for CO, and aircraft contributions are negligible over Home City.

SECTION VII

RELATED PUBLICATIONS

A. AIR QUALITY ASSESSMENT PROCEDURES

ESL-TR-82-33, "Air Quality Procedures for Civilian Airports and Air Force Bases," was developed to serve as a guide for environmental quality personnel who perform air quality assessments. A series of flow diagrams identifies the important agencies in the assessment process, and also what data and methodologies could be used. Step-by-step descriptions of the air quality assessment process, including state requirements are discussed.

This handbook should be consulted prior to performing an emission inventory to ensure that correct procedures are used.

B. AIRCRAFT GENERATION EQUIPMENT EMISSIONS

Emissions estimates from aircraft generation equipment (ground support equipment) can be obtained by using ESL-TR-83-48, "Aircraft Generation Equipment Emisisons Estimator." Emissions factors and the required equations are provided, along with examples which illustrate how to perform the calculations.

C. THE AIR QUALITY ASSESSMENT MODEL

The Air Quality Assessment Model (AQAM) computer program is used by the U.S. Air Force to estimate air pollution concentrations resulting from air installation activities. This complex air quality dispersion model considers every major air pollution source on an airbase. Four major components comprise AQAM: the edit program, the source inventory, the short-term dispersion program, and the plot program. The edit program detects errors in the AQAM input data and ensures input correctness before AQAM is executed. The source inventory identifies the location, emission rate, and pollutant type for every pollutant source. The short-term dispersion program calculates the resultant pollutant levels at various receptor points as a function of meteorological conditions. The plot program displays the output results of AQAM in a clear format.

The following documents are recommended for further information about AQAM:

1. AFWL-TR-74-279, <u>USAF Aircraft Takeoff Length Distances and Climbout Profiles</u>.

2. AFWL-TR-74-304, A Generalized Air Quality Assessment Model for Air Force Operations.

3. AFWL-TR-75-307, Air Quality Assessment Model Data Reduction and Operations Guide.

4. CEEDO-TR-76-33, Air Quality Assessment Model for Air Force Operations - Source Emissions Inventory Computer Code Documentation.

5. CEEDO-TR-76-34, Air Quality Assessment Model for Air Force Operations - Short-Term Emission/Dispersion Computer Code Documentation.

6. Draft Technical Report, Air Quality Assessment Model Data Collection Guide.

7. ESL-TR-81-60, Development of a Computer Emission Inventory Routine for Aircraft Ground Support Equipment, Volumes I and II.

8. ESL-TR-83-40, Technology Transfer of the Air Quality Assessment Model.

SECTION VIII

CONCLUSIONS

This handbook is a preliminary screening procedure to determine the impact of aircraft on ambient air quality. It is not site-specific and can be used at any USAF base. Contained within the report is all the information required to perform a preliminary air quality impact analysis including: (1) present Air Force aircraft, (2) engine emissions factors, (3) LTO and TGO cycle emissions, and (4) aircraft downfield dispersion data.

Procedures and examples to guide environmental personnel in making preliminary aircraft impact analyses are provided. These include (1) calculating annual aircraft emissions and (2) estimating the 1 hour "worst-case" ground-level air pollution concentrations resulting from an aircraft LTO cycle. The analysis guidelines within the report show that either: (1) aircraft pollution impact is negligible, or (2) an aircraft air pollution problem is possible. In the latter case, a more detailed analysis using AQAM or other techniques would be required.

This handbook enables environmental personnel to conduct a preliminary impact analysis of aircraft operations on local air quality. The analysis can be performed at base-level, saving time, manpower, and money. Calculations performed using this information do not predict an aircraft air problem, but could indicate the possibility of one.

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APPENDIX A

LTO AND TGO AIRCRAFT EMISSIONS

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TABLE A-1. A-7 AND A-10 LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

A 7

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	1.36E-02	1.05E-02	1.72E-04	1.72E-05	1.14E-04
TAXI OUT	5.73E-03	4.43E-03	7.23E-05	7.23E-06	4.82E-05
ENGINE CHECK	2.29E-04	2.55E-05	2.67E-03	8.53E-05	1.27E-04
RUNWAY ROLL	4.04E-05	4.49E-06	4.71E-04	1.50E-05	2.24E-05
CLIMB 1	9.92E-05	1.10E-05	1.16E-03	3.69E-05	5.51E-05
CLIMB 2	3.76E-07	4.18E-08	4.39E-06	1.40E-07	2.09E-07
APPROACH 1	5.14E-04	1.11E-04	3.43E-04	1.81E-05	5.04E-05
APPROACH 2	1.91E-04	4.11E-05	1.27E-04	6.73E-06	1.87E-05
LANDING	1.21E-03	9.32E-04	1.52E-05	1.52E-06	1.01E-05
TAXI IN	5.56E-03	4.30E-03	7.01E-05	7.01E-06	4.67E-05
SHUTDOWN	2.72E-03	2.11E-03	3.43E-05	3.43E-06	2.29E-05
TOTAL	3.0E-02	2.2E-02	5.1E-03	2.0E-04	5.2E-04
TOUCH + GO	8.3E-04	1.8E-04	1.7E-03	6.4E-05	1.3E-04

A 10

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	6.25E-03	1.89E-03	1.18E-04	2.36E-06	5.90E-05
TAXI OUT	4.51E-03	1.36E-03	8.50E-05	1.70E-06	4.25E-05
ENGINE CHECK	2.67E-05	1.16E-06	1.16E-04	5.81E-07	1.16E-05
RUNWAY ROLL	2.43E-05	1.06E-06	1.06E-04	5.28E-07	1.06E-05
CLIMB 1	9.35E-05	4.06E-06	4.06E-04	2.03E-06	4.06E-05
CLIMB 2	8.90E-07	3.87E-08	3.87E-06	1.93E-08	3.87E-07
APPROACH 1	4.97E-04	3.59E-05	3.47E-04	1.20E-06	5.99E-05
APPROACH 2	2.53E-04	1.83E-05	1.77E-04	6.10E-07	3.05E-05
LANDING	9.77E-04	2.95E-04	1.84E-05	3.69E-07	9.22E-06
TAXI IN	4.37E-03	1.32E-03	8.24E-05	1.65E-06	4.12E-05
SHUTDOWN	3.13E-03	9.43E-04	5.90E-05	1.18E-06	2.95E-05
TOTAL	2.0E-02	5.9E-03	1.5E-03	1.2E-05	3.3E-04
TOUCH + GO	8.7E-04	6.3E-05	9.6E-04	4.0E-06	1.3E-04

TABLE A-2. B-52D/F LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

B 52D/F

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	3.81E-02	3.39E-02	3.91E-03	5.44E-04	9.41E-04
TAXI OUT	7.42E-02	6.60E-02	7.61E-03	1.06E-03	1.83E-03
ENGINE CHECK	3.81E-02	3.39E-02	3.91E-03	5.44E-04	9.41E-04
RUNWAY ROLL	5.60E-04	2.95E-05	3.24E-03	5.07E-04	2.95E-04
CLIMB 1	6.13E-04	3.23E-05	3.55E-03	5.55E-04	3.23E-04
CLIMB 2	5.77E-04	3.57E-05	3.92E-03	6.13E-04	3.57E-04
APPROACH 1	4.81E-03	8.53E-04	3.53E-03	5.67E-04	6.09E-04
APPROACH 2	1.61E-03	2.85E-04	1.16E-03	1.89E-04	2.04E-04
LANDING	5.44E-03	5.31E-03	1.52E-04	1.10E-05	6.89E-05
TAXI IN	4.29E-02	4.18E-02	1.19E-03	8.68E-05	5.43E-04
SHUTDOWN	1.09E-02	1.06E-02	3.03E-04	2.21E-05	1.38E-04
TOTAL	2.2E-01	1.9E-01	3.3E-02	4.7E-03	6.3E-03
TOUCH + GO	7.8E-03	1.3E-03	1.2E-02	2.0E-03	1.5E-03

TABLE A-3. B-52H LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

B 52 H

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	4.57E-02	5.82E-02	9.80E-04	1.25E-04	5.44E-04
TAXI OUT	8.91E-02	1.13E-01	1.91E-03	2.44E-04	1.06E-03
ENGINE CHECK	4.57E-02	5.82E-02	9.80E-04	1.25E-04	5.44E-04
RUNWAY ROLL	4.98E-04	1.76E-04	2.93E-03	5.07E-04	2.93E-04
CLIMB 1	5.46E-04	1.93E-04	3.21E-03	5.56E-04	3.21E-04
CLIMB 2	6.03E-04	2.13E-04	3.55E-03	6.14E-04	3.55E-04
APPROACH 1	4.32E-03	1.78E-03	3.97E-03	6.78E-04	6.85E-04
APPROACH 2	1.44E-03	5.95E-04	1.33E-03	2.27E-04	2.29E-04
LANDING	5.48E-03	6.99E-03	1.18E-04	1.50E-05	6.53E-05
TAXI IN	3.24E-02	4.13E-02	6.94E-04	8.87E-05	3.86E-04
SHUTDOWN	8.23E-03	1.05E-02	1.76E-04	2.25E-05	9.80E-05
TOTAL	2.3E-01	2.9E-01	2.0E-02	3.2E-03	4.6E-03
TOUCH + GO	7.0E-03	2.9E-03	1.2E-02	2.1E-03	1.6E-03

