Appendix A

Data Required To Evaluate Aircraft Measures

— APPENDIX A —

Data Required To Evaluate Aircraft Measures

The data required to evaluate mitigation measures from aircraft operations are aircraft type, number of LTOs, engine type, engine emission factors, and mode times. The data and sources listed below were used to calculate the reference emissions estimate. The data used was specific to the airports noted in the report. For each measure, the key data and sources (other than the ones below) are detailed in the key inputs and references sections of the measure's discussion. Unless noted in a measure's key inputs section, the data and sources listed below were used to calculate the measure's emission estimate. Contact airlines if more detailed or airport specific data is needed.

The FAA's *Airport Activity Statistics of Certificated Route Air Carriers* is a yearly publication that lists aircraft types and annual LTOs by airport, airline, and aircraft. The type of aircraft, including cargo, and number of LTOs for all service were obtained from the document.

The particular engines that operate on aircraft, engine emissions factors, and default time-in-modes are provided in the U.S. EPA's *Procedures for Emission Inventory Preparation*, Chapter 5 - Aircraft, which is included in this appendix, as well as in *FAA's Aircraft Engine Emissions Database (FAEED)*. FAEED is an automated (computerized) menu-driven procedure for calculating an aircraft emissions inventory. The database was used in conjunction with EPA's report to calculate the commercial aircraft emissions. Default time-in-modes, as provided in FAEED, were chosen for all aircraft except for taxi time. EEA has confidential data from three airlines that provides taxi times for some California airports. Weighted average taxi times based on this data was used in the calculations. When selecting an aircraft's engine, there sometimes is a weighted average option that calculates an average engine's emissions by population market share. This option was chosen when available. When the weighted average option was not available due to lack of sufficient information, the most common engine was chosen.

—— NOTE ——

Energy and Environmental Analysis, Inc. recently updated EPA's *Procedures for Emission Inventory Preparation*, Chapter 5 – Aircraft.

This document is an excellent reference describing the concepts and procedures for developing airport emission inventories and provides information on engines and engine emission factors for commercial and military aircraft. It is reproduced in its entirety beginning on the following page. The default values described have not been approved by ARB. Calculations should be made using actual data, specific to local conditions, to the extent possible.

— CHAPTER 5 —

Emissions From Aircraft

This chapter describes the procedure for calculating emissions from civilian and military aircraft within an inventory area. The basic methodology determines aircraft fleet make-up and level of activity and then calculates air pollutant emissions on an annual basis. Variations to the methodology, which account for seasonal changes or specific operational considerations, are covered also. Finally, changes expected in the fleet in the future and the effect on emissions are briefly described at the end of the chapter.

The inventory methodology and emission factors have been updated since the last edition of this report. This chapter also updates the emission factor information that appears in *Compilation of Air Pollutant Emission Factors, Fourth Edition and Supplements*, AP-42 (Reference 1). Subsequent to the publication of this document, AP-42 will be formally updated and may include some additional data, primarily on general aviation and military aircraft, which was unavailable when this report was prepared.

5.1 Overview Of The Inventory Methodology

Preparing an emissions inventory for aircraft focuses on the emission characteristics of this source relative to the vertical column of air that ultimately affects ground level pollutant concentrations. This portion of the atmosphere, which begins at the earth's surface and is simulated in air quality models, is often referred to as the mixing zone. The aircraft operations of interest within this layer are defined as the landing and takeoff (LTO) cycle. The cycle begins when the aircraft approaches the airport on its descent from cruising altitude, lands, and taxis to the gate. It continues as the aircraft taxis back out to the runway for subsequent takeoff and climbout as it heads back up to cruising altitude. Thus, the five specific operating modes in an LTO are:

- Approach
- Taxi/idle-in
- Taxi/idle-out
- Takeoff
- Climbout

Most aircraft go through a similar sequence during a complete operating cycle. Helicopters may combine certain modes such as takeoff and climbout.

5.1.1 Factors Affecting Emissions

The LTO cycle provides a basis for calculating aircraft emissions. During each mode of operation, the aircraft engines operate at a fairly standard power setting for a given aircraft category. Emissions for one complete cycle for a given aircraft can be calculated by knowing emission factors for specific aircraft engines at those power settings. Then, if the activity of all aircraft in the modeling zone can be determined for the inventory period, the total emissions can be calculated. Each of the dominant factors that affect the emissions from this source is discussed below.

5.1.1.1 **Aircraft Categorization** - For a single LTO cycle, aircraft emissions vary considerably depending on the category of aircraft and the resulting typical flight profile. Aircraft can be categorized by use. Commercial aircraft include those used for scheduled service transporting passengers, freight, or both. Air taxis also fly scheduled service carrying passengers and/or freight but usually are smaller aircraft and operate on a more limited basis than the commercial carriers. Business aircraft support business travel, usually on an unscheduled basis, and general aviation includes most other non-military aircraft used for recreational flying, personal transportation, and various other activities.

For the purpose of creating an emissions inventory, business aircraft are combined with general aviation aircraft because of their similar size, use frequency, and operating profiles. In this inventory methodology they are referred to simply as general aviation. Similarly, air taxis are treated much like the general aviation category because they are typically the same types of aircraft. Military aircraft cover a wide range of sizes, uses, and operating missions. While they often are similar to civil aircraft, they are handled separately because they typically operate exclusively out of military air bases and frequently have distinctive flight profiles. Helicopters, or rotary wing aircraft, can be found in each of the categories. Their operation is distinct because they do not always operate from an airport but may land and takeoff from a heliport at a hospital, police station, or similarly dispersed location. Military rotorcraft are included in the military category and non-military rotorcraft are included in the general aviation category since information on size and number are usually found in common sources. However, they are combined into a single group for calculating emissions since their flight profiles are similar.

Commercial aircraft typically are the largest source of aircraft emissions. Although they make up less than half of all aircraft in operation around a metropolitan area their emissions usually represent a large fraction of the total because of their size and operating frequency. This may not hold true, of course, for a city with a disproportionate amount of military activity or a city with no major civil airports.

5.1.1.2 **Pollutant Emissions** - Aircraft pollutants of significance are hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NO_X), sulfur dioxide (SO_2), and particulates (PM_{10}). The factors that determine the quantity of pollutant emitted are the emission index for each operating mode (pounds of pollutant per 1000 pounds of fuel consumed), the fuel consumption rate, and the duration of each operating mode. HC and CO emission indexes are very high during the taxi/idle phases when aircraft engines are at low power and operate at less than optimum efficiency. The emission indexes fall as the aircraft moves into the higher power operating modes of the LTO cycle. Thus, operation in the taxi/idle mode, when aircraft are on the ground at low power, is a significant factor in calculating total HC and CO emissions. For areas which are most concerned about the contribution of aircraft to the inventory of HC and CO, special attention should be paid to the time the aircraft operate in the taxi/idle modes.

NO_X emissions, on the other hand, are low when engine power and combustion temperature are low but increase as the power level is increased and combustion temperature rises. Therefore the takeoff and climbout modes have the highest NO_X emission rates. If NO_X is a primary concern for the inventory area, special effort should focus on determining an accurate height of the mixing layer, which affects the operating duration of climbout.

Sulfur emissions typically are not measured when aircraft engines are tested. In evaluating sulfur emissions, it is assumed that all sulfur in the fuel combines with oxygen during combustion to form sulfur dioxide. Thus, sulfur dioxide emission rates are highest during takeoff and climbout when fuel consumption rates are high. Nationally the sulfur content of fuel remains fairly constant from year to year at about 0.05% wt. for commercial jet fuel, 0.025% wt. for military fuel, and 0.006% wt for aviation gasoline. This is the basis for the sulfur dioxide emission indexes in the tables included in this methodology. If the sulfur content of fuel varies significantly on a local basis, the emission index can be adjusted according to a ratio of the local value to the national value.

Particulates form as a result of incomplete combustion. Particulate emission rates are somewhat higher at low power rates than at high power rates since combustion efficiency improves at higher engine power. However, particulate emissions are highest during takeoff and climbout because the fuel flow rate also is high. It is particularly difficult to estimate the emissions of this pollutant. Direct measurement of particulate emissions from aircraft engines typically are not available, although emission of visible smoke is reported as part of the engine certification procedure. Particulate emission factors for only a few aircraft engines are included in this chapter.

5.1.1.3 **Aircraft Engines** - The aircraft powerplant is the source of emissions of the key pollutants that result from fuel combustion. Emission rates vary depending on the fuel consumption rate and engine specific design factors. In 1984, EPA established standards for HC emissions. In developing the emission limits, EPA defined an operating regimen to standardize the engine certification testing procedure and method for determining engine HC emissions. The standard applies to jet engines over 6,000 lbs-thrust and emissions are calculated based on a specific LTO cycle. EPA considered in-use engine deterioration when the standards were developed but concluded that, because of the high levels of maintenance of aircraft engines for reasons of safety and fuel economy, emission performance would not deteriorate significantly. The operating parameters used in the standard for the LTO cycle can be used as default values in calculating emissions when more specific information is not known. These default values are defined in later sections of this methodology.

When the standards went into effect, some engines in production could already meet them due to design changes made previously for improved fuel efficiency. Other engines had to be redesigned to reduce their HC emissions so that they could remain in production. In-service engines were not required to be retrofitted in the normal course of periodic servicing and rebuilding. These older engines, many of which remain in service, have HC emissions that exceed the standard. New engine designs, produced since the standards went into effect, have HC emissions much lower than the standards. As a result of design changes made to the engines that meet the HC standard, emissions of CO also generally went down while NO_x emissions tended to increased. However, the change in these pollutants was much less dramatic than the decrease in hydrocarbons. The smoke number for the newer engines also is lower due to specific design changes intended to reduce smoke production, which is regulated by EPA.

5.1.1.4 **Operating Modes** – During the LTO cycle, aircraft operate for different periods of time in various modes depending on their particular category, the local meteorological conditions, and operational considerations at a given airport. The "Time-In-Mode," or TIM, as used in this methodology, takes these factors into consideration. Table 5–1 shows representative LTO cycle times for several aircraft categories.

Duration in approach and climbout depends largely on the local meteorology. Since the period of interest is during operation of the aircraft within the air modeling zone, the inversion layer thickness determines how long the aircraft is in this zone. The inversion layer thickness is also known as the mixing height or mixing zone since the air in this layer is completely mixed and pollutants emitted anywhere within the layer will be carried down to ground level. When the aircraft is above the mixing layer, whether on descent or when climbing to cruising altitude, the emissions tend to disperse, rather than being trapped by the inversion, and have no ground level effect.

TABLE 5-1

Default Time-In-Mode For Various Aircraft Categories[1]

Aircraft	Taxi/ Idle-out	Takeoff	Climbout	Approach	Taxi/ Idle-in	Total
	Time in Mode (Minutes)					
Civil[2]						
Commercial Carrier						
Jumbo, long and medium range jet	19.0	0.7	2.2	4.0	7.0	32.9
Turboprop	19.0	0.5	2.5	4.5	7.0	33.5
Transport- piston	6.5	0.6	5.0	4.6	6.5	23.2
General Aviation						
Business jet	6.5	0.4	0.5	1.6	6.5	15.5
Turboprop	19.0	0.5	2.5	4.5	7.0	33.5
Piston	12.0	0.3	5.0	6.0	4.0	27.3
Helicopter	3.5	—	6.5	6.5	3.5	20.0
Military[3]						
Combat[4]						
USAF	18.5	0.4	0.8	3.5	11.3	34.5
USN[5]	6.5	0.4	0.5	1.6	6.5	15.5
Trainer - Turbine						
USAF T-38	12.8	0.4	0.9	3.8	6.4	24.3
USAF general	6.8	0.5	1.4	4.0	4.4	17.1
USN[5]	6.5	0.4	0.5	1.6	6.5	15.5
Transport - Turbine[6]						
USAF general	9.2	0.4	1.2	5.1	6.7	22.6
USN	19.0	0.5	2.5	4.5	7.0	33.5
USAF B-52 and KC-135	32.8	0.7	1.6	5.2	14.9	55.2
Military - Piston	6.5	0.6	5.0	4.6	6.5	23.2
Military - Helicopter	8.0	—	6.8	6.8	7.0	28.6

1 Source: AP-42 (Reference 1).

2 Civil aircraft data is for large congested metropolitan airports.

3 USAF - U.S. Air Force, USN - U.S. Navy.

4 Fighters and attack aircraft only.

5 Time-in mode is highly variable. Taxi/idle out and in times as high as 25 and 17 minutes, respectively, have been noted. Use local data base if possible.

6 Includes all turbine aircraft not specified elsewhere (i.e., transport, cargo, observation, patrol, antisubmarine, early warning, and utility).

Taxi/idle time, whether from the runway to the gate (taxi/idle-in) or from the gate to the runway (taxi/idle-out), depends on the size and layout of the airport, the amount of traffic or congestion on the ground, and airport-specific operational procedures. Taxi/idle time is the most variable of the LTO modes. Taxi/idle time can vary significantly for each airport throughout the day, as aircraft activity changes, and seasonally, as general travel activity increases and decreases.

The takeoff period, characterized primarily by full-throttle operation, typically lasts until the aircraft reaches between 500 and 1000 feet above ground level when the engine power is reduced and the climbout mode begins. This transition height is fairly standard and does not vary much from location to location or among aircraft categories.

This methodology describes techniques and data sources for determining the critical variables in the inventory calculations. When an inventory is being created for a particular area, the fleet make-up, aircraft activity, and times-in-mode will be specific to that area. Engine emission indexes, on the other hand, depend on the engine design and are provided in reference tables.

Where specific information may be difficult to obtain, simplifying assumptions are discussed. An automated (computerized) calculation procedure, which can simplify data management, has been developed by the Federal Aviation Administration (FAA) with support from EPA and can be obtained from the FAA Technology Division, Office of Environment and Energy, 800 Independence Avenue, SW, Washington, DC 20591, (202) 267-8933. The FAA Aircraft Engine Emission Database (FAEED) includes information on the engines mounted on specific aircraft with emission factors for each of the engines, in addition to a menu-driven procedure for calculating an aircraft emissions inventory.

5.2 Inventory Methodology

The steps in the methodology are basically the same for each aircraft classification and each location, even though several factors used in creating an inventory are site specific.

(1) Identify all airports to be included in the inventory

(2) Determine the mixing height to be applied to the LTO cycle

(3) Define the fleet make-up for aircraft category using each airport

(4) Determine airport activity as the number of LTOs for each aircraft category

(5) Select emission indexes for each category

(6) Estimate a time-in-mode for each aircraft category at each airport

(7) Calculate an inventory based on the airport activity, TIM, and aircraft emission factors.

For a specific region where an emissions inventory is being created, steps one and two, the airports to be included and the mixing height, will be determined largely by the assumptions used in defining the scope of the modeling area. Steps three through six are repeated for commercial aircraft, general aviation, military aircraft, and helicopters. The primary difference in creating an inventory for each type of aircraft is the references used to determine the fleet make-up and activity. The following sections discuss each of these steps. Steps one and two are discussed in terms of the specific modeling area while steps three through six are addressed together for each aircraft category.

5.2.1 Airport Selection

Maps and regional information directories are good sources for identifying civil airports and military air fields. Sectional aeronautical charts, published by the Aeronautical Charts Distribution Division (C44), National Ocean Survey, NOAA, Riverdale, MD 20840, (301) 436-6990 ($5.25 per map), particularly show the location of large and small airports. Specific airports to be included will be limited by the geographic boundaries of the modeling area. A secondary reference is *AOPA's Aviation USA* (Reference 2) which lists publicly and privately owned civil airports, including heliports and seaplane bases, and locates them with directions relative to specific cities, as well as providing latitude and longitude coordinates. Much like the sectional aeronautical charts, this reference provides general information on all but a few small landing strips. These small air fields are unlikely to be considered for most analyses because they have low activity, typically can accommodate only small general aviation aircraft, and therefore, contribute insignificantly to the emissions inventory. (Many private use landing sites are listed in Reference 2 by city and site name but a telephone number is the only information given). *FAA Air Traffic Activity* (Reference 3) lists all airports with air traffic control towers operated by the FAA. While this is a subset of the airports listed in these other references, all of the airports in urban areas with significant air traffic are included.

5.2.2 Mixing Height Determination

The height of the mixing zone influences only the time-in-mode for approach and climbout. This factor is significant primarily when calculating NO_X emissions rather than HC or CO. If NO_X emissions are an important component of the inventory, specific data must be gathered on mixing heights. If NO_X emissions are unimportant, mixing height will have little effect on the results and the default value of 3000 feet can be used for more generalized results.

Mixing height should be determined in conjunction with those responsible for the air quality modeling of the region to insure that assumptions used for creating different sections of the overall inventory are consistent. If the inventory is being created independently of any air quality modeling, the mixing height can be determined by contacting the National Meteorological Center at (301) 763-8298 or alternatively the National Climatic Data Center (NCDC) at (704) 259-0682. Another source of mixing height data is the EPA Office of Air Quality Planning and Standards' SCRAM (Support Center for Regulatory Air Models) Bulletin Board. This electronic date base contains data used by various air quality models. Mixing height data, which appears under the Meteorological Data Main Menu, comes from the NCDC. See Reference 4 for information about accessing this bulletin board. As a third alternative, typical mixing heights can be found on Figures 5–1, 5–2, and 5–3 which come from *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States* (Reference 5). These figures, which show mixing height for a mean annual morning, a mean summer morning, and a mean winter morning, illustrate the seasonal variation in the mixing height. The morning data corresponds to the few hours centered near the morning commuter rush hours, which roughly coincide with the diurnal maximum concentration of slow-reacting pollutants in many urban areas. Figure 5–1, showing annual mixing heights, may be used for creating an annual inventory. If a seasonal inventory is being used for evaluating emissions during a peak ozone period, the summer morning data from Figure 5–2 may be preferred. Episodes lasting two to five days occur most frequently during the winter for much of the U.S. If these episode periods are of primary interest, the data from Figure 5–3 should be used. Reference 5 should be consulted for additional information on the use of these figures. As a final alternative for mixing height, a default of 3000 feet may be used. This value, which is used as the default value for the EPA standard LTO, is incorporated into the calculations used for determining time-in-mode.

FIGURE 5–1
Reproduction Of Figure 1
— FROM REFERENCE 5 —

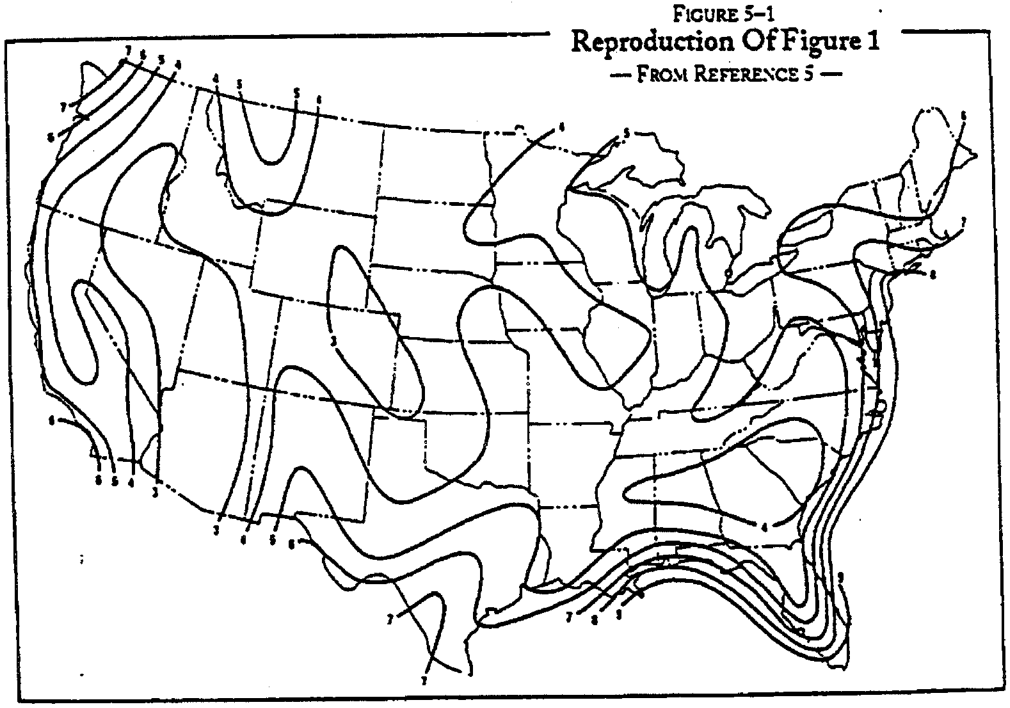

Figure 1. Isopleths (m x 10^2) of mean annual morning mixing heights (see Table B-1 for data).

Figure 5-2

Reproduction Of Figure 4

— From Reference 5 —

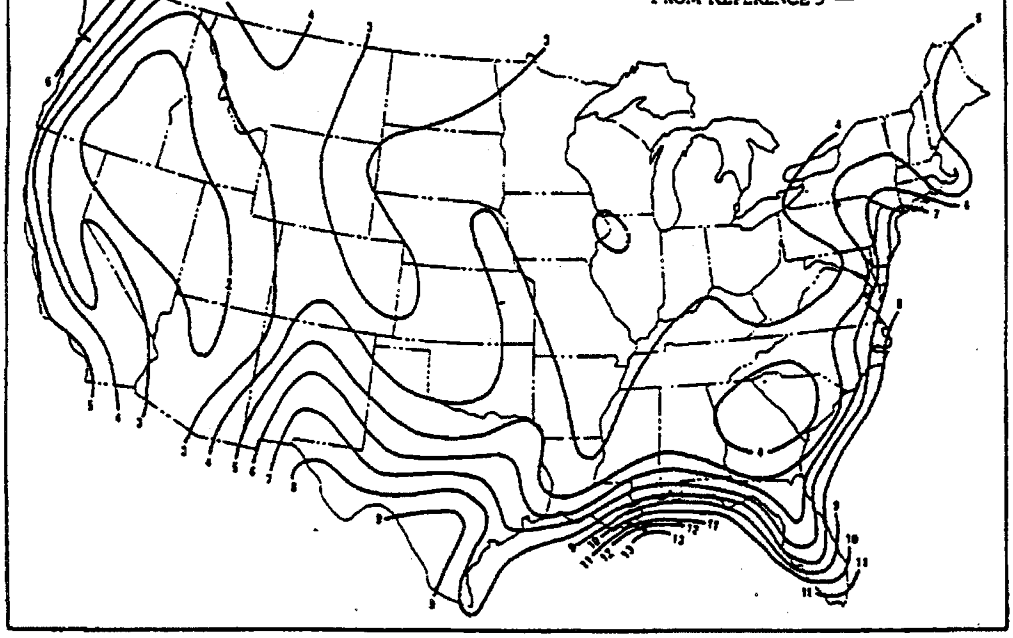

Figure 4. Isopleths (m x 10^2) of mean summer morning mixing heights (see Table B-1 for data).

Figure 5-3

Reproduction Of Figure 2

— From Reference 5 —

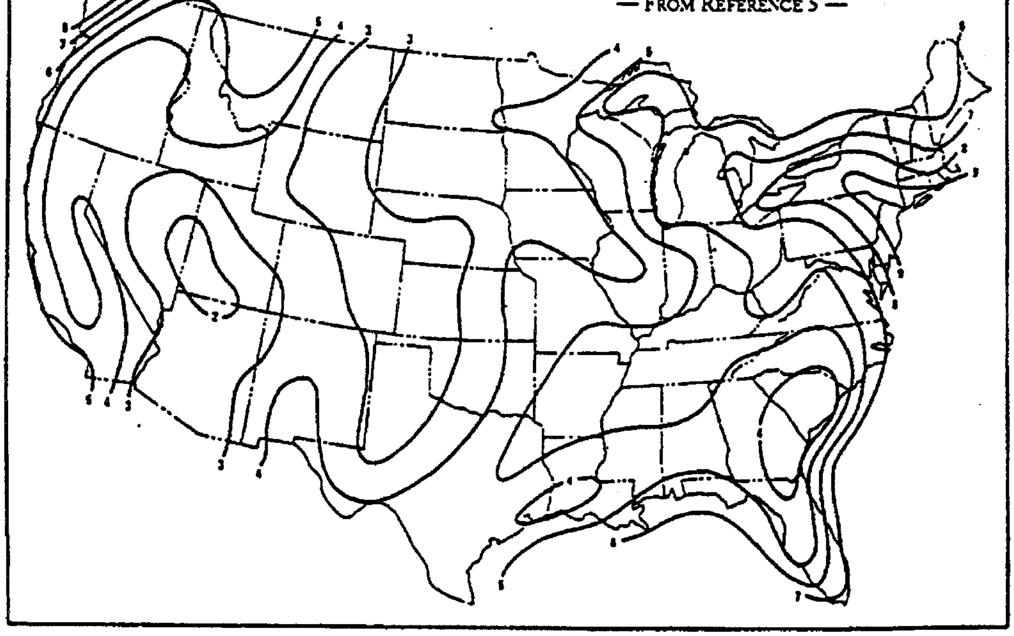

Figure 2. Isopleths (m x 10^2) of mean winter morning mixing heights (see Table B-1 for data).