TABLE A-4. C-5A AND C-5LS LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

C 5A

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	2.30E-02	7.88E-03	1.03E-03	5.14E-06	3.43E-04
TAXI OUT	3.37E-02	1.16E-02	1.51E-03	7.56E-06	5.04E-04
ENGINE CHECK	2.69E-05	7.67E-06	1.07E-03	9.59E-07	3.84E-05
RUNWAY ROLL	2.98E-04	8.51E-05	1.19E-02	1.06E-05	4.26E-04
CLIMB 1	1.42E-04	4.05E-05	5.67E-03	5.06E-06	2.02E-04
CLIMB 2	1.55E-04	4.42E-05	6.19E-03	5.53E-06	2.21E-04
APPROACH 1	3.69E-03	1.24E-03	3.67E-04	1.51E-06	9.41E-05
APPROACH 2	2.33E-03	7.83E-04	2.31E-04	9.49E-07	5.93E-05
LANDING	3.49E-03	1.20E-03	1.56E-04	7.82E-07	5.21E-05
TAXI IN	3.27E-02	1.12E-02	1.47E-03	7.33E-06	4.88E-04
SHUTDOWN	4.59E-03	1.58E-03	2.06E-04	1.03E-06	6.85E-05
TOTAL	1.0E-01	3.6E-02	3.0E-02	4.6E-05	2.5E-03
TOUCH + GO	6.4E-03	2.1E-03	1.3E-02	1.4E-05	6.0E-04

C-5 LS

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	5.14E-03	1.54E-03	3.60E-04	4.11E-06	1.03E-04
TAXI OUT	2.52E-02	7.56E-03	1.76E-03	2.02E-05	5.04E-04
ENGINE CHECK	1.92E-05	3.84E-06	1.53E-03	1.53E-06	3.84E-05
RUNWAY ROLL	1.09E-04	2.18E-05	8.73E-03	8.73E-06	2.18E-04
CLIMB 1	9.38E-05	1.88E-05	7.51E-03	7.51E-06	1.88E-04
CLIMB 2	9.69E-05	1.94E-05	7.75E-03	7.75E-06	1.94E-04
APPROACH 1	5.51E-03	1.65E-03	5.24E-04	4.55E-06	1.14E-04
APPROACH 2	3.35E-03	1.00E-03	3.18E-04	2.77E-06	6.92E-05
LANDING	2.61E-03	7.82E-04	1.83E-04	2.09E-06	5.21E-05
TAXI IN	2.44E-02	7.33E-03	1.71E-03	1.96E-05	4.89E-04
SHUTDOWN	3.43E-03	1.03E-03	2.40E-04	2.74E-06	6.86E-05
TOTAL	7.0E-02	2.1E-02	3.1E-02	8.2E-05	2.0E-03
TOUCH + GO	9.1E-03	2.7E-03	1.7E-02	2.3E-05	5.9E-04

TABLE A-5. C-9A LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

C 9A

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	2.32E-03	4.45E-04	9.28E-05	2.78E-05	4.64E-05
TAXI OUT	5.21E-03	1.00E-03	2.09E-04	6.26E-05	1.04E-04
ENGINE CHECK	1.59E-05	7.94E-06	5.69E-05	3.31E-05	1.32E-05
RUNWAY ROLL	1.31E-04	6.56E-05	4.70E-04	2.73E-04	1.09E-04
CLIMB 1	1.15E-04	5.77E-05	4.13E-04	2.40E-04	9.61E-05
CLIMB 2	1.23E-04	6.17E-05	4.42E-04	2.57E-04	1.03E-04
APPROACH 1	3.12E-03	6.01E-04	1.42E-04	5.27E-05	6.75E-05
APPROACH 2	1.62E-03	3.11E-04	7.34E-05	2.73E-05	3.50E-05
LANDING	1.10E-03	2.10E-04	4.38E-05	1.31E-05	2.19E-05
TAXI IN	5.06E-03	9.71E-04	2.02E-04	6.07E-05	1.01E-04
SHUTDOWN	2.17E-04	4.18E-05	8.70E-06	2.61E-06	4.35E-06
TOTAL	1.9E-02	3.8E-03	2.2E-03	1.1E-03	7.0E-04
TOUCH + GO	5.0E-03	1.0E-03	1.1E-03	6.0E-04	3.1E-04

TABLE A-6. C-130A-G AND C-130H LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

C 130

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	1.96E-03	1.29E-03	2.39E-04	5.10E-05	6.14E-05
TAXI OUT	1.93E-02	1.27E-02	2.35E-03	5.00E-04	6.03E-04
ENGINE CHECK	6.25E-04	1.19E-04	2.77E-03	1.49E-04	2.97E-04
RUNWAY ROLL	1.19E-04	2.27E-05	5.28E-04	2.84E-05	5.68E-05
CLIMB 1	9.47E-05	1.80E-05	4.19E-04	2.25E-05	4.51E-05
CLIMB 2	8.78E-05	1.67E-05	3.89E-04	2.09E-05	4.18E-05
APPROACH 1	1.75E-03	9.79E-04	3.47E-04	7.66E-05	7.90E-05
APPROACH 2	9.03E-04	5.04E-04	1.79E-04	3.95E-05	4.07E-05
LANDING	1.34E-03	8.79E-04	1.63E-04	3.47E-05	4.19E-05
TAXI IN	1.87E-02	1.23E-02	2.28E-03	4.85E-04	5.85E-04
SHUTDOWN	1.75E-03	1.15E-03	2.14E-04	4.55E-05	5.48E-05
TOTAL	4.7E-02	3.0E-02	9.9E-03	1.5E-03	1.9E-03
TOUCH + GO	2.9E-03	1.5E-03	1.4E-03	1.6E-04	2.1E-04

C130 H

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	7.56E-04	6.30E-04	1.00E-04	1.59E-05	4.17E-05
TAXI OUT	7.42E-03	6.19E-03	9.84E-04	1.56E-04	4.10E-04
ENGINE CHECK	5.79E-04	7.23E-05	4.23E-03	2.57E-04	3.62E-04
RUNWAY ROLL	1.10E-04	1.38E-05	8.07E-04	4.90E-05	6.90E-05
CLIMB 1	8.77E-05	1.10E-05	6.41E-04	3.89E-05	5.48E-05
CLIMB 2	8.14E-05	1.02E-05	5.95E-04	3.61E-05	5.09E-05
APPROACH 1	6.71E-04	2.69E-04	2.92E-04	3.71E-05	7.90E-05
APPROACH 2	3.46E-04	1.38E-04	1.51E-04	1.91E-05	4.07E-05
LANDING	5.15E-04	4.30E-04	6.83E-05	1.08E-05	2.85E-05
TAXI IN	7.20E-03	6.00E-03	9.54E-04	1.51E-04	3.98E-04
SHUTDOWN	6.75E-04	5.63E-04	8.94E-05	1.42E-05	3.73E-05
TOTAL	1.8E-02	1.4E-02	8.9E-03	7.8E-04	1.6E-03
TOUCH + GO	1.2E-03	4.4E-04	1.7E-03	1.3E-04	2.3E-04

TABLE A- 7. KC-135A AND C-135B LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

KC 135A

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	2.46E-02	2.00E-02	9.07E-04	4.91E-05	3.78E-04
TAXI OUT	4.32E-02	3.51E-02	1.59E-03	8.64E-05	6.64E-04
ENGINE CHECK	2.46E-02	2.00E-02	9.07E-04	4.91E-05	3.78E-04
RUNWAY ROLL	3.45E-04	2.88E-05	1.63E-03	1.21E-04	1.44E-04
CLIMB 1	4.05E-04	3.37E-05	1.91E-03	1.42E-04	1.69E-04
CLIMB 2	5.74E-04	4.79E-05	2.70E-03	2.01E-04	2.39E-04
APPROACH 1	5.74E-03	2.51E-03	5.83E-04	3.88E-05	1.77E-04
APPROACH 2	1.48E-03	6.48E-04	1.51E-04	1.00E-05	4.56E-05
LANDING	2.93E-03	2.39E-03	1.08E-04	5.67E-06	4.51E-05
TAXI IN	2.09E-02	1.70E-02	7.73E-04	4.19E-05	3.22E-04
SHUTDOWN	5.53E-03	4.50E-03	2.04E-04	1.11E-05	8.50E-05
TOTAL	1.3E-01	1.0E-01	1.1E-02	7.6E-04	2.6E-03
TOUCH + GO	8.3E-03	3.3E-03	5.5E-03	4.0E-04	6.4E-04