5.2.3 Activity and Emissions for Commercial Aircraft

The next four steps relate specifically to creating an emissions inventory for commercial aircraft. The procedures for other aircraft categories are discussed subsequently. Definition of the mix of commercial aircraft that uses each airport (step three) can be found in *Airport Activity Statistics of Certified Route Air Carriers* (Reference 6), published annually by FAA. Figure 5-4, a copy of a page from Table 7 of that report, shows the information that is included by airport. All of the commercial aircraft that used the airport for the given year are listed, along with the number of departures during the year. This is the fleet that should be used for the inventory.

In step four the number of LTOs is determined by aircraft type. Since Reference 6 lists departures, which are equivalent to LTOs, it is again the preferred source. From Table 7, the total departures performed for all service (both scheduled and non scheduled) should be used as the number of LTOs for each aircraft type.

The engines used on each aircraft type must be determined to select the emission factors for step five. Table 5-2 lists aircraft and the corresponding engines used to power them. Many aircraft use only a single engine model, while others have been certified to use engines from two or three different manufacturers. When a single engine is listed for an aircraft model, emissions data for that engine should be used. For aircraft with engines from more than one manufacturer, defining the specific engine mix used on the fleet of aircraft operating at a specific airport may be extremely difficult. Individual airlines probably are the only source of detailed fleet data on specific engine models and they likely do not have it readily available. To develop a representative engine mix for aircraft with more than one engine model, the percentage of each model likely to be found on those aircraft in the U.S. fleet is shown adjacent to the engine model number in Table 5-2. The recommended procedure for compensating for the lack of detailed engine data is using the percentages shown in the table as weighing factors. For example, Boeing 757-200 cargos have been sold to U.S. airlines with Pratt & Whitney PW2040 engines as well as Rolls Royce RB.211-535E4 engines. The number of aircraft with each engine model is 15 and 43, respectively, to give the percentages shown in Table 5-2 of 26 and 74. These percentages can be used to divide the total LTOs for B 757-200s into three groups representing the three engine types. This makes the inventory more representative than assigning a single engine for all B 757-200s, since the emission factors are different for each engine.

After identifying the engines included in the fleet, engine emission factors are used to calculate mass of emissions. For some of the engines shown in Table 5-2, emission factors have never been determined. For these engines it is necessary to use emission factors from an alternative engine. Table 5-3 lists alternative engines recommended by the engine manufacturers. For most of these engines, emission factors are available for a very similar engine, usually one of the same model and

Figure 5-4
Reproduction Of A Page Of Table 7
— From Reference 6 —

TABLE 7—Continued
Aircraft Departures Scheduled and Aircraft Departures Performed, By Community, By Air Carrier, And By Aircraft Type
12 Months Ended December 31, 1990

STATE OR U.S. AREA COMMUNITY (AIRPORT NAME)	CARRIER	OPERATION	TYPE OF AIRCRAFT	TOTAL DEPARTURES PERFORMED: SCHEDULED SERVICE	TOTAL DEPARTURES PERFORMED: NON SCHEDULED SERVICE	TOTAL DEPARTURES PERFORMED: ALL SERVICE	DEPARTURES SCHEDULED
CALIFORNIA—Continued LOS ANGELES/BURBNK/LNG.BCH—Continued (ORANGE COUNTY)—Continued COMMUNITY TOTAL BY CARRIER—Continued							
			B-757-200	2584		2584	
			B-767-200	2438		2438	
			B-767-300	94		94	
			DC-9-80	10749	1	10750	
			A-300-600	186		186	
			A-310-300	341		341	
			B-727-100	108		108	
			B-727-200	140	1	141	
			DC-10-10	7481	3	7484	
			DC-10-30	319	6	325	
			BAE-146-100	4292		4292	
			ALL TYPES	36830	11	36841	37866
	AP—ASPEN AIRWAYS	TOTAL	BAE-146-100	211	3	214	
			ALL TYPES	211	3	214	212
	AS—ALASKA AIRLINES	TOTAL	DC-9-80	10675	10	10685	
			B-727-100	99		99	
			B-727-200	2546	8	2554	
			ALL TYPES	13318	26	13344	13392
	CO—CONTINENTAL	TOTAL	B-737-300	4083	703	4786	
			B-737-200C	2		2	
			DC-9-30	3		3	
			DC-9-80	3790	6	3796	
			A-300-X4	2260	37	2297	
			B-727-100	199	2	201	
			B-727-200	1621	47	1668	
			DC-10-10	424		424	
			DC-10-30	482		482	
			* DC-10-30	1		1	
			B-747	173		173	
			* B-747	1		1	
			B-747-200	421		421	
			* B-747-200	4		4	
			ALL TYPES	13487	795	14282	13716
	DL—DELTA AIR LINES	TOTAL	B-737-200	5684	2	5686	
			B-737-100/200	6247		6247	
			B-757-200	4786	4	4790	
			B-767-200	1206	1	1207	
			B-767-300	2320		2320	
			DC-9-80	124		124	
			B-727-200	14086	26	14112	
			L-1011/100/20	4066	2	4068	
			ALL TYPES	38658	35	38693	38906
	EA—EASTERN AIR LINES	TOTAL	B-757-200	925		925	
			A-300-X4	861	2	863	
			L-1011/100/20	292		292	
			ALL TYPES	2078	2	2080	2086
	FF—TOWER AIR	TOTAL	B-747		1	1	
			ALL TYPES		1	1	1
	FM—FEDERAL EXPRESS	TOTAL	* BEECH 18	25		25	
			* C-208	384		384	
			* B-727-100	1372		1372	
			* B-727-200	803		803	
			* DC-10-10	480		480	
			* DC-10-30	413	3	416	
			* B-747	156	30	186	
			B-747-200		115	115	
			* B-747-200	404	38	442	

NOTE: * = All Cargo Services

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Table 5-2:

Commercial Aircraft Types And Engine Models

Aircraft[1]	Engine Type[2]	No. Of Engines	Engine Model (% of Aircraft) and Manufacturer[3]					
Aerospatiale ATR-42	TP	2	PW120(53)PWC	PW121(47)PWC				
Airbus A-300-B4	TF	2	CF6-50(100)GE					
Airbus A-300-600	TF	2	CF6-80C2A5(100)GE					
Airbus A-310-200	TF	2	CF6-80A3(0)GE	JT9D-7R4E1(100)PW				
Airbus A-310-300	TF	2	CF6-80C2A2(0)GE	PW4152(100)PW				
Airbus A-320-200	TF	2	CFM56-5A(100)GE					
BEECH 18[4]	TP	2	R-985-AN(100)PW[5]					
BEECH BH-C99	TP	2	PT6A-36(100)PWC					
BEECH BH-1900	TP	2	PT6A-65B(100)PWC					
Boeing B-707-300B	TF	4	JT3D-3B(100)PW					
Boeing B-707-300C	TF	4	JT3D-3B(100)PW					
Boeing B-727-100[5]	TF	3	JT8D-7(16)PW	JT8D-7A(4)PW	JT8D-7A/7B(<1)	JT8D-7A/9A(1)PW	JT8D-7B(72)PW	JT8D-7B/9A(<1)PW
			JT8D-7C(4)PW	JT8D-9(1)PW	JT8D-9A(1)PW			
Boeing B-727-100[4,6]	TF	3	JT8D-7A(5)PW	JT8D-7A/7B/7C(1)PW	JT8D-7A/7B/9A(2)PW	JT8D-7B(90)PW	JT8D-7B/9A(1)PW	JT8D-9(1)PW
Boeing B-727-200	TF	3	JT8D-7A(<1)PW	JT8D-7B(16)PW	JT8D-9(20)PW	JT8D-9A(9)PW	JT8D-15(26)PW	JT8D-15A(21)PW
			JT8D-15B(<1)PW	JT8D-17(3)PW	JT8D-17A(1)PW	JT8D-17R(3)PW		
Boeing B-737-100/200	TF	2	JT8D-7B(19)PW	JT8D-9A(39)PW	JT8D-15(10)PW	JT8D-15A(24)PW	JT8D-17(7)PW	JT8D-17A(1)PW
Boeing B-737-200C[5]	TF	2	JT8D-7A(10)PW	JT8D-9/9A(5)PW	JT8D-9A(16)PW	JT8D-15(5)PW	JT8D-17(32)PW	JT8D-17A(32)PW
Boeing B-737-300	TF	2	CFM56-3(100)GE[7]					
Boeing B-737-400	TF	2	CFM56-3(100)GE					
Boeing B-747[4]	TF	4	JT9D-7F(100)PW					
Boeing B-747F[4]	TF	4	JT9D-7F(33)PW	JT9D-7Q(17)PW	JT9D-7R4G2(11)PW	JT9D-7CA(39)PW		
Boeing B-747SP	TF	4	JT9D-7A(85)PW	JT9D-7A-SP(15)PW				
Boeing B-747-200[8]	TF	4	CF6-50(3)GE[9]	CF6-80C2B1(0)GE	JT9D-3A(7)PW	JT9D-7(1)PW	JT9D-7A(55)PW	JT9D-7AH(13)PW
			JT9D-7F(5)PW	JT9D-7Q(13)PW	JT9D-7R4G2(3)PW			
Boeing B-747-400	TF	4	PW4056(100)PW					
Boeing B-757-200	TF	2	RB.211-535E4(1)RR	PW2037(92)PW	PW2040(7)PW			
Boeing B-757-200[4]	TF	2	PW2040(26)PW	RB.211-535E4(74)RR				
Boeing B-767-200	TF	2	CF6-80A2(59)GE	CF6-80C2B2(12)GE[10]	JT9D-7R4D(29)PW			
Boeing B-767-300	TF	2	CF6-80C2B6(100)GE[11]	PW4060(0)PW				
Brit. Air Corp. BAC-111-200	TF	2	Spey Mk 511(100)RR[12]					
Brit. Aero. BAe-146-1	TF	4	ALF502R-5(100)Lyc					
Brit. Aero. BAe-146-2	TF	4	ALF502R-5(100)Lyc					
Brit. Aero. Concorde	TF	4	Olympus 593 Mk610(100)RR					
Brit. Aero. JETSTREAM 31	TP	2	TPE 331-10UF(100)Grt[12]					
CESSNA 404[4]	P	2	TSIO-520-VB(100)Con[12]					
Convair CV-580	TP	2	501D13H(100)All[12]					
Convair CV-640[4]	TP	2	Dart 542-4(100)RR					
de Havilland DASH-7	TP	4	PT6A-50(100)PWC					
de Havilland DHC-6	TP	2	PT6A-20(26)PWC	PT6A-27(74)PWC				
de Havilland DHC-8	TP	2	PW120(17)PWC	PW120A(83)PWC				
EMBRAER13	TP	2	PT6A-34(100)PWC					
EMBRAER EMB-120	TP	2	PW118(85)PWC	PW118A(15)PWC				
Fairchild FH-227	TP	2	Dart 532-7(100)RR					
Fokker 100	TF	2	Tay 620-15(75)RR	Tay 650(25)RR				
Fokker F-27 SERIES	TP	2	Dart 514-7(15)RR	Dart 528-7E(10)RR	Dart 532-7(5)RR	Dart 532-7N(3)RR	Dart 532-7P(24)RR	
			Dart 532-7R(3)RR	Dart 535-7R(9)RR	Dart 536-7E(2)RR	Dart 552-7R(29)RR		
Fokker F-28-1000[14]	TF	2	Spey 555-15(100)RR					
Fokker F-28-4000/6000[14]	TF	2	Spey 555-15H(12)RR	Spey 555-15P(88)RR				

Table 5-2:
Commercial Aircraft Types And Engine Models — Continued

Aircraft	Engine Type[2]	No. of Engines	Engine Model (% of Aircraft) and Manufacturer[3]				
Lockheed L-100-30[4]	TP	4	501D22A(100)All.[12]				
Lockheed L-188A/C	TP	4	501D13(100)All.[12]				
Lockheed L-188A/C[4]	TP	4	501D13(100)All.[12]				
Lockheed L-1011/100/200[6]	TF	3	RB.211-22B(99)RR	RB.211-22B/524B4(1)RR			
Lockheed L-1011-500 TR	TF	3	RB.211-524B4(100)RR				
McDonnell Douglas DC-6[4]	P	4	R2800(100)PW[12]				
McDonnell Douglas DC-6A[4]	P	4	R2800(100)PW[12]				
McDonnell Douglas DC-8-60	TF	4	JT3D-3B(57)PW	JT3D-7(43)PW			
McDonnell Douglas DC-8-61[4]	TF	4	JT3D-3B(100)PW				
McDonnell Douglas DC-8-62[4]	TF	4	JT3D-3B(15)PW	JT3D-3BDL(21)PW	JT3D-7(54)PW		
McDonnell Douglas DC-8-63F[4]	TF	4	JT3D-3B(24)PW	JT3D-7(42)PW	JT3D-735E4(7)PW	JT8D-7(27)PW	
McDonnell Douglas DC-8-70	TF	4	CFM56-2-C1(100)GE				
McDonnell Douglas DC-8-71	TF	4	CFM56-2(100)GE				
McDonnell Douglas DC-9-10	TF	2	JT8D-7(100)PW[12]				
McDonnell Douglas DC-9-15F	TF	2	JT8D-7(15)	JT8D-7A(4)	JT8D-7A/7B(4)	JT8D-7B(77)PW	
McDonnell Douglas DC-9-30[6]	TF	2	JT8D-7A/9A(9)PW	JT8D-7B(68)PW	JT8D-9A(19)PW	JT8D-15(3)PW	JT8D-17(1)PW
McDonnell Douglas DC-9-40	TF	2	JT8D-15(100)PW				
McDonnell Douglas DC-9-50	TF	2	JT8D-17(87)PW	JT8D-17A(13)PW			
McDonnell Douglas DC-9-80[15]	TF	2	JT8D-209(5)PW	JT8D-217(12)PW	JT8D-217A(36)PW	JT8D-217C(25)PW	JT8D-219(22)PW
McDonnell Douglas DC-10-10	TF	3	CF6-6(100)GE				
McDonnell Douglas DC-10-10[4]	TF	3	CF6-6(100)GE				
McDonnell Douglas DC-10-30	TF	3	CF6-50(100)GE				
McDonnell Douglas DC-10-30[4]	TF	3	CF6-50(100)GE				
McDonnell Douglas DC-10-40	TF	3	JT9D-20(100)PW				
McDonnell Douglas MD-11	TF	3	CF6-80C2D1F(100)GE	PW4460(0)PW			
NAMC YS-11	TP	2	Dart 542-10J(25)RR	Dart 542-10K(75)RR			
Saab SF-340A	TP	2	CT7-5A( )GE[16]	CT7-5A2( )GE[16]	CT7-7E( )GE[16]		
SHORTS 360	TP	2	PT6A-65AR(17)PWC	PT6A-65R(55)PWC	PT6A-67R(28)PWC		
Swearingen SWEAR-METRO I	TP	2	TPE 331-11U-611G( )Grt[17]		PT6A-45R( )PW[18]		

1 Source of Aircraft, Type, and No. of Engines is Airport Activity Statistics of Certificated Route Air Carriers (Reference 6).

2 Engine Types: TF - Turbofan, TJ - Turbojet, TP - Turboprop, P - Piston

3 Following the engine model is the percent of aircraft in parentheses which correspond to the particular engine and the engine manufacturer. GE engine data obtained from GE Aircraft Engines: Commercial Program Status (Reference 10) and Office of Combustion Technology, GE Aircraft Engines (Reference 11). Corresponding percents of aircraft refer to U.S. commercial and government aircraft in op P&W, P&WC, and RR engine data obtained from Turbine-Engined Fleets of the World's Airlines 1990 (Reference 12). Corresponding percents of aircraft refer only to U.S. airlines.

Engine Manufacturers:
Con - Teledyne/Continental,
GE - General Electric,
Grt - Garrett AiResearch,
Lyc - Avco/Lycoming, PW - Pratt & Whitney, PWC - Pratt & Whitney Canada, RR - Rolls Royce

4 All Cargo Services.

5 Percent of aircraft assumed 100%.

6 Some aircraft have a mixture of engines. In calculating a weighted average of engine emission factors, assign equivalent weights to all engines in the mixture.

7 Refers to B-737-300 and -500 aircraft.

8 Information from the engine manufacturer suggests using the PW JT9D-7F(modV)/7A(modV) engine emission factors in place of PW JT9D-7 engine emission factors.

9 Refers to B-747-200, -300, and SR aircraft.

10 Refers to B-767-200ER aircraft. GE combined the number of aircraft in operation of B-767-200ER and -300ER aircraft. It is assumed that an equal distribution between the two aircraft models exists.

11 Refers to B-767-300ER aircraft. GE combined the number of aircraft in operation of B-767-200ER and -300ER aircraft. It is assumed that an equal distribution between the two aircraft models exists.

12 Source of engine information is Modern Commercial Aircraft (Reference 20). Percent of aircraft assumed 100%.

13 Assumed EMB-110 aircraft.

14 Information from the engine manufacturer suggests using the RR SPEY Mk555 engine emission factors for all Fokker F-28 aircraft.

15 Assumed MD-80 aircraft.

16 Source of engine information is Modern Commercial Aircraft (Reference 20). Percent of aircraft unknown.

17 Source of engine information is Modern Commercial Aircraft (Reference 20). Engine refers to METRO III aircraft. Percent of aircraft unknown.

18 Source of engine information is Modern Commercial Aircraft (Reference 20). Engine refers to METRO IIIA aircraft. Percent of aircraft unknown

Table 5-3
Alternative Source Of Emission Data For Some Aircraft Engines[1]

Manufacturer	Engine Model	Source for Emissions Data[2]
GE	CF6-6	CF6-6D
	CF6-50	CF6-50E/C1/E1/C2/E2
	CT7-5A	CT7-5
	CT7-5A2	CT7-5
	CT7-7E	CT7-5
GE (SCNECMA)	CFM56-2	CFM56-2B
	CFM56-2-C1	CFM56-2B
	CFM56-5A	CFM56-5A1
P&W	JT3D series	Contact manufacturer[3]
	JT8D-7D	JT8D-7/7A/7B
	JT8D-15B	JT8D-15
	JT9D-3A	Contact manufacturer
	JT9D-7A-SP	JT9D-7F/7A
	JT9D-7AH	JT9D-7F/7A
	JT9D-20	JT9D-7F/7A
	JT9D-70A	JT9D-70/59/7Q
	PW4060	PW4460
RR	RB211-535E5	Contact manufacturer[4]
	RB211-535F5	Contact manufacturer
	TRENT 600 series	Contact manufacturer
	TRENT 700 series	Contact manufacturer
	SPEY MK506	Contact manufacturer
	SPEY MK555-15	SPEY MK555
	SPEY MK555-15P	SPEY MK555
	SPEY MK555-15H	SPEY MK555
	SPEY MK512	Contact manufacturer
	TAY MK651	Contact manufacturer
	Dart 514-7	Dart RDa7
	Dart 528-7E	Dart RDa7
	Dart 532-7	Dart RDa7
	Dart 532-7N	Dart RDa7
	Dart 532-7P	Dart RDa7
	Dart 532-7R	Dart RDa7
	Dart 535-7R	Dart RDa7
	Dart 536-7E	Dart RDa7
	Dart 542-4	Dart RDa10
	Dart 542-10J	Dart RDa10
	Dart 542-10K	Dart RDa10
	Dart 552-7R	Dart RDa7

1 FAA Aircraft Engine Emission Database does not identify these alternative emission factors. A manual adjustment to the database output may be required.
2 As recommended by engine manufacturers.
3 See listing at Reference 21 for contact information.
4 See listing at Reference 25 for contact information.

a related series. For a small number of engines there is no emissions data available and there are no suggested alternatives. In these instances there are three approaches available. First, the needed data may appear in the latest update of the FAEED data base. The FAA should be contacted for the latest version of the data base as mentioned earlier. Second, for an aircraft with several potential engine types, where no emissions data is available for one engine, the recommended procedure is to reallocate the market share among the engines for which data is available. Third, if emission rate information (fuel consumption and emission index) for an engine model still cannot be located the engine manufacturer should be contacted directly. Information on contacting the primary engine manufacturers is listed in the References section below.

After the engine types have been identified, fuel flow rates and emission indexes can be found in Table 5-4. The data in this table has been updated since the last edition of this reference and of AP–42, to include new engine models and to reflect new data on models already in AP–42. The next version of AP–42 may have some additional new data for engines that have not been updated here. (Updates primarily will be for general aviation aircraft engines.) The fuel flow rates and emission indexes that appear in Table 5-4 for commercial aircraft are based on information engine manufacturers provide to FAA and the International Civil Aviation Organization. These data are representative of production engines. Emission indexes are given for specific fuel flow rates which are representative of the power settings used during the different operating modes. The emission index multiplied by the fuel flow rate gives an emission rate.

Step 6 is to specify a time-in-mode for each aircraft type. Take–off time is fairly standard for commercial aircraft and represents the time for initial climb from ground level to about 500 feet. The default take–off time for calculating emissions is 0.7 minutes (42 seconds) and, unless more specific data is available, should be used in this methodology. The time in the approach and climbout modes depends on mixing height. As mentioned earlier, a default mixing height of 3000 feet was assumed for calculating an approach time of 4 minutes and a climbout time of 2.2 minutes, which can be used if specific information on mixing height is unavailable. The procedure for adjusting these times to correspond to a different mixing height is shown below.