C 135B

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	4.57E-02	5.82E-02	9.80E-04	1.25E-04	5.44E-04
TAXI OUT	4.02E-02	5.12E-02	8.61E-04	1.10E-04	4.78E-04
ENGINE CHECK	9.56E-04	3.37E-04	5.62E-03	9.73E-04	5.62E-04
RUNWAY ROLL	2.30E-04	8.12E-05	1.35E-03	2.34E-04	1.35E-04
CLIMB 1	2.70E-04	9.52E-05	1.59E-03	2.75E-04	1.59E-04
CLIMB 2	3.83E-04	1.35E-04	2.25E-03	3.90E-04	2.25E-04
APPROACH 1	2.86E-03	1.32E-03	1.37E-03	2.23E-04	2.86E-04
APPROACH 2	7.40E-04	3.40E-04	3.55E-04	5.77E-05	7.40E-05
LANDING	2.73E-03	3.48E-03	5.85E-05	7.48E-06	3.25E-05
TAXI IN	3.90E-02	4.96E-02	8.35E-04	1.07E-04	4.64E-04
SHUTDOWN	1.03E-02	1.31E-02	2.20E-04	2.82E-05	1.22E-04
TOTAL	1.4E-01	1.8E-01	1.5E-02	2.5E-03	3.1E-03
TOUCH + GO	4.3E-03	1.9E-03	5.7E-03	9.6E-04	7.5E-04

TABLE A-8. C-14L LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

C 141

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	3.00E-02	2.48E-02	5.81E-04	3.55E-05	3.23E-04
TAXI OUT	2.83E-02	2.34E-02	5.47E-04	3.35E-05	3.04E-04
ENGINE CHECK	2.11E-05	7.90E-07	3.16E-04	2.40E-05	2.63E-05
RUNWAY ROLL	1.45E-04	5.45E-06	2.18E-03	1.65E-04	1.82E-04
CLIMB 1	1.11E-04	4.15E-06	1.66E-03	1.26E-04	1.38E-04
CLIMB 2	1.13E-04	4.23E-06	1.69E-03	1.28E-04	1.41E-04
APPROACH 1	1.96E-03	5.15E-04	5.43E-04	5.58E-05	1.43E-04
APPROACH 2	1.49E-03	3.91E-04	4.13E-04	4.24E-05	1.09E-04
LANDING	4.19E-03	3.47E-03	8.10E-05	4.95E-06	4.50E-05
TAXI IN	2.74E-02	2.27E-02	5.31E-04	3.24E-05	2.95E-04
SHUTDOWN	4.50E-03	3.73E-03	8.71E-05	5.32E-06	4.84E-05
TOTAL	9.8E-02	7.9E-02	8.6E-03	6.5E-04	1.8E-03
TOUCH + GO	3.7E-03	9.7E-04	4.5E-03	3.6E-04	5.5E-04

TABLE A-9. F-106 LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

F 106

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	8.07E-03	6.76E-03	2.16E-04	2.16E-05	9.39E-05
TAXI OUT	6.94E-03	5.81E-03	1.86E-04	1.86E-05	8.07E-05
ENGINE CHECK	2.54E-04	1.96E-05	2.35E-03	2.11E-04	1.96E-04
RUNWAY ROLL	5.94E-04	1.49E-06	4.62E-04	2.23E-05	1.49E-04
CLIMB 1	6.58E-04	1.64E-06	5.12E-04	2.47E-05	1.64E-04
CLIMB 2	3.79E-05	2.92E-06	3.50E-04	3.15E-05	2.92E-05
APPROACH 1	8.64E-04	2.57E-04	2.12E-04	2.17E-05	4.94E-05
APPROACH 2	3.20E-04	9.52E-05	7.87E-05	8.05E-06	1.83E-05
LANDING	1.13E-03	9.46E-04	3.02E-05	3.02E-06	1.31E-05
TAXI IN	6.73E-03	5.63E-03	1.80E-04	1.80E-05	7.82E-05
SHUTDOWN	2.02E-03	1.69E-03	5.40E-05	5.40E-06	2.35E-05
TOTAL	2.8E-02	2.1E-02	4.6E-03	3.9E-04	8.9E-04
TOUCH + GO	1.9E-03	3.7E-04	1.2E-03	9.1E-05	2.7E-04

TABLE A-10. F-4C/F AND F-4E LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

F 4-C/F

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	6.23E-03	1.31E-03	2.73E-04	5.47E-05	1.09E-04
TAXI OUT	6.15E-03	1.30E-03	2.70E-04	5.40E-05	1.08E-04
ENGINE CHECK	2.38E-04	2.16E-05	9.61E-04	2.38E-04	1.08E-04
RUNWAY ROLL	5.47E-04	1.37E-06	4.25E-04	2.05E-05	1.37E-04
CLIMB 1	7.74E-04	1.93E-06	6.02E-04	2.90E-05	1.93E-04
CLIMB 2	8.99E-05	8.17E-06	3.64E-04	8.99E-05	4.09E-05
APPROACH 1	9.32E-04	1.09E-04	4.76E-04	1.78E-04	9.91E-05
APPROACH 2	3.37E-04	3.94E-05	1.72E-04	6.45E-05	3.58E-05
LANDING	1.11E-03	2.34E-04	4.87E-05	9.74E-06	1.95E-05
TAXI IN	5.97E-03	1.26E-03	2.62E-04	5.23E-05	1.05E-04
SHUTDOWN	3.90E-04	8.20E-05	1.71E-05	3.42E-06	6.83E-06
TOTAL	2.3E-02	4.4E-03	3.9E-03	7.9E-04	9.6E-04
TOUCH + GO	2.2E-03	1.6E-04	1.7E-03	3.7E-04	3.8E-04

F 4 E

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	4.11E-03	9.23E-04	2.77E-04	2.36E-05	1.03E-04
TAXI OUT	4.06E-03	9.11E-04	2.73E-04	2.33E-05	1.01E-04
ENGINE CHECK	2.14E-04	7.13E-07	1.76E-03	2.64E-04	1.19E-04
RUNWAY ROLL	5.93E-04	1.48E-06	4.61E-04	2.22E-05	1.48E-04
CLIMB 1	8.39E-04	2.10E-06	6.52E-04	3.15E-05	2.10E-04
CLIMB 2	8.09E-05	2.70E-07	6.65E-04	9.98E-05	4.49E-05
APPROACH 1	2.75E-03	6.14E-04	5.45E-04	8.52E-05	9.91E-05
APPROACH 2	9.49E-04	2.12E-04	1.88E-04	2.95E-05	3.43E-05
LANDING	6.76E-04	1.52E-04	4.55E-05	3.88E-06	1.69E-05
TAXI IN	3.94E-03	8.84E-04	2.65E-04	2.26E-05	9.82E-05
SHUTDOWN	2.57E-04	5.77E-05	1.73E-05	1.47E-06	6.41E-06
TOTAL	1.8E-02	3.8E-03	5.1E-03	6.1E-04	9.8E-04
TOUCH + GO	4.6E-03	8.3E-04	2.1E-03	2.6E-04	3.9E-04

TABLE A-11. F-5 AND F-111A LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

F 5

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	6.31E-03	1.06E-03	4.61E-05	1.06E-07	3.55E-05
TAXI OUT	1.18E-02	1.99E-03	8.62E-05	1.99E-07	6.63E-05
ENGINE CHECK	8.31E-04	2.29E-05	7.45E-05	5.16E-07	2.87E-05
RUNWAY ROLL	1.92E-03	5.16E-06	1.47E-04	5.89E-07	7.37E-05
CLIMB 1	9.63E-04	2.59E-06	7.36E-05	2.96E-07	3.70E-05
CLIMB 2	5.55E-04	1.53E-05	4.98E-05	3.45E-07	1.91E-05
APPROACH 1	2.36E-03	2.05E-04	5.76E-05	2.24E-07	3.20E-05
APPROACH 2	3.54E-04	3.08E-05	8.67E-06	3.37E-08	4.81E-06
LANDING	1.77E-03	2.98E-04	1.29E-05	2.98E-08	9.92E-06
TAXI IN	1.14E-02	1.93E-03	8.36E-05	1.93E-07	6.43E-05
SHUTDOWN	8.33E-04	1.40E-04	6.08E-06	1.40E-08	4.68E-06
TOTAL	3.9E-02	5.7E-03	6.5E-04	2.5E-06	3.8E-04
TOUCH + GO	4.3E-03	2.6E-04	1.9E-04	9.3E-07	9.5E-05

F 111 A

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	5.74E-03	4.94E-03	1.83E-04	4.78E-07	7.97E-05
TAXI OUT	1.68E-02	1.44E-02	5.36E-04	1.40E-06	2.33E-04
ENGINE CHECK	1.04E-04	3.90E-06	1.56E-03	5.21E-05	1.30E-04
RUNWAY ROLL	1.21E-03	1.89E-06	1.70E-03	3.98E-04	1.89E-04
CLIMB 1	1.49E-03	2.32E-06	2.09E-03	4.88E-04	2.32E-04
CLIMB 2	2.23E-05	8.34E-07	3.34E-04	1.11E-05	2.78E-05
APPROACH 1	5.58E-04	1.27E-04	2.91E-04	3.03E-06	6.07E-05
APPROACH 2	2.05E-04	4.69E-05	1.07E-04	1.12E-06	2.23E-05
LANDING	1.26E-03	1.09E-03	4.03E-05	1.05E-07	1.75E-05
TAXI IN	1.63E-02	1.40E-02	5.19E-04	1.36E-06	2.26E-04
SHUTDOWN	1.20E-03	1.04E-03	3.84E-05	1.00E-07	1.67E-05
TOTAL	4.5E-02	3.6E-02	7.4E-03	9.6E-04	1.2E-03
TOUCH + GO	2.3E-03	1.9E-04	2.9E-03	5.0E-04	3.5E-04

TABLE A-12. F-111D/E AND F-111F LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

F111 D/E

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	4.27E-03	1.69E-03	2.58E-04	1.78E-06	8.89E-05
TAXI OUT	1.25E-02	4.93E-03	7.53E-04	5.19E-06	2.60E-04
ENGINE CHECK	1.34E-04	1.92E-05	5.38E-03	4.61E-05	1.92E-04
RUNWAY ROLL	1.06E-03	2.66E-06	8.28E-04	3.99E-05	2.66E-04
CLIMB 1	1.31E-03	3.27E-06	1.02E-03	4.90E-05	3.27E-04
CLIMB 2	2.87E-05	4.11E-06	1.15E-03	9.86E-06	4.11E-05
APPROACH 1	6.01E-04	1.64E-04	3.82E-04	4.85E-06	6.07E-05
APPROACH 2	2.07E-04	5.65E-05	1.32E-04	1.67E-06	2.09E-05
LANDING	8.20E-04	3.25E-04	4.95E-05	3.42E-07	1.71E-05
TAXI IN	1.21E-02	4.79E-03	7.30E-04	5.04E-06	2.52E-04
SHUTDOWN	8.94E-04	3.54E-04	5.40E-05	3.73E-07	1.86E-05
TOTAL	3.4E-02	1.2E-02	1.1E-02	1.6E-04	1.5E-03
TOUCH + GO	2.2E-03	2.3E-04	2.8E-03	6.7E-05	4.6E-04

F111 F

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	4.27E-03	1.69E-03	2.58E-04	1.78E-06	8.89E-05
TAXI OUT	1.25E-02	4.93E-03	7.53E-04	5.19E-06	2.60E-04
ENGINE CHECK	1.34E-04	1.92E-05	5.38E-03	4.61E-05	1.92E-04
RUNWAY ROLL	1.06E-03	2.66E-06	8.28E-04	3.99E-05	2.66E-04
CLIMB 1	1.31E-03	3.27E-06	1.02E-03	4.90E-05	3.27E-04
CLIMB 2	2.87E-05	4.11E-06	1.15E-03	9.86E-06	4.11E-05
APPROACH 1	6.01E-04	1.64E-04	3.82E-04	4.85E-06	6.07E-05
APPROACH 2	2.21E-04	6.02E-05	1.41E-04	1.79E-06	2.23E-05
LANDING	9.38E-04	3.71E-04	5.67E-05	3.91E-07	1.95E-05
TAXI IN	1.21E-02	4.79E-03	7.30E-04	5.04E-06	2.52E-04
SHUTDOWN	8.94E-04	3.54E-04	5.40E-05	3.73E-07	1.86E-05
TOTAL	3.4E-02	1.2E-02	1.1E-02	1.6E-04	1.5E-03
TOUCH + GO	2.2E-03	2.4E-04	2.9E-03	6.7E-05	4.6E-04

TABLE A-13. F-15 AND F-16 LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

F 15

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	3.86E-03	5.14E-04	5.30E-04	1.93E-05	1.61E-04
TAXI OUT	3.24E-03	4.32E-04	4.45E-04	1.62E-05	1.35E-04
ENGINE CHECK	1.76E-05	1.95E-06	5.27E-04	6.63E-06	1.95E-05
RUNWAY ROLL	5.57E-04	1.39E-06	4.33E-04	2.09E-05	1.39E-04
CLIMB 1	9.19E-04	2.30E-06	7.15E-04	3.45E-05	2.30E-04
CLIMB 2	4.12E-05	4.58E-06	1.24E-03	1.56E-05	4.58E-05
APPROACH 1	2.79E-04	9.15E-05	3.23E-04	1.30E-05	4.82E-05
APPROACH 2	1.62E-04	5.30E-05	1.87E-04	7.54E-06	2.79E-05
LANDING	5.86E-04	7.81E-05	8.06E-05	2.93E-06	2.44E-05
TAXI IN	3.14E-03	4.19E-04	4.32E-04	1.57E-05	1.31E-04
SHUTDOWN	1.29E-04	1.71E-05	1.77E-05	6.43E-07	5.36E-06
TOTAL	1.3E-02	1.6E-03	4.9E-03	1.5E-04	9.7E-04
TOUCH + GO	1.4E-03	1.5E-04	2.6E-03	7.3E-05	3.6E-04

F 16

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	4.11E-03	5.48E-04	5.66E-04	2.06E-05	1.71E-04
TAXI OUT	1.08E-03	1.44E-04	1.49E-04	5.40E-06	4.50E-05
ENGINE CHECK	2.32E-05	2.58E-06	6.95E-04	8.76E-06	2.58E-05
RUNWAY ROLL	4.72E-06	5.24E-07	1.41E-04	1.78E-06	5.24E-06
CLIMB 1	2.62E-05	2.91E-06	7.85E-04	9.89E-06	2.91E-05
CLIMB 2	3.70E-06	4.12E-07	1.11E-04	1.40E-06	4.12E-06
APPROACH 1	2.31E-05	7.56E-06	2.67E-05	1.07E-06	3.98E-06
APPROACH 2	1.19E-04	3.89E-05	1.37E-04	5.53E-06	2.05E-05
LANDING	3.46E-04	4.62E-05	4.76E-05	1.73E-06	1.44E-05
TAXI IN	1.05E-03	1.40E-04	1.44E-04	5.24E-06	4.37E-05
SHUTDOWN	3.09E-03	4.11E-04	4.24E-04	1.54E-05	1.29E-04
TOTAL	9.9E-03	1.3E-03	3.2E-03	7.7E-05	4.9E-04
TOUCH + GO	1.8E-04	5.1E-05	1.2E-03	1.9E-05	6.2E-05

TABLE A-14. O-2 LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

O 2

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	7.69E-03	1.32E-03	9.98E-06	5.44E-04	5.44E-06
TAXI OUT	3.33E-03	5.69E-04	4.32E-06	2.36E-04	2.36E-06
ENGINE CHECK	2.80E-03	6.12E-05	1.44E-05	5.44E-05	1.63E-06
RUNWAY ROLL	2.71E-04	5.93E-06	1.40E-06	5.27E-06	1.58E-07
CLIMB 1	8.29E-04	1.81E-05	4.27E-06	1.61E-05	4.83E-07
CLIMB 2	2.85E-03	6.23E-05	1.47E-05	5.54E-05	1.66E-06
APPROACH 1	2.70E-03	6.74E-05	1.57E-05	1.17E-04	1.71E-06
APPROACH 2	1.33E-03	3.32E-05	7.73E-06	5.75E-05	8.43E-07
LANDING	1.03E-03	1.76E-04	1.34E-06	7.28E-05	7.28E-07
TAXI IN	3.23E-03	5.52E-04	4.19E-06	2.28E-04	2.28E-06
SHUTDOWN	7.69E-04	1.32E-04	9.98E-07	5.44E-05	5.44E-07
TOTAL	2.7E-02	3.0E-03	7.9E-05	1.4E-03	1.8E-05
TOUCH + GO	7.9E-03	1.9E-04	4.3E-05	2.5E-04	4.8E-06