The mode most likely to vary by time for each specific airport is taxi/idle time. Total taxi/idle time for a very congested airport can be as much as three or four times longer than for an uncongested airport. Taxi/idle-in time typically is shorter than taxi/idle-out time because there are usually fewer delays for aircraft coming into a gate than for aircraft lining up to takeoff. For a large congested airport the taxi/idle-out time can be three times longer than taxi/idle-in time. Taxi/idle time also may vary by aircraft type. For example, wide-body jets may all use special gates at the terminal that place them further from the runway than narrow-body jets or small regional commuter aircraft so their taxi/idle-in and taxi/idle-out times are longer. Because of the variation in taxi/idle time, it is important to get data specific to the airports of interest in the

Table 5-4:
Modal Emission Rates – Civil Aircraft Engines[1]

Model – Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	HC	Emission Rates CO	NOX	SO_2[3]	Particulate
				— lbs per 1000 lbs —				
501D22A[4] All.	Takeoff	100%	39.6	0.28	2.04	9.88	0.54	--
	Climbout	85%	36.63	0.89	2.06	9.22	0.54	--
	Approach	30%	19	1.96	5.1	7.49	0.54	--
	Taxi/Idle	7%	10.17	17.61	43.61	3.52	0.54	--
0-200[4] Con	Takeoff	100%	0.75	20.81	974.1	4.87	0.11	--
	Climbout	85%	0.75	20.81	974.1	4.37	0.11	--
	Approach	40%	0.43	33.22	1187.94	1.14	0.11	--
	Taxi/Idle	7%	0.14	29	644.42	1.58	0.11	--
TSIO-360C[4] Con	Takeoff	100%	2.22	9.17	1081.95	2.71	0.11	--
	Climbout	85%	1.66	9.55	960.8	4.32	0.11	--
	Approach	40%	1.02	11.31	995.08	3.77	0.11	--
	Taxi/Idle	7%	0.19	138.26	592.17	1.91	0.11	--
CF6-6D GE 39.3	Takeoff	100%	229.63	0.3	0.5	40	0.54	--
	Climbout	85%	189.29	0.3	0.5	32.6	0.54	--
	Approach	30%	64.01	0.7	6.5	11.4	0.54	--
	Taxi/Idle	7%	22.86	21	54.2	4.5	0.54	--
CF6-45 GE 45.6	Takeoff	100%	281.22	0.1	1	30.6	0.54	--
	Climbout	85%	234.13	0.1	1.3	26.6	0.54	--
	Approach	30%	80.03	0.7	8.2	10.5	0.54	--
	Taxi/Idle	7%	26.72	32.7	59.2	3.9	0.54	--
CF6-45A/A2 GE 45.6	Takeoff	100%	268.12	0.09	0.43	25.45	0.54	--
	Climbout	85%	219.97	0.14	0.54	21.61	0.54	--
	Approach	30%	78.31	0.35	5.01	9.36	0.54	--
	Taxi/Idle	4%	21.56	2.72	24.04	3.4	0.54	--
CF6-50E/C1/E1/C2/E2 GE 51.8	Takeoff	100%	321.17	0.6	0.5	36.5	0.54	--
	Climbout	85%	254.63	0.7	0.5	29.6	0.54	--
	Approach	30%	87.86	1	5.7	9.7	0.54	--
	Taxi/Idle	3%	22.24	49.3	81.3	2.4	0.54	--
CF6-80A GE 46.9	Takeoff	100%	283.73	0.29	1	29.8	0.54	--
	Climbout	85%	237.44	0.29	1.1	25.6	0.54	--
	Approach	30%	81.35	0.47	3.1	10.3	0.54	--
	Taxi/Idle	4%	19.84	6.29	28.2	3.4	0.54	--
CF6-80A1 GE 46.9	Takeoff	100%	283.73	0.29	1	29.8	0.54	--
	Climbout	85%	237.44	0.29	1.1	25.6	0.54	--
	Approach	30%	81.35	0.47	3.1	10.3	0.54	--
	Taxi/Idle	4%	19.84	6.29	28.2	3.4	0.54	--
CF6-80A2 GE 48.6	Takeoff	100%	298.15	0.3	1	29.6	0.54	--
	Climbout	85%	249.34	0.37	1.1	26.6	0.54	--
	Approach	30%	84.79	0.45	2.8	10.8	0.54	--
	Taxi/Idle	4%	19.84	6.28	28.2	3.4	0.54	--
CF6-80A3 GE 48.9	Takeoff	100%	298.15	0.3	1	29.6	0.54	--
	Climbout	85%	249.34	0.37	1.1	26.6	0.54	--
	Approach	30%	84.79	0.45	2.8	10.8	0.54	--
	Taxi/Idle	4%	19.84	6.28	28.2	3.4	0.54	--
CF6-80C2A1 GE 57.9	Takeoff	100%	317.46	0.08	0.56	32.22	0.54	--
	Climbout	85%	258.34	0.09	0.54	24.85	0.54	--
	Approach	30%	84.13	2	2.19	9.76	0.54	--
	Taxi/Idle	7%	26.32	9.19	42.24	3.99	0.54	--

TABLE 5-4:
Modal Emission Rates – Civil Aircraft Engines[1]
— Continued —

Model – Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates HC	CO	NO_x	SO_2[3]	Particulate
				— lbs per 1000 lbs —				
CF6-80C2A2	Takeoff	100%	280.03	0.14	0.58	27.9	0.54	--
GE	Climbout	85%	230.82	0.11	0.56	20.71	0.54	--
52.5	Approach	30%	76.72	0.25	3.04	9.52	0.54	--
	Taxi/Idle	7%	25	10.74	46.65	3.91	0.54	--
CF6-80C2A3	Takeoff	100%	325	0.08	0.59	34.44	0.54	--
GE	Climbout	85%	264.95	0.1	0.57	25.45	0.54	--
58.9	Approach	30%	85.85	0.21	2.15	10.01	0.54	--
	Taxi/Idle	7%	26.72	9.21	42.18	3.96	0.54	--
CF6-80C2A5	Takeoff	100%	341.4	0.07	0.52	34.35	0.54	--
GE	Climbout	85%	275.4	0.08	0.52	22.56	0.54	--
60.1	Approach	30%	90.87	0.2	1.93	9.11	0.54	--
	Taxi/Idle	7%	27.38	8.99	41.65	3.79	0.54	--
CF6-80C2B1	Takeoff	100%	302.25	0.08	0.58	28.11	0.54	--
GE	Climbout	85%	247.75	0.09	0.55	21.26	0.54	--
56.0	Approach	30%	81.48	0.21	2.37	8.63	0.54	--
	Taxi/Idle	7%	25.93	9.46	43.22	3.73	0.54	--
CF6-80C2B1F	Takeoff	100%	311.25	0.08	0.52	29.06	0.54	--
GE	Climbout	85%	253.04	0.09	0.52	21.34	0.54	--
57.2	Approach	30%	83.6	0.2	2.19	8.97	0.54	--
	Taxi/Idle	7%	27.12	9.68	43.71	3.74	0.54	--
CF6-80C2B2	Takeoff	100%	281.88	0.08	0.57	23.89	0.54	--
GE	Climbout	85%	232.94	0.1	0.55	18.65	0.54	--
52.0	Approach	30%	76.32	0.22	2.65	8.77	0.54	--
	Taxi/Idle	7%	25.4	11.17	48.02	3.7	0.54	--
CF6-80C2B4	Takeoff	100%	321.43	0.08	0.56	29.2	0.54	--
GE	Climbout	85%	262.17	0.09	0.54	21.8	0.54	--
57.2	Approach	30%	65.98	0.21	2.33	8.9	0.54	--
	Taxi/Idle	7%	26.32	9.74	43.91	3.67	0.54	--
CF6-80C2B6	Takeoff	100%	341.14	0.07	0.52	30.81	0.54	--
GE	Climbout	85%	275.27	0.08	0.52	22.94	0.54	--
60.1	Approach	30%	90.74	0.2	1.93	9.11	0.54	--
	Taxi/Idle	7%	27.38	8.99	41.66	3.79	0.54	--
CF6-80C2D1F	Takeoff	100%	337.83	0.08	0.52	32.54	0.54	--
GE	Climbout	85%	268.39	0.1	0.53	23.55	0.54	--
60.2	Approach	30%	85.36	0.21	1.98	9.29	0.54	--
	Taxi/Idle	7%	26.01	9.96	44.41	3.79	0.54	--
CFM56-2A	Takeoff	100%	148.55	0.03	0.9	21.05	0.54	--
GE (SNECMA)	Climbout	85%	122.62	0.04	1	17.18	0.54	--
24.0	Approach	30%	45.64	0.1	3.4	8.62	0.54	--
	Taxi/Idle	7%	17.46	1.17	24.9	4.12	0.54	--
CFM56-2B	Takeoff	100%	132.54	0.05	0.9	19.06	0.54	--
GE (SNECMA)	Climbout	85%	110.72	0.08	0.9	16.3	0.54	--
22.0	Approach	30%	42.59	0.1	3.7	8.14	0.54	--
	Taxi/Idle	7%	16.27	1.67	29.5	3.66	0.54	--
CFM56-3	Takeoff	100%	134.92	0.04	0.9	18.5	0.54	--
GE (SNECMA)	Climbout	85%	111.51	0.05	0.9	16	0.54	--
20.1	Approach	30%	44.71	0.1	3.5	8.4	0.54	--
	Taxi/Idle	7%	16.01	1.83	31	3.9	0.54	--

Table 5-4:
Modal Emission Rates – Civil Aircraft Engines[1]
— Continued —

Model – Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	HC	Emission Rates CO — lbs per 1000 lbs —	NO_x	SO_2[3]	Particulate
CFM56-3B	Takeoff	100%	150.79	0.04	0.9	20.7	0.54	--
GE (SNECMA)	Climbout	85%	123.02	0.05	0.9	17.3	0.54	--
22.0	Approach	30%	47.62	0.08	3.1	9.7	0.54	--
	Taxi/Idle	7%	17.2	1.25	27	4.1	0.54	--
CFM56-3-B4	Takeoff	100%	116.4	0.04	0.9	16.6	0.54	--
GE (SNECMA)	Climbout	85%	96.56	0.05	1.1	14.5	0.54	--
18.5	Approach	30%	35.71	0.11	4.2	8	0.54	--
	Taxi/Idle	7%	14.55	3.33	38.5	3.9	0.54	--
CFM56-3C	Takeoff	100%	156.09	0.04	0.9	20.17	0.54	--
GE (SNECMA)	Climbout	85%	128.31	0.04	1	17.15	0.54	--
23.5	Approach	30%	44.97	0.09	3.2	3.88	0.54	--
	Taxi/Idle	7%	15.87	2.14	33.4	4	0.54	--
CFM56-5A1	Takeoff	100%	142.8	0.23	0.83	28.03	0.54	--
GE (SNECMA)	Climbout	85%	116.4	0.23	0.87	23.1	0.54	--
25.0	Approach	30%	39.68	0.4	2.47	9.48	0.54	--
	Taxi/Idle	7%	14.55	1.53	18	4.36	0.54	--
TFE 731-2	Takeoff	100%	27.12	0.11	1.39	15.25	0.54	--
Grt	Climbout	85%	22.88	0.13	2.03	13.08	0.54	--
3.51	Approach	30%	8.86	4.26	22.38	5.9	0.54	--
	Taxi/Idle	7%	3.17	20.04	58.6	2.82	0.54	--
TFE 731-3	Takeoff	100%	29.76	0.06	1.13	19.15	0.54	--
Grt	Climbout	85%	24.6	0.07	1.62	16.02	0.54	--
3.7	Approach	30%	9.52	1.41	15.56	6.92	0.54	--
	Taxi/Idle	7%	3.44	9.04	47.7	3.72	0.54	--
TPE 331-3[5]	Takeoff	100%	7.63	0.11	0.76	12.36	0.54	1.75
Grt	Climbout	90%	6.82	0.15	0.98	11.86	0.54	1.47
	Approach	30%	4.17	0.64	6.96	9.92	0.54	2.4
	Taxi/Idle	7%	1.97	79.11	61.52	2.36	0.54	2.95
ALF 502L-2	Takeoff	100%	52.9	0.02	0.4	13.43	0.54	-
Lyc	Climbout	85%	42.8	0.02	0.3	12.03	0.54	-
7.50	Approach	30%	15.5	0.18	3.97	6.47	0.54	-
	Taxi/Idle	7%	6.31	6.65	45.63	3.38	0.54	-
ALF 502R-3	Takeoff	100%	45.98	0.06	0.43	11.2	0.54	
Lyc	Climbout	85%	38.1	0.05	0.5	9.94	0.54	
6.69	Approach	30%	13.58	0.29	8.43	6.15	0.54	
	Taxi/Idle	7%	5.71	6.51	44.67	3.3	0.54	
ALF 502R-5	Takeoff	100%	47.37	0.06	0.3	13.53	0.54	
Lyc	Climbout	85%	39.09	0.05	0.25	10.56	0.54	
6.96	Approach	30%	13.68	0.22	7.1	13.53	0.54	
	Taxi/Idle	7%	5.4	5.39	40.93	3.78	0.54	
O-320[4]	Takeoff	100%	1.48	11.78	1077.44	2.19	0.11	
Lyc	Climbout	85%	1.11	12.38	989.51	3.97	0.11	
	Approach	40%	0.78	19.25	1221.51	0.95	0.11	
	Taxi/Idle	7%	0.16	36.92	1077	0.52	0.11	
D-36	Takeoff	100%	83.86	0	0.5	26	0.54	
MKB	Climbout	85%	70.5	0	0.4	22	0.54	
14.3	Approach	30%	27.91	0	2.7	9	0.54	
	Taxi/Idle	7%	0	5.4	20.7	5.5	0.54	

Table 5-4:

Modal Emission Rates – Civil Aircraft Engines[1]

— Continued —

Model – Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates HC	CO	NO_x	SO_2[3]	Particulate
				— lbs per 1000 lbs —				
NK-86 NPO 29.5	Takeoff	100%	267.07	0	1.3	13.6	0.54	--
	Climbout	85%	218.26	0	1.7	10	0.54	--
	Approach	30%	75.66	0	5	3.8	0.54	--
	Taxi/Idle	7%	32.14	4.4	27.6	2.5	0.54	--
IAE V2500 P&W 25	Takeoff	100%	147.22	0.1	0.55	37.13	0.54	--
	Climbout	85%	122.22	0.11	0.55	30.82	0.54	--
	Approach	30%	44.18	0.15	0.77	13.45	0.54	--
	Taxi/Idle	7%	16.4	0.22	7.76	5.91	0.54	--
JT3D-7/7A/7B P&W 13.9	Takeoff	100%	130.85	0.4	1.5	17.1	0.54	--
	Climbout	85%	107.32	0.5	2	13.5	0.54	--
	Approach	30%	37.84	1.6	10.5	5.5	0.54	--
	Taxi/Idle	7%	17.08	10.6	35.5	2.7	0.54	--
JT8D-9/9A P&W 14.5	Takeoff	100%	137.57	0.47	1.24	17.92	0.54	--
	Climbout	85%	111.91	0.47	1.66	14.21	0.54	--
	Approach	30%	39.42	1.73	9.43	5.64	0.54	--
	Taxi/Idle	7%	17.46	10	34.5	2.9	0.54	--
JT8D-11 P&W 15.0	Takeoff	100%	148.28	0.4	1.2	18.9	0.54	--
	Climbout	85%	120.85	0.45	1.9	14.6	0.54	--
	Approach	30%	44.17	1.4	9.4	5.8	0.54	--
	Taxi/Idle	7%	19.25	10	35	2.75	0.54	--
JT8D-15[8] P&W 15.5	Takeoff	100%	155.82	0.25	0.72	19.12	0.54	--
	Climbout	85%	125	0.25	1.01	15.01	0.54	--
	Approach	30%	45.01	1.57	9.12	5.97	0.54	--
	Taxi/Idle	7%	19.54	10.33	33.88	3.01	0.54	--
JT8D-15A P&W 15.5	Takeoff	100%	147.49	0.25	1.08	18.1	0.54	--
	Climbout	85%	118.45	0.33	1.2	13.9	0.54	--
	Approach	30%	41.27	0.65	2.9	6.6	0.54	--
	Taxi/Idle	7%	18.15	2.29	12.43	3.1	0.54	--
JT8D-17[6] P&W 16.0	Takeoff	100%	164.68	0.66	0.75	19.3	0.54	--
	Climbout	85%	131.88	0.75	1.01	15.26	0.54	--
	Approach	30%	46.83	1.86	8.13	6.23	0.54	--
	Taxi/Idle	7%	19.44	9.57	29.56	3.29	0.54	--
JT8D-17A P&W 16	Takeoff	100%	155.16	0.25	1.07	19.1	0.54	--
	Climbout	85%	123.6	0.3	1.16	14.3	0.54	--
	Approach	30%	43.7	0.64	2.88	6.7	0.54	--
	Taxi/Idle	7%	18.53	2.02	12.46	3.2	0.54	--
JT8D-17AR P&W 17.4	Takeoff	100%	180.56	0.21	0.93	24.5	0.54	--
	Climbout	85%	138.49	0.27	1.08	16	0.54	--
	Approach	30%	47.28	0.55	2.68	8	0.54	--
	Taxi/Idle	7%	19.54	1.33	10.7	3.2	0.54	--
JT8D-17R P&W 17.4	Takeoff	100%	187.44	0.21	0.95	25.3	0.54	--
	Climbout	85%	145.9	0.27	1.03	17.6	0.54	--
	Approach	30%	49.67	0.53	2.54	8.4	0.54	--
	Taxi/Idle	7%	20.5	0.95	9.43	3.3	0.54	--
JT8D-209 P&W 19.2	Takeoff	100%	157.54	0.35	1.03	22.8	0.54	--
	Climbout	85%	130	0.5	1.4	19	0.54	--
	Approach	30%	47.51	1.69	4.37	8.8	0.54	--
	Taxi/Idle	7%	17.24	4.03	14.1	3.5	0.54	--

TABLE 5-4:

Modal Emission Rates – Civil Aircraft Engines[1]

— Continued —

Model – Series Manufacturer[2] Rated Dry Output	Mode	Power Setting	Fuel Flow	HC	Emission Rates CO	NOx	SO_2[3]	Particulate
(1000 lbs Thrust)			(lb/min)		— lbs per 1000 lbs —			
JT8D-217/217A/217C	Takeoff	100%	174.6	0.28	0.8	25.7	0.54	--
P&W	Climbout	85%	142.59	0.43	1.23	20.6	0.54	--
20.8	Approach	30%	50.7	1.6	4.17	9.1	0.54	--
	Taxi/Idle	7%	18.15	3.33	12.27	3.7	0.54	--
JT8D-219	Takeoff	100%	179.1	0.27	0.73	27	0.54	--
P&W	Climbout	85%	143.52	0.42	1.2	20.8	0.54	--
21.7	Approach	30%	50.49	1.59	4.07	9.13	0.54	--
	Taxi/Idle	7%	17.78	3.48	12.63	3.6	0.54	--
JT9D-7F(modV)/7A(modV)	Takeoff	100%	286.67	0.3	0.4	46	0.54	--
P&W	Climbout	85%	233.33	0.3	0.4	34.4	0.54	--
46.7	Approach	30%	82.5	0.5	2.9	7.8	0.54	--
	Taxi/Idle	7%	28.97	26	54	3.1	0.54	--
JT9D-7R4D/7R4D1	Takeoff	100%	271.83	0.15	0.51	38.5	0.54	--
P&W	Climbout	85%	221.96	0.12	0.48	32	0.54	--
46.7	Approach	30%	100.44	0.13	1.36	9.8	0.54	--
	Taxi/Idle	7%	27.17	1.25	10	4.1	0.54	--
JT9D-7R4E/E1(AI500)	Takeoff	100%	280.16	0.16	0.57	41.6	0.54	--
P&W	Climbout	85%	228.04	0.13	0.53	34.2	0.54	--
52.4	Approach	30%	86.36	0.13	1.23	10.4	0.54	--
	Taxi/Idle	7%	29.23	1.11	8.27	4.1	0.54	--
JT9D-7R4E1(H) (A1-600)	Takeoff	100%	293.39	0.15	0.67	36.9	0.54	--
P&W	Climbout	85%	241.93	0.13	0.67	29.7	0.54	--
48.5	Approach	30%	84.66	0.22	1.46	8.5	0.54	--
	Taxi/Idle	7%	29.17	3.35	14	3.5	0.54	--
JT9D-7R4G2	Takeoff	100%	321.3	0.15	0.74	41.3	0.54	--
P&W	Climbout	85%	248.68	0.14	0.63	32.1	0.54	--
53.3	Approach	30%	87.17	0.18	1.4	8.8	0.54	--
	Taxi/Idle	7%	29.62	1.55	11.82	3.8	0.54	--
JT9D-7R4H1/H2	Takeoff	100%	332.28	0.15	0.74	45.2	0.54	--
P&W	Climbout	85%	264.42	0.14	0.63	34.2	0.54	--
53.9	Approach	30%	95.6	0.18	1.39	8.9	0.54	--
	Taxi/Idle	7%	32.46	1.48	11.63	3.8	0.54	--
JT9D-70/59/7Q	Takeoff	100%	323	0.2	0.2	31.6	0.54	--
P&W	Climbout	85%	264.5	0.2	0.2	25.6	0.54	--
51.1	Approach	30%	90	0.3	1.7	7.9	0.54	--
	Taxi/Idle	7%	31.35	12	53	3	0.54	--
PW2037	Takeoff	100%	203.44	0.05	0.4	31.1	0.54	--
P&W	Climbout	85%	167.46	0.06	0.41	24.8	0.54	--
37.6	Approach	30%	52.78	0.21	2.3	10.3	0.54	--
	Taxi/Idle	7%	18.65	2.26	23.1	4.4	0.54	--
PW2040	Takeoff	100%	241.01	0.03	0.2	47.7	0.54	--
P&W	Climbout	85%	191.54	0.04	0.2	27.7	0.54	--
40.8	Approach	30%	65.21	0.18	2.6	11	0.54	--
	Taxi/Idle	7%	20.5	2.36	23.6	4.4	0.54	--
PW2041	Takeoff	100%	253.57	0.03	0.2	37	0.54	--
P&W	Climbout	85%	203.18	0.04	0.2	29	0.54	--
42.8	Approach	30%	68.39	0.16	2.5	11	0.54	--
	Taxi/Idle	7%	21.03	2.23	23.1	4.5	0.54	--

Table 5-4:
Modal Emission Rates – Civil Aircraft Engines[1]
— Continued —

Model – Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	HC	CO	NO_x	SO_2[3]	Particulate
				Emission Rates — lbs per 1000 lbs —				
PW4056/4156 P&W 55.9	Takeoff	100%	309.79	0.06	0.44	29.1	0.54	--
	Climbout	85%	255.29	0.01	0.57	22.9	0.54	--
	Approach	30%	87.04	0.13	2	11.6	0.54	--
	Taxi/Idle	7%	27.51	1.92	21.86	4.8	0.54	--
PW4152 P&W 51.9	Takeoff	100%	287.96	0.13	0.12	26.9	0.54	--
	Climbout	85%	236.11	0.16	0.17	22.7	0.54	--
	Approach	30%	78.44	0.15	1.09	11.1	0.54	--
	Taxi/Idle	7%	23.41	0.74	12.76	4.9	0.54	--
PW4158 P&W 57.9	Takeoff	100%	328.18	0.09	0.4	30.2	0.54	--
	Climbout	85%	265.08	0.02	0.54	23.7	0.54	--
	Approach	30%	90.21	0.14	1.88	11.8	0.54	--
	Taxi/Idle	7%	27.91	1.78	20.99	4.8	0.54	--
PW4460 P&W 59.9	Takeoff	100%	350.13	0.1	0.37	32.8	0.54	--
	Climbout	85%	275.8	0.03	0.51	24.7	0.54	--
	Approach	30%	92.99	0.14	1.78	12	0.54	--
	Taxi/Idle	7%	28.17	1.66	20.32	4.9	0.54	--
JT15D-1 P&WC 2.39	Takeoff	100%	19.58	0.01	2.65	7.6	0.54	--
	Climbout	85%	16.4	0.01	3.5	6.77	0.54	--
	Approach	30%	6.75	4.43	40.5	3.44	0.54	--
	Taxi/Idle	7%	3.04	50.5	132	1.75	0.54	--
JT15D-4 P&WC 2.72	Takeoff	100%	22.45	0.09	2.1	9.23	0.54	--
	Climbout	85%	18.92	0.19	3.18	8.56	0.54	--
	Approach	30%	7.8	5.15	32	5.29	0.54	--
	Taxi/Idle	7%	3.45	40	97	2.63	0.54	--
PT6A-27[5] P&WC	Takeoff	100%	7.08	0	1.01	7.81	0.54	--
	Climbout	90%	6.67	0	1.2	7	0.54	--
	Approach	30%	3.58	2.19	23.02	3.37	0.54	--
	Taxi/Idle	7%	1.92	50.17	64	2.43	0.54	--
PT6A-41[4] P&WC	Takeoff	100%	8.5	1.75	5.1	7.98	0.54	--
	Climbout	90%	7.88	2.03	6.49	7.57	0.54	--
	Approach	30%	4.55	22.71	34.8	4.65	0.54	--
	Taxi/Idle	7%	2.45	101.63	115.31	1.97	0.54	--
M45H-01 RR 7.28	Takeoff	100%	65.87	0.75	6.2	11.5	0.54	--
	Climbout	85%	55.03	0.74	7.9	9.3	0.54	--
	Approach	30%	19.31	7.4	51	3.6	0.54	--
	Taxi/Idle	7%	7.01	59.5	178.4	1.5	0.54	--
OLYMPUS 593 MK610 RR 37	Takeoff	100%	841.94	2.9	29	9.5	0.54	--
	Climbout	65%	308.07	1.7	19.9	9.3	0.54	--
	Descent	15%	90.61	22	73.2	2.5	0.54	--
	Approach	34%	154.9	11.4	52.9	3.5	0.54	--
	Taxi/Idle	7%	55.69	33.4	100.1	1.7	0.54	--
RB.211-22B RR 41	Takeoff	100%	246.83	0.36	2.48	34.32	0.54	--
	Climbout	85%	203.97	0.39	4.14	25.63	0.54	--
	Approach	30%	73.15	7.73	26.38	9.05	0.54	--
	Taxi/Idle	7%	30.03	65.37	93.17	2.7	0.54	--
RB.211-524B/B2/B3/B4 RR 49.1	Takeoff	100%	315.21	0.52	1.83	47	0.54	--
	Climbout	85%	256.48	0.4	2.82	33	0.54	--
	Approach	30%	91.67	4.98	20	9.75	0.54	--
	Taxi/Idle	7%	35.98	50.6	82.2	3.53	0.54	--