TABLE A-15. OV-10 LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

OV10

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	1.35E-03	4.20E-04	4.20E-04	2.15E-05	5.67E-05
TAXI OUT	6.19E-04	1.92E-04	1.92E-04	9.88E-06	2.60E-05
ENGINE CHECK	6.26E-05	1.63E-06	2.80E-04	1.93E-05	2.72E-05
RUNWAY ROLL	4.14E-06	1.08E-07	1.85E-05	1.28E-06	1.80E-06
CLIMB 1	1.87E-05	4.88E-07	8.37E-05	5.77E-06	8.13E-06
CLIMB 2	2.01E-05	5.26E-07	9.02E-05	6.22E-06	8.76E-06
APPROACH 1	3.28E-04	1.53E-05	1.62E-04	9.54E-06	1.91E-05
APPROACH 2	2.05E-04	9.52E-06	1.01E-04	5.95E-06	1.19E-05
LANDING	2.29E-04	7.13E-05	7.13E-05	3.66E-06	9.63E-06
TAXI IN	6.00E-04	1.86E-04	1.86E-04	9.58E-06	2.52E-05
SHUTDOWN	1.80E-04	5.59E-05	5.59E-05	2.87E-06	7.56E-06
TOTAL	3.6E-03	9.5E-04	1.7E-03	9.6E-05	2.0E-04
TOUCH + GO	5.8E-04	2.7E-05	4.5E-04	2.8E-05	4.9E-05

TABLE A-16. T-33 LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

T 33

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	2.88E-03	4.42E-04	3.40E-05	1.66E-05	2.27E-05
TAXI OUT	7.87E-03	1.21E-03	9.30E-05	4.53E-05	6.20E-05
ENGINE CHECK	3.92E-04	6.27E-06	4.51E-05	2.51E-07	1.25E-05
RUNWAY ROLL	4.99E-04	7.98E-06	5.74E-05	3.19E-07	1.60E-05
CLIMB 1	6.60E-04	1.05E-05	7.59E-05	4.22E-07	2.11E-05
CLIMB 2	1.30E-03	2.08E-05	1.50E-04	8.34E-07	4.17E-05
APPROACH 1	2.42E-03	1.86E-04	5.44E-05	1.63E-05	2.86E-05
APPROACH 2	2.01E-03	1.55E-04	4.52E-05	1.36E-05	2.38E-05
LANDING	1.94E-03	2.98E-04	2.29E-05	1.12E-05	1.53E-05
TAXI IN	7.64E-03	1.17E-03	9.02E-05	4.39E-05	6.01E-05
SHUTDOWN	4.61E-04	7.08E-05	5.44E-06	2.65E-06	3.63E-06
TOTAL	2.8E-02	3.6E-03	6.7E-04	1.5E-04	3.1E-04
TOUCH + GO	6.5E-03	3.8E-04	3.4E-04	3.1E-05	1.2E-04

TABLE A-17. T-37 AND T-38 LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

T 37

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	1.71E-03	2.52E-04	1.99E-05	7.30E-06	1.33E-05
TAXI OUT	4.72E-03	6.96E-04	5.49E-05	2.01E-05	3.66E-05
ENGINE CHECK	2.65E-04	4.14E-06	2.98E-05	1.66E-07	8.28E-06
RUNWAY ROLL	1.46E-04	2.28E-06	1.64E-05	9.10E-08	4.55E-06
CLIMB 1	2.73E-04	4.27E-06	3.07E-05	1.71E-07	8.54E-06
CLIMB 2	5.28E-04	8.25E-06	5.94E-05	3.30E-07	1.65E-05
APPROACH 1	1.03E-03	1.07E-04	1.64E-05	2.69E-06	9.62E-06
APPROACH 2	2.09E-04	2.17E-05	3.33E-06	5.48E-07	1.96E-06
LANDING	9.77E-04	1.44E-04	1.14E-05	4.17E-06	7.58E-06
TAXI IN	4.58E-03	6.75E-04	5.33E-05	1.95E-05	3.55E-05
SHUTDOWN	2.70E-04	3.98E-05	3.14E-06	1.15E-06	2.10E-06
TOTAL	1.5E-02	2.0E-03	3.0E-04	5.6E-05	1.4E-04
TOUCH + GO	2.1E-03	1.4E-04	1.1E-04	3.8E-06	3.8E-05

T 38

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	6.34E-03	1.07E-03	4.63E-05	1.07E-07	3.56E-05
TAXI OUT	1.31E-02	2.20E-03	9.55E-05	2.20E-07	7.34E-05
ENGINE CHECK	3.46E-04	9.54E-06	3.10E-05	2.15E-07	1.19E-05
RUNWAY ROLL	9.11E-04	2.45E-06	6.97E-05	2.80E-07	3.50E-05
CLIMB 1	9.63E-04	2.59E-06	7.36E-05	2.96E-07	3.70E-05
CLIMB 2	5.78E-04	1.59E-05	5.18E-05	3.59E-07	1.99E-05
APPROACH 1	2.04E-03	1.66E-04	1.09E-04	5.21E-07	4.74E-05
APPROACH 2	2.59E-04	2.11E-05	1.39E-05	6.63E-08	6.02E-06
LANDING	1.72E-03	2.90E-04	1.26E-05	2.90E-08	9.66E-06
TAXI IN	1.27E-02	2.14E-03	9.26E-05	2.14E-07	7.12E-05
SHUTDOWN	8.53E-04	1.44E-04	6.23E-06	1.44E-08	4.79E-06
TOTAL	4.0E-02	6.1E-03	6.0E-04	2.3E-06	3.5E-04
TOUCH + GO	3.9E-03	2.1E-04	2.5E-04	1.3E-06	1.1E-04

TABLE A-18. T-39 AND T-41 LTO AND TGO EMISSIONS

EMISSIONS BY AIRCRAFT TYPE
(METRIC TONS/LTO CYCLE)

T 39

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	1.13E-03	1.48E-04	2.42E-05	3.22E-07	1.61E-05
TAXI OUT	3.05E-03	4.01E-04	6.55E-05	8.73E-07	4.36E-05
ENGINE CHECK	1.49E-05	3.73E-07	1.72E-05	6.34E-07	3.73E-06
RUNWAY ROLL	3.56E-05	8.89E-07	4.09E-05	1.51E-06	8.89E-06
CLIMB 1	9.26E-05	2.31E-06	1.06E-04	3.93E-06	2.31E-05
CLIMB 2	1.05E-04	2.64E-06	1.21E-04	4.48E-06	2.64E-05
APPROACH 1	9.44E-04	1.05E-04	3.18E-05	5.61E-07	1.87E-05
APPROACH 2	2.91E-04	3.22E-05	9.79E-06	1.73E-07	5.76E-06
LANDING	7.53E-04	9.89E-05	1.61E-05	2.15E-07	1.08E-05
TAXI IN	2.96E-03	3.89E-04	6.35E-05	8.46E-07	4.23E-05
SHUTDOWN	1.47E-04	1.93E-05	3.15E-06	4.20E-08	2.10E-06
TOTAL	9.5E-03	1.2E-03	5.0E-04	1.4E-05	2.0E-04
TOUCH + GO	1.5E-03	1.4E-04	2.8E-04	9.6E-06	7.6E-05

T 41

OPERATION	CO	HC	NOX	PM	SOX
STARTUP	1.54E-03	2.63E-04	2.00E-06	1.09E-04	1.09E-06
TAXI OUT	1.67E-03	2.85E-04	2.16E-06	1.18E-04	1.18E-06
ENGINE CHECK	1.40E-03	3.06E-05	7.21E-06	2.72E-05	8.16E-07
RUNWAY ROLL	1.36E-04	2.97E-06	6.99E-07	2.64E-06	7.91E-08
CLIMB 1	2.16E-03	4.72E-05	1.11E-05	4.20E-05	1.26E-06
CLIMB 2	9.53E-04	2.08E-05	4.90E-06	1.85E-05	5.55E-07
APPROACH 1	2.70E-04	2.17E-05	7.68E-07	1.69E-05	1.84E-07
APPROACH 2	9.34E-04	7.50E-05	2.66E-06	5.84E-05	6.38E-07
LANDING	5.15E-04	8.80E-05	6.68E-07	3.64E-05	3.64E-07
TAXI IN	1.61E-03	2.76E-04	2.09E-06	1.14E-04	1.14E-06
SHUTDOWN	3.85E-04	6.58E-05	4.99E-07	2.72E-05	2.72E-07
TOTAL	1.2E-02	1.2E-03	3.5E-05	5.7E-04	7.6E-06
TOUCH + GO	4.4E-03	1.7E-04	2.0E-05	1.4E-04	2.7E-06

TABLE A-19. ONE B-1A LTO AND TGO EMISSIONS

NORMAL FLIGHT PROFILE

OPERATION	CO	HC	NOX	PM	SOX
Startup	3.4594 X E-2	7.2575 X E-3	2.1168 X E-3	2.6611 X E-5	6.0479 X E-4
Taxi Out	9.0065 X E-3	1.8895 X E-3	5.5111 X E-4	6.9282 X E-6	1.5746 X E-4
Runway Roll	1.9835 X E-2	4.4077 X E-5	3.9915 X E-3	4.1512 X E-5	7.9830 X E-4
Climb 1	1.4918 X E-2	3.3141 X E-5	1.7397 X E-2	1.8093 X E-4	3.4794 X E-3
Climb 2	5.2610 X E-4	7.5155 X E-5	2.4085 X E-3	5.0177 X E-6	1.0035 X E-4
Approach 1	5.7400 X E-3	3.0211 X E-4	1.3690 X E-3	1.0622 X E-5	2.3603 X E-4
Approach 2	2.6838 X E-3	2.8218 X E-4	9.1907 X E-4	7.5349 X E-6	1.6798 X E-4
Landing	2.2486 X E-3	4.7174 X E-4	1.3758 X E-4	1.7295 X E-6	3.9308 X E-5
Taxi In	8.0725 X E-3	1.6935 X E-3	4.9394 X E-4	6.2096 X E-6	1.4113 X E-4
Shutdown	8.6485 X E-3	1.8144 X E-3	5.2919 X E-4	6.6527 X E-6	1.5120 X E-4
Arr & Dep Sv	1.5226 X E-2	9.0200 X E-4	8.5000 X E-5	3.0100 X E-4	1.4000 X E-5
Fuel Venting	0.0	0.0	0.0	0.0	0.0
Fill & Spill	0.0	8.7030 X E-3	0.0	0.0	0.0
Touch & Go	7.1417 X E-2	8.3742 X E-4	2.2438 X E-2	2.0484 X E-4	3.9986 X E-3
TOTAL*	1.6352 X E-1	2.3591 X E-2	2.9999 X E-2	5.9475 X E-4	5.8899 X E-3

LOW NOISE FLIGHT PROFILE

OPERATION	CO	HC	NOX	PM	SOX
Startup	3.4594 X E-2	7.2575 X E-2	2.1168 X E-3	2.6611 X E-5	6.0479 X E-4
Taxi Out	9.0066 X E-2	1.8895 X E-2	5.5111 X E-4	6.9282 X E-6	1.5746 X E-4
Runway Roll	1.4369 X E-2	3.1932 X E-5	3.9915 X E-3	4.1512 X E-5	7.9830 X E-4
Climb 1	6.2629 X E-2	1.3917 X E-4	1.7397 X E-2	1.8093 X E-4	3.4794 X E-3
Climb 2	1.4050 X E-4	2.0071 X E-5	2.4085 X E-3	5.0177 X E-6	1.0035 X E-4
Approach 1	4.4847 X E-3	2.3603 X E-4	1.3690 X E-3	1.0622 X E-5	2.3603 X E-4
Approach 2	4.1082 X E-3	4.3194 X E-4	9.1907 X E-4	7.5349 X E-6	1.6798 X E-4
Landing	2.2486 X E-3	4.7169 X E-4	1.3758 X E-4	1.7295 X E-6	3.9308 X E-5
Taxi In	8.0724 X E-3	1.6935 X E-3	4.9394 X E-4	6.2096 X E-6	1.4113 X E-4
Shutdown	8.6485 X E-3	1.8144 X E-4	5.2919 X E-4	6.6527 X E-6	1.5120 X E-4
Arr & Dep Sv	1.5226 X E-2	9.0200 X E-4	8.5000 X E-5	3.0100 X E-4	1.4000 X E-5
Fuel Venting	0.0	0.0	0.0	0.0	0.0
Fill & Spill	0.0	0.0	0.0	0.0	0.0
Touch & Go	0.0	0.0	0.0	0.0	0.0
TOTAL*	2.4299 X E-1	4.6936 X E-2	4.9874 X E-2	9.7364 X E-4	7.6519 X E-3

* Total emission do not include emissions from touch and go

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APPENDIX B

DOWNFIELD POLLUTANT CONCENTRATIONS TABLES

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TABLE B-1. A-7 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT A 7 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	1.11	.82	.55	.02	.04
6	1.01	.75	.47	.02	.03
7	.98	.72	.41	.01	.03
8	.98	.73	.37	.01	.03
9	1.01	.76	.33	.01	.02
10	1.05	.79	.30	.01	.02
11	1.09	.82	.28	.01	.02
13	1.14	.86	.25	.01	.02
15	1.15	.87	.22	.01	.02
17	1.13	.86	.20	.01	.02
19	1.10	.84	.18	.01	.02
21	1.06	.81	.16	.01	.02
23	1.01	.77	.15	.01	.02
27	.92	.71	.13	.01	.01
31	.84	.64	.12	.01	.01
35	.77	.59	.10	.00	.01

TABLE B-2. A-10 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT A 10 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	.85	.25	.07	.00	.01
6	.78	.23	.06	.00	.01
7	.75	.22	.06	0.00	.01
8	.74	.22	.05	0.00	.01
9	.75	.22	.05	0.00	.01
10	.77	.23	.05	0.00	.01
11	.79	.24	.04	0.00	.01
13	.80	.24	.04	0.00	.01
15	.80	.24	.04	0.00	.01
17	.78	.23	.03	0.00	.01
19	.75	.22	.03	0.00	.01
21	.72	.22	.03	0.00	.01
23	.68	.21	.03	0.00	.01
27	.62	.19	.02	0.00	.01
31	.57	.17	.02	0.00	.01
35	.52	.16	.02	0.00	.01

TABLE B-3. B-52D/F WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT B 52D/F NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	15.00	13.52	2.12	.30	.40
6	13.64	12.30	1.85	.26	.36
7	12.77	11.53	1.67	.24	.33
8	12.19	11.02	1.54	.22	.31
9	11.79	10.67	1.44	.20	.30
10	11.47	10.40	1.36	.19	.28
11	11.19	10.14	1.30	.18	.27
13	10.61	9.64	1.19	.17	.26
15	10.02	9.10	1.10	.15	.24
17	9.43	8.57	1.02	.14	.22
19	8.86	8.05	.95	.13	.21
21	8.33	7.57	.89	.12	.20
23	7.85	7.13	.83	.12	.19
27	7.00	6.36	.74	.10	.17
31	6.30	5.73	.66	.09	.15
35	5.72	5.20	.60	.08	.13

TABLE B-4. B-52H WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT B 52 H NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	16.42	20.71	1.21	.19	.29
6	14.89	18.79	1.02	.16	.25
7	13.89	17.54	.90	.14	.23
8	13.22	16.71	.81	.13	.21
9	12.74	16.11	.74	.12	.20
10	12.37	15.65	.68	.11	.19
11	12.04	15.24	.64	.10	.18
13	11.40	14.43	.57	.09	.17
15	10.75	13.62	.52	.08	.16
17	10.11	12.82	.47	.07	.15
19	9.51	12.05	.43	.07	.14
21	8.94	11.33	.40	.06	.13
23	8.42	10.68	.37	.06	.12
27	7.52	9.53	.33	.05	.11
31	6.77	8.59	.29	.04	.10
35	6.15	7.80	.26	.04	.09

TABLE B-5. C-5 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT C 5 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	5.42	1.85	4.47	.01	.23
6	5.10	1.75	3.51	.00	.19
7	4.94	1.69	2.89	.00	.17
8	4.87	1.67	2.49	.00	.15
9	4.85	1.66	2.20	.00	.14
10	4.84	1.66	1.98	.00	.14
11	4.82	1.65	1.81	.00	.13
13	4.72	1.62	1.55	.00	.12
15	4.54	1.56	1.36	.00	.11
17	4.32	1.48	1.22	.00	.10
19	4.10	1.40	1.11	.00	.09
21	3.87	1.33	1.01	.00	.09
23	3.66	1.26	.93	.00	.08
27	3.28	1.13	.81	.00	.07
31	2.96	1.02	.71	.00	.07
35	2.70	.92	.64	.00	.06

TABLE B-6. C-9 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT C 9 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	1.09	.22	.20	.11	.06
6	.99	.20	.16	.09	.05
7	.93	.19	.14	.07	.04
8	.89	.18	.13	.06	.04
9	.86	.17	.11	.06	.04
10	.84	.17	.11	.05	.03
11	.82	.16	.10	.05	.03
13	.78	.15	.09	.04	.03
15	.73	.14	.08	.04	.03
17	.69	.14	.07	.03	.02
19	.64	.13	.06	.03	.02
21	.60	.12	.06	.03	.02
23	.57	.11	.05	.03	.02
27	.50	.10	.05	.02	.02
31	.45	.09	.04	.02	.02
35	.41	.08	.04	.02	.01