Table 5-4:

Modal Emission Rates – Civil Aircraft Engines[1]

— Continued —

Model – Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	HC	CO	NO_x	SO_2[3]	Particulate
				Emission Rates — lbs per 1000 lbs —				
RB.211-524C2	Takeoff	100%	328.04	0	0.66	41.9	0.54	--
RR	Climbout	85%	267.2	0.22	1.63	32.3	0.54	--
50.5	Approach	30%	97.88	4.42	18.9	10.4	0.54	--
	Taxi/Idle	7%	39.68	54.2	81	3.37	0.54	--
RB.211-524D4[6]	Takeoff	100%	322.12	0.02	0.53	56.97	0.54	--
RR	Climbout	85%	257.96	0.42	1.15	41.06	0.54	--
51.9	Approach	30%	94.97	4.68	16.44	9.68	0.54	--
	Taxi/Idle	7%	38.5	45.11	71.87	4.12	0.54	--
RB.211-524G	Takeoff	100%	346.56	2.28	0.59	58.71	0.54	--
RR	Climbout	85%	275.13	1.46	0.43	40.54	0.54	--
56.8	Approach	30%	92.59	1.14	1.01	9.56	0.54	--
	Taxi/Idle	7%	34.39	3.29	13.74	4.63	0.54	--
RB.211-535C	Takeoff	100%	238.1	0.25	0.7	33.71	0.54	--
RR	Climbout	85%	194.45	0.14	0.27	24.89	0.54	--
36.7	Approach	30%	71.43	0.44	0.94	6.37	0.54	--
	Taxi/Idle	7%	26.46	1.44	18.79	3.44	0.54	--
RB.211-535E4	Takeoff	100%	246.03	0.69	1.01	52.7	0.54	--
RR	Climbout	85%	199.74	0.94	1.23	36.2	0.54	--
39.5	Approach	30%	75.4	1.33	1.71	7.5	0.54	--
	Taxi/Idle	7%	25.13	2.85	15.44	4.3	0.54	--
SPEY MK511	Takeoff	100%	117.59	0.98	1.81	23.27	0.54	--
RR	Climbout	85%	96.03	1.32	2.06	19.18	0.54	--
11.3	Approach	30%	36.91	7.23	20.3	7.94	0.54	--
	Taxi/Idle	7%	15.74	56.73	97.96	1.48	0.54	--
SPEY MK511-8	Takeoff	100%	117.56	0.09	0.12	22.7	0.54	--
RR	Climbout	85%	96.03	0.12	0.63	17.3	0.54	--
11.3	Approach	30%	36.77	0.18	2.65	7.2	0.54	--
	Taxi/Idle	7%	16.8	3.69	31.77	3.6	0.54	--
SPEY MK555[7]	Takeoff	100%	73.5	0.74	0.41	19.61	0.54	--
RR	Climbout	85%	60.13	1.27	0.16	15.07	0.54	--
9.89	Approach	30%	22.66	5.43	17.96	6.12	0.54	--
	Taxi/Idle	7%	11.74	71.84	74.68	2.26	0.54	--
TAY MK620-15/MK611-8	Takeoff	100%	100.53	0.8	0.7	21.1	0.54	--
RR	Climbout	85%	83.33	0.3	0.8	16.8	0.54	--
13.8	Approach	30%	30.42	0.9	3.9	5.7	0.54	--
	Taxi/Idle	7%	14.55	3.4	24.1	2.5	0.54	--

1 Source: ICAO Engine Exhaust Emissions Databank (Reference 13) unless otherwise noted.

2 MANUFACTURERS: All. - Allison, Con - Teledyne/Continental, GE - General Electric, Grt - Garrett AiResearch, Lyc - Avco/Lycoming, P&W - Pratt & Whitney, P&WC - Pratt & Whitney Canada, RR - Rolls-Royce

3 SO_2 emissions based on national average sulfur content of aviation fuels from Aviation Turbine Fuels, 1989 (Reference 23).

4 Source of data is AP-42 (Reference 1). Nitrogen oxides reported as NO_2. HC refers to total hydrocarbons (Volatile organics, including unburned hydrocarbons and organic pyrolysis products)

5 Source of data is AP-42 (Reference 1). Source of Particulate data is AP-42 Reference 4 (M. Platt, et al., The Potential Impact of Aircraft Emissions upon Air Quality, APTD-1085, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1971). The indicated reference does not specify series number for this model engine.

6 Source of engine data is ICAO (Reference 13). Data are sales weighted averages of two versions of this engine. The basis is 93% high emission combustors and 7% low emission combustors.

7 Source of engine data is ICAO (Reference 13). Data are sales weighted averages of two versions of this engine. The basis is 77% high emission combustors and 23% low emission combustors.

inventory. Commercial airlines must keep track of their taxi/idle time at each airport for different aircraft types so that their flight schedules reflect anticipated daily and seasonal variations. These data are important to the airlines since they report schedule delays to the Department of Transportation as a measure of their operating performance. Therefore, the airlines' Flight Operations departments at their headquarters locations are the best source of data for taxi/idle time by aircraft type at a particular airport. Since all airlines using a particular airport will experience similar taxi/idle times it is only necessary to get information from a single source. If taxi/idle times are not available for a particular airport, Table 5–1 lists default values of taxi/idle periods, as well as other modes, for different aircraft classifications. For commercial aircraft this information is based on data collected prior to 1971 at large airports during periods of congestion. Idle times that reflect more recent experience will be incorporated in the next version of AP-42. For the inventory calculations, taxi/idle–in and taxi/idle–out time are added together to get a total time for the taxi/idle mode.

The final step in the procedure is to calculate total emissions for each aircraft type and to sum them for a total commercial aircraft emission rate. The following series of equations illustrates the calculation:

Adjust Approach and Climbout TIM to Represent Local Conditions

These equations adjust the times–in–mode, which are based on a default mixing height of 3000 feet, to an airport specific value based on the local mixing height. Equation 5–2 assumes the climbout mode begins with the transition from takeoff to climbout at 500 feet and continues until the aircraft exits the mixing layer.

$$TIM_{app\text{-}C} = 4 * (H/3000) \quad (5\text{-}1)$$

$$TIM_{clm\text{-}C} = 2.2 * [(H-500)/2500] \quad (5\text{-}2)$$

$TIM_{app\text{-}C}$ - time in the approach mode for commercial aircraft, in minutes

$TIM_{clm\text{-}C}$ - time in the climbout mode for commercial aircraft, in minutes

H - mixing height used in air quality modeling for time and region of interest

Calculate Emissions for Each Aircraft Type

$$E_{ij} = \Sigma\, (TIM_{jk}) * (FF_{jk}/1000) * (EI_{ijk}) * (NE_j) \quad (5\text{-}3)$$

E_{ij} = total emissions of pollutant i, in pounds, produced by aircraft type j for one LTO cycle

TIM_{jk} = time in mode for mode k, in minutes, for aircraft type j

FF_{jk} = fuel flow for mode k, in pounds per minute, for each engine used on aircraft type j (from Table 5-4)

EI_{ijk} = emission index for pollutant i, in pounds of pollutant per one thousand pounds of fuel, in mode k for aircraft type j (from Table 5-4)

NE_j = number of engines used on aircraft type j (from Table 5-2)

Calculate Total Emissions for All Commercial Aircraft

$$E_{Ti(C)} = \Sum (E_{ij}) * (LTO_j) \qquad (5\text{-}4)$$

$E_{Ti(C)}$ - total emissions of pollutant i, in pounds, produced by all commercial aircraft operating in the region of interest (where j covers the range of commercial aircraft operating in the area)

LTO_j-total number of LTO cycles for aircraft type j, during the inventory period (annual data available from Reference 6, Table 7)

After completing this series of equations, the inventory of emissions is complete for commercial aircraft. The next series of calculations is a repeat of steps three through six for general aviation aircraft.

5.2.4 Activity and Emissions for General Aviation and Air Taxi Aircraft

Defining the mix and activity level of general aviation and air taxi aircraft is more difficult than for commercial. FAA does not track operations by aircraft model for general aviation aircraft and no other sources of these data cover all states. For some states, this information is available for some airports from the State Airport Authority or from the operations officials at individual airports. Detailed model information for aircraft operating in the inventory area is difficult to locate, except perhaps for air taxis, and may add only relatively small improvement in accuracy to the emissions inventory compared to treating general aviation and air taxis as though they were made up of a representative mix of aircraft. For some smaller airports, air taxi activity may predominate and it may be possible to locate aircraft specific information on the operations there. Where information on specific aircraft is available, the procedure for calculating total engine emissions from general aviation and air taxi aircraft is the same as that followed for commercial aircraft. Table 5-5 shows some examples of the aircraft and engine combinations found in the general aviation and air taxi categories. Information on these categories may be expanded in the next update of AP-42 to include more aircraft and engine combinations as well as emission indices for additional engines.

Where detailed information on specific aircraft mix and activity is unavailable, a single emission index can be used which is made up of a representative fleet mix. This will give a rough estimate of emissions for the category. The following indexes were calculated based on 1988 fleet data[1] for general aviation aircraft.

HC 0.394 pounds per LTO

CO 12.014 pounds per LTO

NO_X 0.065 pounds per LTO

SO_2 0.010 pounds per LTO

1 See memo S. Webb to R. Wilcox dated June 10, 1991.

TABLE 5-5:

General Aviation Aircraft Types And Engine Models[1]

Aircraft	No. Of Seats	No. Of Engines	No. Of Aircraft[2]	Engine	Manu.[3]
Piston					
Sellanca 7GCBC Seaplane	3	1	567	0-320	Lyc
Cessna 150	2	1	13760	O-200	Con
Cessna 337 series	6	2	1151	TSIO-360C	Con
Piper PA-18 series	2	1	3590	0-320[4]	Lyc
Turbojet					
Aerospatiale SN601 Corvette	16	2	1	JT15D-4	PWC
Canadair CL-600 Challenger	13	2	61	ALF502L-2	Lyc
Dassault Bregue Falcon 10	7	2	126	TFE731-2	Grt
Dassault Bregue Falcon 50	10	3	125	TFE731-3	Grt
Gates Learjet 35/36	10	2	67	TFE731-2-2B	Grt
Gates Learjet 35A/36A	10	2	342	TFE731-2-2B	Grt
Israel Aircraft IAI 1124	10	2	151	TFE731-3	Grt
Learjet 31	10	2	6	TFE731-2	Grt
Mitsubishi MU-300 series	11	2	75	JT15D-4	PWC
Turboprop					
de Havilland DHC-6-300	22	2	40	PT6A-27	PWC
Fairchild Pilatus PC6 series	9	1	8	PT6A-27[5]	PWC
Helio Aircraft HST-550A Stallion	10	1	1	PT6A-27	PWC
Piper PA-42 series	11	2	105	PT6A-41[6]	PWC

1 Source of aircraft, corresponding engines, and number of engines is <u>FAA Aircraft Engine Emission Database</u> (Reference 14). Source of number of seats, aircraft type, and number of aircraft is <u>Census of U.S. Civil Aircraft</u> (Reference 7).

2 No. of Aircraft refers to Total U.S. Registered Aircraft as of December 31, 1989.

3 Engine Mnf. Abbreviations: Con - TeledyneContinental, GE - General Electric. Grt - Garrett AiResearch. Lyc - Avco/Lycoming, P&W - Pratt & Whitney. PWC - Pratt & Whitney Canada. RR - Rolls-Royce

4 Engine refers to a PA-18-150 Super aircraft.

5 Engine refers to a PC6/B2-2 aircraft.

6 Engine refers to a PA-42 Cheyenne aircraft.

Since air taxis have fewer of the smallest engines in their fleet and more turboprop and turbojet engines, their emission factors are somewhat different.

HC 1.234 pounds per LTO

CO 28.130 pounds per LTO

NO_X 0.158 pounds per LTO

SO_2 0.015 pounds per LTO

Airport activity for general aviation aircraft and air taxis can be found in *FAA Air Traffic Activity* (Reference 3). Figure 5–5 is a copy of a page from Table 4 which reports airport operations at airports with FAA-operated traffic control towers. Table 22 from the same report lists operations at airports with FAA contractor-operated traffic control towers. In this report, an operation could be either a takeoff or landing, so the number of operations should be divided by two to get LTOs. In addition to these airports, general aviation and air taxi activity is common at smaller airports and landing strips not included in FAA's reporting system. These airports must be contacted directly to determine if information is available on general aviation activity. Air taxi operators located at the airports, may be a source for information on air taxi activity. These steps may have little impact on the inventory and should be considered discretionary.

The annual emissions are then calculated as the product of airport activity in LTOs from Reference 3 and the emission index in pounds per LTO listed above. Total emissions are then summed for general aviation and air taxis.

This simplified estimation procedure is based on the default times-in-mode from Table 5-1. If the detailed estimation procedure is being followed based on specific aircraft and engines, airport specific estimates on time-in-mode might be used if available from airport officials. These data likely vary quite widely because of the many different types of services provided by this aircraft category. The rest of the detailed estimation procedure uses the same set of equations used for commercial aircraft.

Adjust Approach and Climbout TIM to Represent Local Conditions

$$TIM_{app-G} = 6 * (H/3000) \quad (5\text{-}5)$$

$$TIM_{clm-G} = 5 * [(H-500)/2500] \quad (5\text{-}6)$$

TIM_{app-G} - time in the approach mode, in minutes

TIM_{clm-G} - time in the climbout mode, in minutes (assumes transition from takeoff to climbout occurs at 500 feet)

H - mixing height used in air quality modeling for time and region of interest

FIGURE 5–5

Reproduction Of A Page Of Table 4

— FROM REFERENCE 3 —

TABLE 4 • FISCAL YEAR 1989

AIRPORT OPERATIONS AT AIRPORTS WITH FAA-OPERATED TRAFFIC CONTROL TOWERS BY REGION AND BY STATE AND AVIATION CATEGORY-CONTINUED

State and Location Name	Location Identifier	Hub	Total	Air Carrier	Air Taxi	General Aviation	Military
CALIFORNIA—Continued							
CHINO	(CNO)	S					
ITINERANT OPERATIONS			112504	0	147	111106	1251
LOCAL OPERATIONS			111099			111026	73
TOTAL OPERATIONS			223603	0	147	222132	1324
CONCORD	(CCR)	L					
ITINERANT OPERATIONS			121568	2500	7100	110802	896
LOCAL OPERATIONS			141405			141322	83
TOTAL OPERATIONS			262972	2500	7100	252225	979
EL MONTE	(EMT)	N					
ITINERANT OPERATIONS			90343	3	4515	85539	286
LOCAL OPERATIONS			99366			99366	0
TOTAL OPERATIONS			189709	3	4515	184904	286
FRESNO AIR TERMINAL	(FAT)	S					
ITINERANT OPERATIONS			198015	13200	67562	106730	9535
LOCAL OPERATIONS			10204			9461	743
TOTAL OPERATIONS			208219	13200	67562	115191	10278
FULLERTON MUNICIPAL	(FUL)	L					
ITINERANT OPERATIONS			91890	0	3852	88138	49
LOCAL OPERATIONS			65348			65336	13
TOTAL OPERATIONS			157238	0	3852	154525	62
HAWTHORNE	(HHR)	L					
ITINERANT OPERATIONS			54788	0	888	53811	89
LOCAL OPERATIONS			41027			41027	0
TOTAL OPERATIONS			95815	0	888	94838	89
HAYWARD	(HWD)	L					
ITINERANT OPERATIONS			126890	0	4161	122111	621
LOCAL OPERATIONS			125441			125433	8
TOTAL OPERATIONS			252334	0	4161	247544	629
LA VERNE BRACKETT	(POC)	N					
ITINERANT OPERATIONS			95668	0	1612	93857	200
LOCAL OPERATIONS			116006			115997	8
TOTAL OPERATIONS			211674	0	1612	209854	208
LANCASTER FOX AIRPORT	(WJF)	N					
ITINERANT OPERATIONS			63304	0	1227	60910	1167
LOCAL OPERATIONS			74505			73723	782
TOTAL OPERATIONS			137809	0	1227	134633	1949
LIVERMORE MUNICIPAL	(LVK)	L					
ITINERANT OPERATIONS			91976	0	357	91250	369
LOCAL OPERATIONS			116108			116072	36
TOTAL OPERATIONS			208084	0	357	207322	405
LONG BEACH	(LGB)	L					
ITINERANT OPERATIONS			267296	20046	7856	236647	2745
LOCAL OPERATIONS			194481			194436	45
TOTAL OPERATIONS			462177	20046	7856	431083	2790
LOS ANGELES INTERNATIONAL	(LAX)	L					
ITINERANT OPERATIONS			626874	427419	151785	42670	5000
LOCAL OPERATIONS			5363			5311	52
TOTAL OPERATIONS			632237	427419	151785	47981	5052
MODESTO CITY COUNTY	(MOD)	N					
ITINERANT OPERATIONS			81571	0	23519	57450	602
LOCAL OPERATIONS			38305			38010	295
TOTAL OPERATIONS			117876	0	23519	95460	897
MONTEREY	(MRY)	S					
ITINERANT OPERATIONS			88025	8106	19338	57773	2808
LOCAL OPERATIONS			19223			17284	1939
TOTAL OPERATIONS			107248	8106	19338	75057	4747
NAPA COUNTY	(APC)	N					
ITINERANT OPERATIONS			70146	0	478	68732	936
LOCAL OPERATIONS			99958			99414	544
TOTAL OPERATIONS			170103	0	478	168147	1480
OAKLAND INTERNATIONAL	(OAK)	L					
ITINERANT OPERATIONS			277745	74882	57281	144980	602
LOCAL OPERATIONS			125468			125304	164
TOTAL OPERATIONS			403213	74882	57281	270284	966
ONTARIO	(ONT)	S					
ITINERANT OPERATIONS			138686	86181	25018	28864	525
LOCAL OPERATIONS			3082			3080	2
TOTAL OPERATIONS			142080	86181	25018	31944	527
OXNARD VENTURA COUNTY	(OXR)	N					
ITINERANT OPERATIONS			87308	0	21326	65345	635
LOCAL OPERATIONS			48622			47351	1271
TOTAL OPERATIONS			135928	0	21326	112696	1906

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Calculate Emissions for Each Aircraft Type

The emission factors that appear in Table 5-4 for general aviation aircraft have not been updated since the last version of AP-42. The next edition of AP-42 should include updates to much of the date that appears in the table.

$$E_{ij} = \Sigma (TIM_{jk}) * (FF_{jk}/1000) * (EI_{ijk}) * (NE_j) \qquad (5\text{-}7)$$

E_{ij} - total emissions of pollutant i, in pounds, produced by aircraft type j for one LTO cycle.

TIM_{jk} - time in mode for mode k, in minutes, for aircraft type j

FF_{jk} - fuel flow for mode k, in pounds per minute, for each engine used on aircraft type j (from Table 5-4)

EI_{ijk} - emission index for pollutant i, in pounds of pollutant per one thousand pounds of fuel, in mode k for aircraft type j (from Table 5-4)

NE_j - number of engines used on aircraft type j (from Table 5-5)

Calculate Total Emissions for All General Aviation Aircraft

$$E_{Ti(G)} = \Sigma (E_{ij}) * (LTO_j) \qquad (5\text{-}8)$$

$E_{Ti(G)}$ - total emissions of pollutant i, in pounds, produced by all general aviation aircraft operating in the region of interest (where j covers the range of general aviation aircraft operating in the area)

LTO_j - total number of LTO cycles for aircraft type j, during the inventory period

5.2.5 Activity and Emissions for Military Aircraft

FAA Air Traffic Activity (Reference 3) contains information on the number of military operations at airports with FAA-operated traffic control towers. This information can be used in much the same way as for general aviation aircraft, however, military air bases are not included in this reference. The information only addresses military operations at civil airports. Military air bases included in the modeling area should be apparent from maps of the area. For these bases, it likely will be difficult to get good information on fleet make up and activity. In some cases, information may be available from the Office of the Base Commander on fleet make-up and possibly some measure or estimate of activity such as LTOs for one day or one month. Where specific information is available for aircraft type and LTOs, Table 5–6 lists military aircraft and their engines and Table 5–7 lists the modal emission rates for these engines. Much of the data in Table 5–7 has been updated since the last version of AP–42.

Table 5-6:
Military Aircraft Types And Engine Models[1]

Aircraft	Type[2]	Operator[3]	No. Of Engines	Engine Model	Manu.[4]
Combat					
Boeing B52-H Stratofortress	TF	USAF	8	TF33-P-3	PW
Boeing EC-135C	TF	USAF	4	TF33-P-5	PW
Douglas A-4 Skyhawk[5]	TJ	USN	1	J52-P-8B	PW
Douglas A-4M Skyhawk[6]	TJ	USMC	2	J52-P-408	PW
General Dynamics F-16 Fighting Falcon[5]	TF	USAF	1	F101DFE	PW
	TF	USAF/USN	1	F100-PW-200[1]	PW
Grumman A-6 Intruder[5]	TJ	USN	2	J52-P-8B	PW
Grumman E-2 Hawkeye[5]	TP	USN	2	T56-A-16	All.
Grumman EA-6B Prowler[5]	TJ	USMC/USN	2	J52-P-408	PW
Grumman F-14 Tomcat[5]	TF	USN	2	TF30-P-412A	PW
Learjet Corp C-21-A	TF	USAF	2	TFE 731-2-2B	Gr.
Lockheed S-3 Viking[5]	TF	USN	2	TF34-GE-400	GE
LTV Aircraft A-7E Corsair II	TF	USN	1	TF41-A-2	All.
McDonnell Douglas AV-8[5]	TF	USMC	1	F402	RR
McDonnell Douglas F-4 Phantom II[5]	TJ	USAF/USN	2	J79-GE-10B	GE
McDonnell Douglas F-4B Phantom II[6]	TJ	USMC/USN	2	J79-GE-8D	GE
McDonnell Douglas F-4N Phantom II[6]	TJ	USN	2	J79-GE-8D	GE
McDonnell Douglas F-4S Phantom II	TJ	USN	2	J79-GE-10	GE
McDonnell Douglas F-15C/D Eagle	TF	USAF	2	F100-PW-100	PW
McDonnell Douglas F/A-18 Hornet[5]	TF	USN	2	F404-GE-400	GE
McDonnell Douglas RF-4B Phantom II[6]	TJ	USMC	2	J79-GE-8D	GE
Northrop F-5E Tiger II	TJ	USAF/USN	2	J85-GE-21	GE
Northrop F-5F Tiger II	TJ	USAF/USN	2	J85-GE-21	GE
Northrop RF-5E Tigereye	TJ	USAF	2	J85-GE-21	GE
Rockwell OV-10 Bronco[5]	TP	USAF/USMC	2	T76-G-12A	Grt
Vought A-7 Corsair II[5]	TF	USAF/USN	1	TF41-A-2	All.
Trainer					
Boeing T-43A	TF	USAF	2	JT8D-9	PW
CASA C-101 Ariojet	TF		1	TFE 731-2	Grt
FMA Cordoba PAMPA IA.63	TF		1	TFE 731-2	Grt
Grumman Gulfstream	TF	USN	2	Dart RDa7	RR
McDonnell Douglas D F-15	TF	USAF	1	F100-PW-100	PW
McDonnell Douglas F-15 C/D Eagle	TF	USAF	2	F100-PW-100 /200[7]	PW
McDonnell Douglas F/A-18 Hornet[5]	TF	USN	2	F404-GE-400	GE
Mitsubishi T-25	TJ	USN	2	J85-GE-2	GE
Transport					
Australia Govt Nomad 22B	TP		2	250B17B	All.
Australia Govt Nomad 24	TP		2	250B17B	All.
BEECH C-12A/B/C	TP	Army/USAF	2	PT6A-41	PWC
Boeing B-747-200	TF		4	JT9D-7R4G2	PW
Boeing C-135B Stratolifter	TF	USAF	4	TF33-P-5	PW
Boeing E-4A/B NEACP	TF	USAF	4	CF6-50E	GE
Boeing VC-25A	TF	USAF	4	CF6-80C2B1	GE
de Havilland UV-18A	TP	Army	2	PT6A-27	PWC
Fairchild C-26A	TP	NG	2	TPE 331	Grt
Grumman C-1A Trader[5]	P	USN	2	R-1820	W
Grumman Gulfstream	TF	USAF	2	Dart RDa7	RR
LASC Georgia C-141B Starlifter	TF	USAF	4	TF33-P-7	PW
Lockheed C-130E Hercules	TP		4	T56-A-7	All.
Lockheed C-130 Hercules[5]	TP		4	T56-A-16	All.
Lockheed C-141 Starlifter	TF	USAF	4	TF33-P-7	PW
Lockheed L-100 Hercules	TP		4	501D22A	All.

Table 5-6:
Military Aircraft Types And Engine Models[1] — Continued

Aircraft	Type[2]	Operator[3]	No. Of Engines	Engine Model	Manu.[4]
McDonnell Douglas C-9A Nightingale	TF	USAF	2	JT8D-9	PW
McDonnell Douglas C-9B	TF	USN	2	JT8D-9	PW
McDonnell Douglas KC-10A Extender	TF	USAF	3	CF6-50C2	GE
McDonnell Douglas VC-9C	TF	USAF	2	JT8D-9	PW
Utility					
BEECH RU-231J	TP	Army	2	PT6A-41	PWC
BEECH UC-12F/M	TP	USMC/USN	2	PT6A-41	PWC
Helicopter					
Bell UH-1, AH-1S	TS	Army	1	T53-L-11D	Lyc
Boeing Vertol H-46 Sea Knight[5]	TS	USMC/USN	2	T58-GE-8F	GE
Boeing Vertol H-46E Sea Knight[5]	TS	USMC/USN	2	T58-GE-16	GE
Costruzioni HH-3F	TS	USCG	2	T58-GE-5	GE
Kaman H-2 Seasprite[5]	TS	USN	2	T58-GE-8F	GE
Sikorsky H-3 Sea King series[5]	TS		2	T58-GE-8F	GE
Sikorsky H-53 Sea Stallion/ Super Stallion[5]	TS		3	T64-GE-415	GE
Sikorsky HH-3E Jolly Green Giant	TS	USAF	2	T58-GE-5	GE
Sikorsky SH-3E	TS		2	T58-GE-5	GE
Sikorsky SH-3F	TS		2	T58-GE-5	GE
Sikorsky SH-61AA	TS		2	T58-GE-5	GE

1 Source: FAA Aircraft Engine Emission Database (Reference 14) unless otherwise noted.

2 Source of Type information is "Aviation Week & Space Technology "(Reference 16). TYPES: P - Piston, TF - Turbofan, TJ - Turbojet, TP - Turboprop, TS - Turboshaft

3 Source of Operator information is Encyclopedia of Modern Military Aircraft (Reference 17). OPERATORS: Army, NG - National Guard, USAF - U.S. Air Force, USCG - U.S. Coast Guard, USMC - U.S. Marine Corps, USN - U.S. Navy, US - USAF, USCG, USMC, & USN.

4 ENGINE MANUFACTURERS: All. - Allison, GE - General Electric, Grt - Garrett AiResearch, Lyc - Avco/ Lycoming, PW - Pratt & Whitney, W - Curtis Wright

5 Source of aircraft and corresponding engine information is Example of an Air Base Emissions Inventory for the County of San Diego (1987) (Reference 15).

6 Sources:
Engines - Summary Table of Gaseous and Particulate Emissions from Aircraft Engines (Reference 18).
Aircraft, Type, and No. of Engines - "Aviation Week & Space Technology" (Reference 16).
Classification and Operator - Encyclopedia of Modern Military Aircraft (Reference 17).

7 Source: Aviation Week & Space Technology (Reference 16).

Where data on military aircraft operations and fleet make-up cannot be obtained from the base commander, a centralized support office may be able to provide the required information. The Navy (Reference 8)and Air Force (Reference 9) both have environmental support offices responsible for information on emissions from military aircraft including complete inventories for many bases. If inventory information is unavailable after contacting the Navy or Air Force environmental support office, a letter requesting an inventory should be sent to the base commander through the EPA regional office with copies to the appropriate environmental support office.

If data on fleet make up and activity are obtained from the base commander or the environmental support offices, the procedure for calculating an inventory for military aircraft is the

Table 5-7: Modal Emission Rates — Military Aircraft Engines[1] —

Model – Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates HC	CO	NO_x	SO_2[3]	Partic-ulate
				— lbs per 1000 lbs —				
250B17B[4] All.	Takeoff	Military	4.42	0.26	7.81	6.60	0.54	--
	Climbout	95%	4.08	0.37	9.02	5.96	0.54	--
	Approach	30%	1.42	5.18	48.59	2.24	0.54	--
	Idle	Idle	1.05	20.16	97.30	1.43	0.54	--
501D22A[4] All.	Takeoff	Military	39.6	0.28	2.04	8.88	0.54	--
	Climbout	95%	36.63	0.69	2.06	9.22	0.54	--
	Approach	30%	19	1.96	5.10	7.49	0.54	--
	Idle	Idle	10.17	17.61	43.61	3.52	0.54	--
T56-A-7[4] All.	Takeoff	Military	34.65	0.38	2.12	9.28	0.54	1.79[5]
	Climbout	95%	31.8	0.47	2.41	9.22	0.54	1.57[5]
	Approach	30%	17.55	0.47	3.51	7.41	0.54	2.85[5]
	Idle	Idle	9.13	20.99	31.93	3.83	0.54	2.92[5]
T56-A-15[6] All.	Takeoff	100%	39.87	0.18	1.60	11.71	0.54	--
	Climbout	90%	36.45	0.18	1.60	10.18	0.54	--
	Approach	30%	19.10	0.28	3.00	6.38	0.54	--
	Idle	7%	8.23	14.96	17.69	2.50	0.54	--
T56-A-16 All.	Takeoff	Military	36.98	0.16	0.65	10.45	0.54	--
	Climbout	Military	36.98	0.16	0.65	10.45	0.54	--
	Approach	75%	33.27	0.17	0.42	9.93	0.54	--
	Idle	L/S Gr.idle	9.98	27.32	30.11	3.53	0.54	--
T63-A-5A[7] All.	Takeoff	Military	3.58	0.08	7.54	5.07	0.54	--
	Climbout	75%	2.92	0.24	14.31	4.61	0.54	--
	Approach	30%	1.75	3.27	38.59	2.90	0.54	--
	Idle	Gr.idle	1.02	20.30	79.15	1.42	0.54	--
TF41-A-2[7] All.	Takeoff	Intermediate	149.00	0.64	1.64	22.46	0.54	--
	Climbout	Intermediate	149.00	0.64	1.64	22.46	0.54	--
	Approach	75% M/C	100.00	0.73	2.17	16.95	0.54	--
	Idle	Idle	18.17	51.26	94.80	1.71	0.54	--
TF41-A-2 All.	Takeoff	IRP	149.00	0.74	1.62	22.46	0.54	--
	Climbout	IRP	149.00	0.74	1.62	22.46	0.54	--
	Approach	75% M/C	100.00	0.55	2.17	16.95	0.54	--
	Idle	Idle	18.17	59.48	94.73	1.71	0.54	--
0-200[4] Con	Takeoff	100%	0.75	20.81	974.10	4.87	0.11	--
	Climbout	75%	0.75	20.81	974.10	4.97	0.11	--
	Approach	30%	0.43	33.22	1187.84	1.14	0.11	--
	Idle	7%	0.14	29.00	644.42	1.58	0.11	--
T400-CP-400[7] CP	Takeoff	Military	6.87	0.11	0.75	6.68	0.54	--
	Climbout	Cruise	4.72	0.15	2.64	4.90	0.54	--
	Approach	Fl.idle	2.38	7.46	30.71	3.08	0.54	--
	Idle	Gr.idle	2.30	8.98	29.78	3.05	0.54	--
CF6-50E/C1/E1/C2/E2[8] GE 51.79	Takeoff	100%	321.17	0.60	0.50	36.50	0.54	--
	Climbout	85%	254.63	0.70	0.50	29.60	0.54	--
	Approach	30%	87.86	1.00	5.70	9.70	0.54	--
	Idle	3%	22.24	49.30	81.3	2.40	0.54	--
F404-GE-400[7] GE	Takeoff	A/B max	473.28	0.13	23.12	9.22	0.54	--
	Climbout	IRP	134.71	0.31	1.05	25.16	0.54	2.81
	Approach	76%	109.02	0.35	1.09	14.80	0.54	6.1
	Idle	Gr.idle	10.40	58.18	137.34	1.16	0.54	12.38

Table 5-7:

Modal Emission Rates
— Military Aircraft Engines[1] —
Continued

Model – Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	Emission Rates HC	CO	NO_x	SO_2[3]	Particulate
				— lbs per 1000 lbs —				
F404-GE-400	Takeoff	A/B max	473.28	0.13	23.12	9.22	0.54	--
GE	Climbout	IRP	143.12	0.31	1.05	25.16	0.54	--
	Approach	76%	109.02	0.33	1.09	14.80	0.54	--
	Idle	Gr.idle	10.40	58.18	137.34	1.16	0.54	--
J79-GE-8D[7]	Takeoff	Afterburner	571.92	0.91	13.25	4.72	0.54	10.67
GE	Climbout	Military	157.55	0.14	2.07	10.44	0.54	--
	Approach	75% rpm	25.33	4.40	30.61	2.98	0.54	15.34
	Idle	Idle	20.08	16.93	55.70	2.37	0.54	19.12
J79-GE-10[4]	Takeoff	Afterburner	589.83	0.49	17.29	6.82	0.54	8.475
GE	Climbout	Military	163.83	1.63	5.29	15.44	0.54	7.905
	Approach	85%	103.17	0.66	7.37	11.29	0.54	10.825
	Idle	Idle	18.33	8.91	43.64	2.91	0.54	52.559
J79-GE-10B	Takeoff	Afterburner	571.92	1.05	13.25	4.72	0.54	--
GE	Climbout	Military	166.67	1.42	1.63	10.35	0.54	--
	Approach	85% rpm	60.67	2.69	13.63	4.60	0.54	--
	Idle	Idle	20.83	45.47	111.41	1.33	0.54	--
J79-GE-10B[7]	Takeoff	Afterburner	583.33	0.52	14.56	4.51	0.54	4.43
GE	Climbout	75% Thrust	126.30	1.60	2.74	8.26	0.54	--
	Approach	30% Thrust	57.03	2.94	20.04	4.23	0.54	9.50
	Idle	Idle	20.83	39.19	111.41	1.33	0.54	15.73
J85-GE-2	Takeoff	Military	48.17	0.45	21.56	6.40	0.54	--
GE	Climbout	Military	48.17	0.45	21.56	6.40	0.54	--
	Approach	75% Thrust	35.92	0.64	28.38	5.67	0.54	--
	Idle	Idle	9.33	11.86	111.86	3.68	0.54	--
J85-GE-2[7]	Takeoff	Military	48.17	0.45	21.56	6.40	0.54	--
GE	Climbout	75%	35.92	0.64	28.38	5.67	0.54	--
	Approach	30%	17.42	2.40	65.53	4.02	0.54	--
	Idle	Gr.idle	9.33	11.86	111.86	3.68	0.54	--
J85-GE-21[4]	Takeoff	Afterburner	177.50	0.10	36.40	5.60	0.54	--
GE	Climbout	Military	53.33	0.25	21.56	5.00	0.54	--
	Approach	85%	20.00	2.58	46.25	2.92	0.54	--
	Idle	Idle	6.67	24.25	159.00	1.25	0.54	--
T58-GE-5[4]	Climbout	70%	14.77	0.79	5.64	7.22	0.54	0.90[5]
GE	Approach	50%	14.77	0.79	5.64	7.22	0.54	0.90[5]
	Idle	Idle	2.22	96.99	169.17	1.50	0.54	0.75[5]
T58-GE-8F	Climbout	Max.cont.	11.42	0.85	12.96	4.90	0.54	-
GE	Approach	Approach	9.68	1.30	17.28	4.47	0.54	-
	Idle	Idle	2.20	151.34	178.44	1.43	0.54	-
T58-GE-8F[7]	Takeoff	Takeoff	13.10	0.40	9.03	5.47	0.54	--
GE	Climbout	Approach	9.68	1.12	17.28	4.47	0.54	-
	Approach	Cruise	10.45	0.80	14.13	4.68	0.54	-
	Idle	Idle	2.20	130.42	178.44	1.43	0.54	-
T58-GE-16[7]	Takeoff	Military	17.00	1.32	7.73	11.60	0.54	--
GE	Climbout	5% Normal	12.98	0.63	10.89	9.47	0.54	--
	Approach	60% Normal	10.93	0.38	14.56	7.88	0.54	-
	Idle	Gr.idle	2.50	40.91	139.73	3.03	0.54	-

Table 5-7:
Modal Emission Rates
— Military Aircraft Engines[1] —
Continued

Model - Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	HC	Emission Rates CO	NO_x	SO_2[3]	Particulate
				— lbs per 1000 lbs —				
T64-GE-6B[7] GE	Takeoff	Max.cont.	23.80	0.55	1.50	10.11	0.54	--
	Climbout	Military	22.83	0.51	1.87	9.80	0.54	--
	Approach	75% hp	17.72	0.41	4.27	7.50	0.54	--
	Idle	Idle	5.35	13.24	57.27	2.75	0.54	--
T64-GE-413[7] GE	Takeoff	Maximum	28.68	0.27	0.49	11.42	0.54	--
	Climbout	Intermediate	27.68	0.34	0.67	10.92	0.54	--
	Approach	75% hp	21.45	0.35	1.94	8.54	0.54	--
	Idle	Idle	4.33	17.28	51.83	2.62	0.54	--
T64-GE-415[7] GE	Takeoff	Max.rated	33.42	0.19	1.47	10.83	0.54	--
	Climbout	Military	31.93	0.28	1.29	9.99	0.54	--
	Approach	75%	24.88	0.13	2.10	8.09	0.54	--
	Idle	Idle	4.48	24.35	74.33	2.12	0.54	--
T64-GE-415 GE	Climbout	Military	31.93	0.33	1.29	9.99	0.54	--
	Approach	75% hp	24.88	0.16	2.10	8.09	0.54	--
	Idle	Idle	4.48	28.25	74.33	2.12	0.54	--
TF34-GE-400[7] GE	Takeoff	Military	63.33	0.39	5.95	7.51	0.54	2.11[10]
	Climbout	75% rpm	7.67	2.63	33.57	3.42	0.54	6.85[10]
	Idle	Idle	8.08	14.99	90.98	1.69	0.54	3.26[10]
TF34-GE-400 GE	Takeoff	Military	63.33	0.39	5.95	7.51	0.54	--
	Climbout	Military	63.33	0.39	5.95	7.51	0.54	--
	Approach	Military	63.33	0.39	5.95	7.51	0.54	--
	Idle	Idle	8.08	17.40	90.98	1.69	0.54	--
T76-G-12A[7] Grt	Climbout	Military	6.37	0.05	1.69	7.18	0.54	--
	Approach	High idle	3.53	6.13	24.59	4.50	0.54	--
	Idle	Gr.start	3.00	10.21	28.29	4.30	0.54	--
T76-G-12A Grt	Takeoff	Military	6.37	0.06	1.69	7.18	0.54	--
	Climbout	Military	6.37	0.06	1.69	7.18	0.54	--
	Approach	High idle	3.53	7.12	24.59	4.50	0.54	--
	Idle	High idle	3.53	7.12	24.29	4.50	0.54	--
	Idle	Gr.start	3.00	11.85	28.59	4.30	0.54	--
TFE 731-2[8] Grt 3.51	Takeoff	100%	27.12	0.11	1.39	15.25	0.54	--
	Climbout	85%	22.88	0.13	2.03	13.08	0.54	--
	Approach	30%	8.86	4.26	22.38	5.90	0.54	--
	Idle	7%	3.17	20.04	58.60	2.92	0.54	--
T53-L-11D[7] Lyc	Takeoff	Takeoff	11.50	0.27	3.85	7.75	0.54	--
	Climbout	Military	11.42	0.26	3.34	6.34	0.54	--
	Approach	Nor.rated	10.75	0.57	6.83	6.43	0.54	--
	Idle	Fl.idle	3.70	13.57	37.79	2.53	0.54	--
	Idle	Gr.idle	2.42	58.09	31.51	1.58	0.54	--
T53-L-11D Lyc	Takeoff	Takeoff	11.50	0.32	3.85	7.75	0.54	--
	Climbout	Military	11.42	0.30	3.34	6.34	0.54	--
	Approach	Nor.rated	10.75	0.66	6.83	6.43	0.54	--
	Idle	Fl.idle	3.70	15.75	37.79	2.53	0.54	--
	Idle	Gr.idle	2.42	67.41	31.51	1.58	0.54	--

Table 5-7:
Modal Emission Rates — Military Aircraft Engines[1] — Continued

Model - Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	HC	Emission Rates CO	NOx	SO_2[3]	Particulate
				— lbs per 1000 lbs —				
F100-PW-100[4] P&W	Takeoff	Military	736.67	0.10	55.10	16.50	0.54	0.00[11]
	Climbout	95%	173.33	0.05	1.80	44.00	0.54	0.33[11]
	Approach	30%	50.00	0.60	3.00	11.00	0.54	0.33[11]
	Idle	Idle	17.67	2.26	19.34	3.96	0.54	0.09[11]
F101DFE P&W	Takeoff	Military	167.88	0.10	0.90	19.69	0.54	--
	Climbout	Military	167.88	0.10	0.90	19.69	0.54	--
	Approach	75% Thrust	109.77	0.20	0.90	12.04	0.54	--
	Idle	Idle	14.45	4.10	44.2	2.58	0.54	--
J52-P-6B[7] P&W	Takeoff	Military	105.47	0.33	3.01	9.00	0.54	7.75
	Climbout	75% Thrust	66.28	0.65	6.00	5.84	0.54	13.13
	Approach	3000lbsThrust	38.35	0.82	16.57	3.91	0.54	--
	Idle	Idle	11.90	23.88	86.37	2.07	0.54	19.94
J52-P-8B[7] P&W	Takeoff	Military	122.83	0.93	0.71	13.05	0.54	--
	Climbout	75% Thrust	72.00	0.58	3.00	10.10	0.54	--
	Approach	3000lbsThrust	38.33	1.72	10.54	6.34	0.54	--
	Idle	Idle	11.33	42.20	63.78	1.79	0.54	--
J52-P-8B P&W	Takeoff	Military	122.83	1.08	0.71	13.05	0.54	--
	Climbout	Nor.rated	102.17	0.69	0.87	12.13	0.54	--
	Approach	75% Thrust	72.00	0.67	3.00	10.10	0.54	--
	Idle	Idle	11.33	48.96	63.78	1.79	0.54	--
J52-P-408[7] P&W	Takeoff	Military	157.98	0.57	1.47	12.32	0.54	--
	Climbout	Intermed 2	95.87	0.67	3.18	8.38	0.54	--
	Approach	Intermed 1	42.45	1.40	11.12	6.17	0.54	--
	Idle	Idle	12.98	28.33	55.96	2.38	0.54	--
J57-P-10 P&W	Takeoff	Military	139.50	1.00	1.16	10.37	0.54	--
	Climbout	Military	139.50	1.00	1.16	10.37	0.54	--
	Approach	75% Thrust	94.50	0.88	3.21	7.40	0.54	--
	Idle	Idle	18.33	112.10	80.52	1.87	0.54	--
J57-P-10[7] P&W	Takeoff	Military	139.50	0.86	1.16	10.37	0.54	--
	Climbout	Nor.rated	120.83	1.00	1.79	9.00	0.54	--
	Approach	75% Thrust	94.50	0.76	3.21	7.40	0.54	--
	Idle	Idle	18.33	96.60	80.52	1.87	0.54	--
J57-P-420[7] P&W	Takeoff	Afterburner	662.02	2.54	14.20	5.16	0.54	--
	Climbout	75% Thrust	96.12	1.09	4.32	6.99	0.54	--
	Approach	30% Thrust	56.98	4.54	14.83	4.45	0.54	--
	Idle	Idle	22.03	76.46	80.74	1.53	0.54	--
JT8D-9/9A[8] P&W 14.5	Takeoff	100%	137.57	0.47	1.24	17.92	0.54	--
	Climbout	85%	111.91	0.47	1.66	14.21	0.54	--
	Approach	30%	39.42	1.73	9.43	5.64	0.54	--
	Idle	7%	17.46	10.00	34.50	2.90	0.54	--
JT9D-7R4G2[8] P&W 53.84	Takeoff	100%	321.30	0.15	0.74	41.30	0.54	--
	Climbout	85%	248.68	0.14	0.63	32.10	0.54	--
	Approach	30%	87.17	0.18	1.40	8.80	0.54	--
	Idle	7%	29.62	1.55	11.82	3.80	0.54	--

TABLE 5-7:
Modal Emission Rates – Military Aircraft Engines[1] — Continued —

Model – Series Manufacturer[2] Rated Dry Output (1000 lbs Thrust)	Mode	Power Setting	Fuel Flow (lb/min)	HC	CO	NO_x	SO_2[3]	Particulate
				Emission Rates — lbs per 1000 lbs —				
TF30-P-6C[7] P&W	Takeoff	Military	111.67	0.91	1.56	13.29	0.54	--
	Climbout	75% Thrust	59.33	0.54	4.75	7.38	0.54	--
	Approach	30% Thrust	33.83	1.84	14.87	4.77	0.54	--
	Idle	Idle	11.17	12.92	70.58	2.03	0.54	--
TF30-P-412A P&W	Takeoff	Afterburner	796.67	0.20	10.79	4.79	0.54	--
	Climbout	Military	117.50	0.77	1.38	19.60	0.54	2.98[12]
	Approach	75% Thrust	71.67	1.48	3.43	10.74	0.54	7.99[12]
	Idle	Idle	15.33	36.45	55.60	3.22	0.54	8.96[12]
TF33-P-3/5/7[4] P&W	Takeoff	Afterburner	166.32	0.30	1.30	11.00	0.54	8.00[5]
	Climbout	Military	122.05	0.40	1.80	9.00	0.54	14.00[5]
	Approach	85%	63.28	3.79	9.01	7.30	0.54	13.96[5]
	Idle	Idle	14.10	91.96	88.53	1.77	0.54	5.20[5]
Dart RDa7[4] RR	Takeoff	Military	23.48	6.21	3.40	6.04	0.54	--
	Climbout	95%	0.80	1.72	3.41	4.45	0.54	--
	Approach	30%	10.75	0.00	33.30	0.85	0.54	--
	Idle	Idle	6.85	62.09	91.51	0.71	0.54	--
F402 RR	Takeoff	100%	178.53	0.41	2.70	14.80	0.54	--
	Climbout	100%	178.53	0.41	2.70	14.80	0.54	--
	Approach	85%	103.10	0.73	8.20	8.00	0.54	--
	Idle	Idle	18.95	18.80	106.30	1.70	0.54	--
F402[7] RR	Takeoff	100%	178.53	0.40	2.70	14.80	0.54	--
	Climbout	85%	103.10	0.70	8.20	8.00	0.54	--
	Idle	Idle	18.95	18.80	106.30	1.70	0.54	--
J65-W-5F[7] W	Takeoff	Military	115.77	0.61	5.31	5.23	0.54	--
	Climbout	8000 rpm	99.50	0.72	7.39	5.71	0.54	--
	Approach	7450 rpm	72.83	0.95	12.61	7.30	0.54	--
	Idle	Idle	22.00	9.78	47.16	2.46	0.54	--
R-1820 W	Takeoff	IRP	19.43	94.68	531.73	1.72	0.54	--
	Climbout	IRP	14.37	48.49	435.03	2.09	0.54	--
	Approach	75% M/C	5.38	5.57	384.83	6.50	0.54	--
	Idle	Idle	1.48	150.56	474.16	0.00	0.54	--

1 Source: Example of an Air Base Emissions Inventory for the County of San Diego (1987) (Reference 15) unless otherwise noted.