TABLE B-7. C-130A-E WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT C 130 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	2.96	1.88	.92	.11	.15
6	2.82	1.79	.81	.10	.14
7	2.73	1.75	.74	.09	.13
8	2.67	1.71	.69	.09	.12
9	2.62	1.68	.64	.08	.12
10	2.57	1.65	.61	.08	.11
11	2.51	1.62	.58	.08	.11
13	2.38	1.54	.52	.07	.10
15	2.23	1.44	.48	.07	.09
17	2.09	1.35	.44	.06	.08
19	1.95	1.26	.40	.06	.08
21	1.83	1.18	.37	.06	.07
23	1.71	1.11	.35	.05	.07
27	1.52	.98	.30	.05	.06
31	1.36	.88	.27	.04	.05
35	1.23	.79	.24	.04	.05

TABLE B-8. C-130H WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT C130 H NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	1.21	.91	1.03	.08	.14
6	1.14	.87	.88	.07	.12
7	1.10	.85	.77	.06	.11
8	1.07	.83	.70	.06	.10
9	1.05	.82	.64	.05	.10
10	1.03	.81	.59	.05	.09
11	1.00	.79	.55	.05	.09
13	.94	.75	.48	.04	.08
15	.89	.70	.43	.04	.07
17	.83	.66	.39	.03	.07
19	.77	.62	.36	.03	.06
21	.72	.58	.33	.03	.06
23	.68	.54	.30	.03	.05
27	.60	.48	.26	.02	.05
31	.54	.43	.23	.02	.04
35	.48	.39	.21	.02	.04

TABLE B-9. C-135B WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT C 135B NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	6.03	7.43	1.44	.24	.20
6	5.77	7.13	1.22	.21	.18
7	5.67	7.04	1.07	.18	.16
8	5.70	7.10	.96	.16	.15
9	5.80	7.24	.88	.15	.15
10	5.92	7.40	.81	.13	.14
11	6.01	7.53	.75	.12	.13
13	6.06	7.61	.67	.11	.13
15	5.96	7.49	.60	.10	.12
17	5.76	7.25	.54	.09	.11
19	5.52	6.95	.50	.08	.10
21	5.26	6.63	.46	.07	.10
23	5.00	6.31	.43	.07	.09
27	4.53	5.71	.37	.06	.08
31	4.11	5.18	.33	.05	.07
35	3.75	4.73	.30	.05	.07

TABLE B-10. C-141 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT C 141 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	4.81	3.90	.76	.06	.11
6	4.47	3.63	.64	.05	.10
7	4.31	3.51	.55	.04	.09
8	4.26	3.47	.49	.04	.08
9	4.27	3.49	.45	.03	.08
10	4.30	3.52	.41	.03	.08
11	4.33	3.54	.38	.03	.07
13	4.30	3.52	.34	.03	.07
15	4.18	3.43	.30	.02	.07
17	4.02	3.30	.28	.02	.06
19	3.83	3.15	.25	.02	.06
21	3.64	2.99	.23	.02	.05
23	3.46	2.84	.22	.02	.05
27	3.11	2.56	.19	.01	.05
31	2.82	2.32	.17	.01	.04
35	2.57	2.11	.15	.01	.04

TABLE B-11. F-4C-D WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT F 4 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	1.31	.23	.34	.06	.08
6	1.19	.21	.29	.05	.07
7	1.12	.21	.26	.04	.06
8	1.08	.20	.23	.04	.06
9	1.06	.20	.21	.04	.05
10	1.05	.20	.20	.03	.05
11	1.04	.20	.18	.03	.05
13	1.01	.20	.16	.03	.04
15	.97	.19	.15	.03	.04
17	.93	.18	.13	.02	.04
19	.88	.17	.12	.02	.03
21	.83	.16	.11	.02	.03
23	.78	.16	.11	.02	.03
27	.70	.14	.09	.02	.02
31	.63	.13	.08	.02	.02
35	.57	.11	.07	.01	.02

TABLE B-12. F-4E WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT F 4 E NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	.99	.17	.48	.05	.09
6	.89	.16	.41	.05	.07
7	.83	.15	.36	.04	.06
8	.80	.15	.32	.04	.06
9	.78	.15	.29	.03	.05
10	.76	.15	.27	.03	.05
11	.75	.15	.25	.03	.05
13	.72	.14	.22	.03	.04
15	.69	.14	.20	.02	.04
17	.65	.13	.18	.02	.04
19	.62	.13	.16	.02	.03
21	.58	.12	.15	.02	.03
23	.55	.11	.14	.02	.03
27	.49	.10	.12	.01	.03
31	.44	.09	.11	.01	.02
35	.40	.08	.10	.01	.02

TABLE B-13. F-5A WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT F 5A NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	2.66	.34	.07	0.00	.04
6	2.40	.32	.06	0.00	.03
7	2.25	.30	.05	0.00	.03
8	2.15	.30	.05	0.00	.03
9	2.08	.29	.04	0.00	.02
10	2.03	.29	.04	0.00	.02
11	1.98	.28	.04	0.00	.02
13	1.87	.27	.03	0.00	.02
15	1.77	.26	.03	0.00	.02
17	1.66	.25	.03	0.00	.02
19	1.55	.23	.02	0.00	.01
21	1.46	.22	.02	0.00	.01
23	1.37	.21	.02	0.00	.01
27	1.22	.18	.02	0.00	.01
31	1.10	.17	.02	0.00	.01
35	.99	.15	.02	0.00	.01

TABLE B-14. F-15 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT F 15 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	.76	.11	.31	.01	.07
6	.68	.10	.27	.01	.06
7	.64	.09	.24	.01	.06
8	.62	.09	.22	.01	.05
9	.60	.08	.20	.01	.05
10	.60	.08	.19	.01	.05
11	.59	.08	.18	.01	.04
13	.57	.08	.17	.01	.04
15	.55	.08	.15	.01	.04
17	.52	.07	.14	.01	.04
19	.50	.07	.13	.01	.03
21	.47	.06	.12	.00	.03
23	.44	.06	.11	.00	.03
27	.40	.05	.10	.00	.03
31	.36	.05	.09	.00	.02
35	.33	.04	.08	.00	.02

TABLE B-15. F-16 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT F-16 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	.24	.03	.26	.00	.02
6	.21	.03	.23	.00	.02
7	.21	.03	.20	.00	.02
8	.22	.03	.18	.00	.02
9	.24	.03	.17	.00	.02
10	.26	.04	.16	.00	.02
11	.29	.04	.15	.00	.02
13	.32	.04	.14	.00	.02
15	.34	.05	.13	.00	.02
17	.34	.05	.12	.00	.02
19	.34	.05	.12	.00	.02
21	.33	.04	.11	.00	.02
23	.32	.04	.10	.00	.02
27	.30	.04	.09	.00	.01
31	.27	.04	.08	.00	.01
35	.25	.03	.07	.00	.01

TABLE B-16. F-111A WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT F 111A NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	2.80	2.10	.79	.12	.11
6	2.63	2.01	.67	.10	.09
7	2.54	1.96	.59	.08	.09
8	2.48	1.94	.53	.07	.08
9	2.43	1.92	.48	.07	.07
10	2.39	1.90	.44	.06	.07
11	2.35	1.88	.41	.06	.07
13	2.24	1.81	.36	.05	.06
15	2.12	1.72	.32	.04	.05
17	1.99	1.62	.29	.04	.05
19	1.87	1.52	.27	.03	.05
21	1.76	1.43	.24	.03	.04
23	1.65	1.35	.23	.03	.04
27	1.47	1.20	.20	.02	.04
31	1.32	1.08	.18	.02	.03
35	1.19	.98	.15	.02	.03

TABLE B-17. F-111D WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT F111D NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	2.10	.71	1.17	.02	.14
6	1.98	.68	1.00	.02	.12
7	1.91	.67	.89	.01	.11
8	1.86	.66	.80	.01	.10
9	1.83	.66	.73	.01	.09
10	1.80	.65	.67	.01	.09
11	1.76	.64	.62	.01	.08
13	1.68	.62	.55	.01	.08
15	1.59	.59	.49	.01	.07
17	1.49	.55	.44	.01	.06
19	1.40	.52	.40	.01	.06
21	1.32	.49	.37	.01	.05
23	1.24	.46	.34	.01	.05
27	1.10	.41	.30	.00	.04
31	.99	.37	.26	.00	.04
35	.89	.33	.23	.00	.03

TABLE B-18. F-111F WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT F111F NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	2.14	.73	1.17	.02	.14
6	2.01	.69	1.01	.02	.12
7	1.93	.68	.89	.01	.11
8	1.88	.67	.80	.01	.10
9	1.84	.66	.73	.01	.09
10	1.81	.65	.67	.01	.09
11	1.78	.65	.62	.01	.08
13	1.69	.62	.55	.01	.08
15	1.60	.59	.49	.01	.07
17	1.50	.56	.44	.01	.06
19	1.41	.52	.40	.01	.06
21	1.32	.49	.37	.01	.05
23	1.24	.46	.34	.01	.05
27	1.10	.41	.30	.00	.04
31	.99	.37	.27	.00	.04
35	.89	.34	.23	.00	.03