2 MANUFACTURERS: All. - Allison, Con - Teledyne/Continental, CP - United Aircraft of Canada, GE - General Electric, Grt - Garrett AiResearch, Lyc - Avco/Lycoming, P&W - Pratt & Whitney, RR - Rolls-Royce, W - Curtis Wright

3 SO_2 emissions based on national average sulfur content of aviation fuels from Aviation Turbine Fuels, 1989 (Reference 23).

4 Source of data is AP-42 (Reference 1). Nitrogen oxides reported as NO_2. HC refers to total hydrocarbons (Volatile organics, including unburned hydrocarbons and organic pyrolysis products).

5 Includes all "condensable particulates", and thus may be much higher than solid particulates alone (Reference 1).

6 Source of data is FAA Aircraft Engine Emission Database (Reference 14).

7 Source of data is Summary Tables of Gaseous and Particulate Emissions from Aircraft Engines (Reference 18).

8 Source of data is ICAO Engine Exhaust Emissions Databank (Reference 13).

9 Includes all "condensable particulates," and thus may be much higher than solid particulates alone. Data are interpolated values assumed for calculational purposes, in the absence of experimental data (Reference 1).

10 Particulate data refers to TF34-GE-400A engine.

11 Particulates refer to dry particulates only (Reference 1).

12 Source of Particulate data is Table 4, Particulate Mass Emissions From the TF-30-P-414 Engine, Summary Tables of Gaseous and Particulate Emissions from Aircraft Engines. (Reference 18).

same as that used for both commercial and general aviation. The calculations for each subsequent step follow.

Adjust Approach and Climbout TIM to Represent Local Conditions

$$TIM_{app\text{-}M} = 4 * (H/3000) \quad (5\text{-}9)$$

$$TIM_{clm\text{-}M} = 1.4 * [(H-500)/2500] \quad (5\text{-}10)$$

$TIM_{app\text{-}M}$ - time in the approach mode for military aircraft, in minutes

$TIM_{clm\text{-}M}$ - time in the climbout mode for military aircraft, in minutes (assumes transition from takeoff to climbout occurs at 500 feet)

H - mixing height used in air quality modeling for time and region of interest

Calculate Emissions for Each Aircraft Type

$$E_{ij} = \Sigma\,(TIM_{jk}) * (FF_{jk}/1000) * (EI_{ijk}) * (NE_j) \quad (5\text{-}11)$$

E_{ij} - total emissions of pollutant i, in pounds, produced by aircraft type j for one LTO cycle

TIM_{jk} - time in mode for mode k, in minutes, for aircraft type j

FF_{jk} - fuel flow for mode k, in pounds per minute, for each engine used on aircraft type j (from Table 5-7)

EI_{ijk} - emission index for pollutant i, in pounds of pollutant per one thousand pounds of fuel, in mode k for aircraft type j (from Table 5-7)

NE_j - number of engines used on aircraft type j (from Table 5-6)

Calculate Total Emissions for All Military Aircraft

$$E_{Ti(M)} = \Sigma\,(E_{ij}) * (LTO_j) \quad (5\text{-}12)$$

$E_{Ti(M)}$ - total emissions of pollutant i, in pounds, produced by all military aircraft operating in the region of interest (where j covers the range of military aircraft operating in the area)

LTO_j - total number of LTO cycles for aircraft type j, during the inventory period

After completing the emissions inventory for military aircraft, the overall inventory is complete, made up of emissions from commercial, general aviation, and military aircraft. The final three sections of the report address changes to the inventory due to alternative operating practices, addition of minor emission sources, and changes to the aircraft fleet in the future.

5.3 Variations To The Inventory Calculation Procedure

There are several variations to the basic inventory procedure that can adjust the period covered by the inventory or address some operational procedures followed by some pilots or airlines that affect aircraft emissions. These adjustments to the inventory are discussed in this section.

5.3.1 Variability of Activity - Daily and Seasonal

The calculation procedure described in the methodology does not address daily or seasonal variations. If the air quality modeling period requires emissions data that accounts for these variations, certain adjustments must be made to the equations. The daily or seasonal variations will be exhibited in LTOs, mixing height, and idle time, primarily idle-out.

The references for determining LTOs in Section 5.2 give data on an annual basis and adjustment may be necessary to capture changes over time. The frequency of LTOs at most civil airports are reasonably uniform during daylight hours with lower activity during the night and uniform during week days with lower activity on the weekends, although some airports that cater to recreational flying may show higher activity on weekend days. For most large urban airports, LTOs are uniform on a monthly basis with a slight increase in activity during the summer, which typically is a time of high travel, although some regions may attract more travelers during the winter as a result of their climate. The seasonal variation in activity at smaller urban airports or airports that serve smaller cities may be more pronounced because of factors that affect travel on a local basis such as tourism or seasonal business activity. Obtaining specific information on daily and seasonal variation is difficult. The best source likely will be the airport operators, many of who keep some type of records of activity such as total number of LTOs, number of visitors/passengers, number of cars using the parking lots, or some similar measure that may be representative of the daily or seasonal variation in use of the airport. Another source of information on the daily and weekly variation of LTOs is published flight schedules. These schedules can be reviewed to evaluate the number of scheduled flights during daylight hours versus night-time hours or week day versus weekend. It would be difficult to use this source to evaluate seasonal variations.

Mixing height changes throughout the day and from season to season depending on meteorological conditions such as wind, cloud cover, temperature, and humidity. The adjustments to the time in approach and climbout mode should be based on a weighted average of the mixing heights for the time periods of interest, using variations in LTOs as the weighing factors. See Section 5.2.2 for more information about determining the mixing height.

Taxi/idle time may vary in proportion to variations in LTOs because they are partially a function of airport congestion such that the greater number of LTOs the more likely that airport congestion will increase the time for aircraft to taxi to the runway. The airlines' scheduling departments are the best sources of taxi/idle-time data and their projections typically show daily variations estimated for a particular season. Airport operators also may have information on taxi/idle time variation during a day or from one season to another. Availability of this data will be highly variable.

5.3.2 Operational Activity that Affects Aircraft Emissions

There are variations to standard operating procedures which pilots follow that will affect the aircraft's emissions. Two examples, which may be found in commercial operations, are single-engine taxiing and derated takeoff. Both of these procedures have the potential to save fuel as well as reduce emissions. Where detailed air quality modeling is being performed, these refinements may merit consideration. However, in most cases these procedures are performed at the discretion of the pilots and their use may not be consistent or predictable.

5.3.2.1 **Reduced Engine Taxiing** - Single-engine taxiing or reduced-engine taxiing is, as the name implies, taxiing with one or more engines shutdown. This is usually practiced during taxi-out. An aircraft can taxi using a single engine at idle without significantly increasing the emissions of that engine since adequate power for taxi generally is available at idle power setting. The emissions reductions are equal to the calculated emissions of the engines that are shutdown. The change to the calculation procedure to account for single-engine taxiing is shown in Equation 5-13.

$$E_{ij} = \Sigma\,(TIM_{jk}) * (FF_{jk}/1000) * (EI_{ijk}) * (NE_{jk}) \qquad (5\text{-}13)$$

E_{ij} - total emissions of pollutant i, in pounds, produced by aircraft type j

TIM_{jk} - time in mode for mode k, in minutes, for aircraft type j

FF_{jk} - fuel flow for mode k, in pounds per minute, for each engine used on aircraft type j (from Table 5-4)

EI_{ijk} - emission index for pollutant i, in pounds of pollutant per one thousand pounds of fuel, in mode k for aircraft type j (from Table 5-4)

NE_{jk} - number of engines used on aircraft type j, for mode k (from Table 5-2)

NE for the taxi/idle-out mode would be the number of engines actually used rather than the number on engines shown in Table 5–2.

5.3.2.2 **Derated Take–off** - A derated take–off is a procedure where the pilot sets the throttle for takeoff at less than 100%. The derated throttle setting is determined based on worst-case operating conditions, i.e., performance of the aircraft as though it were at maximum weight on a hot day. In some cases this may allow a takeoff throttle setting of 90% or less. To adjust the emissions calculations to account for this change, engine manufacturers recommend a linear interpolation between the takeoff and climbout fuel flow rates and emission factors. Information on the degree and frequency of derating for takeoff should be collected directly from the airlines.

Other operational factors may affect engine exhaust emissions, such as the use of full throttle, reverse thrust to decelerate the aircraft during landing. These effects may also be significant and are being evaluated by EPA. Any additional information on operational factors will be included in the next update to AP-42.

5.3.3 Particulate Emissions

As mentioned in Section 5.1.1.2, very few measurements have been made of particulate emissions from aircraft engines. However, for most turbine engines, EPA does limit the amount of smoke that may be emitted. This limit is specified as a smoke number. Attempts have been made to derive a correlation between smoke and particulates which could be used to create a particulate emission index based on smoke number. Thus far, these efforts do not match experimental results very closely. If particulates are of concern for the inventory area it may be of help to discuss the issue further with the engine manufacturers or the FAA Office of Environment and Energy.

5.4 Other Emission Sources

When large aircraft are on the ground with their engines shutdown they need power and preconditioned air to maintain the aircraft's operability. If a ground-based power and air source is unavailable, an auxiliary power unit (APU), which is part of the aircraft, is operated. These units are essentially small jet engines which generate electricity and compressed air. They burn jet fuel and generate exhaust emissions like larger engines. In use, APUs essentially run at full throttle. Emission factors for some APUs used by the military are included in Table 5–8 and are representative of, or the same as, those used by commercial airlines. It will be necessary to contact

Table 5-8:
Modal Emission Rates – Auxiliary Power Units[1]

Model-Series	Mode	Fuel Flow (lb/min)	Emission Rates (lb/1000 lb) HC	CO	NO_x	SO_2
GTC85-72	No Load	1.75	5.36	37.43	3.28	0.54
	Load	3.50	0.13	14.83	3.88	0.54
GTCP100-54	No Load	3.75	1.61	12.48	6.32	0.54
	Load	6.88	0.16	5.89	5.95	0.54
GTPC95-2	No Load	2.18	2.16	18.75	4.39	0.54
	Load	4.88	0.36	3.20	5.65	0.54
T-62T-27	No Load	0.83	2.96	29.53	5.31	0.54
	Load	1.70	7.79	42.77	3.94	0.54
WR27-1	No Load	2.33	0.60	3.48	2.13	0.54
	Load	2.33	0.21	5.66	4.63	0.54

1 Source: Summary Table of Gaseous and Particulate Emissions from Aircraft Engines (Reference 18).

the airlines directly to find out whether APUs are used regularly at a specific airport and, if so, how long an aircraft is expected to stay at a gate with the APU running.

For general aviation aircraft, there are evaporative emissions that result from refueling and fuel spillage. Emissions also occur from preflight checks of the aircraft and diurnal temperature cycles that cause the fuel tanks to vent. Refueling emissions are addressed in Volume I, Section 5.4.1. EPA is continuing to evaluate the other emission sources and may provide information in the next update to AP-42.

5.5 Effect Of Future Changes To The Fleet

Airlines continually acquire newer aircraft, gradually phasing out older models. While commercial aircraft often remain in service for more than 25 years, over time, this process phases out the aircraft using engines that do not meet EPA's hydrocarbon emission standard. The current world aircraft fleet averages 12.4 years old according to the 1990 World Jet Inventory published by the Boeing Corporation (Reference 24). Significant among the older aircraft are engines that do not meet the EPA standard such as the Spey MK511 and older JT8Ds and CF6-50s. The JT8Ds and CF6-50s are prevalent on B-727s, DC-9s, and DC-10s, many nearly 20 years old. As new aircraft are added to the fleet the older aircraft are the most likely to be retired. The effect is one of replacing older, dirty engines with newer engines on the new aircraft that are much cleaner from an emissions standpoint. Airport noise regulations also are forcing changes to the commercial aircraft fleet. National noise regulations which were recently passed by Congress are forcing airlines to phase out use of loud aircraft by 2000. This can be accomplished by retiring the loud, older aircraft, replacing their engines with newer, quieter ones, or modifying the engines to muffle the noise. The first two alternatives result in aircraft with reduced emissions. Because this legislation is so new, the airlines are yet to formulate specific plans meeting the requirements. However, as the equipment is updated, the changes to the fleet will be reflected in FAA's reports on aircraft activity. Since there is a significant engineering and development leadtime for producing new aircraft engines, most of the commercial aircraft to be added to the fleet in the next five to seven years will be powered by engines that are included in Tables 5-2, 5-3 and 5-4.

Since specific plans to upgrade their fleets have not been announced recently by the airlines, it is difficult to project what future changes will be and how they will effect the inventory of emissions for all locations. Some carriers will update their fleets more quickly than others so there may be changes that can be captured on an area specific basis. If it is desirable to project changes to the inventory for this source category, the predominant airlines for the airports included in the inventory area should be contacted for their specific plans. EPA is continuing to look at better data sources and methods for projecting changes to aircraft fleet emissions.

Another change that will affect future emissions from aircraft is the growth in travel. Air travel has experienced strong growth over the past several years and this growth is expected to continue for the foreseeable future. Many existing airports are near capacity and others will reach their capacity limits in the near future. This will have two effects: air traffic at small feeder airports and regional hubs will grow and the current major hubs will experience additional congestion. The net effect these changes will have on air quality is unclear. Increased congestion at some airports will increase taxi/idle times but the expanded use of smaller airports may relieve congestion at others.

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Appendix B

FAA Advisory Circular 91-41:

Ground Operational Procedures For Aircraft Engine Emission Reduction And Fuel Conservation

AC NO: 91-41

DATE: MARCH 12, 1974

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: GROUND OPERATIONAL PROCEDURES FOR AIRCRAFT ENGINE EMISSION REDUCTION AND FUEL CONSERVATION

1. PURPOSE. This Advisory Circular recommends ground operational procedures that will minimize air pollution from aircraft ground operations and conserve fuel.

2. BACKGROUND. The Clean Air Amendments of 1970 directed the Administrator of the Environmental Protection Agency, after consultation with the Secretary of Transportation, to set aircraft emission standards. The Amendments also require EPA to study aircraft emissions with regard to their effect on health and welfare. As one result of this study, EPA issued an Advance Notice of Proposed Rule Making proposing to limit the number of engines used for taxi to and from the runway. Concurrently, the existing and projected shortfall of aviation fuel required the analysis of fuel conservation measures by FAA. This study also included the possibility of reducing the number of engines required for taxi. Study estimates indicated substantial reductions in carbon monoxide and hydrocarbon emissions are possible as well as a significant fuel savings.

   The FAA, EPA, ATA and ALPA investigated the possibility of reducing the number of operating engines on turbojet aircraft for the taxi and ground idle modes. As a consequence of this investigation, an operational evaluation was conducted at Atlanta International Airport. Test results led to the conclusion that operating fewer engines on three- and four-engine turbojet aircraft is in many cases feasible when taxiing from the runway to the terminal after landings or during protracted holds, but should not be a mandatory requirement at any time.

3. RECOMMENDED PROCEDURES. Operators of three- and four-engine turbojet aircraft should develop procedures for reducing emissions and fuel usage and submit them to FAA. The following taxi and ground idle procedures under the conditions and limitations judged appropriate by the aircraft operator and the pilot-in-command are recommended.

FAA Form 1320-7 (12-71) SUPERSEDES PREVIOUS EDITION

Initiated by: AEQ-10

PART 87—CONTROL OF AIR POLLUTION FROM AIRCRAFT AND AIRCRAFT ENGINES

AUTHORITY: Secs. 231, 301(a), Clean Air Act, as amended (42 U.S.C. 7571, 7601(a)).

SOURCE: 47 FR 58470, Dec. 30, 1982, unless otherwise noted.

Subpart A—General Provisions

§ 87.1 Definitions.

(a) As used in this part, all terms not defined herein shall have the meaning given them in the Act:

"Act" means the Clean Air Act, as amended (42 U.S.C. 7401 et seq.).

"Administrator" means the Administrator of the Environmental Protection Agency and any other officer or employee of the Environmental Protection Agency to whom authority involved may be delegated.

"Aircraft" means any airplane for which a U.S. standard airworthiness certificate or equivalent foreign airworthiness certificate is issued.

"Aircraft engine" means a propulsion engine which is installed in or which is manufactured for installation in an aircraft.

"Aircraft gas turbine engine" means a turboprop, turbofan, or turbojet aircraft engine.

"Class TP" means all aircraft turboprop engines.

"Class TF" means all turbofan or turbojet aircraft engines except engines of Class T3, T8, and TSS.

"Class T3" means all aircraft gas turbine engines of the JT3D model family.

"Class T8" means all aircraft gas turbine engines of the JT8D model family.

"Class TSS" means all aircraft gas turbine engines employed for propulsion of aircraft designed to operate at supersonic flight speeds.

"Commercial aircraft engine" means any aircraft engine used or intended for use by an "air carrier," (including those engaged in "intrastate air transportation") or a "commercial operator" (including those engaged in "intrastate air transportation") as these terms are defined in the Federal Aviation Act and the Federal Aviation Regulations.

"Commercial aircraft gas turbine engine" means a turboprop, turbofan, or turbojet commercial aircraft engine.

"Emission measurement system" means all of the equipment necessary to transport and measure the level of emissions. This includes the sample system and the instrumentation system.

"Engine Model" means all commercial aircraft turbine engines which are of the same general series, displacement, and design characteristics and are usually approved under the same type certificate.

"Exhaust emissions" means substances emitted to the atmosphere from the exhaust discharge nozzle of an aircraft or aircraft engine.

"Fuel venting emissions" means raw fuel, exclusive of hydrocarbons in the exhaust emissions, discharged from aircraft gas turbine engines during all normal ground and flight operations.

"In-use aircraft gas turbine engine" means an aircraft gas turbine engine which is in service.

"New aircraft turbine engine" means an aircraft gas turbine engine which has never been in service.

"Power setting" means the power or thrust output of an engine in terms of kilonewtons thrust for turbojet and turbofan engines and shaft power in terms of kilowatts for turboprop engines.

"Rated output (rO)" means the maximum power/thrust available for takeoff at standard day conditions as approved for the engine by the Federal Aviation Administration, including reheat contribution where applicable, but excluding any contribution due to water injection.

"Rated pressure ratio (rPR)" means the ratio between the combustor inlet pressure and the engine inlet pressure achieved by an engine operating at rated output.

"Sample system" means the system which provides for the transportation of the gaseous emission sample from the sample probe to the inlet of the instrumentation system.

"Secretary" means the Secretary of Transportation and any other officer or employee of the Department of Transportation to whom the authority involved may be delegated.

"Shaft power" means only the measured shaft power output of a turboprop engine.

"Smoke" means the matter in exhaust emissions which obscures the transmission of light.

"Smoke number (SN)" means the dimensionless term quantifying smoke emissions.

"Standard day conditions" means standard ambient conditions as described in the United States Standard Atmosphere, 1976, (i.e., Temperature =15°C, specific humidity =0.00 kg/H_2O/kg dry air, and pressure =101325 Pa.)

"Taxi/idle (in)" means those aircraft operations involving taxi and idle between the time of landing roll-out and final shutdown of all propulsion engines.

"Taxi/idle (out)" means those aircraft operations involving taxi and idle between the time of initial starting of the propulsion engine(s) used for the taxi and turn on to duty runway.

[47 FR 58470, Dec. 30, 1982, as amended at 49 FR 31875, Aug. 9, 1984]

§ 87.2 Abbreviations.

The abbreviations used in this part have the following meanings in both upper and lower case:

FAA Federal Aviation Administration, Department of Transportation.
HC Hydrocarbon(s).
hr. Hour(s).
LTO Landing takeoff
min. Minute(s).
rO Rated output.
rPR Rated pressure ratio.
sec. Seconds.
SP Shaft power.
SN Smoke number.
T Temperature, degrees Kelvin.
TIM Time in mode.
W Watt(s).
° Degree.
% Percent.

[47 FR 58470, Dec. 30, 1982, as amended at 49 FR 31875, Aug. 9, 1984]

§ 87.3 General requirements.

(a) This part provides for the approval or acceptance by the Administrator or the Secretary of testing and sampling methods, analytical, techniques, and related equipment not identical to those specified in this part. Before either approves or accepts any such alternate, equivalent, or otherwise nonidentical procedures or equipment, the Administrator or the Secretary shall consult with the other in determining whether or not the action requires rulemaking under sections 231 and 232 of the Clean Air Act, as amended, consistent with the Administrator's and the Secretary's responsibilities under sections 231 and 232 of the Act. (42 U.S.C. 7571, 7572).

(b) Under section 232 of the Act, the Secretary issues regulations to insure compliance with this part.

(c) With respect to aircraft of foreign registry, these regulations shall apply in a manner consistent with any obligation assumed by the United States in any treaty, convention or agreement between the United States and any foreign country or foreign countries.

§ 87.4 [Reserved]

§ 87.5 Special test procedures.

The Administrator or the Secretary may, upon written application by a manufacturer or operator of aircraft or aircraft engines, approve test procedures for any aircraft or aircraft engine that is not susceptible to satisfactory testing by the procedures set forth herein. Prior to taking action on any such application, the Administrator or the Secretary shall consult with the other.

§ 87.6 Aircraft safety.

The provisions of this part will be revised if at any time the Secretary determines that an emission standard cannot be met within the specified time without creating a safety hazard.

§ 87.7 Exemptions.

(a) *Exemptions based on flights for short durations at infrequent intervals.* The emission standards of this part do not apply to engines which power aircraft operated in the United States for short durations at infrequent intervals. Such operations are limited to:

(1) Flights of an aircraft for the purpose of export to a foreign country, including any flights essential to demonstrate the integrity of an aircraft prior to its flight to a point outside the United States.

(2) Flights to a base where repairs, alterations or maintenance are to be performed, or to a point of storage, and flights for the purpose of returning an aircraft to service.

(3) Official visits by representatives of foreign governments.

(4) Other flights the Secretary determines, after consultation with the Administrator, to be for short durations at infrequent intervals. A request for such a determination shall be made before the flight takes place.

(b) *Exemptions for very low production models.* The emissions standards of this part do not apply to engines of very low total production after the date of applicability. For the purpose of this part, "very low production" is limited to a maximum total production for United States civil aviation applications of no more than 200 units covered by the same type certificate after January 1, 1984.

(1) A maximum annual production rate after January 1, 1984 of 20 units covered by the same type certificate; and

(2) A maximum total production after January 1, 1984 of 200 units covered by the same type certificate.

(c) *Exemptions for New Engines in Other Categories.* The emissions standards of this part do not apply to engines for which the Secretary determines, with the concurrence of the Administrator, that application of any standard under § 87.21 is not justified, based upon consideration of:

(1) Adverse economic impact on the manufacturer.

(2) Adverse economic impact on the aircraft and airline industries at large.

(3) Equity in administering the standards among all economically competing parties.

(4) Public health and welfare effects.

(5) Other factors which the Secretary, after consultation with the Administrator, may deem relevant to the case in question.

(d) *Time Limited Exemptions for In Use Engines.* The emissions standards of this part do not apply to aircraft or aircraft engines for time periods which the Secretary determines, with the concurrence of the Administrator, that any applicable standard under § 87.11(a), § 87.31(a), or § 87.31(c), should not be applied based upon consideration of the following:

(1) Documentation demonstrating that all good faith efforts to achieve compliance with such standard have been made.

(2) Documentation demonstrating that the inability to comply with such standard is due to circumstances beyond the control of the owner or operator of the aircraft.

(3) A plan in which the owner or operator of the aircraft shows that he will achieve compliance in the shortest time which is feasible.

(4) Applications for a determination that any requirements of § 87.11(a), § 87.31(a) or § 87.31(c) do not apply shall be submitted in duplicate to the Secretary in accordance with procedures established by the Secretary.

(e) The Secretary shall publish in the FEDERAL REGISTER the name of the organization to whom exemptions are granted and the period of such exemptions.

(f) No state or political subdivision thereof may attempt to enforce a standard respecting emissions from an aircraft or engine if such aircraft or engine has been exempted from such standard under this part.

[47 FR 58470, Dec. 30, 1982, as amended at 49 FR 31875, Aug. 9, 1984; 49 FR 41002, Oct. 18, 1984]

Subpart B—Engine Fuel Venting Emissions (New and In-Use Aircraft Gas Turbine Engines)

§ 87.10 Applicability.

(a) The provisions of this subpart are applicable to all new aircraft gas turbines of classes T3, T8, TSS and TF equal to or greater than 36 kilonewton rated output, manufactured on or after January 1, 1974, and to all in-use aircraft gas turbine engines of classes T3, T8, TSS and TF equal to or greater than 36 kilonewton rated output manufactured after February 1, 1974.

(b) The provisions of this subpart are also applicable to all new aircraft gas turbines of class TF less than 36 kilonewton rated output and class TP manufactured on or after January 1, 1975 and to all in-use aircraft gas turbines of class TF less than 36 kilonewton rated output and class TP manufactured after January 1, 1975.

[49 FR 41002, Oct. 18, 1984]

§ 87.11 Standard for fuel venting emissions.

(a) No fuel venting emissions shall be discharged into the atmosphere from any new or in-use aircraft gas turbine engine subject to the subpart. This paragraph is directed at the elimination of intentional discharge to the atmosphere of fuel drained from fuel nozzle manifolds after engines are shut down and does not apply to normal fuel seepage from shaft seals, joints, and fittings.

(b) Conformity with the standard set forth in paragraph (a) of this section shall be determined by inspection of the method designed to eliminate these emissions.

Subpart C—Exhaust Emissions (New Aircraft Gas Turbine Engines)

§ 87.20 Applicability.

The provisions of this subpart are applicable to all aircraft gas turbine engines of the classes specified beginning on the dates specified.

§ 87.21 Standards for exhaust emissions.

(a) Exhaust emissions of smoke from each new aircraft gas turbine engine of class T8 manufactured on or after February 1, 1974, shall not exceed: Smoke number of 30.

(b) Exhaust emissions of smoke from each new aircraft gas turbine engine of class TF and of rated output of 129 kilonewtons thrust or greater, manufactured on or after January 1, 1976, shall not exceed:

$SN = 83.6(r0)^{-0.274}$ (r0 is in kilonewtons).

(c) Exhaust emission of smoke from each new aircraft gas turbine engine of class T3 manufactured on or after January 1, 1978, shall not exceed: Smoke number of 25.

(d) Gaseous exhaust emissions from each new commercial aircraft gas turbine engine that is manufactured on or after January 1, 1984, shall not exceed:

(1) Classes TF, T3, T8 engines equal to or greater than 26.7 kilonewtons rated output:

Hydrocarbons: 19.6 grams/kilonewton rO.

(2) Class TSS:

Hydrocarbons $=140(0.92)^{rPR}$ grams/kilonewton rO.

(e) Smoke exhaust emissions from each gas turbine engine of the classes specified below shall not exceed:

(1) Class TF of rated output less than 26.7 kilonewtons manufactured on or after (one year from date of publication):

$SN=83.6(ro)^{-0.274}$ (ro is in kilonewtons) not to exceed a maximum of SN=50.

(2) Classes T3, T8, TSS and TF of rated output equal to or greater than 26.7 kilonewtons manufactured on or after January 1, 1984:

$SN=83.6(ro)^{-0.274}$ (ro is in kilonewtons) not to exceed a maximum of SN=50.

(3) Class TP of rated output equal to or greater than 1,000 kilowatts manufactured on or after January 1, 1984:

$SN=187(ro)^{-0.168}$ (ro is in kilowatts)

(f) The standards set forth in paragraphs (a), (b), (c), (d), and (e) of this section refer to a composite gaseous emission sample representing the operating cycles set forth in the applicable sections of Subpart G of this part, and exhaust smoke emissions emitted during operations of the engine as specified in the applicable sections of Subpart H of this part, measured and calculated in accordance with the procedures set forth in those subparts.

[47 FR 58470, Dec. 30, 1982, as amended at 49 FR 31875, Aug. 9, 1984]

Subpart D—Exhaust Emissions (In-use Aircraft Gas Turbine Engines)

§ 87.30 Applicability.

The provisions of this subpart are applicable to all in-use aircraft gas turbine engines certified for operation within the United States of the classes specified beginning on the dates specified.

§ 87.31 Standards for exhaust emissions.

(a) Exhaust emissions of smoke from each in-use aircraft gas turbine engine of Class T8, beginning February 1, 1974, shall not exceed: Smoke number of 30.

(b) Exhaust emissions of smoke from each in-use aircraft gas turbine engine of class TF and of rated output of 129 kilonewtons thrust or greater, beginning January 1, 1976, shall not exceed:

$SN=83.6(rO)^{-0.274}$ (rO is in kilonewtons).

(c) The standards set forth in paragraphs (a) and (b) of this section refer to exhaust smoke emissions emitted during operations of the engine as specified in the applicable section of Subpart H of this part, and measured and calculated in accordance with the procedures set forth in this subpart.

[47 FR 58470, Dec. 30, 1982, as amended at 48 FR 2718, Jan. 20, 1983]

Subparts E-F—[Reserved]

Subpart G—Test Procedures for Engine Exhaust Gaseous Emissions (Aircraft and Aircraft Gas Turbine Engines)

§ 87.60 Introduction.

(a) Except as provided under § 87.5, the procedures described in this subpart shall be the test program to determine the conformity of new aircraft gas turbine engines with the applicable standards set forth in this part.

(b) The test consists of operating the engine at prescribed power settings on an engine dynamometer (for engines producing primarily shaft power) or thrust measuring test stand (for engines producing primarily thrust). The exhaust gases generated during engine operation are sampled continuously for specific component analysis through the analytical train.

(c) The exhaust emission test is designed to measure hydrocarbons, carbon monoxide and carbon dioxide concentrations, and to determine mass emissions through calculations during a simulated aircraft landing-takeoff cycle (LTO). The LTO cycle is based on time in mode data during high activity periods at major airports. The test for propulsion engines consists of a least the following four modes of engine operation: Taxi/idle, takeoff, climbout, and approach. The mass emission for the modes are combined to yield the reported values.

(d) When an engine is tested for exhaust emissions on an engine dynamometer or test stand, the complete engine shall be used with all accessories which might reasonably be expected to influence emissions to the atmosphere installed and functioning, if not otherwise prohibited by § 87.62(a)(2). Use of service air bleed and shaft power extraction to power auxiliary gearbox-mounted components required to drive aircraft systems is not permitted.

(e) Other gaseous emissions measurement systems may be used if shown to yield equivalent results and if approved in advance by the Administrator or the Secretary.

[47 FR 58470, Dec. 30, 1982, as amended at 49 FR 31875, Aug. 9, 1984]

§ 87.61 Turbine fuel specifications.

For exhaust emission testing, fuel meeting the specifications listed below shall be used. Additives used for the purpose of smoke suppression (such as organometallic compounds) shall not be present.

Property and Allowable Range of Values

Specific gravity at 15 °C: 0.78–0.82.
Distillation temperature, °C: 10% boiling point, 160–201; final boiling point, 240–285.
Net heat of combustion, kJ/kg: 42,860–43,500.
Aromatics, volume %: 15–20.
Naphthalenes, volume %: 1.0–3.0.
Smoke point, mm: 20–28.
Hydrogen, mass %: 13.4–14.0.
Sulfur, mass %: less than 0.3%.
Kinematic viscosity at −20 °C, mm/s: 4.0–6.5.

[49 FR 41002, Oct. 18, 1984]

§ 87.62 Test procedure (propulsion engines).

(a)(1) The engine shall be tested in each of the following engine operating modes which simulate aircraft operation to determine its mass emission rates. The actual power setting, when corrected to standard day conditions, should correspond to the following percentages of rated output. Analytical correction for variations from reference day conditions and minor variations in actual power setting should be specified and/or approved by the Secretary:

Mode	Class		
	TP	TF, T3, T8	TSS
Taxi/idle	(1)	(1)	(1)
Takeoff	100	100	100
Climbout	90	85	65
Descent	NA	NA	15
Approach	30	30	34

[1] See paragraph (a)(2) of the section.

(2) The taxi/idle operating modes shall be carried out at a power setting of 7% rated thrust unless the Secretary determines that the unique characteristics of an engine model undergoing certification testing at 7% would result in substantially different HC emissions than if the engine model were tested at the manufacturers recommended idle power setting. In such cases the Secretary shall specify an alternative test condition.

(3) The times in mode (TIM) shall be as specified below:

Mode	Class		
	TP	TF, T3 or T8	TSS
Taxi/idle (minutes)	26.0	26.0	26.0
Takeoff	0.5	0.7	1.2
Climbout	2.5	2.2	2.0
Descent	N/A	N/A	1.2
Approach	4.5	4.0	2.3

(b) Emissions testing shall be conducted on warmed-up engines which have achieved a steady operating temperature.

§ 87.63 [Reserved]

§ 87.64 Sampling and analytical procedures for measuring gaseous exhaust emissions.

The system and procedures for sampling and measurement of gaseous emissions shall be as specified by Appendices 3 and 5 to ICAO Annex 16.

Volume II. Aircraft Engine Emissions, First Edition, June 1981, which are incorporated herein by reference. This document can be obtained from the International Civil Aviation Organization, P.O. Box 400, Succursale: Place de L'Aviation Internationale, 1000 Sherbrooke Street West, Montreal, Quebec, Canada H3A 2R2 at $3.00 per copy. It is also available for inspection at the Office of the Federal Register Information Center, Room 8301, 1100 L Street, N.W., Washington, D.C. 20408. This incorporation by reference was approved by the Director of the Federal Register on September 3, 1982. These materials are incorporated as they exist on the date of the approval and a notice of any change in these materials will be published in the FEDERAL REGISTER. Frequent changes are not anticipated.

§§ 87.65—87.70 [Reserved]

§ 87.71 Compliance with gaseous emission standards.

Compliance with each gaseous emission standard by an aircraft engine shall be determined by comparing the pollutant level in grams/kilonewton/thrust/cycle or grams/kilowatt/cycle as calculated in § 87.64 with the applicable emission standard under this part.

Subpart H—Test Procedures for Engine Smoke Emissions (Aircraft Gas Turbine Engines)

§ 87.80 Introduction.

Except as provided under §87.5, the procedures described in this subpart shall be the test program to determine the conformity of new and in-use gas turbine engines with the applicable standards set forth in this part. The test is essentially the same as that described in §§ 87.60 through 87.62, except that the test is designed to determine the smoke emission level at various operating points representative of engine usage in aircraft. Other smoke measurement systems may be used if shown to yield equivalent results and if approved in advance by the Administrator or the Secretary.

§ 87.81 Fuel specifications.

Fuel having specifications as provided in § 87.61 shall be used in smoke emission testing.

§ 87.82 Sampling and analytical procedures for measuring smoke exhaust emissions.

The system and procedures for sampling and measurement of smoke emissions shall be as specified by Appendix 2, Volume II, Aircraft Engine Emissions to ICAO Annex 16, Aircraft Engine Emissions, First Edition, June 1981. This document can be obtained from the International Civil Aviation Organization, P.O. Box 400, Succursale: Place de L'Aviation Internationale, 1000 Sherbrooke Street West, Montreal, Quebec, Canada H3A 2R2 at $3.00 per copy. It is also available for inspection at the Office of the Federal Register Information Center, Room 8301, 1100 L Street, N.W., Washington, D.C. 20408. This incorporation by reference was approved by the Director of the Federal Register on September 3, 1982. These materials are incorporated as they exist on the date of the approval and a notice of any change in these materials will be published in the FEDERAL REGISTER. Frequent changes are not anticipated.

§§ 87.83—87.88 [Reserved]

§ 87.89 Compliance with smoke emission standards.

Compliance with each smoke emission standard shall be determined by comparing the plot of SN as a function of power setting with the applicable emission standard under this part. The SN at every power setting must be such that there is a high degree of confidence that the standard will not be exceeded by any engine of the model being tested. The level of confidence required, a practical interpretation of the requirement for total compliance, and a testing program to assure compliance will be established by the Secretary prior to January 1, 1984, and shall be approved by the Administrator.

PARTS 88–99—[RESERVED]

Appendix D

High Density Traffic Airports

14CFR 93.121

Subpart K—High Density Traffic Airports

§ 93.121 Applicability.

This subpart designates high density traffic airports and prescribes air traffic rules for operating aircraft, other than helicopters, to or from those airports.

[Amdt. 93-21, 35 FR 16592, Oct. 24, 1970, as amended by Amdt. 93-27, 38 FR 29464, Oct. 25, 1973]

§ 93.123 High density traffic airports.

(a) Each of the following airports is designated as a high density traffic airport and, except as provided in § 93.129 and paragraph (b) of this section, or unless otherwise authorized by ATC, is limited to the hourly number of allocated IFR operations (takeoffs and landings) that may be reserved for the specified classes of users for that airport:

IFR OPERATIONS PER HOUR

AIRPORT

Class of user	LaGuardia [4]	Newark	O'Hare [2, 3]	Washington National [1]
Air carriers	48	40	120	37
Commuters	14	10	25	41
Other	6	10	10	12

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	Air carriers	Commuters	Other
1500	69	15	2
1600	74	12	2
1700	80	13	0
1800	75	10	2
1900	63	12	2

[1] Washington National Airport operations are subject to modifications per Section 93.124.

[2] The hour period in effect at O'Hare begins at 6:45 a.m. and continues in 30-minute increments until 9:15 p.m.

[3] Operations at O'Hare International Airport shall not—

(a) Except as provided in paragraph (c) of the note, exceed 62 for air carriers and 13 for commuters and 5 for "other" during any 30-minute period beginning at 6:45 a.m. and continuing every 30 minutes thereafter.

(b) Except as provided in paragraph (c) of the note, exceed more than 120 for air carriers, 25 for commuters, and 10 for "other" in any two consecutive 30-minute periods.

(c) For the hours beginning at 5:45 a.m., 7:45 a.m., 11:45 a.m., 7:46 p.m. and 8:45 p.m. the hourly limitations shall be 105 for air carriers, 40 for commuters and 10 for "other," and the 30-minute limitations shall be 58 for air carriers, 20 for commuters and 5 for "other." For the hour beginning at 3:45 p.m., the hourly limitations shall be 115 for air carriers, 30 for commuters and 10 for "others", and the 30-minute limitations shall be 60 for air carriers, 15 for commuters and 5 for "other."

[4] Operations at LaGuardia Airport shall not—

(a) Exceed 26 for air carriers, 7 for commuters and 3 for "other" during any 30-minute period.

(b) Exceed 48 for air carriers, 14 for commuters, and 6 for "other" in any two consecutive 30-minute periods.

(b) The following exceptions apply to the allocations of reservations prescribed in paragraph (a) Of this section.

(1) The allocations of resevations among the several classes of users do not apply from 12 midnight to 6 a.m. local time, but the totala hourly limitation remains applicable.

(2) [Reserved]

(3) The allocation of 37 IFR reservations per hour for air carriers except commuters at Washington National Airport does not include charter flights, or other nonscheduled flights of scheduled or supplemental air carriers. These flights may be conducted without regard to the limitation of 37 IFR reservations per hour.

(4) The allocation of IFR reservations for air carriers except commuters at LaGuardia, Newark, O'Hare, and Washington National Airports does not include extra sections of scheduled flights. The allocation of IFR reservations for scheduled commuters at Washington National Airport does not include extra sections of scheduled flights. These flights may be conducted without regard to the limitation upon the hourly IFR reservations at those airports.

(5) Any reservation allocated to, but not taken by, air carrier operations (except commuters) is available for a scheduled commuter operation.

(6) Any reservation allocated to, but not taken by, air carrier operations (except commuters) or scheduled commuter operations is available for other operations.

(c) For purposes of this subpart—

(1) The number of operations allocated to "air carriers except commuters," as used in paragraph (a) of this section refers to the number of operations conducted by air carriers with turboprop and reciprocating engine aircraft having a certificated maximum passenger seating capacity of 75 or more or with turbojet powered aircraft having a certificated maximum passenger seating capacity of 56 or more, or, if used for cargo service in air transportation, with any aircraft having a maximum payload capacity of 18,000 pounds or more.

(2) The number of operations allocated to "scheduled commuters," as used in paragraph (a) of this section, refers to the number of operations conducted by air carriers with turboprop and reciprocating engine aircraft having a certificated maximum passenger seating capacity of less than 75 or by turbojet aircraft having a certificated maximum passenger seating capacity of less than 56, or, if used for cargo service in air transportation, with any aircraft having a maximum payload capacity of less than 18,000 pounds.

(3) Notwithstanding the provisions of paragraph (c)(2) of this section, a limited number of operations allocated for "scheduled commuters" under paragraph (a) of this section may be conducted with aircraft described in § 93.221(e) of this part pursuant to the requirements of § 93.221(e).

[Doc. No. 9113, 34 FR 2603, Feb. 26, 1969, as amended by Amdt. 93-37, 45 FR 62408, Sept. 18, 1980; Amdt. 93-44, 46 FR 58048, Nov. 27, 1981; Amdt. 93-46, 49 FR 8244, Mar. 6, 1984; Amdt. 93-57, 54 FR 34906, Aug. 22, 1989; 54 FR 37303, Sept. 8, 1989; Amdt. 93-59, 54 FR 39843, Sept. 28, 1989; Amdt. 93-62, 56 FR 41207, Aug. 19, 1991]

§ 93.125 Arrival or departure reservation.

Except between 12 Midnight and 6 a.m. local time, no person may operate an aircraft to or from an airport designated as a high density traffic airport unless he has received, for that operation, an arrival or departure reservation from ATC.

[Doc. No. 9974, Amdt. 93-25, 37 FR 22794, Oct. 25, 1972]

§ 93.129 Additional operations.

(a) *IFR.* The operator of an aircraft may take off or land the aircraft under IFR at a designated high density traffic airport without regard to the maximum number of operations allocated for that airport if the operation is not a scheduled operation to or from a high density airport and he obtains a departure or arrival reservation, as appropriate, from ATC. The reservation is granted by ATC whenever the aircraft may be accommodated without significant additional delay to the operations allocated for the airport for which the reservations is requested.

(b) *VFR.* The operator of an aircraft may take off and land the aircraft under VFR at a designated high density traffic airport without regard to the maximum number of operations allocated for that airport if the operation is not a scheduled operation to or from a high density airport and he obtains a departure or arrival reservation, as appropriate, from ATC. The reservation is granted by ATC whenever the aircraft may be accommodated without significant additional delay to the operations allocated for the airport for which the reservation is requested and the ceiling reported at the airport is at least 1,000 feet and the ground visibility reported at the airport is at least 3 miles.

(c) For the purpose of this section a "scheduled operation to or from the high density airport" is any operation regularly conducted by an air carrier or commuter between a high density airport and another point regularly served by that operator unless the service is conducted pursuant to irregular charter or hiring of aircraft or is a nonpassenger flight.

(d) An aircraft operator must obtain an IFR reservation in accordance with procedures established by the Administrator. For IFR flights to or from a high density airport, reservations for takeoff and arrival shall be obtained prior to takeoff.

[Doc. No. 9113, 34 FR 2603, Feb. 26, 1969, as amended by Amdt. 93-25, 37 FR 22794, Oct. 25, 1972; Amdt. 93-44, 46 FR 58049, Nov. 27, 1981; Amdt. 93-46, 49 FR 8244, Mar. 6, 1984]

§ 93.130 Suspension of allocations.

The Administrator may suspend the effectiveness of any allocation prescribed in § 93.123 and the reservation requirements prescribed in § 93.125 if he finds such action to be consistent with the efficient use of the airspace. Such suspension may be terminated whenever the Administrator determines that such action is necessary for the efficient use of the airspace.

[Amdt. 93-21, 35 FR 16592, Oct. 24, 1970, as amended by Amdt. 93-21, 35 FR 16636, Oct. 27, 1970; Amdt. 93-27, 38 FR 29464, Oct. 25, 1973]

§ 93.133 Exceptions.

Except as provided in § 93.130, the provisions of §§ 93.123 and 93.125 do not apply to—

(a) The Newark Airport, Newark, NJ;

(b) The Kennedy International Airport, New York, NY, except during the hours from 3:00 p.m. through 7:59 p.m., local time; and

(c) O'Hare International Airport from 9:15 p.m. to 6:44 a.m., local time.

[Doc. No. 24471, Amdt. 93-46, 49 FR 8244, Mar. 6, 1984]

(b) Within the airspace below 3,000 feet MSL within the perimeter defined for the Ketchikan Control Zone, regardless of whether that control zone is in effect.

[Doc. No. 26653, 56 FR 48094, Sept. 23, 1991, as amended by Amdt. 93-63, 56 FR 65662, Dec. 17, 1991]

EFFECTIVE DATE NOTE: By Amdt. 93-63, 56 FR 65662, Dec. 17, 1991, §93.151 was amended by revising the introductory text, effective September 16, 1993. For the convenience of the user, the revised text follows.

§ 93.151 Applicability.

This subpart prescribes special air traffic rules and communications requirements for persons operating aircraft, under VFR, below 2,500 feet MSL within the lateral boundaries of the surface area of the Class E airspace area designated for Ketchikan International Airport, Alaska, excluding that airspace below 600 feet MSL and—

* * * * *

Appendix E

FAA Advisory Circular 150/5240-7

A Fuel/Energy Conservation Guide For Airport Operators

AC NO: 150/5240-7

DATE: February 19, 1974

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: A FUEL/ENERGY CONSERVATION GUIDE FOR AIRPORT OPERATORS

1. PURPOSE. This advisory circular identifies potential areas where fuel and energy usage can be conserved to assist airport operators in their voluntary actions in reducing fuel and energy consumption. Appendices 1 and 2 contain specific suggested areas.

2. GENERAL.

   a. The Nation faces a critical shortage of fuel and other forms of energy. To meet this situation, the Nation must take strong effective countermeasures. The President has set as a national goal, the independence of the United States from reliance on other nations for fuel, the development of new domestic sources, and the expansion of those already in production. Actions have already been taken through legislation to enable greater production and to spur the development of fuel and energy resources to meet these goals. As an interim measure, the President has launched a nationwide energy conservation drive with a goal of seven percent reduction in energy consumption by the Federal Government and a five percent reduction by the general public within the next year.

   b. Recent actions, such as the passage of the Alaskan Pipeline legislation, to increase domestic supplies have been implemented. However, oil from the large North Slope reserve is not anticipated to be delivered by the pipeline until 1977. In the meantime, efforts such as allocation of fuel oil and conversion to coal burning systems are being taken where possible to keep essential facilities and industries in operation.

   c. The Administrator has stated that the FAA will review its air traffic control procedures to see what changes can be made to expedite traffic flow and thus conserve fuel from that direction. In addition, he has encouraged airports to use the FAA airport grant-in-aid programs to increase airport operational capacities.

Initiated by: AAS-560

3. USE OF GUIDELINES. Airport operators, in their review of their operations and procedures to identify areas where fuel and energy can be conserved, should use these guidelines as an aid to stimulate ideas for further savings. In the implementation of these energy conservation measures, only those changes that will not lower the level of safety should be implemented. The services of local FAA Airports District Offices and Regional Offices (see AC 150/5000-3B) personnel are available to assist in this effort.