TABLE B-19. KC-135A WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT KC 135A NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	8.86	7.08	.85	.06	.18
6	8.02	6.42	.72	.05	.16
7	7.48	6.00	.63	.04	.15
8	7.12	5.71	.57	.04	.14
9	6.87	5.52	.52	.03	.13
10	6.67	5.36	.49	.03	.12
11	6.50	5.23	.46	.03	.12
13	6.16	4.96	.41	.03	.11
15	5.81	4.69	.38	.02	.10
17	5.47	4.41	.35	.02	.10
19	5.14	4.15	.32	.02	.09
21	4.84	3.91	.30	.02	.09
23	4.56	3.68	.28	.02	.08
27	4.07	3.29	.24	.02	.07
31	3.67	2.96	.22	.01	.06
35	3.33	2.69	.20	.01	.06

TABLE B-20. O-2 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT O 2 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	1.42	.14	.01	.07	.00
6	1.24	.12	.00	.06	.00
7	1.13	.11	.00	.06	.00
8	1.07	.11	.00	.05	.00
9	1.03	.11	.00	.05	.00
10	1.01	.11	.00	.05	.00
11	.99	.12	.00	.05	.00
13	.96	.12	.00	.05	.00
15	.92	.12	.00	.05	.00
17	.88	.11	.00	.05	.00
19	.84	.11	.00	.05	.00
21	.79	.11	.00	.05	.00
23	.75	.10	.00	.04	.00
27	.68	.09	.00	.04	0.00
31	.61	.08	.00	.04	0.00
35	.56	.08	.00	.03	0.00

TABLE B-21. OV-10 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT OV10 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	.17	.04	.11	.01	.01
6	.15	.04	.09	.01	.01
7	.14	.04	.08	.01	.01
8	.13	.04	.08	.01	.01
9	.13	.04	.07	.00	.01
10	.13	.04	.07	.00	.01
11	.13	.04	.07	.00	.01
13	.14	.04	.07	.00	.01
15	.13	.04	.06	.00	.01
17	.13	.04	.06	.00	.01
19	.12	.04	.06	.00	.01
21	.12	.03	.05	.00	.01
23	.11	.03	.05	.00	.01
27	.10	.03	.04	.00	.01
31	.09	.03	.04	.00	.01
35	.09	.03	.04	.00	.00

TABLE B-22. T-33 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT T 33 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	1.85	.24	.05	.01	.02
6	1.65	.22	.04	.01	.02
7	1.54	.21	.04	.01	.02
8	1.46	.20	.03	.01	.02
9	1.40	.19	.03	.01	.01
10	1.36	.19	.03	.01	.01
11	1.32	.18	.03	.01	.01
13	1.23	.17	.02	.01	.01
15	1.15	.16	.02	.01	.01
17	1.08	.15	.02	.01	.01
19	1.01	.14	.02	.01	.01
21	.94	.13	.02	.01	.01
23	.88	.13	.02	.01	.01
27	.78	.11	.01	.00	.01
31	.70	.10	.01	.00	.01
35	.63	.09	.01	.00	.01

TABLE B-23. T-37 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT T 37 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	1.00	.13	.02	.00	.01
6	.90	.12	.02	.00	.01
7	.85	.11	.02	.00	.01
8	.81	.11	.02	.00	.01
9	.78	.11	.02	.00	.01
10	.76	.10	.01	.00	.01
11	.74	.10	.01	.00	.01
13	.70	.10	.01	.00	.01
15	.66	.09	.01	.00	.01
17	.61	.09	.01	.00	.01
19	.57	.08	.01	.00	.01
21	.54	.08	.01	.00	.01
23	.50	.07	.01	.00	.00
27	.45	.06	.01	.00	.00
31	.40	.06	.01	.00	.00
35	.36	.05	.01	.00	.00

TABLE B-24. T-38 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT T 38 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	2.52	.36	.05	0.00	.03
6	2.31	.34	.04	0.00	.02
7	2.20	.33	.04	0.00	.02
8	2.12	.32	.03	0.00	.02
9	2.07	.31	.03	0.00	.02
10	2.03	.31	.03	0.00	.02
11	1.99	.31	.03	0.00	.02
13	1.90	.30	.03	0.00	.02
15	1.80	.28	.02	0.00	.01
17	1.69	.27	.02	0.00	.01
19	1.59	.25	.02	0.00	.01
21	1.49	.24	.02	0.00	.01
23	1.40	.22	.02	0.00	.01
27	1.25	.20	.02	0.00	.01
31	1.12	.18	.01	0.00	.01
35	1.01	.16	.01	0.00	.01

TABLE B-25. T-39 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT T 39 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	.64	.08	.03	.00	.01
6	.58	.07	.03	.00	.01
7	.54	.07	.03	.00	.01
8	.52	.07	.02	.00	.01
9	.50	.06	.02	.00	.01
10	.49	.06	.02	.00	.01
11	.47	.06	.02	0.00	.01
13	.45	.06	.02	0.00	.01
15	.42	.05	.02	0.00	.01
17	.39	.05	.02	0.00	.01
19	.37	.05	.01	0.00	.01
21	.34	.04	.01	0.00	.01
23	.32	.04	.01	0.00	.01
27	.29	.04	.01	0.00	.01
31	.26	.03	.01	0.00	.00
35	.23	.03	.01	0.00	.00

TABLE B-26. T-41 WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT T 41 NORMAL 1 LTO

ATMOSPHERIC CONDITIONS WORST CASE
STABILITY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER)				
	CO	HC	NOX	PT	SO2
5	.73	.07	.00	.03	0.00
6	.64	.06	.00	.03	0.00
7	.57	.06	.00	.03	0.00
8	.53	.06	.00	.03	0.00
9	.50	.05	.00	.03	0.00
10	.48	.05	.00	.02	0.00
11	.46	.05	.00	.02	0.00
13	.43	.05	.00	.02	0.00
15	.40	.05	.00	.02	0.00
17	.37	.05	.00	.02	0.00
19	.35	.04	.00	.02	0.00
21	.33	.04	.00	.02	0.00
23	.31	.04	.00	.02	0.00
27	.27	.04	.00	.02	0.00
31	.25	.03	.00	.01	0.00
35	.22	.03	.00	.01	0.00

TABLE B-27. BIA WORST-CASE DOWNFIELD CONCENTRATIONS

AIRCRAFT B-1A NORMAL 1 LTO
ATMOSPHERIC CONDITIONS WORST CASE
STARTILTY CATEGORY 6
WIND SPEED (METERS/SECOND) 1.00
WIND DIRECTION TAILWIND
TEMPERATURE (F) 38.00
MIXING DEPTH (METERS) 115.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER) CO	HC	NOx	PT	SO2
3	42.58	2.84	9.02	.10	1.87
4	47.31	4.83	8.45	.13	1.79
5	43.35	5.64	6.69	.14	1.44
6	40.18	5.94	5.57	.14	1.22
7	33..85	5.52	4.24	.13	.94
8	28.61	4.83	3.44	.11	.77
9	24.59	4.22	2.90	.10	.65
11	21.51	3.72	2.50	.09	.56
13	19.10	3.32	2.21	.08	.50
15	17.18	3.00	1.98	.07	.45
17	14.31	2.51	1.64	.06	.37
19	12.28	2.16	1.41	.05	.32
21	10.77	1.89	1.23	.04	.28

ATMOSPHERIC CONDITIONS AVERAGE CASE
STABILITY CATEGORY
WIND SPEED (METERS/SECOND) 3.90
WIND DIRECTION HEADWIND
TEMPERATURE (F) 55.00
MIXING DEPTH (METERS) 975.00

DISTANCE FROM START OF TAKE-OFF (KM)	RECEPTOR CONCENTRATION DATA (MICROGRAMS/CU. METER) CO	HC	NOx	PT	SO2
3	19.25	.89	4.65	.05	.95
4	16.49	1.39	3.19	.03	.67
5	10.41	.71	2.20	.02	.45
6	8.16	.60	1.71	.02	.35
7	6.14	.60	1.18	.02	.25
8	4.98	.57	.90	.02	.19
9	4.10	.50	.72	.01	.15
11	3.44	.43	.59	.01	.13
13	3.09	.38	.54	.01	.11
15	2.56	.33	.44	.01	.09
17	1.88	.25	.32	.01	.07
19	1.43	.19	.24	.01	.05
21	1.13	.16	.19	.00	.04

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