4. HOW TO OBTAIN ADDITIONAL COPIES OF THIS CIRCULAR AND OTHER REFERENCES. Additional copies of this circular, AC 150/5240- , A Fuel/Energy Conservation Guide for Airport Operators, as well as reference a below, may be obtained free of charge from the Department of Transportation, Distribution Unit, TAD-484.3, Washington, D.C. 20590.

a. Advisory Circular 150/5000-3B, Address List for Regional Airports Divisions and Airports District Offices.

b. The Asphalt Handbook (MS-4) may be obtained from the Asphalt Institute, Asphalt Institute Building, College Park Maryland 20740.

CLYDE W. PACE, JR.
Director, Airports Service

APPENDIX 1. GUIDELINES FOR FUEL/ENERGY CONSERVATION ON AIRPORTS

Following are areas where possible fuel/energy savings may be achieved.

1. LIGHTING.

   a. Street lighting.

   b. Auto parking area lighting.

   c. Lighting in public waiting areas, concourses, concession areas, and administrative areas.

   d. Apron and aircraft parking area lighting.

   e. Taxiway and runway lighting.

   NOTE: Airports which have grant agreements, surplus property agreements, or certification agreements with the Federal Government should consult the local FAA Airports District Office or Regional Airports Division personnel if changes will affect those agreements prior to making the changes. It is of utmost importance that users be advised of changes in the airfield lighting arrangements, such as going from runway lights being on all night to lights on by request or by radio control operation. To accomplish this notification, an appropriate Notice to Airmen (NOTAM) should be issued as well as using other effective means, such as state aviation publications.

2. POWER, HEATING, AND AIR CONDITIONING.

   a. Adjust heating and air conditioning controls to reduce demand on fuel and electrical power.

   b. Reduce use of escalators, people movers, and elevators during period of low activity.

   c. Install dock curtains at cargo loading docks to prevent heat loss around rear of trucks and door openings.

   d. Install shades and/or curtains on windows to reduce heat loss/gain in building areas.

   e. Make prudent use of all motor driven equipment, such as baggage handling conveyors and tractors.

   f. Keep heating and cooling equipment in good operating condition.

   g. Determine need for improving building insulation, including installation of storm windows/doors and weather stripping.

h. Reduce washroom and kitchen water heat temperature consistent with local health authority requirements.

3. ADMINISTRATION.

a. Review airport operations manual to determine if requirements or procedures can be changed that will provide a fuel savings.

b. Review fire department training and practice procedures for potential fuel savings.

c. Review airport procedures to determine what actions can be deferred or time intervals extended between actions where energy or fuel savings can be achieved.

d. Pursue an active energy conservation program with concessionaires, tenants, and Fixed Base Operators.

APPENDIX 2. GUIDELINES FOR FUEL/ENERGY CONSERVATION ON AIRPORTS - CONSTRUCTION AND MAINTENANCE

The following are examples of where fuel/energy savings may be achieved. An engineering analysis for each project should be conducted for identifying savings.

1. Construct taxiways, aprons, holding aprons, or other facilities that will expedite the movement of aircraft on the ground.

2. Substitution of asphalt emulsions in lieu of cut-back asphalts and road oils.

3. Reduction of mixing temperatures for hot-mix asphalt concrete mixtures. Normally, hot-mixes are produced at the lowest practical temperature that will permit proper mixing, lay-down, and compaction. Unfortunately, as a practical matter, the temperature of mixing is further controlled by the temperature needed to dry the aggregate. For maximum energy conservation, the contractor must employ all practical methods to produce and supply aggregates to the dryer at the lowest possible moisture content. This will permit dry-aggregates to enter the pugmill at the lowest possible temperature, but not less than 225 degrees Fahrenheit. The mixing temperature can then be further adjusted so that the particular asphalt cement being used will have a kinematic viscosity near 300 centistokes at the mixing temperature. Data on the temperature-viscosity relationship is most important to consideration of lower mixing temperatures and should be obtained from the producer of each asphalt cement used. Manual Series 4 (MS-4) titled "The Asphalt Handbook" contains more information and is published by the Asphalt Institute. When using lower temperature mixes, it may be necessary to require insulation of trucks or other hauling units in order to retain enough heat for spreading and compaction.

4. Avoiding cold weather operations that would require heating of aggregates and mixing water for concrete production.

5. Using asphalt-rejuvenation and light scarification in lieu of heater-planer operation.

Appendix F

References For Mitigation Measure Information

Sources Of Mitigation Measure Information

Source	AIRSIDE					LANDSIDE								
	Aircraft	Airfield	ATC	GSE	Fuel	Facility	Maintenance	Construction	Park	Road	Transit	(Fuel	(Park	(Rideshare
1	X					X								
2	X	X		X							X	X	X	X
3	X			X										
4											X			
5	X													
6	X	X	X	X						X	X			X
7								X						
8	X	X	X	X	X									
9				X	X	X		X	X	X		X		
10									X	X	X		X	X
11									X		X		X	
12						X					X		X	X
13	X		X											
14	X		X			X				X	X			
15	X			X				X	X	X	X		X	X
16									X	X	X			
17	X	X	X	X	X	X			X	X	X	X		
18								X		X	X		X	X
19											X			
20	X	X	X	X	X	X	X		X		X	X	X	X
21	X		X	X	X						X		X	X
22	X	X	X			X								
23											X		X	X
24	X			X										
25	X			X										
26				X										
27	X			X										
28						X			X		X		X	X
29	X			X										
30	X			X										
31	X			X							X			
32									X		X		X	X
33	X	X				X			X	X	X			
34									X				X	
35				X										
36				X										
37											X	X		
38									X		X		X	X
39	X													
40								X						
41						X			X		X		X	
42									X		X			
43											X	-	X	X
44									X	X	X		X	
45	X			X										
46	X	X	X	X	X	X	X		X	X	X	X	X	X
47	X		X	X	X			X		X	X	X	X	X
48			X											
49											X	X		
50	X	X	X			X								
51	X	X	X						X	X	X		X	X
52	X	X	X											
53						X			X		X		X	
54						X			X	X	X		X	X
55											X		X	X
56	X		X											
57	X													

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Appendix G

Mitigation Measure Ranking

— APPENDIX G —

Mitigation Measure Ranking

This appendix provides a relative ranking of the emission mitigation measures described in this report. It was added at the request of the Air Resources Board to illustrate the impact of the mitigation measures at different airports. The measures are ranked for aircraft, GSE, and ground access vehicles by pollutant (HC, CO, NO_x, and PM_{10}) for large, medium, and small airports. The 1990 levels of activity for Los Angeles International Airport (large), Sacramento Metropolitan Airport (medium), and Long Beach Airport (small) were used to simulate emissions generation both uncontrolled and with mitigation measures applied. This is not to imply that all measures necessarily are appropriate for these particular airports. For example, to illustrate the congestion relief measures it was assumed that the uncontrolled emissions represented congested conditions. This is not necessarily accurate for these airports. Site specific conditions must be considered when applying any mitigation measures. Also, the analysis was performed applying the measures as described in the body of the report. Where more than one option was available the option giving the maximum emissions reduction was used. For example, when converting GSE to alternative fuels maximum conversion to electricity and OEM optimized CNG were assumed rather than more limited use of electricity or CNG conversion of existing equipment.

There are several factors the reader should keep in mind in using these tables. First, as mentioned above for the congestion relief measures, many of these measures are very sensitive to site-specific factors. As a result, the order in which they are listed should be considered a general indicator of their potential not a definitive assessment. Second, several measures potentially have aviation system-wide effects, which could be very expensive, and may not be appropriate as control measures applied at a single airport. Examples include fleet modernization and aircraft engine emission standards. They could be very effective, however, if applied regionally, nationally, or internationally. Third, as discussed in the report, the aircraft measures should be considered in the context of their effect on all pollutants. For example, using larger aircraft to reduce the total number of LTOs may show a significant HC benefit and a high ranking in one table but at the same time there may be a significant NO_x penalty, which cannot be isolated or avoided, and would be ranked low on the NO_x table. Finally, the tables do not necessarily represent specific control strategies. For example, one table ranks the measures by their effect on CO emissions at a small airport. It is unlikely that CO emissions at a small airport would be a significant contributor to a CO nonattainment problem. Thus these measures would not be an important part of a CO control strategy.

Each table in this appendix ranks measures from the most cost effective first to the least cost effective, which depends on both the potential reductions and the cost to implement each measure (to get a relative cost per ton measure). To evaluate emission reduction potential generally, however, an order of magnitude estimate of the emissions of the pollutant covered by the table is provided. This estimate corresponds to the emissions of the individual pollutant calculated as part of the reference emissions used throughout the report. The reduction potential times the emissions estimate gives an estimate of the tons of pollutant affected by a given measure. Note that the reduction potentials are not additive and should be analyzed in combination to determine the potential benefit of multiple measures. Also, there is very little data available for calculating the cost of implementing the measures. The authors based the rankings on their judgement of relative cost effectiveness. Some results are simply noted as indeterminate and no ranking is implied. ARB staff did not have the opportunity to review the detailed calculations supporting the information presented in the Appendix G tables.

AIRCRAFT SOURCES — LARGE AIRPORTS

HC ...POLLUTANT 2,500 ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Single/Reduced Engine Taxiing	22%	Very Low	Measure may result in cost savings. Easy to implement.
Congestion Reduction	25%	Low to Moderate	Benefit and cost highly site specific
Derated Takeoff	0 - 1%	Very Low	Easy to implement. HC benefit small but positive.
Tow Aircraft to Runway	Indeterminate	Moderate	Reduction potential probably large.
Take Passengers to Aircraft	64%	Indeterminate	Cost to implement highly site specific.
Reduce Reverse Thrust	0 - 1%	High	Cost to implement highly site specific.
Fleet Modernization	62%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
Use Larger Aircraft	33%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
New Engine Standards	Indeterminate	Indeterminate	This measure has aviation system-wide effects and would have very poor cost effectiveness if all costs assigned to a single airport. Would be most effective applied nationally or internationally.
Increase Load Factor	Indeterminate	Indeterminate	
Limit Aircraft Operations	Indeterminate	Indeterminate	
Manage Fleet to Minimize Emissions	Indeterminate	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.

CO ...POLLUTANT 6,000 ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Single/Reduced Engine Taxiing	21%	Very Low	Measure may result in cost savings. Easy to implement.
Congestion Reduction	24%	Low to Moderate	Benefit and cost highly site specific
Derated Takeoff	0 - 1%	Very Low	Easy to implement. CO benefit small but positive.
Tow Aircraft to Runway	Indeterminate	Moderate	Reduction potential probably large.
Take Passengers to Aircraft	58%	Indeterminate	Cost to implement highly site specific.
Reduce Reverse Thrust	0 - 1%	High	Cost to implement highly site specific.
Fleet Modernization	38%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally

* Emission Reduction Potential
** Per One Ton Reduction

CO ...CONTINUED

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Use Larger Aircraft	11%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
New Engine Standards	Indeterminate	Indeterminate	This measure has aviation system-wide effects and would have very poor cost effectiveness if all costs assigned to a single airport. Would be most effective applied nationally or internationally.
Increase Load Factor	Indeterminate	Indeterminate	
Limit Aircraft Operations	Indeterminate	Indeterminate	
Manage Fleet to Minimize Emissions	Indeterminate	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally

NOx ...POLLUTANT 3,500 ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Single/Reduced Engine Taxiing	3%	Very Low	Measure may result in cost savings. Easy to implement.
Derated Takeoff	3%	Very Low	Easy to implement.
Reduce Reverse Thrust	10%	High	Cost to implement highly site specific.
Congestion Reduction	3%	Moderate to High	Benefit and cost highly site specific
Tow Aircraft to Runway	Indeterminate	Moderate	
New Engine Standards	10%	Indeterminate	This measure potentially has aviation system-wide effects If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally
Increase Load Factor	Indeterminate	Indeterminate	
Limit Aircraft Operations	Indeterminate	Indeterminate	
Manage Fleet to Minimize Emissions	Indeterminate	Indeterminate	This measure potentially has aviation system-wide effects If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally
Take Passengers to Aircraft	-8%	Indeterminate	Cost to implement highly site specific.
Fleet Modernization	-8%	Indeterminate	This measure potentially has aviation system-wide effects If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally
Use Larger Aircraft	-84%	Indeterminate	This measure has aviation system-wide effects and would have very poor cost effectiveness if all costs assigned to a single airport.

* Emission Reduction Potential
** Per One Ton Reduction

AIRCRAFT SOURCES — MEDIUM AIRPORTS

HC ...POLLUTANT **50** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Single/Reduced Engine Taxiing	21%	Very Low	Measure may result in cost savings. Easy to implement.
Congestion Reduction	22%	Low to Moderate	Benefit and cost highly site specific
Derated Takeoff	0 - 1%	Very Low	Easy to implement. HC benefit small but positive.
Tow Aircraft to Runway	Indeterminate	Moderate	Reduction potential probably large.
Take Passengers to Aircraft	47%	Indeterminate	Cost to implement highly site specific.
Reduce Reverse Thrust	0 - 1%	High	Cost to implement highly site specific.
Fleet Modernization	22%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
Use Larger Aircraft	33%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
New Engine Standards	Indeterminate	Indeterminate	This measure has aviation system-wide effects and would have very poor cost effectiveness if all costs assigned to a single airport. Would be most effective applied nationally or internationally.
Increase Load Factor	Indeterminate	Indeterminate	
Limit Aircraft Operations	Indeterminate	Indeterminate	
Manage Fleet to Minimize Emissions	Indeterminate	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.

CO ...POLLUTANT **200** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Single/Reduced Engine Taxiing	20%	Very Low	Measure may result in cost savings. Easy to implement.
Congestion Reduction	21%	Low to Moderate	Benefit and cost highly site specific
Derated Takeoff	0 - 1%	Very Low	Easy to implement. CO benefit small but positive
Tow Aircraft to Runway	Indeterminate	Moderate	Reduction potential probably large.
Take Passengers to Aircraft	39%	Indeterminate	Cost to implement highly site specific.
Reduce Reverse Thrust	0 - 1%	High	Cost to implement highly site specific.
Use Larger Aircraft	11%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.

* Emission Reduction Potential
** Per One Ton Reduction

CO ...CONTINUED

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Fleet Modernization	3%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
New Engine Standards	Indeterminate	Indeterminate	This measure has aviation system-wide effects and would have very poor cost effectiveness if all costs assigned to a single airport. Would be most effective applied nationally or internationally.
Increase Load Factor	Indeterminate	Indeterminate	
Limit Aircraft Operations	Indeterminate	Indeterminate	
Manage Fleet to Minimize Emissions	Indeterminate	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally..

NOx ...POLLUTANT 250 ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Single/Reduced Engine Taxiing	3%	Very Low	Measure may result in cost savings. Easy to implement.
Derated Takeoff	2%	Very Low	Easy to implement.
Reduce Reverse Thrust	7%	High	Cost to implement highly site specific.
Congestion Reduction	2%	High	
Tow Aircraft to Runway	Indeterminate	Moderate	
New Engine Standards	10%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
Increase Load Factor	Indeterminate	Indeterminate	
Limit Aircraft Operations	Indeterminate	Indeterminate	
Manage Fleet to Minimize Emissions	Indeterminate	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
Take Passengers to Aircraft	-18%	Indeterminate	Cost to implement highly site specific.
Fleet Modernization	-26%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
Use Larger Aircraft	-84%	Indeterminate	This measure has aviation system-wide effects and would have very poor cost effectiveness if all costs assigned to a single airport.

* Emission Reduction Potential
** Per One Ton Reduction

MITIGATION MEASURE RANKING

AIRCRAFT SOURCES — SMALL AIRPORTS

HC ...POLLUTANT 15 ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Single/Reduced Engine Taxiing	14%	Very Low	Measure may result in cost savings. Easy to implement.
Congestion Reduction	21%	Low to Moderate	Benefit and cost highly site specific
Derated Takeoff	0 - 1%	Very Low	Easy to implement. HC benefit small but positive.
Reduce Reverse Thrust	1%	High	Cost to implement highly site specific.
Take Passengers to Aircraft	45%	Indeterminate	
Tow Aircraft to Runway	Indeterminate	Moderate	
Use Larger Aircraft	33%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
Fleet Modernization	6%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally
New Engine Standards	Indeterminate	Indeterminate	This measure has aviation system-wide effects and would have very poor cost effectiveness if all costs assigned to a single airport. Would be most effective applied nationally or internationally.
Increase Load Factor	Indeterminate	Indeterminate	
Limit Aircraft Operations	Indeterminate	Indeterminate	
Manage Fleet to Minimize Emissions	Indeterminate	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.

CO ...POLLUTANT 90 ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Single/Reduced Engine Taxiing	13%	Very Low	Measure may result in cost savings. Easy to implement.
Congestion Reduction	22%	Low to Moderate	Benefit and cost highly site specific
Derated Takeoff	0 - 1%	Very Low	Easy to implement. CO benefit small but positive.
Take Passengers to Aircraft	37%	Indeterminate	Cost to implement highly site specific.
Tow Aircraft to Runway	Indeterminate	Moderate	
Reduce Reverse Thrust	0 - 1%	High	Cost to implement highly site specific.
Use Larger Aircraft	11%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally

* Emission Reduction Potential
** Per One Ton Reduction

CO ...CONTINUED

MEASURE	ERP*	RELATIVE COST**	COMMENTS
New Engine Standards	Indeterminate	Indeterminate	This measure has aviation system-wide effects and would have very poor cost effectiveness if all costs assigned to a single airport. Would be most effective applied nationally or internationally.
Increase Load Factor	Indeterminate	Indeterminate	
Limit Aircraft Operations	Indeterminate	Indeterminate	
Manage Fleet to Minimize Emissions	Indeterminate	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
Fleet Modernization	-7%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.

NOx ...POLLUTANT 125 ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Single/Reduced Engine Taxiing	2%	Very Low	Measure may result in cost savings. Easy to implement.
Derated Takeoff	2%	Very Low	Easy to implement.
Reduce Reverse Thrust	9%	High	Cost to implement highly site specific.
Congestion Reduction	3%	Moderate to High	Benefit and cost highly site specific
Tow Aircraft to Runway	Indeterminate	Moderate	
New Engine Standards	10%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally
Increase Load Factor	Indeterminate	Indeterminate	
Limit Aircraft Operations	Indeterminate	Indeterminate	
Manage Fleet to Minimize Emissions	Indeterminate	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
Take Passengers to Aircraft	-19%	Indeterminate	Cost to implement highly site specific.
Fleet Modernization	-1%	Indeterminate	This measure potentially has aviation system-wide effects. If so it could have very poor cost effectiveness at a single airport. Would be most effective applied regionally or nationally.
Use Larger Aircraft	-84%	Indeterminate	This measure has aviation system-wide effects and would have very poor cost effectiveness if all costs assigned to a single airport.

* Emission Reduction Potential
** Per One Ton Reduction

GSE SOURCES — LARGE AIRPORTS

HC ...POLLUTANT **100** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Fixed Electrical Systems	90%	Low to Moderate	
Fixed Air-conditioning Systems	35%	Low to Moderate	
Alternative Fuels Conversion	60%	High	

CO ...POLLUTANT **5,000** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Alternative Fuels Conversion	97%	Low	
Fixed Electrical Systems	84%	Low	
Fixed Air-conditioning Systems	35%	Low	

NOx ...POLLUTANT **275** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Alternative Fuels Conversion	76%	Low	
Fixed Electrical Systems	76%	Low	
Fixed Air-conditioning Systems	33%	Low to Moderate	

PM ...POLLUTANT **10** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Alternative Fuels Conversion	100%	Very High	High cost reflects low uncontrolled emissions.
Fixed Electrical Systems	100%	Very High	High cost reflects low uncontrolled emissions.
Fixed Air-conditioning Systems	100%	Very High	High cost reflects low uncontrolled emissions.

* Emission Reduction Potential
** Per One Ton Reduction

GSE SOURCES — MEDIUM AIRPORTS

HC ...POLLUTANT **10** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Fixed Electrical Systems	81%	Low to Moderate	
Fixed Air-conditioning Systems	34%	Low to Moderate	
Alternative Fuels Conversion	79%	High	

CO ...POLLUTANT **375** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Alternative Fuels Conversion	97%	Low	
Fixed Electrical Systems	69%	Low	
Fixed Air-conditioning Systems	33%	Low	

NOx ...POLLUTANT **25** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Alternative Fuels Conversion	77%	Low	
Fixed Electrical Systems	72%	Low	
Fixed Air-conditioning Systems	33%	Low to Moderate	

PM ...POLLUTANT **1.0** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Alternative Fuels Conversion	100%	Very High	High cost reflects low uncontrolled emissions
Fixed Electrical Systems	100%	Very High	High cost reflects low uncontrolled emissions
Fixed Air-conditioning Systems	100%	Very High	High cost reflects low uncontrolled emissions

* Emission Reduction Potentia
** Per One Ton Reductio

GSE SOURCES — SMALL AIRPORTS

HC ...POLLUTANT **5** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Fixed Electrical Systems	84%	Low to Moderate	
Fixed Air-conditioning Systems	33%	Low to Moderate	
Alternative Fuels Conversion	78%	High	

CO ...POLLUTANT **150** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Alternative Fuels Conversion	96%	Low	
Fixed Electrical Systems	70%	Low	
Fixed Air-conditioning Systems	33%	Low	

NOx ...POLLUTANT **10** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Alternative Fuels Conversion	77%	Low	
Fixed Electrical Systems	73%	Low	
Fixed Air-conditioning Systems	33%	Low to Moderate	

PM ...POLLUTANT **0.5** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Alternative Fuels Conversion	100%	Very High	High cost reflects low uncontrolled emissions.
Fixed Electrical Systems	100%	Very High	High cost reflects low uncontrolled emissions.
Fixed Air-conditioning Systems	100%	Very High	High cost reflects low uncontrolled emissions.

* Emission Reduction Potential
** Per One Ton Reduction

HC ...POLLUTANT **2,500** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low	
Trip Reduction TCMs	3%	Low to Moderate	
Alternative Fuels	35%	Moderate to High	

CO ...POLLUTANT **24,000** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low	
Trip Reduction TCMs	3%	Low to Moderate	
Alternative Fuels	35%	Moderate to High	

NOx ...POLLUTANT **2,500** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low	
Trip Reduction TCMs	3%	Low to Moderate	
Alternative Fuels	20%	Moderate to High	

PM ...POLLUTANT **900** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low	
Trip Reduction TCMs	3%	Low to Moderate	
Alternative Fuels	100%	Moderate to High	

* Emission Reduction Potential
** Per One Ton Reduction

VEHICLE SOURCES — MEDIUM AIRPORTS

HC ...POLLUTANT **50** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low	
Alternative Fuels	35%	Moderate to High	
Trip Reduction TCMs	3%	Moderate to High	

CO ...POLLUTANT **1,300** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low	
Alternative Fuels	35%	Moderate to High	
Trip Reduction TCMs	3%	Moderate to High	

NOx ...POLLUTANT **200** .. TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low	
Alternative Fuels	20%	Moderate to High	
Trip Reduction TCMs	3%	Moderate to High	

PM ...POLLUTANT **40** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low to Moderate	
Alternative Fuels	100%	Moderate to High	
Trip Reduction TCMs	3%	Moderate to High	

* Emission Reduction Potential
** Per One Ton Reduction

Vehicles

Small Airports

VEHICLE SOURCES — SMALL AIRPORTS

HC ...POLLUTANT **65** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low to Moderate	
Trip Reduction TCMs	3%	Low to Moderate	
Alternative Fuels	35%	High	

CO ...POLLUTANT **700** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low to Moderate	
Trip Reduction TCMs	3%	Low to Moderate	
Alternative Fuels	35%	High	

NOx ...POLLUTANT **100** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low to Moderate	
Trip Reduction TCMs	3%	Low to Moderate	
Alternative Fuels	20%	Moderate to High	

PM ...POLLUTANT **15** ...TONS OF EMISSIONS — Per Year Order Of Magnitude

MEASURE	ERP*	RELATIVE COST**	COMMENTS
Idle/Circulation Management TCMs	20%	Low to Moderate	
Alternative Fuels	100%	Moderate	
Trip Reduction TCMs	3%	Moderate	

* Emission Reduction Potential
** Per One Ton Reduction